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Leaving Certificate Physics Examination Paper

SOLUTIONS

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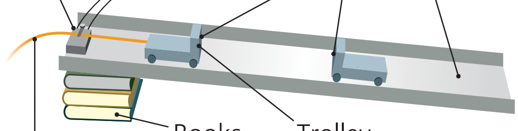
SECTION A

1.



(3 × 3)

TIP: The labelled diagram should include two moveable masses (trolleys), a smooth track, a method of attaching the two bodies (magnets/Velcro) and some form of timing sensor (ticker timer/tape or light gates/sails).

The student should make the following measurements:

Mass of trolleys

Choose one of the following methods for measurement of distance/time (ticker timer or light gate):

Ticker timer method (if used):
- Number of spaces ("n") on ticker tape multiplied by $\frac{1}{50}$s for time measurement.
- Total length of "n" spaces on ticker tape for distance measurement.

Light gate method (if used):
- Time measured for sail to pass through light gate.
- Length of sail attached to moving trolley that passes through light gate.

Calculations:

Ticker timer method (if used):
- Divide the total length of ticker tape spaces ("n" spaces) by the total time elapsed ("n" $\times \frac{1}{50}$s). This then gives you the velocity of the trolley at each stage.

Light gate method (if used):
- Divide the horizontal length of sail by the total time elapsed (light gate measurement). This then gives you the velocity of the trolley at each stage. **(4 × 3)**

TIP: It is important to clearly label your diagram with the equipment you are going to describe later. If the ticker timer is being used, you need to reference the appropriate method of counting spaces and then divide this by the time elapsed. In the case of a 50Hz ticker timer, each space is $\frac{1}{50}$ second. However, if familiar with the light gate method, you must use the horizontal sail length (length of card attached to trolley) and then divide this by the time the light beam was broken, as the trolley passed.

Momentum (ρ) = mass (m) × velocity (v)

Initial momentum: $\rho_1 = m_A \times u \Rightarrow \rho_1 = 325.1 \times 10^{-3}\text{kg} \times 0.84\text{m.s}^{-1} \Rightarrow \rho_1 = 0.273\text{kg m.s}^{-1}$

Final momentum: $\rho_2 = m_{A+B} \times v \Rightarrow \rho_2 = (325.1 \times 10^{-3} + 349.8 \times 10^{-3})\text{kg} \times 0.41\text{m.}s^{-1} \Rightarrow \rho_2 = 0.277\text{kg m.s}^{-1}$

$0.273\text{kg m.s}^{-1} \approx 0.277\text{kg m.s}^{-1}$

$$\therefore \rho_1 \approx \rho_2$$ **(3 × 3)**

TIP: It should be noted that because the first body was the only one moving initially, it holds all initial momentum in the experiment. However, once an impact has occurred and the two bodies join (coalesce), their combined mass is taken into account for the calculation of the final momentum. It would be very unusual to have initial and final momentum exactly equal, due to inherent errors; therefore, as long as they are approximately equal, this proves the principle of conservation of momentum.

The student needs to take account of the weight of the masses and the friction generated by movement. **(2 × 4)**

TIP: As with all mechanics linear motion experiments, there will always be an issue with friction between the trolley and track, as well as dust or dirt in the wheels of the trolley or on the track. Always keep the appropriate errors and precautions in mind when dealing with mandatory experiments.

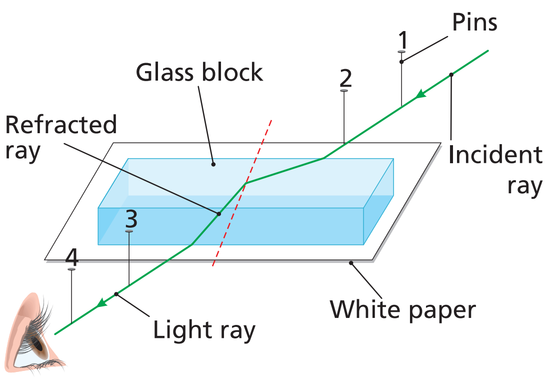
The student may have utilised the following measures to reduce the potential errors (choose any one):

- Dust track
- Oil wheels of trolley
- Raise track just enough to overcome friction but not so much as to cause unwanted acceleration
- Use a horizontal air track and blower to reduce friction **(2)**

TIP: As you can see, there is a good deal of crossover between some mechanics mandatory experiments, when it comes to errors and precautions. By understanding the basics of reducing frictional errors, you can easily prepare for this type of concluding question in the exam.

2. 23° is inconsistent with the rest of the data given **(4)**

TIP: On examination of the data, it can be seen that as the angle of incidence increases, the corresponding angle of refraction increases. However, as the angle of incidence moves from 40° to 50°, the corresponding angle of refraction moves from 27° to 23° respectively. This clearly shows an error.



TIP: Make sure to label all essential equipment that you are going to reference in the associated method below.

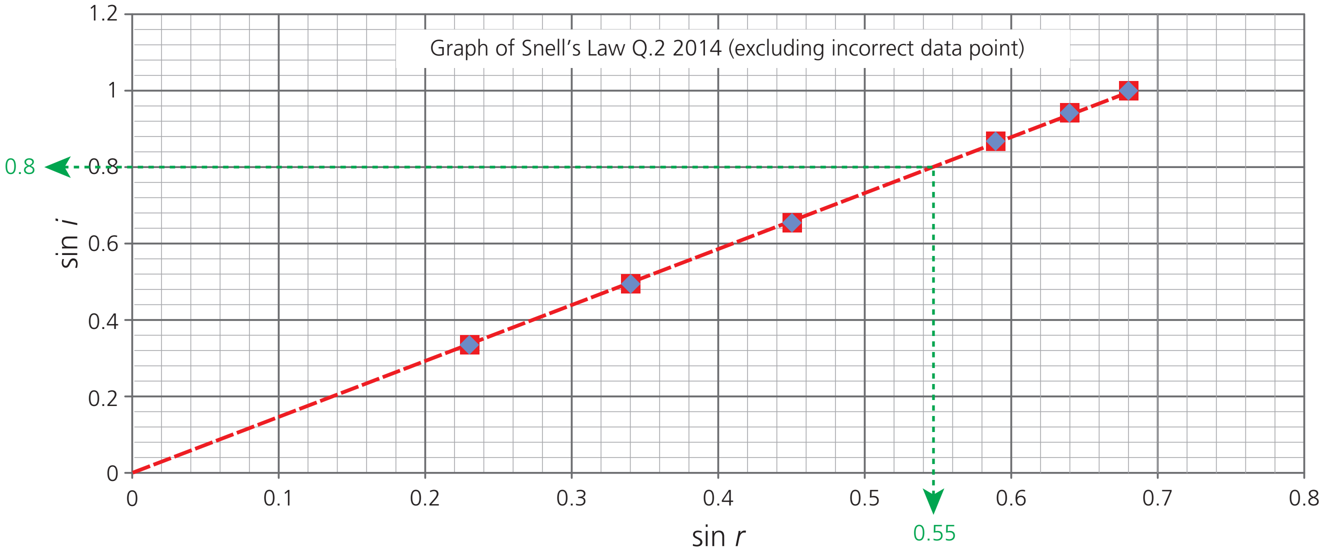
Method:

1. Place the glass block on a white sheet and board and draw an outline. Make sure to keep the block within this outline during the whole experiment.
2. Place two pins (1 & 2) into the paper as shown in the diagram.
3. Lean down and look into the block from the other side.
4. Close one eye and move your head until you cannot see pin 1 due to pin 2 being in the way.
5. Place pins 3 and 4 into the paper to mark this line of sight.
6. Mark with a pencil where each pin is in the paper and remove the pins and block.
7. Join the ray from 1 & 2 (refracted ray) and ray from 3 & 4 (incident ray).
8. Draw a normal at point of incidence to both rays and measure the incident/refracted angles.
9. Draw a graph of sin *i* against sin *r* to verify Snell's law. **(4 × 3)**

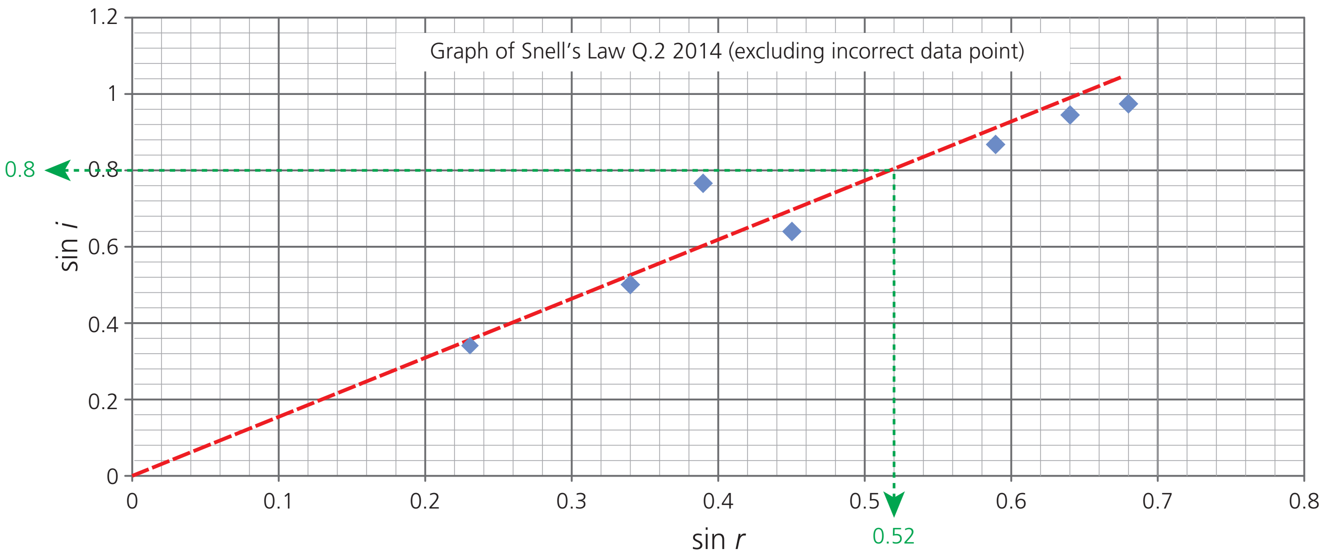
TIP: It should be noted that you may use whichever method you are familiar with. If you choose to use the ray box or laser method, you will still need to mark the incident and refracted rays and follow the above method from point 7. The important thing is to break the method down into simple, clear, concise steps that you can easily remember, as if you were picturing the experiment being done again.

Angle of Incidence (degrees)	Angle of refraction (degrees)	sin *i*	sin *r*
20	13	0.34	0.23
30	20	0.5	0.34
40	27	0.64	0.45
50	***23***	***0.77***	***0.39***
60	36	0.87	0.59
70	40	0.94	0.64
80	43	0.98	0.68

(Incorrect data value highlighted)



Or:



TIP: It is a good idea to show all angle calculations separately and if necessary, the incorrect data can be highlighted. A best fit line is also necessary to use for calculating the refractive index of the material used. As can be seen in either graph above, by finding the *x*–*y* value of the best fit line (dotted red), you can use the formula $\frac{\sin i}{\sin r}$ to calculate *n* (refractive index).

Slope of Graph including incorrect data point:

$$\text{Slope} = \frac{y}{x} \Rightarrow \text{slope} = \frac{\sin i}{\sin r} \Rightarrow \text{slope} = \frac{0.8}{0.52} = 1.53$$

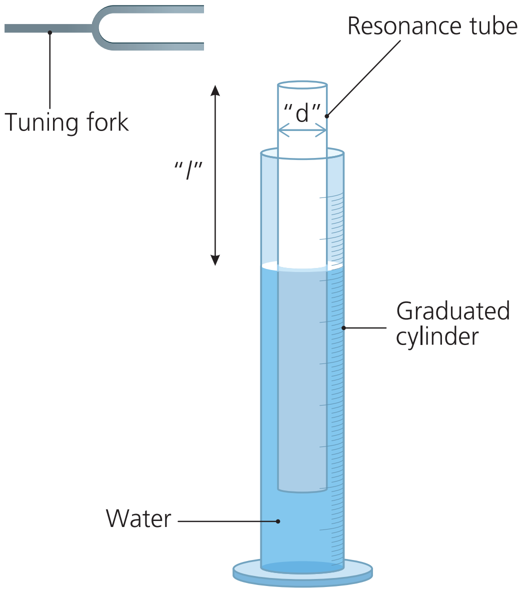
Slope of Graph excluding incorrect data point:

$$\text{Slope} = \frac{y}{x} \Rightarrow \text{slope} = \frac{\sin i}{\sin r} \Rightarrow \text{slope} = \frac{0.8}{0.55} = 1.46$$ **(6 × 3)**

> **TIP:** Once a suitable graph is asked for, it is usual to manipulate the data in some way to graph it. In this case, the Sine of each angle is required for the graph. At this point, the best fit line going through the origin is used to gain the slope and, hence, the refractive index. It is best to exclude the incorrect data value for this graph as it has already been highlighted in the question as being inconsistent. As long as a good accurate graph, with at least 6 out of 7 points, is used to gain this value for *n*, there will some leeway given to the calculation of the slope.

Choose any two reasons:
- Best fit line can pass through origin to average data
- Outlier data can be identified
- Slope gives a mean of data **(4 + 2)**

3.



(3 × 3)

> **TIP:** Make sure to include all essential parts of the apparatus, such as the source of sound (tuning fork), the means of varying column length (resonance tube in water) and the points of measurement (l & d).

Method:
1. Set up apparatus as shown in diagram.
2. Adjust the resonance tube in the water, so as to have the shortest column of air between the top of the tube and the water.
3. Strike the highest frequency tuning fork and hold just above the tube.
4. Keeping the fork just above the tube, adjust the length of air column by raising the tube slowly.
5. The first position of resonance will occur when you hear the first maximum amplitude (loudness) sound coming from the resonance tube. **(3 × 3)**

$c = 4f(l + 0.3d)$

$c = (5412)(0.162 + (0.3)(0.0115))$

$c = (2048)(0.162 + 0.00345)$

$c = (2048)(0.16545)$

$c = 338.8\text{m.s}^{-1}$ **(3 × 3)**

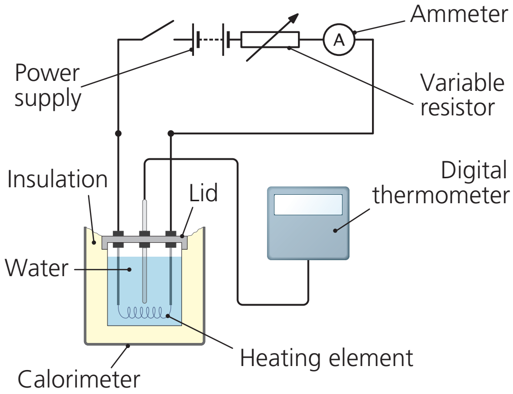
The reason it was necessary to measure the diameter of the air column was due to the fact that the sound wave exists approximately 0.3 times the internal diameter above the resonance tube. **(6)**

TIP: Given that the wave formula is $c = f\lambda$, and a quarter wavelength is present in the resonance tube at first resonance position, we then get $c = f(4l)$. However, we know that the actual quarter wavelength antinode is present $0.3d$ above the tube. This then converts our wave formula into $c = f(4(l + 0.3d))$.

The other student could have subtracted the first length (l_1) from the second length (l_2), to gain a value for half a wavelength. They then could have doubled this figure to gain the final value of wavelength. The formula could then have been used $c = f\lambda$, with $2(l_2 - l_1)$ being the value for λ. **(3 + 2 + 2)**

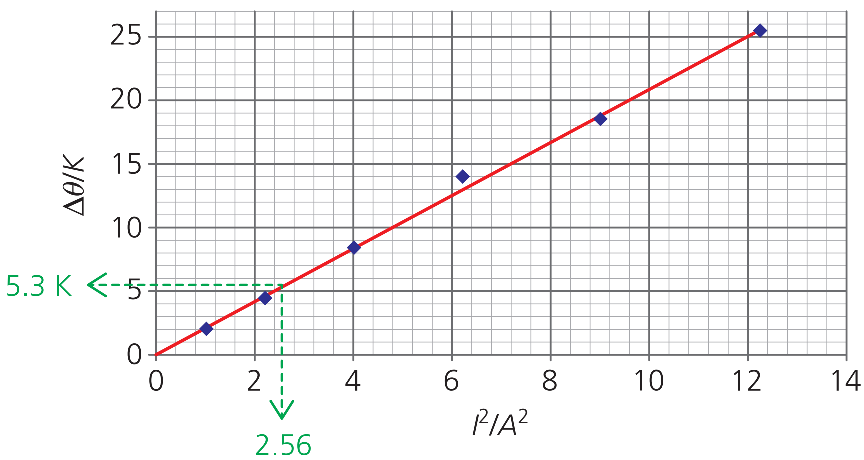
TIP: It is required to know that resonance occurs in a closed tube when the antinode is present at the open end of the tube. This happens first when a quarter wavelength is present and next, when three quarters of a wavelength is present. Therefore by subtracting the first length $\left(\frac{1}{4}\lambda\right)$ from the next $\left(\frac{3}{4}\lambda\right)$, you can gain a value for $\frac{1}{2}\lambda$. When this is doubled as shown above, a value for λ is achieved to use in the wave formula.

4.



(4 × 3)

$\frac{I^2}{A^2}$	$\frac{\Delta\theta}{k}$
1	2
2.25	4.5
4	8.5
6.25	14
9	18.5
12.25	25.5



(4 × 3)

TIP: Before you attempt to draw the graph, calculate the values of current squared and associated temperature change for each. Remember that Joule's Law is based on the square of the current being proportional to the rise in temperature achieved. Make sure to use at least six points and draw a best fit line through the origin.

A straight line through the origin shows the verification of Joule's Law as it is stated that the square of the current is proportional to the rise in temperature. **(6)**

TIP: Whenever you are asked for verification of a law and you have drawn a straight line through the origin, be sure to mention this in your explanation.

As seen in the graph above, when a current of 1.6A flows for 4 minutes, a corresponding temperature rise of 5.3 K is achieved. Therefore a final temperature of 25.3°C is the highest temperature reached. **(3 + 3)**

TIP: Make sure to square the 1.6A before plotting a line in your graph, to find the corresponding temperature (1.6A squared = 2.56). Also, make sure to add the temperature rise to the initial temperature to calculate the highest temperature reached in this experiment (20°C + 5.3°C = 25.3°C).

A fixed mass of water was used because Joule's Law is based on all other factors being constant, to obtain the proportional relationship of current squared to temperature rise. **(4)**

TIP: The power required to raise the temperature of a substance is proportional to mass, as well as other factors. Therefore, mass is fixed in this experiment, so as to look only at current versus temperature.

SECTION B

5. *Answer any eight questions from (a), (b), (c), etc.* **(8 × 7)**

(a) Boyle's Law:

The volume of a gas is inversely proportional to its pressure, as long as temperature is constant.

(b) $T^2 = \frac{4\pi^2 R^3}{GM}$

$\frac{1}{T^2} = \frac{GM}{4\pi^2 R^3}$

$\frac{4\pi^2 R^3}{T^2} = GM$

$\frac{4\pi^2 R^3}{T^2 G} = M$

$\frac{4\pi^2 (9.4 \times 10^6)^3}{(7.6 \times 60 \times 60)^2 (6.7 \times 10^{-11})} = M$

$6.54 \times 10^{23}\text{kg} = M$

(c) (i) emf

(ii) Length of column

(d) $\Delta\theta = 20°\text{C} - 11°\text{C} = 9°\text{C} = 9\text{K}$ change

Area = 3m^2

Time = 1 hour = 3600s

U-value = $2.8\ \text{wm}^{-2}\text{K}^{-1}$ = 2.8 Joules every second per metre squared per 1 Kelvin temperature change.

Energy lost = (2.8)(3600)(3)(9) = 272160J or 272.16kJ

(e) Choose any 1 pair:

- Red & Cyan
- Green & Magenta
- Blue & Yellow

(f) (i) Negative electrons & positive holes

(ii) Negative electrons

(g) RCD = Residual Current Device
MCB = Miniature Circuit Breaker

(h) $E = 5.85\text{eV} = (5.85)(1.6 \times 10^{-19}) = 9.36 \times 10^{-19}\text{J}$

$\varphi = 4.50\text{eV} = (4.5)(1.6 \times 10^{-19}) = 7.2 \times 10^{-19}\text{J}$

$E = \varphi + E_K$

$E - \varphi = E_K$

$9.36 \times 10^{-19} - 7.2 \times 10^{-19} = E_k$

$2.16 \times 10^{-19}\text{J} = E_k$

TIP: You could give your answer in eV by subtracting the work function from the incident photon energy. This would give you a value of 1.35eV. However, in other questions, you can be asked to calculate the velocity of the emitted electron and this would require an answer in Joules, rather than eV.

(i) Choose any two:
- Dense core
- Positive core
- Mainly empty space

(j) Choose any two:
- 1st experimental verification of Einstein's $E = mc^2$
- 1st transmutation of matter by artificially accelerated particles
- 1st artificial splitting of a nucleus
- 1st prototype of later linear particle accelerators

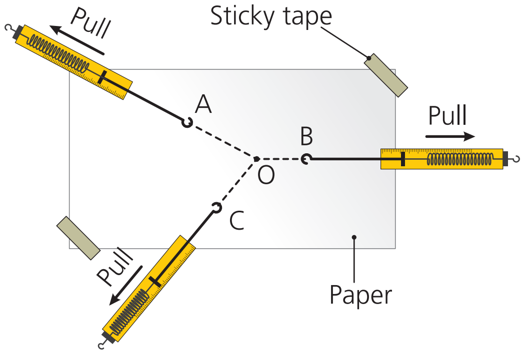
A galvanometer may be converted into a voltmeter by connecting a large value resistor (multiplier) in series with it.

6. Scalars are quantities of magnitude only (e.g. time, length, speed, area…)

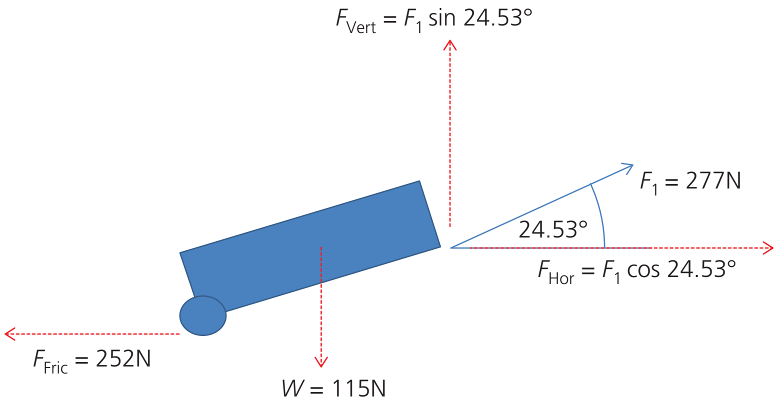
Vectors are quantities of magnitude and direction (e.g. velocity, displacement, force…) **(8)**

To find the resultant of two forces:

1. Set up three newton (spring) balances as in the diagram below. Each newton balance is connected to the same centre point, which is at rest.
2. Take any two balance vectors and draw them on the paper.
3. The resultant of these two vectors will be equal in magnitude but opposite in direction to the third force vector as show by the red dotted line in the diagram.



(3 × 3)



TIP: It is usually a good idea to draw a simple force diagram first and show the resolved vertical/horizontal forces that are to be calculated.

$F_{Hor.} = F_1 \cos 24.53° = 251.999N \approx 252N$

$F_{Vert.} = F_1 \sin 24.53° = 115.002N \approx 115N$

Horizontal net force = 252N (golfer) – 252N (friction) ≈ 0N

Vertical net force = 115N (golfer) – 115N (weight) ≈ 0N **(9)**

Since the net forces, both vertically and horizontally, appear to approximately cancel, this shows that speed is constant and the trolley & bag is not accelerating. **(3)**

Derivation of $F = ma$

$F \propto$ Rate of change of momentum

$$F \propto \frac{\text{Change in momentum}}{\text{Time taken}}$$

Since the change in momentum is equal to the difference between the final and the initial momentum,

$$F \propto \frac{\text{Final momentum} - \text{Initial momentum}}{\text{Time taken}}$$

$$F \propto \frac{\rho_2 - \rho_1}{t}$$

Since $\rho = mv$,

$$F \propto \frac{mv - mu}{t}$$

Taking out m as a factor,

$$F \propto \frac{m(v-u)}{t}$$

Writing out proportionality as an equation with constant of proportionality k,

$$F = k\frac{m(v-u)}{t}$$

But $\frac{v-u}{t} = a$ by definition, so

$$F = kma$$

Finally, set $k = 1$:

$F = ma$ **(9)**

$F = ma$

$\Rightarrow F = m\left(\frac{v-u}{t}\right)$

$\Rightarrow F = \left(\frac{mv-mu}{t}\right)$

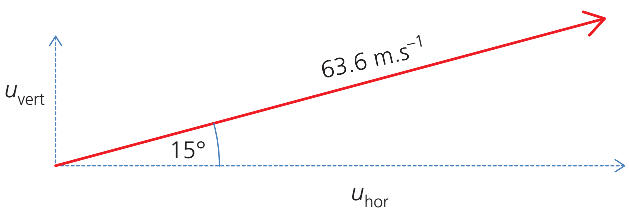
$\Rightarrow 5.3 \times 10^3 = \left(\frac{(45 \times 10^{-3})(v) - (45 \times 10^{-3})(0)}{0.54 \times 10^{-3}}\right)$

$\Rightarrow 5.3 \times 10^3 = \frac{((45 \times 10^{-3})(v)}{0.54 \times 10^{-3})}$

$\Rightarrow \frac{(5.3 \times 10^3)(0.54 \times 10^{-3})}{45 \times 10^{-3}} = v$

$63.6 \text{m.s}^{-1} = v$ **(9)**

TIP: Since you were asked to derive Newton's 2nd Law of motion previously, it is often wise to keep this in mind when calculating the next part. It is for this reason that we use $F = \frac{mv-mu}{t}$ here.



Resolve the velocity into vertical (u_{vert}) and horizontal (u_{hor}) components.

$u_{vert} = 63.6 \sin 15° = 16.46 \text{m.s}^{-1}$

$u_{hor} = 63.6 \cos 15° = 61.43 \text{m.s}^{-1}$

Maximum height means $u_{vert} = 0 \text{m.s}^{-1}$

$\therefore v^2 = u^2 + 2as$

$\Rightarrow (0)^2 = (16.46)^2 + 2(-9.8)s$

$\Rightarrow 0 = 270.96 - 19.6s$

$\Rightarrow -270.96 = -19.6s$

$\Rightarrow \frac{-270.96}{-19.6s} = s$

$\Rightarrow 13.82\text{m} = s$ **(3 × 3)**

TIP: You may also use $\frac{1}{2}mv^2 = mgh$ to calculate maximum height. In this case, mass cancels on both sides of the equation and you solve for height.

7. (i) Diffraction is the spreading out of a wave as it moves through a gap or around an obstacle. **(2 × 3)**

(ii) Interference is when waves meet and combine to form a resultant amplitude made up of each wave's individual amplitude. **(3)**

$c = f\lambda$

$\Rightarrow \frac{c}{\lambda} = f$

$\Rightarrow \frac{3 \times 10^8}{709 \times 10^{-9}} = f$

$\Rightarrow 4.23 \times 10^{14}\text{Hz} = f$

$E = hf$

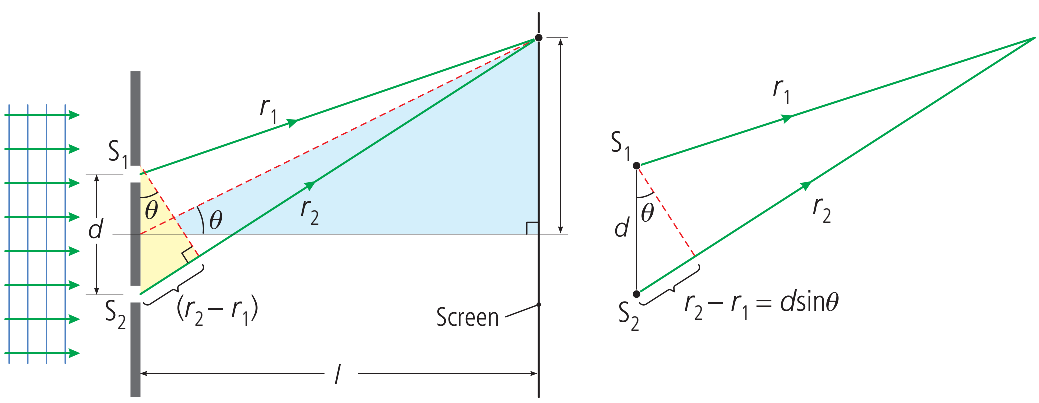
$\Rightarrow E = (6.626 \times 10^{-34})(4.23 \times 10^{14})$

$\Rightarrow E = 2.8 \times 10^{-19}\text{J}$ **(3 × 3)**

TIP: Make sure to convert the wavelength to a frequency before using $E = hf$. Remember that energy is proportional to the frequency of a photon, as explained by Einstein in the Photoelectric section of your course.

The light receptive sensors in the eye are located in the retina. **(3)**

Choose any two:
- A laser is a collimated beam of light, whereas a vapour lamp is not
- A laser consists of a single frequency of light
- A laser has more inherent power
- A laser is a coherent beam of light **(4 + 2)**



Derivation of $n\lambda = d \sin \theta$

Each slit gives a point source of light a distance d apart. The screen is a distance l from the slits. Wherever a bright fringe occurs, the difference in distance from that point on the screen to each slit is an integer multiple of wavelengths. From the diagram, this distance is $r_2 - r_1$. So:

$r_2 - r_1 = n\lambda$

Since the distance for l is relatively very large compared to d, we can use trigonometric ratios:

$$\sin\theta = \frac{\text{opposite}}{\text{hypotenuse}} = \frac{r_2 - r_1}{d}$$

This can be seen in close up in the diagram. So:

$$d\sin\theta = r_2 - r_1$$

Putting (1) and (2) together gives:

$$d\sin\theta = n\lambda$$ **(5 × 3)**

TIP: Sometimes it can be helpful to use a diagram to explain the derivation, as shown here. In this case, a diagram is required but even if it is not, you may use it to aid description.

$n\lambda = d\sin\theta$

$\Rightarrow \dfrac{n\lambda}{\sin\theta} = d$

$\Rightarrow \dfrac{(2)(709 \times 10^{-9})}{\sin 34.6°} = d$

$\Rightarrow 2.497 \times 10^{-6}\text{m} = d$

$\dfrac{1}{d}$ = no. of lines per metre

$\dfrac{1}{2.497 \times 10^{-6}}$ = no. of lines per metre

4.0045×10^{5} = no. of lines per metre

$\therefore \dfrac{4.0045 \times 10^{5}}{1000}$ = no. of lines per mm

$\Rightarrow$ 400 lines per mm **(3 × 3)**

TIP: It is important to pay close attention to the units required in the answer. Usually, the value of *d* is for metres but the answer required here is per mm and hence you need to divide by 1000 at the end.

If white light replaced the laser, you would observe a spectrum of colours being dispersed by the grating. **(5)**

8. A **chain reaction** is a fission reaction in which at least one neutron is emitted in order to carry on the reaction.

Nuclear fission is the splitting of a large nucleus into two similar smaller nuclei with the release of neutrons and energy. **(3 × 3)**

A moderator may be made from graphite or heavy water. **(3)**

(i) The **moderator** slows down 'fast' neutrons between the fuel rods. 'Slow' neutrons are far more likely to cause further fission. Without the moderator, radiative capture would occur.

(ii) Control rods are used to lower or raise between the fuel rods. They can absorb neutrons being emitted from the fuel rods. If all of the control rods are lowered, no chain reaction occurs between the fuel rods. To gain more energy production, the **control rods** are raised proportionally. **(2 × 6)**

(iii) A heat exchanger is used to transfer heat produced in the reactor core to a water tank, capable of producing steam. This steam is then used to drive a turbine that generates electricity. The advantage of the heat exchanger is that the core temperature can be regulated by coolant and the heat emitted in the core can be used to convert water to steam. **(3 + 3 + 4)**

$$^{238}_{92}\text{U} + ^{1}_{0}n \rightarrow ^{239}_{94}\text{Pu} + 2\,^{0}_{-1}\beta$$ **(10 × 1)**

TIP: Make sure to check that all atomic and mass numbers equate on each side of the equation. Also, remember that a beta particle will have an atomic number of –1, due to the neutron splitting into a proton and electron.

1 U-235 fission generates 202MeV

$\therefore$ 1 U-235 fission generates $(202 \times 10^{6})(1.6 \times 10^{-19})$ Joules

$\Rightarrow$ 1 U-235 fission generates 3.232×10^{-11}J

35% of 1 U-235 fission = $3.232 \times 10^{-11}\text{J} \times 35\%$

$= 1.1312 \times 10^{-11}$J

$1 \text{ GW} = 1 \times 10^9 \text{ W} = 1 \times 10^9 \text{J.s}^{-1}$

$\therefore$ 1 GW over 1 day $= 1 \times 10^9 \text{J.s}^{-1} \times 60 \times 60 \times 24$

$= 8.64 \times 10^{13} \text{J}$

$\therefore$ No. of fissions required for 1 GW over 1 day with 35% efficiency

$= \dfrac{8.64 \times 10^{13} \text{J}}{1.1312 \times 10^{-11} \text{J}} = 7.638 \times 10^{24}$ nuclei **(4 ×3)**

TIP: It can be helpful to state exactly what a Watt is in terms of joules before you work out energy required.

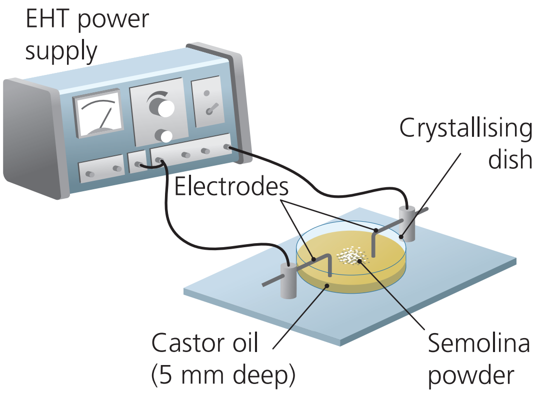
9. Capacitance is the ratio of charge to the voltage (potential difference) across the capacitor.

TIP: You may also define capacitance by stating the formula and giving the associated notation meaning of each letter.

An electric field is any region of space in which charges exert a force.

The field can be illustrated by electric field lines. **(4 × 3)**

To demonstrate electric field lines:
1. Set up the equipment as shown below.
2. Sprinkle semolina powder on the oil surface.
3. Use two EHT (extra high tension) plates to apply an electric field across the oil.
4. Because the semolina grains are of low density, they line up in the shape of the applied field.



(4 × 3)

(i) $C = \dfrac{Q}{V}$

$\Rightarrow CV = Q$

$\Rightarrow (12 \times 10^{-6})(6) = Q$

$\Rightarrow 72\mu C = Q$ **(2 × 3)**

(ii) $W = \dfrac{1}{2} CV^2$

$\Rightarrow W = \dfrac{1}{2}(12 \times 10^{-6})(6)^2$

$\Rightarrow W = 216\mu J$ **(2 × 3)**

If d increases by a factor of 3 and $C = \dfrac{\varepsilon A}{d}$; then C decreases by a factor of 3.

$\therefore C = \dfrac{12\mu F}{3} = 4\mu F$ **(4)**

Choose any two:
- A capacitor stores electrostatic potential energy, while a battery stores chemical energy.
- A capacitor gives a changing supply of current as it discharges, while a battery gives a constant current.
- A capacitor can discharge very quickly, while a battery takes a much longer time.
- A capacitor has a limited amount of energy that it can store, while a battery can store much more energy. **(4 + 2)**

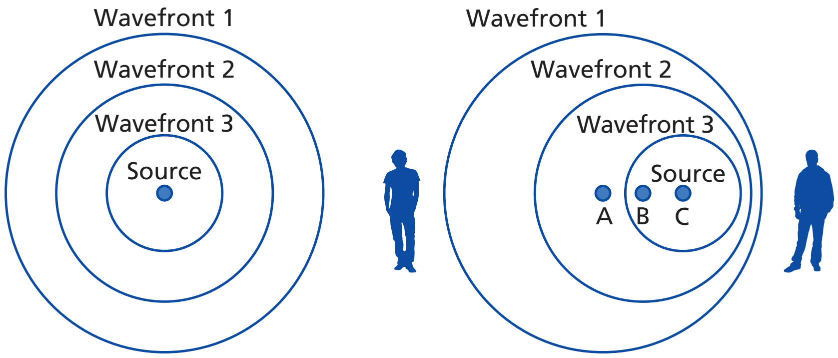
Polarisation is the confining of a wave to a single plane. **(2 × 3)**

TIP: If you vertically polarise a transverse wave, the wave will only consist of perpendicular vibrations in the vertical direction. If you horizontally polarise a transverse wave, the wave will only consist of perpendicular vibrations in the horizontal direction.

Choose any one:
- Camera flash
- Tuning circuits
- Defibrillator
- Flash guns
- Smoothing circuits **(4)**

10. The Doppler Effect is the apparent change in frequency due to the relative motion of source and observer. **(2 × 3)**

If a source emits waves, they travel outwards from it in all directions. If the source is stationary, the wavefronts will be equally spaced as the constant frequency wave travels out (see diagram below).



However, if the source is moving, by the time the second wavefront is emitted, the source has changed position (see diagram above).
- Wavefront 1 was emitted when the source was at A.
- Wavefront 2 was emitted when the source was at B.
- Wavefront 3 was emitted when the source was at C.

This means that the wavefronts will be bunched up at one side (in the direction of motion) and paced out on the other side.
- For the person on the left in the diagram, the crests of the wavefronts would appear to be further apart. If the wavefronts are more spaced out, then the frequency must appear lower.
- For the person on the right in the diagram, the wavefronts would appear to be closer together. If the wave-fronts are more bunched up, the frequency must appear higher. **(4 × 3)**

TIP: It can be much easier to explain some phenomena with good diagrams. Practice drawing good clear Doppler Effect diagrams and you will find it easier to reference them when explaining how the effect occurs.

If the source is travelling towards the observer:

$$f' = \frac{fc}{c-u}$$

$f' = 820\text{Hz}, f = 750\text{Hz}, c = 340\text{m.s}^{-1}, u = ?$

$$\Rightarrow (820) = \frac{(750)(340)}{(340)-u}$$

$\Rightarrow (820)(340 - u) = (750)(340)$

$\Rightarrow 278800 - 820u = 255000$

$\Rightarrow 277800 - 255000 = 820u$

$\Rightarrow 23800 = 820u$

$\Rightarrow \frac{23800}{820} = u$

$\Rightarrow 29\text{m.s}^{-1} = u$ **(4 × 3)**

TIP: Make sure you identify the correct formula for which way the source is moving relative to the observer. Then list your values before inserting them into the formula.

Choose any two:
- Speed gun (police use)
- Red shift/Blue shift star velocity measurement
- Weather equipment
- Ultrasound medical equipment **(2 × 2)**

An observer would know if a wheatstone bridge is balanced as there would be a zero deflection on the galvanometer, showing that no current was flowing between the bridges. **(2 × 2)**

$\frac{R_1}{R_2} = \frac{R_3}{R_4}$

$R_1 = 5.1\Omega$, $R_2 = 11.9\Omega$, $R_3 = ?$, $R_4 = 40.5\Omega$

$\Rightarrow \frac{5.1}{11.9} = \frac{R_3}{40.5}$

$\Rightarrow 0.429 = \frac{R_3}{40.5}$

$\Rightarrow (0.429)(40.5) = R_3$

$\Rightarrow 17.36\Omega = R_3$ **(2 × 3)**

TIP: By first stating the formula for a wheatstone bridge and then listing the variables, it is easy to calculate the missing resistance to balance the bridges.

$\rho = \frac{RA}{l}$

$\Rightarrow \rho l = RA$

$\Rightarrow \frac{\rho l}{A} = R$

Or (if using πr^2 for area of wire):

$\rho = \frac{R\pi r^2}{l}$

$\Rightarrow \rho l = R\pi r^2$

$\Rightarrow \frac{\rho l}{\pi r^2} = R$

Or (if using $\pi\left(\frac{d}{2}\right)^2$ for area of wire):

$\rho = \frac{R\pi d^2}{4l}$

$\Rightarrow 4\rho l = R\pi d^2$

$\Rightarrow \frac{4\rho l}{\pi d^2} = R$ **(2 × 3)**

TIP: Use the formulae you are familiar with and manipulate to get *R* on its own.

If radius is doubled, then the resistance is multiplied by $\frac{1}{2^2}$

Therefore, it decreases by a factor of 4. **(2 × 3)**

TIP: As you can see, by using the formula with radius contained in it, you can easily see how doubling radius causes the overall answer to decrease by 4.

11. (a) (i) Gravitational

Weak Nuclear

Electromagnetic **(3 × 2 + 1)**

(ii) $e^- + e^+ \rightarrow 2hf$ **(4 + 3)**

TIP: You may also state the electron and positron as $2mc^2$ and you may state the $2hf$ as 2 gamma photons, if desired.

(iii) $e^- + e^+ \rightarrow 2hf$

$\Rightarrow 2mc^2 \rightarrow 2hf$

$\Rightarrow 2(9.1 \times 10^{-31})(3 \times 10^8)^2 \rightarrow 2(6.626 \times 10^{-34})f$

$\Rightarrow (1.82 \times 10^{-30})(9 \times 10^{16}) \rightarrow 1.3252 \times 10^{-33}f$

$\Rightarrow 1.638 \times 10^{-13} \rightarrow 1.3252\ 10^{-33}f$

$\Rightarrow \frac{1.638 \times 10^{-13}}{1.3252 \times 10^{-33}} \rightarrow f$

$\Rightarrow 1.236 \times 10^{20}\text{Hz} \rightarrow f$ **(4 + 3)**

TIP: As you can see, it is easier to state the electron-positron pair as $2mc^2$ first, so as to allow for the $E = mc^2$ energy conversion required for $E = hf$.

(iv) The photons move in opposite directions so as to conserve momentum. **(4 + 3)**

(v) ${}^{11}_{6}\text{C} \rightarrow {}^{11}_{5}\text{B} + {}^{0}_{1}\text{e} + v_e$ **(7 × 1)**

TIP: Make sure that all atomic and mass numbers equal in the equation. You may also show the existence of the electron neutrino here but it is not strictly necessary in all questions.

(vi) $\lambda = \frac{\ln 2}{T_{\frac{1}{2}}}$

$\Rightarrow \lambda = \frac{0.693}{20 \times 60}$

$\Rightarrow \lambda = \frac{0.693}{1200}$

$\Rightarrow \lambda = 0.000578\ \text{s}^{-1}$ **(4 + 3)**

TIP: When calculating decay constant, remember to convert all half-lives into seconds first.

(vii) The half-life of Carbon-11 is so short that it would decay before it could be used, if it were produced too far away. **(7)**

(viii) $F = qvB; F = \frac{mv^2}{r}$

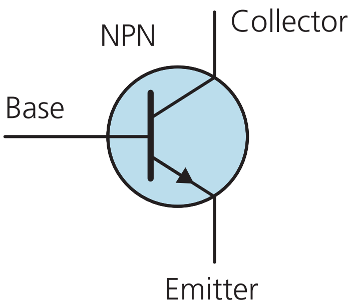
$\Rightarrow qvB = \frac{mv^2}{r}$

(divide by v): $\Rightarrow qB = \frac{mv}{r}$

$\Rightarrow qrB = mv$ (momentum $= mv$) **(7)**

TIP: By equating the force on a charged particle moving with circular motion formulae, you can isolate momentum to give this expression.

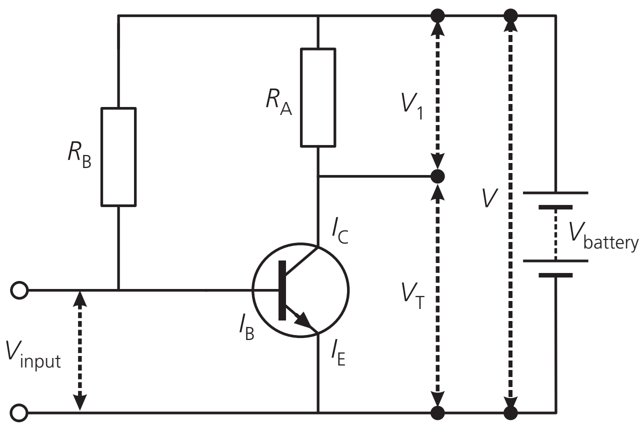
(b) (i)



(4 + 3)

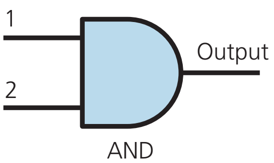
(ii) $I_e = I_b + I_c$ **(7)**

(iii)



(4 + 3)

(iv)



Input 1	Input 2	Output
1	1	1
1	0	0
0	1	0
0	0	0

(4 + 3)

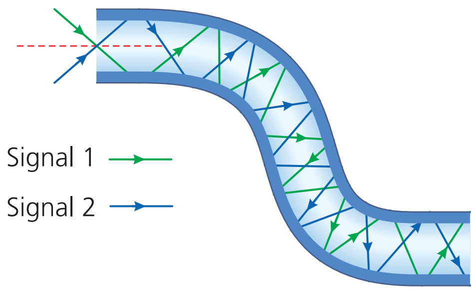
(v) Choose any two:

- A photodiode allows current to flow when light is incident on it, whereas an LED emits light when a current flows through it.
- A photodiode is connected in reverse bias, whereas an LED is connected in forward bias.
- A photodiode can be connected without a protective resistor, whereas an LED requires the use of a protective resistor. **(4 + 3)**

(vi) When an excited electron drops back to a lower energy level, and recombines with a positive hole, a photon is released, characteristic of that energy difference. **(7)**

(vii) The mechanism by which it transmits light safely and securely is as follows (see diagram below):

1. Light enters the core at such an angle as to be greater than the critical angle. Because of this, total internal reflection occurs. (Signal 1 and signal 2 represent multiple light signals entering the optical fibre.)
2. The light then reflects back and forth as it moves through the fibre but always staying within the core.



(4 + 3)

(viii) $\sin C = \dfrac{c_{glass}}{c_{air}}$

$\Rightarrow C = \sin^{-1}\left(\dfrac{c_{glass}}{c_{air}}\right)$ **(4 + 3)**

12. (a) Hooke's Law: Whenever an object is deformed through bending, stretching or compression, there is a restoring force that is directly proportional to the displacement, as long as the elastic limit is not exceeded. **(2 + 2)**

> **TIP:** You may also use the formula $F = -ks$ and give the notation associated with these variables/constant.

$F = -ks$

$\Rightarrow \dfrac{F}{-k} = s$

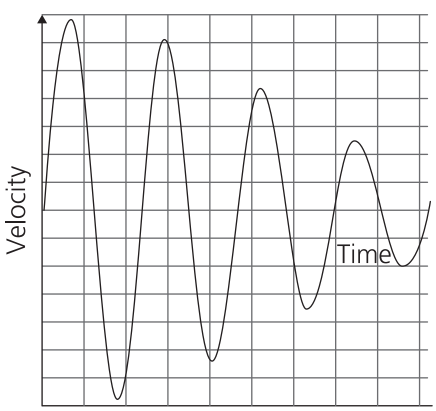
$(F = 20 \times 10^{-3}\text{kg} \times 9.8\text{m.s}^{-2} = 0.196\text{N})$

$\Rightarrow \dfrac{0.196}{-12} = s$

$\Rightarrow 1.6333 \times 10^{-2}\text{m} = s$ (16.33mm)

$\therefore$ new length of spring = 25mm (original) + 16.33mm (extension) = 41.33mm **(3 + 3)**

> **TIP:** Make sure to convert the mass into force by multiplying by gravity. Also, be careful with converting metres into mm for the final extension length.



(3 × 3)

> **TIP:** Any body exhibiting SHM will eventually dampen. However, it will follow a sinusoidal shape.

$\omega^2 = \frac{k}{m}$

$\Rightarrow \omega^2 = \frac{12}{20 \times 10^{-3}}$

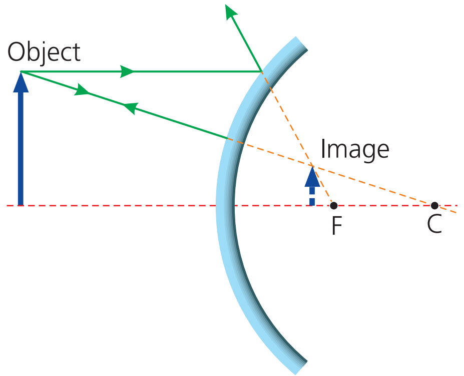
$\Rightarrow \omega^2 = 600$

$T = \frac{2\pi}{\omega}$

$\Rightarrow T = \frac{2\pi}{\sqrt{600}}$

$\Rightarrow T = 0.256s$ **(3 × 3)**

(b) Reflection is the bouncing of light off a surface. **(3)**



(3 × 3)

Diameter of sphere = 30cm ∴ r = 10cm ⇒ ∴ f = 5cm

Object distance (u) = 30cm

A convex mirror always gives a virtual image and uses the formula:

$\frac{1}{u} - \frac{1}{v} = -\frac{1}{f}$

$\Rightarrow \frac{1}{30} - \frac{1}{v} = -\frac{1}{5}$

$\Rightarrow \frac{1}{30} + \frac{1}{5} = \frac{1}{v}$

$\Rightarrow 0.233 = \frac{1}{v}$

⇒ 4.28cm = v (Virtual image behind the mirror) **(4 × 3)**

Concave mirrors give virtual upright magnified images to aid dental examination. **(4)**

(c) The **specific latent heat** (l) of a substance is the amount of heat energy required to change the state of 1kg of the substance without a change in temperature. Unit: J kg^{-1} **(2 × 3)**

Volume of each ice cube = $(\text{length})^3 \Rightarrow (2.5\text{ cm})^3 \Rightarrow 15.625\text{ cm}^3$

Volume of 3 ice cubes = $(3)(15.625)\text{ cm}^3 = 46.875\text{ cm}^3$

Mass = Density × Volume ⇒ Mass = $(0.92\text{g.cm}^{-3})(46.875\text{cm}^3)$ ⇒ Mass = 43.125g **(2 × 3)**

Let temperature change from –20°C → 0°C = 20

Let temperature change from 0°C → Final Temp. = θ_2

Let final temperature of water in glass = θ_2

Let temperature change of water in glass = 24°C – θ_2

(Heat Change from –20°C → 0°C) + (State change of added ice) + (Heat Change from 0°C → Final Temp.) = (Heat Change from 24°C → Final Temp.)

$mc\Delta\theta + ml + mc\Delta\theta = mc\Delta\theta$

$mc\Delta\theta_1 + ml + mc\Delta\theta_2 = mc(24°C - \Delta\theta_2)$ **(2 × 3)**

$\Rightarrow (43.125 \times 10^{-3})(2100)(20) + (43.125 \times 10^{-3})(3.3 \times 10^5) + (43.125 \times 10^{-3})(4200)(\theta_2)$
$= (500 \times 10^{-3})(4200)(24°C - \theta_2)$ **(4 × 2)**

TIP: These type of heat questions can be simplified by stating the variables first and then laying out the formula ready for substitution. As you can see, by allowing the final temperature of the water to be θ_2, we can state the temperature changes easily. Also, make sure to state each mass in kilograms.

$\Rightarrow 1.81125 \times 10^3 + 1.423125 \times 10^4 + 181.125\theta_2 = 5.04 \times 10^4 - 2100\theta_2$

$\Rightarrow 1.60425 \times 10^4 + 181.125\theta_2 = 5.04 \times 10^4 - 2100\theta_2$

$\Rightarrow 181.125\theta_2 + 2100\theta_2 = 5.04 \times 10^4 - 1.60425 \times 10^4$

$\Rightarrow 2281.125\theta_2 = 3.43575 \times 10^4$

$\Rightarrow \theta_2 = \frac{3.43575 \times 10^4}{2281.125}$

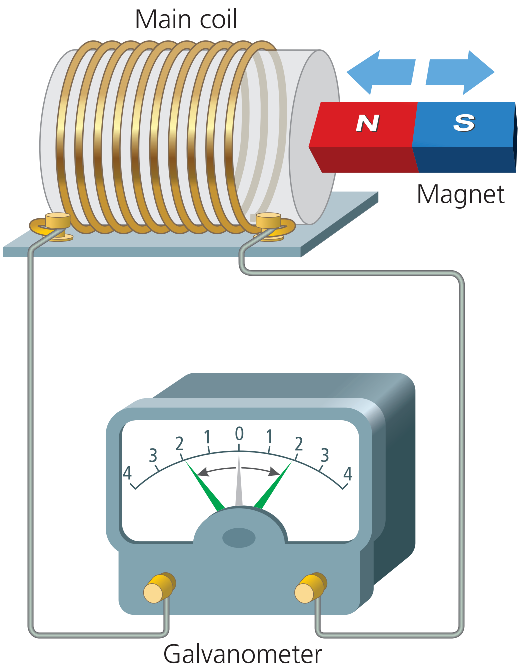
$\Rightarrow \theta_2 = 15.06°°C$ **(2)**

(d) Faraday's law of electromagnetic induction: The magnitude of induced emf is directly proportional to the rate of change of flux. **(2 × 3)**

To demonstrate Faraday's law of electromagnetic induction

(This demonstrates Faraday's law on the relative movement of coil/magnet.)

1. Set up the experiment as shown below.
2. As the north pole approaches the coil, the galvanometer needle twitches one way.
3. As the north pole moves away, the galvanometer needle twitches the other way.
4. If the magnet and coil are kept stationary, no movement takes place on the galvanometer.
5. It will be seen that the speed of approach of the magnet is proportional to the induced current. It will also be observed that the orientation of the magnetic pole affects the induced current direction.



(3 × 3)

A falling magnet will cause a changing magnetic field in the pipe (coil).

This would induce an emf in the pipe, due to the changing magnetic field.

This emf causes a current to flow in the pipe.

This current will generate a magnetic field such as to oppose the falling magnet, as per Lenz's Law. **(3 + 3 + 4 + 3)**

SECTION A

1. By balancing the metre stick horizontally at the fulcrum, you can determine the point of centre of gravity. This can be done by suspending the metre stick from a string. **(3)**

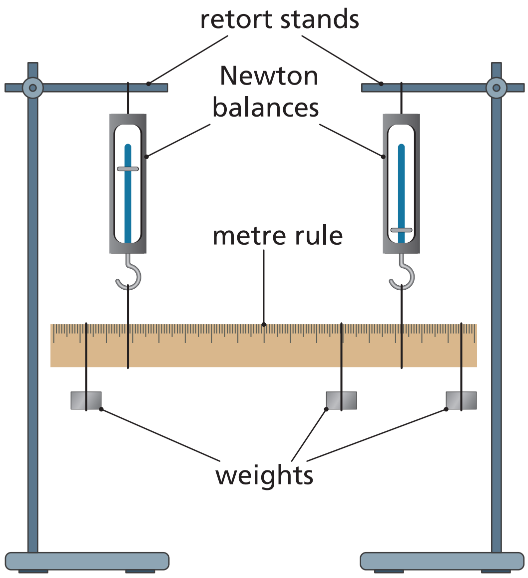
> **TIP:** Although, in practice, you can usually find the centre of gravity by balancing the metre stick on your finger, it is far more precise to suspend the metre stick from a thin string, to see the exact measurement on the ruler for the centre of gravity.

The metre stick may not have been completely uniform because of wear and tear. **(3)**

> **TIP:** As the metre stick gets used in a laboratory, it may get worn down or chipped at the ends. For this reason, it is good practice to measure distances with the inside graduations of the metre stick rather than from zero at the end.

The metre stick can be assumed to be in equilibrium when it is not moving. **(6)**

> **TIP:** In the case of this experiment, static equilibrium is being studied. Therefore, no upward/downward or clockwise/anticlockwise motion is to be present.



(2 × 3)

(i) Turning moment = Force × Perpendicular distance

$M = F \times d$

Clockwise moments:

$M_C = (2N \times 38.6 \times 10^{-2}m) + (3N \times 28.2 \times 10^{-2}m) + (4.6N \times 15.4 \times 10^{-2}m) = 0.772Nm + 0.846Nm + 0.7084Nm$
$= 2.3264Nm$

(ii) Anticlockwise moments:

$M_{AC} = (5.7N \times 19.7 \times 10^{-2}m) + (1.3N \times 0.3 \times 10^{-2}m) + (4N \times 30 \times 10^{-2}m) = 1.1229Nm + 0.0039Nm + 1.2Nm$
$= 2.3268Nm$ **(5 × 3)**

> **TIP:** The common mistake here is to forget about the turning effect of the metre stick itself. Because the centre of gravity of the metre stick is 50.3cm and the turning moments are taken about the 50cm mark, it has an anticlockwise turning effect. The other aspect to be careful of is the cm measurements when you are stating moments in Nm. By writing each cm as a 10^{-2}m, you can avoid errors early on in the calculation.
>
> The last point to watch is to know how to determine if a force is exerting clockwise or anticlockwise moments. Picture the metre stick fixed at the 50cm mark and identify each force in turn to see whether it rotates the stick clockwise or anticlockwise.

The two laws being proved here are:

Upward forces = Downward forces

TIP: In this case, (2N + 3N + 1.3N + 4N) = 10.3N Downward/(5.7N + 4.6N) = 10.3N Upward. The metre stick weight is a force downwards, even though it is not stated in the table.

The sum of the clockwise moments ≈ the sum of the anticlockwise moments. **(4 + 3)**

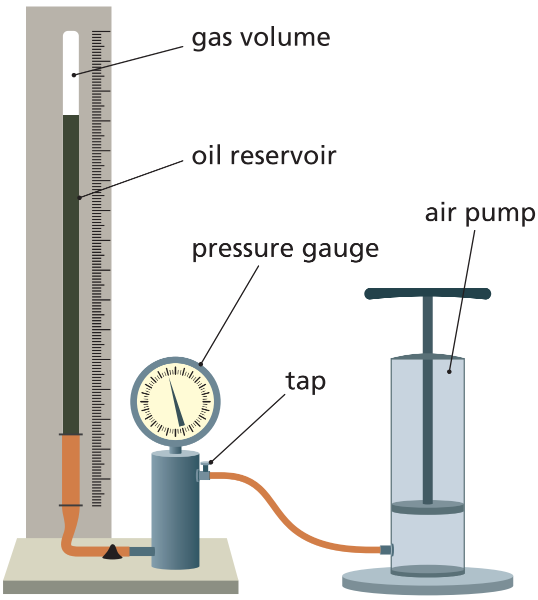
TIP: Even though they are not exactly equal, they are within experimental limits of being equal.

2. *X* and *Y* represent pressure and volume of gas. **(2 × 3)**

TIP: Height of column or length may also be accepted here but, using Boyle's Law, it is safer to state pressure against volume readings.

The units used for pressure can be Pa, kPa, mbar, Nm^{-2}, atm or cm Hg.

The units used for volume can be cm^3, mm^3, m^3 or litres. **(2 × 2)**



(3 × 3)

X	120	160	200	240	280	320
1/*X*	0.0083	0.00625	0.005	0.0042	0.0036	0.0031
Y	52	39.1	31.1	25.9	22.2	19.6
1/*Y*	0.019	0.026	0.032	0.039	0.045	0.051

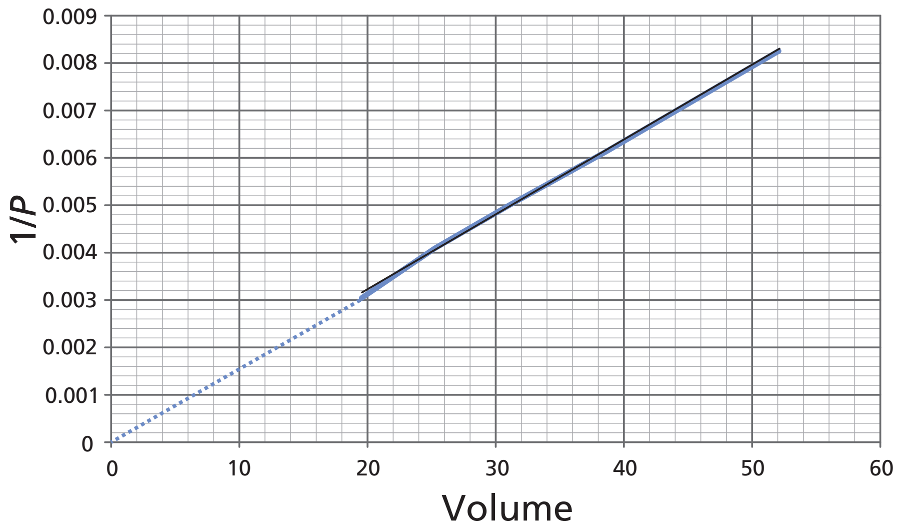
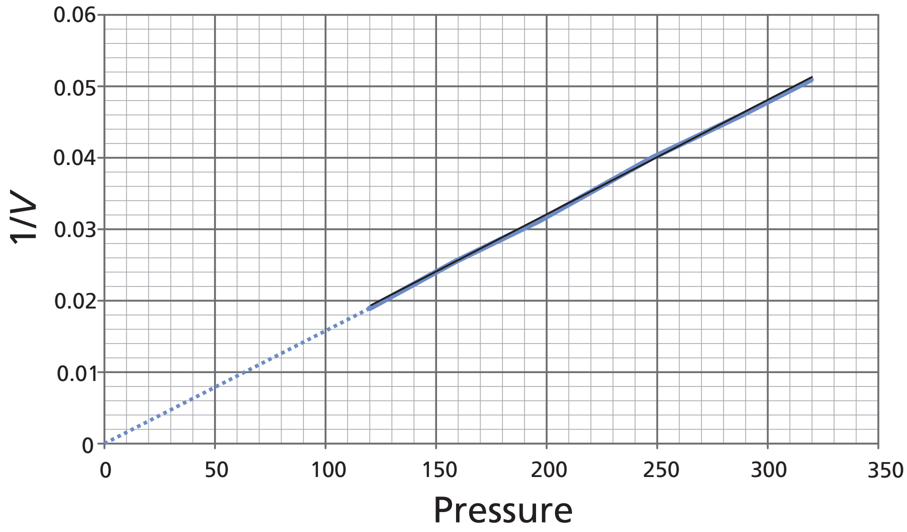


Fig. 2.1

OR



(12)

Fig. 2.2

TIP: As long as you graph one value against the inverse of the other, it will correctly illustrate Boyle's Law. This can be Pressure against 1/Volume OR Volume against 1/Pressure.

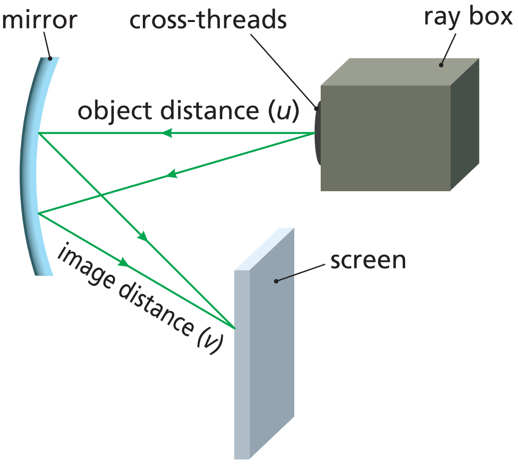
The table of figures can be manipulated to show one set of data as a reciprocal, while the other remains the same or both reciprocals can be shown and you use one of them.

In the case of Fig. 2.1 above, *Y* remained untouched but the reciprocal of *X* was used with it. However, in Fig. 2.2, *X* remained untouched and was used with the reciprocal of *Y*.

The graph used verifies Boyle's Law because there is a straight line through the origin which shows that one value is inversely proportional to the other value. Therefore, $P \propto \frac{1}{V}$. **(3)**

TIP: Anytime you have a straight line through the origin, proportionality is shown. It is also acceptable to say that pV = constant here.

3.



(3 × 3)

Choose any two from the following:

- Avoid unnecessary parallax error with the ruler.
- Try to gain sharpest image.
- Have the screen and mirror vertical.
- Place a hard backing on the screen to avoid movement.
- Measure from the pole of the mirror.
- Measure from the back of the mirror. **(2 × 3)**

If the object was inside the focal distance of the mirror, no real image would have been formed on the screen. **(6)**

> **TIP:** The reason that an approximate value for *f* is usually gained at the beginning of this experiment is to avoid virtual image formation when the object is inside the focal length.

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$$

First set of data: $\frac{1}{u}+\frac{1}{v}=\frac{1}{f} \Rightarrow \frac{1}{24}+\frac{1}{72.5}=\frac{1}{f} \Rightarrow 0.0555=\frac{1}{f} \Rightarrow 18.03\text{cm}=f$

Second set of data: $\frac{1}{u}+\frac{1}{v}=\frac{1}{f} \Rightarrow \frac{1}{32}+\frac{1}{40.3}=\frac{1}{f} \Rightarrow 0.0561=\frac{1}{f} \Rightarrow 17.84\text{cm}=f$

Third set of data: $\frac{1}{u}+\frac{1}{v}=\frac{1}{f} \Rightarrow \frac{1}{40}+\frac{1}{33}=\frac{1}{f} \Rightarrow 0.0553=\frac{1}{f} \Rightarrow 18.08\text{cm}=f$

Fourth set of data: $\frac{1}{u}+\frac{1}{v}=\frac{1}{f} \Rightarrow \frac{1}{48}+\frac{1}{27.9}=\frac{1}{f} \Rightarrow 0.0567=\frac{1}{f} \Rightarrow 17.64\text{cm}=f$

Average value for $f=\frac{(18.03+17.84+18.08+17.64)}{4}=\frac{71.59}{4}=17.898\text{cm}=17.9\text{cm}$ **(15)**

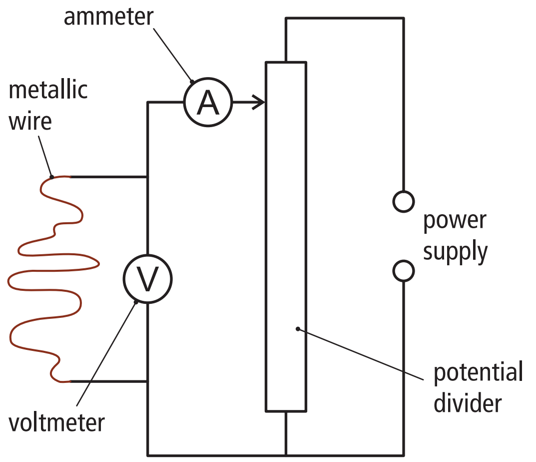
> **TIP:** You could also use a graph to find the focal length of the mirror but remember to graph $\frac{1}{u}$ against $\frac{1}{v}$ and take the axes intercept points to average the value of *f*. If drawing a graph, the following figures can be used:

u/cm	24.0	32.0	40.0	48.0
1/*u*	0.042	0.031	0.025	0.021
v/cm	72.5	40.3	33.0	27.9
1/*v*	0.014	0.025	0.030	0.036

An approximate value of focal length could be gained by focusing a distant object and measuring the image distance. **(4)**

> **TIP:** Since distant light rays are essentially taken as parallel rays, they will all converge at the focal point. Therefore, the image distance will equal *f*.

4.



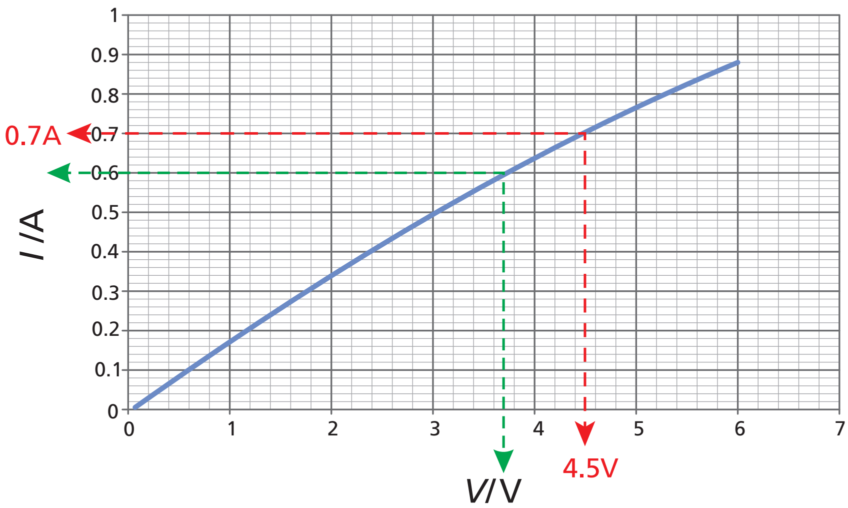
(3 × 3)

The potential difference can be varied by using a variable power supply or by using a potential divider/rheostat/potentiometer. **(6)**

A variable power supply can be varied by adjusting its output.

A rheostat is used to vary potential difference by moving the sliding contact.

A potentiometer changes resistance and therefore potential difference by turning the dial to change the length of carbon track covered in the device. **(3)**



TIP: Make sure to draw a smooth curve that uses all points given. The values of voltage and current do not have to be adapted for the graph.

(3 × 3)

Using an arbitrary value from the graph of 0.6A, we can see a corresponding value of 3.7V.

$V = IR$

$V/I = R$

$4.5/0.6 = R$

$6.43\Omega = R$ **(6)**

TIP: Since the graph is essentially linear, the slope method may be used.

If taking values from your graph, make sure to show your work and corresponding values used.

The graph shows that as the voltage increases, so does the current. However, the graph is not linear because the increasing temperature causes increasing resistance in a metallic conductor. **(4 + 3)**

TIP: It is always a good idea to keep all electricity experiments in mind when answering these questions. By linking the variation of resistance to temperature with Ohm's Law, this answer can be seen.

SECTION B

5. *Answer any eight questions from (a), (b), (c), etc.* **(8 × 7)**

(a) $v = u + at \Rightarrow (0) = (16) + (-2.5)t \Rightarrow \frac{-16}{-2.5} = t \Rightarrow 6.4\text{s} = t$

(b) The total momentum of a system before an interaction is equal to the total momentum of the system after an interaction, as long as no external force acts on it.

(c) Since particles in a solid cannot move freely, convection is not an effective method of heat transfer.

(d) Storage heaters are used for the following reasons:
- They have a high specific heat capacity.
- Because of this, they take a long time to heat, when electricity is cheaper.
- In turn, they take a long time to release the heat during the day, when they are turned off and electricity would have been more expensive.

(e) $n = \frac{c_1}{c_2} \Rightarrow c_2 = \frac{c_1}{n} \Rightarrow c_2 = \frac{3 \times 10^8}{2.42} \Rightarrow c_2 = 1.24 \times 10^8 \text{m.s}^{-1}$

(f) One volt is the potential difference between two points when 1 Joule of work is required to move 1 C of charge from one point to the other.

(g)

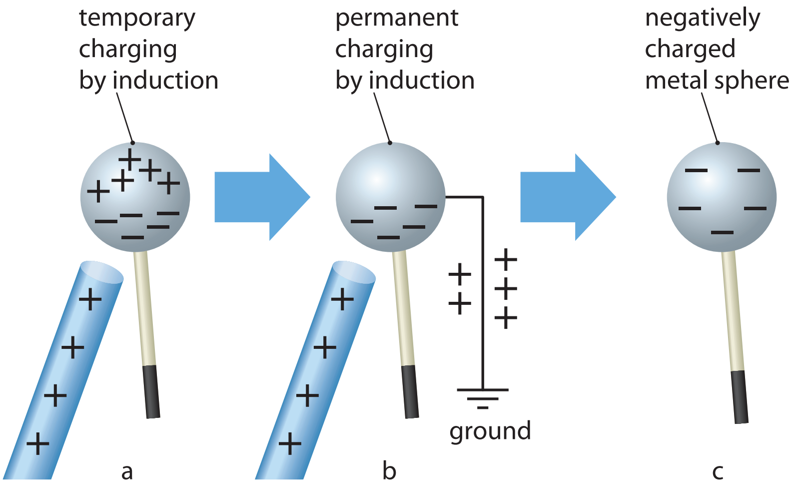


Fig. 5.1

1. Hold a negatively charged rod near an insulated metal sphere and the charge separates (see Fig. 5.1a).
2. Earth the sphere. The electrons that are required to neutralise the sphere will travel up the earth to the sphere, from the ground (see Fig. 5.1b). (This can be done by touching the sphere; the electrons travel through you.)
3. Remove the earth (e.g. your finger).
4. Remove the rod. The sphere is now left with a net negative charge by induction (see Fig. 5.1c).

(h) Threshold frequency is the minimum frequency at which photons will cause the emission of electrons from the surface of a metal. Therefore, this statement means any photon with a frequency below 1.04×10^{15}Hz will not cause photoemission of zinc.

(i) Choose any one from the following:
- Fewer greenhouse gases: Fossil fuels produce more greenhouse gases when combusted.
- More energy produced per mass of fuel: Nuclear fission generates far higher quantities of heat and therefore electricity than regular fossil fuels.
- More useful radioisotope secondary products produced: Radioisotopes generated in a reactor can have other uses later.
- Lower industrial accident rate: Nuclear power generation has a much higher safety rate than any other fossil fuel industry.

(j) $f = \frac{2m_{electron}c^2}{h}$

TIP: This expression of frequency comes from the equation $hf = 2mc^2$ and relates to the pair production of a positron and electron by a photon.

OR

When an electron returns to its original energy level and recombines with a positive hole, a photon of light is released, proportional to the energy difference.

6. (i) Every mass in the universe attracts every other mass with a force, along the line of their centres, that is proportional to the product of their masses and inversely proportional to the square of the distance between them. **(6)**

TIP: It is also acceptable to state Newton's Law as the formula but correct explanation of each letter must also be given.

(ii) Angular velocity is the rate of change of angle with respect to time. **(3)**

Derivation:

$v = \frac{s}{t}$

From $\theta = \frac{s}{r}$, we get $s = r\theta$, so:

$v = \frac{r\theta}{t}$

Since $\omega = \frac{\theta}{t}$:

$v = r\omega$ **(6)**

(iii) (a) $\omega = \frac{2\pi}{T} \Rightarrow \omega = \frac{2\pi}{(92 \times 60) + 50} \Rightarrow \omega = \frac{2\pi}{5570} \Rightarrow \omega = 1.1 \times 10^{-3} s^{-1}$ **(6)**

TIP: Make sure to convert the minutes and seconds into all seconds for periodic time here.

(b) $v = r\omega \Rightarrow v = (6.783 \times 10^6)(1.1 \times 10^{-3}) \Rightarrow v = 7651.5 m.s^{-1}$ **(6)**

TIP: Many of the circular motion questions just require looking at the available formulae and choosing the correct one that gives you the variable required.

(iv) The ISS experiences centripetal acceleration. **(3)**

The gravitational force provides this centripetal acceleration. **(3)**

TIP: Make sure you state that it is gravitational force and not 'gravity' that provided this force.

(v) $F = \frac{mv^2}{r} \Rightarrow F = \frac{(4.5 \times 10^5)(7651.5)^2}{(6.37 \times 10^6 + 4.13 \times 10^5)} \Rightarrow F = 3.884 \times 10^6 N$ **(6)**

TIP: You may also use $F = mr\omega^2$ to calculate this force. However, make sure to add the radius of the Earth to the height above the Earth in order to state radius of motion.

$F = \frac{GmM}{r^2} \Rightarrow \frac{1}{F} = \frac{r^2}{GmM} \Rightarrow M = \frac{Fr^2}{Gm} \Rightarrow M = \frac{(3.884 \times 10^6)(6.37 \times 10^6 + 4.13 \times 10^5)^2}{(6.7 \times 10^{-11})(4.5 \times 10^5)}$

$M = \frac{1.787 \times 10^{20}}{3.015 \times 10^{-5}} \Rightarrow M = 5.93 \times 10^{24} kg$ **(9)**

TIP: Once again, make sure to factor in the radius of the Earth as well as height above Earth when dealing with satellite radius.

(vi) Since the occupants of the ISS are in the ISS, both the occupants and ISS are experiencing equal gravitational effects and therefore are accelerating at the same rate relative to each other. **(3)**

TIP: The same effect is observed in a free-falling plane where the occupants are also in free fall. This procedure is used for astronaut training.

(vii) A geostationary satellite has a period of 1 day. **(5)**

7. Resonance is the transfer of energy between two bodies of the same or similar natural frequency. **(6)**

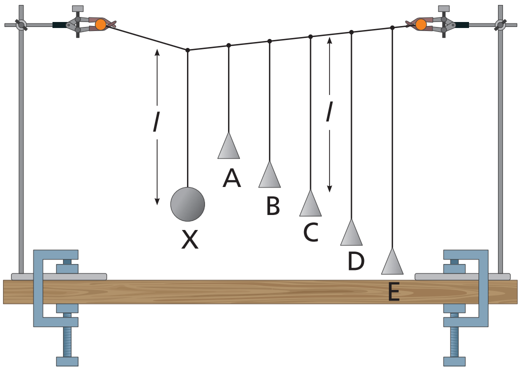


Fig. 7.1

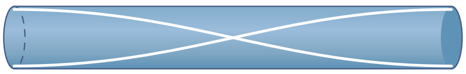
1. Set up the equipment as shown in Fig. 7.1, with pendulums of various lengths.
2. Attach a mass X of the same length string (l) as one of the pendulums.
3. When you swing the mass, the pendulum of similar length (l) (in this case pendulum C) will begin to swing as well. This demonstrates the resonance caused by the natural frequency applied from the swinging mass. **(3 × 3)**

TIP: You may also use the mandatory experiment on the speed of sound to demonstrate resonance with a vibrating tuning fork and column of air but make sure to keep the description brief as only 9 marks are available for this part.

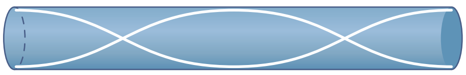
Overtones or harmonics are the names given to multiples of natural frequency. **(5)**

TIP: Overtones are multiples of fundamental frequency and the first overtone is 2*f*. Harmonics are integer multiples of fundamental frequency and the first harmonic is *f*.

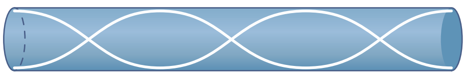
550Hz (fundamental frequency):

 **(6)**

1100Hz (2*f*):

 **(6)**

1651Hz (3*f*):

 **(3)**

TIP: It is also a good idea to label the nodes and antinodes in each diagram. Note how fundamental frequency has 1 node and 2 antinodes, 2*f* has 2 nodes and 3 antinodes, and 3*f* has 3 nodes and 4 antinodes. In an open pipe of each harmonic, there should be one more antinode than node in each diagram.

$c = f\lambda$

If the length of the tube is 30cm, then we can assume wavelength is twice this length at fundamental frequency, since only half a wavelength is present in the first diagram. Therefore, $\lambda = 0.6$m:

$\Rightarrow c = (550)(0.6) \Rightarrow c = 330\text{m.s}^{-1}$ **(3 × 3)**

TIP: If you used the value of 1100Hz, the diagram associated with this has a full wavelength present and so you would use $\lambda = 0.3$m. In this case: $c = f\lambda \Rightarrow c = (1100)(0.3) \Rightarrow c = 330\text{m.s}^{-1}$ as well.

Likewise, if you used 1651Hz and the third diagram, there are 1½ wavelengths present and so $\lambda = 0.2$m. Using this figure: $c = f\lambda \Rightarrow c = (1651)(0.2) \Rightarrow c = 330\text{m.s}^{-1}$. Therefore, as harmonics change, the wavelength also changes to keep speed constant.

μ = mass per unit length: 12m length and 48g mass gives us a value of : $48 \times 10^{-3}\text{kg}/12\text{m} = 0.004 \text{ kg m}^{-1}$

$f = \frac{1}{2l}\sqrt{\frac{T}{\mu}} \Rightarrow (\text{sq.}) : f^2 = \frac{1}{4l^2}\frac{T}{\mu} \Rightarrow 4f^2l^2\mu = T \Rightarrow 4(173)^2(0.64)^2(0.004) = T \Rightarrow 196\text{N} = T$ **(4 × 3)**

TIP: Make sure you calculate μ before substituting it into the formula. It is often easier to rearrange the formula as above to isolate the letter required before substituting in the values. In this case, tension is manipulated before calculating it.

8. (a) F = Transformer/Iron core

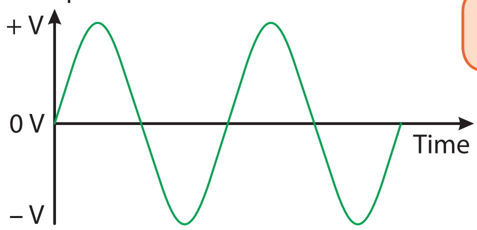
G = Diode

H = Capacitor **(3 × 3)**

The diode (G) rectifies the current from a.c. to d.c. **(6)**

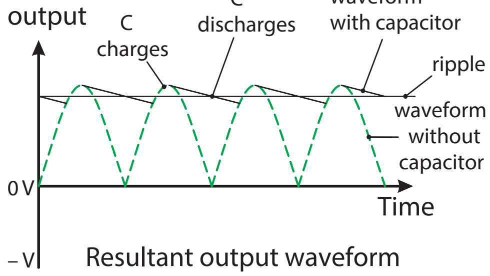
TIP: Remember that diodes allow one-way current flow. Therefore, any alternating current only has one direction allowed through the diode and the other direction is blocked as reverse bias. This is called rectification.

(i) AC input



TIP: Because of the capacitor being present, there is a slight 'smoothing effect' that needs to be shown.

(ii) Rectifier output



(12)

$W = \frac{1}{2}CV^2 \Rightarrow W = \frac{1}{2}(2200 \times 10^{-6})(16)^2 \Rightarrow W = 0.2816J$ **(3 × 3)**

(b) According to Joule's Law, current has a heating effect. This translates to a massive energy loss when electricity is distributed across the country.

To reduce energy loss through heat, mains electricity is 'stepped up' to raise it from low voltages to EHT (extra high tension) voltages. This can be in the region of many kV. **(6)**

(i) Diameter = 18mm

Therefore, radius = 9mm

Therefore, area of circular wire = $\pi r^2 \Rightarrow (\pi)(9 \times 10^{-3})^2 \Rightarrow \pi(8.1 \times 10^{-5}) \Rightarrow 2.545 \times 10^{-4}\text{m}^2$

$$\rho = \frac{RA}{l} \Rightarrow \frac{1}{\rho} = \frac{l}{RA} \Rightarrow R = \frac{\rho l}{A}$$

$$R = \frac{(2.8 \times 10^{-8})(3 \times 10^{3})}{2.545 \times 10^{-4}} \Rightarrow R = \frac{8.4 \times 10^{-5}}{2.545 \times 10^{-4}} \Rightarrow R = 0.33\Omega$$ **(3 × 3)**

TIP: It is easier to calculate the cross-sectional area first and then substitute it into the resistivity formula. Also, when looking for the value of resistance, it can be simpler to manipulate the formula to have *R* on its own on the left of the equation and then substitute in the values.

(ii) $W = I^2Rt \Rightarrow W = (250)^2\,(0.33)(600) \Rightarrow W = 1.238 \times 10^7\text{J}$ **(5)**

TIP: Make sure to convert all quantities to their correct units before multiplying out the result. In this particular question, 10 minutes needs to change to 600 seconds.

9. 1 Becquerel = 1 disintegration per second. **(6)**

Choose one from the following:
- Geiger–Müller tube (G–M tube)
- Solid state detector **(3)**

Name	Penetrating power	Ionising power	Rate of deflection in EM fields
alpha	lowest	greatest	behaves as a + particle
beta	medium	medium	behaves as a – particle
gamma	greatest	lowest	no deflection

(3 × 3)

Nuclear fission is the splitting of a large nucleus into two similar smaller nuclei with the release of neutrons and energy. **(3 + 3 + 2)**

$^{131}_{53}\text{I} \rightarrow\ ^{131}_{54}\text{Xe} +\ ^{0}_{-1}\text{e}$ **(9 × 1)**

40 days = (40 days/8 days) half-lives = 5 half-lives

$\therefore \frac{1}{2^n}$ of sample remains $\Rightarrow \frac{1}{2^5}$ of sample remains $\Rightarrow \frac{1}{32}$ of sample remains **(2 × 3)**

TIP: By working out how many half-lives have passed, you can either manually keep halving the sample 5 times or use $\frac{1}{2^n}$ of sample calculation, where *n* = number of half-lives.

$$\lambda = \frac{\ln 2}{T_{\frac{1}{2}}} \Rightarrow \lambda = \frac{0.693}{(30 \times 365 \times 24 \times 60 \times 60)} \Rightarrow \lambda = \frac{0.693}{9.4608 \times 10^{8}\text{s}} \Rightarrow 7.32 \times 10^{-10}\text{s}^{-1}$$ **(3 × 2)**

TIP: Decay constant is always measured in per seconds. Therefore, you need to convert half-life to seconds before using in the formula.

$$A = \lambda N \Rightarrow \frac{A}{\lambda} = N \Rightarrow \frac{5000}{7.32 \times 10^{-10}} = N \Rightarrow 6.83 \times 10^{12} \text{ atoms} = N$$ **(3 + 6)**

TIP: Radioactive decay generally only includes the two formulae here. Therefore, always try to find one answer in one of the formulae and then substitute into the other formula as shown for decay constant here.

10. *Answer either part (a) or part (b).*

(a) Cockcroft and Walton used an extra high tension (EHT) to create a potential difference capable of accelerating the protons. **(6)**

The alpha particles were detected when they collided with the zinc sulphide screen and caused scintillations (flashes) of light for each individual particle collision. **(6)**

$H_1^1 + Li_3^7 \rightarrow He_2^4 + He_2^4 + \text{K. E.}$ **(9)**

The historical significance was due to:

- First artificial splitting of a nucleus
- First experimental verification of Einstein's $E = mc^2$
- First transmutation due to artificially accelerated particles **(3)**

$E = \frac{1}{2}mv^2$

$E = \text{eV}$

TIP: Energy can be calculated by multiplying the voltage (p.d.) by the electron charge. This gives us electronVolts (eV) energy.

However, speed calculation can also be worked out from the kinetic energy formula $\frac{1}{2}mv^2$. Therefore, by calculating eV energy and kinetic energy and equating them, we can find the velocity of the electron that was accelerated. Notice from the equation earlier that kinetic energy can be contained in nuclear reaction equations.

$$\frac{1}{2}mv^2 = \text{eV} \Rightarrow \frac{1}{2}(1.67262171 \times 10^{-27})v^2 = (1.6 \times 10^{-19})(700 \times 10^3) \Rightarrow 8.363 \times 10^{-28}v^2 = 1.12 \times 10^{-13}$$

$$v^2 = \frac{1.12 \times 10^{-13}}{8.363 \times 10^{-28}} \Rightarrow v^2 = 1.3392 \times 10^{14} \Rightarrow v = \sqrt{1.3392 \times 10^{14}} \Rightarrow v = 1.157 \times 10^7 \text{m.s}^{-1}$$ **(4 × 3)**

TIP: Make sure to use the mass of a proton when calculating the kinetic energy. This value can be found in the tables of formulae if not given in the question.

The tube is evacuated to prevent collision of the particles with gas particles in air. This allows for a free path of acceleration. **(3)**

High velocity is used to allow the creation of new particles on collision. The greater the velocity, the greater the energy involved in the reaction. The high velocity also is required to overcome the repulsive forces between nuclei. **(4)**

Magnets are used to direct the particles in a circular direction. **(4)**

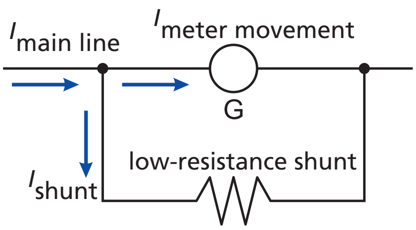
TIP: You should know from the section on circular motion and electromagnetism that a charged particle will move in a circular pattern within an EM charged field. This concept is also seen in a CRT to direct electrons on an *x/y* plane.

Circular accelerators take up less space than linear accelerators. They also allow for greater velocities since you can continue to accelerate particles prior to collision. **(3)**

No, neutrons have no charge and therefore cannot be controlled by EM fields. **(2 × 3)**

(b) A moving coil galvanometer operates on the principle of a current-carrying conductor experiencing a force in a magnetic field. **(6)**

(i)



TIP: Make sure to have a small resistance inserted in parallel to the galvanometer for ammeter conversion.

$I_{\text{main line}} = I_{\text{shunt}} + I_{\text{meter movement}}$ **(6)**

(ii) $I_{\text{main line}} = I_{\text{meter movement}}$

$V_{\text{desired voltmeter}} - V_{\text{meter movement}} = V_{\text{multiplier}}$ **(6)**

TIP: Make sure to have a large resistance inserted in series to the galvanometer for voltmeter conversion.

Voltage$_s$ (shunt) = Voltage$_g$ (galvanometer)

($V = IR$): $I_s \times R_s = I_g \times R_g$

Current through shunt resistor = (5 – 0.002A) = 4.998A **(3 × 3)**

TIP: Since the shunt resistor is in parallel with the galvanometer, the current is split between the two paths. If the galvanometer has 2mA passing through it, the shunt resistor must have (5A–2mA) passing through it.

$(4.998)(R_s) = (2 \times 10^{-3})(100)$

$$R_s = \frac{(2 \times 10^{-3})(100)}{4.998} \Rightarrow R_s = \frac{0.2}{4.998} \Rightarrow R_s = 40.016 \times 10^{-3}\Omega \ (40.016\text{m}\Omega)$$ **(2 × 3)**

Choose one from the following that is also based on the moving coil galvanometer:

- Moving coil loudspeaker
- d.c. motor **(6)**

A: Generates a very high voltage.

B: Produces sparks between the gap. **(2 × 6)**

The induction coil may be used for the following:

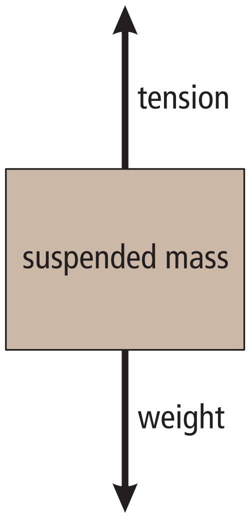
- Spark plugs in cars/engines
- Electric fences for voltage pulses **(5)**

11. (a) The direction of vibration of longitudinal waves is parallel to the direction in which the wave is travelling. **(8 × 7)**

The direction of vibration of transverse waves is perpendicular to the direction in which the wave is travelling.

(b) $s = vt \Rightarrow s = (5000\text{m})(27\text{m.s}^{-1}) \Rightarrow s = 135 \times 10^3\text{m}$ (135km)

(c)



(d) $W = mg \Rightarrow \frac{W}{g} = m \Rightarrow \frac{49}{9.8} = m \Rightarrow 5\text{kg} = m$

TIP: Remember that tension is also measured in Newtons and must equal weight here, when the suspended mass is at rest.

(e) The motion of the mass will be simple harmonic motion (SHM), when moving on the spring relative to the mass.

(f) $T = \frac{2\pi}{\omega} \Rightarrow$ (square both sides:) $T^2 = \frac{4\pi^2}{\omega^2} \Rightarrow \omega^2 = \frac{4\pi^2}{T^2}$

$(a = -\omega^2 s)$: $a = -\left(\frac{4\pi^2}{T^2}\right)s \Rightarrow a = \frac{4\pi^2 s}{T^2}$

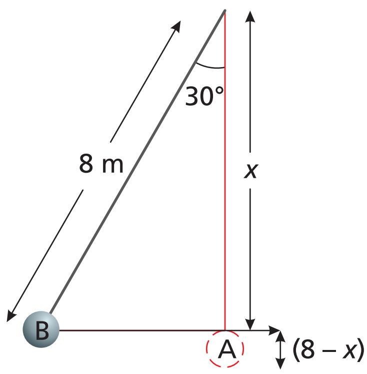
TIP: Use your formulae to identify the variables you want in the answer. In this case, a and T are required. Therefore, by manipulating ω in terms of T, you can substitute it into another formula. The minus in the formula is only needed for direction purposes and does not affect this final answer.

(g) $a_{max.} = \frac{4\pi^2 s}{T^2} \Rightarrow a_{max.} = \frac{4\pi^2(0.8 \times 10^{-2})}{(17)^2} \Rightarrow a_{max.} = \frac{0.3158}{289} \Rightarrow a_{max.} = 0.0011\text{m.s}^{-2}$

(h) According to Faraday's Law of Electromagnetic Induction, a changing magnetic field in a coil induces an emf.

12. *Answer any two of the following parts (a), (b), (c), (d).*

(a) Energy cannot be created or destroyed, but is converted from one form to another. **(4)**



$\text{Cos } 30^\circ = \frac{\text{Adjacent}}{\text{Hypotenuse}}$

$\text{Cos } 30^\circ = \frac{x}{8}$

$8\text{Cos}30^\circ = x$

$6.928\text{m} = x$

$\therefore (8 - x) = (8 - 6.928) = 1.072\text{m}$ (height through which it has been raised)

$E = mgh$ (potential energy of raised bob)

$E = (6)(9.8)(1.072) = 63.02\text{J}$ **(3 × 3)**

$E(\text{kinetic}) = E(\text{potential})$

TIP: According to conservation of energy, the energy forms will convert. Therefore, just allow the potential energy to equal the kinetic energy and calculate the value of *v* for velocity.

$\frac{1}{2}mv^2 = 63.02\text{J}$

$v^2 = \frac{63.02}{\frac{1}{2}m} \Rightarrow v^2 = \frac{63.02}{\frac{1}{2}(6)} \Rightarrow v^2 = \frac{63.02}{3} \Rightarrow v^2 = 21.01 \Rightarrow v = \sqrt{21.01} \Rightarrow v = 4.58\text{m.s}^{-1}$ **(3 × 3)**

$W = Fs \Rightarrow W/s = F \Rightarrow 63.02/5 \times 10^{-3} = F \Rightarrow 12604\text{N} = F$ **(2 × 3)**

TIP: You may use any combination of Newton's formulae here to calculate retarding force. This could also be done by calculating acceleration and then using $F = ma$.

(b) Dispersion is the separation of light into its constituent colours. **(6)**

When a narrow beam of light passes through a prism, its constituent colours are dispersed with red being deviated least, whereas light passing through a grating will have red diffracted most.

A prism will only show one observable spectrum, whereas a grating will produce multiple spectra. **(2 × 3)**

Another example of light dispersion is the production of a rainbow. **(4)**

Excited electrons moving between different energy levels cause light to be emitted as photons. **(3)**

$n\lambda = d\text{Sin}\theta \Rightarrow n = \frac{d}{\lambda} \Rightarrow n = \frac{3.33 \times 10^{-6}}{589 \times 10^{-9}} \Rightarrow n = 5.66$

TIP: Make sure to calculate the grating constant separately as $\frac{1 \times 10^{-3}\text{m}}{300}$

Also, in order to find the maximum or highest order image, you can let $\theta = 90^\circ$. This means $\text{Sin}90^\circ = 1$ in the formula.

Therefore, the highest order image would be 5. **(3 × 3)**

TIP: Only the next lowest integer value of *n* may be used as you cannot have partial orders of light. Be careful about what question is being asked, as sometimes the total number of orders is required and, in this case, 5 + 5 + 0 order would = 11 images.

(c) 1 Coulomb = the charge that passes through a point when 1 Ampere flows for 1 second. **(6)**

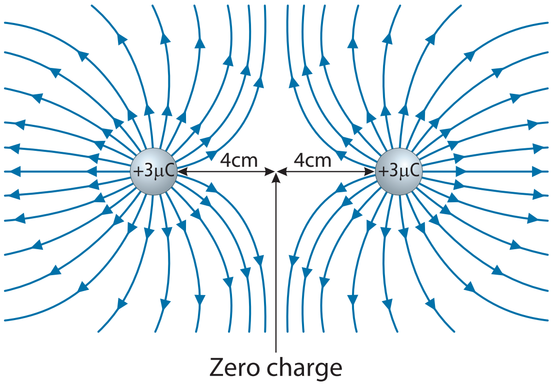
Coulomb's Law:

The electrostatic force between two point charges is proportional to the product of their charges and inversely proportional to the square of the distance between them. **(3)**

$$F = \frac{1}{4\pi\varepsilon}\frac{Q_1Q_2}{d^2}$$

$$F = \frac{1}{4\pi\varepsilon}\frac{Q_1Q_2}{d^2} \Rightarrow F = \left(\frac{1}{4\pi(8.9 \times 10^{-12})}\right)\left(\frac{(3 \times 10^{-6})(3 \times 10^{-6})}{(8 \times 10^{-2})^2}\right) \Rightarrow F = (8.9413 \times 10^9)\left(\frac{(9 \times 10^{-12})}{6.4 \times 10^{-3}}\right)$$

$\Rightarrow F = (8.9413 \times 10^9)(1.406 \times 10^{-9}) \Rightarrow F = 12.64\text{N}$ **(3 × 3)**

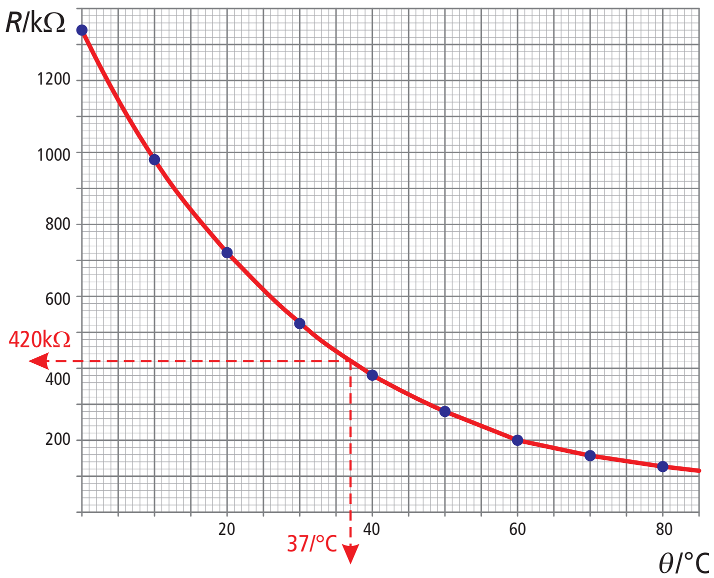


(3 + 3 + 4)

TIP: Since the charges are positive, the lines of force move out from the charge.

Since the charges are equal, the point of zero field strength is exactly halfway between them, at 4cm along the straight line point to point distance and moving out as shown.

(d) A thermometric property is a physical property that changes measurably with temperature. **(6)**



37°C **(6)**

TIP: By drawing an arrow to the curve at 420Ω and dropping down an arrow to the temperature scale axis, you can see that the corresponding temperature for this resistance is 37°C. A certain allowance is made for close to 37° being read from the graph.

0°C = 0μV

100°C = 815μV

Therefore, every 1μV = $\left(\frac{100}{815}\right)$°C

Therefore, every 1μV = 0.1227°C

A rise of 319μV = 319(0.1227°C) = 39.14°C **(3 × 3)**

TIP: By assuming a linear graph and taking the proportional change of temperature to resistance, any corresponding value can be found by knowing how much each μV means.

Each device has a different thermometric property. This causes different changes with temperature. **(4 + 3)**

TIP: It is for this reason that standard thermometers are used.

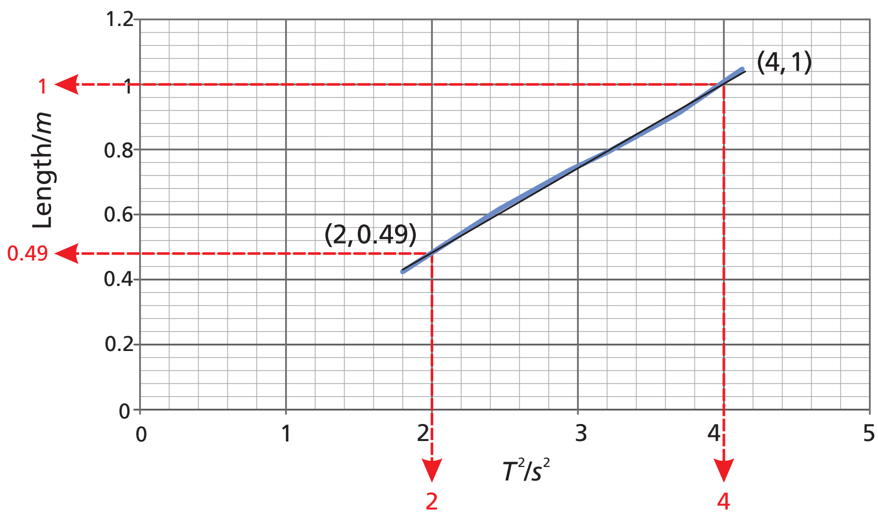
SECTION A

1. Length of pendulum was measured using a metre rule from the suspension point to the centre of gravity of the bob. The centre of gravity would be a single radius within the spherical bob. This would be labelled *l*. **(4 × 3)**

> **TIP:** If you used a split cork to suspend the pendulum, you would measure length from there. The reason for measuring one radius into the spherical bob is that the centre of the sphere is the centre of gravity you are measuring to.

The periodic time is measured by recording the time for a number *n* of oscillations. You would then divide this time by *n* to calculate the time for one period. This would be labelled *T*. **(2 × 3)**

> **TIP:** It is usual to record the time for between 30 and 50 periods of motion and then divide the total time by this number of oscillations. By doing this, you are gaining a good average periodic time for use in the formula.



> **TIP:** Make sure to draw the appropriate graph, that is length against time squared.
>
> Draw a good, best-fit straight line using at least three-quarters of the graph page and allow for the fact that an accurate graph will be required for further calculations.

To calculate *g* from this graph, you need to use the formula $g = 4\pi^2\left(\frac{l}{T^2}\right)$.

> **TIP:** Because l/T^2 is essentially the slope, choose two arbitrary points from your line and calculate slope. Then substitute this into the formula.

$$\text{Slope} = \frac{y_2 - y_1}{x_2 - x_1} \Rightarrow \text{slope} = \frac{1 - 0.49}{4 - 2} \Rightarrow \text{slope} = 0.255$$

$$g = 4\pi^2\left(\frac{l}{T^2}\right) \Rightarrow g = 4\pi^2(0.255) \Rightarrow g = 10.07\text{m.s}^{-2}$$ **(15)**

> **TIP:** Because you were asked to calculate *g* from your graph, it is important to show the examiner how you gained the value of l/T^2. By calculating the slope, you are gaining a good average from your graph but you must use your own values and not the actual data points.
>
> When you have substituted the value for the slope into the formula, you can see if it is accurate, as you should know the value for gravity. In terms of this question, a value between 9.5 and 11m.s^{-2} was acceptable.

You can improve your result by (choose any two from the following):

- Increasing the total number of oscillations
- Using a more precise digital timer
- Using a longer string and ensuring it is inextensible, you will have a more accurate length measurement with less percentage error **(4 + 3)**

> **TIP:** As with any experiment involving length, it is usual to increase length to lower percentage error, as small mistakes in measurement become less important.

2.

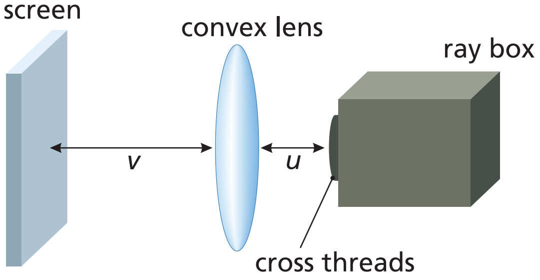


Fig. 2.1

1. Before using the equipment as shown in Fig. 2.1, approximate the focal length of the lens by focusing a distant object onto a screen and measuring image distance (*v*). This distance will be the approximate focal length (because of distant parallel rays converging at the focal point).
2. Make all distances of *u* greater than this approximate focal length. (This ensures all images will be real.)
3. Set up the equipment as shown in Fig. 2.1, making sure the lens and screen are steady.
4. Turn on the ray box and adjust the screen distance until a sharp image of the cross-threads is in focus.
5. Measure *u* and the corresponding distance *v* and record them in a table.
6. Repeat at least four times for different values of *u* and *v*.
7. Plot a graph from the results recorded in the table $\left(\text{ensure that the axes are } \frac{1}{u} \text{ and } \frac{1}{v}\right)$. **(5 × 3)**

TIP: The apparatus for this experiment is quite simple but, in the diagram, you must show where *u* and *v* are measured.

Given that the image being in focus is based on your interpretation, it is difficult to get a perfect value for *v* (image distance). Also, you need to measure from the centre of the lens to the screen, which is difficult to achieve. **(4)**

TIP: Whenever experiments are concerned with the location of images, it is wise to get a group of people to measure the distance and average the results.

First dataset: $\frac{1}{u}+\frac{1}{v}=\frac{1}{f} \Rightarrow \frac{1}{12}+\frac{1}{64.5}=\frac{1}{f} \Rightarrow 0.083+0.016=\frac{1}{f} \Rightarrow 0.099=\frac{1}{f} \Rightarrow 10.12\text{cm}=f$

Second dataset: $\frac{1}{u}+\frac{1}{v}=\frac{1}{f} \Rightarrow \frac{1}{18}+\frac{1}{22.1}=\frac{1}{f} \Rightarrow 0.056+0.045=\frac{1}{f} \Rightarrow 0.101=\frac{1}{f} \Rightarrow 9.92\text{cm}=f$

Third dataset: $\frac{1}{u}+\frac{1}{v}=\frac{1}{f} \Rightarrow \frac{1}{23.6}+\frac{1}{17.9}=\frac{1}{f} \Rightarrow 0.042+0.056=\frac{1}{f} \Rightarrow 0.098=\frac{1}{f} \Rightarrow 10.18\text{cm}=f$

Fourth dataset $\frac{1}{u}+\frac{1}{v}=\frac{1}{f} \Rightarrow \frac{1}{30}+\frac{1}{15.4}=\frac{1}{f} \Rightarrow 0.033+0.065=\frac{1}{f} \Rightarrow 0.098=\frac{1}{f} \Rightarrow 10.18\text{cm}=f$

Average value of $f=\frac{10.12+9.92+10.18+10.18}{4}=10.10\text{cm}$ **(5 × 3)**

TIP: It is a good idea to show each line as this will help you spot any arithmetical errors that may have arisen. As you can see from the individual values of *f*, they are approximately the same, since as *u* increases, *v* decreases and vice versa.

TIP: You may also use the graphical method to solve the average value for *f*. In order to do this, you need to graph 1/*u* against 1/*v* and extend the graph to cut each axis. Where the line cuts the 1/*u* axis, 1/*v* = 1/*f*. Where the line cuts the 1/*v* axis, 1/*u* = 1/*f*. You then take the two values for *f* you have gathered and average them to get the final value for *f*. This method will usually take longer than the above calculations so be aware of time if doing it. However, if you are specifically asked to find a value for *f*, from your graph, you have to solve for *f* this way.

It is difficult because the image is virtual and no image will be formed on the screen. **(6)**

TIP: It is because of the difficulty in locating virtual images that an approximate focal length is used to only gain real images.

3.

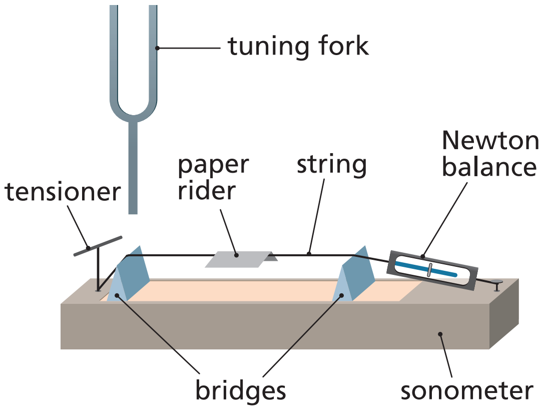
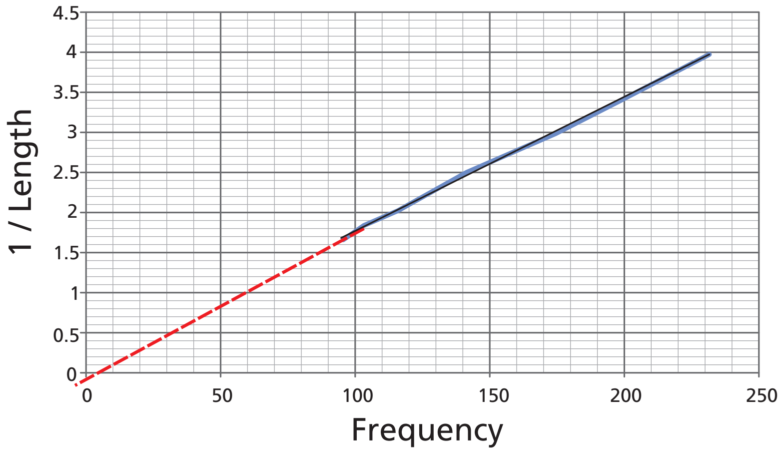


Fig. 3.1

1. Set up the equipment as shown in Fig. 3.1.
2. Adjust the bridges on the sonometer until the string is as long as is practicably possible.
3. Strike the lowest frequency tuning fork and place the base of its handle on one of the bridges.
4. While holding the tuning fork on the bridge, adjust the tensioner until resonance occurs and the paper rider falls off the string.
5. The paper rider should be on the middle of the string (antinode). (Keep tension constant from here.)
6. Record the value of length *l* between the bridges and the tuning fork frequency.
7. Now strike the next highest frequency tuning fork and place it on the same bridge.
8. Keeping the tension constant, adjust the length by moving the other bridge until resonance occurs again.
9. Record the length of the wire and the tuning fork frequency.
10. Repeat steps 5–7 for the rest of the tuning forks and record all frequency and lengths. **(5 × 3)**

l	0.603	0.553	0.503	0.453	0.403	0.353	0.303	0.253
f	95	102	114	126	141	165	194	232
l/*f*	1.66	1.81	1.99	2.21	2.48	2.83	3.30	3.95



(4 × 3)

TIP: As can be seen from the data given, you need to use the reciprocal of length in this graph. This is also evident from the word 'suitable' being used in relation to the type of graph asked for.

When you have drawn a good, best-fit line through the data points, make sure to extend the graph to the origin to show the proportional relationship of *f* to 1/*l*. This extension is shown as a red dotted line in the graph on the left.

Fundamental frequency also depends on (choose one):

- Tension: $f \propto \sqrt{T}$
- Mass per unit length: $f \propto \sqrt{\frac{1}{\mu}}$ **(6)**

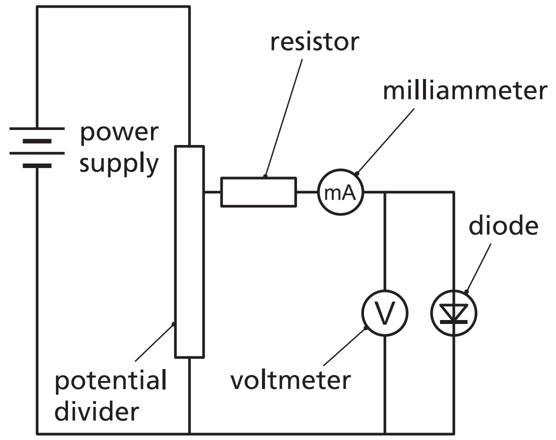
TIP: It is also useful to note that by looking at the formula for fundamental frequency, you can see the other factors involved. However, given you need to know the mandatory experiment on the relationship of frequency to tension, this should be evident.

Tension:
Keep length fixed throughout the experiment.

Use differing frequency tuning forks and adjust tension to locate resonance. Resonance will occur as before with the paper rider falling off the string. Tension can be adjusted by a tensioner or applying weights. **(7)**

TIP: The experiment for tension is the obvious one to use here since you do not need to know the experiment for adjusting mass per unit length.

4.



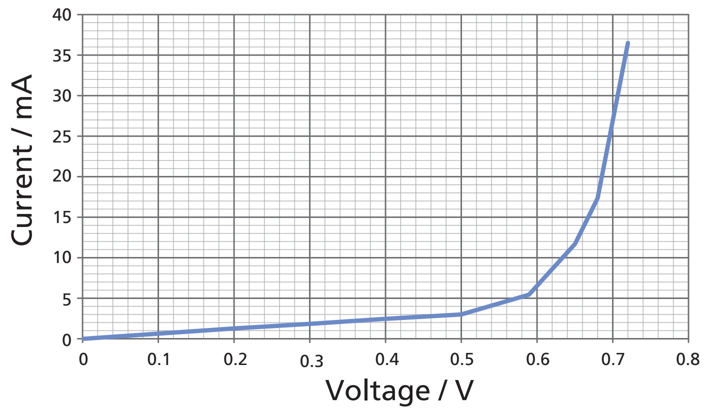
(3 × 3)

TIP: Make sure you show the arrangement for the diode in forward bias, as you will not gain the current readings given if the diode is in reverse bias.

p.d. was varied by adjusting the power supply or by using the variable resistor (rheostat/potential divider). **(3)**

The p.d. was measured using a voltmeter placed in parallel with the diode. **(6)**

TIP: Ensure that the voltmeter is placed in parallel in order to read the same voltage as the diode in the parallel path.



(4 × 3)

TIP: Try to draw a smooth curve showing the way in which current sharply rises after junction voltage has been reached.

Use at least three-quarters of the graph page to draw the graph and label the axes clearly and in the right units.

No, resistance varies as current is not proportional to voltage. This is shown from the graph not being linear or a straight line through the origin. **(6)**

TIP: It is very common to be asked for verification of a proportional relationship. If the graph is not linear, this is not the case.

If the diode is placed in reverse bias, the milliammeter needs to be replaced with a microammeter as the only current showing will be very small leakage current. The voltmeter must also be placed in parallel with the now reversed diode and microammeter. **(4 + 3)**

TIP: If the voltage is too high, you may get a larger current as breakdown occurs but, usually, you will only be asked about forward bias and junction voltage with specific data reading.

SECTION B

5. *Answer any eight questions from (a), (b), (c), etc.* **(8 × 7)**

(a) The distance between Cork and Sligo is 7.73cm; therefore, the displacement between them, according to the scale of the map = (7.73)(37.5km) = 290km North.

> **TIP:** This is a very unusual question as it requires you to physically measure a question on the paper as opposed to your own answer. However, remember that only an estimate is required here and a certain amount of leeway will be given in the accepted answer. By stating how you calculated the distance and then displacement, you can lower your chance of error marks.
>
> Also, displacement is a vector and requires a direction to be given here.

(b) Choose any one from the following:

- Tidal motion of water
- A mass on a spring oscillating about a point
- A vibrating tuning fork
- The shadow of a particle undergoing circular motion

(c) Speed of aircraft = (4)(330) = 1320m.s^{-1}

Convert to km/h: $1320\text{m.s}^{-1} = \dfrac{1.32\text{km}}{\frac{1}{3600}\text{h}} = 4752\text{km.h}^{-1}$

> **TIP:** You can convert the speed of sound to km/h first and then multiply by 4 or do as above and work out the speed in m.s^{-1} and then change each value to km.h^{-1}.

(d) $P = \dfrac{1}{f} \Rightarrow \dfrac{1}{P} = f \Rightarrow \dfrac{1}{2} = f \Rightarrow 0.5\text{m} = f$

> **TIP:** The minus may be inserted here but it only serves to show that the power is that of a concave diverging lens.

(e) Choose any three from the following:

- Sufficient suspended droplets of water in the air
- Clear bright sunlight
- Sun behind the observer
- Observer at correct angle to view rainbow

> **TIP:** Although simple answers such as the observer has their eyes open or are able to see may be true, it is presumed valid physics answers are required.

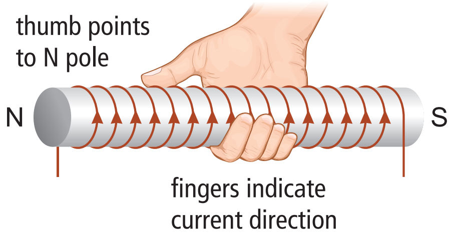
(f) Radiation.

> **TIP:** This may also be answered with electromagnetic radiation or photons.

(g) Choose any two from the following:

- Convection currents in the air close to the smoker
- Pressure differences between the interior/exterior of the building
- Wind blowing into the building
- Diffusion of particles in the air

(h)



(i) 100g $\rightarrow$ 12.5g = 8:1 mass change

Therefore, the new mass is $\frac{1}{8}$ of the original or $\frac{1}{2^3}$ of the original.

Therefore, 3 half-lives occurred in the 30 minutes.

$3\left(T_{\frac{1}{2}}\right) = 30$ minutes $\therefore T_{\frac{1}{2}} = 10$ minutes

TIP: The first thing to do in this question is to determine how many half-lives occurred and then let them equal the total time. This can also be done line-by-line as follows:
Original mass = 100g
1 half-life = 50g
2 half-lives = 25g
3 half-lives = 12.5g

(j) Ernest Walton was the Irish physicist involved in the development of the linear accelerator.

OR

The induction coil was invented by Nicholas Callan.

6. (i) $g = \frac{Gm}{d^2} \Rightarrow g = \frac{(6.6742 \times 10^{-11})(5.97 \times 10^{24})}{(6.36 \times 10^6 + 31 \times 10^3)^2} \Rightarrow g = \frac{3.9845 \times 10^{14}}{(6.391 \times 10^6)^2} \Rightarrow g = \frac{3.9845 \times 10^{14}}{4.085 \times 10^{13}} \Rightarrow 9.76\text{m.s}^{-2}$ **(6 + 3 + 3)**

TIP: You may also use the ratio of normal gravity to the new gravity in the following formula to gain the answer:
$\frac{g_1}{g} = \frac{d^2}{d_1^2}$.

(ii) $F = ma$ $(W = mg) \Rightarrow F = (180)(9.76) = 1755.9\text{N}$ **(6)**

TIP: Whichever method you used in part (a), carry the answer for acceleration due to gravity into this part. By substituting it into the standard force equation, you can calculate the downward force or weight.

(iii) $s = ut + \frac{1}{2}at^2 \Rightarrow s = (0)(13) + \frac{1}{2}(9.76)(13)^2 \Rightarrow s = 824.72\text{m}$ **(3 × 3)**

Choose any two from the following:
- Initial velocity (u) is zero.
- There is no air resistance or buoyancy.
- Gravity remains constant from point of fall for the next 13s. **(2 + 1)**

(iv) Height after the next 4 minutes and 36 seconds = 31000m – (824.72m + 5000m) = 25175.28m
Average speed = distance divided by time

Therefore, average speed $= \frac{25175.28}{276} = 91.22\text{m.s}^{-1}$ **(3 × 3)**

TIP: Just remember to convert the 4 minutes and 36 seconds into 276 seconds, as well as 25.17528km into 25175.28m, to calculate speed in metres per second.

(v) Pressure = Force/Area $\Rightarrow$ Pressure $\times$ Area = Force
Force (8.5m diameter): Force = $P(2\pi r^2) \Rightarrow F = P(2)(\pi)(4.25)^2 \Rightarrow F = 113.49P$
Force (1.8m diameter): Force = $P(2\pi r^2) \Rightarrow F = P(2)(\pi)(0.9)^2 \Rightarrow F = 5.089P$

Amount that 8.5m diameter is greater than 1.8m diameter $= \dfrac{113.49P}{5.089P} = 22.3$ times **(3 × 3)**

> **TIP:** It is also possible to cancel the common elements in this part by placing the force for 8.5m over the 1.8m and being left with just the ratio of their radii squared $\left(\dfrac{(4.25)^2}{(0.9)^2}\right)$. This will give you a ratio of 22.3:1 as well.
>
> Just remember to divide the diameter of the hemispherical parachute by 2 to gain the radius required here.

(vi) Upthrust = $mg \Rightarrow$ Upthrust = (180)(9.81) $\Rightarrow$ Upthrust = 1766N **(3 + 3 + 2)**

> **TIP:** Upthrust is just another force and therefore can be worked out as $F = ma$ or $W = mg$. However, in this case, constant velocity is mentioned, which actually means terminal velocity here. When a body is travelling at terminal velocity, the upthrust will equal its weight and no further acceleration takes place.
>
> You will also notice that the weight here is greater than the previous part, since acceleration due to gravity has increased being closer to the Earth.

7. A = Infrared (IR)
B = Ultraviolet (UV) **(6)**

> **TIP:** Infrared will always be next to visible red and ultraviolet will always be next to visible violet.

To detect IR in the EM spectrum:
1. Shine white light through a quartz prism or grating to disperse it onto a screen.
2. Place a thermometer just outside the red end of the spectrum and you should notice a heating effect, showing the presence of invisible IR.

OR

To detect UV in the EM spectrum:
1. Shine white light through a quartz prism or grating to disperse it onto a screen.
2. Place a piece of paper with Vaseline on it just outside the violet side of the spectrum and you should begin to see it glow, thereby showing the presence of invisible UV light. **(3 + 3 × 2)**

$$c = f\lambda \Rightarrow f = \frac{c}{\lambda} \Rightarrow f = \frac{3 \times 10^8}{4} \Rightarrow c = 7.5 \times 10^7\text{Hz}$$

Therefore, this radiation is from the short wave radio or TV/FM radio section shown. **(3 × 3)**

> **TIP:** All EM waves travel at 3×10^8m.s^{-1} in a vacuum. If you are not given a value for c, assume this. Although you are only given the exponential values for each section, you should be able to clearly see that short wave TV/FM radio contains frequencies between 10^7 and 10^9.

In interference, waves from different sources combine to form a resulting amplitude made up of each wave's individual amplitude.

In diffraction, this is the spreading out of a wave as it moves through a gap or around an obstacle. **(4 × 3)**

No, a diffraction grating that diffracts light cannot also diffract X-rays. **(3)**

Choose any one from the following:
- Line spacing in diffraction grating is too large for X-ray diffraction to also occur.
- Line spacing in diffraction grating must match the wavelength present for diffraction.
- X-rays require much smaller widths between grating lines. **(6)**

Longitudinal is another type of wave motion. **(3)**

- Transverse waves can be polarised; longitudinal waves cannot be polarised.
- Transverse waves have a direction of vibration that is perpendicular to the direction in which the wave is travelling. Longitudinal waves have a direction of vibration that is parallel to the direction in which the wave is travelling. **(4 + 4)**

8. (i) Nuclear fission is the splitting of a large nucleus into two similar, smaller nuclei with the release of neutrons and energy. Nuclear fusion is the joining of two small nuclei to create a larger single nucleus with the release of energy. **(4 × 3)**

(ii) Choose two from the following:

- Nuclear fusion produces little or no radioactive/harmful by-products compared to nuclear fission.
- Nuclear fusion releases significantly higher amounts of energy than nuclear fission.
- The fuel required for nuclear fusion is relatively cheap and plentiful, whereas fission requires very expensive radioisotopes, such as uranium. **(2 × 6)**

(iii) Mass of reactants: (2.014102 + 3.016049)u = 5.030151u
Mass of products: (4.002603 + 1.008672)u = 5.011275u
Decrease in mass: (5.030151 – 5.011275)u = 0.018875u
Kg mass equivalent: $0.018875 \times 1.66 \times 10^{-27} = 3.1333 \times 10^{-29}$kg
Energy produced: $E = mc^2 \Rightarrow E = (3.1333 \times 10^{-29})(3 \times 10^8)^2 \Rightarrow E = 2.82 \times 10^{-12}$ J **(6 × 3)**

TIP: It is simpler to work out mass difference in 'u' first and then make one conversion to kg. You may use the value for 'u' given in the question at the time or from the tables. Always make sure to convert to kg before using $E = mc^2$.

You may also give your answer in eV. If this is asked for, divide the Joule answer by the charge on an electron (1.6×10^{-19}) to gain the answer. In this case, it would be 17.62MeV.

(iv) $F = \dfrac{Q_1 Q_2}{4\pi\varepsilon d^2} \Rightarrow F = \dfrac{(1.602 \times 10^{-19})(1.602 \times 10^{-19})}{4\pi(8.854 \times 10^{-12})(2 \times 10^{-9})^2} \Rightarrow F = \dfrac{2.566 \times 10^{-38}}{4.4505 \times 10^{-28}} \Rightarrow F = 5.766 \times 10^{-11}$N **(3 × 3)**

TIP: Free space assumes you can use 8.854×10^{-12} for ε_0. The only other thing to bear in mind is that although deuterium and tritium are of different masses, they still only have one proton each and this gives them the same positive charge of 1.602×10^{-19}C each.

(v) High temperatures are required for very high speeds. This increases kinetic energy to the point where they can combine and overcome the Coulomb force of repulsion between each nucleus present. **(5)**

9. Resistance is the ratio of voltage to current. **(3)**

TIP: You may also give this as a formula but explain the letters involved.

(i) $V_{total} = V_1 + V_2 + V_3$

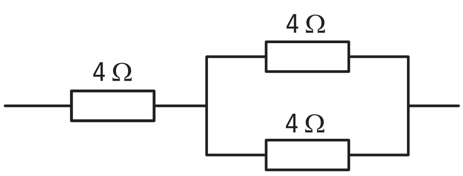
Since $V = IR$:

$I_{total} R_{total} = I_{total} R_1 + I_{total} R_2 + I_{total} R_3$

Divide by I_{total}:

$R_{total} = R_1 + R_2 + R_3$ **(15)**

(ii)



(3 + 6)

(iii) The fuse is always connected in the live to protect against too much current flowing. Because of the heating effect of current, if too much current flows, the fuse will melt and break the circuit. **(11)**

(iv) If a galvanometer is connected between points A and C, and no deflection is observed, then the bridge is balanced. **(6)**

TIP: If the current differs between one bridge and another, the difference in current will flow through the galvanometer and register as a deflection.

(v) $\frac{R_1}{R_2} = \frac{R_3}{R_4} \Rightarrow \frac{2200}{1000} = \frac{R_3}{440} \Rightarrow (2.2)(440) = R_3 \Rightarrow 968\Omega = R_3$ **(6)**

(vi) If black paper causes resistance to change, then the resistor must be affected by light. Therefore, it is a light-dependent resistor (LDR). **(3)**

TIP: You may also refer to this resistor as a photoresistor. However, the main point here is recognising that the only factor to change the resistance is light incident on it. This should help to choose which device is present.

Choose any one from the following:

- Light meters
- On/off switch for street lights
- Traffic light controls
- Automatic doors
- Burglar systems **(3)**

10. *Answer either (a) or (b).*

(a) (i) A positron is an electron that has a positive charge. **(6)**

TIP: The positron is the antiparticle of the electron and was the first antimatter particle to be named.

(ii) ${}^{0}_{-1}e + {}^{0}_{-1}e \rightarrow \gamma \rightarrow \gamma$ **(6)**

TIP: You may also give the equation as: $e^+ + e^2 \rightarrow 2\gamma$.

(iii) In this reaction, mass is converted into energy. **(3)**

Two photons are produced in order to conserve momentum. **(3)**

TIP: You need to keep the conservation laws of mass–energy, charge and momentum in mind when answering each of these types of question.

$E = mc^2 \Rightarrow E = (9.1093826 \times 10^{-31})(3 \times 10^8)^2 \Rightarrow E = 8.198444 \times 10^{-14}\,\text{J}$

$E = hf \Rightarrow f = \frac{E}{h} \Rightarrow f = \frac{8.198444 \times 10^{-14}}{6.626069 \times 10^{-34}} \Rightarrow f = 1.237 \times 10^{20}\,\text{Hz}$ **(5 × 3)**

TIP: Make sure you calculate only the energy released from a single electron/positron since two photons are produced and each gains half the energy conversion. When you have the number of Joules liberated, use $E = hf$ to calculate the equivalent frequency of photon that could be created.

The photons generally have greater frequency than the minimum calculated because the colliding electron/positron would most likely have initial kinetic energy before pair annihilation. This extra energy can then be added into the equation as well as rest mass. **(3)**

(iv) High speeds are required to overcome repulsive forces of like charge particles. **(6)**

TIP: This was also asked in the question on why high temperatures are involved in fusion reactions.

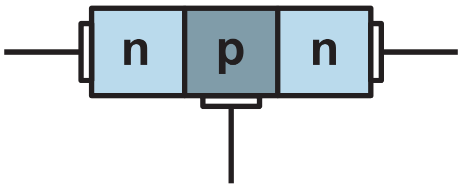
Charged particles are given high speeds from EM control of particle accelerators, such as cyclotrons or linear accelerators. **(6)**

TIP: This is why only charged particles can be accelerated in these types of accelerator. You may be asked why neutral particles cannot be manipulated in accelerators and this can be explained in the same way.

(v) They would violate the conservation of charge law. **(8)**

TIP: As already stated, keep the conservation laws in mind when answering many of these types of question about why certain events can/cannot happen.

(b)

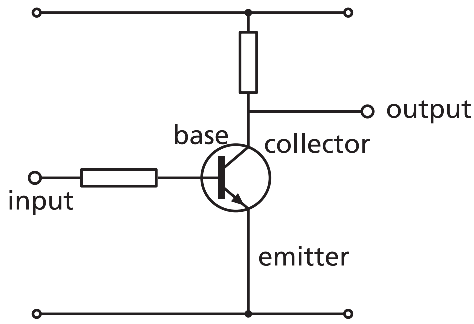


(6)

The two outer negative layers have electron majority carriers and are of a thicker structure. These are the emitter/collector section. **(6)**

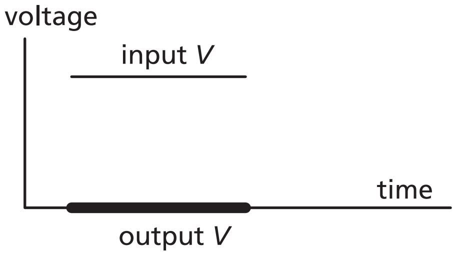
The middle layer has positive holes as majority carriers and is of a thin structure. This is the base section. **(6)**

(i)



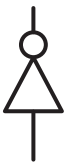
(15)

(ii)



(9)

(iii)



I/P	O/P
0	1
1	0

(9)

(iv) Transistors may be used for switching or voltage amplification. **(5)**

11. (a) If wind speed doubles, power increases by a factor of 8. **(8 × 7)**

TIP: This can be seen by the formula given where *P* is proportional to the cube of wind velocity.

(b) Because the wind is slowed down – as opposed to stopped – only some of the energy can be extracted.

(c) Electromagnetic induction occurs when a changing magnetic field induces an emf, which in turn produces a current.

(d) A transformer is used to change the output voltage to 230V.

(e) Sound intensity would double when moving from 200m away to 150m away.

TIP: Sound intensity levels are 42dB at 200m and 45dB at 150m. This represents a 3dB change. Every 3dB change equates to a halving/doubling of sound intensity. It is usual for sound-related questions to move in stages of 3dB to calculate this.

(f) $T = \frac{2\pi r}{v} \Rightarrow v = \frac{2\pi r}{T} \Rightarrow v = \frac{2\pi(30)}{(3)} \Rightarrow v = 62.83\text{m.s}^{-1}$

(g) A diode or rectifier is usually used to convert a.c. to d.c. as they only allow one-way current direction.

(h) Choose any one from the following:
- Biomass
- Geothermal
- Solar
- Wave

12. *Answer any two questions from (a), (b), (c) or (d).*

(a) (i) $T = \frac{2\pi}{\omega} \Rightarrow \omega = \frac{2\pi}{T} \Rightarrow \omega = \frac{2\pi}{0.8} \Rightarrow \omega = 7.854\text{s}^{-1}$ **(6)**

(ii) Any particle changing direction is also accelerating. **(4)**

TIP: This is a common point about circular motion. Even though a particle is moving at constant speed in a circle, it must also be accelerating as it is also constantly changing direction.

(iii) $a = \omega^2 r \Rightarrow a = (7.854)^2(2) \Rightarrow a = 123.37\text{m. s}^{-2}$ **(9)**

TIP: The acceleration in this case can also be stated as being towards the centre of orbit, given that acceleration is a vector and has direction.

(iv) Kinetic energy $= \frac{1}{2}mv^2 \Rightarrow E = \frac{1}{2}(7.26)(15.71)^2 \Rightarrow E = 895.67\text{J}$ **(9)**

TIP: You can use the formula that $v = \omega r$ to substitute in the value for v. In this case $v = (7.854)(2) = 15.71\text{m.s}^{-1}$.

(b) (i) $n = \frac{\text{Sin } i}{\text{Sin } r} \Rightarrow \text{Sin } r = \frac{\text{Sin } i}{n} \Rightarrow \text{Sin } r = \frac{\text{Sin}(60)}{1.5} \Rightarrow \text{Sin } r = 0.5774 \Rightarrow r = \text{Sin}^{-1}(0.5774) \Rightarrow r = 35.26°$

Therefore, $\theta = 90° - 35.26° = 54.74°$ **(4 × 3)**

TIP: Remember that the angles of incidence and refraction are those measured between the normal and incident/refractive rays. Therefore, the initial angle given of 30° shows us that the angle of incidence is actually 60°. Also, the final answer for the refractive angle as 35.26° shows us that the actual value for θ is 54.74°.

TIP: It is also important to make sure your calculator is in the correct mode of DRG/DEG for these calculations.

(ii) $n = \frac{1}{\text{Sin } C} \Rightarrow \text{Sin } C = \frac{1}{n} \Rightarrow \text{Sin } C = \frac{1}{1.5} \Rightarrow \text{Sin } C = 0.67 \Rightarrow C = \text{Sin}^{-1}(0.67) \Rightarrow C = 41.81°$

Therefore, the angle θ would be 90° – 41.81° = 48.19° **(9)**

(iii) $n = \frac{c_a}{c_g} \Rightarrow C_{glass} = \frac{C_{air}}{n} \Rightarrow C_{glass} = \frac{2.9979 \times 10^8}{1.5} \Rightarrow C_{glass} = 2 \times 10^8 \text{m.s}^{-1}$ **(7)**

(c) (i) The graph shows three main stages. The first increasing temperature stage shows the crushed ice increasing in temperature until it reaches melting point of 0°. The second stage shows that the ice is changing state and latent energy is being used. This continues with no temperature change until all of the ice has changed state to water. The last stage shows that the melted ice starts to increase in temperature again as more heat is added to it. This results in an increase in temperature. **(4 × 3)**

(ii) A heating coil with a joulemeter may have been used to monitor constant energy supply. **(6)**

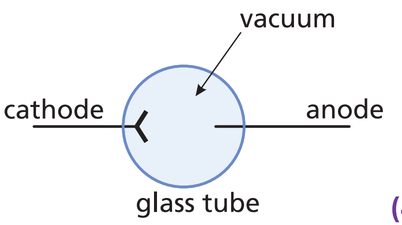
TIP: It would also be common to connect an ammeter and rheostat into the circuit as you would in the Joule's Law experiment, in order to keep the heating effect constant throughout the experiment.

(iii) Energy required to melt ice only = 59000J – 10000J = 49000J

$E = ml \Rightarrow \frac{E}{m} = l \Rightarrow \frac{49000}{150 \times 10^{-3}} = l \Rightarrow 3.267 \times 10^5 \text{J kg}^{-1} = l$ **(10)**

TIP: Only use the energy supplied to melt the ice to calculate the specific latent heat of fusion. Any other energy supplied was only used to raise temperature before and after melting.

(d) (i)



(4 × 3)

(ii)

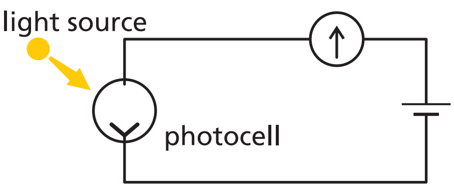


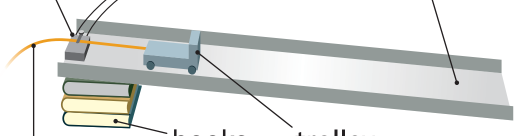
Fig. 12.1

1. Arrange the equipment as shown in Fig 12.1.
2. By varying the distance between the light source, photo-current also varies.
3. In order to increase the current, bring the light source closer to the photocell. **(4 × 3)**

(iii) Choose any one from the following:
- Burglar systems
- Fire alarms
- Pilot light monitors
- Automatic doors
- Soundtrack synchronisation
- Photocopiers **(4)**

SECTION A

1.



(3 × 3)

> **TIP:** You may also use any equipment you are familiar with, such as motion sensors, to measure velocity. The important thing to remember is always show the crucial equipment that is required to verify conservation of momentum. In this case, a method of measuring initial and final velocity is required along with the mass of the colliding trolleys.

In order to enable the trolley to move with constant velocity, the track must be raised just enough to overcome friction but not so much that it accelerates the trolley. **(6)**

> **TIP:** It would also be acceptable to mention the precautions you would take in this type of experiment, such as oiling wheels or dusting the track.

Constant velocity is demonstrated by equal spacing between the dots on the ticker tape or, in the case of using a set of light gates, an equal time interval would show on both. **(6)**

> **TIP:** If you were using a data-logger connected to a motion sensor, a horizontal velocity–time graph indicates constant velocity.

Ticker tape method:

1. Measure the distance between the dots with a metre rule (s).
2. Count the number of spaces between the dots (n).
3. Each space is $\frac{1}{50\text{s}}$. Therefore, time is $\frac{n \times 1}{50\text{s}}$ (t).
4. Velocity $= \frac{s}{t}$.

OR

Light gate method:

1. Measure the length of sail (s).
2. Record the time interval from the light gate (t).
3. Velocity $= \frac{s}{t}$.

OR

Data-logger method:

1. Select distance–time graph function on data-logger.
2. Select the calculation of slope from this graph.
3. Slope of a distance–time graph = velocity. **(9)**

$\rho = m \times v$

Initial momentum: $\rho = m \times v \Rightarrow \rho = (230 \times 10^{-3})(0.53) \Rightarrow \rho = 0.1219\text{kg m.s}^{-1}$

Final momentum: $\rho = m \times v \Rightarrow \rho = (390 \times 10^{-3})(0.32) \Rightarrow \rho = 0.1248\text{kg m.s}^{-1}$

Momentum is conserved since $0.1219\text{kg m.s}^{-1} \approx 0.1248\text{kg m.s}^{-1}$ **(8)**

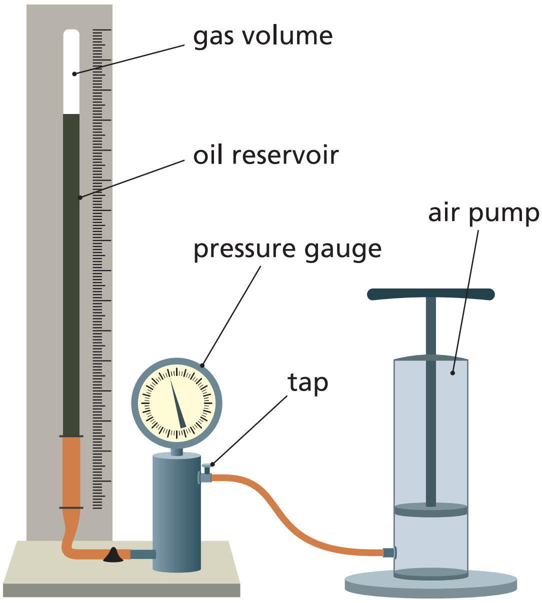
> **TIP:** Remember that momentum is measured in kg m.s^{-1}. Therefore, make sure all units are in kg and m.s^{-1} when getting their product. It is expected that you will not get an exact initial and final momentum because of errors, but as long as they are almost equivalent, this verifies the principle of conservation of momentum.

Choose any one from the following:

- Use a digital balance to record the mass of trolleys.
- Allow more time to pass to calculate initial/final velocity.
- Take an average of distance readings to reduce parallax error. **(2)**

> **TIP:** If a metre rule is involved, parallax will be present. By placing the rule perpendicular to the object you are measuring or by taking more averages, you will reduce this error. However, it is worth noting that parallax is a good standard error to keep in mind for these mandatory experiment questions.

2.



(4 × 3)

TIP: You may also use the apparatus whereby you turn a screw gauge to change volume and read a Bourdon gauge for pressure. As long as you include apparatus that has the means of varying volume and reading both volume and pressure, you have covered the required apparatus.

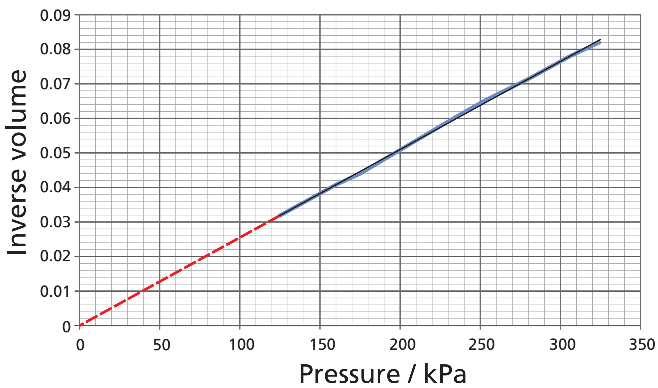
Pressure was varied by changing volume. This could be done by using a pump, screw gauge, piston or any other suitable means. **(3)**

Pressure was measured from the Bourdon gauge (pressure gauge) and volume was recorded from the graduated scale on the side of the container. **(2 × 2)**

TIP: If you use the apparatus above, you need to make sure you read the gas volume and not the oil level.

A time interval has to be allowed for the temperature of the gas to cool after changing pressure. When the gas has been agitated, it needs time to reach thermal equilibrium again. **(3)**

TIP: Boyle's Law relies on temperature being constant. Therefore, you need to keep this as close to constant as possible during the experiment readings.



The graph verifies Boyle's Law because a straight line through the origin shows the proportional relationship of pressure to the inverse of volume.

pV = constant **(6 × 3)**

TIP: As can be seen from the graph, the red dotted line is the extension that shows the graph travelling through the origin. This is necessary to verify Boyle's Law.

You should draw a good straight line through the points given and allow at least three-quarters of the graph page to show the graph. You should also know that an extension of the graph is required and leave space for it. A good number of marks is given for a good graph and you should appropriate time for it. Also, pay particular attention to the word 'suitable' as it implies a calculation has to be done to the given figures before graphing them. In this case, you must use the inverse of volume, instead of just volume.

3. A source of monochromatic light could be a laser or sodium vapour lamp. **(3)**

TIP: Whichever source you use, you should be able to describe the method that goes with it, in later questions.

Laser method:

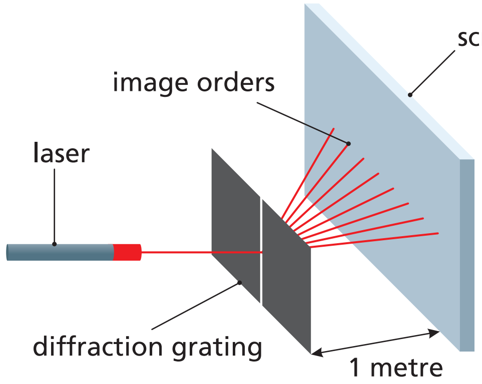


Fig. 3.1

1. Set up the equipment as shown in Fig. 3.1, with the screen set 1m away from the grating. Label this distance *a*.
2. Make sure the grating is perpendicular to the laser beam.
3. When the laser shines through the grating, it will diffract into different orders onto the screen.
4. Measure the distances between the first order fringes and label them 2*b*.
5. Repeat these measurements for each order, labelling the distance to the screen as *a* and the distance between the orders as 2*b*.
6. Record the measurements in the table for each order.
7. Calculate the diffraction constant *d* from the diffraction grating you are using.
   (Remember that $d = \dfrac{1 \times 10^{-3}}{\text{numbers of lines per mm}}$.)
8. From the table, you can calculate the angles of deviation (θ) for each order using the Tan ratio from trigonometry. This calculation is achieved by stating $\text{Tan}\theta = \dfrac{b}{a}$.
9. When you have all of the angles, you can use the formula $n\lambda - d\sin\theta$ to find wavelength.

OR

Spectrometer method:

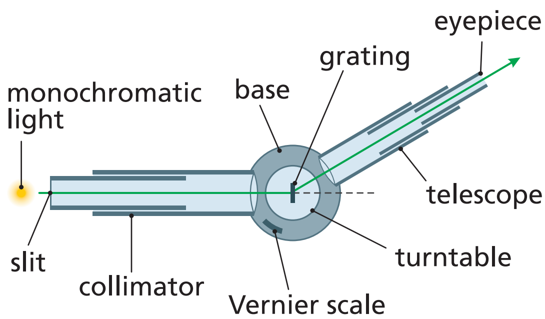


Fig. 3.2

1. Set up the equipment as shown in Fig. 3.2.
2. Allow a few minutes for the lamp to warm up and emit its characteristic colour.
3. Adjust the eyepiece until the cross-threads are in focus.
4. Adjust the telescope while viewing a distant object to gain focus.
5. While looking through the telescope at the light source, adjust the slit until it is as narrow as possible but still allowing light through the slit.
6. Level the turntable with the screws.

7. Place the diffraction grating in the holder perpendicular to the turntable.
8. As you look through the telescope, locate the first order image on one side and centre the cross-threads on the bright fringe.
9. Record the reading on the Vernier scale.
10. Locate the first order image at the other side and record the reading on the Vernier scale.
11. Repeat steps 8–10 for the other orders of images.
12. Calculate the diffraction constant *d* from the diffraction grating you are using.

    $\left(\text{Remember that } d = \frac{1 \times 10^{-3}}{\text{numbers of lines per mm}}.\right)$
13. Record all values for left and right order angles in the table and calculate the average angle of diffraction for each order.
14. Use the formula to calculate wavelength. **(3 × 3)**

TIP: When describing experiments, you need only put in a simple bullet point method and may not need the full method as shown. It is very important to practise these mandatory descriptions beforehand and picture the experiment as you would have done it. Only choose the experiment method you are familiar with and can picture clearly, as this will make it easy to recall the main steps. As you can see, the spectrometer method can sometimes be easier to describe as the angles are on the Vernier scale and do not require trigonometry to calculate. However, the laser method is easier to draw and do as a practical.

$$d = \frac{1 \times 10^{-3}\text{m}}{400} \Rightarrow d = 2.5 \times 10^{-6}$$

TIP: It is easier to work out the grating constant based on the number of lines per mm as opposed to per metre. To do this, write 1mm (1×10^{-3}m) on top and divide by the number of lines per mm. The answer will then be in metres and suitable for use in the formula.

$$n\lambda = d\text{Sin}\theta$$

First order: Average θ: $\left(\frac{14.90 + 14.81}{2}\right) = 14.855$

$$n\lambda = d\text{Sin}\theta \Rightarrow (1)(\lambda) = (2.5 \times 10^{-6})(\text{Sin}14.855) \Rightarrow \lambda = 640.93\text{nm}$$

Second order: Average θ: $\left(\frac{30.98 + 31.01}{2}\right) = 30.995$

$$n\lambda = d\text{Sin}\theta \Rightarrow (2)(\lambda) = (2.5 \times 10^{-6})(\text{Sin}30.995) \Rightarrow 2\lambda = 1287.41 \Rightarrow \lambda = \left(\frac{1287.41}{2}\right) \Rightarrow \lambda = 643.70\text{nm}$$

Average $\lambda = \left(\frac{640.93\text{nm} + 643.70\text{nm}}{2}\right) = 642.32\text{nm}$ **(4 × 3)**

TIP: The important aspect of this question is to carefully lay out your variables before substituting them into the formula separately. Calculate *d* and then work out the average value of θ for first and second order images. Calculate the value of λ for each order and then average these. By taking a little extra time to state your values first before substituting, you minimise the risk of arithmetical errors or blunders. You also show the examiner exactly what you are aiming to work out.

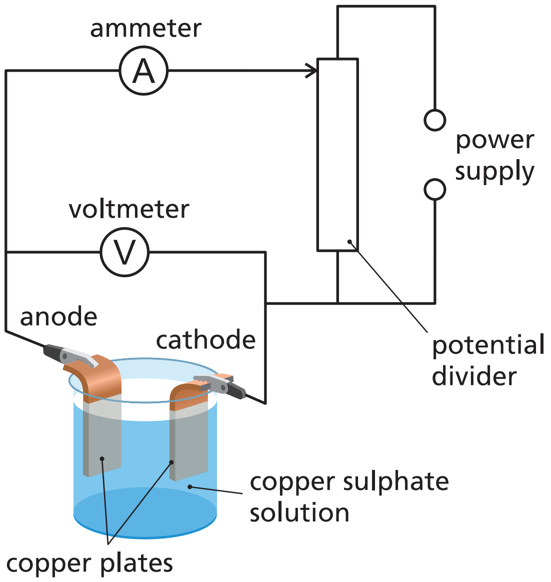
(i) Longer wavelength means increased diffraction and more spaced-out images. **(6)**

(ii) By reducing the number of lines per mm, you are diffracting the light less and the bright images produced will be closer together. **(6)**

TIP: The more lines per mm or bigger wavelength of light, the more the wave is diffracted and deviates by a greater angle. Imagine trying to squeeze a bigger and bigger wave through a narrow grating and it will deviate out more and more as it passes through.

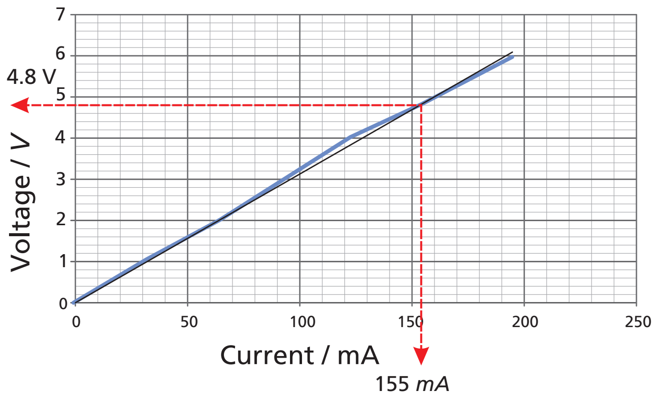
(iii) Instead of gaining single bright monochromatic fringes, you will get a multicoloured spectrum of fringes equivalent to the colours of the rainbow, since the white light has been split into its constituent colours by the grating. **(4)**

4.



(3 × 3)

p.d. was varied by adjusting the power supply or by adjusting the variable resistor (rheostat/potential divider). **(3)**



(4 × 3)

TIP: The graph should be a good best-fit line with clearly labelled axes and take up at least three-quarters of the graph page. It is usually assumed that you will be asked to calculate results from your graph; therefore, it is very important to draw an accurate, easy-to-read graph that you can demonstrate to the examiner how you gained your results.

Using the graph, we know it goes through the origin. Therefore, the slope can be calculated as y/x with one set of coordinates. Taking values from your own graph of (4.8,0.155), the slope is 4.8/0.155 = 30.97Ω. **(6)**

TIP: Using Ohm's Law, we know that $V = IR$. Therefore, $V/I = R$. Therefore, by calculating slope, you are working out R. Because the graph goes through the origin, you only need to divide one value of voltage by one value of current, but remember to use *mA* for current.

The cathode began to be coated with fresh copper and increased in mass. At the same time, the anode lost mass. **(5 + 5)**

TIP: You may also refer to the concentration of the electrode solution as the copper is eroded from the anode and deposited on the cathode.

SECTION B

5. *Answer any eight questions from (a), (b), (c), etc.* **(8 × 7)**

(a) $v^2 = u^2 + 2as \Rightarrow (0)^2 = (20)^2 + 2a(50) \Rightarrow 0 = 400 + 100a \Rightarrow -400 = 100a \Rightarrow \frac{-400}{100} = a \Rightarrow -4\text{m.s}^{-2} = a$

$F = ma \Rightarrow F = (1500)(-4) \Rightarrow F = -6000\text{N}$

> **TIP:** By stating each variable and using signs to denote positive or negative acceleration, you can see if an answer is right. A body slowing down should have a negative acceleration (retardation) as shown here. This then translates into a negative retarding force.

(b) Because gravitational force is affected by the distance from a body's centre, then as the distance from the Earth's centre changes, so too does the value of *g* (gravitational acceleration).

> **TIP:** You may also refer to the fact that the Earth is an oblate spheroid and not spherical. This would result in differing distances from the centre as you moved around it.

(c) A convex mirror will give a greater field of view and enable the user to see more.

(d) The relative motion between source and/or observer causes the Doppler effect.

(e) $C = \frac{\varepsilon A}{d} \Rightarrow \frac{Cd}{\varepsilon} = A \Rightarrow \frac{(5 \times 10^{-12})(2 \times 10^{-2})}{(8.854 \times 10^{12})} = A \Rightarrow 0.0113\text{m}^2 = A$

(f) If the RCD is rated at 30mA, this means that if current exceeds 30mA between the live and neutral, the RCD will 'trip' and break the current.

> **TIP:** You may also say that current of more than 30mA flows to earth.

(g) Millikan is associated with the charge on an electron (1.6×10^{-19}C).

(h) Light intensity affects current in a photocell.

> **TIP:** This is because of the photoelectric effect and each photon causing an electron to be emitted.

(i) Neutrons are used to cause further fission in a chain reaction or to initiate fission in the first place.

> **TIP:** The initial reaction is caused by a neutron striking the nucleus, which then releases further neutrons to continue on the chain reaction.

(j) A baryon has 3 quarks, whereas a meson has a quark and antiquark.

OR

Choose any two from the following:

- Use lower resistance wire.
- Laminate the core.
- Lower magnetic flux leakage.
- Reduce hysteresis.

6. (a) The moment of a force is the magnitude of the force multiplied by the perpendicular distance from the axis to the force. **(6)**

Given the toy has such a low centre of gravity, it is very stable. When the toy is in a vertical position, it has no turning effect but when it is in a non-vertical position, it has a turning effect about the fulcrum which returns it back to the vertical position. **(6)**

> **TIP:** The same principle can be seen in safety cups where they don't fall over due to their low centre of gravity and rounded shape. It is also seen in large vehicles that can lean quite an amount before their centre of gravity moves outside the base and falls over.

(b) Conditions necessary for equilibrium are:

The vector forces sum to zero.

> **TIP:** This means all upward forces equal downward forces or left forces equal right forces.

The sum of the moments equal zero, about any point. **(6 + 3)**

> **TIP:** This means that the sum of the anticlockwise moments equals the sum of the clockwise moments about any point.

Clockwise moment: (40)(9.8)(0.8) = 313.6Nm

Anticlockwise moments: (30)(9.8)(1.8) = 529.2Nm

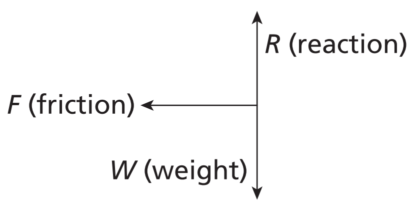
Therefore, the anticlockwise moment is (529.2 – 313.6)Nm more and requires to be cancelled to balance the see-saw:

$(45)(9.8)(x) = 215.6 \Rightarrow 441x = 215.6$

$\Rightarrow x = \frac{215.6}{441} \Rightarrow x = 0.489\text{m} \Rightarrow x = 0.49\text{m}$ from fulcrum, to the right. **(12)**

> **TIP:** The first mistake to avoid here is to change mass to weight since weight is a force. You need only multiply mass by gravity to do this. Next, you need to see which child is exerting the greater moment and add the third child to balance this out. In this case, an additional clockwise moment is required which means adding the mass of the third child on the right of the fulcrum.

(c)



(3 × 3)

$F = m\omega^2 r \Rightarrow \frac{F}{mr} = \omega^2 \Rightarrow \sqrt{\frac{F}{mr}} = \omega \Rightarrow \sqrt{\frac{50}{(32)(2.2)}} = \omega \Rightarrow \sqrt{0.7102} = \omega \Rightarrow 0.843\text{rad.s}^{-1} = \omega$ **(9)**

> **TIP:** By substituting the force of friction into the formula for angular velocity, you can see what angular velocity will cancel it. Remember that friction is considered a 'lazy' force and will only increase to match the motion but will not exceed its set limit of 50N in this question.

The child should remain stationary if friction were not present. **(5)**

> **TIP:** Think of low friction surfaces and how things can slip past each other when in motion. For example, if a tablecloth is quickly pulled from under cups/saucers, the cloth can move but leave the cups/saucers reasonably stationary.

7. (a) $mc\Delta\theta$ (milk) = ml (steam) + $mc\Delta\theta$ (water) **(6)**

TIP: The energy that is supplied by the steam changing state and cooling down is all transferred to the milk. Remember that when the steam has changed state, it is a temperature change from 100˚C water to the final temperature of 70˚C. For this reason, we can state the formula above as $mc\Delta\theta$ (water).

It is always a good idea to write these energy equations in terms of what you start with on one side of the equals (milk) and what you add on the other side of the equals (steam).

$$(160 \times 10^{-3})(3900)(50) = (m_s)(2.34 \times 10^6) + (m_s)(4180)(30)$$

$$31200 = 2.34 \times 10^6\, m_s + 125400 m_s$$

$$31200 = 2465400 m_s$$

$$\frac{31200}{2465400} = m_s$$

$$12.66 \times 10^{-3}\text{kg} = m_s \quad \textbf{(6)}$$

TIP: To avoid decimal errors, it can be a good idea to state all masses in kg and use exponentials. Also, try to have a good estimate of what your answer should be. You should expect that only a few grams of steam would be added for this temperature change and expect a mass of this magnitude.

Remember also to state the temperature changes for each part before substituting them in, to avoid mixing them up. The milk is heating up from 20˚C to 70˚C ($\Delta\theta = 50$) and the steam is cooling from 100˚C to 70˚C ($\Delta\theta = 30$).

Energy gained by the spoon = energy lost by the hot drink

$C\Delta\theta$ (spoon) = $mc\Delta\theta$ (hot drink)

TIP: The spoon's mass is not given and only heat capacity is required in the answer. Therefore, you need only use the formula for heat capacity rather than specific heat capacity. It is still an energy equation, though.

$$(C)(48) = (172.66 \times 10^{-3})(4.05 \times 10^3)(2)$$

TIP: The mass of the hot drink is now 160g (original milk) + 12.66g from the added steam giving a total mass of 172.66g. Also the SHC of the hot drink is given in the question as it is now a mixture of milk and water.

$$48C = 1398.546$$

$$C = \frac{1398.546}{48}$$

$$C = 29.14\ \text{J.K}^{-1} \quad \textbf{(4} \times \textbf{3)}$$

(b) Choose any two from the following:

- Conduction losses – by changing the insulation material, it can be reduced.
- Radiation losses – by using a bright reflective surface inside, it can be reduced.
- Convection losses – by insulating and covering with a lid, it can be reduced.
- Evaporation losses – by placing a lid on the container, it can be reduced. **(4 + 4 & 3 + 3)**

(c) The principle of operation of a thermocouple is based on one junction being kept at a constant reference temperature (reference junction) and the other junction being heated (hot junction). As the hot junction increases in temperature relative to the reference junction, the emf developed increases. Therefore, the emf is the thermometric property involved. **(3 × 3)**

To calibrate a thermocouple, do the following:

1. Place one junction in melting ice (0˚C) and the other junction in water.
2. Connect a voltmeter to the thermocouple and place a thermometer in the water.
3. Heat the water in steps of 10˚C and note temperature versus emf value at each stage.
4. Plot a graph of emf versus temperature for this thermocouple. **(3 × 3)**

TIP: The calibration curve experiment is essentially the same for all the devices used. The only difference is the specific device but the common part is the gradual incremental heating of the water and the recording of the thermometric data versus temperature.

8. (a) Waves with the same frequency that are in step or a fixed amount out of step are known as coherent waves. **(6)**

Total destructive interference also requires same amplitude of waves and each wave being exactly 180° out of phase. **(8)**

> **TIP:** Destructive interference can vary in amount but total destructive interference can only happen when a crest meets a trough of the same size each time.

(i) P = Node

Q = Antinode **(6)**

(ii) 5/4 λ present in pipe.

Therefore, $5/4\lambda = 0.9$m

Therefore, $\lambda = 4/5\ (0.9\text{m})$

$\lambda = 0.72$m

$c = f\lambda \Rightarrow c/\lambda = f \Rightarrow 340/0.72 = f \Rightarrow 472.22\text{Hz} = f$ **(9)**

> **TIP:** Always refer back to the wave formula for frequency. State the variables and see what is required. In this case, you had speed of sound but needed wavelength. This could be gained from the diagram provided.

(iii) $\therefore\ \lambda/4 = 0.9\text{m} \Rightarrow \lambda = 3.6\text{m} \Rightarrow c = f\lambda \Rightarrow 340 = f_0\lambda \Rightarrow 340/3.6 = f_0 \Rightarrow 94.44\text{Hz} = f_0$ **(6)**

> **TIP:** Fundamental frequency occurs when the wave has one antinode present at the open end of the pipe and quarter of the wavelength is there.

Closed pipes produce only odd harmonics. **(3)**

(b) $\text{Intensity} = \dfrac{\text{Power}}{\text{Area}} \Rightarrow I = \dfrac{100}{4\pi r^2} \Rightarrow I = \dfrac{100}{4\pi(8)^2} \Rightarrow I = \dfrac{100}{804.25} \Rightarrow I = 0.124\ \text{Wm}^{-2}$ **(6)**

> **TIP:** Given that the speaker emits sound in all directions, it can be assumed that the sound propagates spherically. Therefore, we can use a formula for the area of a sphere in this case, with 8m as the radius of the sphere.

$\text{Half intensity} = \dfrac{0.124}{2}\ \text{Wm}^{-2} = 0.062\ \text{Wm}^{-2}$

$\text{Intensity} = \dfrac{\text{Power}}{\text{Area}} \Rightarrow 0.062 = \dfrac{100}{4\pi r^2} \Rightarrow \dfrac{(0.062)(4\pi)}{100} = \dfrac{1}{r^2} \Rightarrow \dfrac{100}{(0.062)(4\pi)} = r^2 \Rightarrow \sqrt{\dfrac{100}{(0.062)(4\pi)}}$

$= r \Rightarrow \sqrt{128.35} = r \Rightarrow 11.33\text{m} = r$ **(4 × 3)**

> **TIP:** It should be known that any change of 3dB means a halving/doubling of sound intensity. Therefore, in this question a 3dB drop means you half the intensity from the first question and substitute it into the formula to find the new distance from the speaker (radius). In this particular question, they are asking for overall distance but it is common to ask by how much you would increase distance. In this type of question, the answer would be 3.33m extra, if it came up.

9. (a) Coulomb's Law states that the electrostatic force between charges is proportional to the product of their charges and inversely proportional to the square of the distance between them. **(6)**

TIP: You may also state this law as the formula but make sure to give the meaning of each letter.

Original force: $F = \frac{(Q)(3Q)}{4\pi\varepsilon d^2} \Rightarrow F = \frac{3Q^2}{4\pi\varepsilon d^2}$ **(6)**

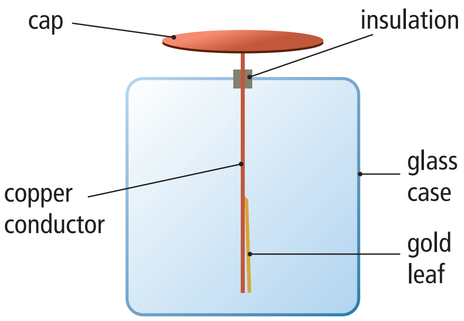
New force: $F' = \frac{(2Q)(2Q)}{4\pi\varepsilon d^2} \Rightarrow F' = \frac{4Q^2}{4\pi\varepsilon d^2}$ **(6)**

Ratio of F: F' $\frac{F'}{F} = \frac{\frac{4Q^2}{4\pi\varepsilon d^2}}{\frac{3Q^2}{4\pi\varepsilon d^2}} \Rightarrow \frac{F'}{F} = \frac{4}{3}$ (cancel common elements) $\Rightarrow F' = \frac{4}{3}F$ **(6)**

TIP: When the two spherical conductors are touched off each other, they equalise charge so as to have 4Q divided equally between them. This accounts for the 2Q each.

When this occurs, it is safe to find the ratio of the two forces using Coulomb's Law and cancel the common elements to get a final force in terms of F.

(b)



(3)

The frame needs to be earthed to allow a potential difference to exist between the leaves and frame. It is also earthed for safety. **(3)**

To charge an electroscope by induction:

1. Bring a positively charged rod near the cap of the electroscope.
2. The gold leaf diverges.
3. Touch your finger off the cap to earth the electroscope.
4. The gold leaf drops as it is earthed.
5. Remove your finger from the cap.
6. Remove the charged rod and the leaf diverges again, showing it is charged. **(3 × 3)**

TIP: If you use a positive rod to charge it initially, the electroscope will be negatively charged at the end. However, if you use a negative rod to initially charge it, you will end up with a positively charged electroscope.

(c) According to Faraday's Law, all static charge resides on the outside of a conductor. Therefore, a full-body metal suit acts like a Faraday cage and protects the user on the inside of the suit. **(5)**

TIP: The suit will also protect the user from any external electric fields in the vicinity.

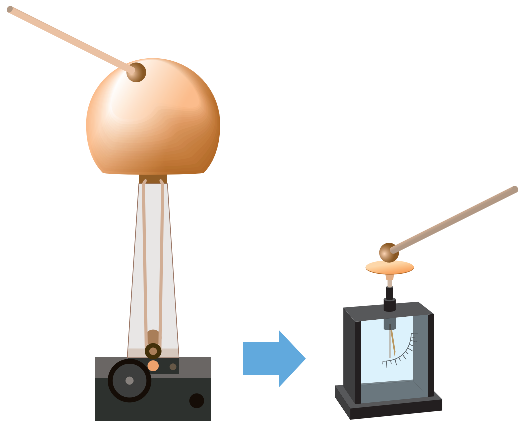


Fig. 9.1

To demonstrate that all static charge resides on the outside of a conductor:

1. Make sure the Van de Graaff generator is charged.
2. Touch a proof plane on the outside of the Van de Graaff dome and then test with an electroscope to show it has gained charge (see Fig. 9.1).
3. Earth the proof plane.
4. Touch a proof plane in the inside of the Van de Graaff dome and test with an electroscope to show the absence of charge.

This shows that charge resides on the outside of a conductor. **(4 × 3)**

TIP: By proving Faraday's Law here, it can be extended to show that any metal conductor will have all static charge on the outside like a metal suit.

10. *Answer either (a) or (b).*

(a) Momentum, mass–energy and charge are all conserved in a nuclear reaction. **(3 × 2)**

$^{228}_{88}\mathbf{x} \rightarrow {}^{228}_{89}\mathbf{y} + {}^{0}_{-1}\mathbf{e}$ **(3 × 3)**

The proposal of the existence of neutrinos solved the conservation problem. **(3)**

Fundamental forces in order of strength, from weakest to strongest:

- Gravitational
- Weak nuclear
- Electromagnetic
- Strong nuclear **(9)**

The weak nuclear force is involved in beta decay. **(3)**

Due to the kinetic energy involved, energy is converted into matter, according to $E = mc^2$. **(3)**

$p + p \rightarrow p + p + \pi^+ + \pi^-$ **(3 × 3)**

Mass of pi meson: 273 × mass of an electron = $(273)(9.109 \times 10^{-31}\text{kg}) = 2.4869 \times 10^{-28}\text{kg}$.

TIP: This can be gained from your tables. If you are ever stuck for information and need inspiration, it can be very helpful to look through the relevant parts of the tables to guide you as to how to proceed next. In this case, you should know $E = mc^2$ is relevant and therefore you need to know the mass of a pion.

$E = mc^2 \Rightarrow E = 2mc^2$ (energy for 2 pions) $\Rightarrow E = (2)(2.4869 \times 10^{-28})(3 \times 10^8)^2$
$E = 44.76 \times 10^{-12}\text{J}$

(Convert Joules to electronvolts): $E = \dfrac{44.76 \times 10^{-12}}{1.602 \times 10^{-19}} \Rightarrow E = 279.94 \times 10^6 \text{ eV} \approx 280\text{MeV}$

Therefore, each proton would require $\frac{280\text{MeV}}{2} = 140\text{MeV}$ **(4 × 3 + 2)**

TIP: Given that particle physics uses very small masses and energy values, it is important to list carefully each part and practise using exponentials. Whenever you need to convert from Joules to electronvolts, it is only necessary to factor in the charge on an electron, as shown in this question.

(b) A current-carrying conductor in a magnetic field will experience a force. **(6)**

TIP: You may also state that this force will cause a turning effect or torque that is used in the operation of an electric motor. This use of electricity and magnetism is often asked in relation to a kinetic energy conversion in a motor.

A = Split ring commutator
B = Carbon brush **(6)**

Function of A = The commutator enables current direction to change every 180°, which ensures that the coil constantly rotates in the same direction.

Function of B = The brushes press against the coil to allow constant current flow as the coil rotates. **(3)**

The material used for B is usually carbon. **(3)**

TIP: Brushes can also be said to be made from graphite.

Choose any two properties from the following:

- Soft
- Good conductor
- Self-lubricating
- Low resistance **(2 + 1)**

Choose any three factors from the following:

- Magnetic flux density (*B*)
- Number of turns (*N*)
- Area of coil (*A*)
- Current (*I*) **(3 × 1)**

TIP: Remember that torque is a turning effect that comes from force; therefore, magnetic flux density and current are sure to be relevant here.

No, back emf would oppose current flow if the motor jammed. **(6)**

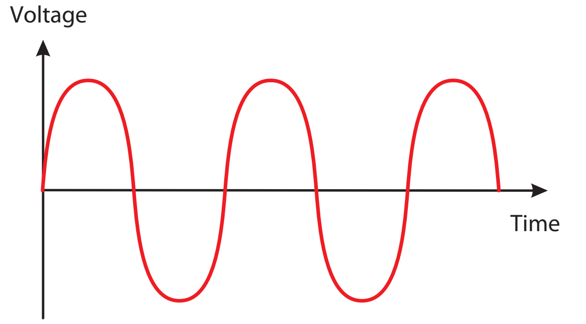
TIP: According to Lenz's Law and Faraday's Law, magnetic field change would be required to cause back emf that opposes original current flow. This would not occur in a jammed motor.

The motor would eventually burn out or overheat due to excess current. **(6)**

TIP: One of the main effects of current is heat; therefore, too much current will cause an undesirable heating effect.

If the split ring commutator is replaced by split rings, a d.c. motor can be converted to an a.c. generator. A handle would also be required to rotate the coil. **(6)**

TIP: If you were to actually generate the a.c., you would need a mechanical method of causing the coil to rotate. For this reason, a handle to turn the coil would be simplest. If you consider simple dynamos, they need to have some method of being rotated to produce current, e.g. water running over them in a turbine.



(9)

Choose any two from the following:
- More powerful magnet being used
- More turns in the coil
- Faster mechanical rotation of the coil **(3 + 2)**

11. (a) Filament lamp: **(8 × 7)**

60W = 60 Joules per second

$\therefore$ Energy efficiency $= \frac{\text{Output}}{\text{Input}} \times 100 \Rightarrow E = \frac{8}{60} \times 100 \Rightarrow E = 13.33\%$

CFL:

11W = 11 Joules per second

$\therefore$ Energy efficiency $= \frac{\text{Output}}{\text{Input}} \times 100 \Rightarrow E = \frac{8}{11} \times 100 \Rightarrow E = 72.73\%$

TIP: The main thing here is to remember that Watts are Joules per second. Therefore, convert the 60W input into Joules per second to compare with the output.

(b) The UV radiation is absorbed by the fluorescent coating. This then raises the electrons to a higher energy level. When the electrons return to their normal state, they emit lower energy photons of white light.

(c) $E = hf \Rightarrow E = (6.63 \times 10^{-34})(f) \Rightarrow E = (6.63 \times 10^{-34})(c/\lambda) \Rightarrow E = (6.63 \times 10^{-34})\left(\frac{3 \times 10^{8}}{254 \times 10^{-9}}\right)$

$\Rightarrow E = (6.63 \times 10^{-34})(1.1811 \times 10^{15}) \Rightarrow E = 7.83 \times 10^{-19}$ J

TIP: Make sure to convert wavelength to frequency when using Planck's constant in $E = hf$.

(d) The UV is absorbed by the fluorescent coating. This then raises the electrons to a higher energy level. When the electrons return to their normal state, they emit photons.

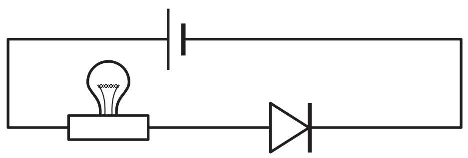
TIP: This is essentially the same question as part (b) being asked in a different way and with more reference to the energy states within the atoms of fluorescent coating.

(e) Given that UV energy is absorbed and visible photons emitted, energy transfer is occurring.

TIP: It is also relevant to state that with less than 100 per cent efficiency as in part (a), some of the initial energy must be converted to other forms, such as heat.

(f) The light is connected to an a.c. supply that alternates direction.

(g)



TIP: You may also insert a bulb instead of a resistor to show its correct use here.

(h) By mixing primary colours of red, green and blue LEDs, white light can be produced.

12. *Answer any two of the following parts (a), (b), (c), (d).*

(a) Whenever an object is deformed through bending, stretching or compression, there is a restoring force that is directly proportional to the displacement, as long as the elastic limit is not exceeded. **(6)**

TIP: You may also use a formula version but make sure to explain each letter.

The body vibrates with simple harmonic motion (SHM) because the acceleration is proportional to the displacement ($a \propto s$). **(6)**

TIP: You may also say that $a \propto -s$, to show the directional relationship of acceleration always pointing towards equilibrium.

$\omega^2 = 16 \Rightarrow \omega = 4$

$T = \frac{2\pi}{\omega} \Rightarrow \left(f = \frac{1}{T}\right) : f = \frac{\omega}{2\pi} \Rightarrow f = \frac{4}{2\pi} \Rightarrow f = 0.64$ Hz **(3 × 3)**

TIP: All that is required here is a manipulation of the periodic time formula to calculate frequency, since $1/f = T$.

(i) $a_{max} = -\omega^2 s \Rightarrow a_{max} = -(16)(0.05) \Rightarrow a_{max} = -0.80$

Maximum force (F_{max}) occurs when acceleration is maximum and minimum force (F_{min}) occurs when acceleration is minimum. **(3)**

Therefore:

$F_{max} = ma \Rightarrow F_{max} = (250 \times 10^{-3})(-0.80) \Rightarrow F_{max} = 0.2\text{N}$

(ii) $F_{min} = ma \Rightarrow F_{min} = (250 \times 10^{-3})(0) \Rightarrow F_{min} = 0\text{N}$ **(2 × 2)**

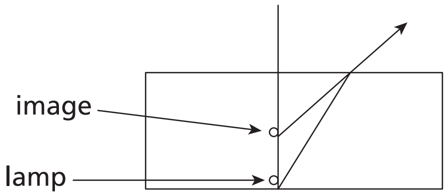
TIP: The minus can be left out in these formulae since only magnitude is asked but be aware that they exist for other questions. Also, knowing that there is zero acceleration and hence zero force at equilibrium will help with this question.

(b) Laws of Refraction of Light are:

- The incident ray, refracted ray and normal all lie on the same plane.
- The ratio of the sine of angle of incidence to the sine of angle of refraction is a constant. **(6)**

TIP: The second law can also be given as Snell's Law formula and the letters explained:

$$\frac{\text{Sin } i}{\text{Sin } r} = \text{n}.$$



(4 + 3)

Snell's window is caused in the water due to total internal reflection (TIR) occurring as light emerges from the pool. **(3)**

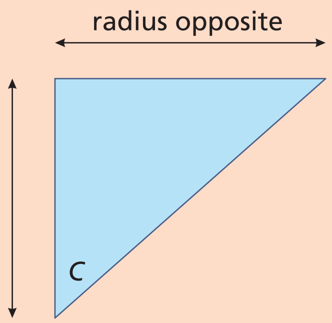
TIP: This results in a circle of light being formed but all light outside the critical angle being reflected back under the water surface.

$n = \frac{1}{\text{Sin } C} \Rightarrow \frac{1}{n} = \text{Sin } C \Rightarrow \frac{1}{1.33} = \text{Sin } C \Rightarrow 0.7519 = \text{Sin } C \Rightarrow \text{Sin}^{-1}(0.7519) = C \Rightarrow 48.75° = C$

Radius of transparent disc = (1.8)(Tan 48.76˚) = 2.053m

Area of transparent disc $= \pi r^2 \Rightarrow A = (\pi)(2.053)^2 \Rightarrow A = 13.24\text{m}^2$ **(4 × 3)**

TIP: By drawing a suitable triangle, it will be clear to see why the Tan ratio can be used to find the radius. In this case, the depth of 1.8m is the adjacent side and the radius is the opposite side of the right-angled triangle.



Using this triangle, the radius can be easily calculated from $\text{Tan}\theta = \dfrac{\text{opposite}}{\text{adjacent}}$

(c) Give the following answers:

- Current
- Resistance
- Time **(3 + 2 + 2)**

TIP: You may also refer to current as current squared given the Joule's Law relationship.

(i) $P = I^2R \Rightarrow \dfrac{P}{I^2} = R \Rightarrow \dfrac{2.7}{(20)^2} = R \Rightarrow 6.75 \times 10^{-3}\Omega$ **(3 × 3)**

(ii) $\rho = \dfrac{RA}{l} \Rightarrow \dfrac{\rho l}{R} = A \Rightarrow \dfrac{(1.7 \times 10^{-8})(1)}{(6.75 \times 10^{-3})} = A \Rightarrow 2.519 \times 10^{-6}\text{m}^2$

Area $(A) = \pi r^2 \therefore 2.519 \times 10^{-6}\text{m}^2 = \pi r^2 \Rightarrow$

$\dfrac{2.519 \times 10^{-6}}{\pi} = r^2 \Rightarrow \sqrt{\dfrac{2.519 \times 10^{-6}}{\pi}} = r \Rightarrow 8.95 \times 10^{-4}\text{m} = r$

Diameter $= 2 \times r \therefore d = 2(8.95 \times 10^{-4}\text{m}) = 1.79 \times 10^{-3}\text{m}$ **(4 × 3)**

TIP: It is vital to be really careful here as all the formulae are easily accessible. Make sure to always express your answer in standard units and give the diameter answer required rather than stopping at radius only.

(d) (i) A suitable detector would be a G–M tube attached to a rate-meter or scaler counter. **(6)**

TIP: A solid state detector could also be used here.

(ii) As the paper thickness varies, so too does the count rate. As thickness increases, absorption increases and so count rate decreases. **(9)**

(iii) Any alpha source would not pass easily through paper, due to their poor penetrating ability. **(4)**

(iv) $T_{\frac{1}{2}} = \dfrac{\ln 2}{\lambda} \Rightarrow \lambda = \dfrac{\ln 2}{T_{\frac{1}{2}}} \Rightarrow \lambda = \dfrac{0.693}{(28.78 \times 365.25 \times 24 \times 60 \times 60)} \Rightarrow 7.63 \times 10^{-10}\,\text{s}^{-1} = \lambda$ **(3)**

TIP: 365 days may also be used and accepted here for converting half-life into seconds but make sure to do this conversion before substituting into the formula.

$$A = -\lambda N \Rightarrow \frac{A}{\lambda} = N \Rightarrow \frac{4250}{7.63 \times 10^{-10}} = N \Rightarrow 5.57 \times 10^{12} \text{ atoms}$$ **(6)**

TIP: If using 365 days, the following answer would be gained:

$$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda} \Rightarrow \lambda = \frac{\ln 2}{T_{\frac{1}{2}}} \Rightarrow \lambda = \frac{0.693}{(28.78 \times 365 \times 24 \times 60 \times 60)} \Rightarrow \lambda \Rightarrow 7.77 \times 10^{-10}\ \text{s}^{-1} = \lambda$$

$$A = -\lambda N \Rightarrow \frac{A}{\lambda} = N \Rightarrow \frac{4250}{7.77 \times 10^{-10}} = N \Rightarrow 5.47 \times 10^{12} \text{ atoms.}$$

SECTION A

1. Ticker tape method/Light gate method:

1. Calculate initial velocity from the $\frac{\text{distance}}{\text{time}}$ measurements (this is named *u*).

> **TIP:** In the ticker tape method, you need to measure the distance travelled between a certain number of spaces on the tape. You then divide this distance by the time corresponding to the number of spaces (each space is 1/50s).
>
> In the light gate method, you need to divide the distance of the length of sail by the time recorded on the light gate when the sail breaks the light beam.

2. Calculate final velocity from the $\frac{\text{distance}}{\text{time}}$ measurements (this is named *v*).

> **TIP:** This velocity is achieved by the same method as the initial velocity but at a time towards the end of the experiment.

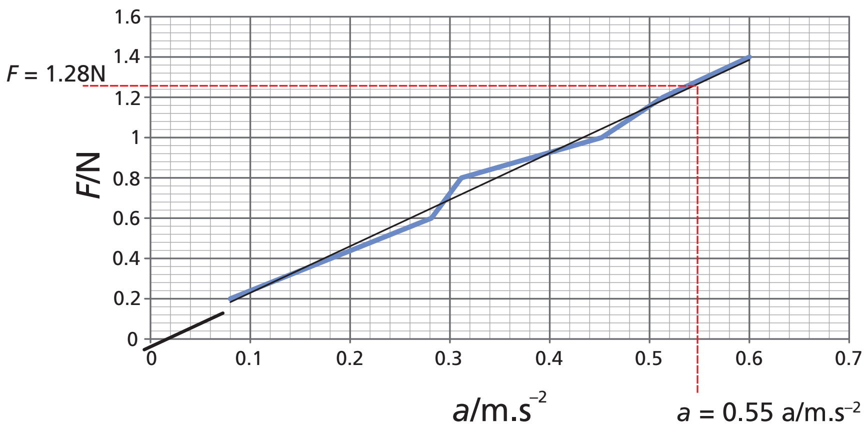
3. Measure the time interval between *u* and *v* and name it *t*.
4. Calculate acceleration by using any of Newton's equations of motion $\left(\text{e.g. } a = \frac{v-u}{t}\right)$.

> **TIP:** You may measure distance between *u* and *v*, which is denoted as *s* and then use an equation such as $v^2 = u^2 + 2as$ to calculate acceleration.

Data-logging method:

1. Locate the sensor facing the trolley.
2. Select Start and release the body.
3. Select Stop at the end and display the graph of velocity versus time.
4. The slope of this graph is acceleration and can be calculated from the data-logger. **(4 × 3)**

> **TIP:** It is more important to list the actual programming steps when describing data-logger use. The ticker tape/light gate methods use the classical physics mathematical methods. If you wish to prepare more for later mechanics questions, the ticker tape/light gate method provides more understanding and practice of how values are achieved. By learning data-logger steps, you only learn how to use a calculator and not how to calculate.



$a = 0.55$ a/m.s^{-2} **(16)**

> **TIP:** Make sure to draw a large graph with a best-fit trend line and use at least three-quarters of the graph page. If you are asked to use your graph to find an answer, it is vitally important to spend appropriate time on drawing it as the chances of gaining further marks depends on its accuracy.

$F = ma$

Therefore: $F/a = m$

The slope of your graph is the change in y divided by the change in x, therefore, $m = \frac{y_2 - y_1}{x_2 - x_1}$

Therefore, slope = F/a

$m = \frac{1.28 - 0}{0.55 - 0} \Rightarrow m = 2.3 \therefore m = 2.33$kg **(6)**

> **TIP:** Because the best-fit line of force against acceleration can be extended through the origin, we can take (0,0) as one of the values for the slope. Whenever a line goes through the origin, it is always best to use the origin as one point and therefore the formula for the slope actually becomes $m = y/x$.
>
> Since $F = ma$, then $F/a = m$. This enables us to calculate the mass of the body in this experiment from the slope. It is acceptable to be within a suitable range of answers for this, as you are using a graph. In this case, from 2.1kg to 2.4kg was allowed.

Choose any one from the following:

- Friction between trolley and track – this can be reduced by dusting the track and oiling the trolley wheels.
- Track not raised enough or raised too much – you can limit errors by having the track raised just enough to overcome friction but not to accelerate without applied force.
- Sail not always perpendicular to light beam – by using an unsteady or thin sail, the distance may not always be constant when breaking the light beam; therefore, use a steady definite piece of card at a right angle to the beam. **(6)**

2. The water may have been pre-cooled with ice or stored in a fridge beforehand. **(6)**

A steam trap is used to only deliver dry steam to the calorimeter. **(6)**

> **TIP:** It is important that only dry steam is added because adding steam that contains liquid water will affect the latent measurements.

The mass of (water and calorimeter) is subtracted from the mass of (water, calorimeter and steam) to gain the mass of the added steam. **(6)**

> **TIP:** It is common to ask about calculating mass of added material in heat questions.

The more a sensitive thermometer is used, the greater the accuracy of the experiment and less percentage error involved. **(6)**

> **TIP:** By including more sensitive graduations of temperature, the less percentage error is involved with the temperature measurement part of the experiment. Because heat experiments depend on the $\Delta\theta$ part of the calculation, a thermometer with finer graduations can make a big difference. For example, using a glass thermometer with a tolerance of 0.5°C rather than a digital thermometer with tolerance of 0.1°C affects the percentage error.

Heat energy gained by water and calorimeter = Heat energy lost by added steam

> **TIP:** Remember that heat energy will either be latent or heat change. Both are measured in Joules and as long as you have amounts of Joules on each side of the equals sign, you can solve them quickly.

$mc\Delta\theta$(water) + $mc\Delta\theta$(calorimeter) = ml(vaporisation) + $mc\Delta\theta$(steam)

$(61.8 \times 10^{-3})(4180)(11.8) + (34.6 \times 10^{-3})(390)(11.8) = (1.2 \times 10^{-3})(l) + (1.2 \times 10^{-3})(4180)(80)$

> **TIP:** The equation required for fusion or vaporisation is easy to practise as it almost always involves letting energy gained = energy lost. By placing what you started with on one side (calorimeter and water) and what you added on the other side of the equals (steam or ice), you can just let their energy change equal.
>
> The only other aspect to be careful of is the units. Make sure to practise changing all masses into kg, as these experiments often give you the quantities in *g*.

$3048.22 + 159.23 = 1.2 \times 10^{-3} l + 401.28$

$3207.45 = 1.2 \times 10^{-3} l + 401.28$

$3207.45 - 401.28 = 1.2 \times 10^{-3} l$

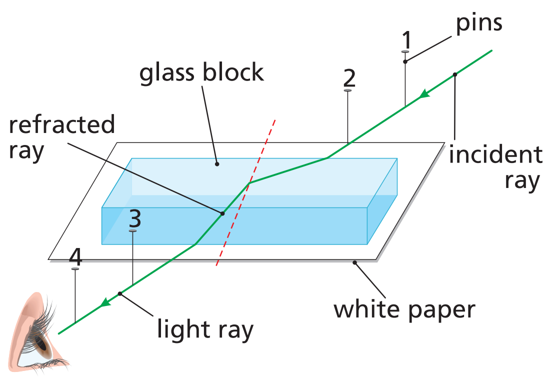
$2806.17 = 1.2 \times 10^{-3} l$

$\frac{2806.17}{1.2 \times 10^{-3}} = l$

2.34×10^{6} J kg^{-1} = l (specific latent heat of vaporisation) **(16)**

TIP: It is a good idea to have the rough value of the specific latent heat of vaporisation and specific latent heat of fusion in order to double-check your answer in case of a simple exponential mistake. (i.e. 2.3×10^{6} (vaporisation)/3.3×10^{5} (fusion).

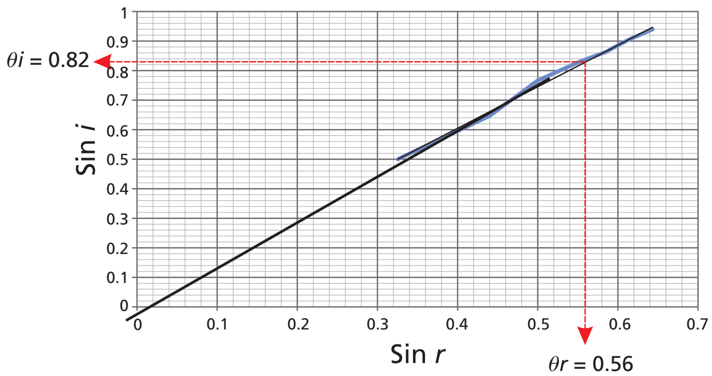
3.



(4 × 3)

TIP: You may also use a ray box and glass block to show the ray entering the block (incident ray) and the ray refracted in the block (refracted ray). However, the angle of incidence (θi) and angle of refraction (θr) will still be between the incident ray and normal and refracted ray and normal as in the diagram on the left.

The important parts of this apparatus are those that are critical to the results. You need a medium to refract the light (i.e. glass block) and a set of incident/refracted/normal lines to calculate the angles.



The graph verifies Snell's Law as it is a straight line passing through the origin. This shows the proportionality of Sin i to Sin r and also shows that Sin i/Sin $r = n$ (constant). **(4 + 4 × 3)**

Slope = y/x ∴ slope = Sin i/Sin $r \Rightarrow$ slope = $\frac{0.82}{0.56} \Rightarrow$ Slope = 1.46

$\Rightarrow n = 1.46$ **(6)**

TIP: Whenever you are asked for the verification of a law from a graph, if it is a straight line passing through the origin, state this as it shows proportionality.

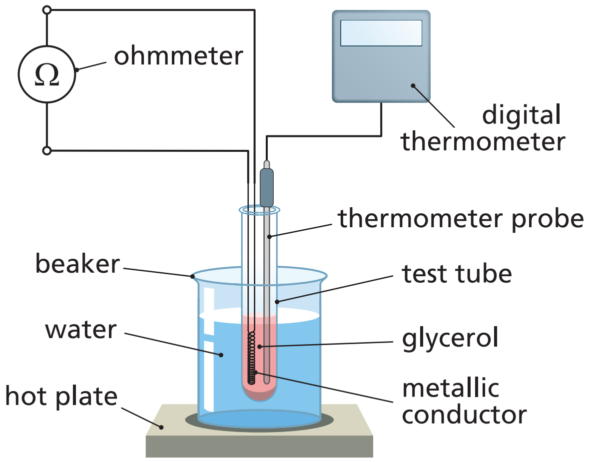
TIP: It is very common to use the slope to calculate a result from a graph. Remember that if a graph passes through the origin, you need only choose one value of (x,y) to calculate the slope as the other value in the formula is (0,0). In this graph, the slope is y/x = Sin i/Sin $r = n$.

It is also acceptable to be within a certain range of values. In the case of this question, any value between 1.38 and 1.52 was acceptable.

If the student went below 30°, the percentage error would have been very large when reading from the protractor. This is even more so when the value of the refractive angle is less. **(6)**

TIP: Always think about the effect of percentage error when taking readings. Larger measurements lower percentage error, as a graduation mistake would not have as big an impact on the overall result as a small measurement.

4.



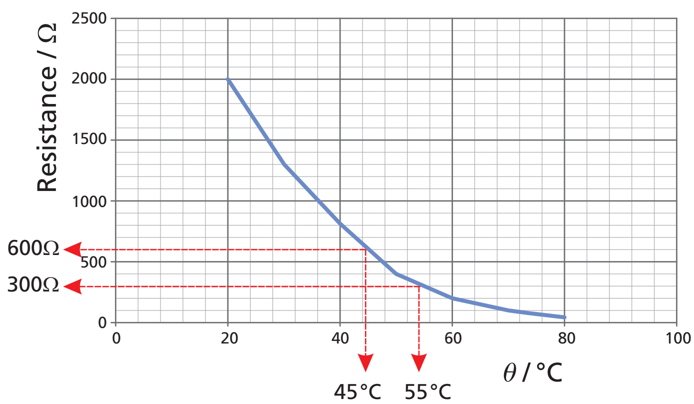
(3 × 3)

The resistance was measured with an ohmmeter. **(6)**

TIP: It is important to have the ohmmeter in the same test tube of glycerol as the thermistor. This ensures that they are both at the same temperature for comparing readings.

The temperature was varied using the hot plate. **(6)**

TIP: If you used a hot plate you could vary the temperature by changing the setting. However, if you used a Bunsen burner, you would need to mention that you increased or decreased gas flow to vary temperature.



(4 × 3)

TIP: When the graph is not linear or supposed to be linear, draw as smooth a curve as you can. It is also important in this experiment not to let the curve reach zero for resistance as this does not occur here. It tends down to 0Ω but does not reach it.

As can be seen from the graph, at 45°C the resistance corresponds to 600Ω, whereas at 55°C, the resistance is 300Ω. This means a decrease of 300Ω occurred in a temperature change of 10K.

This equates to 30Ω per 1K change or $30\Omega K^{-1}$. **(3)**

TIP: You need to show your workings on your graph and make it as clear as possible to the examiner how you got the corresponding readings. You also need to be very careful about your answer. It is an easy mistake to miss the fact that they are asking for resistance per Kelvin, as opposed to the overall resistance change over 10K. That is why we received an answer of 30Ω per 1K. It is acceptable to calculate an answer in the range of 28–32Ω/K.

Finally, do not get confused between Celsius or Kelvin. In absolute terms, they have a different reading, but in graduations they follow the same incremental size with a difference of 45°C–55°C being a 10K jump as well as a 10°C jump.

Because oil is a good conductor of heat, it is a good choice for an experiment that relies on heat measurements. **(4)**

SECTION B

5. *Answer any eight questions from (a), (b), (c), etc.* **(8 × 7)**

(a) The vector sum of the forces is zero.

TIP: This basically means that the forces up equal the forces down and/or the forces left equal the forces right.

The sum of the moments about any point is zero.

TIP: Again, this can be expanded to mean that the sum of the clockwise moments equal the sum of the anticlockwise moments when taken about any point.

(b) $n = 1/\text{Sin } C \Rightarrow 1/n = \text{Sin } C \Rightarrow \text{Sin}^{-1}(1/n) = C \Rightarrow \text{Sin}^{-1}(1/1.46) = C \Rightarrow \text{Sin}^{-1}(0.6849) = C \Rightarrow 43.23° = C$

TIP: It is important to make sure that your calculator is in DEG/DRG mode for doing any trigonometric operations such as the inverse of sine.

(c) A = Turntable
B = Telescope

(d) Latent changes need to occur as snow changes into water. This requires energy before the temperature can rise.

TIP: There is a good deal of energy required to change a solid to a liquid before temperature change can occur. In this case, the latent heat of fusion for water needs to be taken into account.

(e) $C = Q/V \Rightarrow Q = CV \Rightarrow Q = (5 \times 10^{-6})(120) \Rightarrow Q = 6 \times 10^{-4} C$ (600μC).

(f) Capacitors are used for tuning.

(g) The magnitude of induced emf is directly proportional to the rate of change of flux.

TIP: You may also use the formula $E \propto \frac{\varphi}{dt}$, but insert the explanation for each unit.

(h) $V_{rms} = \frac{V_{peak}}{\sqrt{2}} \Rightarrow V_{rms} = \frac{300}{\sqrt{2}} \Rightarrow V_{rms} = 212V$

(i) Radon gas.

(j) Choose any two from the following:
- Greater velocity
- Less space required
- Increased energy
- More control on collision scenarios

TIP: This question only requires you to analyse logically why circular accelerators were designed. By having a circular track, you can continue to accelerate particles prior to collision as well as use less physical space by bending the track.

OR

Every current-carrying conductor will experience a force when placed in a magnetic field.

TIP: The hint in this question comes from the term 'moving-coil galvanometer'. In order to get an object to move when current is being measured, you should think of the effects of current that could cause movement.

6. Every mass in the universe attracts every other mass with a force proportional to the product of their masses and inversely proportional to the square of the distance between them. **(6)**

TIP: This can also be given as the correct formula but with fully explained notation: $F = \frac{Gm_1 m_2}{d^2}$.

$g \propto \frac{1}{d^2} \Rightarrow g \propto \frac{1}{(3d)^2} \Rightarrow g$ (3 times from Earth's centre) $= \frac{g}{9} \Rightarrow g$ (3 times from Earth's centre) $= \frac{9.81}{9}$

$\Rightarrow g = 1.09 \text{m.s}^{-2}$ **(4 × 3)**

TIP: Twice the radius above the Earth means that the distance is three times the radius of the Earth from the centre of the Earth. This means you need to use a distance of 3*r*.

TIP: You may also use the actual measurements for radius, gravitational constant (*G*) and mass, and calculate the exact figure for gravitational acceleration by allowing for the following:

$$d = 3 \times \text{radius} = (3)(6.36 \times 10^6) = 1.908 \times 10^7 \text{m}$$

$$F = \frac{Gm_1m_2}{d^2} \Rightarrow (F = ma)\text{: } ma = \frac{Gm_1m_2}{d^2} \Rightarrow \text{(divide by } m\text{): } a = \frac{Gm_1}{d^2} \Rightarrow a = \frac{(6.7 \times 10^{-11})\,(6 \times 10^{24})}{(1.908 \times 10^7)^2} \Rightarrow a = \frac{(4.02 \times 10^{14})}{3.64 \times 10^{14}} \Rightarrow a = 1.1\text{m.}$$

However, as you can see, this will take longer and there is more room for error. In this method, marks are given if you make a mistake, whereas the simpler division of gravity by 9 needs to be exact.

(i) According to Newton's First Law of Motion, every body will remain at constant velocity or rest unless an external force acts on it. Since the craft has momentum, it will continue at this rate in the absence of any other forces. **(6)**

TIP: Although there is gravitational force acting on the craft, it is small enough so as not to noticeably decrease the velocity of the craft. The initial momentum that the craft has is large enough to keep moving for a significant time in the presence of small gravitational pull.

(ii) As the craft moves farther from the Earth, their gravitational weight decreases but as they near the moon, their weight increases again. **(6)**

TIP: Their weight near the moon will be less than their original weight (their weight near the Earth).

(iii) When the gravitational pull of the moon equals the gravitational pull of the Earth, these two opposing gravitational forces will cancel and cause weightlessness. **(3)**

TIP: It should be noted that they will never be completely weightless as all bodies within the universe will be exerting gravitational pull, as well as the moon and Earth. However, in tangible terms, they will appear weightless when the moon and Earth forces cancel each other. This will occur closer to the moon than the Earth because of the lesser mass of the moon.

Gravitational force from Earth = gravitational force from Moon $\frac{Gm_Em}{d^2} = \frac{Gm_Mm}{d^2}$

(divide by *G*): $\frac{m_Em}{(d_{\text{Earth–astronaut}})^2} = \frac{m_Mm}{(d_{\text{Moon–astronaut}})^2}$

(divide by *m*): $\frac{m_E}{(d_{\text{Earth–astronaut}})^2} = \frac{m_M}{(d_{\text{Moon–astronaut}})^2}$

$$\frac{m_E}{m_M} = \frac{(d_{\text{Earth–astronaut}})^2}{(d_{\text{Moon–astronaut}})^2}$$

$81 = \frac{(d_{\text{Earth–astronaut}})^2}{(d_{\text{Moon–astronaut}})^2}$

(square root): $9 = \frac{d_{\text{Earth–astronaut}}}{d_{\text{Moon–astronaut}}}$

Therefore, the ratio of distance for Earth-astronaut to Moon-astronaut is 9:1.

TIP: Add the parts (9 + 1) = 10 and divide the overall distance by 10 to calculate 1 part.

$\frac{3.84 \times 10^8}{10} = 3.84 \times 10^7\text{m}$ (1 part)

Therefore, the distance from Earth to astronaut = $(9)(3.84 \times 10^7\text{m}) = 3.456 \times 10^8\text{m}$

TIP: Subtract the radius of the Earth to calculate the distance from the surface of the Earth to the astronaut.

$3.456 \times 10^8\text{m} - 6.36 \times 10^6\text{m} = 3.39 \times 10^8\text{m}$ **(9)**

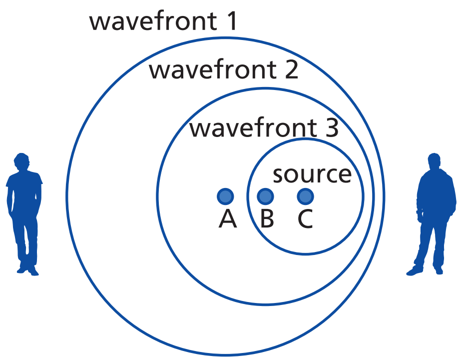
TIP: As can be seen from this question, it helps to look at the figures given in the question. You could try to set up a quadratic equation from letting the force of attraction between the Earth and astronaut equal the force of attraction between the moon and astronaut and substitute distance as *x* to solve. But it is easier to just use the ratio of masses given to cancel like terms and work out the distance based on a ratio. However, make sure to subtract the radius of the Earth or moon when working this out as the distance given is between the bodies' centres and not their surfaces.

(iv) $T = \frac{2\pi r}{v} \Rightarrow v = \frac{2\pi r}{T} \Rightarrow v = \frac{2\pi\,(3.84 \times 10^8)}{(27.3 \times 24 \times 60 \times 60)} \Rightarrow v = \frac{2.4127 \times 10^9}{2.359 \times 10^6} \Rightarrow v = 1022.9\text{m. s}^{-1}$ **(9)**

TIP: When you have been given the figure for periodic time, you should know to rearrange the formula for periodic time to calculate velocity. Then just remember to convert time into seconds before dividing it in.

(v) The gravitational force of the moon is too weak for it to sustain an atmosphere. **(5)**

7. The Doppler effect is the apparent change in frequency due to the relative motion of source and observer. **(6)**



If the source is moving from A to B to C, the wavefronts emitted at each stage will be as shown in the diagram, corresponding to wavefront 1 emitted at A, wavefront 2 emitted at B, and wavefront 3 emitted at C.

The person on the right will see the wavefronts bunched up as the source approaches them. This will cause an apparent decrease in wavelength (apparent increase in frequency) to this person.

However, the person on the left will see the wavefronts more spaced out as the source departs. This will cause an apparent increase in wavelength (apparent decrease in frequency) to this person. **(4 × 3)**

The Doppler effect can be demonstrated by attaching a sound source, that is continuously making noise, to a string and rotating it around your head. You will notice the wavelength appear to change as the sound source moves away or towards you. **(3 × 3)**

TIP: When asked to demonstrate any experiment, you can choose any method you wish, as long as it demonstrates the principle being examined. In this case, you need to do an experiment that involves a moving sound source. This can be any fast-moving source approaching and/or going away from you.

The red shift is caused by the star moving away from the observer. This movement causes the light being emitted to appear to increase in wavelength and moves it into the red portion of the visible spectrum. **(6)**

Because the light from the star is of a higher wavelength than the calibrated laboratory value, it can be deduced that the star is moving away. **(3)**

TIP: The important point here is to identify which is the actual frequency and which is the apparent frequency. The laboratory measurement will always be the actual one since it has been carefully measured in a laboratory setting, whereas the frequency observed is travelling from a moving star.

It is also vital to check whether you are looking at frequency or wavelength. A higher wavelength means a lower frequency. A lower frequency means the star is moving away from the observer.

Actual frequency (f): $c = f\lambda \Rightarrow \frac{c}{\lambda} = f \Rightarrow \frac{3 \times 10^8}{587 \times 10^{-9}} = f \Rightarrow 5.11073 \times 10^{14}\text{HZ} = f$

Apparent frequency (f'): $c = f\lambda \Rightarrow \frac{c}{\lambda} = f \Rightarrow \frac{3 \times 10^8}{590 \times 10^{-9}} = f \Rightarrow 5.08475 \times 10^{14}\text{HZ} = f'$

$f' = \frac{fc}{c+u} \Rightarrow 5.08475 \times 10^{14} = \frac{(5.11073 \times 10^{14})(3 \times 10^8)}{3 \times 10^8 + u}$

$\Rightarrow (5.08475 \times 10^{14})(3 \times 10^8 + u) = (5.11073 \times 10^{14})(3 \times 10^8)$

$\Rightarrow 1.5254 \times 10^{23} + 5.08475 \times 10^{14}u = 1.5332 \times 10^{23}$

$\Rightarrow 5.08475 \times 10^{14}u = 1.5332 \times 10^{23} - 1.5254 \times 10^{23}$

$\Rightarrow 5.08475 \times 10^{14}u = 7.8198 \times 10^{20}$

$\Rightarrow u = \frac{7.8198 \times 10^{20}}{5.08475 \times 10^{14}} \Rightarrow u = 1.533 \times 10^6\text{m.s}^{-1}$ **(15)**

TIP: Since the Doppler formula uses frequencies to calculate answers, make sure to convert wavelength into frequency first and state which is apparent and which is actual.

It is then important to identify which formula to use and substitute in the correct figures.

Finally, it is best to write shorter versions of your intermediate answers on the page as shown above, but try to keep the actual figures in your calculator as you progress to hold on to all the important decimal places.

Choose any one from the following:

- Speed cameras
- Radar
- Medical applications in imaging
- Temperature and blood flow
- Acoustic measurements **(5)**

8. Electric current is the flow of charge or electrons. **(6)**

The other two effects of electric current are magnetic and chemical. **(6)**

(i) (a) Switch A will operate the fan speed as switch B will activate the heating coil to heat the air being blown by the fan. **(3)**

TIP: Notice how the fan is connected in series with switch A. Therefore, it can only operate when A closes the circuit. Once it is operational, a rheostat or variable resistor controls the amount of power the fan receives.

(b) Switch B closes and activates the heating coil to heat the air being blown. **(6)**

TIP: Switch B is connected in series with the heating coil but in parallel with the fan. This explains how the hairdryer can blow cold air when B is open and hot air when B is closed. You should also notice how switch A has to be closed for the hairdryer to work as you would not want a device that can heat up but not blow air.

(ii) (a) $P = IV \Rightarrow \frac{P}{V} = I \Rightarrow \frac{2000}{230} = I \Rightarrow 8.7\text{A} = I$

(b) $V = IR \Rightarrow \frac{V}{I} = R \Rightarrow \frac{230}{8.7} = I \Rightarrow 26.4\Omega = R$ **(9)**

TIP: It is best to calculate what you can first. In this case, power is given and voltage is in the diagram. It is clear that current can be calculated first. When you have current and voltage, it is very simple to use Ohm's Law to gain resistance.

Remember, you do not have to stick to an exact order as long as you logically apply formulae and carry the correct figures through the question.

(iii) Cross-sectional area (A) $= \pi r^2 \Rightarrow A = (\pi)\left(\frac{0.17 \times 10^{-3}}{2}\right)^2 \Rightarrow A = 2.27 \times 10^{-8}\text{m}^2$

TIP: It is easier to halve the diameter to find the radius and then use this to calculate area.

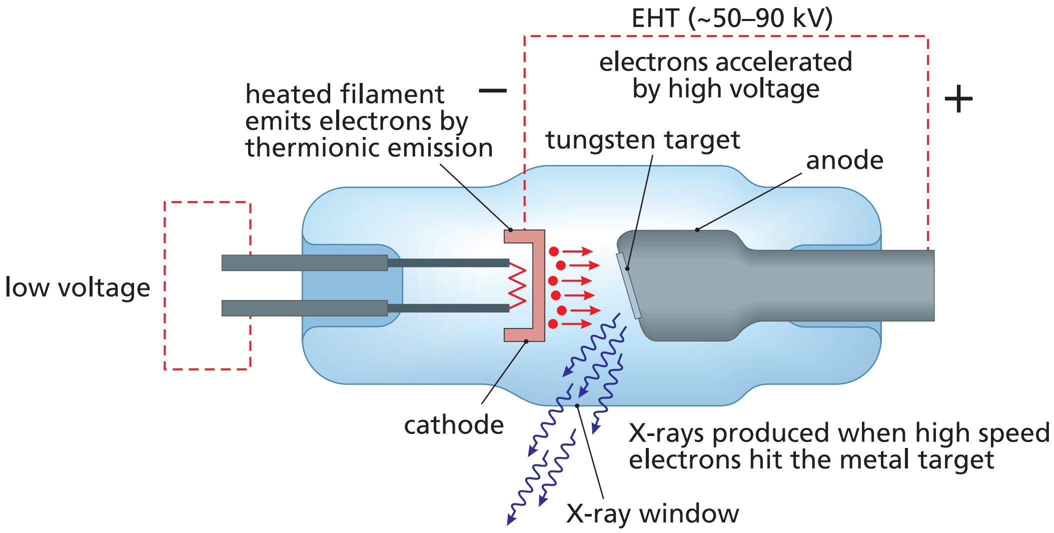
$\rho = \frac{RA}{l} \Rightarrow l = \frac{RA}{\rho} \Rightarrow l = \frac{(26.4)(2.27 \times 10^{-8})}{1.1 \times 10^{-6}} \Rightarrow l = \frac{5.9923 \times 10^{-7}}{1.1 \times 10^{-6}} \Rightarrow l = 0.5448\text{m}$ **(18)**

TIP: As seen here, manipulate the formula to move the letter you want on its own, on one side of the equals sign. Then substitute in the figures you have and make sure they are all in standard units.

(iv) If the fan was not working properly, the coil would become hotter and its resistance would increase. This would decrease the current through the coil. **(2 × 4)**

> **TIP:** It should be noted that although switch A is required to be closed to keep the current moving through the coil, the fan may break and the coil would still work as the current could then pass through the coil and back to the power supply. Try to picture the current actually moving through the circuit to see where it would travel and how it would affect the components.

9. Thermionic emission is the emission of electrons from the surface of a hot metal. **(6)**



(4 × 3)

> **TIP:** The important parts of this diagram are the ones integral to the production of X-rays. Since high-speed electrons colliding with a target are required, you have to show the cathode undergoing thermionic emission and a very high voltage accelerating the electrons to the target anode.

X-rays are high-frequency electromagnetic radiation. They differ from light rays because they can penetrate many types of matter and cause ionisation. **(12)**

> **TIP:** Although both light and X-rays are part of the EM spectrum, you need to focus on the main differences such as the high-frequency penetration and energy of the X-rays. Both will cause photographic emulsion to be exposed though, since this was one of the first indications of the existence of X-rays.

Choose any two from the following:

- Medical scans of bone and/or tissue
- Security scans in airports
- Structural analysis for industry
- Cancer therapy **(2 × 3)**

Most of the incident energy of the electrons is converted to heat. This influences the target integrity, as a material of high specific heat capacity and high-melting point is required, such as tungsten. **(9)**

(i) $E = QV \Rightarrow E = (1.6 \times 10^{-19})(40 \times 10^{3}) \Rightarrow E = 6.4 \times 10^{-15}\text{J}$ **(6)**

> **TIP:** Remember that electronvolts (eV) are measured in Joules because charge by voltage is energy. Therefore, when calculating kinetic or potential energy in cathode ray tubes or X-ray tubes, you need to multiply the charge by voltage applied to work out the energy involved.

(ii) $E = hf \Rightarrow \frac{E}{h} = f \Rightarrow \frac{6.4 \times 10^{-15}}{6.6 \times 10^{-34}} = f \Rightarrow 9.7 \times 10^{18}\text{Hz}$ **(5)**

> **TIP:** When you have energy and are asked for frequency, it is a simple calculation using Planck's constant to equate the two figures. Frequency is proportional to energy.

10. *Answer either part (a) or part (b).*

(a) (i) Antimatter is matter composed of antiparticles with the same mass but opposite charge as another particle. **(6)**

The first antimatter particle was the positron or antielectron. Its symbol is e^+ or $\bar{e}$. **(6)**

When a particle meets its antiparticle, the combined mass is converted into electromagnetic energy. **(6)**

TIP: In the case of pair annihilation, the resulting EM radiation will most likely be gamma photons moving away from each other.

(ii) Pair production is the simultaneous creation of a particle and its antiparticle from electromagnetic energy. **(6)**

$E = hf \Rightarrow E = (6.6 \times 10^{-34})(3.6 \times 10^{20}) \Rightarrow E = 2.376 \times 10^{-13}\text{J}$

$E = mc^2 \Rightarrow E = 2(9.1 \times 10^{-31})(3 \times 10^8)^2 \Rightarrow E = 1.638 \times 10^{-13}\text{J}$

Pair production: $E = 2mc^2 + E_{K1} + E_{K2} \Rightarrow 2.376 \times 10^{-13} = 1.638 \times 10^{-13} + E_{K1} + E_{K2}$

$\Rightarrow 2.376 \times 10^{-13} - 1.638 \times 10^{-13} = 2(E_K) \Rightarrow 7.38 \times 10^{-14} = 2(E_K) \Rightarrow 3.69 \times 10^{-14}\text{J} = E_K$ **(15)**

TIP: Physics is the study of matter and energy. If you can express any quantity in mass or energy, it can be converted to its equivalent. In this question, it is simpler to work out the energy equivalent of the photon frequency and the electron's mass conversion. Then by calculating how much extra energy you have, you only need to divide this in two to see how much kinetic energy each particle receives. It is safe to assume that the excess energy will be split evenly between the two particles as they have identical mass but opposite charge.

(iii) $u + \bar{u} = \pi^0$ with a charge of zero

$u + \bar{d} = \pi^+$ with a charge of +1

$d + \bar{u} = \pi^-$ with a charge of –1

$d + \bar{d} = \pi^0$ with a charge of zero **(4 × 3)**

TIP: It is important to know that up and down quarks/antiquarks make pions. As long as they consist of any particle and antiparticle from these, they will make a pion of different charge as shown. Sometimes it can be missed that an up and anti-up or down and anti-down can go together.

James Joyce used 'quark' for the first time in *Finnegans Wake*. **(5)**

TIP: However, it was Murray Gell-Mann who chose to use the term 'quark' after reading it in the novel.

(b) Intrinsic conduction is conduction due to the negative electrons and positive holes in a pure semiconductor material. **(6)**

Extrinsic conduction is conduction due to the controlled addition of impurities increasing the charge carriers in the material. **(3)**

(i) D_1 and D_4 flash in the first half-cycle; then D_2 and D_3 flash in the next half-cycle. This occurs every cycle per second. **(9)**

TIP: This is a full-wave rectifier circuit showing the arrangement of four diodes to enable a bridge circuit and two-way alternating current using diodes.

It can be observed that when D_1 and D_4 are flashing, they are forward biased, whereas D_2 and D_3 are reverse biased and not flashing. This then reverses and the opposite occurs. This shows that one set of diodes will always be forward biased, while the other set are reverse biased. **(6)**

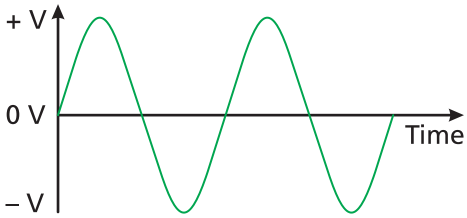
At 50Hz, the frequency of flashing increases to 50 cycles per second. Since humans have a limitation on seeing frequency this high, it will appear as a continuous light rather than flashing. **(3)**

TIP: It is interesting to note that if the question was what a camera would pick up, you would see more flashing, as the camera could pick up this frequency of refresh rate, but the human eye cannot. This is why monitors sometimes show up lines on their screen when they are recorded on a camera.

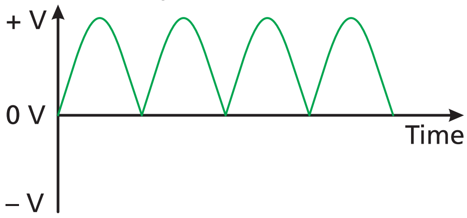
(ii) The resistor R limits the current and acts as a protection device for overloads. **(6)**

Output voltage could be displayed on a CRT or data-logger. **(6)**

AC input



Rectifier output



(6 + 6)

(iii) Because some voltage will be dropped across the LED, this energy conversion will result in an output voltage lower than input voltage. **(5)**

> **TIP:** The law of conservation of energy cannot be broken. If a device uses energy, it will be needed from somewhere and this is how it can show with an output lower than input.

11. (a) Choose any two from the following: **(8 × 7)**

- Travel through a vacuum
- Travel at the speed of light
- Can undergo any phenomena of waves
- Are EM radiation

(b) $P = W/t \Rightarrow P = \frac{0.36}{(3 \times 60)} \Rightarrow P = 2 \times 10^{-3}$ Watts

$\text{SAR} = \frac{\text{Power}}{\text{Number of kilograms}} \Rightarrow \text{SAR} = \frac{2 \times 10^{-3}}{10 \times 0^{-3}} \Rightarrow \text{SAR} = 0.2\text{W kg}^{-1}$

> **TIP:** Rather than working out the number of Joules per second per kilogram, it is easier to work out the power (Joules per kilogram) and then calculate how much power per kilogram is required.

(c) The radio frequency energy absorbed by the body is converted to heat energy and transferred around the body.

(d) Low-frequency EM waves are not very penetrating because of their low energy and long wavelength size.

> **TIP:** The higher the frequency, the more energy and penetration that is present in the wave.

(e) Audible frequency range for humans is 20Hz–20kHz.

(f) Choose any two from the following:

- Keep the phone as far away from your head as possible.
- Alternate ears being used during a long call.
- Limit call length.
- Keep the antenna away from your head.
- Use hands-free/loudspeaker function.

(g) $c = f\lambda \Rightarrow c/f = \lambda \Rightarrow \frac{3 \times 10^8}{1.2 \times 10^9} = \lambda \Rightarrow 0.25\text{m} = \lambda$

Therefore, $\frac{1}{4}(0.25\text{m}) = 0.0625\text{m}$

TIP: It is easy to forget the simpler steps required here such as one-quarter of wavelength. Make sure to refer back to the question to see you have finished all relevant parts, to avoid missing easy marks.

(h) Cancer can be caused by (choose any one from the following):
- Gamma rays
- X-rays
- UV rays

TIP: This refers back to the previous point in that high-frequency EM radiation is more penetrating and can cause ionisation of cells.

12. *Answer any two of the following parts (a), (b), (c), (d).*

(a) (i) 1. Start 1m from the wall and press the Start button.

2. Stand stationary for 5s.

3. Increase the distance from the wall to 3m steadily, in a time of 6s.

4. Stand stationary for another 7s.

5. Move steadily back to 1m from the wall in 4s. **(14)**

TIP: There are not too many marks going for this experiment, so keep it simple. You may also describe a simple version of the tuning fork above the resonance tube which is used in the speed of sound experiment.

(ii) Velocity in $\text{m.s}^{-1} = \frac{18000\text{m}}{3600\text{s}} = 5\text{m.s}^{-1}$

Time in seconds: 6 minutes = 360s; (14–6) minutes = 480s; (19–14) minutes = 300s

Area under the graph = displacement:

Area in three stages (s_1, s_2 & s_3):

s_1: ½(base)(perpendicular height) = ½(360)(5m.s^{-1}) = 900m (Triangle)

s_2: (base)(perpendicular height) = (480)(5m.s^{-1}) = 2400m (Rectangle)

s_3: ½(base)(perpendicular height) = ½(300)(5m.s^{-1}) = 750m (Triangle)

s_1, s_2 and s_3 = 900m + 2400m + 750m = 4,050m

Average velocity $= \frac{4{,}050\text{m}}{1{,}140\text{s}} = 3.55\text{m.s}^{-1}$ **(14)**

TIP: It is more acceptable to convert all units to m.s^{-1} and seconds at the beginning and then use the graph to calculate the final answer with these numbers.

When you know the velocity and time, it is just a matter of working out the area under the graph to find the total distance covered. Then distance divided by time gives average velocity.

(b) (i) Atomic numbers: (U) 92 + (n) 0 = (Ba) 56 + (X) + (3n) 0 $\Rightarrow$ 92 – 56 = X $\Rightarrow$ 36 = X

Mass numbers: (U) 235 + (n) 1 = (Ba) 141 + (X) + (3n) 3 $\Rightarrow$ 236 – 144 = X $\Rightarrow$ 92 = X

Therefore, missing element X = $^{36}_{92}\text{Kr}$ **(6)**

TIP: The mass number is only important for mass energy. However, it is the atomic number of 36 that defines the element and enables you to identify the missing element from the periodic table.

(ii) Energy released = 202.5MeV $\Rightarrow E = (202.5 \times 10^6)(1.6 \times 10^{-19}) \Rightarrow E = 3.24 \times 10^{-11}$J

Mass difference: $E = mc^2 \Rightarrow \frac{E}{c^2} = m \Rightarrow \frac{3.24 \times 10^{-11}}{(3 \times 10^8)^2} = m \Rightarrow 3.6 \times 10^{-28}\text{kg} = m$ **(9)**

TIP: Remember that an electronvolt (eV) is just the charge on an electron multiplied by the applied voltage. By converting eV into Joules, it is easy to use $E = mc^2$ to find the mass difference.

(iii) A chain reaction is a fission reaction in which at least one neutron is emitted in order to carry on the reaction. **(6)**

TIP: A simple diagram showing a chain reaction may also be suitable to answer this question.

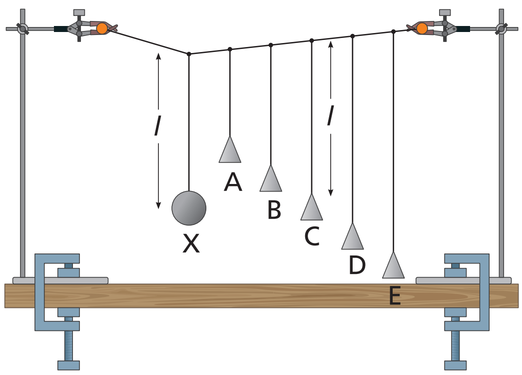
In order for a chain reaction to occur, there needs to be at least critical mass of fuel present. It is also necessary for at least one further neutron to cause further fission. **(3)**

(iv) Choose any one from the following:

- Radioactive waste leakage or disposal problems
- Radiation leaks/exposure
- Explosion hazards **(4)**

(c) Resonance is the transfer of energy between two bodies with similar natural frequency. **(6)**

A simple experiment to show this is Barton's pendulums:



TIP: It is not necessary to know the full workings of a data-logger for this question. The only information required is to interpret a distance–time graph and break it into its constituent stages.

Fig. 12.1

1. Set up equipment as in Fig. 12.1 with pendulums of various lengths.
2. Attach a mass X of the same length string (l) as one of the pendulums.
3. When you swing the mass, the pendulum of similar length l (in this case pendulum C) will begin to swing as well. This demonstrates the resonance caused by the natural frequency applied from the swinging mass. **(9)**

Choose any two from the following:

- Pitch: depends on frequency
- Quality: depends on the number of overtones present and their relative harmony
- Loudness: depends on the amplitude or intensity of sound present **(3 × 3)**

Every instrument emits its own unique combination of fundamental frequency and overtones/harmonics. **(4)**

TIP: It is for this reason that some instruments are considered to be of different quality to others. You may also refer to the fact that closed pipes emit odd multiples of fundamental frequency and open pipes emit all multiples of fundamental frequency.

(d) Electric field strength is the force per unit charge in an electric field. It is measured in $N.C^{-1}$ or $V\ m^{-1}$. **(9)**

(3)

Electric field strength from 2μC towards left, as per diagram:

$$E_1 = \frac{Q}{4\pi\varepsilon_0 d^2} \Rightarrow E_1 = \frac{2 \times 10^{-6}}{4\pi(8.9 \times 10^{-12})(0.1)^2} \Rightarrow E_1 = \frac{2 \times 10^{-6}}{1.1184 \times 10^{-12}} \Rightarrow E_1 = 1.788 \times 10^6\ N\ C^{-1}$$

Electric field strength from 5μC towards left, as per diagram:

$$E_2 = \frac{Q}{4\pi\varepsilon_0 d^2} \Rightarrow E_2 = \frac{5 \times 10^{-6}}{4\pi(8.9 \times 10^{-12})\ (0.15)^2} \Rightarrow E_2 = \frac{5 \times 10^{-6}}{2.5164 \times 10^{-12}} \Rightarrow E_2 = 1.987 \times 10^6\ N\ C^{-1}$$

Total electric field strength at P:

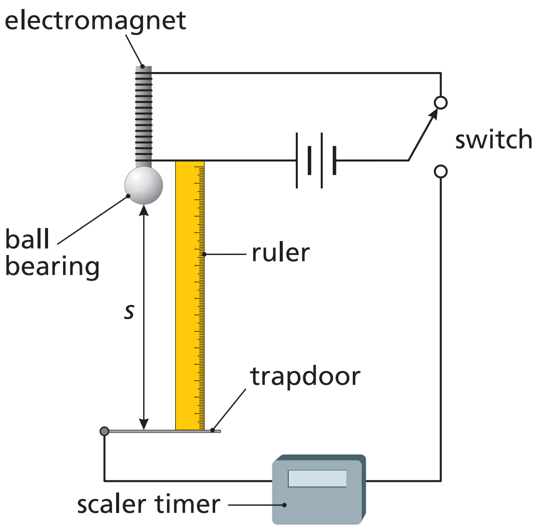
$E_1 + E_2 = 1.788 \times 10^6 + 1.987 \times 10^6 = 3.77 \times 10^6\ N\ C^{-1}$ **(4 × 3)**

TIP: Make sure not to confuse force between charges and electric field strength. The only difference is electric field strength has one value of *Q* on top of the equation as it is per unit charge. Once you have chosen the formula, it is sometimes easier to work out the electric field strength individually per charge and then calculate the algebraic sum of the strengths as above. This can work better when forces or strengths are moving in opposing directions.

Point discharge will occur with a large electric field strength, high charge density or large potential at a point. **(4)**

SECTION A

1. A sample apparatus such as this can be used:



(6)

TIP: As long as the critical pieces of equipment that give you the ability to measure distance and time are present, you will get most of the marks.

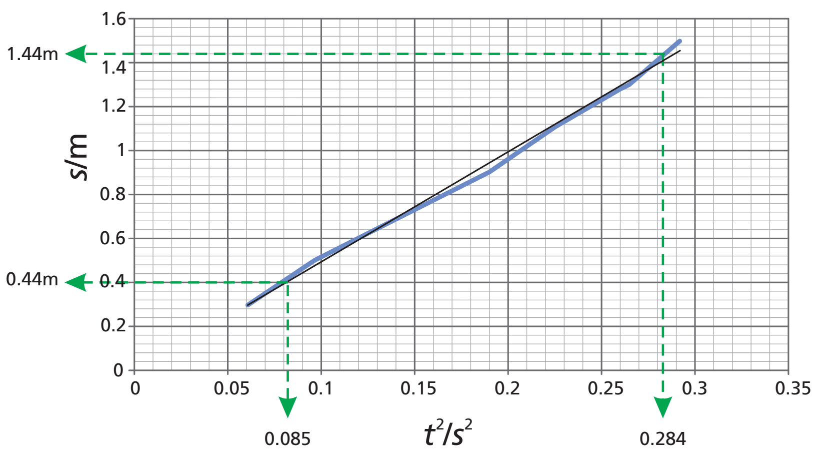
As shown on diagram. **(3)**

TIP: The more you can label on your diagram, the easier it is to answer these types of questions and ensure maximum marks.

The timer started when the ball left the release mechanism and the timer stopped when the ball hit the trapdoor or pressure plate. The timer was connected to a scaler timer which showed this duration of time. **(6)**

TIP: Even if the question seems straightforward, make sure to list all steps clearly to give a comprehensive answer.

s/cm	30	50	70	90	110	130	150
t/ms	247	310	377	435	473	514	540
t^2/s^2	0.0610	0.0961	0.1421	0.1892	0.2237	0.2642	0.2916



$$\text{Slope} = \frac{y_2 - y_1}{x_2 - x_1} \Rightarrow m = \frac{(1.44) - (0.44)}{(0.284) - (0.085)} \Rightarrow m = \frac{1}{0.199} \Rightarrow m = 5.025$$

$2 \times \text{slope} = \text{gravity} \therefore 2(5.025) = 10.05\text{m.s}^{-2} =$ **(7 × 3)**

TIP: The slope method for calculating g is based on $2s/t^2 = g$. Since the slope of this graph $= s/t^2$ (y/x); $2s/t^2 = 2 \times$ slope.

Air resistance can be reduced by using a small dense rounded object. Also draughts should be minimised or the experiment conducted in a vacuum. **(2 + 2)**

2. Image distance was measured by measuring the distance from the image on the screen to the centre of the lens. Image distance was only recorded when a sharp focused image was seen on the screen. **(12)**

TIP: You may also mention using multiple measurements to minimise parallax and decrease error.

Choose any two from the following:

- Make sure you always measure from the centre of the lens.
- Take multiple readings of distance and average.
- Try to hold the ruler perpendicular to minimise parallax error.
- Measure from internal graduations on the ruler, as readings taken from the end may incorporate errors from wear and tear. **(6)**

You may use the intercept method from a graph or calculate *f* three times from the data given and average the results.

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f} \Rightarrow \frac{1}{20}+\frac{1}{65.2}=\frac{1}{f} \Rightarrow 0.065=\frac{1}{f} \Rightarrow \frac{1}{0.065}=f \Rightarrow 15.31\text{cm}=\text{f}$$

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f} \Rightarrow \frac{1}{30}+\frac{1}{33.3}=\frac{1}{f} \Rightarrow 0.063=\frac{1}{f} \Rightarrow \frac{1}{0.063}=f \Rightarrow 15.78\text{cm}=f$$

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f} \Rightarrow \frac{1}{40}+\frac{1}{25.1}=\frac{1}{f} \Rightarrow 0.065=\frac{1}{f} \Rightarrow \frac{1}{0.065}=f \Rightarrow 15.42\text{cm}=f$$

TIP: The third reading when kept in the calculator gives this reading but when rounded here looks similar to the first reading. Make sure to keep all figures in the calculator until you have found the reciprocal for *f*.

Average for *f* = (15.31cm + 15.78cm + 15.42cm) divided by 3 = 15.5cm. **(15)**

TIP: You may also use a graph and intercept method to find the two values for *f* where your graph cuts the *x*-axis and *y*-axis. You could then average these to gain a final value for *f*. However, this is a quite long method and since you were not specifically asked to draw a graph or use a graph to calculate *f*, it is easier to use your optics formula above as shown.

When the object was placed inside the focal length (less than 15.5cm), no real image would be possible and only a virtual image would be produced. This would be difficult as the method of no parallax would need to be introduced. **(7)**

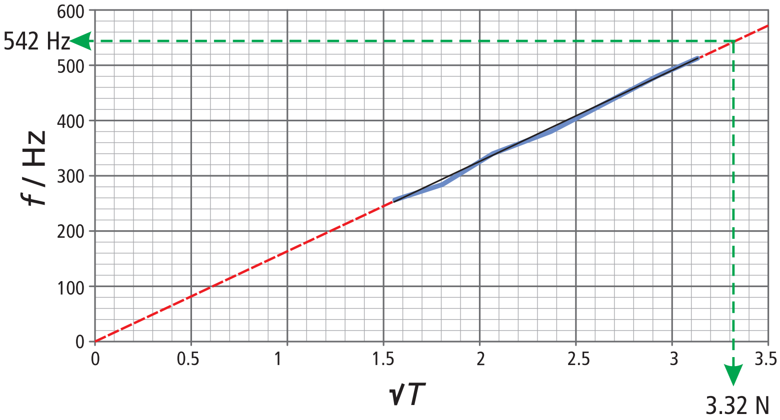
TIP: It is for this reason that we find the approximate focal length at the beginning of this experiment by focusing a distant object onto the screen and measuring the image distance.

3. The tension would be measured by using a Newton balance attached to the string or it may have been measured by pan and weights being used to tension the string. If the pan and weights were used, this would have been measured with a set of scales. **(3)**

Resonance would be seen to occur when the string vibrates at maximum amplitude. This could be observed by placing a paper rider at the middle of the string where the antinode occurs and waiting until it jumps/falls off the string due to vibration. **(3)**

TIP: It is essential to describe the equipment you are familiar with. If you used a tensioner and Newton balance to read the tension, then describe this. However, if you used a pan containing weights, you need to describe how you recorded the total weight of this applying tension to the string as it hangs down.

f/Hz	256	288	320	341	384	480	512
T/N	2.4	3.3	3.9	4.3	5.7	8.5	9.8
$\sqrt{T}$	1.55	1.82	1.98	2.07	2.39	2.92	3.13



(15)

The graph shows that frequency is proportional to the square root of tension, as the data can be extended to form a straight line through the origin. **(6)**

TIP: Make sure to calculate the square root of tension correctly before plotting it on your graph. It is best to copy the table of data and add in a new row showing the values for $\sqrt{T}$. When you have the values, plot frequency against $\sqrt{T}$, correctly labelling the axis and then draw a smooth best-fit straight line.

(i) From the graph, you can draw a dotted line perpendicularly up from 3.32N (the $\sqrt{11\text{N}}$), until it intersects the line. Then draw a dotted line over to the *y*-axis horizontally and read the value for frequency. It should be approximately 542Hz with a range of ±10Hz, depending on the accuracy of your graph. **(6)**

TIP: It is very important to draw a good, accurate graph when further data is required from it. It is also important to clearly show dotted lines for the examiner to see how you gained your answer from the graph. As you can see from the table of data, 11N is beyond the figures given and an extension on your graph is required. This shows that the same precaution is always needed for graph questions. Make sure to read ahead and see if you need to leave room on your graph page for an extension to the existing data.

(ii) $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}} \Rightarrow$ (square:) $f^2 = \frac{1}{4l^2}\frac{T}{\mu} \Rightarrow \mu = \frac{1}{4l^2}\frac{T}{f^2} \Rightarrow \mu = \frac{1}{4(0.4)^2}\frac{(11)}{(542)^2} \Rightarrow \mu = 5.85 \times 10^{-5}\text{kg m}^{-1}$ **(7)**

4. Make sure the wire is taut and straight. Only measure the distance between the points at which resistance is being measured. **(6)**

TIP: In a resistivity question, it is always a good idea to keep the idea of reducing errors in mind, such as using a taut wire, reducing kinks, only measuring between certain points and not heating the wire.

In order to find the average diameter of the wire, you can use a digital Vernier callipers or a micrometer. No matter which is used, you still need to zero the instrument first before recording individual diameter readings.

Place the wire carefully between the jaws of the instrument and take the reading. Repeat this procedure at different points along the wire and average them. **(15)**

TIP: Try not to scrape the wire as you measure it since this causes heating. Also, make sure to convert your readings to metres and if using πr^2 to calculate the cross-sectional area later, remember to halve the diameter to gain the radius measurement.

Using radius:

Cross-sectional area (A) = πr^2: $(\pi)(0.155 \times 10^{-3})^2 = 7.55 \times 10^{-8} m^2$

OR

Using diameter:

Cross-sectional area (A) = $\frac{\pi d^2}{4} = \frac{\pi\,(0.31 \times 10^{-3})^2}{4} = 7.55 \times 10^{-8} m^2$

$\rho = \frac{RA}{l} = \rho = \frac{(7.9)\,(7.55 \times 10^{-8})}{0.546} \Rightarrow \rho = 1.092 \times 10^{-6}\,\Omega m$ **(15)**

TIP: It is easier to calculate area first and make sure it is in m^2. Then list all values for R, A and l. Finally, substitute them into the formula and gain the final answer. It may take a little longer to write but it reduces the possibility of error.

As temperature increases, resistance increases. Also, as temperature increases, length and diameter of wire can increase with expansion. **(4)**

SECTION B

5. *Answer any eight questions from (a), (b), (c), etc.* **(8 × 7)**

(a) Boyle's Law states that the volume of a fixed mass of gas is inversely proportional to its pressure, as long as temperature is constant.

(b) $T^2 \propto R^3$.

OR

The period squared is proportional to the radius cubed.

OR

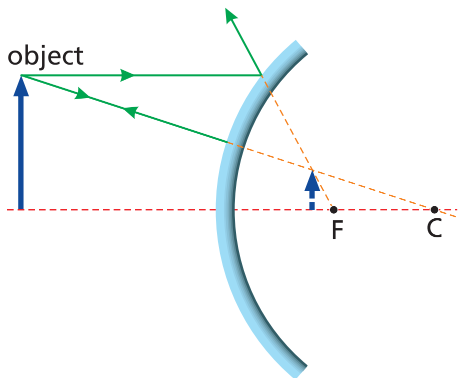
$T^2 = \frac{4\pi^2 R^3}{GM}$ (with all variables explained).

TIP: When asked for the relationship here, you may explain it as a formula or in words but the main parts of the period squared and radius cubed need to be stated.

(c) Different thermometers have different thermometric properties and therefore give different proportional readings. To ensure consistency of reproducible measurements, you need a standard thermometer.

(d) Change from 85dB to 94dB = 9dB increase.
Every 3dB change is a doubling/halving.
Therefore, a 9dB increase = 3(doubling) changes = 2^3 = a factor of 8.

(e)



TIP: Make sure to limit this image formation to any two rays that intersect. If you try to draw more than two rays, inaccuracies may show up in the intersection. The most important part of this question is to produce a virtual image.

(f) Electric field strength is the force per unit charge in an electric field. Its unit is the $N.C^{-1}$ or the $V.m^{-1}$.

(g) RCDs stop current flow when the size of the current entering the circuit differs from the size of the current leaving the circuit.

(h) $E = -N\dfrac{\varphi_2 - \varphi_1}{\Delta t} \Rightarrow E = -(20)\dfrac{(1.4 - 2.3)}{0.4} \Rightarrow E = 45\text{V}$

TIP: Remember that the minus in front of this formula only refers to the opposing induced emf as described in Lenz's Law. The change in magnetic flux is not important if it increases or decreases.

(i) X-rays are produced by very fast-moving electrons that are accelerated towards a metal anode target of high melting point.

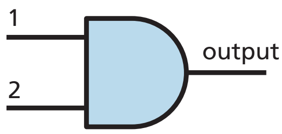
(j) The four fundamental forces from weakest to strongest are:

- Gravitational
- Weak nuclear
- Electromagnetic
- Strong nuclear

OR

(j)

Input 1	Input 2	Output
1	1	1
1	0	0
0	1	0
0	0	0



AND

TIP: You may include the diagram as well or a statement about the inputs having to both be high to have the output high, but full marks only are given for the table here.

6. Newton's Laws of Motion are:

All bodies will remain at rest or at constant velocity unless an external force acts on them.

The rate of change of a body's momentum is proportional to the net force applied and will act in the direction of the force.

Every action has an opposite but equal reaction. **(4 × 3)**

$F \propto$ Rate of change of momentum

$$F \propto \frac{\text{Change in momentum}}{\text{Time taken}}$$

Since the change in momentum is equal to the difference between the final and the initial momentum,

$$F \propto \frac{\text{Final momentum} - \text{Initial momentum}}{\text{Time taken}}$$

$$F \propto \frac{P_2 - P_1}{t}$$

Since $p = mv$,

$$F \propto \frac{mv - mu}{t}$$

Taking out m as a factor,

$$F \propto \frac{m(v-u)}{t}$$

Writing the proportionality as an equation with constant of proportionality k,

$$F = k\frac{m(v-u)}{t}$$

But $\dfrac{v-u}{t} = a$ by definition, so

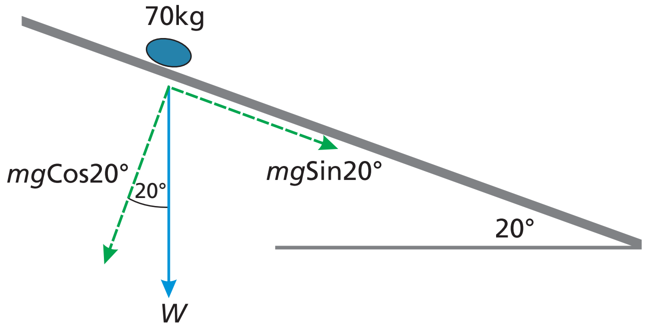
$$F = kma$$

Finally, set $k = 1$:

$F = ma$ **(10)**

(i) $v^2 = u^2 + 2as \Rightarrow (12.2)^2 = (0)^2 + 2a(25) \Rightarrow 148.84 = 0 + 50a \Rightarrow \frac{148.84}{50} = a \Rightarrow 2.977\text{m.s}^{-2} = 2.98\text{m.s}^{-2}$ **(6)**

(ii)



$W = mg\text{Sin}20° \Rightarrow W = (70)(9.8)(0.3420) \Rightarrow W = 234.63\text{N}$ **(6)**

TIP: The most difficult thing to work out in the question above is which component to apply Sin and Cos to. Cos always gets applied to the attached angle, which in the diagram above is 20°. Therefore, Sin applies to the 20° angle that gives the parallel to slope component. The attached angle is the one in which it is physically attached between the original vector and the new vector.

(iii) $F = ma$ (net force) $\therefore ma = F(\text{parallel to slope}) - F_{\text{friction}}$

$(70)(2.98) = 234.63 - F_{\text{friction}}$

$208.38\text{N} = 234.63\text{N} - F_{\text{friction}}$

$F_{\text{friction}} = 234.63\text{N} - 208.38\text{N}$

$F_{\text{friction}} = 26.25\text{N}$ **(6)**

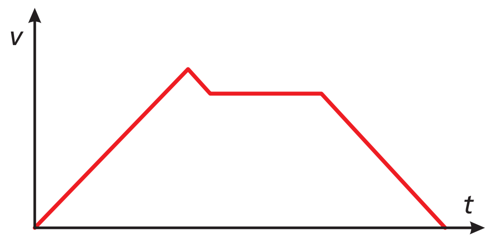
TIP: $F = ma$ works for net force. Therefore, if you already know the acceleration of the skateboarder, then this must have come from the net force, where the initial force had the force of friction subtracted from it as above.

$F = \frac{mv^2}{r} \Rightarrow F = \frac{(70)(10.5)^2}{10} \Rightarrow F = 771.75\text{N}$ **(6)**

TIP: If the question takes a change into a different section of the course such as circular motion, just list the variables and find the formula that fits. You have been given *m*, *v* and *r* and you are asked for *F*.)

$E_K = E_P \Rightarrow \frac{1}{2}mv^2 = mgh \Rightarrow$ (divide by m) $\frac{1}{2}v^2 = gh \Rightarrow v^2 = 2gh \Rightarrow \frac{v^2}{2g} = h \Rightarrow \frac{(10.5)^2}{2(9.8)} = h \Rightarrow 5.63\text{m} = h$ **(6)**

TIP: You are also free to use an equation of motion such as $v^2 = u^2 + 2as$ to find the value for *s*, when $v = 0$ (max Ht).



(4)

TIP: You may put in actual velocities but, for the number of marks here, it is unnecessary. As long as you show the velocity starting from the origin at rest and show the slight velocity change when the skateboarder hits the flat part of the ramp, you will be fine.

7. Diffraction is the spreading out of a wave as it moves through a gap or around an obstacle. **(6)**
Dispersion is the separation of light into its constituent colours. **(6)**

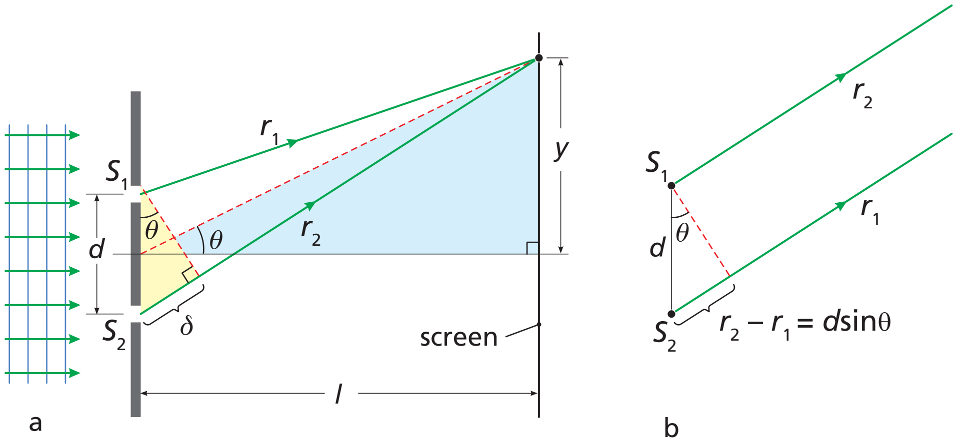


Fig. 7.1

Derivation of $n\lambda = d\sin\theta$:

Each slit gives a point of source of light a distance *d* apart. The screen is a distance *l* from the slits.

Wherever a bright fringe occurs, the difference in distance from that point on the screen to each slit is an integer multiple of wavelengths. From Fig. 7.1, this distance is $r_2 - r_1$. Therefore, $r_2 - r_1 = n\lambda$

Because the distance for *l* is relatively very large (compared to *d*), we can use trigonometric ratios:

$$\text{Sin}\theta = \frac{\text{opposite}}{\text{hypotenuse}} = \frac{r_2 - r_1}{d}$$

So:

$$d\text{Sin}\theta = r_2 - r_1$$

Therefore:

$$d\text{Sin}\theta = n\lambda \ \textbf{(12)}$$

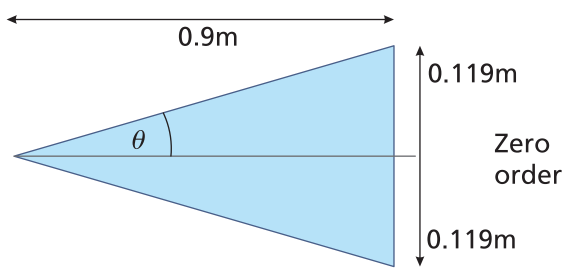
(i) $d = \frac{1 \times 10^{-3}}{80} = 1.25 \times 10^{-5}$

To calculate the angle of deviation for the third order image, use trigonometry:

$$\text{Tan}\theta = \frac{\text{opp}}{\text{adj}} \Rightarrow \text{Tan}\theta = \frac{0.119}{0.9} \Rightarrow \theta = \text{Tan}^{-1}\left(\frac{0.119}{0.9}\right) \Rightarrow \theta = 7.53°$$

$$n\lambda = d\text{Sin}\theta \Rightarrow (3)(\lambda) = (1.25 \times 10^{-5})(\text{Sin } 7.53°) \Rightarrow \lambda = \frac{(1.25 \times 10^{-5})\,(\text{Sin } 7.53°)}{3} \Rightarrow \lambda = 546\text{nm}$$

TIP: A range of ±5nm will be allowed here.



(4 × 3)

TIP: As with most formulae questions, sort out the variables first by calculating *d* and *θ* and then stating each figure before substituting it into the formula. If possible, keep the numbers in the calculator as you calculate it, so as not to lose any significant figures.

You can use any method you wish to find the angle required for third order images but the one shown on the left is based on finding the angle between zero order and third order.

(ii) For maximum diffraction, $\theta = 90°$. Therefore, $n\lambda = d\text{Sin}90° \Rightarrow n\lambda = d(1) \Rightarrow n = \frac{d}{\lambda} \Rightarrow n = \frac{1.25 \times 10^{-5}}{546 \times 10^{-9}}$
$\Rightarrow n = 22.89$

Therefore, the total number of images is 22 (one side) + 1 (zero order) + 22 (other side) = 45 **(9)**

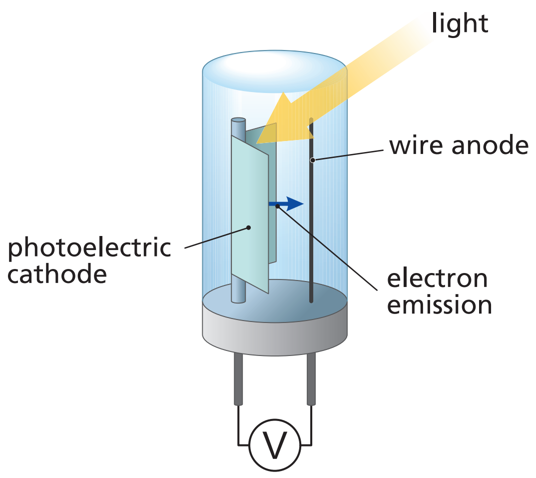
TIP: When working out the maximum number of orders possible, always allow $n = d/\lambda$ and take the next lowest integer. However, don't forget to factor in the same number of images on each side and the zero order image as well.

(iii) Because each constituent colour has its own wavelength, it diffracts differently from the other colours. These all constructively interfere to produce a series of bright images. **(9)**

(iv) Because the central image occurs at $\theta = 0°$, all individual colours converge here and produce a single white fringe. **(2)**

8. A photon is a quanta of EM energy. **(6)**

TIP: You may also refer to photons as packets or bundles of energy/light/EM radiation.



TIP: You may also mention the tube being at low pressure or evacuated and the outer casing of the tube being made of glass.

(12)

$\varphi = hf_0 \Rightarrow \varphi = (6.6 \times 10^{-34})\,(5.2 \times 10^{14}) \Rightarrow \varphi = 3.432 \times 10^{-19}\text{J}$ **(6)**

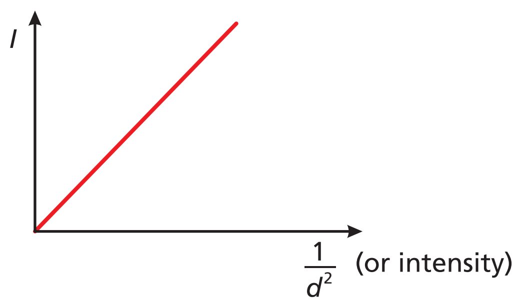
$hf = \varphi + ½mv^2 \Rightarrow hf - \varphi = ½mv^2 \Rightarrow$

$$\frac{hf-\varphi}{\frac{1}{2}m} = v^2 \Rightarrow \sqrt{\frac{hf-\varphi}{\frac{1}{2}m}} = v \Rightarrow \sqrt{\frac{(6.6\times10^{-34})(5.455\times10^{14}) - (3.432\times10^{-19})}{\frac{1}{2}(9.1\times10^{-31})}} = v \Rightarrow 1.922 \times 10^5\text{m.s}^{-1}$$ **(9)**

TIP: Remember to convert the wavelength of 550nm to frequency of 5.455×10^{14}Hz before multiplying by h. It is a common mistake to use wavelength when hf = energy in this equation.

It is also important to note that this is just an energy equation in Joules: hf is in Joules; φ is in Joules and $½mv^2$ is in Joules as they are all forms of energy.

Because the value of threshold frequency (f_0) is 5.2×10^{14}Hz, any frequency less than this will not have sufficient energy to release an electron for current. **(6)**



(6)

The intensity of light was varied by changing the distance between the source and photocell. **(5)**

Light consists of packets of energy (photons) and is therefore corpuscular (non-wave) in nature. **(6)**

TIP: When asked about conclusions concerning a photoelectric question, revert back to Einstein's photoelectric explanation and how light is made of quanta of energy and is proportional to frequency. This is most often the area being examined.

9. (i) Potential difference is the work required to move a charge of 1C from one point to another. **(6)**

TIP: The unit of voltage can also be written as $J.C^{-1}$, which also defines the unit of voltage, as it states 1V is the work per unit charge.

(ii) Capacitance is the charge per unit volt. **(6)**

TIP: Again, the formula for capacitance is $C = Q/V$, which gives us the above definition.

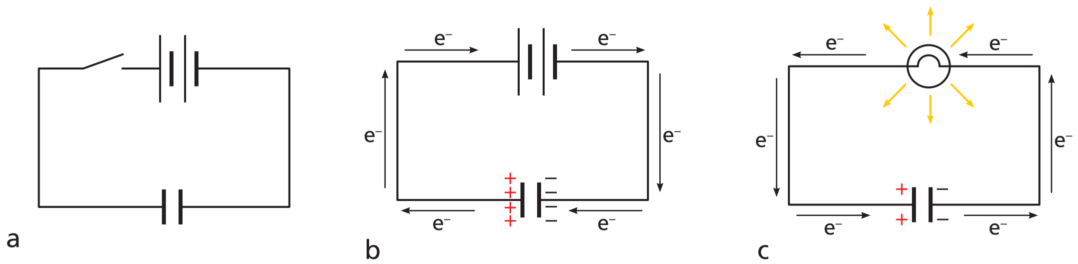


Fig. 9.1

1. Close the circuit in Fig. 9.1a.
2. Electrons move from the left capacitor plate to the positive terminal of the battery.
3. Electrons also move from the negative terminal of the battery to the right capacitor plate.
4. This causes the left capacitor plate to become positively charged and the right capacitor plate to become negatively charged.
5. If the two plates of the capacitor are now of a different charge, there is a potential difference (pd) between them.
6. When the pd of the capacitor = pdf of the battery, there is no pdf between them and the battery ceases to cause current flow. (Current stops in circuit and capacitor is now fully charged (Fig. 9.1b.)
7. Remove the battery and replace with a bulb (Fig. 9.1c).
8. The pdf in the capacitor now acts like a temporary battery and reverses its current flow by sending the electrons from the right plate through the bulb and back to the left plate.
9. This causes the bulb to flash as the capacitor discharges.
10. The time taken to charge the capacitor is much greater than the time taken to discharge it. **(14)**

(i) $C = Q/V \Rightarrow CV = Q \Rightarrow (64 \times 10^{-6})(2500) = Q \Rightarrow 0.16\text{C}$ **(6)**

(ii) $W = ½CV^2 \Rightarrow W = ½(64 \times 10^{-6})(2500)^2 \Rightarrow W = 200\text{J}$ **(9)**

TIP: Any time energy stored is mentioned, you should know to immediately use this formula above.

(iii) $I = Q/t \Rightarrow I = \frac{0.16}{10 \times 10^{-3}} \Rightarrow I = 16\text{A}$ **(9)**

(iv) $P = W/t \Rightarrow P = \frac{200}{10 \times 10^{-3}} \Rightarrow P = 20\text{kW}$ **(6)**

TIP: These calculation questions above are perfect examples of how a great deal of marks can be gained very quickly if you can move seamlessly between topic questions. Each question is based on simple formulae that rely on the answer before. You need only be familiar with the concept of how capacitance links to charge, how charge links to current, and how power is the rate at which work is done.

10. *Answer either part (a) or part (b).*

(a) The protons were accelerated by a high voltage. **(4)**

The alpha particles were detected on each side by a scintillation being produced on a phosphor screen. **(4)**

$^{7}_{3}Li + ^{1}_{1}H \rightarrow ^{4}_{2}He + ^{4}_{2}He$ **(4 × 3)**

Mass of reactants = $1.1646 \times 10^{-26} + 1.6726 \times 10^{-27} = 1.33186 \times 10^{-26}$kg

Mass of products = $2(6.6447 \times 10^{-27}) = 1.32894 \times 10^{-26}$kg

Loss in mass = 1.33186×10^{-26}kg – 1.32894×10^{-26}kg = 2.92×10^{-29}kg

Energy released: $E = mc^2 \Rightarrow E = (2.92 \times 10^{-29})(2.9979 \times 10^{8})^2 \Rightarrow E = 2.624 \times 10^{-12}$J **(9)**

> **TIP:** Make sure you work out the mass of each side of the equation carefully and then calculate the difference in mass. Only then use $E = mc^2$ to calculate the net energy involved.

According to Rutherford's experiment on the structure of the atom, the atom is mainly empty and therefore most protons would not have collided with the lithium nucleus. **(6)**

Kinetic energy of the colliding protons can be converted into new particles of mass. **(6)**

> **TIP:** It is for this reason that accelerators like the cyclotron were developed to increase the kinetic energy of colliding particles to produce new and more varied particles.

Total collision energy = 4GeV

Therefore, total collision energy = $(4)(1 \times 10^{9})(1.6 \times 10^{-19}) = 6.4 \times 10^{-10}$J

$E = mc^2 \Rightarrow E/c^2 = m \Rightarrow 6.4 \times 10^{-10}/2.9979 \times 10^{8} = m \Rightarrow 7.121 \times 10^{-27}$kg **(9)**

> **TIP:** You can only use the collision energy of 4GeV here as the initial colliding protons still exist after the collision and so are not involved in the mass/energy conversion.

Circular accelerators can generate greater velocities/energy and also use less space given their shape of tunnel. **(6)**

(b) Electromagnetic induction occurs when a changing magnetic field induces an emf, which in turn produces a current. **(6)**

Nicholas Callan. **(3)**

An induction coil can produce very high voltages from low voltage inputs of a d.c. source. **(6)**

The emf that is induced is proportional to the number of turns, according to $E = -N\frac{d\varphi}{dt}$. **(6)**

Thicker wire has lower resistance and therefore can carry a larger current with lower heat losses. **(6)**

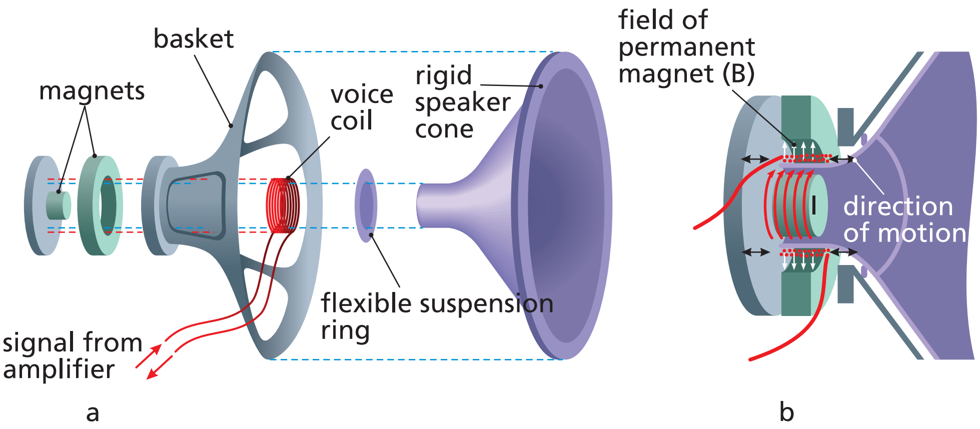
By wrapping the coils on the same soft iron core, greater efficiency and less energy losses occur. **(3)**

Choose any two from the following:

- IR
- Microwave
- TV
- Radio **(2 × 3)**

All EM waves travel at the speed of light in a vacuum and undergo (choose any one from the following):

- Reflection
- Refraction
- Diffraction
- Interference
- Polarisation (like all transverse waves) **(2)**



1. The tube is connected to a rigid speaker cone.
2. When current flows through the coil from the amplifier, it creates a magnetic field in the coil. This causes the coil and tube to move forward and back along the central magnet.
3. This varying frequency of movement is transmitted as a matching frequency of sound through the rigid cone.
4. Therefore, the frequency of input current affects the frequency of output sound. **(18)**

> **TIP:** This question is quite short and demonstrates how knowing the basics of a specific piece of equipment can pay off. There is a good deal of information in applied electricity but if you knew how the induction coil worked reasonably well, you would have no problem with this question.

11. (a) $1350 \times 8 \times 3600 = 3.9 \times 10^7$J **(8 × 7)**

> **TIP:** As long as you know that solar constant is the number of Joules per second (Watts) per square metre of surface, you can correctly multiply this out. Just remember to convert 1 hour to 3600s, since Watts are Joules per second.

(b) The black surface is a good absorber of heat energy.

(c) $Q = mc\Delta\theta \Rightarrow Q = (500)(4200)(50 - 20) \Rightarrow Q = 6.3 \times 10^7$J

> **TIP:** This is a straightforward heat change formula. Just make sure to convert all units to kg and use the temperature difference for $\Delta\theta$.

(d) There is more heat energy used when a material changes state. This enables a large amount of energy to be absorbed and released.

(e) Conduction, convection and radiation.

(f) The evacuated outer walls prevent heat loss through conduction and convection. The internal walls are silvered to reflect heat and trap it to prevent radiation loss.

(g) A heat pump transfers energy from one place to another. It essentially removes heat from one location (making it colder) and releases heat in another place (making it hotter).

(h) Geothermal is unaffected by weather and seasonal daylight as it continually operates underground transferring ground heat.

12. *Answer any two of the following parts (a), (b), (c), (d).*

(a) Hooke's Law states that whenever an object is deformed through bending, stretching or compression, there is a restoring force that is directly proportional to the displacement, as long as the elastic limit is not exceeded. **(6)**

$F = ma \Rightarrow F = mg \Rightarrow F = (0.5)(9.8) \Rightarrow F = 4.9\text{N}$

TIP: Work out the force in Newtons before substituting into $F = -ks$.

$F = -ks \Rightarrow 4.9 = -k(30 \times 10^{-3}) \Rightarrow 4.9/30 \times 10^{-3} = -k \Rightarrow 163.33 \text{ N m}^{-1} = k$ **(9)**

TIP: The minus in front of the k only relates to the direction of restoring force and not the magnitude of k.

Also, the displacement to be used for this question is the amount by which the spring extended when the mass was placed on it. In this case, 30mm was used.

The motion of the sphere is that of simple harmonic motion with the acceleration proportional to the displacement and directed towards the equilibrium point of 330mm. **(4)**

$F = ma$

$F = -ks$

Therefore, $ma = -ks \Rightarrow (0.5)(a) = -(163.33)(20 \times 10^{-3}) \Rightarrow 0.5a = 3.2666 \Rightarrow (\times 2)\ a = 6.533 \text{ m.s}^{-2}$ **(9)**

TIP: If you can equate two formulae to find the missing value for acceleration, this is the simplest method to solve the question. Always think about $F = ma$ in mechanics questions as it appears many times.

(b) The addition of phosphorus to silicon causes it to become n-type as more electrons are free to conduct. This process of doping increases extrinsic conduction.

The addition of boron to silicon causes it to become p-type as more positive holes are free to conduct as charge carriers. This process of doping increases extrinsic conduction. **(3 + 3)**

The electrons and positive holes cross the junction and meet. This causes an area of no free charge carriers which forms the depletion layer, with a junction voltage on each side of it. **(9)**

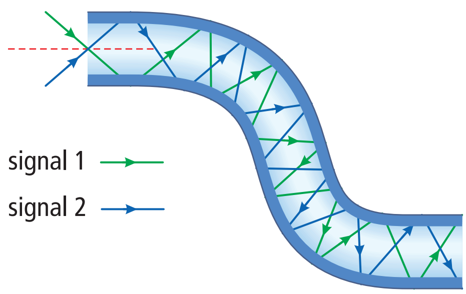
(i) In forward bias, the depletion layer narrows as electrons and positive holes are forced into it. Eventually, when the applied voltage reaches the junction voltage level, the diode conducts.

(ii) In reverse bias, the depletion layer widens and no conduction occurs but breakdown of the layer may happen if too much voltage is applied. **(6 + 3)**

Choose any one from the following:

- Rectification of a.c.
- LEDs
- Integrated circuits **(4)**

(c) 1. Light enters the core at such an angle as to be greater than the critical angle. Because of this, total internal reflection occurs.
2. The light then reflects back and forth as it moves through the fibre but always staying within the core.
3. This continues for many kilometres until it reaches its source. **(9)**



The cladding is of a lower refractive index because if light attempts to leave the core, it is moving from a denser to a rarer medium and this causes the light to bend away from the normal. This forces the light back into the core again, by total internal reflection (TIR). (This helps to keep the information intact and secure.) **(6)**

$$n = \frac{c_1}{c_2} \Rightarrow n = \frac{c_{air}}{c_{glass}} \Rightarrow 1.55 = \frac{3 \times 10^8}{c_{glass}} \Rightarrow c_{glass} = \frac{3 \times 10^8}{1.55} \Rightarrow c_{glass} = 1.94 \times 10^8 \text{m.s}^{-1}$$ **(7)**

Every 2km, intensity of power halves.
8km = 4(2km) $\therefore$ power is decreased by a factor of $2^4 = 16$
If initial power is 10W: final power after 8km = 10W/16 = 0.625W **(6)**

(d) (i) An alpha particle consists of a helium nuclei with 2 protons and 2 neutrons. **(3)**

(ii) Alpha particles are produced from the disintegration of americium since it is an unstable radioactive element. **(6)**

(iii) Alpha radiation has very short range and very poor penetration. Because of this, it mainly stays within the structure of the smoke detector. **(4)**

$$\lambda = \frac{\ln 2}{T_{\frac{1}{2}}} \Rightarrow T_{\frac{1}{2}} = \frac{\ln 2}{\lambda} \Rightarrow T_{\frac{1}{2}} = \frac{0.693}{5.1 \times 10^{-11}} \Rightarrow T_{\frac{1}{2}} = 1.359 \times 10^{10}\text{s}$$

To convert seconds to years: $\frac{1.359 \times 10^{10}\text{s}}{365.25 \times 24 \times 60 \times 60} = 430.59$ years $= 430.6$ years **(9)**

> **TIP:** It is easy to miss the question asking for years here, since decay constant is in seconds. Always make sure your answer is as asked. In the case of second-year conversion, it is best to use a value of 365.25 days per year when there are more than 4 years, so as to allow for leap year duration.

Because Americium-241 has such a short half-life compared to universal age, it is unlikely to naturally exist in nature. Also, it is not a member of a decay series and therefore has no natural parent element. **(6)**

> **TIP:** In the case of questions where you may not know the answer, you can still make logical reasoned responses by looking at the figures given. For example, in this question, just think of the half-life in terms of the age of the universe and reason it out.

SECTION A

1. By increasing the number of oscillations, the student can decrease the percentage error in the experiment. Also, by taking the time for 30 oscillations, you can gain a better average of a single oscillation time. **(3)**

TIP: Remember, you must always focus on reducing percentage error, wherever possible. This may involve taking more oscillations, extending time measurements or increasing the physical length measured. Always look at the key measurements in the experiment and see how percentage error can decrease as you change them.

In order to keep length constant, in this experiment, the string must be securely fixed between a split cork suspension point or equivalent suspension fixture. It also needs to be an inextensible (doesn't stretch) string. **(6)**

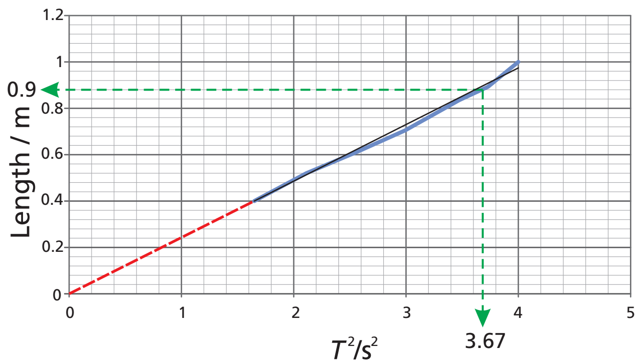
TIP: You need to keep the relationship between periodic time and length in mind here. For this relationship to hold, all other factors must remain constant: $g = 4\pi^2\left(\frac{l}{T^2}\right)$.

Both measurements need to change here. You need to change cm to metres and the periodic time given for 30 oscillations needs to be divided by 30 to gain the average periodic time for one oscillation. After this, the single periodic time must be squared to use as per the formula.

l/m	0.4	0.5	0.6	0.7	0.8	0.9	1
t/s (1 oscillation)	1.28	1.42	1.58	1.72	1.82	1.93	2
T^2/s^2	1.64	2.02	2.5	2.96	3.31	3.73	4

(5 × 3)

TIP: Make sure to label axes correctly as length (m) against T^2 (s^2).



TIP: Plot each point carefully. Generally, you are given an allowance of one point being off, but do not automatically rely on this every time. Join the points with a smooth best-fit straight line and continue to the origin. In the case of this graph, the red dotted line shows the extension to the origin. Once you see a linear graph, it is safe to state that one quantity is proportional to the other.

In this case: $T^2 \propto l$. This also adheres to the previous relationship equation $\left(g = 4\pi^2\left(\frac{l}{T^2}\right)\right)$. **(4)**

TIP: Using your graph, take two points and calculate the slope (e.g. (0,0) and (3.67,0.9)). Put these into the slope formula to get a slope of 0.245.

The values for the slope (3.67,0.9) can be any set of coordinates from your line but not from the exact data points given in the question. Make sure to choose your own points and show, using dotted lines, where they came from. This is shown by green dotted lines here.

By using this slope in the equation: $\left(g = 4\pi^2\left(\frac{l}{T^2}\right)\right)$, you get a value for $g = 9.68\text{m.s}^{-2}$ **(4 × 3)**

TIP: It is important to use your graph to gain the slope data. Do not use the given points in the formula. Remember that any line passing through the origin can use (0,0) as one point in the slope formula, making it a lot easier to calculate.

The range of slope can be anything from 0.24 to 0.25, which will yield a range of gravity from 9.4m.s^{-2} to 9.9m.s^{-2}.

2. Any reasonable answer such as:

Make sure energy losses before the experiment cancel out energy losses after the experiment.

OR

The time to melt the ice was reduced, thereby reducing errors.

OR

Using a larger mass of ice requires warmer water to complete the experiment. **(3)**

TIP: It is common to ask about using warm water at the beginning of the fusion experiment just as it is common to ask about using cold water at the beginning of the vaporisation experiment. In both cases, it is to balance out energy losses at the beginning/end of the experiments. Remember that if using ice, use warm water initially, and if using steam use cold water initially.

In order to correctly balance out the errors, you should aim to start with water that is an equal number of degrees on the other side of equilibrium from the final temperature. For example, if doing the specific latent heat (SLH) of fusion of ice with a room temperature of 20°C and an expected final temperature of 5°C, you should start the experiment with water at a temperature of 35°C. This way, the water is 15°C above room temperature and the final temperature of the water is also 15°C below room temperature. Likewise, if conducting the SLH vaporisation experiment with a room temperature of 20°C and an expected final temperature of 32°C, you should start the experiment with an initial temperature of approximately 8°C.

The ice needs to be dried to avoid placing any extra liquid water into the calorimeter. It needs to be melting in order to be at the phase change point of fusion (i.e. melting ice is at 0°C). **(3 × 4)**

TIP: The important points of this question are 'dried' and 'melting'.

Subtract the mass of (calorimeter and water) from the mass of (calorimeter and water and ice). **(6)**

TIP: This is a simple statement about how you calculated the mass. This question can sometimes extend to how you found the mass in terms of equipment and, in this case, you need to mention the mass balance being used to measure the mass of each before subtraction.

Midpoint of initial and final temperature = (30.5 + 10.2) divided by 2 = 20.35°C. **(6)**

TIP: This relates to the first question tip. By aiming to have the initial temperature the same amount above room temperature as the final temperature is below it, you need only find the midpoint of initial and final temperatures to estimate room temperature. A range of ±1°C will usually be accepted here.

(i) Energy lost is a combination of heat change for the calorimeter and water:

$Q = mc\Delta\theta$ (cal) + $mc\Delta\theta$ (water) = $(60.5 \times 10^{-3})(390)(20.3) + (58.3 \times 10^{-3})(4200)(20.3)$

Q = 5449.6365J (This can be rounded to 5446.6J.) **(3 × 3)**

TIP: Make sure to use kg for mass. This is one of the most common mistakes. A simple way of avoiding decimal place conversion is to use scientific notation instead, as above (e.g. 60.5g = 60.5×10^{-3}kg). Also, note how the temperature change for the calorimeter and water always match each other.

(ii) In order to calculate the specific latent heat of fusion for the ice, we need to calculate the energy required to change the state of the ice and heat the liquid once it melts:

$Q = ml$(fus) + $mc\Delta\theta$ (ice) = $(15.1 \times 10^{-3})(l) + (15.1 \times 10^{-3})(4200)(10.2) = 15.1 \times 10^{-3} l + 646.884$

Now let the energy lost by the calorimeter and water equal the energy required for state change/heat gain in the ice:

$$5449.6365 = 15.1 \times 10^{-3}l + 646.884$$

$$5449.6365 - 646.884 = 15.1 \times 10^{-3}l$$

$$4802.7525 = 15.1 \times 10^{-3}l$$

$$\frac{4802.7525}{15.1 \times 10^{-3}} = l$$

$3.181 \times 10^5 \text{Jkg}^{-1} = l$ **(3 × 3)**

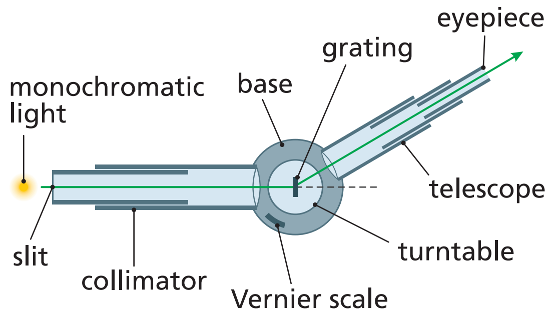
TIP: In the case of this question, you are asked to calculate the energy lost separately from the energy gained. It is more common to calculate the full equation in one go by allowing the energy lost to equal the energy gained. The best way to deal with this is to think about what you have on one side of the equals and what you are adding on the other side of the equals.

Make sure to practise converting everything to kg, because the units are in this form. By using exponentials, you reduce the risk of moving decimal places.

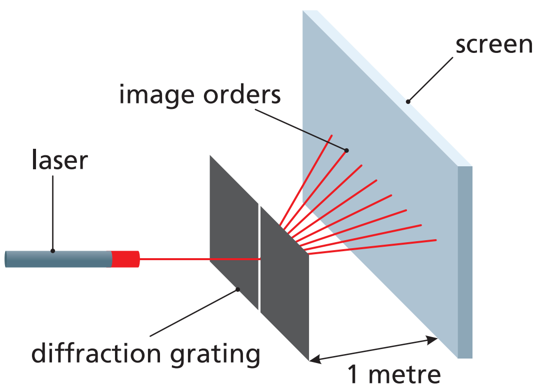
One of the common mistakes is to confuse the temperature difference ($\Delta\theta$) for each part of the equation. To play it safe, list these first before substituting into the question. Whether the experiment is for fusion or vaporisation, the $\Delta\theta$ for the existing water and calorimeter will always be the difference between initial and final temperatures. However, for fusion you are looking for temperature changes between 0°C and the final temperature, and for vaporisation you are looking for the difference between 100°C and the final temperature. Remember $\Delta\theta$ means difference in temperature and no minus is used.

The $\Delta\theta$ for the existing water and calorimeter at the start of the experiment will always match but the $\Delta\theta$ for the added ice will be different.

3.



TIP: Depending on the apparatus you are familiar with, list the key components. If you are using the spectrometer, you need to draw and label the spectrometer, light source (monochromatic) and diffraction grating.



TIP: If you are using the laser method, you need to show and label a laser source, diffraction grating, screen and metre measurement.

(4 × 3)

TIP: The key to knowing which equipment to show and label depends on the required measurements. If something is integral to the formula, it needs to be there. In the case of the spectrometer, the Vernier scale is part of the spectrometer and will enable you to record the angle of deviations. However, in the case of the laser, you need to use the trigonometric ratio Tan to calculate the angles of deviation. This means a metre stick and screen is required to record the adjacent and opposite measurements.

When you have identified the central image, the first order image is either the next bright fringe on the left or right of this. **(3)**

TIP: In the case of either method, the zero order is the straight through image. Identify this first before proceeding with the experiment.

Spectrometer method:

- Focus the crosshairs of the telescope on the zero order image to identify it.
- Move the telescope to the left and record the angle of the first order image on the left when it is clearly focused in the centre of the crosshairs.
- Slowly move the telescope to the right, as you look through it. Pass the zero order and stop when the crosshairs are focused on the first image to the right.
- Record this angle now. The angle between the first order images is the arc of degrees between these two measurements of left and right first order images.

TIP: This can be simply implied by stating that you subtract the recorded measurement on one side from the other side. This gives you the difference between the left and right first order images.

OR

Laser method:

- Measure the length between the grating and zero order image. Label this as x.
- Now measure the length between the right first order image and zero order on the screen. Label this as y.
- Using x as adjacent length and y as opposite length, use the Tan ratio to calculate the angle. This is the angle of first order on the right.
- Repeat this procedure for the first order image on the left and add this angle to the one from the right. This is the angle between the first order images. **(3 × 3)**

TIP: The laser method is a simpler set-up and procedure but does require knowledge of trigonometry to calculate the angles. Even if you only want to use the laser method, you still need to know the parts and operation of the spectrometer for section B questions.

Whether you use the spectrometer or laser method, the formula is still the same. Write down the formula and list the parts you will substitute in for first order, second order and third order images.

TIP: Remember that the angles you will use for first, second and third order images will be half of the figures given, as you only require the angle between zero order and the image (not between the two images as given).

Also, calculate d and state it before substituting it in.

TIP: Remember that d has units of 'per m'. Therefore, by calculating it as a metre, you eliminate possible errors, e.g. if the grating has 500 lines per mm, then calculate it as 1×10^{-3}m divided by 500. $\frac{1 \times 10^{-3}}{500} = 2 \times 10^{-6}\text{m}^{-1}$.

Now calculate each order individually with the formula: $n\lambda = d\text{Sin}\theta$:

First order: $(1)(\lambda) = (2 \times 10^{-6})(\text{Sin}17.1) = 5.8808 \times 10^{-7}\text{m} = 5.88 \times 10^{-7}\text{m}$

TIP: The angle used here is 34.2° divided by 2 = 17.1°.

Second order: $(2)(\lambda) = (2 \times 10^{-6})(\text{Sin}35.8) \Rightarrow \lambda = \frac{(2 \times 10^{-6})\ (\text{Sin}35.8)}{2} \Rightarrow \lambda = 5.8496 \times 10^{-7}\text{m} = 5.85 \times 10^{-7}\text{m}$

TIP: The angle used here is 71.6° divided by 2 = 35.8°.

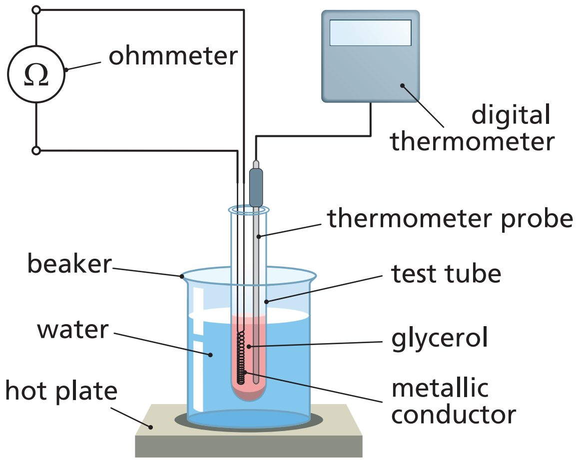
Third order: $(3)(\lambda) = (2 \times 10^{-6})(\text{Sin}60.8) \Rightarrow \lambda = \frac{(2 \times 10^{-6})\ (\text{Sin}60.8)}{3} \Rightarrow \lambda = 5.8195 \times 10^{-7}\text{m} = 5.82 \times 10^{-7}\text{m}$

TIP: The angle used here is 121.6° divided by 2 = 60.8°.

Now average the three calculations of λ: $\dfrac{5.88 \times 10^{-7} + 5.85 \times 10^{-7} + 5.82 \times 10^{-7}}{3}$
$= 5.85 \times 10^{-7}$m
$= 5.585$nm **(4 × 3 + 4)**

TIP: Make sure not to average the angles for the three orders before substituting in to the formula. Also, by stating the numbers you are going to use in the formula, you enable the examiner to see what you are using, in case you miscalculated the angles or *d*. This makes it easier for the examiner to follow your calculations.

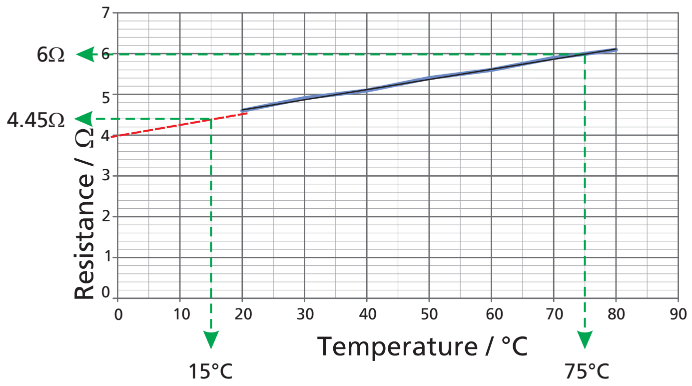
4.



TIP: Draw and label the integral components needed to draw the graph and calculate resistance at any temperature. This includes a metallic conductor in a container of liquid (the liquid could be glycerol or any one of high specific heat capacity (SHC) to allow for a good equilibrium of temperature), a thermometer in the same container as the conductor, a heat source to heat the beaker of water the container is in, and an ohmmeter physically connected to the metallic conductor to register resistance.

TIP: This experiment is almost identical to the thermistor vs. resistance one and only differs with the metallic conductor equipment. The thermometer may be a digital or glass model but it must be with the metallic conductor to register the same temperature as the metallic conductor is experiencing.

(3 × 3)



TIP: Make sure to label each axis and leave room to extend your graph into the *y*-axis to gain a good *y*-intercept. The graph should be a good straight line from the given points.

Graphs should take up at least three-quarters of the graph page and be clearly labelled. Read ahead in your question to ascertain if the graph needs extending at any point before you commit yourself to not leaving enough room.

(4 × 3)

(i) $m = \dfrac{y_2 - y_1}{x_2 - x_1} \Rightarrow m = \dfrac{(6) - (4.45)}{(75) - (15)} \Rightarrow m = \dfrac{1.55}{60} \Rightarrow m = 0.026$

The slope is 0.026 in this case.

Now substitute 0.026 for m, –20 for x and 4.1 for c into $y = mx + c$

$y = (0.026)(-20) + (4.1) \Rightarrow y = 3.58$

TIP: The easiest method to do this mathematically is to find the slope and *y*-intercept and use in the $y = mx + c$ formula. The slope needs to be calculated from any two points from your graph using $\dfrac{y_2 - y_1}{x_2 - x_1}$.

TIP: The *y*-intercept is gained by extending your graph back until it cuts the *y*-axis. This is shown as a red dotted line on the graph above. As can be seen, the value for the *y*-intercept is 4.1.

Resistance (y) will come out as 3.58Ω **(6 + 6)**

TIP: Resistance is considered as *y* in this formula as resistance is on the *y*-axis. A range of 3.5Ω–3.7Ω is acceptable here.

(ii) Again, using the value for 80° and the y-intercept value for 0°, you can get the difference between these to gain this answer: 6.1Ω – 4.1Ω = 2Ω

A range of 1.9Ω – 2.1Ω would be accepted here. **(6)**

TIP: Both of the above calculations need to come from the graph as it is specifically asked for. If you use the table you will get considerably less or zero marks depending on the marking scheme being used.

(iii) The metallic conductor is only linear for a narrow range of temperature. **(1)**

TIP: As long as you make any relevant statement such as this or a statement relating to electron collisions and molecular movement, you will gain the marks.

SECTION B

5. *Answer any eight questions from (a), (b), (c), etc.* **(8 × 7)**

(a) Whenever an object is floating, the weight of the fluid displaced will equal the object's weight.

(b) Calculate the force at the head of the thumbtack:

Force = Pressure × Area $\Rightarrow F = (12)(500 \times 10^{-6}\text{m}^2) \Rightarrow F = 6 \times 10^{-3}\text{N}$

Now use this force at the point: $P = F/A \Rightarrow P = \dfrac{6 \times 10^{-3}}{0.3 \times 10^{-6}} \Rightarrow P = 2 \times 10^4\text{Pa}$

TIP: The important thing in this question is to convert the units correctly. Make sure to change the 500mm^2 into m^2. Each mm^2 is equal to 1×10^{-6}m^2. Therefore, 500mm^2 = 500×10^{-6}m^2. Likewise, the point has an area of 0.3mm^2, which equals 0.3×10^{-6}m^2.

(c) Frequency is inversely proportional to length $\left(f \propto \dfrac{1}{l}\right)$.

TIP: Whenever possible state the relationship or formula but give the legend as well saying what each letter corresponds to.

(d) Since light is of a very small wavelength and diffraction increases as gap decreases, the window gap is considered relatively too large to diffract the light.

(e) Because a higher percentage of electrical energy is converted into light energy.

TIP: Note the use of efficient here and think about percentage input versus output to answer it.

(f) $F = EQ \Rightarrow F = (5)(1.6 \times 10^{-19}) \Rightarrow F = 8 \times 10^{-19}\text{N}$

TIP: By looking at the figures given, a suitable formula is easily identified here, as you are asked for Force (F) and given E and Q.

(g) (i) Electrons and positive holes.

(ii) Ions.

TIP: Remember that one of the factors that makes the semiconductor different is the dual charge carriers present.

(h) Electric field and magnetic field.

(i) Geiger–Müller tube (G–M tube), which operates on ionisation.

OR

Solid state detector, which operates on ion-pair formation.

OR

Cloud chamber, which operates on ionisation and cloud condensation.

(j) No charge/very small mass/very little interaction with other matter.

TIP: Logically, you should see that for something to be difficult to detect, it must be difficult to detect mass and/or charge.

A labelled diagram using a galvanometer symbol in series with a resistor.

TIP: The resistor must be of a quite large value and can be labelled as a 'multiplier'.

6. The force of attraction between two masses is proportional to the product of their masses and inversely proportional to the square of the distance between their centres. **(6)**

TIP: Again, you can state the formula but give correct legend notation for each letter.

Centripetal force or gravitational force. **(3)**

The force always points towards the centre of the body it orbits (i.e. towards the Earth). **(3)**

List the values for each letter in the formula and substitute into: $g = \frac{GM}{R^2}$

$$g = \frac{(6.6 \times 10^{-11})\,(6 \times 10^{24})}{(6.4 \times 10^6 + 400 \times 10^3)^2} \Rightarrow g = 8.564\text{m.s}^{-2} = 8.6\text{m.s}^{-2}$$ **(11)**

TIP: The catch to be aware of is to add the height to the radius of the Earth before squaring the distance. Also, make sure to correctly convert to metres as shown above.

Remember, Newton's formula is based on the distance between centres.

The astronaut is in a constant state of free fall. **(3)**

Centripetal force = Gravitational force

From the two formulae for the forces: $mr\omega^2 = \frac{GMm}{r^2}$

Dividing both sides by mr: $\omega^2 = \frac{GM}{r^3}$

From $T = \frac{2\pi}{\omega}$ we get $\omega = \frac{2\pi}{T}$, so:

$$\left(\frac{2\pi}{T}\right)^2 = \frac{GM}{r^3}$$

Square $\omega = \frac{2\pi}{T}$:

$$\frac{4\pi^2}{T^2} = \frac{GM}{r^3}$$

Invert the equation:

$$\frac{T^2}{4\pi^2} = \frac{r^3}{GM}$$

Then:

$$T^2 = \frac{4\pi^2 r^3}{GM}$$

OR

$$T^2 = \frac{4\pi^2 (r+h)^3}{GM}$$ **(4 × 3)**

TIP: This is a very important derivation to know. It is not necessary to detail it exactly as per your textbook, but you need a logical step-by-step approach to show where each part came from.

List the values for each letter in the formula and substitute into: $T^2 = \frac{4\pi^2 (r+h)^3}{GM}$

$$T^2 = \frac{4\pi^2 (6.8 \times 10^6)^3}{(6.6 \times 10^{-11})(6 \times 10^{24})} \Rightarrow T^2 = \frac{1.2413 \times 10^{22}}{3.96 \times 10^{14}} \Rightarrow T^2 = 3.1346 \times 10^7 \Rightarrow$$

$T = \sqrt{3.1346 \times 10^7} \Rightarrow T = 5.599 \times 10^3 s = 93.31$ minutes $= 1.56$ hours **(6)**

TIP: Remember to calculate the radius of orbit using the radius of Earth and 400km height. All other figures are as given.

By converting the answer into minutes and hours, you gain a better picture of its orbit time, which enables you to verify how realistic the answer is. By doing this, a simple exponential slip may be spotted.

Because the ISS has a different orbit to a geostationary one, it will have a different period to the Earth's rotation and be at a different point each orbit. **(6)**

24 hours divided by 1.56 hours = 15 whole rotations. But there may have been a sunrise at the beginning of this time; therefore, we can take the answer 15 or 16 (if we include an extra sunrise at the beginning). **(6)**

TIP: When doing this part, you need to take the next lowest integer answer and ignore the remainder. By giving both answers using minimum or maximum number of sunrises, you allow for either possibility and avoid delay in deciding.

7. Resistivity can be seen as the resistance of a 1m side cube of material or stated as a formula and correct notation given: $\rho = \frac{RA}{l}$.

Its unit is the ohm metre (Ωm). **(3 × 3)**

TIP: By looking at the formula, you can sometimes construct a definition using the quantities stated, as well as the unit required.

Convection is the transfer of heat energy by the circulating currents of a liquid or gas medium, whereas radiation is the transfer of heat energy by electromagnetic energy, without the need for a medium. **(4 + 4)**

(i) $\rho = \frac{RA}{l} \Rightarrow \rho = \frac{(12)(1.1 \times 10^{-3})}{40} \Rightarrow \rho = 1.1404 \times 10^{-6} \Rightarrow \rho = 1.14 \times 10^{-6}\,\Omega\text{m}$ **(3 × 3)**

TIP: Remember to convert all units to metres and to use the radius of the wire for this formula. The diameter is initially given.

(ii) $W = Pt$ (Energy = Power × Time) ⇒ Heat Energy = (1050)(120) ⇒ Heat Energy = 1.26×10^5J
96% efficiency = 96% of 1.26×10^5J = 1.21×10^5J **(3 × 3)**

TIP: To avoid confusion, work out the actual heat energy for 100 per cent efficiency first and then find the percentage efficiency required.

Earth the toaster or suitably insulate the internal parts from the outer walls. **(9)**

TIP: In the case of this type of question, any suitable domestic electricity answer will suffice. You may even go so far as to talk about limiting shocks by using RCDs.

The stages by which electrons gain energy and move to a higher state are:

- Electrons gain energy.
- Electrons raise to a higher energy state.
- Electrons eventually fall back to a lower energy state.
- When they return to their original energy state, they emit a photon of light of a particular frequency (i.e. red), **(4 × 3)**

TIP: This question is an interesting mix of resistance, power, domestic electricity and atomic structure. However, when questions mix material such as here, they often are not as difficult, to allow you to jump between material. It is only by knowing all the syllabus that a student can fully gain from a question such as this.

8. Electromagnetic induction occurs when a changing magnetic field induces an emf which in turn produces a current. **(6)**

The magnitude of the induced emf is directly proportional to the rate of change of flux. **(6)**

The direction of an induced current is always such as to oppose the change producing it. **(6)**

TIP: These laws are also known as Faraday's Law of Electromagnetic Induction and Lenz's Law. Because of the nature of the opposite effect of Lenz's Law, it is best to state these in words but, as a safeguard, the formula and annotated legend for each symbol of the formula could also be given.

The induced emf in the copper sheet causes a current to flow, which in turn produces a magnetic field that opposes the magnet's movement, according to Lenz's Law. This then dampens the magnet's swing and slows it down. **(4 × 3)**

TIP: Remember that the start of a question introduces you to the concepts that will be examined in more detail. If you were able to state Faraday's and Lenz's laws successfully, then the question here is just a simple application of them. Try to think of the question as a whole idea rather than a lot of separate parts.

The swing of the magnet is a pairing of potential and kinetic energy which converts into electrical/magnetic and heat energy. **(6)**

TIP: This question incorporates some simple energy conversion mechanics. You could easily see this type of question appearing with a conservation of energy format or pendulum operation.

(i) $\text{time} = \dfrac{\text{distance}}{\text{speed}} \Rightarrow t = \dfrac{5 \times 10^{-2}}{5} \Rightarrow t = 0.01\text{s}$ **(6)**

TIP: By converting all units to metres or m.s^{-1}, you eliminate possible errors from mismatched units.

(ii) $\varphi = BA \Rightarrow \varphi = (8)(2.5 \times 10^{-3}) \Rightarrow \varphi = 0.02\text{ Wb}$ **(7)**

TIP: Again, by changing the area of the loop cutting the magnetic field, you assure yourself of calculating standard units. In this case, a 5cm square loop is $5 \times 10^{-2}\text{m} \times 5 \times 10^{-2}\text{m}$, which equals $2.5 \times 10^{-3}\text{ m}^2$. When you have area ($A$) and magnetic flux density (B), it is easy to see which formula to use for magnetic flux (φ).

(iii) $E = \Delta\varphi/\Delta t \Rightarrow E = \dfrac{0.02\text{Wb}}{0.01\text{s}} \Rightarrow E = 2\text{V}$ **(7)**

TIP: This induced emf can also be calculated as (final magnetic flux – initial magnetic flux) divided by the time taken, but you will still receive the same answer.

9. Refraction is the bending of light at a boundary as it passes from one transparent medium to another. **(6)**

TIP: Remember you do not need the exact wording above. It can be any logical statement referring to bending light rays and media of different refractive indices. You can also use a diagram of light rays bending at a boundary to assist your answer.

Snell's Law states that the ratio of the sine of angle of incidence to the sine of angle of refraction is a constant. **(6)**

TIP: You may also state this as a formula but use the correct notation: $\dfrac{\sin i}{\sin r} = n$.

(i) $P = 1/f \Rightarrow 64\text{m}^{-1} = 1/f \Rightarrow \dfrac{1}{64} = f \Rightarrow 0.0156\text{m} = f$. Therefore, $1.56\text{cm} = f$ **(4 × 3)**

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \Rightarrow \frac{1}{u} + \frac{1}{2} = \frac{1}{1.56} \Rightarrow \frac{1}{u} = \frac{1}{1.56} - \frac{1}{2} \Rightarrow \frac{1}{u} = 0.14 \Rightarrow u = 7.14\text{cm}$$

TIP: Because we are referring to the eye here, it is best to keep the units in cm to better estimate the accuracy of the answer. If we converted to metres, it would be difficult to appreciate how reasonable the answer was.

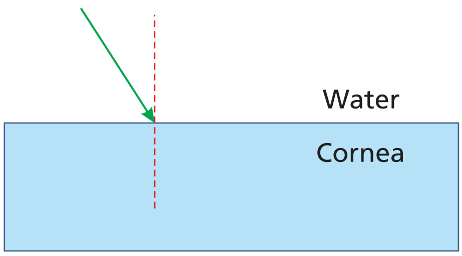
(ii) $P_{max} = P_1 + P_2 \Rightarrow 64 = 38 + P_2 \Rightarrow 64 - 38 = P_2 \Rightarrow 26\text{m}^{-1} = P_2$ **(3)**

TIP: Because the cornea is of a fixed power and the variable internal lens can change power based on the power of accommodation, we need only find this lens power here. In other questions, you may be examined on how the internal lens changes power and for this you would refer to the ciliary muscles.

$\frac{\text{Sin } i}{\text{Sin } r} = n \Rightarrow \frac{\text{Sin } 37}{\text{Sin } 27} = n \Rightarrow 1.3256 = n \Rightarrow 1.33 = n$ **(6)**

TIP: The main thing to watch here is which angle is incidence and which is refraction. However, if you remember that any ray going from rare to dense will have a value for *n* greater than 1, you will be sure of your answer.

The other common mistake that can be made here is not having the calculator in the correct mode. Make sure you are in DEG/DRG mode for all of these questions.



(6)

TIP: Considering both water and the cornea have almost the same refractive index, you will have virtually no refraction between these media. This is examined further in the next question.

(i) Referring to the previous question, light is not refracted at the cornea underwater due to the cornea and water having the same refractive index. **(6)**

(ii) 26m^{-1}. **(3)**

TIP: Since the cornea is essentially redundant underwater with no goggles on, then the only converging power in the eye is from the internal lens, which we previously calculated as 26m^{-1}.

(iii) The eye is essentially long sighted here since the internal lens is not powerful enough to converge a focused image onto the retina. **(3)**

TIP: You can verify this by using the power of the internal lens and the distance between lens and retina.

(iv) By wearing goggles underwater there is an air/cornea interface for light to initially refract before hitting the internal lens. This means that the eye behaves normally as it would above water. **(5)**

TIP: As you can see, each question here is short and simple but relies on a progression of thought from the mathematical answers at the start to the effect of removing one of the converging layers. Remember to always keep the previous parts of the question in mind as you move on to the next.

10. *Answer part (a) or part (b).*

(a) Gravitational: infinite range
Weak nuclear: 10^{-18}m range
Electromagnetic: infinite range
Strong nuclear: 10^{-15}m range **(8)**

TIP: It is a useful exercise to remember these forces in order of magnitude, as shown here, from weakest to strongest, as this sometimes is asked. The gravitational and EM both have infinite ranges and both follow the inverse square law of magnitude.

Up, top and charm (u,t,c). **(3 × 2)**
Baryon: 3 quarks.
Meson: 1 quark and 1 antiquark. **(3 + 3)**
Up, up and down (u,u,d). **(3)**

Net charge = zero, as charge must be conserved in this reaction. **(6 + 3)**

TIP: This is one of those questions in which you just need to remember the laws of conservation that all charge, mass and momentum must be conserved. Since the number of positive protons is the same before and after the collision, then the pions must have a sum of neutral charge when added.

(i) Energy required to produce 1 pion = $1 \times mc^2 \Rightarrow 1(2.482 \times 10^{-28})(2.9979 \times 10^8)^2$

$\Rightarrow E = 2.2327 \times 10^{-11}$ J

Energy required to produce 3 pions = $3 \times mc^2 \Rightarrow 3(2.482 \times 10^{-28})(2.9979 \times 10^8)^2$

$\Rightarrow E = 6.6980 \times 10^{-11}$ J

Therefore, the energy after the collision must be the difference between the incident energy and the energy required to make the pions:

2GeV – 6.6980×10^{-11} J = remaining kinetic energy in this reaction.

TIP: Make sure you convert the incident 2GeV energy into Joules before subtracting.

$(2 \times 10^9)(1.6022 \times 10^{-19}) - 6.6980 \times 10^{-11} \Rightarrow 3.2044 \times 10^{-10} - 6.6980 \times 10^{-11} = 2.5346 \times 10^{-10}$ J
$= 2.535 \times 10^{-10}$ J **(6 × 3)**

TIP: It is also acceptable to convert both quantities into eV and express the combined kinetic energy in this manner. If this was the case, the 2GeV would be 2×10^9 eV and the pion production energy would be $\left(\frac{6.6980 \times 10^{-11}}{1.6022 \times 10^{-19}}\right) = 4.18047 \times 10^8$ eV.

The net kinetic energy would then be: 2×10^9 eV – 4.18047×10^8 eV = 1.58195×10^9 eV. As long as you make sure that the energy equals on each side of the equation, it does not matter if you calculate energy in eV or Joules.

To summarise the above reaction:

2 protons (with 2Gev between them) = 2 protons + 3 pions (with 2.535×10^{-10} J between them).

(ii) The extra kinetic energy could have produced more pions. Therefore, divide the kinetic energy by the energy required to produce a pion from the previous part:

Number of potential pions produced = $\frac{2.535 \times 10^{-10}\text{ J}}{2.2327 \times 10^{-11}\text{ J}} = 11.35$ pions

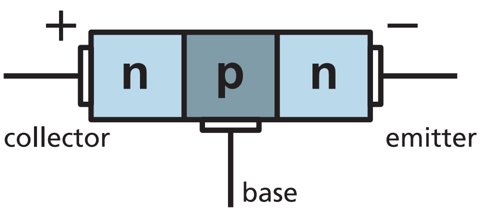
Therefore, the total number of pions would equal the existing 3 pions from part (i) and a potential another 11 pions = 14 pions. **(3 + 3)**

TIP: You need to take the next lowest integer for the number of pions, as you cannot get a fraction of a pion produced.

It also shows the simple nature of calculating mass production in this section. By dividing energy provided by the energy required, you can see what could be produced. It is for this reason that circular accelerators were developed to provide more and more collision energy to produce more and more variety of particles.

It is also important to note that eV and Joules are both energy units and can be used in equations. But if you are using $E = mc^2$, you must have the mass in kg and you will get Joules in your answer.

(b)



(6)

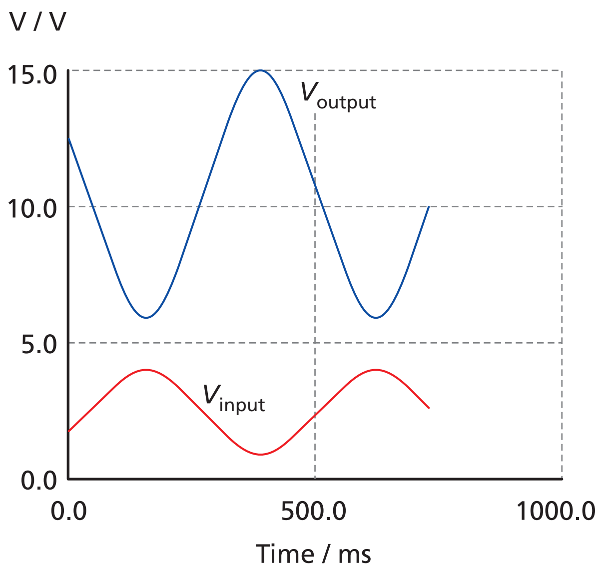
TIP: Diagram should show with labels the three layers (emitter, base and collector).

Emitter current, base current and collector current. **(3)**

$I_e = I_c + I_b$ **(6)**

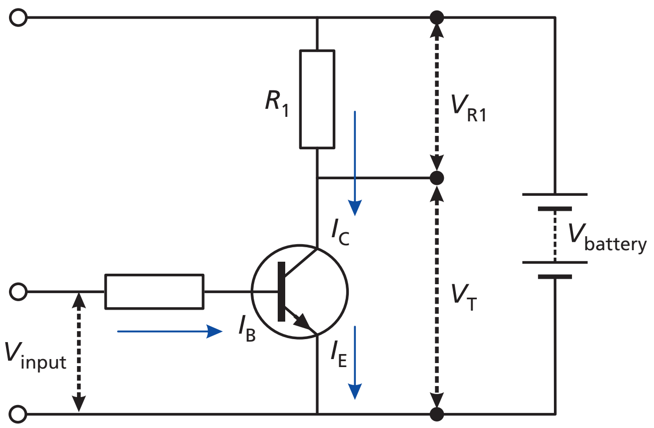
(i) The bias resistor is required to make sure that the base–emitter junction will always be forward biased. **(6)**

(ii) The load resistor will convert any change in the collector current to a similar large change in the voltage. **(6)**



(3 × 3)

TIP: Make sure to have the output larger than input and 180° out of phase.



(4 × 3)

TIP: Make sure to have a resistor in series with the power supply and a resistor protecting the base.

Input 1	Output
1	0
0	1

(4 + 4)

TIP: As can be seen from the applied electricity question, it is firmly based on being able to draw circuit diagrams. It is also common to be asked about the functions and locations of each resistor in a transistor circuit.

11. (a) 373.15K. **(8 × 7)**

(b) The newton is defined as being the force that gives a mass of 1kg an acceleration of 1m.s^{-2}.

TIP: You may also describe the newton from $F = ma$ and list the force, mass and acceleration units as well as their relationship. This will essentially give you the same answer as above.

(c) State the quantities you have and list the correct formula for this. Then substitute in the numbers to calculate the answer:

$$F = \frac{mv - mu}{\Delta t} \Rightarrow F(\Delta t) = (mv - mu) \Rightarrow (9 \times 10^3)\ (0.6 \times 10^{-3}) = \text{change in momentum}$$

5.4kg m.s^{-1} = change in momentum

TIP: Using Newton's Second Law, you should know that the rate of change of a body's momentum is proportional to the force applied. The use of this was given to you in the previous question, when the newton was asked to be defined and $F = ma$ could have been given as part of the answer.

The initial momentum of any object at rest is zero; therefore, you can use $mv - mu$ but allow for mu = zero.

(d) Choose any three from the following:
- Gamma
- X-ray
- UV
- Visible
- IR
- Microwave
- TV/radio

(e) The photoelectric effect is the emission of electrons from the surface of a metal, when EM radiation of a suitable frequency is incident on it.

(f) Light travels in discrete packets or quanta of energy (photons).

Light has a wave–particle duality.

The energy of EM radiation is proportional to frequency ($E = hf$).

TIP: This question is essentially asking for Einstein's explanation of the photoelectric law and how it changed thinking at the time. This was referred to in the above passage in the question.

(g) $E = hf \Rightarrow E = (6.6 \times 10^{-34})(3.3 \times 10^{14}) \Rightarrow E = 2.178 \times 10^{-19}\text{J} = 2.18 \times 10^{-19}\text{J}$

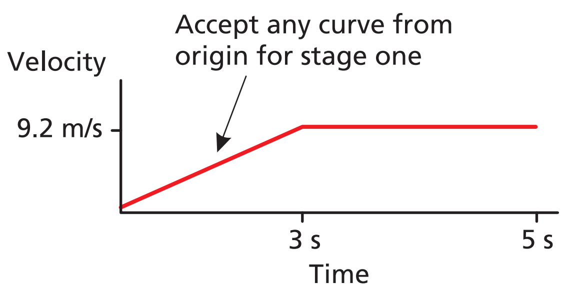
TIP: By correctly identifying the important nature of energy being proportional to frequency from the previous question, this is a simple calculation to now apply.

(h) $E = mc^2 \Rightarrow E/c^2 = m \Rightarrow \dfrac{100 \times 10^6}{(3 \times 10^8)^2} = m \Rightarrow 1.11 \times 10^{-9}\text{kg} = m$

TIP: STS questions can sometimes mix a lot of material but they never get too difficult. In order to approach these questions correctly, you need to think of all possible tangents of information. Remember energy and mass connect physics. If you can express any calculation in Joules, you can let it equal any other energy equation. This is the basis for Einstein's $E = mc^2$.

12. *Answer any two of the following parts (a), (b), (c), (d).*

(a) Energy cannot be created or destroyed but converted from one form to another. **(4)**



TIP: Make sure both stages are clearly shown on the graph and try to keep it as scaled as possible to give a good indication of the time and velocity in each stage.

(3 + 3)

Distance travelled = area under the graph $\Rightarrow s = (.5)(3)(9.2) + (2)(9.2) = 32.2\text{m}$. **(6)**

TIP: It is important to use your graph when asked. If you resort to using an equation of motion, you may lose significant marks for not using the graph. The graph needs to be split into easy-to-calculate shapes, such as rectangles and triangles, and then combining the answers.

Let potential energy = kinetic energy to calculate:

$$mgh = \frac{1}{2}mv^2 \Rightarrow \text{(divide by } m\text{)}: gh = \frac{1}{2}v^2 \Rightarrow \text{(divide by } g\text{)}: \frac{\frac{1}{2}v^2}{g} \Rightarrow h = \frac{\frac{1}{2}(9.2)^2}{9.8} \Rightarrow h = 4.32\text{m}$$

Therefore, maximum height: 4.32m + 1.1m = 5.42m **(4 × 3)**

TIP: You could also use the equation of motion $v^2 = u^2 + 2as$ and substitute in 0m.s^{-1} for v as maximum height means zero velocity here. This would also give you the answer required for s.

(b) (i) Quality depends on the the number and relative strength of overtones present. **(3)**

(ii) Loudness depends on amplitude and intensity of sound entering the ear. **(3)**

TIP: Loudness could also be affected by the resonant frequencies for each animal. Humans have a specific resonant frequency between 2000Hz and 4000Hz and this would seem louder. A dBA meter measures sound and takes this into account.

The Doppler effect is the apparent change in frequency due to the relative motion of source and/or observer. **(6)**

$$f' = \frac{fc}{c - u} \text{ (approaching)}$$

$$f' = \frac{(1520)(340)}{340 - 55} \Rightarrow f' = 1813.33\text{Hz}$$

$$f' = \frac{fc}{c + u} \text{ (moving away)}$$

$$f' = \frac{(1520)(340)}{340 + 55} \Rightarrow f' = 1308.35\text{Hz}$$

Change in frequency = 1813.33Hz – 1308.35Hz = 504.98Hz **(4 × 3)**

TIP: The Doppler formula is in your tables, but you need to be very careful how you choose which formula for approaching and departing sources. It is also a good idea to list your variables before substituting them into the formulae.

Choose any one from the following:

- Red shift/blue shift for star motion
- Radar
- Speed traps **(4)**

(c) $^{238}_{92}\text{U} + ^{1}_{0}\text{n} \qquad ^{139}_{56}\text{Ba} + ^{97}_{36}\text{Kr} + 3\,^{1}_{0}\text{n}$ **(4 × 3)**

TIP: Make sure to use your tables and always double-check that the atomic and mass numbers equate on each side.

The neutrons are slowed to avoid radiative capture because only slow neutrons cause further fission. **(6)**

The moderator slows the neutrons down through collisions. **(3)**

TIP: This is explained further when you know about the parts of the nuclear reactor and the moderator in particular, which may be made from heavy water or graphite.

Any positive advantage:

- Cheaper energy
- No CO_2 emissions or greenhouse gases
- Lower accident rate

Any negative disadvantage:

- Radioactive waste management
- Potential accident/leak hazards **(4 + 3)**

(d) Capacitance is the ratio of charge to voltage. **(6)**

TIP: This may also be given as an annotated formula of $C = Q/V$ and explain the symbols.

The important stages of this charging process are:

1. Bring a charged object near the electroscope.
2. When the leaf has diverged, earth the electroscope and remove the earth again.
3. Remove the charged object and the electroscope is charged. **(4 + 3 + 3)**

TIP: A diagram may help in showing this but pay close attention to time as this only carries 10 marks.

1. Connect an electroscope to the parallel plate capacitor.
2. Earth one of the plates and place a charge on the other plate.
3. Separate the plates.
4. The gold leaf diverges from the rod in the electroscope, showing voltage increases.
5. Increasing voltage means decreasing capacitance. **(4 × 3)**

TIP: This experiment above could be done a number of ways. You may also directly connect a multimeter set to capacitance reading and separate the plates to show capacitance decreasing. The main concept to keep in mind about the effect of distance on a capacitor is that by measuring voltage, you can see what is happening to capacitance from the formula $C = Q/V$. As voltage increases, capacitance decreases; as voltage decreases, capacitance increases.

SECTION A

1. By pivoting the metre stick on a wedge or hanging it on a thread, you can find the centre of gravity point, when it is balanced. **(6)**

The weight of the metre stick can be measured by placing on a Newton balance. **(6)**

TIP: If it helps, a diagram can also be given here to show the centre of gravity point.

It may not be at the 50cm mark due to wear and tear of the metre stick. **(3)**

TIP: If you think about the metre sticks you have used, remember that you would usually measure from graduations within the metre stick as the end may be worn or chipped.

The metre stick would have been horizontal and at rest. **(4)**

TIP: You can also refer to the laws of equilibrium here and state about the sum of the moments being zero and the upward/downward forces cancelling.

(i) Net force on the metre stick: Forces up: 4.5 + 5.7 = 10.2N

Forces down: 2.0 + 3.0 + 4.0 + 1.2 = 10.2N

Therefore, net force = 10.2N(up) – 10.2N(down) = 0N **(3)**

TIP: It is a common mistake to omit the metre stick weight. Remember that the metre stick will exert its force through the centre of gravity point. In this case, the 1.2N given acts down through the 50.4cm mark. The 50.4cm will only come into play for the calculation of moments.

(ii) Taking the vertical axis at 0cm:

Clockwise moments: (2N)(0.115m) + (3N)(0.383m) + (1.2N)(0.504m) + (4N)(0.802m)

= 0.23Nm + 1.149Nm + 0.6048Nm + 3.208Nm = 5.1918Nm = 5.2Nm **(6)**

TIP: You can take the moments about any axis but it is quite easy to take zero cm and work your way across the metre stick to calculate moments, as done in the previous part.

(iii) Taking the vertical axis at 0cm:

Anticlockwise moments: (4.5N)(0.262m) + (5.7N)(0.704m) = 1.179Nm + 4.0128Nm = 5.1918Nm = 5.2Nm **(6)**

TIP: The question may also ask why the figures do not cancel exactly; this can be allowed for with errors such as parallax and the metre stick not being perpendicular to the Newton balances.

The laws of equilibrium require the upward forces and downward forces to cancel each other:

$F_{up} = F_{down} \Rightarrow$ 10.2N = 10.2N

They also require the sum of moments about an axis to sum to zero:

Clockwise moments – Anticlockwise moments = Sum of moments $\Rightarrow$ 5.2Nm – 5.2Nm = 0Nm **(6)**

2. The copper was heated by placing in hot water or by applying another source of energy to it. **(6)**
Its temperature was measured using a thermometer or temperature probe. **(3)**

(i) Energy lost by the copper is purely heat change, therefore: $E = mc\Delta\theta$

$E = (30.2 \times 10^{-3})(390)(78.5) = 924.57\text{J} = 924.6\text{J}$ **(7)**

TIP: Make sure to convert all measurements into kg using exponentials. Also list your variables before substituting them into the formula for heat change. By doing this, you are allowing for simple arithmetical errors should they occur.

(ii) Heat lost by copper = Heat gained by water and calorimeter

$$924.6 = mc\Delta\theta(\text{water}) + mc\Delta\theta\ (\text{calorimeter})$$
$$924.6 = (45.5 \times 10^{-3})(c)(4.5) + (55.7 \times 10^{-3})(390)(4.5)$$
$$924.6 = 0.2048c_{(\text{water})} + 97.75$$
$$924.6 - 97.75 = 0.2048c$$
$$826.85 = 0.2048c$$
$$\frac{826.85}{0.2048} = c$$
$$4.038 \times 10^3 = 4.04 \times 10^3 \text{J kg}^{-1}\text{ K}^{-1}$$ **(9)**

TIP: The specific heat capacity of water can be obtained by allowing for the heat lost by the copper to equal the heat gained by the calorimeter and water. This is a simple energy equation of heat transfer with no state change. As long as you allow energy values to equal, it should work out simply. It is also worth having an idea of the value you require to double-check. The specific heat capacity of water is approximately 4200J kg^{-1} K^{-1}, depending on purity. Keep this figure in mind and you will easily spot if you forgot to convert g to kg.

Choose any two from the following:

- Insulation
- Using a low SHC thermometer
- Adding the copper smoothly without splashing and with little delay
- Using cold water to balance heat losses before and after the experiment **(6 + 6)**

By increasing mass, percentage error decreases, due to mass measurement or greater change in temperature. **(3)**

TIP: Any change in quantities that improve accuracy are usually due to minimising percentage error. It is always advisable to lower percentage error where possible. In the case of this question, by adding more copper, the temperature should raise more and the mass of the copper would have less room for error. For example, if you are using a glass thermometer to measure temperature and can only reasonably measure every ½ degree, a reading of 10 degrees would have a 5 per cent potential error, whereas a reading of 20 degrees would only have a 2.5 per cent potential error.

3. The image of light from a distant object is focused onto a screen. You can then measure the distance from the mirror to the screen to determine the focal length. **(6 + 2)**

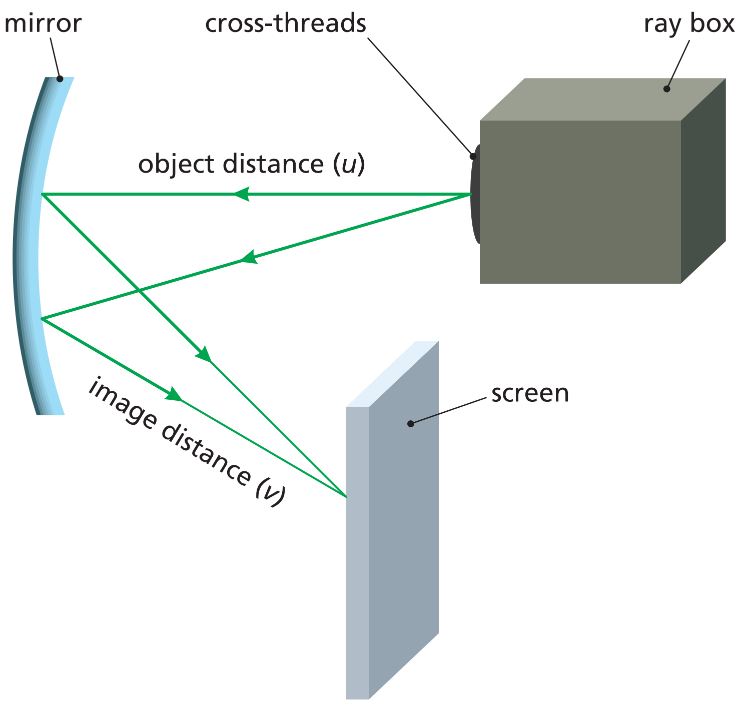
TIP: This is a common introduction question for focal length of mirror or lens. By focusing parallel light rays from a distant object, the rays will converge at the focal point. Therefore, the focused image will always appear a focal length away from the mirror or lens.

The advantage of finding an approximate focal length could be to gain a rough estimate of the focal length for later verification of your answer. It could also be to make sure you do not place the object within the focal length during the experiment. This avoids virtual image formation and difficulties in locating a real image. **(2)**

TIP: The main purpose of this precaution is to make sure you always place the object outside the focal length and therefore will be able to focus a real image onto the screen quickly and easily.

The image was clearly focused by moving the mirror and/or screen until a clear image was found.

TIP: Make sure the integral parts of the experiment are here, such as the concave mirror, screen, object and ruler. The diagram should be clearly labelled with *u* and *v* annotated.



(6 + 6)

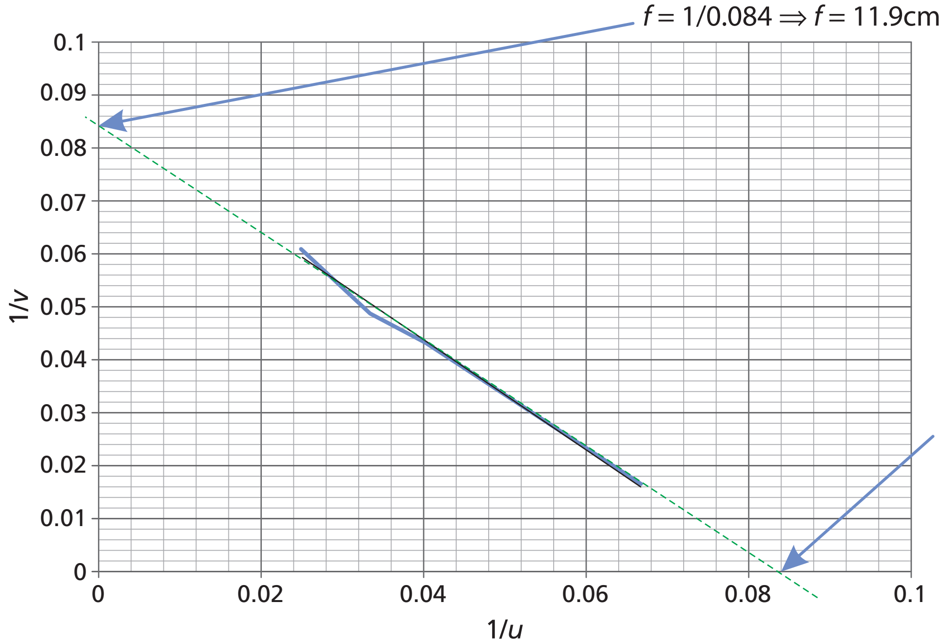
TIP: The better the labelled diagram, the easier it is to describe how a procedure was done. As long as you can refer to a good diagram, you can save time explaining how you find particular measurements.

Where the line cuts the $1/v$ axis, $1/u = 0$.

$1/v = 1/f$

If $1/v = 0.084$; $1/f = 0.084$

$f = 1/0.084 \Rightarrow f = 11.9\text{cm}$



If $1/u = 0.082$; $1/f = 0.082$

$f = 1/0.082 \Rightarrow f = 12.2\text{cm}$

TIP: It is acceptable to be within a certain range. In the case of this question, 12cm ± 1cm is allowed.

TIP: Copy the *u* and *v* data in the table and extend the table above and below with a new row at the top and bottom. In the top row, place the values for $1/u$ and in the bottom row, place the values for $1/v$. These are the values you will use to plot the graph.

TIP: Make sure to scale the graph to be at least two-thirds of the graph page in size. Allow for the fact that you will need to extend your linear best-fit line through both the *x* and *y* axes to gain the results you need for average focal length.

TIP: When you have drawn a best-fit line, cut each axis with an extended line (dotted line in this graph).

Calculate focal length for each point where the line cuts the axes:

Where the line cuts the $1/u$ axis, $1/v = 0$. By using the optics formula: $1/u + 1/v = 1/f$,

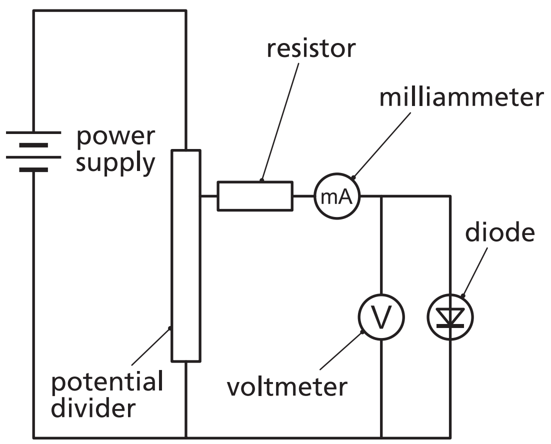
we get $1/u = 1/f$.

Therefore, if you get the reciprocal of $1/u$ here, you will get the answer for f.

In this graph, it should be approximately 12.05cm. **(6 × 3)**

TIP: Whenever you get a mandatory question on the concave mirror or convex lens, you will almost certainly be asked to draw a suitable graph. This involves getting the reciprocal values of *u* and *v* and graphing them. You will then need to extend your line to cut each axis and read the values at these points. Each of these points will be equal to $1/f$. Once you get the reciprocal of $1/f$, you can average each value of *f* and get a final value for focal length. Practise this graph and method of calculating *f* as there are a lot of marks for doing it right, whereas very few marks are given for just using the formula.

4.

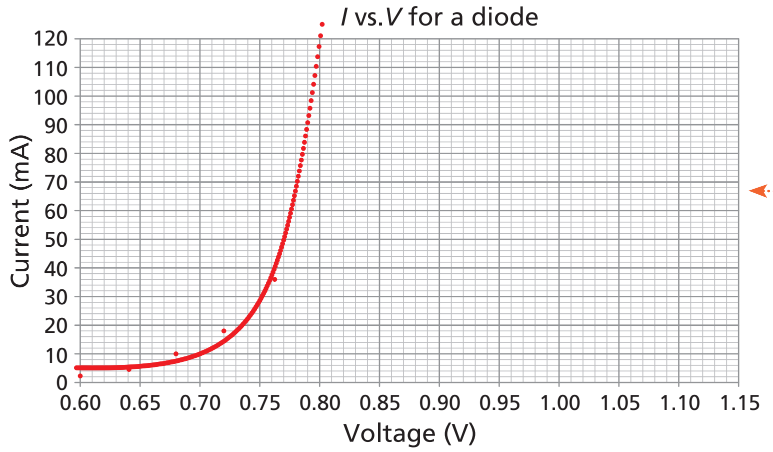


(3 × 3)

In the case of the circuit diagram given on the left, a potential divider was used to adjust the voltage being delivered to the diode. **(3)**

The p.d. was measured by the parallel voltmeter shown on the left. **(3)**

TIP: Make sure all essential components are included – power supply, voltmeter, diode in forward bias and milliammeter – to measure voltage and current as per experiment title. Also, make sure the voltmeter is in parallel with the diode and the milliammeter is in series.



TIP: Make sure the graph takes up at least three-quarters of the graph page and is of a smooth nature when drawn. Also, label all axes.

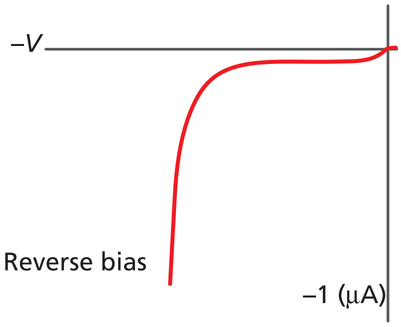
(3 × 3)

From the graph, junction voltage is estimated to be within 0.6V – 0.73V. **(3)**

TIP: Junction voltage is the point at which the diode appears to begin conducting properly. As you can see from the graph, just after 0.6V, the current begins to rise, and as long as you take a reading before it really increases, you will be fine.

In order to place the diode in reverse bias, the student could have reversed the power supply or reversed the diode. They then would have had to change the milliammeter to a microammeter, so as to allow for smaller leakage current readings of a much lower magnitude. **(2 × 3)**

Characteristic graph



(3 + 4)

TIP: Sketch of reverse bias shows leakage current only in the microammeter magnitude and no junction voltage. Also, voltage is shown as being negative.

SECTION B

5. *Answer any eight questions from (a), (b), (c), etc.* **(8 × 7)**

(a) Archimedes' principle states that whenever an object is totally or partially immersed in a fluid, it experiences an upthrust that is equal to the weight of the fluid it displaces.

(b) A filament bulb gives much higher percentage heat energy than light energy from the electrical energy conversion.

(c) Perspiration on the skin takes latent energy from the body in order to evaporate. This serves to cool the body down by removing energy.

TIP: Perspiration is essentially the same concept as a heat pump changing liquids to gases by removing heat energy from food. However, in a heat pump, the gases are also changed back to liquids by releasing the heat energy out the back of the fridge radiator fins.

(d) Infra-red radiation can be detected as heat energy by a thermometer, thermographics or a thermogram film.

(e) $n = 1/\text{Sin}C \Rightarrow 1/n = \text{Sin}C \Rightarrow \text{Sin}^{-1}(1/n) = C \Rightarrow \text{Sin}^{-1}(1/1.35) = C \Rightarrow 47.8° = \text{C}$

(f) $W = ½CV^2 \Rightarrow W = (1/2)(5 \times 10^{-6})(20)^2 \Rightarrow W = 1 \times 10^{-3}\,\text{J} = 1\text{mJ}$

TIP: Any time you are asked for stored energy in a capacitance question, this is the only formula to use.

(g) As a magnet freely rotates it will line up with the earth's magnetic North–South, as like poles repel and unlike poles attract.

(h) The ampere is based on the force between two current-carrying conductors in a magnetic field.

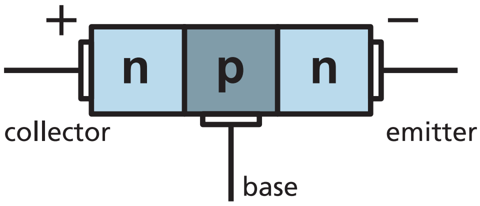
TIP: This is not the full definition of the ampere but just states the principle on which the amp can be defined. If you wish, you can give the full amp definition.

(i) Electrons are accelerated by an extra high tension.

(j) A kaon is a meson.

TIP: Remember mesons consist of a quark and an antiquark.

OR



TIP: Show the three layers with the base, emitter and collector clearly labelled.

6. Hooke's Law states that whenever an object is deformed through bending, stretching or compression, there is a restoring force that is directly proportional to the displacement, as long as the elastic limit is not exceeded. **(3 + 3)**

TIP: As long as you mention the main parts of the formula, you will get the marks here. Restoring force is proportional to displacement/extension.

$F = ks \Rightarrow (F = ma) \Rightarrow ma = ks \Rightarrow (300 \times 10^{-3})(9.8) = (k)(85 \times 10^{-3}) \Rightarrow 2.94 = 85 \times 10^{-3}\, k$

$\Rightarrow \dfrac{2.94}{85 \times 10^{-3}} = k = 34.588 = k \Rightarrow 34.6\ \text{N m}^{-1} = k$ **(3 × 3)**

TIP: If you are unsure of how to integrate force and displacement, look at the figures given at the end of the question. As gravity is given, you should have an indication that it plays a part somewhere. In this case, $F = ma$ and then you can let this $= ks$.

Don't forget to change all units to metres, newtons and kg.

The displacement from equilibrium is also important to see where the spring moved from 200mm to 285mm. Remember that 285mm is now the natural resting length with the mass attached and should be taken into account when the spring is undergoing simple harmonic motion (SHM) later.

$F = ma$
$ma = -ks\ (F = ma)\ (F = -ks)$
$a = -(k/m)s$
or $a \propto -s$
or $a = -\omega^2 s\ (k/m = \omega^2)$ **(4 × 3)**

TIP: The relationship between acceleration and displacement needs to take SHM into account. It should be always directed towards equilibrium (minus is shown) and it is always proportional to displacement (constant or k/m shown). Whenever you need to involve acceleration, $F = ma$, often comes into play.

The sphere has an acceleration which is proportional to its displacement from equilibrium and is always directed towards the equilibrium point. **(2 × 3)**

TIP: This is merely a restating of the principles of SHM.

(i) $T = \dfrac{2\pi}{\omega}$

$\Rightarrow (\omega^2 = k/m) \Rightarrow \omega^2 = \dfrac{34.6}{300 \times 10^{-3}} \Rightarrow \omega^2 = 115.33 \Rightarrow \omega = 10.7$

(insert ω value): $T = \dfrac{2\pi}{10.7} \Rightarrow 0.58 \Rightarrow \omega = 0.6\text{s}$ **(4 × 3)**

TIP: When you are asked for a value such as period, just write the formula and see what is required. In this case, you need ω. You were already asked for the relationship between acceleration and displacement; so it should be fresh in your mind as to how to calculate it and substitute in.

(ii) $a = -\omega^2 s \Rightarrow a = -(10.7)^2(25 \times 10^{-3}) \Rightarrow a = -2.89\text{m.s}^{-2}$ **(3 × 3)**

(iii) If acceleration is zero, then there must be no displacement from the equilibrium point. Therefore, the length of the spring remains at 285mm. **(2)**

TIP: Knowing how acceleration changes and which direction it acts is the most important aspect of SHM. Once you can define SHM, you are well on the way to answering it.

7. The Doppler effect is the apparent change in frequency due to the relative motion of source and/or observer. **(6)**

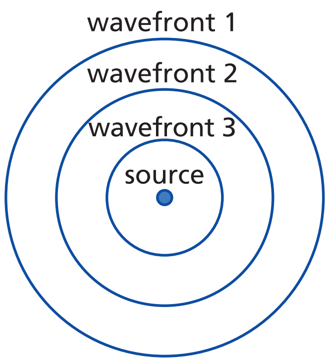


Fig. 7.1

As seen in Fig. 7.1, when a source is non-moving, the wavefronts all appear the same distance apart and the wave is unchanging.

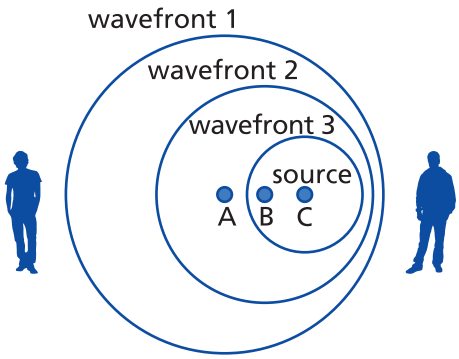


Fig. 7.2

However in Fig. 7.2, when the source is moving, the wavefronts can appear bunched up as they approach a person or stretched apart as they move away from the observer. This gives the perceived frequency change which seems higher frequency when moving towards and lower frequency when moving away.

In Fig. 7.2, wavefront 1 is emitted when the source is at A, wavefront 2 is emitted when the source is at B, and wavefront 3 is emitted when the source is at C. **(4 × 3)**

TIP: This set of diagrams is a good way of demonstrating Doppler when you need to explain a complex idea. By simply showing it, you have less to explain. As in many concepts in physics, a good, clear labelled diagram can be invaluable.

Emission line spectra are produced when a gaseous element receives energy such as heat. The electrons are excited to a higher energy state. Once the excited electrons fall back to their original energy state, they emit a photon of light equivalent to their energy ($E = hf$). **(4 × 3)**

TIP: You may also describe how monochromatic light can be passed through a diffraction grating to produce a line spectrum.

No, it is moving away because the wavelength from the star has increased, meaning frequency has decreased. Decreasing frequency shows that it is moving away from the observer. **(3 + 5)**

(i) $c = f\lambda \Rightarrow$ (in this case, we can call f: f', since it is apparent frequency): $c = f'\lambda$

$$c/\lambda = f' \Rightarrow \frac{3 \times 10^8}{720 \times 10^{-9}} = f' \Rightarrow 4.17 \times 10^{14}\text{Hz} = f'$$ **(3 + 3)**

TIP: You really need to work out the frequency from the moving star, but if you used the 656nm wavelength since it is the actual wavelength, you would not have been penalised here. However, it is safer to use the apparent frequency when the star is mentioned.

(ii) $f' = \frac{fc}{c+u}$ (moving away)

$$4.17 \times 10^{14} = \frac{(4.57 \times 10^{14})(3 \times 10^{8})}{3 \times 10^{8} + u}$$

$$(4.17 \times 10^{14})(3 \times 10^{8} + u) = (4.57 \times 10^{14})(3 \times 10^{8})$$

$$1.251 \times 10^{23} + 4.17 \times 10^{14}u = 1.371 \times 10^{23}$$

$$4.17 \times 10^{14}u = 1.371 \times 10^{23} - 1.251 \times 10^{23}$$

$$4.17 \times 10^{14}u = 1.2 \times 10^{22}$$

$$u = \frac{1.2 \times 10^{22}}{4.17 \times 10^{14}}$$

$u = 2.88 \times 10^{7}\text{m.s}^{-1}$ **(4 × 3)**

TIP: In order to answer this question, you need to calculate the actual frequency for the hydrogen spectrum in the laboratory and substitute in for *f*. As in all of these formulaic questions, state your formula, say which one it is for, and substitute in all of the variables you have listed beforehand.

8. Electric field strength is the force per unit charge in an electric field. Its unit is the N.C^{-1} or the V.m^{-1} **(3 × 3)**

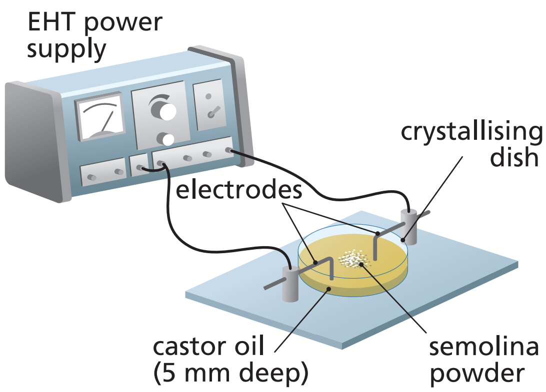


Fig. 8.1

To demonstrate electric field lines:

1. Set up the equipment as in Fig. 8.1.
2. Sprinkle semolina powder on the oil surface.
3. Use two EHT (extra high tension) plates to apply an electric field across the oil.
4. Because the semolina grains are of low density, they line up in the shape of the applied field. **(4 × 3)**

TIP: The important point about this experiment is that an extra high tension voltage is required to give appropriate strength to line up the semolina particles.

(i) $E = F/Q \Rightarrow E = \dfrac{\frac{Q_1 Q_2}{4\pi\varepsilon d^2}}{Q_1} \Rightarrow \dfrac{Q_2}{4\pi\varepsilon d^2} \Rightarrow E = \dfrac{4}{4\pi(8.9 \times 10^{-12})(22 \times 10^{-2})^2} \Rightarrow E = 7.39 \times 10^{11}\text{N.C}^{-1}$ **(3 × 3)**

TIP: Electric field strength is defined as the force per unit Coulomb. This essentially means dividing the Coulomb force of attraction by charge. When you do this, you are left with a single charge on the top of the equation as shown above. Some formula will show this as:

$$E = \frac{(4)(1)}{4\pi(8.9 \times 10^{-12})(22 \times 10^{-2})^2}$$

but this is the same as just having a single charge of 4C on top. It also means that if you then introduce a new charge into the electric field, you need only multiply the electric field strength by this new charge to gain the force of attraction/repulsion.

You also need to be careful with the value for distance as the dome has a radius of 15cm (diameter = 30cm) and the charge of 4C is 7cm from the dome. Therefore, a distance of 22cm is required overall.

(ii) $F = EQ \Rightarrow F = (7.39 \times 10^{11})(5 \times 10^{-6}) \Rightarrow F = 3.69 \times 10^{6}\text{N}$ **(2 × 3)**

TIP: As previously said, all you need to do when you already have electric field strength is multiply the new charge present by *E* to gain the force of attraction/repulsion in newtons.

Because all the like charges repel, they all move apart an equal distance on the exterior of the dome. This is also according to Faraday. **(6)**

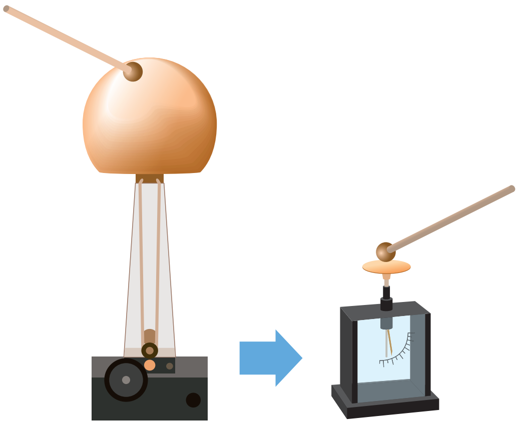


Fig. 8.2

TIP: You could also mention co-axial cable but a simple example is sufficient given the amount of marks being given here.

To demonstrate that all static charge resides on the outside of a conductor:

1. Make sure the Van de Graaff generator is charged.
2. Touch a proof plane on the outside of the Van de Graaff dome and then test with an electroscope to show it has gained charge (see Fig. 8.2).
3. Earth the proof plane.
4. Touch a proof plane in the inside of the Van de Graaff dome and test with an electroscope to show the absence of charge.

This shows that charge resides on the outside of a conductor.
(4 × 3)
An application of this effect would be building a Faraday cage to protect personnel or equipment. **(2)**

9. (i) Resistance is the ratio of voltage to current ($R = V/I$), **(2 × 3)**

(ii) Resistivity can be seen as the resistance of a 1m side cube of material or stated as a formula and correct notation given: $\rho = \frac{RA}{l}$

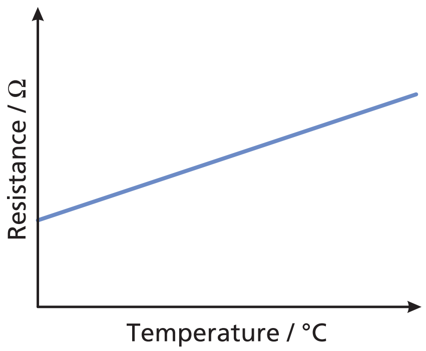
Its unit is the ohm metre (Ωm). **(2 × 3)**

TIP: By looking at the formula, you can sometimes construct a definition using the quantities stated, as well as the unit required.

(i) $\frac{R_1}{R_2} = \frac{l_1}{l_2} \Rightarrow \frac{R_1}{20} = \frac{282}{718} \Rightarrow R_1 = (20)\left(\frac{282}{718}\right) \Rightarrow R_1 = 7.86\Omega$ **(3 × 3)**

(ii) $\rho = \frac{RA}{l} \Rightarrow \rho = \frac{(7.86)(\pi(11 \times 10^{-3})^2)}{220 \times 10^{-3}} 1.36 \times 10^{-6}\ \Omega\text{m}$ **(3 × 3)**

TIP: The most common error in resistivity is not converting the diameter into a cross-sectional area in m^2. Make sure to list your radius in metres first and then calculate area as πr^2.



(6)

TIP: As no numbers are given, only the characteristic shape is required but the important aspect is that the value for resistance is greater than zero when it cuts the *y*-axis.

(i) As temperature falls below zero, resistance decreases. **(3)**

(ii) As length increases, resistance increases. **(4)**

(iii) As diameter increases, resistance decreases. **(4)**

Resistance is a ratio of voltage to current, therefore choose any one of the following:

- Ohmmeter
- Multimeter
- Wheatstone bridge
- A combination of ammeter and voltmeter **(6)**

If using ohmmeter:

- It is smaller and quicker to use but it is less accurate and prone to losing calibration over time.

OR

If using Wheatstone bridge:

- It is more portable and more accurate but quite expensive.

OR

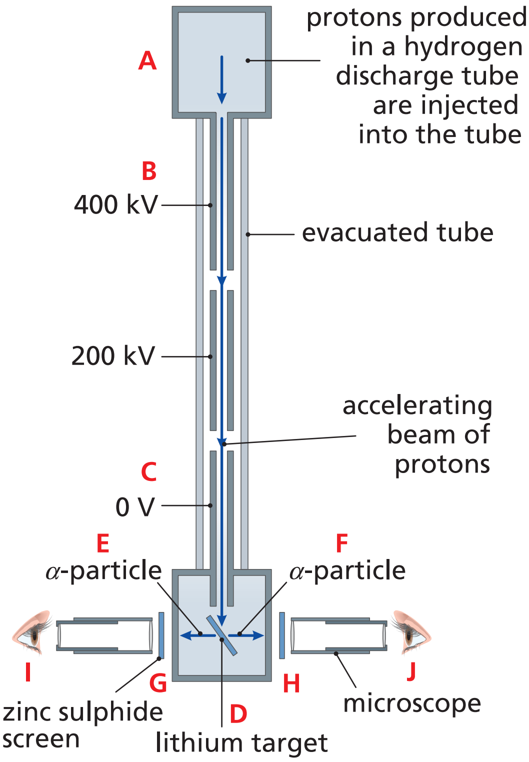
If using ammeter and voltmeter:

- It is simple to calculate but less accurate for similar reasons as above for ohmmeter. **(2 + 1)**

10. *Answer either part (a) or part (b).*

(a)

(i)



(3 + 3)

TIP: You do not need as detailed a diagram but you do need the critical elements of the system to be shown such as an EHT, anode and cathode for acceleration, proton chamber and lithium target with 2 alpha-particles being emitted.

$E = QV$ & $E = ½mv^2$

$$\therefore \frac{1}{2}mv^2 = QV \Rightarrow v^2 = \frac{QV}{\frac{1}{2}m} \Rightarrow v^2 = \frac{(1.6022 \times 10^{-19})(700 \times 10^3)}{\frac{1}{2}(1.6726 \times 10^{-27})} \Rightarrow v^2 = 1.341 \times 10^{14} \Rightarrow v = 1.16 \times 10^7 \text{m.s}^{-1}$$

(4 × 3)

TIP: By knowing that energy can be electronvolts (QV) or kinetic energy of the moving protons ($1/2\ mv^2$), you can equate them and solve for the missing velocity. This same procedure is sometimes asked in the cathode ray tube or X-ray tube questions when asked to calculate the velocity of electrons based on the voltage applied.

$^7_3Li + ^1_1H \longrightarrow 2^4_2He$ **(3 × 3)**

TIP: You can also list hydrogen as a *p* or alpha as an *α*.

Mass of reactants = 1.1646×10^{-26}(lithium) + 1.6726×10^{-27}(proton) = 1.33186×10^{-26}kg

Mass of products = $2(6.6443 \times 10^{-27})$(alpha) = 1.32886×10^{-26}kg

Difference in mass = 1.33186×10^{-26}kg – 1.32886×10^{-26}kg = 3.00×10^{-29}kg

Disintegration energy = $mc^2 = (3.00 \times 10^{-29})(3 \times 10^8)^2 = 2.7 \times 10^{-12}$J **(4 × 3)**

TIP: It is very important to make sure you have the difference in mass in kg before you substitute it into $E = mc^2$. This equation will only work when you have the final mass difference to check the energy equivalence.

(ii) Both have equal masses and magnitude of charge but they are of opposite charge sign. An electron is matter and a positron is antimatter. **(5)**

Pair annihilation occurs when they meet, with the release of gamma photons. **(3)**

(iii) Fermi postulated the existence of the neutrino to explain the missing momentum. **(6 + 3)**

(b) Energy cannot be created or destroyed but converted from one form to another. **(6)**

Electrical energy to mechanical kinetic energy. **(6)**

(i) A commutator reverses current every half cycle and ensures that the coil keeps rotating in one direction. **(5)**

(ii) The carbon brushes keep contact between the power supply and the coil and allow current to keep flowing as the coil rotates. **(5)**

(iii) The magnet provides the magnetic field which is needed for the current-carrying coil to interact with. **(5)**

A current-carrying coil in a magnetic field will experience a force. **(9)**

Advantages of an induction motor over a d.c. motor (choose any one from the following):

- Less sparking
- Less friction
- Fewer voltage fluctuations
- Less electrical interference
- Fewer parts to replace/wear out. **(5)**

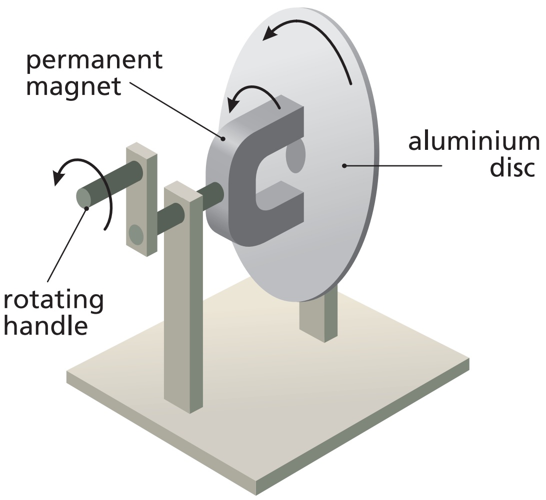


Fig. 10.1

To demonstrate the principle of the induction motor operation:

1. Rotate the permanent magnet as shown in Fig. 10.1.
2. The moving magnet lines of flux will cut the disc.
3. This will cause a changing magnetic field in the disc, which induces an emf.
4. According to Lenz's Law, the disc will attempt to oppose this change by opposing the direction of magnet movement.
5. This will cause an equal but opposite force, as per Newton's Third Law, and force the disc to rotate in the same direction as the magnet rotation.
6. The disc will lag the magnet rotation in speed. **(5 × 3)**

11. (a) Nuclear fission is the splitting of a large nucleus into two similar smaller nuclei with the release of neutrons and energy. **(8 × 7)**

(b) Work = Power × Time $\Rightarrow$ $W = (300 \times 10^9)(60)$ $\Rightarrow$ $W = 1.8 \times 10^{13}$J

(c) Fission is easier to control and initiate than fusion.

(d) Isotopes are the same element with the same atomic number but different atomic mass numbers due to differing numbers of neutrons present.

(e) The moderator slows down fast neutrons to allow for further fission and limit radiative capture.

(f) Silicon has the resistivity between that of a good conductor and good insulator.

(g) (1400)(20)(0.2) = 5600W

TIP: By multiplying the solar constant by the area involved, you gain the full power but at 20 per cent we need to multiply this by 0.2 to calculate the total power available in Watts or Joules per second.

(h) The sun gets its energy from nuclear fusion of hydrogen.

12. *Answer any two of the following parts (a), (b), (c), (d).*

(a) Friction is a force that opposes motion. **(6)**

TIP: Net force always comes from the $F = ma$ equation. In the case of this question, you are given the actual value for a and so can use the formula directly.

(i) $F = ma \Rightarrow F = (750)(1.2) \Rightarrow F = 900$N East **(6)**

(ii) $F_{net} = F_{car} - F_{friction} \Rightarrow 900 = 2000 - F_{friction} \Rightarrow 900 - 2000 = F_{friction} \Rightarrow -1100\text{N} = F_{friction}$

Therefore, frictional force is 1100N West. **(6)**

TIP: The minus in this answer comes from the opposing direction of friction. If the car is travelling East, the −1100N must be acting West.

$F = ma \Rightarrow F/m = a \Rightarrow -1100/750 = a \Rightarrow -1.47\text{m.s}^{-2} = a$ **(5)**

TIP: Notice how the negative frictional value gives you the negative acceleration, which will ultimately slow the car to rest.

$v^2 = u^2 + 2as \Rightarrow (0)^2 = (25)^2 + 2(-1.47)(s) \Rightarrow 0 = 625 - 2.94s \Rightarrow -625 = -2.94s \Rightarrow \dfrac{-625}{-2.94} = s \Rightarrow$ 213m **(5)**

TIP: As long as you keep the signs of convention for direction, the answer will work out, but you need to make sure you apply the minus signs when required here.

(b) Sound intensity is the rate of sound energy incident on 1m^2 at a right angle to the direction of motion of sound. **(6)**

TIP: The unit of Watts per metre squared can also give you this definition as power per m^2.

Surface area of spherical sound wave from speaker = $4\pi r^2 = (4)(\pi)(3)^2 = 113.1\text{m}^2$

(Divide the sound intensity by the surface area 3m away): $\dfrac{25 \times 10^{-3}}{113.1} = 2.21 \times 10^{-4}\ \text{Wm}^{-2}$ **(3 × 3)**

TIP: You could also presume that the sound is hemispherical and divide the 25mW by $2\pi r^2$, which would eventually give you a sound intensity of 4.42×10^{-4} Wm^{-2}. The important thing to bear in mind is that sound moves out according to an inverse square law, and if the speaker is curved, it will disperse as per a hemisphere or sphere shape.

(i) Change would be increased by 2.21×10^{-4} Wm^{-2}. **(6)**

TIP: If the hemisphere shape was used, this change would be: 4.42×10^{-4} Wm^{-2}.

(ii) 3dB. **(3)**

TIP: It is very common to equate 3dB changes with halving or doubling of sound intensity. Keep this in mind when doing sound questions.

dBA (decibel adapted) meters are used, which weight certain frequencies to allow for the human ear responding to frequencies between 2000Hz and 4000Hz more than others. **(4)**

(c) The magnitude of induced emf is directly proportional to the rate of change of flux. **(6)**

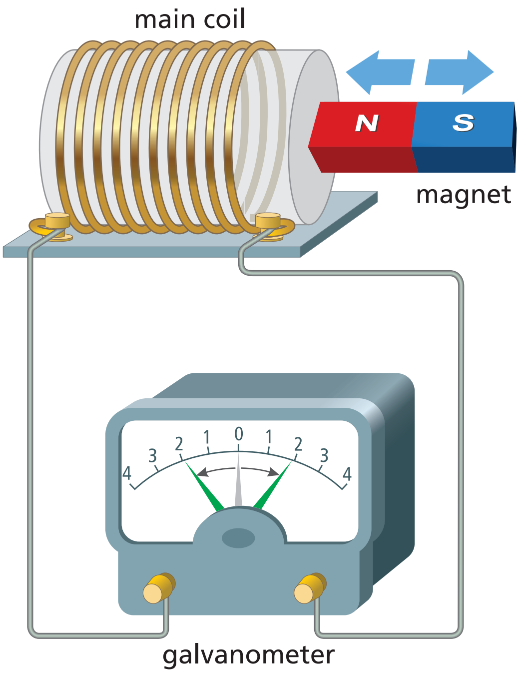


Fig. 12.1

To demonstrate Faraday's Law of Electromagnetic Induction:

1. Set up the experiment as shown in Fig. 12.1.
2. As the North pole approaches the coil, the galvanometer needle twitches one way.
3. As the North pole moves away, the galvanometer needle twitches the other way.
4. Reversing the magnet shows the opposite effects.
5. If the magnet and coil are kept stationary, no movement takes place on the galvanometer. **(4 × 3)**

As a resistor is connected into the circuit in series with the ammeter and power supply, the current will be reduced. **(4)**

The reason for the decrease in current is that a back emf will be induced in the coil due to the self-inductance of the coil. **(6)**

TIP: You may also refer to Lenz's Law here to further illustrate the point.

(d) Half-life is the time taken for half of the nuclei of a radioactive source to decay. **(6)**

TIP: You may also refer to the halving of activity to explain half-life.

${}^{14}_{6}C \longrightarrow {}^{0}_{-1}6 + {}^{14}_{7}N$ **(3 × 3)**

8.4Bq divided by 2.1 Bq (half-life) = 4

Therefore, 2 half-lives occurred (1/4 activity).

2×5730 years = 11460 years **(6)**

TIP: Remember that activity halves every half-life. This means that the number of half-lives can be calculated by $\frac{1}{2^n}$, where n = the number of half-lives. If there were 2 half-lives, then $\frac{1}{2^2}$ of the sample remains = $\frac{1}{4}$ of the sample (i.e. 2.1 Bq).

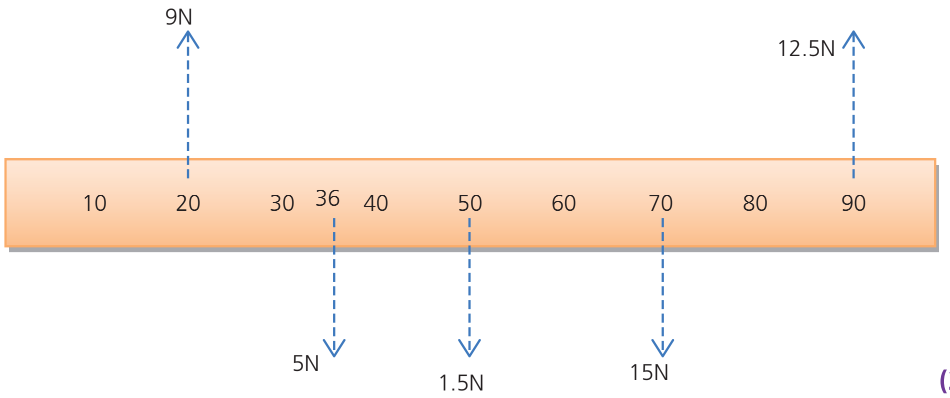
G–M tube (Geiger–Müller counter) which operates on ionisation of gas.

Solid state detector which relies on electron hole pairs being created in the semiconductor material. **(6 + 1)**

SECTION A

1. (i) The student measured the upward forces by using a newton balance. **(4)**

(ii)



(2 × 3)

> **TIP:** Make sure to show all forces (upward and downward) and include the actual weight of the metre stick acting through the centre of gravity point (50cm).

(iii) (a) Upward Forces: 9N + 12.5N = 21.5N

(b) Downward Forces: 5N + 1.5N + 15N = 21.5N

(c) The sum of forces equal zero ⇒ Upward = Downward ⇒ 21.5N = 21.5N **(6 + 6 + 3)**

> **TIP:** If the forces do not equal, make sure you allowed for the weight of the metre stick as well.

(iv) (a) Anticlockwise moments about 0cm mark:

(Moment = Force × Perpendicular Distance from Fulcrum)

∴ Moment #1 = (9N × 0.2m) = 1.8Nm

Moment #2 = (12.5N × 0.9m) = 11.25Nm

Total AC moments = (1.8Nm + 11.25Nm) = 13.05Nm

(b) Clockwise moments about 0cm mark:

(Moment = Force × Perpendicular Distance from Fulcrum)

∴ Moment #1 = (5N × 0.36m) = 1.8Nm

Moment #2 = (1.5N × 0.5m) = 0.75Nm

Moment #3 = (15N × 0.7m) = 10.5Nm

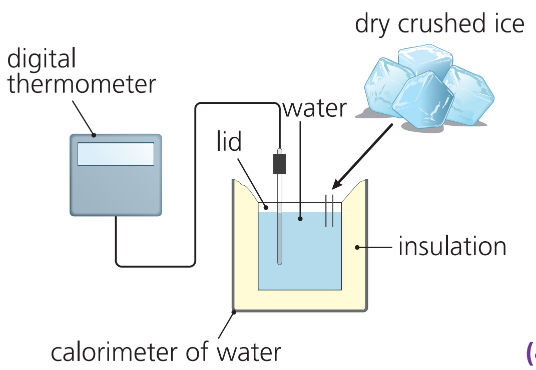
Total AC moments = (1.8Nm + 11.25Nm) = 13.05Nm **(6 + 6)**

> **TIP:** Make sure to convert all distances to metres before multiplying them.

(c) The sum of the moments about a point equal zero. (i.e. Anticlockwise moments = Clockwise moments) **(3)**

> **TIP:** There are times when the clockwise and anticlockwise moments will not equal exactly but will be very close. This is due to possible errors and can still verify the law of equilibrium.

2. (i)



(4 × 3)

> **TIP:** When drawing an experiment diagram, always think of the measurements required to calculate results. The parts in the diagram should be such as to allow you to take all measurements (e.g. water, ice, temp).

(ii) Mass of calorimeter
Mass of water
Mass of dried ice
Initial temperature before adding ice
Final temperature after ice has been added and melted **(6 + 2 × 3)**

TIP: You may also state masses measured in terms of "water, water & calorimeter, water & calorimeter & ice", to infer all individual masses.

(iii) The ice was crushed by placing it in a towel and striking it with a heavy weight or hammer **(4)**

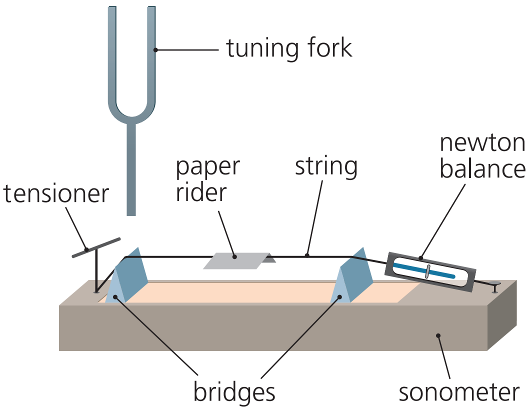
TIP: Any reasonable method of crushing the ice while it is contained in a bag or towel is fine.

(iv) Choose any:

- Crushed ice melts faster
- Crushed ice has greater surface area
- Smaller pieces have greater chance of all being at 0˚C **(6)**

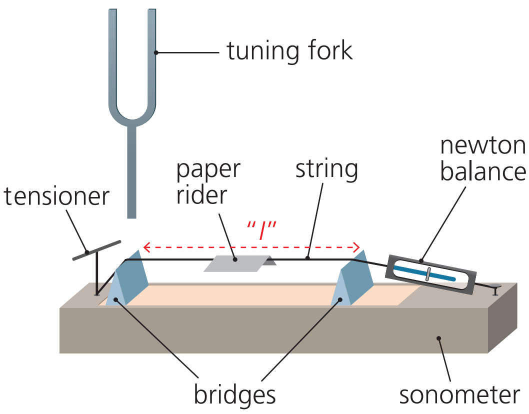
(v) The experiment was repeated to increase accuracy and gain a better average of the specific latent heat of fusion of ice. **(6)**

3. (i)



(3 × 3)

(ii)



The length *"l"* was measured between the two bridges as seen in the diagram **(6)**

TIP: It is reasonable to just add this measurement line for length to the existing diagram but it is shown on a separate diagram here to highlight the change. For this reason, it is a good idea to use a different colour pen to show the change on your first diagram drawn.

(iii) The string could have been set vibrating by striking a tuning fork and placing it on the bridge. **(3)**

TIP: A signal generator may have also being used to apply a signal, rather than a tuning fork.

(iv) The frequency was determined by reading the value off the tuning fork. **(6)**

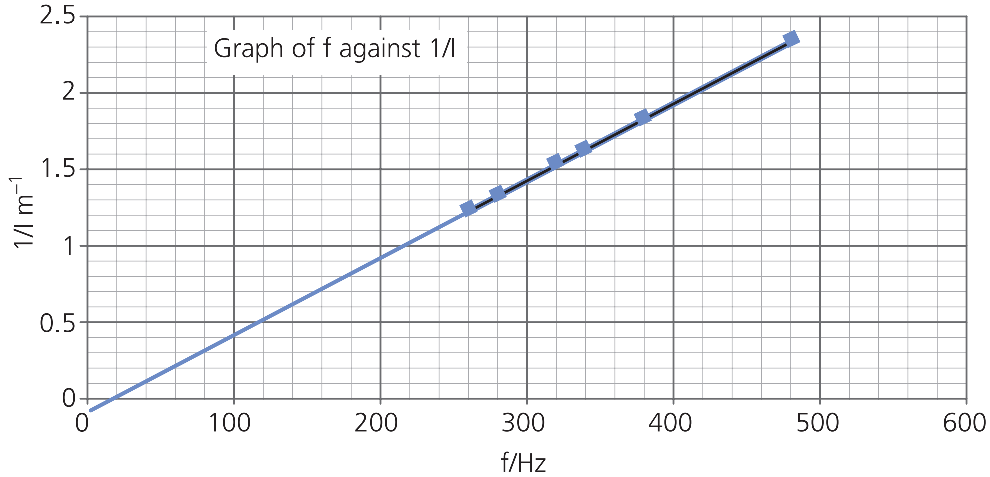
TIP: If a signal generator was used to apply a signal, the frequency value could be read off the display.

(v)

f(Hz)	256	288	320	341	384	480
l(m)	0.80	0.71	0.64	0.60	0.53	0.43
1/l (m^{-1})	1.25	1.41	1.56	1.67	1.89	2.33

(5 × 1)

TIP: At least 5 values should be correctly calculated in the table to gain full marks.



The graph is a straight line graph showing the proportionality between frequency and 1/length. **(3 × 3 + 2)**

TIP: The graph should have at least 5 points shown correctly, along with a best fit line and all axes labelled correctly.

4. (i) Choose any:

- The voltage was changed by varying the power supply
- The voltage was changed by varying the resistance
- The voltage was changed by varying the battery
- The voltage was changed by using a potential divider **(6)**

(ii) Part X measures current (Ammeter) **(6)**

TIP: Current is always measured in series using an ammeter.

(iii) Part Y measures voltage (Voltmeter) **(6)**

TIP: Voltage is always measured in parallel using a voltmeter.

(iv) The graph is broken into two main parts:
1st Part: The current is increasing linearly with the increase in voltage until about 0.6V. The current is relatively low but following a proportional relationship.
2nd Part: Once voltage exceeds 0.6V, the current starts to increase rapidly with voltage increase. **(6 × 2)**

TIP: Make sure you compare the two parts of the graph by mentioning the "rapid" increase in the 2nd part compared to the 1st part.

(v) Choose any:

- Reverse the diode polarity
- Reverse the battery polarity **(6)**

(vi) The 330Ω resistor is present to protect the circuit and limit the possible current flowing. **(4)**

SECTION B

5. **(8 × 7)**

(a) Total Force exerted = 540N (weight of bucket) + 800N (weight of concrete) = 1340N
Total Distance covered = 75m
Work = Force × Distance (W = Fd)
W = (1340N)(75m) = 1.005×10^5Nm

TIP: Remember that weight is a force. Make sure to combine the bucket and contents to calculate the total force.

(b) Vectors → Force, Velocity
Scalars → Time, Mass

(c) A capacitor is used in a camera flash to discharge quickly

(d) The Doppler Effect is an apparent change in frequency due to the relative motion of the source and/or observer.

(e) Lens shown is a convex lens (converging)

It can be used for any of the following:

- Magnifying glass
- Spectacles
- Camera lenses
- Binocular lenses

(f) The **U-value** of a material is the amount of heat energy that can be transmitted across 1m^2 of its surface every second, so long as there is a temperature difference of 1K each side of the material.

(g) Component shown is an LDR (Light Dependent Resistor)

(h) Choose any:

- Prism
- Diffraction Grating

(i) X-Rays are produced when high velocity electrons strike a metal target

(j) $E = mc^2$
$\Rightarrow E = (4 \times 10^9 kg)(3 \times 10^8 m.s^{-1})^2$
$\Rightarrow E = 3.6 \times 10^{26} J$

6. A force is anything that causes an object to change velocity or accelerate.
Its unit is Newtons or $kg.m.s^{-2}$ **(3 × 3)**

Newton's law of universal gravitation
Every mass in the universe attracts every other mass with a force, along the line of the centres, that is proportional to the product of their masses and inversely proportional to the square of the distance between them. **(3 × 3)**

TIP: You may also use the formula for Newton's Universal Law of Gravitation, but you would need to explain the notation used, to gain full marks.

$$g = \frac{GM}{d^2}$$

$$\Rightarrow g = \frac{(6.7 \times 10^{-11})(6.4 \times 10^{23})}{(3.4 \times 10^6)^2}$$

$\Rightarrow g = 3.7 m.s^{-2}$ **(10)**

Although the mass of the "Curiosity" rover would be the same wherever it was, its weight would change depending on the gravity present. Therefore, with Mars having a lesser gravity, the weight would be less on Mars and therefore the friction would be less. This is the reason why the wheels would not need to be as strong as on Earth. **(6)**

(i) Weight = mass × gravity
W = mg

$\Rightarrow W = (899kg)(9.8m.s^{-2})$

$\Rightarrow W = 8.8 \times 10^3N$ **(6)**

(ii) 899kg **(6)**

TIP: Mass is constant, no matter what the location. Therefore only the weight will change.

(iii) $W = mg$

$\Rightarrow W = (899kg)(3.7m.s^{-2})$

$\Rightarrow W = 3.3 \times 10^3N$ **(4)**

TIP: Make sure to use the previous calculation for the gravity of Mars in this part.

Choose any:

- Microwaves
- Infra-red
- Visible light
- Ultra-violet
- X-Rays
- Gamma rays **(6)**

7. (a) (i) Heat is a form of energy, measured in Joules **(6)**

(ii) Temperature is the degree of hotness or coldness of a body, measured in Kelvin/˚C/˚F **(6)**

(iii) Choose any:

- Pressure of a gas at constant volume
- Volume of a gas at constant pressure
- emf of a thermocouple
- Colour change of crystals
- Length of a column of liquid
- Electrical resistance **(6)**

(iv) Choose any:

Celsius (°C)

Fahrenheit (°F) **(6)**

(v) 310K = (310 – 273)°C = 37°C **(6)**

TIP: You may also use 273.15 as the conversion figure from Kelvin to Celsius, which would give you a final answer of 36.85°C. It is also possible to use Fahrenheit from part (iv). This would give you a Fahrenheit figure of 98.33°F, by using the formula: $F = \frac{9}{5}C + 32$.

(b) (i) Heat is transferred in metals by conduction. **(6)**

TIP: Conduction can also be explained by the vibration of atoms transferring energy.

(ii) Choose any:

- Convection
- Radiation **(2 × 4)**

(iii) As the heat is applied to the centre of the apparatus, heat conducts along each material. The best conductor will transfer the heat to the other end first, causing the piece of wood to fall, as the wax melts. **(6)**

(iv) Choose any:

- Use the same amount of metal for each strip of material
- Use the same length of metal for each material
- Use the same amount of wax for each metal
- Make sure the heat being applied is equally dispersed between all metals in the centre **(6)**

TIP: If you can limit the variables in an experiment to one independent variable, you are ensuring a fair test.

8. (i) Reflection is the bouncing of light off a surface **(2 × 3)**

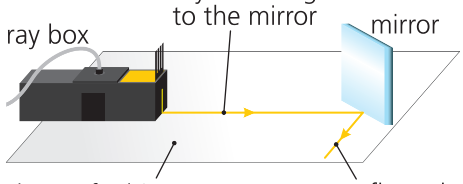
(ii) Laws of Reflection of light:

1. The incident ray, reflected ray and normal all lie in the same plane.
2. The angle of incidence(i) equals the angle of reflection(r). **(9)**

(iii) Choose any:

- Optic fibres
- Binoculars
- Mirrors
- Cat's Eyes (road use)
- Optical toys
- Endoscopy **(5)**

(iv) **To demonstrate the laws of reflection**



1. Place a ray box on a sheet of white paper as shown below.
2. Adjust the ray box to produce a narrow beam. (This can be achieved by using a slit in front of the light source.)
3. Place a mirror in front of the light beam and use a pencil to outline its position on the paper.
4. Point the ray box light beam at the mirror and mark the rays striking/bouncing off the mirror.
5. Once the mirror is removed, draw a normal at the point of incidence (the point at which the light hit the mirror).
6. Using a protractor, measure the angles of incidence and reflection.
7. Repeat the experiment for different values of incidence and reflection.
8. You should also notice that the ray stayed on the paper for the whole experiment, thereby proving that the light remained on a single plane. This demonstrates the first law of reflection.
9. You should notice from your results that the angles of incidence will always equal their associated angles of reflection. This demonstrates the second law of reflection. **(4 × 3)**

(v) **Refraction** is the bending of light at a boundary as it passes from one transparent medium to another. **(6)**

(vi) Critical Angle ("C") **(6)**

TIP: The Critical angle is the angle of incidence at which the corresponding angel of refraction is 90°.

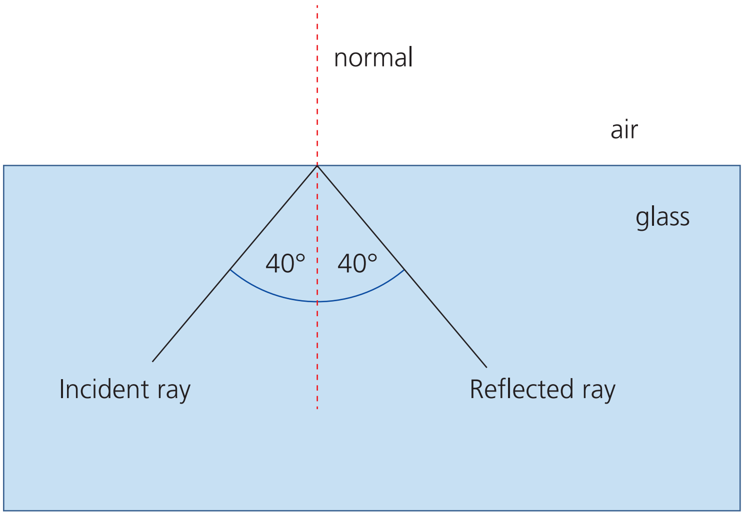
(vii) $n = \frac{1}{\text{Sin } c}$

$\Rightarrow n = \frac{1}{\text{Sin } 38}$

$\Rightarrow n = 1.62$ **(6)**

TIP: Make sure your calculator is in degree mode for this type of calculation.

(viii)



(6)

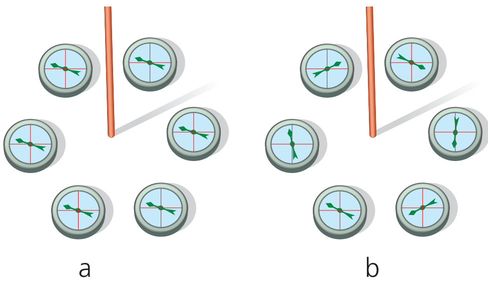
TIP: Once an incident ray exceeds the critical angle, which is 38˚, the ray will totally internally reflect with an angle equal to the incident angle.

9. (i) A **magnetic field** is a region in which the force of attractive/repulsive forces can be experienced. **(2 × 3)**

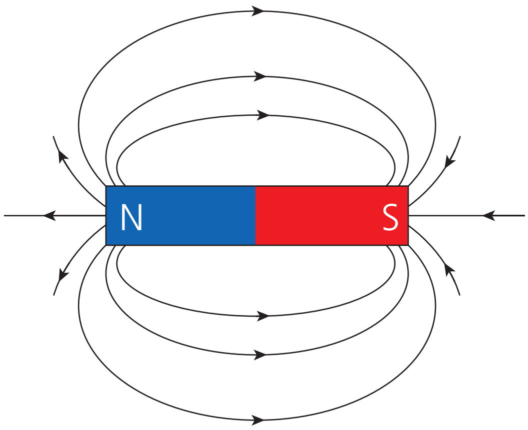
(ii) A compass will experience the force in the region of the magnetic field and the needle will point in the direction of the magnetic field lines. **(6)**

(iii) **To demonstrate plotting a magnetic field in a long straight wire:**

1. Place a number of plotting compasses on a flat piece of card, with a long straight conductive wire passing vertically through it as in diagram (a). Note how the compasses are all pointing in the same direction, lining up with the Earth's magnetic field.
2. Pass a current through the conductor. The compasses should line up to show the circular field lines, as in diagram (b). These can be verified from the right-hand grip rule. **(4 × 3)**



(iv)



(6)

TIP: Make sure the field lines point away from the North pole and towards the South pole.

(v) When the magnet is moved towards the coil, the galvanometer needle deflects, as current is induced in the coil from electromagnetic induction. **(2 × 3)**

(vi) When the magnet is stationary, no needle deflection occurs in the galvanometer. **(6)**

TIP: It is only when there is a "changing" magnetic field that electromagnetic induction occurs.

(vii) **Electromagnetic induction** occurs when a changing magnetic field induces an emf, which in turn produces a current.

The deflection of the galvanometer needle only happens with a current being produced by a changing magnetic field. **(6 + 3)**

(viii) A greater speed of movement in the magnet would cause the rate of magnetic field changing to increase. Therefore a greater deflection of the galvanometer needle would occur, indicating greater current induced. **(5)**

10. (i) Radioactivity is the spontaneous decay of nuclei of atoms with the emission of one or more types of radiation energy. **(2 × 3)**

> **TIP:** The emitted radiation may be alpha, beta or gamma.

(ii) This diagram indicates that there are three types of radiation. One type is positively charged, the other type is negatively charged and the last type is neutral. **(6)**

> **TIP:** A positive charge will be repelled by another positive. A negative charge will be attracted by a positive and a neutral charge will be unaffected in direction.

(iii) Gamma (γ) is unaffected by the electric field (no. 2) **(3)**

(iv) Alpha (α) is positively charged (no. 1) **(3)**

(v) Beta (β) is negatively charged (no. 3) **(3)**

(vi) Alpha, Gamma, Beta (1, 2, 3 in order) **(9)**

(vii) Choose any:

- Enriched Uranium (U)
- Plutonium (Pu)
- Thorium (Th) **(6)**

(viii) The neutrons strike another nucleus, cause fission and are then used to continue the chain reaction. **(6)**

(ix) The control rods absorb neutrons. If the control rods are lowered, they will absorb more neutrons and slow/stop the rate of reaction.

If they are raised, they will allow the rate of reaction to increase. **(6)**

> **TIP:** It is the available neutrons that cause further fissions and hence a possible chain reaction. By limiting the number of available neutrons by absorbing them, the rate of further nuclear fission can be changed.

(x) Every half-life = 8 days. Therefore 24 days $= \frac{24}{8}$ *half-lives* = 3 *half-lives*

After 1 half-life, the fraction of Iodine-131 remaining $= \frac{1}{2}$

After 2 half-lives, the fraction of Iodine-131 remaining $= \frac{1}{4}$

After 3 half-lives, the fraction of Iodine-131 remaining $= \frac{1}{8}$ **(8)**

> **TIP:** You can also calculate the fraction of a sample remaining by multiplying it by $\frac{1}{2^{\text{no. half-lives}}}$.
> In this case, 3 half-lives $= \frac{1}{2^3} = \frac{1}{8}$

11. **(8 × 7)**

(a) Evaporation is the changing of a liquid to a gas. This is achieved by the liquid absorbing heat energy.

(b) As molecules are given more heat energy, they will move faster.

> **TIP:** You can see the effect of heat energy on molecules, when you apply heat to water and they begin to "boil" and move rapidly.

(c) As a gas rises through the atmosphere, its temperature decreases.

(d) Gravity causes the heavier water droplets to fall back to earth.

(e) **Convection** is the transfer of heat energy by the circulation of the heated parts of a liquid or gas.

(f) The cloud's strong electric field creates a conductive path between the cloud and earth's surface.

(g) Choose any:
- Van De Graaff
- Gold Leaf Electroscope
- Capacitor

(h) Light travels much faster than sound and reaches us first.

TIP: Speed of sound is approximately $340 m.s^{-1}$ and the speed of light is $3 \times 10^8 m.s^{-1}$

12. (a) Speed is a scalar and only has magnitude but no direction.
Velocity is a vector and has both magnitude and direction. **(6)**

(i) $v = u + at$

$\Rightarrow v - u = at$

$\Rightarrow \frac{v-u}{a} = t$

$\Rightarrow \frac{(15)-(0)}{(0.5)} = t$

$\Rightarrow \frac{15}{0.5} = t$

$\Rightarrow 30\ m.s^{-1} = t$ **(5)**

TIP: The bus started from rest and so $u = 0 m.s^{-1}$. List all the variables you have and choose the best equation of motion to use.

(ii) $s = ut + \frac{1}{2}at^2$

$\Rightarrow s = (15)(100) + \frac{1}{2}(0)(100)^2$

$\Rightarrow s = 1500m$ **(5)**

TIP: Since the bus is now only travelling at top speed of $15 m.s^{-1}$ and not accelerating, we are left with $s = ut$ as the equation to use.

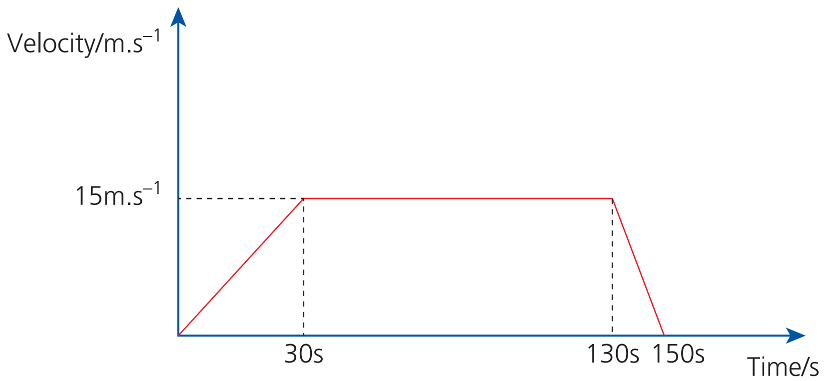
(iii) $a = \frac{v-u}{t}$

$\Rightarrow a = \frac{(0)-(15)}{(20)}$

$\Rightarrow a = -\frac{15}{(20)}$

$\Rightarrow a = -0.75 m.s^{-1}$ **(5)**

TIP: Once the bus is coming to rest, we can let $v = 0 m.s^{-1}$. Also note the negative sign of the acceleration answer showing it is slowing down.



(7)

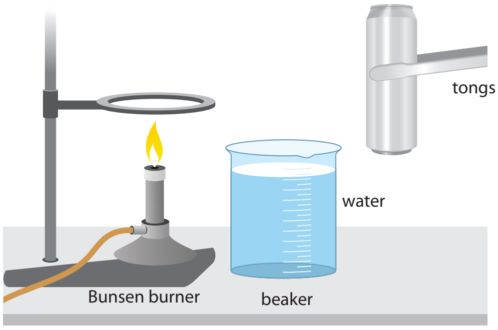
TIP: Notice how the slope of the negative acceleration is steeper, since it has a greater magnitude than the initial acceleration (0.75 > 0.5).

(b) The unit of pressure is the Pascal (Pa) or Nm^{-2} or bar **(5)**

To demonstrate atmospheric pressure:

1. Place a small amount of water in an empty cleaned aluminium can (see diagram).
2. Carefully heat it over a Bunsen burner, using tongs and making sure the top opening is unobstructed.
3. Once you hear the water boiling and see steam, remove the can from the heat.
4. Immediately invert the can in a beaker of cold water.
5. The water seals the can. The absence of air inside the can is unable to counteract the atmospheric pressure pushing from the outside.

The can immediately collapses.



(3 × 3)

Archimedes' principle: whenever an object is totally or partially immersed in a fluid, it experiences an upthrust that is equal to the weight of the fluid it displaces. **(6)**

The upthrust (buoyancy force) caused by the liquid is (10N – 7N) = 3N **(4)**

No, the object will sink as the upthrust is only 3N; whereas the weight of the object is 10N. Therefore the object has more weight than upthrust. **(2 × 2)**

(c) (i) A = wavelength (λ)

B = amplitude **(2 × 5)**

(ii) Frequency = no. cycles per second passing a fixed point. Therefore $f = \frac{20}{1} = 20Hz$ **(6)**

(iii) $c = f\lambda$

$\Rightarrow c = (20)(1.5)$

$\Rightarrow c = 30m.s^{-1}$ **(6)**

(iv) Longitudinal waves cannot be polarised **(6)**

> **TIP:** You may give any type of longitudinal wave here to gain full marks as it only asks for a type.

(d) (i) Resistance is the ratio of current to voltage ($R = \frac{V}{I}$ or Voltage is proportional to Current) **(6)**

(ii) Total Resistance in series = $R_1 + R_2 \Rightarrow (50\Omega) + (450\Omega) = 500\Omega$ **(4)**

(iii) $V = IR$

$\Rightarrow \frac{V}{R} = I$

$\Rightarrow \frac{6}{500} = I$

$\Rightarrow 1.2 \times 10^{-3}\ A = I$ **(6)**

(iv) $V = IR$

$V = (1.2 \times 10^{-3})(50)$

$V = 0.6V$ **(6)**

(v) The resistance of the circuit would decrease if the temperature were increased. **(6)**

> **TIP:** It is important to note that resistance increases as temperature increases for a metallic conductor but resistance decreases as temperature increases for a thermistor, as shown here.

SECTION A

1. (i)

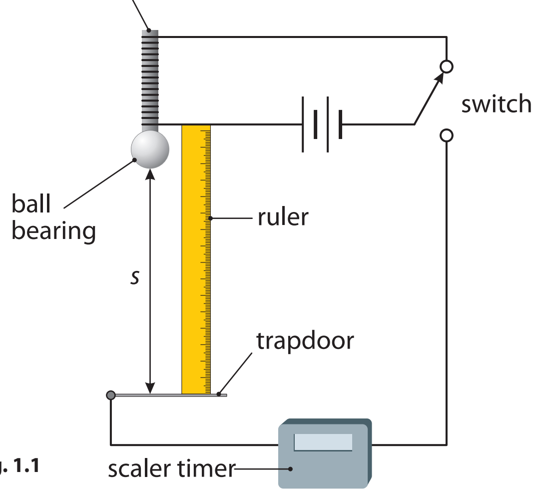


Fig. 1.1

OR

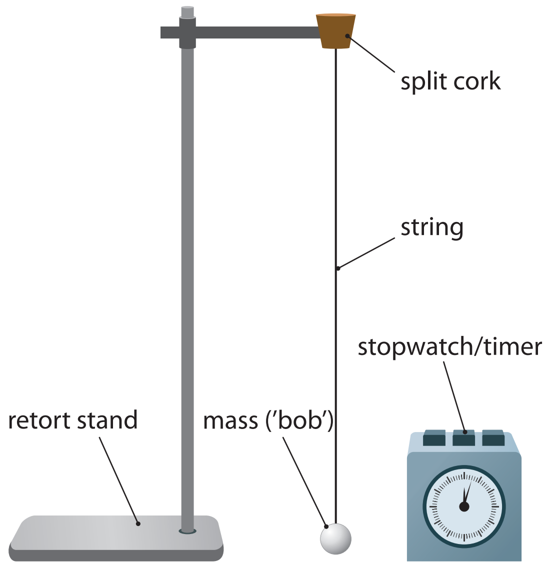


Fig. 1.2

(6 + 2 × 3)

(ii) Free-fall method (Fig. 1.1)

- Measurements required: displacement (*s*), Time (*t*)

Pendulum method (Fig. 1.2)

- Measurements required: length of pendulum (*l*), Periodic time (*T*) **(2 × 3)**

TIP: You may use either method to measure gravity. However, make sure the measurements and descriptions chosen match the diagram given.

TIP: You may also use the data-logger method with a picket fence and photo gate. In this case, the measurements are just given as the result on the calculator of the data-logger, by taking the slope of a velocity versus time graph.

(iii) Free-fall method (Fig. 1.1) measurements required:

- Displacement (*s*) – measured by using a metre stick to record the distance from the bottom of the ball bearing to the trapdoor top surface.
- Time (*t*) – measured by reading the scalar timer result that started timing as the ball first left the holder and stopped timing automatically as the ball hit the trapdoor.

Pendulum method (Fig. 1.2) measurements required:

- Length of pendulum (*l*) – measured by using a metre stick to record the distance from the centre of gravity of the bob to the suspension point of the split cork.
- Periodic time (*T*) – measured using a stopwatch to record a multiple of periodic times and dividing the total time to calculate a single value of *T*. **(6 + 3)**

TIP: If using the data-logger, the slope of the graph of velocity (*v*) versus time (*t*) will yield a value for acceleration due to gravity. Therefore, the data-logger is measuring distance and time from the gaps in the picket fence as it passes through the light gate.

(iv) Diagram 1 (free-fall method):

(Second equation of motion) $\underline{s} = ut + \frac{1}{2}at^2$

($u = 0\text{m.s}^{-1}$, a = gravity): $s = \frac{1}{2}gt^2$

(multiply by 2): $2s = gt^2$

(Divide by t^2): $2s/t^2 = g$

By substituting in the values for *s* and *t*, *g* can be calculated.

TIP: It is suitable to just use the final line $2s/t^2 = g$, but if you are unsure, use the original equation of motion to show how it is derived.

Diagram 2 (pendulum method):

$$g = \frac{4\pi^2 l}{T^2}$$

By substituting in the values for l and T, g can be calculated. **(3 × 3)**

TIP: This formula can be taken straight from the tables of formulae.

TIP: If using a data-logger or if using a graph from the mandatory method 1 and 2, g can also be gained. The slope of the velocity–time graph on the data-logger will give you g.
In the case of the free-fall method, twice the slope of the graph will give you g.
In the case of the pendulum method, $4\pi^2$ multiplied by the slope of l/T^2 will give you g.

(v) Choose any one from the following precautions:
Diagram 1 (free-fall method):

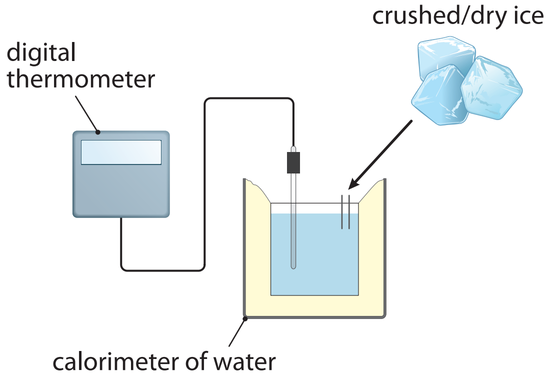
- Use smallest value of t.
- Average values of g.
- Reduce parallax of displacement measurement by averaging readings.

Diagram 2 (pendulum method):

- Swing pendulum through a small angle less than 5 degrees.
- Reduce parallax of length measurement by averaging readings. **(4)**

TIP: Averaging readings or results as well as attempting to minimise parallax is always a good precaution to use.

2. (i)



(4 × 3)

(ii) The ice should be crushed and melting, as well as dried prior to use. **(6)**

TIP: Remember that melting ice is at 0˚C. Therefore, by using melting ice, only latent changes will be measured as opposed to heat and latent changes.

(iii) By using melting ice, the student would know it is at 0˚C. **(3)**

(iv) The student subtracted the mass of (calorimeter and water) from the final mass of (calorimeter and water and ice) to find the mass of the ice. **(3 × 3)**

TIP: You may also mention that a top pan balance was used to gain these mass readings.

(v) Choose either one from the following:

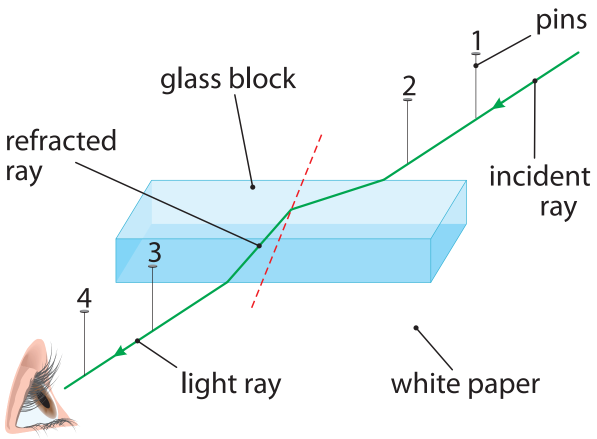
- Ice will melt faster.
- The heat lost at the beginning of the experiment will cancel the heat gained at the end of the experiment. **(6)**

TIP: Warm water will emit heat as it tries to go to room temperature. However, ice water below room temperature will take in heat as it tries to get to room temperature. These errors can be minimised by using hot water initially.

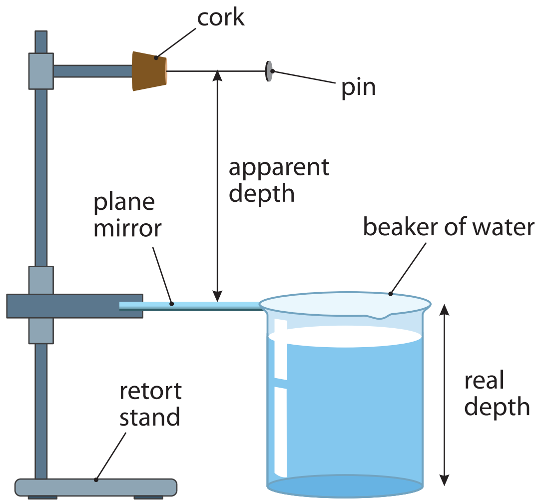
(vi) Choose any one from the following:

- Make sure the ice is dry.
- Keep stirring the mixture.
- Add a large amount of ice to a large amount of water.
- Avoid splashing.
- Add ice as quickly as possible. **(4)**

3. (i) Method 1:



OR Method 2:



(6 + 2 × 3)

TIP: You could also use a ray box or laser for method 1 to trace the light rays as they pass through the block.

(ii) Method 1: Block:

- Angle of incidence (*i*)
- Angle of refraction (*r*) (using protractor to measure angles between incident ray and normal and refracted ray and normal)

Method 2: Liquid:

- Real depth
- Apparent depth (using a ruler for real depth and position of no parallax for apparent depth) **(6 + 6)**

(iii) Method 1: Block

$$n = \frac{\text{Sin } I}{\text{Sin } r}$$

Method 2: Liquid

$$n = \frac{\text{Real depth}}{\text{Apparent depth}}$$

(10)

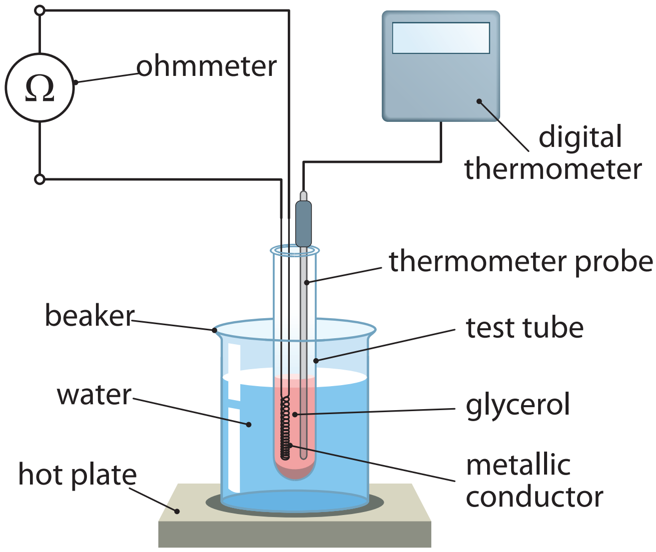
(iv) Choose any one from the following:

- Reduce errors
- Average results
- In order to draw a graph of Sin *i* against Sin *r*. **(6)**

TIP: If you used a block to calculate critical angle, you could have used $n = 1/\text{Sin } C$ as well.

TIP: The slope of a Sin *i* against Sin *r* graph will give you refractive index, but remember that you must use the Sin of the angles when plotting the graph.

4. (i)

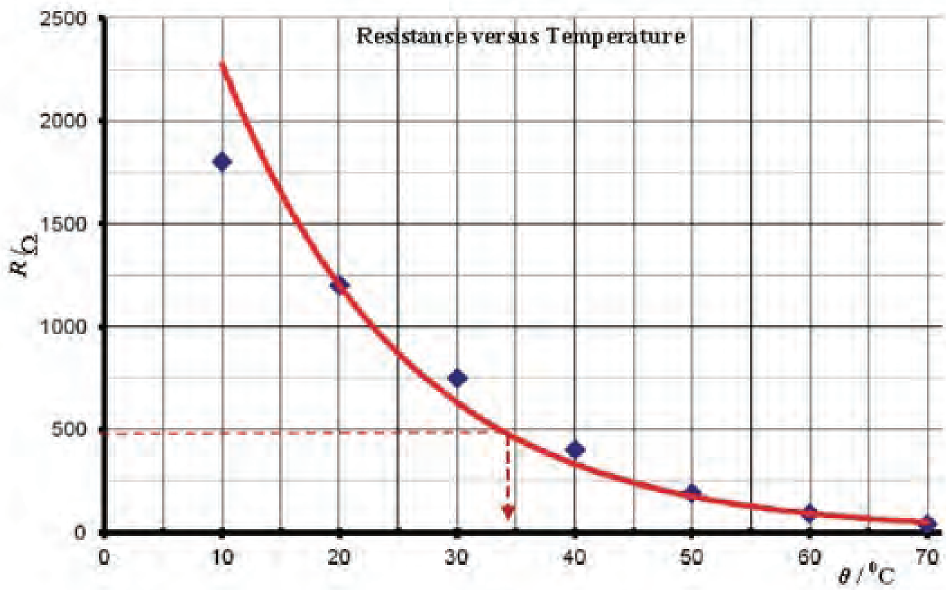


(4 × 3)

(ii) The resistance of the thermistor could be measured by either of the following:

- Ohmmeter connected to the thermistor
- Voltmeter and ammeter connected to the thermistor in order to calculate resistance from Ohm's Law **(6)**

(iii)



(4 × 3)

(iv) As can be seen from the dotted red line on the graph, when resistance is 500Ω, the corresponding temperature is 34˚C. **(4)**

TIP: If you are given one value, you can use this to draw a line to the curve and bring another line to the other axis to read the corresponding value. There is some leeway in results as your own graph will be taken into account when reading corresponding values. This shows that a large accurate graph is required for these questions.

(v) Resistance will decrease as temperature increases. However, the relationship is not linear because the graph is a curve rather than a straight line. **(6)**

SECTION B

5. (a) (i) Vector quantity (choose any one from the following): **(8 × 7)**

- Displacement
- Velocity
- Force

(ii) Scalar quantity (choose any one from the following):

- Distance
- Speed

(b) Moment = Force × Perpendicular distance

$M = Fd \Rightarrow M = (50)(0.1) \Rightarrow M = 5\text{Nm}$

(c) Rutherford

TIP: Rutherford used the gold foil experiment and alpha radiation to discover the structure of the nucleus and atom.

(d) Threshold of hearing is the lowest intensity sound that can be heard.

TIP: The threshold of hearing is a sound intensity of $1\times10^{-12}\text{W m}^{-2}$. This is taken to be the lowest sound intensity a human can hear at a frequency of 1000Hz (1kHz).

(e) Total internal reflection (TIR).

TIP: You may also refer to light reflecting but TIR is required for full marks.

(f) Choose any one from the following:

- Camera lenses
- Glasses (for viewing)
- Binoculars
- Magnifying glass

(g) Brown or red.

(h) Choose any one from the following:

- Temporary battery to store charge
- d.c. blocker
- a.c. conductor
- Filtering, smoothing
- Camera flash
- Flash gun

(i) The photoelectric effect is the emission of electrons from the surface of a metal when light of a suitable frequency is incident on it.

(j) Choose any one from the following:

- Geiger–Müller tube (G–M tube)
- Solid state detector
- Cloud chamber
- Bubble chamber
- Photographic film

6. (a) Momentum is mass multiplied by velocity.

(b) Force is mass multiplied by acceleration. **(2 × 6)**

TIP: Both of these definitions can be found by looking at the formulae in the tables: $\rho = mv$, $F = ma$.

The total momentum of a system before an interaction is equal to the total momentum of the system after an interaction, so long as no external force acts on it. **(2 × 3)**

TIP: You can also state this principle by writing the equation and giving the explanation of the symbols used:

$$m_1u_1 + m_2u_2 = m_1v_1 + m_1v_2$$

m_1, m_2 = masses 1 and 2 (kg); u_1, u_2 = initial velocity of masses 1 and 2 (m.s^{-1}); v_1v_2 = final velocity of masses 1 and 2 (ms^{-1}).

By using the conservation of momentum, as the momentum of air moves one way, the equal momentum of the craft moves in the opposite direction **(2 × 3)**

(i) $\rho = mv \Rightarrow \rho = (5000)(10) \Rightarrow \rho = 50000\text{kgm.s}^{-1}$ **(6)**

(ii) 50000kgm.s^{-1} **(4)**

TIP: According to the conservation of momentum, the momentum before the collision will equal the momentum after the collision.

(iii) $\rho = mv \Rightarrow \dfrac{\rho}{m} = v \Rightarrow \dfrac{50000}{(5000 + 1000)} = v \Rightarrow 8.3\text{m.s}^{-1} = v$ **(6)**

(iv) $\rho = mv \Rightarrow \rho = (5000)(8.3) \Rightarrow \rho = 41500\text{kgm.s}^{-1}$ **(4)**

(v) $\text{Force} = \dfrac{\text{Change in momentum}}{\text{Time taken}} \Rightarrow F = \dfrac{(50000 - 41500)}{0.3} \Rightarrow F = \dfrac{8300}{0.3} \Rightarrow F = 27.8\text{kN}$ **(6)**

TIP: This formula comes directly from Newton's Second Law of Motion and the rate of change of a body's momentum being proportional to the force applied.

(vi) Because of the increased time of contact between the driver's head and the airbag, it means that there is a less severe sharp force applied to the driver. **(6)**

7. (a) Frequency is the number of wave cycles passing a point per second. **(6)**

$c = f\lambda$ **(6)**

TIP: You may also state how the frequency of a wave (f) is inversely proportional to the wavelength of the wave (λ).

(i) As the student moves from A to B, the amplitude or loudness will increase and decrease. **(6)**

(ii) This changing amplitude is caused by the phenomenon of interference. **(4)**

(iii)

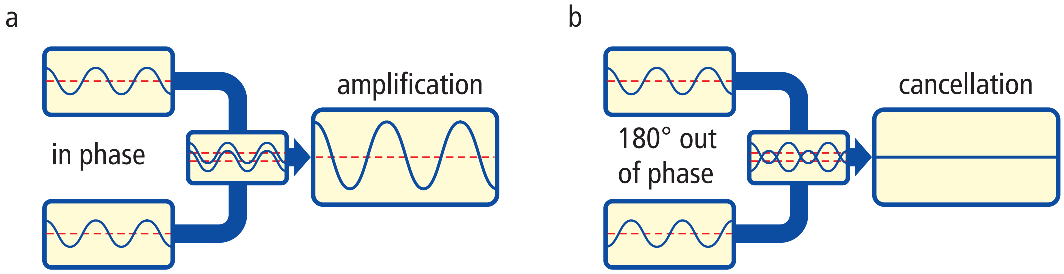


Fig. 7.1

In Fig. 7.1a, two waveforms meet when their crests and troughs are at the same place (they are in phase). Their crests add to form a bigger crest and their troughs add to form a bigger trough (constructive interference).

In Fig. 7.1b, the two waveforms meet crest to trough (they are 180° out of phase); when added, the waveforms cancel out and produce a zero amplitude (destructive interference). **(6 + 3)**

(iv) It is an important factor in venues to have equal zones of sound intensity to enable everyone to hear the same thing. **(6)**

(b) (i) Fundamental frequency is the minimum main frequency of a vibrating object.

Overtones are multiples of the fundamental frequency. **(6 + 3)**

(ii) Tension or length can be changed to vary the note. **(4)**

TIP: It should be known that tension, length and string material all affect frequency.

(iii) Resonance is the transfer of energy between two bodies with the same natural frequency. **(2 × 3)**

8. (a) (i) Unit of current is the ampere (amp) (A). **(6)**

(ii) Any metal, such as copper, gold, silver, etc. **(3)**

(iii) Choose any one from the following:

- Primary cell
- Battery
- Mains a.c. power source
- Secondary cell
- Thermocouple **(6)**

(iv) Negative electrons and positive holes are the charge carriers. **(8)**

(v) Ohmic metallic conductor. **(6)**

TIP: A linear I–V graph shows a metal obeying Ohm's Law.

(b) (i) A magnetic field is a region in which the force of attractive/repulsive forces can be experienced. Magnetic field lines are lines drawn to show the direction of a magnetic field at any point. **(2 × 3)**

(ii)

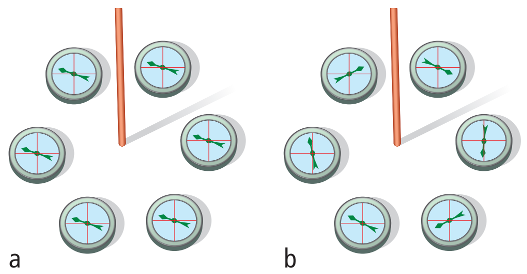


Fig. 8.1

TIP: You may also describe the field lines as being shown with iron filings. It is also important to mention a full circuit being made with the power supply and wire.

To demonstrate plotting a magnetic field in a long straight wire:

1. Connect the wire to a power supply.
2. Place a number of plotting compasses on a flat piece of card, with a long straight conductor passing vertically through it, as in Fig. 8.1a. Note how the compasses are all pointing approximately north–south.
3. Pass a current through the conductor. The compasses should line up to show the circular field lines, as in Fig. 8.1b.
4. Sketch the circular field shown. **(5 × 3)**

(iii) Choose any one from the following:

- Loudspeaker
- d.c. motor
- Transformer
- Induction coil
- Electromagnet **(6)**

9. (i) Heat is a form of energy. **(6)**

TIP: You may also state the formula for heat but remember to explain each symbol given: $Q = mc\Delta\theta$.

(ii) Heat can be transferred by conduction, convection and radiation. **(3 × 3)**

(iii)

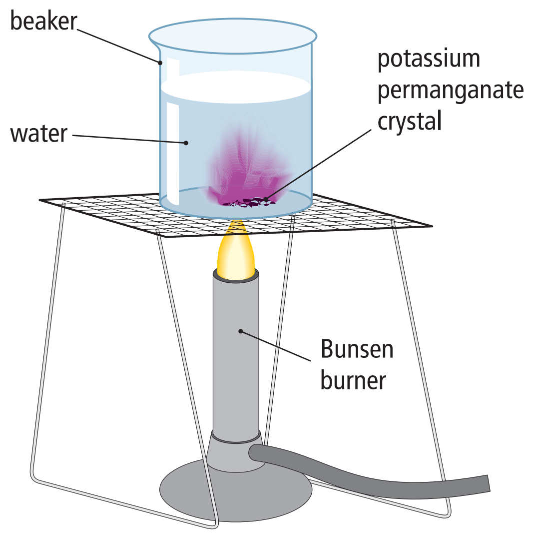


Fig. 9.1

To demonstrate convection:

1. Set up the equipment as in Fig. 9.1.
2. Drop the potassium permanganate crystal using a filter funnel to keep it in one place at the bottom of the water.
3. Heat the water and note how the potassium permanganate moves through the water with the convection current. **(3 × 3)**

(iv) The heating element should be at the bottom of the kettle. **(6)**

TIP: This is because of the fact that hot water rises and cold water falls, allowing the water to be heated evenly.

(v) The handle is made of an insulating material to enable the user to touch it safely. **(4)**

(vi) Choose any one from the following:

- Ceramic
- Plastic
- Wood **(4)**

(vii) $Q = mc\Delta\theta \Rightarrow Q = (1.3)(4200)(80 - 10) \Rightarrow Q = 3.8 \times 10^5$ J **(3 × 3)**

TIP: Make sure to put all masses in kg and to use the difference between initial and final temperature as $\Delta\theta$.

(viii) $\text{Power} = \dfrac{\text{Energy converted}}{\text{Time taken}} \Rightarrow P = \dfrac{W}{t} = \dfrac{3.8 \times 10^5}{(60 \times 3)} \Rightarrow P = \dfrac{3.8 \times 10^5}{180}$ 2111.W **(3 × 3)**

TIP: Make sure time is in seconds here by converting 3 minutes to 180 seconds. The answer you receive is in Watts as this is the unit of power.

10. (i) X-rays are high frequency electromagnetic radiation. **(6)**

TIP: You may also refer to high frequency as high energy or low wavelength.

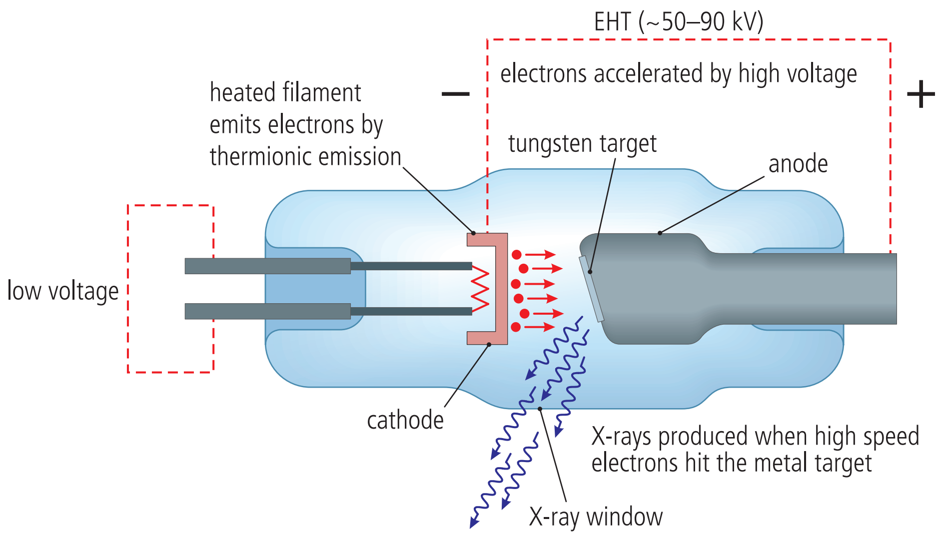
(ii) Choose any one from the following:

- Penetrates to enable images of inside the body or of bones
- Precise small dimensions to enable selective scanning of only the affected part of the body **(6)**

(iii) Choose any one from the following:

- Industrial metal/structure integrity
- Weld inspection
- Airport security scans
- Astronomy **(6)**

(iv)



(4 × 3)

(v) Electrons are emitted by thermionic emission from the cathode. **(6)**

(vi) The extra high voltage is to accelerate the electrons sufficiently to produce X-rays on impact. **(6)**

(vii) X-rays are produced and the target is heated. **(6)**

(viii) Tungsten or a suitable metal with a high melting point. **(4)**

(ix) Choose one from the following:

- Lead shielding
- Reduce exposure time/amount
- Protective clothing **(4)**

11. (a) A network of high voltage transmission stations and high voltage power lines. **(8 × 7)**

(b) High voltage reduces heat losses.

(c) A lower voltage is safer for domestic customers.

TIP: By reducing heat loss, you are also reducing energy loss.

(d) Choose any two renewable sources from the following:

- Wind
- Wave
- Solar
- Hydroelectric
- Biomass
- Geothermal

Choose any two non-renewable sources from the following:

- Coal
- Oil
- Gas
- Peat
- Nuclear

TIP: Even though nuclear is non-renewable, it is often seen as renewable since it will never run out in our lifetime.

(e) a.c. alternates direction at a set frequency and originates from a different power supply.
d.c. flows in one direction only and originates from a different power source to a.c.

(f) A step-down transformer converts high voltage to lower voltage.

TIP: A step-up transformer would have the opposite effect of transforming a low voltage to higher voltages.

(g) Electromagnetic induction is used to transform voltages in a transformer.

(h) Kilowatt-hours (kWh).

12. (a) Pressure is the force per unit area. **(6)**

TIP: You may also state this as its formula but make sure to explain the symbols used: $P = F/A$.

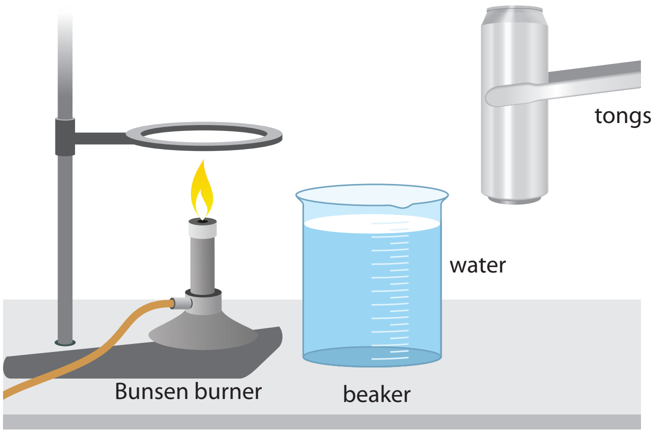


Fig. 12.1

To demonstrate atmospheric pressure:

1. Place a small amount of water in an empty cleaned aluminium can (see Fig. 12.1).
2. Carefully heat it over a Bunsen burner, using tongs and making sure the top opening is unobstructed.
3. When you hear the water boiling and see steam, remove the can from the heat.
4. Immediately invert the can in a beaker of cold water.
5. The water seals the can. The absence of air inside the can is unable to counteract the atmospheric pressure pushing from the outside.
6. The can immediately collapses. **(3 × 3)**

TIP: You may also describe similar experiments that show atmospheric pressure such as a card on top of a glass of water which is then inverted.

Pressure at 50m: $p = \rho g h \Rightarrow p = (1 \times 10^3)(9.8)(50) \Rightarrow p = 4.9 \times 10^5$Pa

Pressure at 20m: $p = \rho g h \Rightarrow p = (1 \times 10^3)(9.8)(20) \Rightarrow p = 1.96 \times 10^5$Pa

Pressure difference from 50m to 20m: $p = 4.9 \times 10^5\text{Pa} - 1.96 \times 10^5\text{Pa} = 2.94 \times 10^5$Pa **(13)**

(b) (i) Dispersion is the separating of light into its constituent colours or frequencies. **(6)**

TIP: You may also refer to constituent wavelengths or even to differing speeds of light for each colour.

(ii) A spectrum of colour is observed between X and Y. **(6)**

TIP: You may also list the colours in order as red, orange, yellow, green, blue, indigo, violet.

(iii) Dispersion shows that white light is made up of different colours. **(4)**

(iv) A diffraction grating can be used to disperse light. **(6)**

(v) Choose any one from the following:

- Rainbow
- Oil slick reflection
- DVD/CD reflection spectrum **(6)**

(c) Coulomb's Law: The electrostatic force between two point charges is proportional to the product of their charges and inversely proportional to the square of the distance between them. **(6)**

TIP: You may also state Coulomb's Law as a formula but remember to explain each symbol used:

$$F = \frac{1}{4\pi\epsilon}\frac{Q_1Q_2}{d^2}$$ F = force (N), ϵ = permittivity ($F\,m^{-1}$), Q_1, Q_2 = charges (C), d = distance between charges (m).

(i) Choose any one from the following:

- Measuring potential difference
- Detecting charge
- Indicating nature of charge
- Measuring capacitance
- Test whether a material is an insulator or conductor **(6)**

(ii) An electroscope can be given a positive charge by:
1. Bring a negative charge near to the electroscope cap.
2. While holding the negative charge near the cap, earth the cap.
3. Remove your finger and then remove the negative charge.
4. The electroscope is now positively charged. **(6)**

> **TIP:** The opposite effect can be achieved by initially using a positively charged rod and earthing the cap. This will then result in a negatively charged electroscope. You may also earth the electroscope with your finger in this experiment, as electrons will travel through you.

(iii) If you touch the cap when it is charged, the leaves will collapse. **(4)**

(iv) As you touch the cap, electrons flow from the earth through you to the positively charged electroscope, so as to neutralise it. This results in the leaves collapsing. **(6)**

(d) (i) Nuclear fission is the splitting of a large nucleus into two smaller similar sized nuclei with the release of neutrons and energy. **(6)**

(ii) Uranium or plutonium may be used as a fuel. **(6)**

> **TIP:** You may also say enriched uranium or uranium with a sufficient concentration of U-235.

(iii) The control rods may be lowered to decrease the rate of reaction or raised to increase the rate of reaction. **(6)**

> **TIP:** The control rods are usually made from boron or cadmium and are used to absorb neutrons and slow the fission reaction. By covering the fuel rods, the reaction is slowed.

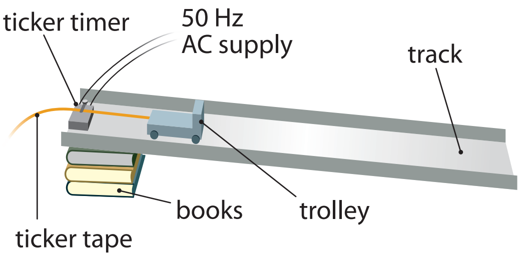
(iv) The heat generated is taken by the coolant to the heat exchanger. It turns water to steam here. This steam drives the turbines to produce electricity. **(6)**

> **TIP:** It is interesting to note that the method of producing electricity is very similar in most power stations. Whether you use fossil fuels to burn or nuclear material to undergo fission, it is still steam that turns turbines and makes electricity.

(v) Choose any one from the following:
- Risk of leaks
- Pollution
- Nuclear fallout
- Storing nuclear waste
- Risk to environment or animal health **(4)**

SECTION A

1. (i)



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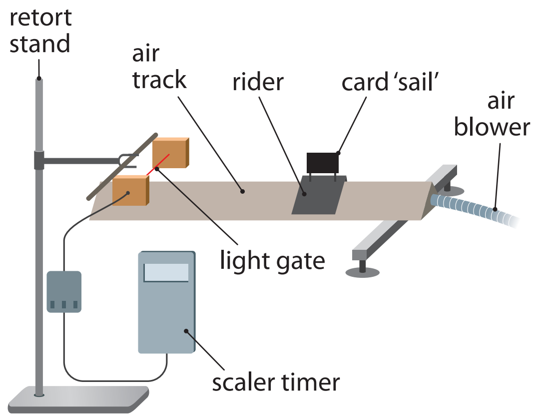


(6 + 3 + 3)

> **TIP:** You may list whichever method is familiar, including using data-logging equipment attached to motion sensors. The main thing to bear in mind when showing apparatus is to include any equipment that is essential to gaining the data. In the case of acceleration, you need a method of measuring velocity (e.g. light gates and sail or ticker timer and ticker tape) as well as a track to keep the motion linear).

(ii) Final velocity can be measured by (choose any one from the following):

Ticker timer:
1. Measure the physical distance between the dots (s).
2. Count the number of spaces between the dots (n).
3. Calculate the time by multiplying the number of spaces (n) by 1/50 s (t).
4. Calculate velocity by using $v = s/t$.

Light gate:
1. Measure the length of the sail (s).
2. Record the time from the timer attached to the light gate (t).
3. Calculate velocity by using v = s/t.

Data-logger:
1. Use a motion sensor attached to the data-logger and select velocity from a distance–time graph of motion. **(6)**

(iii) The student also took the measurements for distance and time. **(6)**

> **TIP:** The student may have also taken a measurement of the mass used to apply a force in the case of the air track method.

(iv) Acceleration $= \dfrac{\text{change in velocity}}{\text{time taken}} \Rightarrow a = \dfrac{v - u}{t}$ **(10)**

> **TIP:** The student may have also used Newton's second and third equation of motion: $v^2 = u^2 + 2as$ to calculate acceleration.

(v) Choose any one from the following:
- Dust the track
- Clean/oil wheels of trolley
- Take a good average of dots from the ticker tape
- Verify distance measurements with group members
- Discard beginning/end dots of tape **(6)**

2. (i)

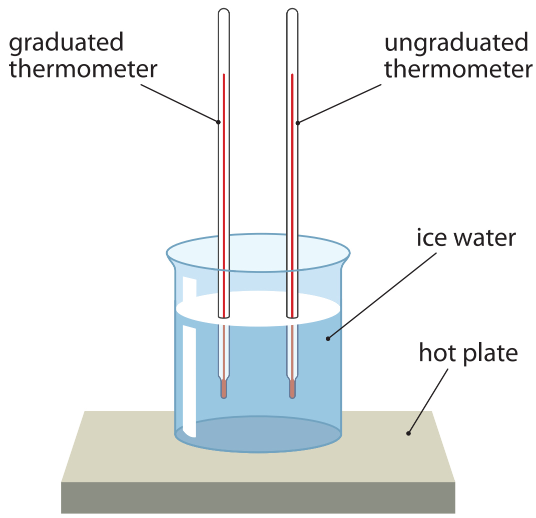


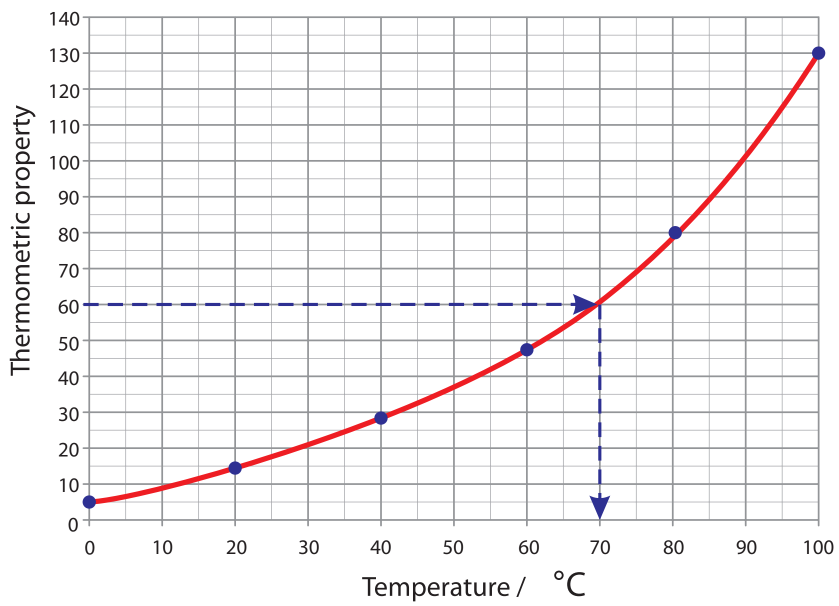
Fig. 2.1

1. Set up the equipment as shown in Fig. 2.1.
2. Add ice to the beaker of water and place both the thermometers in the water.
3. Allow the thermometers to settle at a steady column length.
4. Mark the ungraduated thermometer and record the temperature on the graduated thermometer.
5. Turn on the hot plate and heat the water until the graduated thermometer shows an increase of 10°C.
6. Again, mark the ungraduated thermometer and record the temperature.
7. Repeat these steps another five times, increasing the temperature by 10°C each time.
8. Use the lengths of column and associated temperatures to plot a graph. **(4 × 3)**

TIP: As with all mandatory experiments, make sure to choose essential equipment. In the case of this experiment, you need to gather enough data to plot a calibration curve. This means using a graduated thermometer to measure temperature and an ungraduated thermometer to mark as temperature changes. You may also list a metre rule to take length of column measurements for the graph.

(ii) The thermometric property is length of column and it was measured with a metre rule. **(7 + 3)**

(iii)



TIP: Make sure to draw a smooth curve joining the points and carefully note that temperature is supposed to be on the x-axis. If this graph is going to be used later in the question to work out a value, it is vital to make the graph clear and use at least three-quarters of the graph page provided. It is a good idea to read ahead to see if you need to make graphs bigger than the data given in case you have to estimate results from the shape of the graph.

(4 × 3)

(iv) When the thermometric property is 60, the corresponding temperature is 70˚C. **(6)**

TIP: As you can see on the graph above, we do not know what the thermometric property is but we do know its axis. Mark 60 on the y-axis and draw a dotted line across until it intersects the curve. Then drop a dotted line down to read the corresponding temperature. This is the value required, which is 70˚C. There will be a certain range allowed when using your graph to answer questions and, in the case of this graph, you are allowed to get a result between 67˚C and 73˚C.

3. (i)

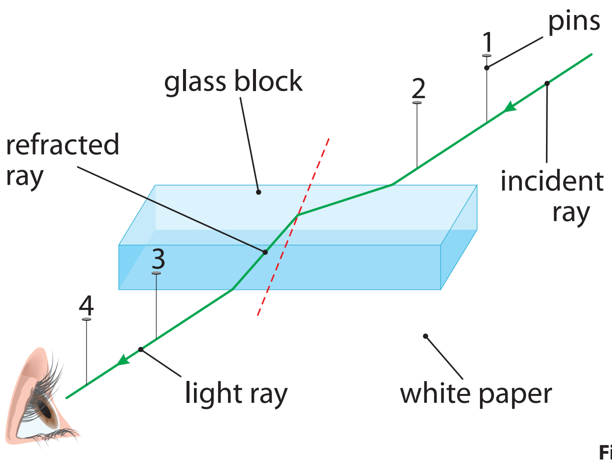


Fig. 3.1 **(3 × 3)**

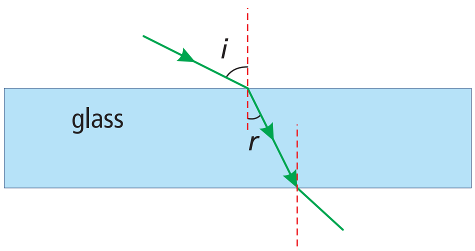
TIP: You may also show the metre rule and protractor. It is also acceptable to use the ray box to show the light ray instead of using pins. In this case, you still need to mark the block and incident/refracted rays to measure the angles.

(ii) 1. Place the glass block on the paper and board and draw an outline of the block. Keep the block within this outline for the experiment.

2. Place two pins (1 and 2) into the paper, as shown in Fig. 3.1. The pins should make an acute angle with the block.
3. Lean down and look into the block from the other side, as shown in Fig. 3.1.
4. Closing one eye, move your head until you cannot see pin 1 because pin 2 is in the way.
5. Place pins 3 and 4 into the board to mark this line of sight.
6. Using a pencil, mark where each pin is in the board.
7. Remove the pins and block and draw the incident (pins 1 and 2) and emergent ray (pins 3 and 4).
8. Join the incident and emergent ray. (This is your refracted ray, which passed through the block.)
9. Draw a normal at the point of incidence and mark in ϑi and ϑr. Measure these with a protractor. **(6 + 3)**

TIP: If you used the ray box, you would do the following:
1. Place the glass block on the paper and draw an outline of the block. Keep the block within this outline.
2. Shine a narrow ray of light through the block using a ray box.
3. Mark where the ray enters/leaves the block.
4. Remove the block and join the incoming/outgoing ray.
5. Draw a normal at the point of incidence and mark in the angle of incidence (ϑi) and angel of refraction (ϑr).

(iii)



(6)

TIP: As you can see, the angle of incidence is between the incident ray and the normal at point of incidence. The refracted ray is between the refracted ray (inside where the block was) and the normal.

(iv)

Angle of incidence *i*	Angle of refraction *r*	sin *i*	sin *r*	$\frac{\sin i}{\sin r}$
25°	16°	**0.423**	**0.276**	**1.533**
35°	22°	**0.574**	**0.375**	**1.531**
50°	30°	**0.766**	**0.500**	**1.532**
60°	34°	**0.866**	**0.559**	**1.549**

(9)

TIP: This Snell's Law experiment is based on the ratio of the Sin of angle of incidence to the Sin of angle of refraction being a constant (*n*). It is very important that you always check your calculator is in DRG/DEG mode to calculate these answers. When calculating from the Sin of the angle back to the angle, you need to use the inverse Sin button (Sin^{-1}) on the decimal (e.g. $\text{Sin}^{-1}(0.423) = 25^\circ$). However in the case of this question, you need only apply the Sin function to each angle and write it to 3 decimal places.

(v) Snell's Law: $n = \text{Sin } i/\text{Sin } r$. The average value for $n = \dfrac{1.533 + 1.531 + 1.532 + 1.549}{4} = 1.536$

The values for Sin *i*/Sin *r* all approximately equal around 1.5. This verifies that the ratio of Sin *i* to Sin *r* is a constant (*n*). **(7)**

TIP: If you are given a number of values for refractive index (*n*), average them to gain a final value for *n*. By knowing Snell's Law both in word and as a formula, you can easily move between the questions asked. Every time you are asked to verify a result, it will usually be based on a straight-line graph or a set of figures all working out similarly.

4. (i) X could be an ammeter, a milliammeter, a galvanometer or a multimeter. **(6)**

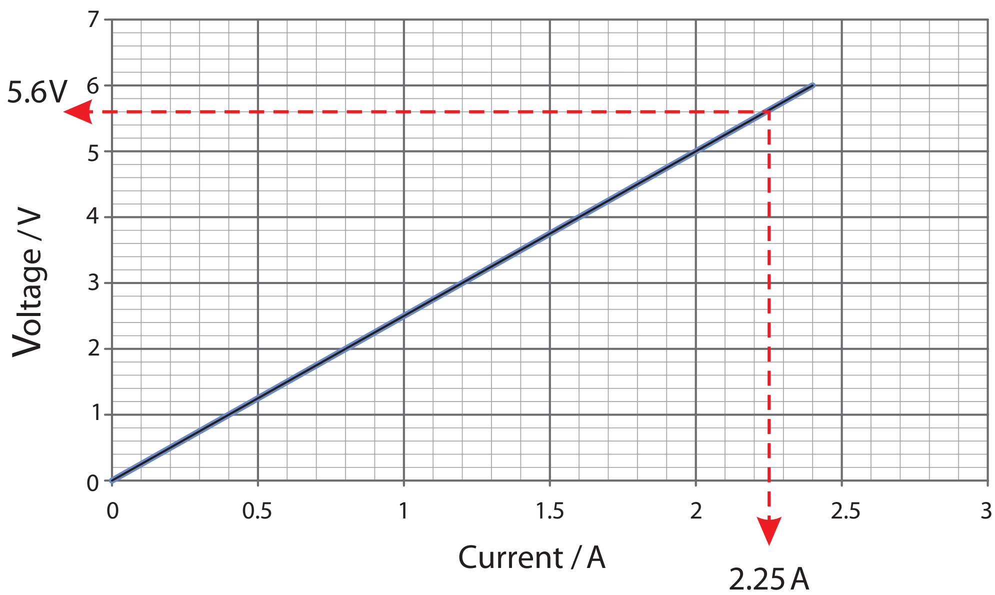
TIP: The important thing about device X is that it is measuring current and therefore needs to be an instrument from the above list. You should know this from the apparatus of the mandatory experiment and the fact that the experiment is measuring current and voltage.
The other thing to give you a clue is that current is always measured in series, whereas voltage is measured in parallel. Device X is in series and device Z is in parallel.

(ii) Y is a variable resistor (rheostat/potential divider). Its function is to keep the voltage stable as well as limiting the current. **(6)**

TIP: As said previously by knowing the equipment, you should know that the variable resistor is required to keep voltage stable.

(iii) The potential difference was measured with a voltmeter at position Z. **(6)**

TIP: Z could also be a multimeter.



(4 × 3)

TIP: Your graph should take up at least three-quarters of the graph page and have clearly labelled axes. It should also be a good straight line through the origin.

$$\text{Slope} = \frac{y_2 - y_1}{x_2 - x_1} \Rightarrow m = \frac{(5.6) - (0)}{(2.25) - (0)} \Rightarrow m = \frac{5.6}{2.25} \Rightarrow m = 2.49$$ **(3)**

Therefore, the resistance of the copper sulphate is 2.49Ω (2.5Ω). **(7)**

SECTION B

5. (a) $W = F \times d \Rightarrow W = (500)(2000) \Rightarrow W = 1 \times 10^6 J$ **(8 × 7)**

> **TIP:** Make sure to convert all units into the standard form before multiplying, e.g. 2km = 2000m. The answer can also be written as 1000000J, if required.

(b) Potential energy depends on mass, gravity and/or height.

> **TIP:** The formula for potential energy is $E_K = mgh$; therefore, any of the three letters *m*, *g* or *h* will be suitable here.

(c) A barometer can be used to measure atmospheric pressure.

(d) Resonance is the transfer of energy between two bodies with the same natural frequency.

> **TIP:** You may also phrase this as one body causing another body to oscillate at greater amplitudes because of similar natural frequencies.

(e) A low U-value means that a low amount of energy is lost through building material.

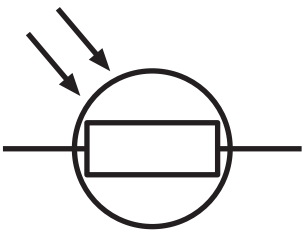
(f) Choose any one from the following:
- Copper is a good conductor of electricity.
- Copper doesn't corrode.
- Copper is cheaper than a lot of conductors.

(g) The magnet will line up with the Earth's magnetic field.

(h) A transformer is based on electromagnetic induction and the ratio of turns between the primary and secondary coils.

> **TIP:** If the primary coil has fewer turns than the secondary coil, the voltage will be stepped up. Whereas if the primary coil has more turns than the secondary coil, the voltage will be stepped down.

(i)



(j) Nuclear fusion.

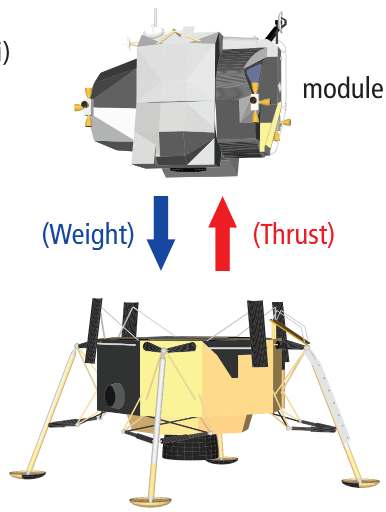
6. Acceleration due to gravity is the acceleration caused by the pulling force exerted by the Earth's mass. **(6)**

Weight on the Earth: $W = mg \Rightarrow W = (800)(9.8) \Rightarrow W = 7840N$

Weight on the moon: $W = mg \Rightarrow W = (800)(1.6) \Rightarrow W = 1280N$ **(9)**

> **TIP:** As you can see, the mass of a body does not change depending on where it is situated. However, the weight of an object depends on the acceleration due to gravity of the body it is attracted to. In the case of the Earth versus the moon, the acceleration due to gravity is 9.8/1.6 greater on the Earth: this is 6.125 times greater. If you multiply 1280N by 6.125, you will get the weight on earth of 7840N.

(i)



(6)

(ii) $F_{net} = F_{upward} - F_{weight} \Rightarrow F_{net} = (2000)-(mg) \Rightarrow F_{net} = 2000-(600)(1.6) \Rightarrow F_{net} = 2000 - 960 \Rightarrow F_{net} = 1040N$ **(6)**

TIP: Resultant force is also net force here. Net force can be calculated when the total force has all other forces subtracted. Make sure to convert the mass of the space module into a weight force by multiplying by the gravity present.

(iii) $F = ma \Rightarrow 1040 = (600)a \Rightarrow 1040/600 = a \Rightarrow 1.73m.s^{-2} = a$ **(6)**

TIP: Final acceleration of a body comes from net force. Therefore, substitute whatever answer you got in part (ii) to calculate the acceleration of the module. $F = ma$ always requires net force to be substituted in for F.

(iv) $v = u + at \Rightarrow v = (0) + (1.73)(20) \Rightarrow v = 34.67m.s^{-1}$ **(6)**

TIP: The final answer here for v was gained by keeping the figure for acceleration in the calculator and then multiplying it by 20s. However, if you use the rounded figure from part (iii), this is still acceptable and will give you a velocity of $34.6m.s^{-1}$.

(v) No, it would not be able to lift off as the weight of the module on Earth is greater than the upward thrust force available.

Upward thrust = 2000N
Weight on Earth = mg = (600)(9.8) = 5880N
5880N > 2000N **(3 + 6)**

(vi) The mass of the moon is less than the mass of the Earth. **(5)**

TIP: Newton's universal gravitation is based on the product of masses and the square of the distance between them. The mass of the moon is significantly less than the Earth and so has less gravitational acceleration.

(vii) Since the moon does not have an atmosphere, it will not create a drag effect on the craft and therefore will not exert extra friction due to the shape of the module. **(3)**

7. (i) Diffraction is the spreading out of a wave as it moves through a gap or around an obstacle. **(6)**

Interference is when two waves combine to form a resultant amplitude made up of each wave's individual amplitude. **(6)**

(ii)

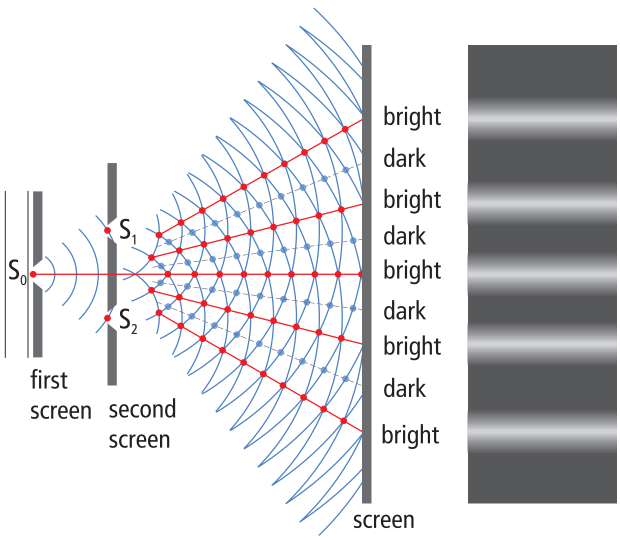
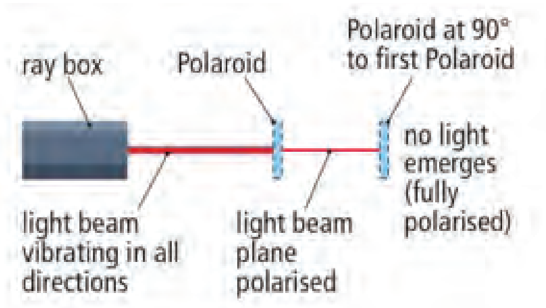


Fig 7.1

1. A single monochromatic light source is placed behind slit S_0. Light passing through S_0 is diffracted, and hits slits S_1 and S_2.
2. As the light passes through slits S_1 and S_2, it is diffracted once again, producing two coherent wave sources.
3. The coherent wave sources overlap and interference occurs.
4. Constructive interference produces bright fringes on the screen (Fig. 7.1); destructive interference produces dark fringes. **(4 × 3)**

(iii) Polarisation is the confining of a transverse wave to a single plane. **(6)**

(iv)



As the light beam passes through the first piece of Polaroid, it is plane polarised and confined to one plane only. However, when it passes through the second piece of polaroid, which is at 90 degrees to the first sheet of Polaroid, the light is completely polarised and no light emerges through. This demonstrates the polarisation of light. **(4 × 3)**

(v) Transverse waves are the only waves that can be polarised. Therefore, light is a transverse electromagnetic wave. **(9)**

(vi) Polaroid sunglasses can reduce the polarised reflected light which causes glare. Ordinary sunglasses cannot do this. **(5)**

8. (i) The wire connected to the fuse is brown. **(6)**

TIP: The fuse is always connected in the live. The live wire is brown but may also be red.

(ii) A fuse protects from too much current as it melts because of the heating effect of over-current. **(6)**

(iii) One of the main effects of current is heating. The fuse is made of a thin wire that melts when too much current flows through it. This then breaks the circuit and stops the current flowing. **(6 + 3)**

(iv) $P = VI \Rightarrow P/V = I \Rightarrow 900/230 = I \Rightarrow 3.9\text{A} = I$

Therefore, a fuse rated at 5A would be most suitable as it would allow the normal current of 3.9A through but if the current went slightly higher than normal, the fuse would melt and break the circuit. **(3 × 3)**

TIP: By looking at the available fuse ratings given in the question, you can see that 5A or 13A are the only fuses capable of allowing normal current through. However, the 13A is a great deal higher than the normal current if something goes wrong and, therefore, the 5A is the safer option to use.

(v) A lower rating fuse would melt and break during normal current flow and therefore stop the equipment working at all times. **(6)**

(vi) Choose any one from the following:

- MCB (miniature circuit breaker)
- RCD (residual current device)
- Trip switch **(6)**

(vii) Number of kWh = 0.9kW × 1.5hrs = 1.35kWh **(8)**

TIP: The units are kilowatt hours. This means converting the power to kilowatts (900W = 0.9kW) and converting the minutes to hours (90 mins = 1.5 hrs). Then multiply them to calculate the kilowatt hours used.
You may also gain partial marks if you work out the total number of Joules used:
Power = 900W P = 900 Joules every second
If the vacuum cleaner is used for 90 minutes: 900J × 60s × 90min = 4860000J.

(viii) 1.35kWh × €0.22 = 29.7c (€0.297) **(6)**

TIP: Whatever answer you gained in part (vii), multiply this by the cost of each unit to calculate the cost of energy used.

9. (i) Kelvin (K). **(6)**

(ii) $t/°C = T/K - 273.15$. **(6)**

(iii) Heat is a form of energy. **(6)**

TIP: Given that heat is referred to as either causing a rise in temperature and/or a state change, you can also refer to heat in terms of the formulae and then explain the letters : $Q = mc\Delta\theta / Q = ml$.

(iv) Heat can be transferred by conduction, convection and radiation. **(6)**

(v) Change in state can refer to any change between solid ⟷ liquid and liquid ⟷ vapour. **(3)**

(vi) Specific latent heat of a substance is the amount of heat energy required to change the state of 1kg of the substance without a change in temperature. **(6)**

(vii) $Q = ml \Rightarrow Q = (20 \times 10^{-3})(3.34 \times 10^{5}) \Rightarrow Q = 6.68 \times 10^{3}\text{J}$ **(3 × 3)**

TIP: Make sure to convert the numbers into the standard form before substituting into the formula. The most common mistake is not changing grams to kilograms. All energy can be listed in Joules.

(viii) $Q = mc\Delta\theta \Rightarrow Q = (20 \times 10^{-3})(4180)(5) \Rightarrow Q = 418\text{J}$ **(3 × 3)**

TIP: Again, make sure to convert all units correctly. There are only two main formulae for heat. If it is a state change, you use $Q = ml$; if it is a heat change, you use $Q = mc\Delta\theta$. Just make sure to substitute in the temperature change for $\Delta\theta$ and not the actual temperature.

(ix) By stirring the mixture, you are achieving a good equilibrium of temperature throughout. This will also help the ice to melt more quickly. **(5)**

10. Choose one particle and its properties from the following:

	proton	**neutron, etc.**
mass	1 (amu)	1 (amu)
charge	+1	0
location	inside nucleus	inside nucleus

(3 × 3)

(i) A = Cathode
B = Anode
C = Fluorescent screen **(3 × 3)**

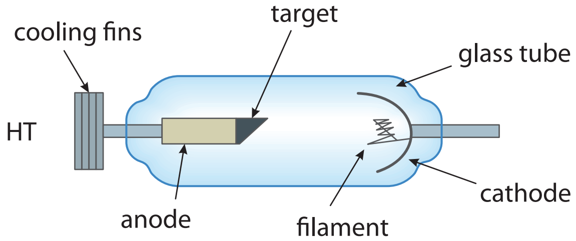
(ii) Choose any two from the following:
- Cathode: This is heated and undergoes thermionic emission to emit electrons.
- Anode: This attracts the emitted electrons and accelerates them.
- Screen: This causes scintillations every time an electron strikes it. **(6 + 3)**

(iii) The electrons can be deflected in an electromagnetic field. **(6)**

(iv) When the electrons hit the screen at C, they cause a scintillation (flash). **(6)**

TIP: Each scintillation is a sharp spot of light that, with the help of all the other scintillations, produce a picture. The scintillation comes from the energy of the electron being converted to light as it hits at high velocity.

(v) A vacuum is required so that the electrons do not collide with air particles and can pass easily through the tube. **(3)**



(3 × 3 + 2)

Choose any one from the following:
- Wear protective clothing.
- Use lead shielding or glass between the tube and operator.
- Restrict exposure or dosage.
- Monitor all exposure and radiation dosage received. **(3)**

11. (a) Nuclear fission is the splitting of a large nucleus into two similar smaller nuclei with the release of neutrons and energy. **(8 × 7)**

(b) Radioactivity is the spontaneous decay (splitting) of a nucleus with the emission of radiation.

TIP: The three types of radiation emitted can be alpha, beta or gamma.

(c) A chain reaction is a fission reaction in which at least one neutron is emitted in order to carry on the reaction by causing further fission.

(d) The control rods absorb neutrons and therefore can control the power output by regulating the rate of reaction.

(e) Choose any one from the following:
- Cadmium
- Boron
- Iridium
- Silver
- Steel

(f) Since the isotopes present in the reactor, from the fission, were still decaying, further heat was generated.

(g) Too much heat would cause overheating and possible melting of the reactor, which would lead to radiation leaks and possible explosions.

(h) Choose any one from the following:
- Little or no greenhouse gases emitted
- Cheap energy
- Plentiful supply of fuel
- Very efficient

12. (a) The total momentum of a system before an interaction is equal to the total momentum of the system after an interaction, so long as no external force acts on it. **(6)**

TIP: The use of 'system' here is to include all factors of a collision so that the velocities and masses of everything colliding is taken into account.

(i) $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$
$\Rightarrow (1500)(0) + (80)(0) = (1500)v_1 + (80)(60)$
$\Rightarrow 0 = 1500v_1 + 4800$
$\Rightarrow -4800 = 1500v_1$
$\Rightarrow -4800/1500 = v_1$
$\Rightarrow -3.2\text{m.s}^{-1} = v_1$ **(2 × 3)**

TIP: As you can see, the final recoil velocity is negative as it is going in the opposite direction to the cannonball. You should also see that the initial momentum of the system was zero since both cannon and cannonball were at rest. Because of this, both momenta of cannon and cannonball should also equal zero at the end. By stating your formula and variables first and then substituting them in, you reduce the chance of error.

(ii) $E_K = ½ mv^2 \Rightarrow E_K = ½ (1500)(3.2)^2 \Rightarrow E_K = 7680J$ **(2 × 3)**

TIP: As long as you substitute in the value for velocity in part (i), you will still get the marks.

The cannon recoiled because momentum had to be conserved and therefore the cannon had to move in the opposite direction to the cannonball. **(4)**

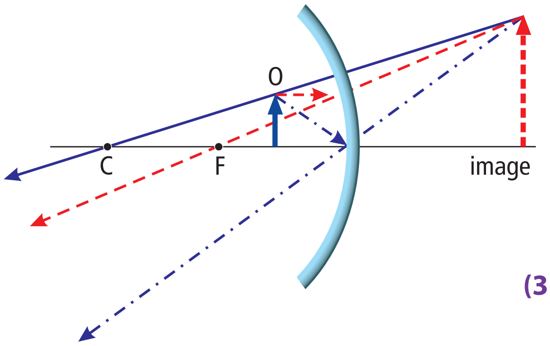
Because the cannon has a larger mass and greater resistance between it and the ground, it will come to rest more quickly than the cannonball. **(6)**

(b) The incident ray, reflected ray and normal all lie on the same plane.

The angle of incidence is equal to the angle of reflection. **(6)**

By focusing a distant object onto a screen and measuring the image distance (v), you can approximate focal length (f), as u should equal f. **(3 × 3)**

TIP: This originates from the fact that all parallel rays will converge at the focal point. Because a distant object is essentially reflecting parallel rays, its image will appear at the focus ($u = f$).



(3 x 3)

Choose any one from the following:

- Floodlights
- Dentist's mirror
- Make-up mirror
- Headlights
- Telescopes **(4)**

(c) (i) Doppler effect. **(6)**

(ii)

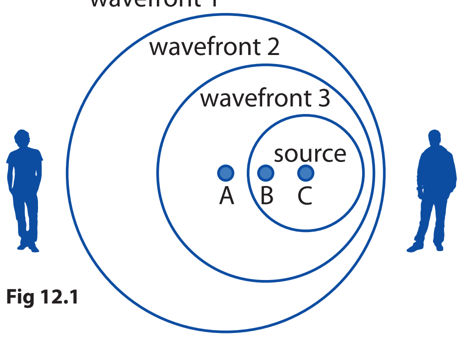


Fig 12.1

If the source is moving, by the time the second wavefront is emitted, the source has changed position:

- Wavefront 1 was emitted when the source was at A.
- Wavefront 2 was emitted when the source was at B.
- Wavefront 3 was emitted when the source was at C.

This means that the wavefronts will be bunched up at one side (in the direction of motion) and spaced out at the other side.

- For the person on the left of Fig. 12.1, the crests of the wavefronts would appear to be further apart. If the wavefronts are more spaced out, the frequency must appear lower.
- For the person on the right of Fig. 12.1, the crests of the wavefronts would appear to be closer. If the wavefronts are more bunched up, the frequency, must appear higher.

This explains the Doppler effect. **(4 × 3)**

(iii) No, since the firemen and fire engine are both relatively moving together. Since there is no relative motion between them, the sound remains the same. **(4)**

(iv) Choose any one from the following:

- Speed traps/guns
- Ultrasonic scanning
- Blood flow meters
- Red shift/blue shift star measurement
- Radar **(6)**

(d) (i) The capacitor charges up as current flows. When it is fully charged, current ceases. The capacitor will then temporarily store the energy. **(6)**

(ii) The capacitor will discharge the current back through the bulb very quickly. **(6)**

(iii) The capacitor discharges far more quickly than it charges. As soon as the energy has all been transferred, the bulb goes out again. **(6)**

(iv) $Q = CV \Rightarrow Q = (200 \times 10^{-6})(6) \Rightarrow Q = 1.2 \times 10^{-3} C$ **(6)**

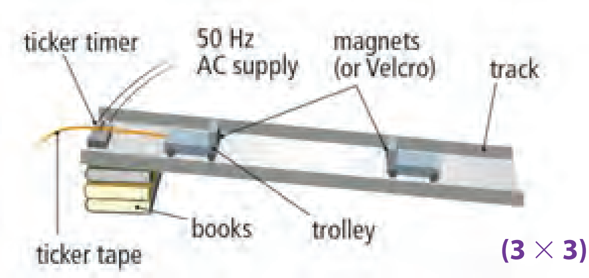
TIP: If asked to calculate a value and two out of three variables in the formula are given, it should be simple to list the variables and substitute in as appropriate.

(v) Choose any one from the following:

- Radio tuning
- Filtering
- Smoothing circuits
- Camera flashes
- Flash guns
- Phone chargers **(4)**

SECTION A

1. (i)



(3 × 3)

TIP: Make sure to include all equipment that is essential to measure the individual masses, and initial/final velocity, as momentum is a product of Mass × Velocity.

It is also acceptable to show any other equipment set-up you are familiar with, such as an air track and photo gates or a data-logger connected to a motion sensor. Whichever apparatus you start with, use the same equipment for descriptions of measurement that follow. (For example, if you are using light gates, you need to mention how sail length and time were measured, or if you were using a ticker timer, you will have to describe the measurement of distance and time from the tape.)

(ii) The mass of the trolley was measured using a top pan balance or electronic balance. **(6)**

TIP: Remember they are looking for mass here and not weight. The measurement must be in kg.

(iii) Velocity can be measured by the following methods:

Ticker timer:

- Measure the physical distance between the dots (*s*).
- Count the number of spaces between the dots (*n*).
- Calculate the time by multiplying the number of spaces (*n*) by 1/50 s (*t*).
- Calculate velocity using $v = s/t$.

Light gate:

- Measure the length of the sail (*s*).
- Record the time from the timer attached to the light gate (*t*).
- Calculate velocity using $v = s/t$.

Data-logger:

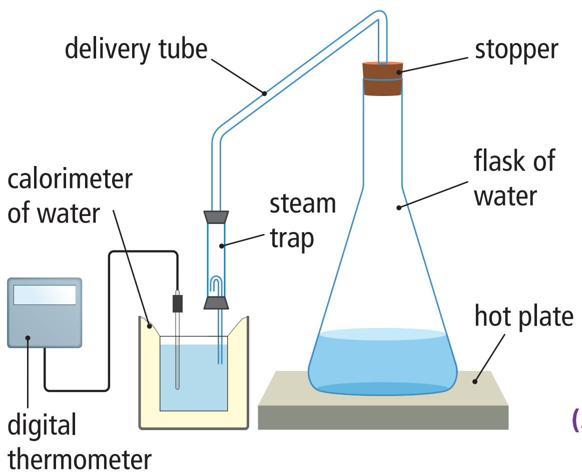
- Use a motion sensor attached to the data-logger and select velocity from a distance–time graph of motion. **(4 × 3)**

(iv) Momentum is calculated by multiplying mass by velocity ($\rho = mv$). **(6)**

(v) The principle of conservation of momentum states that the momentum before an interaction must equal the momentum after an interaction. In the case of this experiment, that means that the sum of the Mass × Velocity of each trolley before the collision must equal the sum of the Mass × Velocity of the two trolleys after collision. This can be given by the formula: $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$. **(7)**

TIP: This experiment is often conducted by moving a trolley at constant velocity towards another trolley at rest. Then the two trolleys move off together at constant velocity. To verify the principle of conservation of momentum, you would need to find the momentum of the first trolley and let it equal the momentum of both trolleys ($(m_1 + m_2)(v)$). This is because the second trolley initially has no momentum because it is at rest. If the two trolleys were stuck together like this, your formula could be stated as: $m_1u_1 + m_2u_2 = (m_1 + m_2)(v)$. However, you should always state what each letter in the formula stands for.

2. (i)



(3 × 3)

(ii) Final temperature of water – initial temperature of water = temperature change

$\Rightarrow$ 19˚C – 10˚C = 9˚C **(6)**

TIP: It is not important for the calculation of energy to differentiate between rise or fall in temperature. The formulae are only concerned with $\Delta\theta$ (change in temperature).

(iii) The mass of cold water was calculated by subtracting the mass of the (cold water and calorimeter) from the mass of the (cold water, calorimeter and steam). **(7)**

TIP: This is a common question asked for this topic and should be well prepared.

(iv) The steam was dried by using a steam trap angled upwards to the collection flask. **(6)**

(v) (a) $Q = mc\Delta\theta \Rightarrow Q = (67.5 \times 10^{-3}\text{kg})(4180)(9) \Rightarrow Q = 2539.4\text{J}$ (water)

$Q = mc\Delta\theta \Rightarrow Q = (73.4 \times 10^{-3}\text{kg})(390)(9) \Rightarrow Q = 257.6\text{J}$ (calorimeter)

Total heat energy gained: 2539.4J + 257.6J = 2797J **(6)**

TIP: It is best to calculate the heat energy separately so as to simplify the work. It is also a good idea to list the values of each variable before substituting them into the formula. To avoid decimal mistakes, it is good practice to state the mass in 10^{-3} kg instead.

(b) $Q = mc\Delta\theta \Rightarrow Q = (1.03 \times 10^{-3}\text{kg})(4180)(81) \Rightarrow Q = 348.7\text{J}$ (water) **(3)**

TIP: The common mistake in this question is to mix up the $\Delta\theta$ for each side of the equation. While the temperature change may be 9˚C for the calorimeter and water, it is 81˚C for the steam, since the steam had an initial temperature of 100˚C and the final temperature of the overall mixture was 19˚C. This is another good reason to state your values first before substituting them in.

(c) $mc\Delta\theta(\text{water}) + mc\Delta\theta(\text{calorimeter}) = ml(\text{steam}) + mc\Delta\theta(\text{added steam})$

$2539.4\text{J} + 257.6\text{J} = ml + 348.7\text{J}$

$2797\text{J} - 348.7\text{J} = ml$

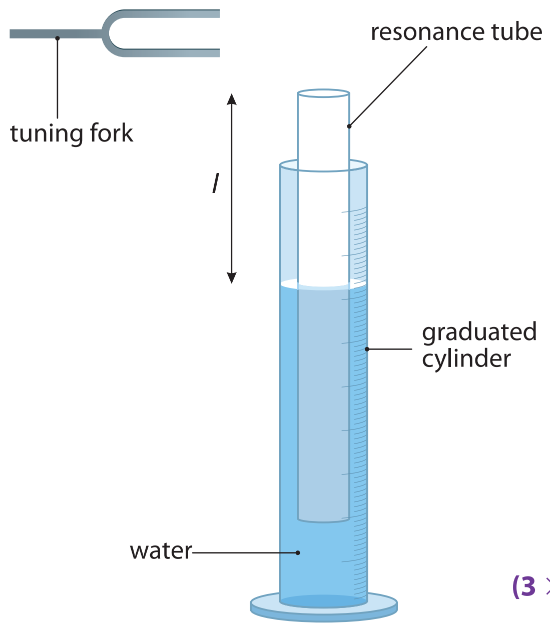
$2448.3\text{J} = ml$

$2448.3\text{J}/1.03 \times 10^{-3} = l$

$2.38 \times 10^{6}\text{J kg}^{-1}$ **(3)**

TIP: Remember that heat questions like this are just energy equations. As long as everything is in kg and you work out the energy for each part, you can let the energy gained equal the energy lost. In the case of this question, the energy was gained by the water and calorimeter and lost by the added steam. The only other thing you have to remember is to use $mc\Delta\theta$ for heat change and ml for state change. Notice, though, how the water and calorimeter stay on the left of the equation and the added material stays on the right. This way, you are letting heat gain equal heat loss.

3. (i)



(3 × 3)

TIP: It is important to label the length of air column as opposed to the water level, since the speed of sound experiment is based on the resonating air above the water. You may also use a signal generator instead of a tuning fork here.

(ii) If using a tuning fork, the frequency can be read off the fork. If you used a signal generator, it would be displayed on the generator or read from the dial. **(6)**

TIP: Don't overcomplicate answers by presuming more is required than necessary. Think about the experiment and how you knew the value for frequency. Sometimes a simple statement is all that is required, such as reading the frequency off the tuning fork.

(iii) Measure the length of the vibrating air column (l).
Measure the diameter of the resonance tube used (d).
Record the frequency applied (f).
$\lambda = 4(l + 0.3d)$ is used to calculate the wavelength with these readings. **(3 × 3)**

> **TIP:** Make sure to convert your length and diameter readings into metres. Then list your values and substitute them into the above formula.
>
> When using the standard formula: $c = 4f(l + 0.3d)$, you can adapt it to match the above formula by using the following steps: $c = 4f(l + 0.3d) \Rightarrow (c = f\lambda): f\lambda = 4f(l + 0.3d) \Rightarrow$ (divide by f): $\lambda = 4(l + 0.3d)$.

(iv) To calculate speed of sound, you can use the following formula:
$c = 4f(l + 0.3d)$ **(4 × 3)**

(v) Repeating experiments gives better averages and greater accuracy. **(4)**

> **TIP:** As you can see, the same formula appears in different forms and all that is required is to state the variables and substitute them in. You may also use the λ value from part (iii) and substitute it into the wave formula with frequency: $c = f\lambda$.

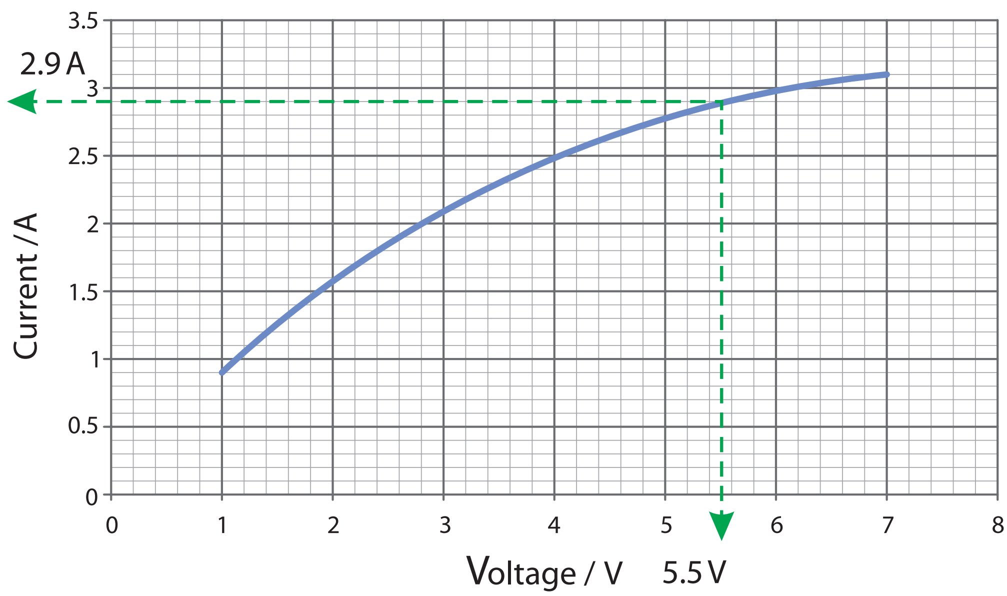
4. (i) X = Voltmeter, which measures voltage. **(4)**

> **TIP:** A multimeter may also be used but it still needs to be set to measure voltage.
> As you can see from the diagram, X is in parallel with the filament lamp. Voltage is always measured in parallel. The other clue is that the experiment is measuring current and voltage; therefore, it must be one of these.

(ii) Y = Variable resistor, which varies resistance and therefore can change voltage and/or current. **(6)**

> **TIP:** You may also call this a rheostat, potentiometer or potential divider.

(iii)



(4 × 3)

> **TIP:** Make sure to clearly label the axes and use at least three-quarters of the graph page. Once the points are plotted, draw a smooth curve joining the points. You may also extend the graph down to the origin to show the relationship from zero.

(iv) The graph shows a non-ohmic relationship which is not proportional. However, it does show that as voltage increases, so too does current. **(9)**

> **TIP:** The main relationships that you are looking for in these type of questions are either linear showing proportionality or non-linear showing non-proportionality. Other than that, just state what you see. If the graph rises or falls, mention it.

(v) From the graph, where 5.5V is drawn up to the curve, and a line drawn across to find the associated current, a value of 2.9A is gained. **(9)**

> **TIP:** The important point here is to show your work on the graph as a certain allowance will be made if the graph is not perfectly accurate. However, by drawing a nice big graph, you minimise the chance of error.

SECTION B

5. (a) Friction is any force that resists motion between bodies in contact. **(8 × 7)**

> **TIP:** Remember that friction will always oppose motion. Therefore, it will always act in the opposite direction to the direction of motion.

(b) $g = \frac{GM}{R^2}$

(c) Choose any one from the following:
- Scissors
- Tap
- Door handle
- Door on a hinge
- Tongs

(d) Interference.

(e) Conduction, convection and radiation.

(f) Choose any two from the following:
- Shaving mirror
- Make-up mirror
- Headlights
- Floodlights

(g) Yellow and green.

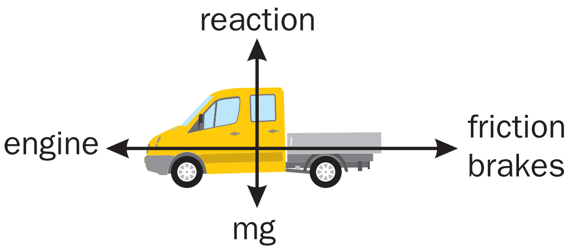
(h) An MCB (miniature circuit breaker) trips (turns off) the current if it exceeds a set limit.

(i) Choose any one from the following:
- Measure potential difference present
- Identify type of charge present
- Detect charge
- Test whether a material is an insulator or conductor

(j) Choose any one from the following:
- Solar/Wind/Tidal – not always available and not constant
- Biomass – uses up valuable crop areas that could be used for food
- Geothermal – expensive to install

6. All bodies will remain at rest or at constant velocity unless an external force acts on them. **(6)**

(i)



(3 × 3)

(ii) $u = 15\text{m.s}^{-1}$, $v = 0\text{m.s}^{-1}$, $a = ?$, $s = ?$, $t = 0.4\text{s}$

$a = \frac{v-u}{t} \Rightarrow a = \frac{(0)-(15)}{(0.4)} \Rightarrow a = 37.5\text{m.s}^{-2}$ **(3 × 3)**

> **TIP:** When asked to use Newton's equations of motion or any similar formula, it is a good idea to list the variables as above and then choose the equation that only has one variable missing.

(iii) $F = ma \Rightarrow F = (1400)(37.5) \Rightarrow F = 52500\text{N}$ **(6)**

TIP: Net force always comes from $F = ma$. If asked to calculate mass or acceleration in this type of question, make sure to find the net force first before using this formula. Remember also that $F = ma$ is a special case of Newton's Second Law of Motion.

(iv) $E_K = \frac{1}{2} mv^2 \Rightarrow E_K = \frac{1}{2}(1400)(15)^2 \Rightarrow E_K = 157500\text{J}$ **(6)**

TIP: It is also safe to say that the energy lost in the collision is 157500J, as all of the moving energy converted.

(v) Choose any two from the following:

- Heat
- Sound
- Deformation of the car and/or tree
- Light
- Potential energy **(3 × 3)**

TIP: Kinetic energy exists only in moving bodies. Therefore, when the object reduces velocity, the kinetic energy must convert to another form.

(vi) Because the back seat passenger has momentum, a sudden stop will result in them moving at high velocity forwards. Newton's First Law states that all objects remain at constant velocity or rest unless an unbalanced force acts on it. This means the passenger becomes a moving weapon in the car.

To reduce the risk of injury a seatbelt can restrain the passenger from moving as much. **(4 + 7)**

TIP: The seatbelt is an example of Newton's First Law where the external force can change the velocity of the body.

7. (i) Reflection is the bouncing of a wave off an object. Refraction is the bending of a wave as it enters a different medium and changes speed **(2 × 6)**

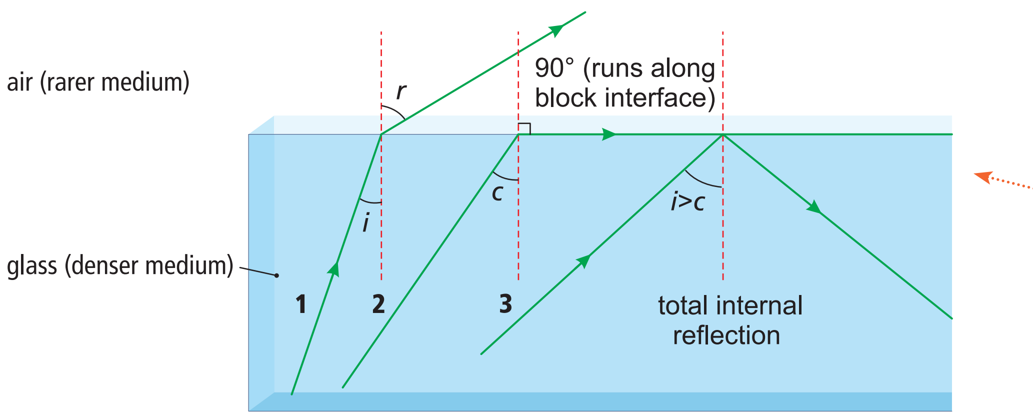
(ii) Choose any one from the following:

- Optical instruments such as telescopes or binoculars
- Optical fibres
- Mirrors **(3)**

(iii) The incident ray, reflected ray and normal all lie in the same plane.

The angle of incidence (i) equals the angle of reflection (r). **(9)**

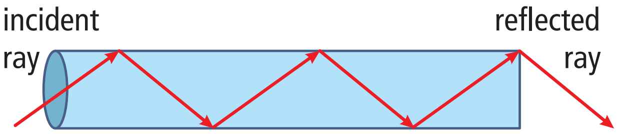
(iv)



TIP: This can also be shown with the semicircular block experiment, where the incident ray hits the curved side of the block at 90˚ and refracts/reflects when it exits the flat side. The main point is to see where the critical angle is reached and refraction becomes reflection.

When the angle of incidence (i) equals the critical angle (c), the angle of refraction = 90˚. When the angle of incidence exceeds the critical angle, total internal reflection occurs and the angle of incidence equals the angle of reflection, as per the laws of reflection. **(9)**

(v) The critical angle is the angle of incidence in the denser medium that results in an angle of refraction of 90˚ in the rarer medium. **(6)**

(vi) 

(9)

(vii) Choose two from the following:

- Optical fibres are cheaper than copper cables over long distances.
- Optical fibres are thinner.
- Optical fibres are more durable.
- Optical fibres carry more information.
- Optical fibres need no electricity.
- Optical fibres are more flexible. **(5)**

TIP: They can also be used to attach to drill tips and instrument tips to view areas being worked on in dentistry and keyhole surgery.

(viii) Optical fibres can be used in endoscopy to view inside the body. **(3)**

8. (a) (i) A thermometric property is a physical property that changes measurably and repeatedly with temperature change **(6)**

(ii) Choose any two from the following:

- Length of column
- Colour change
- Emf
- Resistance
- Pressure at constant volume
- Volume at constant pressure **(6)**

(iii) Choose any two from the following:

- Alcohol thermometer
- Mercury thermometer
- Electrical resistance thermometer
- Thermocouple
- Digital thermometer
- Constant volume thermometer **(2 × 2)**

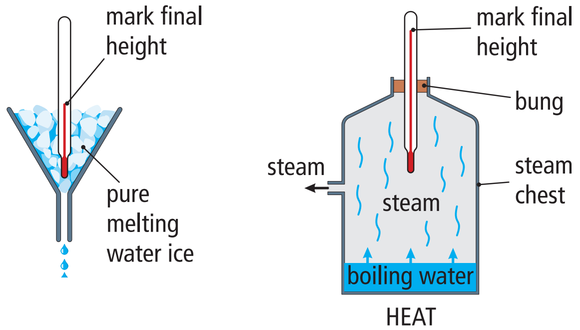
(iv) 

Fig. 8.1 (a) **(b)**

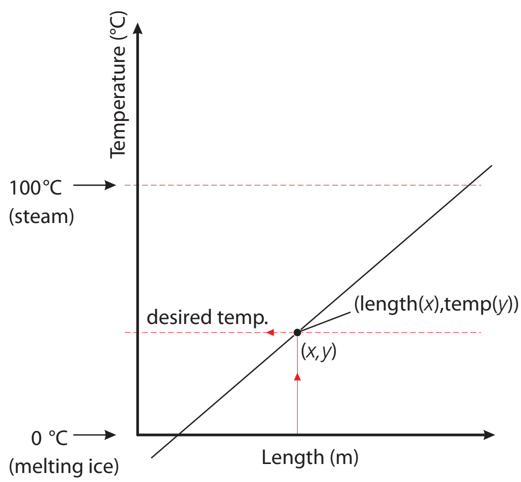


Fig. 8.2

To graduate two thermometers at ice and steam points, do the following:

1. To calibrate a thermometer, you need to take a number of readings and plot a graph to obtain a proportional relationship to use when reading later temperatures. For example, to calibrate a mercury glass thermometer, you would use 0°C and 100°C.
2. To measure 0°C, place the thermometer in melting ice (see Fig. 8.1a). When the mercury level has stayed constant, note the length of the column.
3. To measure 100°C, place the thermometer in steam above pure boiling water. Again, wait for the level to stabilise and note the length (see Fig. 8.1b).
4. On graph paper, draw axes of Temperature (°C) against Length (m). Plot the lengths of the column for 0°C and 100°C. Draw a straight line between them, extending in both directions (see Fig. 8.2).
5. From this graph, you can now measure any temperature based on the length of the column of mercury. Use your graph to find the corresponding temperature for each length. **(4 × 3)**

(v) A standard thermometer is required because all different thermometric properties give different proportional temperature results. Therefore, a single standard thermometer is needed to compare results accurately. **(6)**

TIP: It is not necessarily the case that there is a single standard thermometer but rather a set thermometer that all experiments use to compare results each time. As long as the same type of thermometric property is used in each experiment, the results can be seen to be valid.

(b) (i) $Q = mc\Delta\theta \Rightarrow Q = (500 \times 10^{-3})(4180)(85) \Rightarrow Q = 177650\text{J} = 1.78 \times 10^5\text{J}$ **(3 × 3)**

TIP: The important part of heat calculations is to identify what change has occurred. Is it heat or state? Whichever it is, you must use the correct formula. Make sure to put all numbers in the correct form of kg or Joules. Also, if calculating a heat change, you need to only put in the temperature change and not the actual final temperature. In the case of the question here, the water changed from an initial temperature of 15˚C to a final temperature of 100˚C. This is a $\Delta\theta$ of 85 when put into the formula.

(ii) 2kW = 2000J.s^{-1}. Therefore, 2000J is supplied every second. **(3)**

TIP: It is common to mix power and heat in questions. Remember that 1 Watt = 1 Joule per second.

(iii) $P = \frac{W}{t} \Rightarrow t = \frac{W}{P} \Rightarrow t = \frac{1.78 \times 10^5}{2000} \Rightarrow t = 89\text{s}$ **(6)**

TIP: When you know how much energy is supplied per second, it is just a matter of dividing this into the energy required, to see the time taken. This can be seen to come from the formula given here. If you used the actual energy required from part (i) before it was rounded, you may get an answer of 88.825s. This answer is fine as long as you show the answer in part (i).

(iv) Any good insulator such as plastic or wood, which would not transfer too much heat to burn your hand. **(4)**

TIP: As long as you list a material that will not conduct too much heat to your hand, you will gain marks.

9. (a) Faraday's Law of Electromagnetic Induction states that the magnitude of induced emf is directly proportional to the rate of change of flux. **(9)**

TIP: You may also give this answer as a formula but you will also need to explain the letters.

(i) When the magnet is moved, the needle on the meter deflects. **(6)**

(ii) When the magnet is stationary, the needle on the meter also remains stationary. **(3)**

(iii) A changing magnetic field will induce an emf. The emf is shown by the meter deflection.

It is only when the magnet actually moves relative to the coil that the magnetic field changes in the coil. This could occur whether the magnet and/or coil moves.

However, when the magnet is stationary, the magnetic field does not change in the coil; therefore, no emf is induced and the meter remains stationary. **(3 × 3)**

(iv) By changing the speed of magnet, the following could occur:

If the speed slowed down, there would be less deflection as the rate of magnetic field change would reduce.

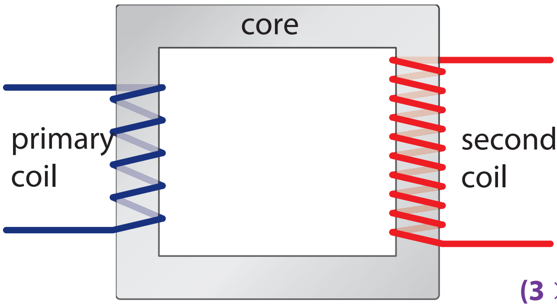
If the speed increased, there would be more deflection as the rate of magnetic field change would also increase. **(5)**

TIP: Remember that Faraday's Law is based on the rate of change of magnetic flux. Rate means per second. Therefore, the faster it occurs, the more emf induced.

(b) (i) a.c. means alternating current. **(6)**

TIP: Alternating current means the current keeps changing direction and alternating which way it flows at a set periodic rate.

(ii)



(3 × 3)

(iii) $\frac{V_s}{V_p} = \frac{N_s}{N_p} \Rightarrow = (V_p)\frac{N_s}{N_p} \Rightarrow V_s = (230)\frac{600}{200} \Rightarrow V_s = 690\text{V}$ **(3 × 3)**

TIP: Primary means input and secondary means output in these questions. Because there are three times as many turns of wire in the output, there will also be three times as much voltage in the output.

10. (i) Radioactivity is the spontaneous break-up of a nucleus with the emission of one or more types of radiation. **(6)**

(ii) Beta (β) and gamma (γ) are the other two types of radiation. **(6)**

(iii)

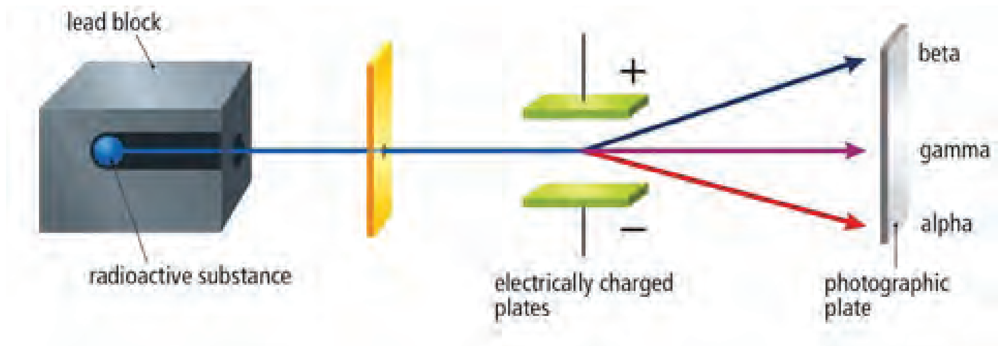


Fig. 10.1

To demonstrate deflection of radiation by EM fields, do the following:

1. Set up a source that will emit radiation through electrically charged plates (see Fig. 10.1).
2. You will observe that the alpha will be attracted towards the negative plate and repelled from the positive plate.
3. The beta will behave in an opposite manner, being attracted to the positive plate.
4. The gamma will be unaffected as it holds no charge.
5. The photographic plate can be replaced by a fluorescent screen if scintillations are required.

OR

Fig. 10.2

To demonstrate the ionising ability of radiation, do the following:

1. An electroscope can be used to show the ionising ability of each source.
2. Using a negatively charged electroscope, hold a source safely near the cap of the electroscope (see Fig. 10.2).
3. You will observe that the alpha source causes the leaves to fall quickest. The beta source is the next most ionising.
   The gamma has little effect. This shows that the bigger radiation particles cause more powerful collisions and therefore knock off electrons more easily.

OR

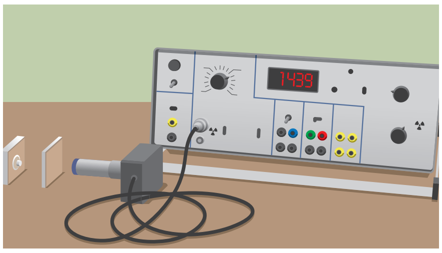


Fig. 10.3

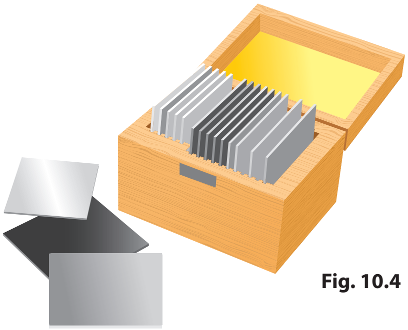


Fig. 10.4

To demonstrate the penetration ability of radiation, do the following:

1. Set up a Geiger counter to record radiation count with a scalar timer (see Fig. 10.3).
2. Record the background radiation count, so as to subtract this from any subsequent counts.
3. Place each source (alpha, beta and gamma) in the source holder in turn, facing the G-M tube. (Make sure all necessary safety precautions are taken to prevent the source pointing at people.)
4. Place a different number and type of barriers for each source and estimate penetration depth. The absorbers are usually paper, aluminium or lead (see Fig. 10.4).
5. By taking the count rate minus the background count for each source and thickness/type of barrier, you can calculate the penetration ability of each type of radiation. **(4 × 3)**

(iv) Choose any three from the following:

Name	Symbol	Structure	Relative charge	Relative mass
alpha	α	helium nucleus	+2	4
beta	β	electron	–1	approximately 0
gamma	γ	energy (EM)	0	0

Name	Penetrating power	Ionising ability	Rate of deflection in EM fields
alpha	lowest	greatest	behaves as a + particle
beta	medium	medium	behaves as a – particle
gamma	greatest	lowest	no deflection

(3 × 3)

(v) Isotopes are atoms with the same atomic number but differing atomic mass. **(6)**

TIP: The number of protons (atomic number) defines the element but the number of neutrons in the nucleus determines the isotope present.

(vi) Radon can cause lung cancer and other diseases. **(5)**

(vii) Each half-life = 4 days.
Therefore, after 4 days: ½ of the radon gas remains.
After 8 days (2 × 4 days): ¼ of the radon gas remains.
After 12 days (3 × 4 days): $^1/_8$ of the radon gas remains. **(6)**

TIP: In order to calculate the amount remaining after half-lives, it can sometimes be easier to just list each half-life and calculate it this way. You may also use the $½^n$ formula, where n = the number of half-lives and $½^n$ = the amount remaining, e.g. 3 half-lives mean $n = 3$; $½^3 = {}^1/_8$ remaining.

(viii) Choose any two from the following:

- Smoke detectors
- Food irradiation
- Medical use
- Industrial tracers
- Energy source **(6)**

11. (a) Heinrich Hertz. **(8 × 7)**

(b) Albert Einstein.

(c) The energy from the light transfers to the electrons on the surface of the metal and the electrons gain enough energy to leave.

(d) Metals are good conductors because they have loosely bound electrons capable of transferring energy easier than insulators.

(e) Light is a form of energy and when it hits your skin, it transfers some of its energy to the skin particles.

(f) Intensity of light refers to the number of photons of light present. Therefore, as more photons hit the metal, more electrons gain energy and more electrons leave the surface.

(g) Frequency affects the actual individual energy of each photon. Therefore, as frequency is changed up or down, the speed with which an electron leaves also changes.

> **TIP:** This is an important part of the photoelectric effect as described by Einstein. Intensity affects the number of electrons leaving but frequency affects whether they can leave or how fast they do leave. Each photon of light can only interact with one electron at a time.

(h) Choose any one from the following:

- Burglar alarm systems
- Photocopying
- Automatic door sensors
- Synchronised soundtracks
- Smoke alarms
- Light meters
- Photodiodes

12. (a) Boyle's Law states that the volume of a fixed mass of gas is inversely proportional to its pressure, as long as temperature remains constant. **(6)**

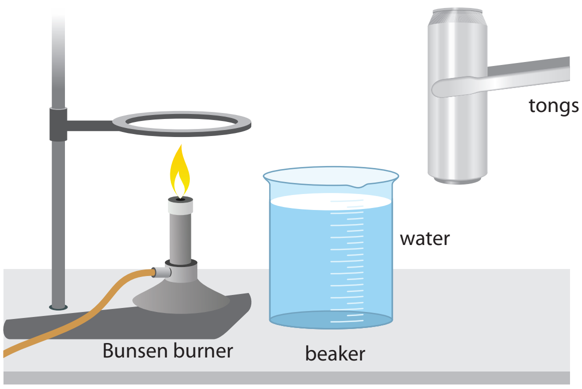


Fig 12.1

1. Place a small amount of water in an empty clean aluminium can (see Fig. 12.1).
2. Carefully heat the can over a Bunsen burner, using tongs and making sure the top opening is unobstructed.
3. When you hear the water boiling and see steam, remove the can from the heat.
4. Immediately invert the can in a beaker of cold water.
5. The water seals the can. The absence of air inside the can is unable to conteract the atmospheric pressure pushing from the outside.
6. The can immediately collapses. **(4 × 3)**

PV is a constant (*k*).

Therefore, let $P_1V_1 = P_2V_2 \Rightarrow \frac{P_2V_1}{P_2} = V_2 \Rightarrow \frac{(4.2 \times 10^6)(5)}{3 \times 10^4} = V_2 \Rightarrow \frac{(2.1 \times 10^7)}{3 \times 10^4} = V_2 \Rightarrow 700 \text{ litres} = V_2$ **(10)**

> **TIP:** $PV = k$ is a constant, and according to Boyle's Law as long as temperature is constant, as one decreases, the other increases. Therefore, as pressure decreased in this question, volume will increase proportionally. It is easier to rearrange the formula as shown here and substitute in the numbers you have to find the missing value for volume.

(b) Loudness depends on amplitude.

Pitch depends on frequency.

TIP: Frequency may also affect loudness as different species hear different frequencies in their own way. For this reason, we have dBA meters (decibel adapted) to weight certain frequencies that humans hear louder.

Quality depends on the number of overtones present and their relative strengths. **(6 + 2 × 3)**

(i) The frequency limits of audibility are the range of frequencies that humans can normally hear. These go from the lowest frequency of 20Hz to the highest frequency of 20000Hz. **(6)**

(ii) Ultrasonic is above our range of hearing ability as its frequency is above 20kHz. **(4)**

(iii) Time for bat signal to leave bat and return = 0.02s
Therefore, the time for the bat signal to reach wall is half this = 0.01s
Speed = distance by time:

$s = d/t \Rightarrow st = d \Rightarrow (340)(0.01) = d \Rightarrow 3.4\text{m} = d$ **(6)**

TIP: The trick here is to recognise that reflection has taken place and halve the time given since the wave has travelled to the wall and back. The same principle is asked in sonar when a ship sends out a signal and waits for it to reflect back before reading it again.

(c) Electric current is the flow of electrons. Its unit of measurement is the ampere (A). **(3 × 3)**

Three effects are heating, chemical and magnetic. **(4)**

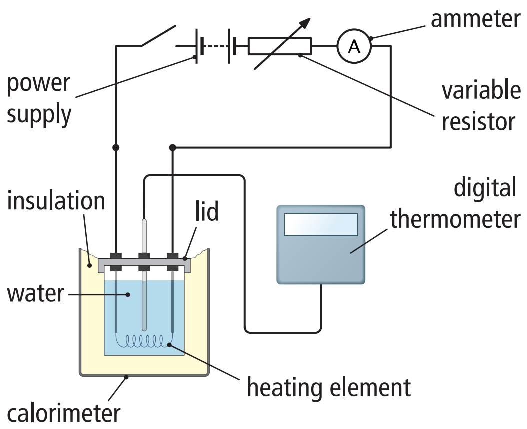


Fig. 12.2

To demonstrate heating effect, do the following:
1. Set up the equipment as shown in Fig. 12.2.
2. Apply a constant current through the element for a constant time and record the temperature rise.
3. Keeping time and volume of water constant, apply greater amounts of current each time.
4. It will be seen that the temperature rise in each case is proportional to the square of the current applied. (Greater current produces greater temperature rise, in the same time.)

OR

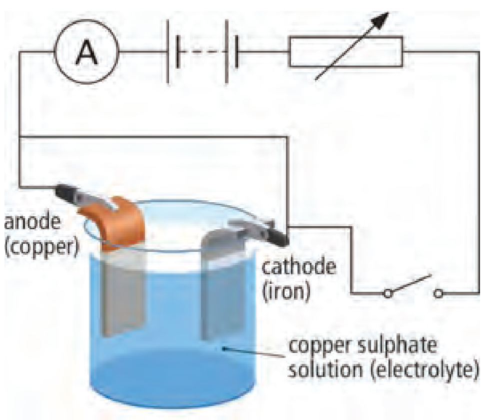


Fig 12.3

To demonstrate chemical effect, do the following:
1. Set up a circuit as shown in Fig. 12.3.
2. You will notice bubbles forming at the electrodes.
3. Copper atoms at the anode surface lose two electrons and become part of the copper sulphate electrolyte solution as copper ions. This means the anode is dissolving.
4. Copper ions in the electrolyte receive electrons from the iron cathode and become copper atoms again. This means the iron cathode is coated in copper.
5. This shows the chemical effect of current, known as electroplating.

OR

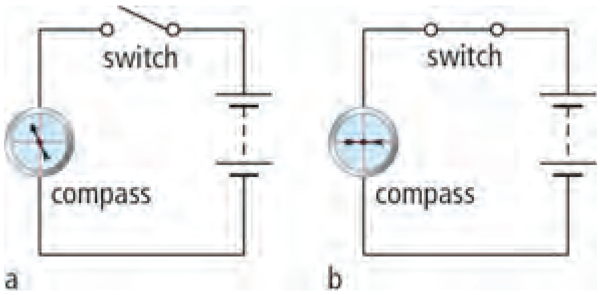


Fig. 12.4

To demonstrate magnetic effect, do the following:

1. Connect the circuit with a compass sitting on a wire as shown in Fig. 12.4a.
2. Close the switch as shown in Fig. 12.4b. You will notice that the compass needle deflects, thereby showing a magnetic effect caused by the flowing current.
3. If you open the switch again, the current stops flowing and the needle returns to its normal position. **(3 × 3)**

$$P = VI \Rightarrow P/V = I \Rightarrow \frac{120}{24} = I \Rightarrow 5\text{A} = I$$ **(6)**

(d) (i) Alpha particles are helium nuclei with two protons and two neutrons. **(6)**

(ii) Most went straight through, some deflected by a small angle, and very few were deflected straight back at the source. **(6)**

(iii) It showed that the atom is mainly empty space and has a dense positive core at the centre. **(6)**

> **TIP:** This was shown because most alpha particles missed the nucleus and went straight through. Those that deflected must have gone close to the nucleus and were repelled. The very few that hit the nucleus were deflected straight back. Because very few did this, it proved that there was a very small dense nucleus at the centre.

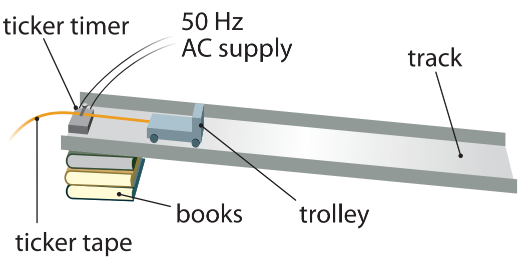
(iv) Ernest Rutherford. **(6)**

(v) Choose any one from the following:

- G–M tube (Geiger–Müller tube)
- Cloud chamber
- Gold leaf electroscope
- Photographic emulsion film
- Ionisation tube **(4)**

SECTION A

1. (i)



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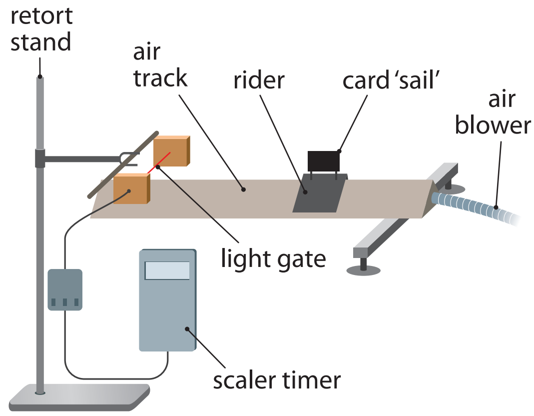


(3 × 3)

TIP: You only need to show the apparatus you are familiar with. However, make sure to only answer later questions based on the diagram you use. It is presumed that if you show one way of doing the experiment, you will continue to answer any questions on this method within the same question.

The basic equipment required is that which will give you the figures you need. In the case of force and acceleration, you need to show the applied force (weights, pan, pulley) and the method of measuring acceleration (ticker timer/ticker tape or sail/light gates).

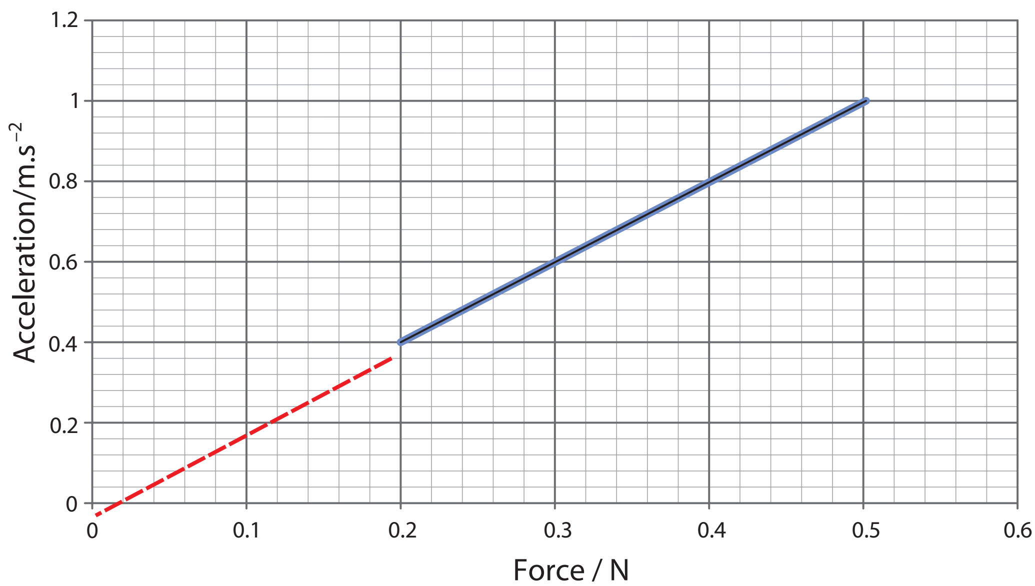
(ii) The applied force was measured by weighing the pan and weights with a balance. **(6)**

(iii) Choose any one from the following:

- Oil the wheels of the trolley.
- Dust the track.
- Incline the track at such an angle so as to minimise friction. **(6)**

TIP: Remember that force requires weight measurements in newtons and not mass in kg.

(iv)



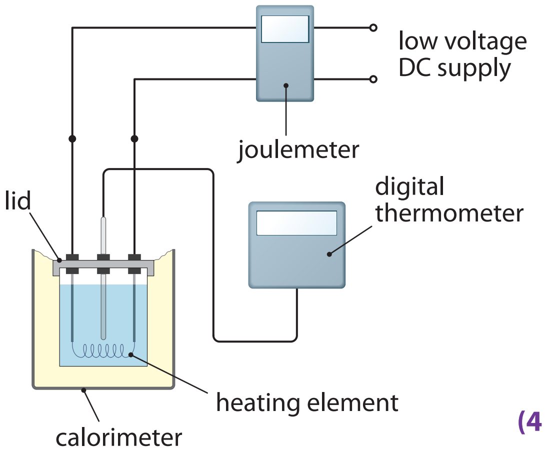
(4 × 3)

TIP: Make sure to use at least three-quarters of the graph page and draw a best-fit line through the points. It is also acceptable to extend your graph to the origin since zero force would produce zero acceleration according to $F = ma$.

(v) The graph shows that acceleration is proportional to force applied. **(7)**

TIP: You can also say every time you get this shape of graph that a straight line through the origin verifies the law or, in this case, proves that force is proportional to acceleration.

2. (i)



TIP: You may also use a heated block of metal instead of the water. In the case of the above method, the power supply supplies the energy to the heating element.

In addition to this, you may show the balance for measuring the mass of calorimeter and water, as well as a stirrer to achieve a good equilibrium of temperature throughout the experiment.

(4 × 3)

(ii) Mass of metal block: Measure the block on an electronic balance.
Mass of water: (mass of calorimeter + water) – (mass of calorimeter) = mass of water **(6)**

TIP: This is a common question in this topic and just requires a simple statement of how you would calculate only the mass of the material being examined.

(iii) The other measurements necessary in this experiment are initial temperature, final temperature and energy supplied. **(6 + 3)**

TIP: Think about the experiment and what is required to fill in the formula. You need to know temperature change (final temperature – initial temperature) as well as the energy supplied to change the temperature *($\Delta\theta$)*.

(iv) Block of metal: $Q = mc\,\Delta\theta$
Water: $Q = mc\,\Delta\theta$ (water) + $mc\,\Delta\theta$ (calorimeter) **(7)**

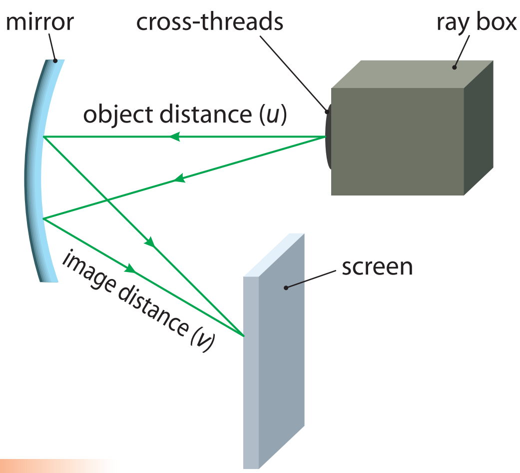
TIP: Make sure to stick with the method you chose at the beginning. If you are measuring the specific heat capacity of water, you need to factor in the calorimeter in the energy equation. However, if it is just a block of metal being heated, you just need to let the energy supplied equal its heat change. Whichever one you use, it is always good practice to list the letters in the formula and what they stand for.

(v) Choose any one from the following:

- You may have started with the water at a temperature below room temperature, so as to balance out energy losses and gains in the experiment.
- Repeat the experiment a number of times to gain a good average.
- Insulate the calorimeter to reduce heat losses. **(6)**

TIP: When the water is below room temperature at the beginning, it will take in heat as it tries to warm to room temperature. However, when the water is above room temperature at the end of the experiment, it will lose heat as it tries to reach room temperature. By pre-cooling the water, you are introducing a heat gain at the beginning to balance out the heat loss at the end, and so reduce errors.

3. (i)



TIP: It is a good idea to always list where *u* and *v* are. As well as securing good marks for this diagram, it also reminds you of where each one is, when using them in calculation.

(4 × 3)

(ii) As shown above, *u* and *v* are shown:

- *u* is between the cross threads and mirror.
- *v* is between the mirror and screen. **(2 × 3)**

TIP: Make sure that the cross-threads (crosswire) are mentioned, as it is this object that is being illuminated and so it is from here that object distance is measured.

(iii) The real image was located by moving the cross-threads and/or screen until a clear focused image was resolved. **(6)**

TIP: It is best to gain averages of the image given that it is very difficult to decide on the best focused image available.

(iv) First image: $\frac{1}{u}+\frac{1}{v} = \frac{1}{f} \Rightarrow \frac{1}{20}+\frac{1}{65} = \frac{1}{f} \Rightarrow 0.05 + 0.015 = \frac{1}{f} \Rightarrow 0.0654 = \frac{1}{f} \Rightarrow 15.29\text{cm} = f$

Second image: $\frac{1}{u}+\frac{1}{v} = \frac{1}{f} \Rightarrow \frac{1}{30} + \frac{1}{32} = \frac{1}{f} \Rightarrow 0.033 + 0.031 = \Rightarrow 0.0646 = \frac{1}{f} \Rightarrow 15.48\text{cm} = f$

Third image: $\frac{1}{u}+\frac{1}{v} = \frac{1}{f} \Rightarrow \frac{1}{50}+\frac{1}{23} = \frac{1}{f} \Rightarrow 0.02 + 0.043 = \frac{1}{f} \Rightarrow 0.0635 = \frac{1}{f} \Rightarrow 15.75\text{cm} = f$

Average value of focal length $= \frac{15.29\text{cm} + 15.48\text{cm} + 15.75\text{cm}}{3} - 15.51\text{cm}$ **(4 × 3)**

TIP: It is best to show each line of work with the values for *u* and *v* stated for each formula line. Then average all results for *f*. Do not make the mistake of averaging *u* and *v* figures first.

(v) By repeating an experiment, accuracy is improved and errors are reduced. **(4)**

TIP: It is always safe to list reducing errors or increasing accuracy as a reason for precautions in an experiment. It is very common to ask about the reason for taking a precaution in a mandatory experiment and the main answer is usually to reduce percentage error.

4. (i) Resistance was measured by using an ohmmeter or multimeter. **(6)**

TIP: It is also acceptable to use a voltmeter and ammeter to measure voltage and current. You can then use Ohm's Law to calculate resistance: $V = IR$. Therefore $V/I = R$.

(ii) The length of wire was measured when it was taut. The physical length was taken as the distance between the two crocodile clips, using a metre rule. **(4)**

TIP: It is important in the resistivity experiment to make sure the wire is taut and has no kinks as this would give you a false reading for length when using the formula.

(iii) Vernier callipers (or digital callipers) or micrometer can be used to measure diameter. **(6)**

The wire was measured at different points so as to average the diameter of the wire for calculating resistance. **(6)**

TIP: The wire may not be uniform and by averaging diameter, errors are significantly reduced.

(iv) Average diameter = $\dfrac{0.21 \times 10^{-3}\text{m} + 0.20 \times 10^{-3} + 0.18 \times 10^{-3}\text{m}}{3} = 0.197 \times 10^{-3}\text{m}$

Therefore, average radius of wire $= \dfrac{0.197 \times 10^{-3}\text{m}}{2} = 0.0985 \times 10^{-3}\text{m}$

Cross-sectional area = area of a circle =
$A = \pi r^2 \Rightarrow A = \pi(0.0985 \times 10^{-3})^2 \Rightarrow A = \pi(9.702 \times 10^{-9}) \Rightarrow A = 3.048 \times 10^{-8}\ \text{m}^2$. **(3 × 3)**

TIP: Given that the area of a circle formula is used quite often with the value for radius, it is easier to find the average diameter and half it to get the radius. Then you need only use πr^2 to calculate the area of a circular wire. It is also good practice to convert all units to metres before placing them in the formulae. This way you know that the answer will be in m^2.

(v) $\rho = \dfrac{RA}{l} \Rightarrow \rho = \dfrac{(20.2\Omega)(3.04 \times 10^{-8}\text{m}^2)}{48.8 \times 10^{-2}} \Rightarrow 1.26 \times 10^{-6}\Omega\text{m}$ **(3 × 3)**

TIP: The safest way of calculating this answer is to state all variables before starting and then substitute the numbers in for each letter. By having all units in the proper units, the answer will come out in the correct Ωm units.
The most common mistake in this type of question is usually centred on incorrect magnitudes of units. Practice converting cm to metres (10^{-2}m) and mm to metres (10^{-3}m).

SECTION B

5. (a) Boyle's Law states that the volume of a fixed mass of gas is inversely proportional to its pressure, as long as temperature is constant. **(8 × 7)**

(b) $\rho = \dfrac{m}{V} \Rightarrow \rho V = m \Rightarrow (2400)(50) = m \Rightarrow 120000\text{kg} = m$

(c) Archimedes' Principle states that whenever an object is totally or partially immersed in a fluid, it experiences an upthrust equal to the weight of the fluid it displaces.

(d) Snell.

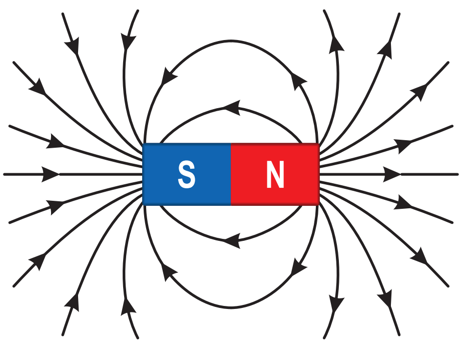
(e) 0˚C = 273.15K 28˚C = (273.15 + 28)K = 301.15K

TIP: As long as you allow for a 273.15 conversion any time you are asked to convert Celsius/Kelvin, you will gain marks.

(f) Choose any one from the following:

- Light waves travel faster than sound waves.
- Light waves travel through a vacuum and sound does not.
- Light is a transverse wave and sound is a longitudinal wave.

(g)



TIP: Make sure to show the direction of magnetic field lines moving from the north to the south of the magnet.

(h) Choose any one from the following:
- Temporarily storing charge
- Flash guns
- Filtering
- Smoothing
- Tuning radio

(i) Doping is the addition of controlled amounts of impurity to increase extrinsic conduction.

(j) Fission.

TIP: Controlled fusion has not been perfected and so fission is needed here but you would still gain partial marks for identifying fusion.

6. (a) Momentum is the product of mass by velocity. **(6)**

(b) Kinetic energy is energy due to movement. **(6)**

TIP: You may also use a formula and list the variables to define this.

The principle of conservation of momentum states that the total momentum of a system before an interaction is equal to the total momentum of a system after an interaction, so long as no external force acts on it. **(3 × 3)**

TIP: You may also use the formula of $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$ but you will need to list the meaning of all variables as well.

The principle of conservation of momentum applies in a rocket launch as the momentum of the rocket rising vertically equals the momentum of the rocket exhaust gases moving in the opposite direction downwards. **(3)**

TIP: When asked to apply a principle of physics to a real world example, just use your own words to describe what is happening. In the case of the rocket, just picture it slowly moving up in reaction to a huge amount of gas being expelled down.

(i) (momentum of first skater) : $p = mv \Rightarrow p = (50)(6) \Rightarrow p = 300$ kg m.s^{-1}
(momentum of second skater) : $p = mv \Rightarrow p = (70)(0) \Rightarrow p = 0$ kg m.s^{-1} **(2 × 3)**

(ii) Combination of skaters' momentum : 300 kg m.s^{-1} + 0 kg m.s^{-1} = 300 kg m.s^{-1} **(6)**

TIP: Remember that the principle of conservation of momentum has to take the full system into account which includes both skaters before and after the interaction (collision).

(iii) $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2 \Rightarrow 300 + 0 = (m_1 + m_2)v \Rightarrow 300 = (50 + 70)v \Rightarrow 300 = 120v \Rightarrow 300/120 = v \Rightarrow 2.5\ \text{m.s}^{-1} = v$ **(6)**

TIP: You can change the formula to combine $m_1 + m_2$ on the right of the equals when the two masses combine after impact. This is because both skaters are moving together with the one velocity. If the two skaters moved away from each other after the collision, you would need to have a separate velocity for each but this does not happen in this question.

(iv) Kinetic energy of first skater (E_{K1}): $\frac{1}{2}mv^2 = \frac{1}{2}(50)(6)^2 = \frac{1}{2}(50)(36) = 900$J
Kinetic energy of second skater (E_{K2}): $\frac{1}{2}mv^2 = \frac{1}{2}(70)(0)^2 = \frac{1}{2}(70)(0) = 0$J **(2 × 3)**

TIP: The most common error here is forgetting to follow BOMDAS and squaring the velocity first. By using brackets and carefully calculating each part of the formula, you can avoid this error.

(v) Kinetic energy of both skaters (E_{K3}): $\frac{1}{2}mv^2 = \frac{1}{2}(120)(2.5)^2 = \frac{1}{2}(120)(6.25) = 375$J **(4)**

(vi) The kinetic energy is not conserved in this interaction as the values before and after differ. **(4)**

TIP: This is just a simple statement of what you see in the figures. Whether you made an arithmetical error or not, just stick to stating the difference between your figures. However, you should be aware that energy cannot increase after an interaction as this would break the law of conservation of energy.

7. (i) X = Wavelength
Y = Amplitude **(2 × 3)**

TIP: Amplitude is always measured from base line equilibrium to the crest or trough.

(ii) Frequency is the number of wave cycles passing a point per second. **(6)**

(iii) Natural frequency is the frequency that objects tend to vibrate at when allowed to be set in motion. **(6)**

TIP: This is also the frequency at which objects resonate.

(iv) $c = f\lambda \Rightarrow c/f = \lambda \Rightarrow \frac{340}{250}\lambda \Rightarrow 1.36\text{m} = \lambda$ **(3 × 3)**

TIP: As with all formula-based questions, list your variables after writing the formula and then carefully substitute them into it. As long as all variables are in the standard units, the answer will also be in the correct standard units.

(v) Loudness depends on amplitude of the wave.

TIP: It is also acceptable to mention the energy of the wave as sound intensity is energy per area. It is partially right to say frequency affects loudness but this is dependent on the particular resonant frequency of the species hearing it. dBA meters use this principle to weight certain frequencies since they seem louder to humans.

Pitch depends on frequency of the wave. **(3 × 3)**

TIP: Since frequency and wavelength are related by $c = f\lambda$, wavelength can also be given as a reason for pitch change.

When an object has a note of the same or similar frequency applied to its natural frequency, it may resonate to the point of shattering. In the case of an opera singer, they may achieve a high enough note to match the natural resonant frequency of the glass and therefore shatter it as it vibrates. **(6)**

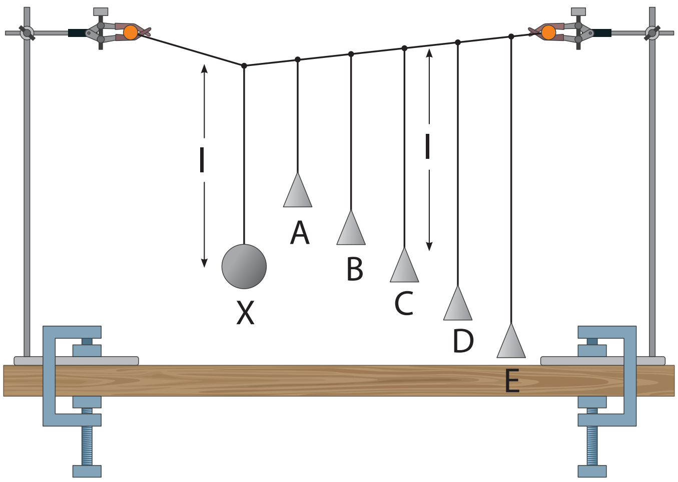


Fig. 7.1

1. Set up equipment as in Fig. 7.1, with pendulums of various lengths.
2. Attach a mass × of the same length string (*l*) as one of the pendulums.
3. When you swing the mass, the pendulum of similar length *l* (in this case pendulum C) will begin to swing as well. This demonstrates the resonance caused by the natural frequency applied from the swinging mass. **(4 × 3 + 2)**

TIP: You may list any experiment that correctly demonstrates resonance such as one of the mandatory sonometer experiments and the resonance of a paper rider.

8. (a) Heat is a form of energy. **(6)**

Heat is transferred in a solid by the transfer of kinetic energy from molecule to molecule. This means heat transfers without the overall movement of matter from one side to another. **(3 × 3)**

TIP: Solid matter heat transfer can also be explained by defining conduction.

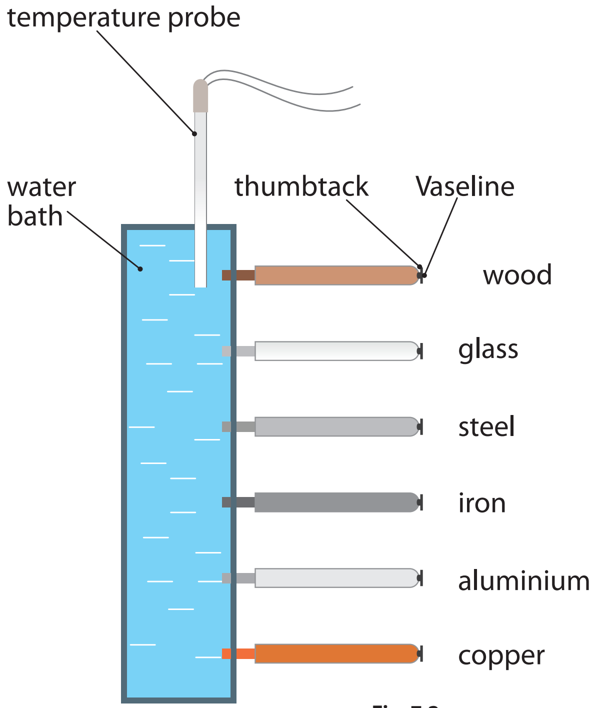


Fig. 7.2

1. Set up equipment as in Fig. 7.2, with Vaseline on the end of each rod.
2. Stick a thumbtack to the Vaseline.
3. Fill the water bath with hot water.
4. The rod that conducts heat the best will melt the Vaseline the quickest. The rate of melted Vaseline determines the rate of conductivity and will cause the thumbtacks to fall off the rods in that order.

(4 × 3)

TIP: Wax may also be used along with any other light objects that can fall off and demonstrate the conductivity of different materials.

U-value is the amount of heat energy that can be transmitted across 1m^2 of a material's surface every second, so long as there is a temperature difference of 1K each side of the material. **(6)**

TIP: You may also mention that U-value can be seen as the measure of thermal insulation where a high U-value means a good conductor and a low U-value means good insulation.

In order to reduce U-value, you need to increase insulation such as double glazing or have thicker insulation in walls. **(4)**

TIP: Mention of a heat-saving measure, such as closing doors or windows, will gain some marks (though not full marks).

(b) (i) The sun's energy is transferred by radiation. **(3)**

(ii) Black surfaces are better absorbers of heat energy than those painted another colour. **(3)**

(iii) Convection currents in the water travel from the solar panel (collector) through the pipes to the hot water tank and heating coil. **(3)**

(iv) Because hot water rises, the cold water enters near the bottom at the heating coil and is heated and rises up the tank. **(4)**

(v) Advantages (choose any one from the following):
- Lower costs
- Unlimited supply of energy
- No greenhouse gases

Disadvantages (choose one from the following):
- Depends on sunshine exposure times
- High cost of installation
- Will only work with other backup systems to allow other energy supplies to be used in case of low sunshine **(2 × 3)**

9. (a) Coulomb's Law states that the electrostatic force between two point charges is proportional to the product of their charges and inversely proportional to the square of the distance between them. **(3 × 3)**

TIP: You may also use the formula to define this but you will need to explain each of the variables.

(i) Electric fields may be detected using an electroscope. **(3 × 3)**

TIP: You may also mention any electric field meter or fluorescent bulb that can show the presence of electric fields.

(ii) Coulomb (C). **(4)**

(iii) Lightning conductors provide a safe path from where the lightning strikes to ground. **(6)**

TIP: Lightning conductors also allow for point discharge and neutralisation of thunder clouds, so as to prevent a strike from occurring.

(iv) Any good conductive metal such as copper or aluminium may be used. **(4)**

TIP: The whole point of a lightning conductor is to provide a low resistance path to the earth for the electricity. Therefore, good conductors are required.

(b) Ohm's Law states that the current flowing through a conductor is proportional to the potential difference between its ends, so long as the temperature remains constant. **(6)**

TIP: You may also state Ohm's Law as $V = IR$, with the variables explained.

(i) $\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} \Rightarrow \frac{1}{R_{total}} = \frac{1}{15} + \frac{1}{30} \Rightarrow \frac{1}{R_{total}} = 0.067 + 0.033 \Rightarrow \frac{1}{R_{total}} = 0.1$ **(6)**

$R_{total} = \frac{1}{0.1} \Rightarrow R_{total} = 10\Omega$

TIP: It is a common mistake to accidentally add resistances when you see them. Make sure you carefully identify if the resistances are in series or in parallel. When they are in parallel, the combined resistance will be less than the individual resistances.

(ii) Total resistance $= 10\Omega + 10\Omega + 4\Omega = 24\Omega$ **(6)**

TIP: When you have calculated the equivalent resistance of the two parallel resistors, you can then add this to the other resistor in series, along with the bulb which is rated at 4Ω.

(iii) $V = IR \Rightarrow \frac{V}{R} = I \Rightarrow \frac{12}{24} = I \Rightarrow 0.5\text{A} = I$ **(6)**

10. (i) Thermionic emission occurs at the filament where electrons are released. **(6)**

(ii) Tungsten should be used. **(6)**

TIP: You need a metal with a very high melting point such as tungsten to allow for consistent thermionic emission and no melting.

(iii) Choose any three from the following:

- EM (electromagnetic) waves
- Travel at the speed of light
- Highly penetrating
- Ionising
- Cause photographic film to expose
- Cause fluorescence
- Zero mass
- Zero charge **(3 × 3)**

(iv) Choose any two from the following:
- Medical scans
- Cancer therapy
- Structural integrity of pipes
- X-ray scans in airports
- Thickness measurements in industry **(2 × 3)**

(v) It protects from radioactive leaks as it shields radiation within the device. **(5)**

(vi) The photoelectric effect is the emission of electrons from the surface of a metal when EM radiation of a suitable frequency is incident on it. **(2 × 3)**

(vii)

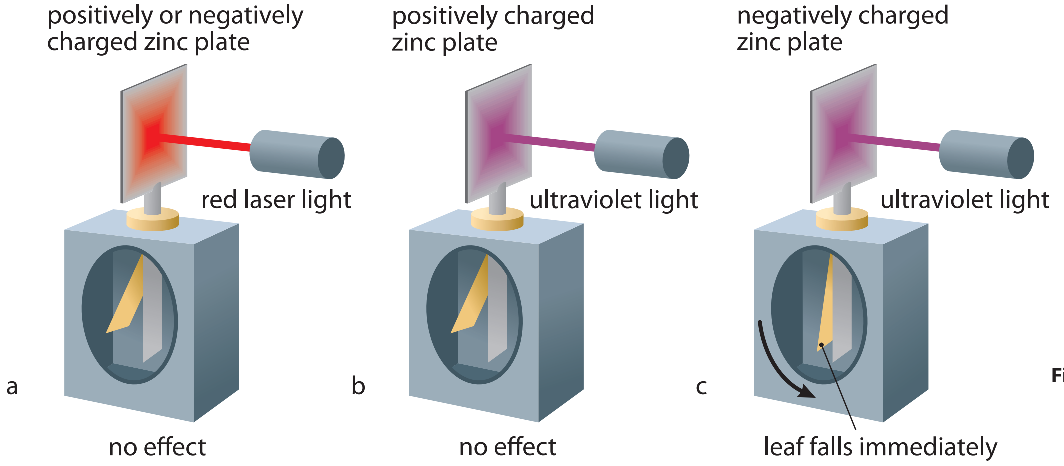


Fig. 10.1

To demonstrate the photoelectric effect:
1. Charge an electroscope by induction.
2. Set up three scenarios, as in Fig. 10.1.
3. In Fig. 10.1a, the zinc plate, whether positive or negative, will be unchanged by red light, showing red is of too low a frequency to work.
4. In Fig. 10.1b, the UV light will not affect a positive plate as it does not have an excess of electrons to allow them to leave.
5. In Fig. 10.1c, UV light causes electrons to leave a negatively charged plate because of the photoelectric effect. This causes the gold leaf to fall as it loses charge. Any light with a frequency greater than or equal to UV will have this effect on negatively charged zinc. **(4 × 3)**

(viii) Choose any two from the following:
- Soundtrack synchronisation
- Burglar alarms
- Automatic doors
- Light sensors **(2 × 3)**

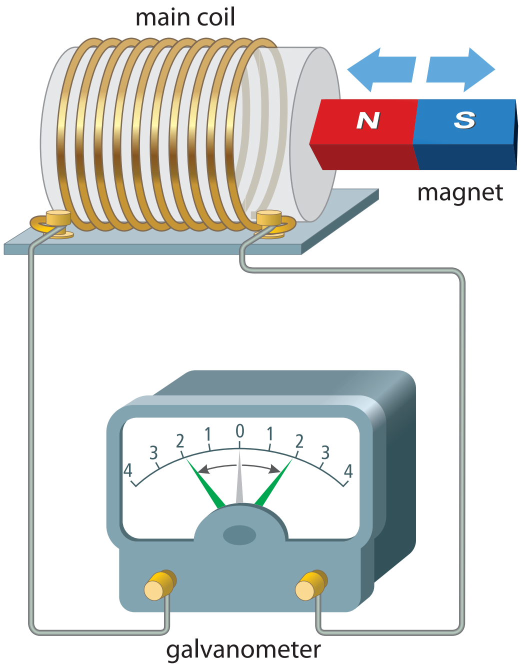
11. (a) Hans Christian Oersted. **(8 × 7)**

(b) A wire carrying an electric current can act as a magnet and attract iron filings.

(c) The wires will attract when current flows in the same direction in both parallel wires.

(d) The wires will repel if the currents flow in opposite directions in the two parallel wires.

(e)



(f) Electromagnetic induction.

TIP: These last few questions can be taken directly from the paragraph.

(g) Energy converts from kinetic to electric.

(h) It is only when the magnet is moving that electricity is generated. This shows that a changing magnetic field is required to generate electricity by electromagnetic induction.

12. (a) (i) $F = ma \Rightarrow F/m = a \Rightarrow \dfrac{60}{120} a \Rightarrow 0.5\text{m.s}^{-2} = a$ **(6)**

(ii) $v = u + at \Rightarrow v = (0) + (0.5)(15) \Rightarrow v = 7.5\ \text{m.s}^{-1}$ **(6)**

(iii) $s = ut + ½\, at^2 \Rightarrow s = (0)(15) + ½\,(0.5)(15)^2 \Rightarrow s = 56.25\text{m}$ **(3)**

TIP: Always make sure to note the important words such as 'from rest' to identify an initial velocity of 0m.s^{-1}. Then list the variables and choose the equation of motion that only has one variable to find.

(iv) The bike will eventually stop due to friction and air resistance. **(6)**

TIP: Although Newton's First Law of Motion states that all objects will continue at constant velocity, we need to factor in that by stopping pedalling, the only net force on the bike is now the one slowing it.

(v)

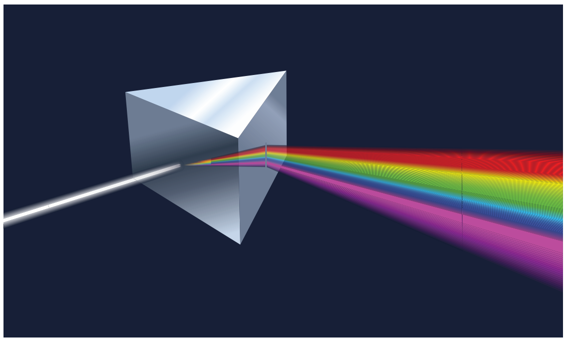
$$v^2 = u^2 + 2as \Rightarrow v^2 - u^2 = 2as \Rightarrow \frac{v^2 - u^2}{2s} = a \Rightarrow \frac{(0)^2 - (7.5)^2}{2(80)} = a \Rightarrow -0.352\text{m.s}^{-2} = a$$

TIP: By finding acceleration first, you can then substitute this into the next equation to gain time to stop.

$$v = u + at \Rightarrow v - u = at \Rightarrow \frac{v - u}{2s} = t \Rightarrow \frac{(0) - (7.5)}{-0.352} = t \Rightarrow 21.33s = t$$ **(7)**

TIP: By listing each variable with the correct sign, you can be sure of the correct answer. For example, acceleration is negative and final velocity is zero; therefore, the minuses cancel in the last equation and give you a positive time answer of 21.33s.

(b) Dispersion of light is the splitting of light into its constituent colours. **(6)**



1. Shine white light through a prism onto a screen.
2. You should see a clear spectrum of the constituent colours of white light.
3. The colours seen should be red, orange, yellow, green, blue, indigo and violet. **(4 × 3)**

TIP: You may also mention using a diffraction grating or CD to disperse the light. Not all of the seven constituent colours may be clearly discernible but as long as you mention a few different colours, you should gain the marks.

Choose any one from the following:
- Rainbow
- Colours on soap bubbles
- Colours on oil emulsion
- CDs/DVDs showing colours as they are moved **(4)**

Red, green and blue are the primary colours and therefore are the only ones needed to create all other colours. **(6)**

(c) (i) A fuse will melt when too much current passing through it causes it to heat past its set limit. This will then break the circuit. **(6)**

(ii) By only allowing a maximum current to flow before breaking, the fuse will act as a safety device for over-current. **(4)**

(iii) An MCB is a miniature circuit breaker used as a safety device in circuits. **(3)**

(iv) An RCD (residual current device) mainly protects people in contact with the equipment as it shuts off the current in the event of a fault. **(6)**

(v) Earthing provides a safe route to ground for the electricity if a fault develops in the circuit. This prevents the electricity going through the person. **(6)**

(vi) Choose any one from the following:
- Keep appliances away from water.
- Make sure to use properly rated fuses.
- Do not overload sockets.
- Make sure the wires are not frayed or the equipment cracked. **(3)**

(d) Radioactivity is the disintegration of nuclei with the emission of radiation. **(6)**

TIP: This radiation may be any or all of alpha, beta or gamma.

(i) There are three types as one type is being stopped by the paper (alpha); one is being stopped by aluminium (beta) and the last is being stopped by concrete (gamma). **(3)**

(ii) The three types are alpha (paper), beta (aluminium) and gamma (concrete). **(2 × 3)**

(iii) Choose any one from the following:
- Cancer
- Cell damage
- Genetic mutation
- Radiation poisoning **(3)**

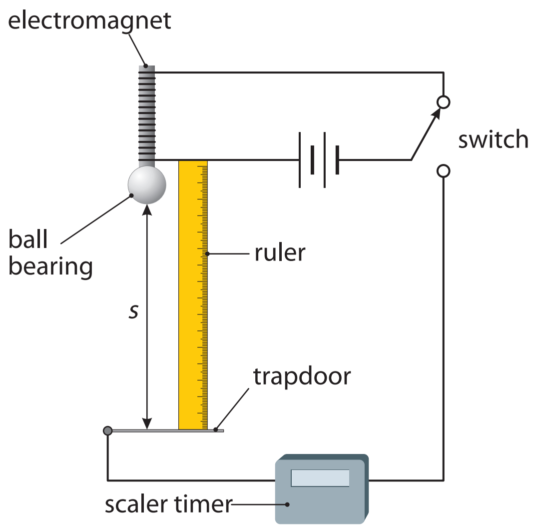
(iv) Choose any two from the following:
- Wear protective clothing.
- Wear gloves.
- Do not smoke.
- Do not drink or eat near radiation.
- Do not point the source at any person.
- Use shielding. **(4)**

(v) Choose any two from the following:
- Medical scans
- Food irradiation
- Industrial tracers
- Energy production **(2 × 3)**

TIP: When asked about uses or dangers with radiation, just apply common sense to how you would deal with a dangerous substance that contains a lot of energy. It has benefits but must be handled with care.

SECTION A

1. (i)



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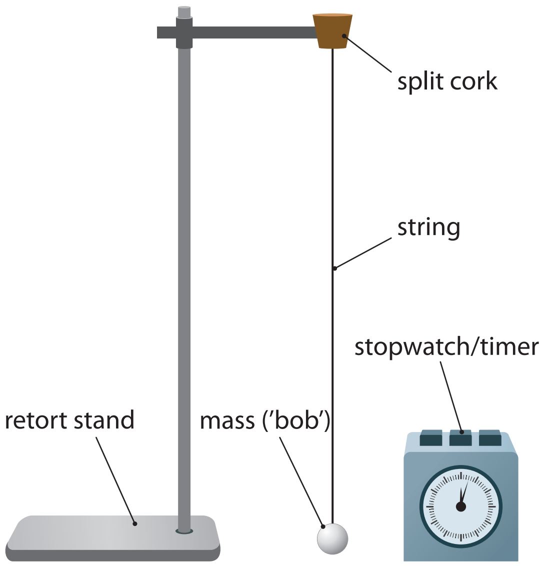


(6 + 2 × 3)

TIP: Whichever method you use, be very familiar with how you take the measurements. Make sure that when you choose a method for gravity measurement, you know how to calculate for *g*. You may also choose the method where a data-logger/photo gate is used with a picket fence to calculate *g*.

The main thing to remember when asked to draw a labelled diagram for an experiment is to ensure the critical items of apparatus are labelled and clearly drawn. These are the ones on which the experiment depends for obtaining measurements. In the case of the free-fall experiment, it would be a release mechanism, ruler and timer. In the case of the pendulum, it would be a split cork, string, bob, ruler and stopwatch.

(ii)
- Free-fall method: Distance (m) and time (s).
- Pendulum method: Length of pendulum (m) and period of pendulum (s).
- Data-logger method: Identified velocity versus time and calculated the slope of the graph. **(2 × 3)**

(iii) Choose any one from the following:
- Free-fall method: Distance measured with a metre stick and time measured with a scaler timer.
- Pendulum method: Length of pendulum measured with a metre stick and period of pendulum timed for many oscillations with a stopwatch and averaged to gain the duration of 1 oscillation.
- Data-logger method: Start/stop program for light gate and picket fence dimensions. **(3 + 6)**

(iv) Free-fall method: $g = 2s/t^2$

TIP: $s = ut + \frac{1}{2}at^2 \Rightarrow$ (x2) $2s = 2ut + at^2 \Rightarrow$ ($u = 0\text{m.s}^{-1}$ (rest)) $2s = at^2 \Rightarrow 2s/t^2 = a \Rightarrow$ ($a = g$) $2s/t^2 = g$

The value for acceleration is gravity here and once distance (*s*) and time (*t*) is known for the free-fall drop, *g* can be calculated.

Pendulum method: $g = \dfrac{4\pi^2 l}{T^2}$

TIP: This comes from the formula:

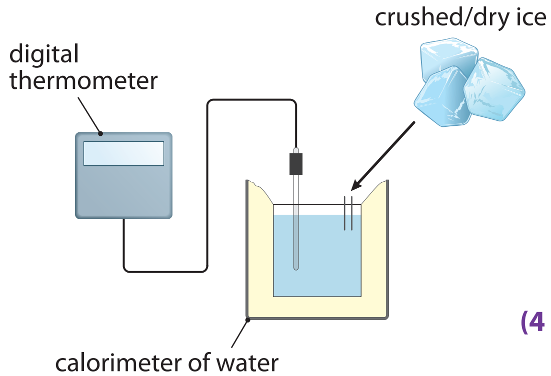
$$T = 2\pi\sqrt{\frac{l}{g}} \Rightarrow \text{(sq.)}\, T^2 = 4\pi^2\left(\frac{l}{g}\right) \Rightarrow g = 4\pi^2\left(\frac{l}{T^2}\right)$$

When you identify the values for length of pendulum (*l*) and periodic time (*T*), you can calculate *g*.

Data-logger method: By using the program on the data-logger, a value for *g* can be obtained from the slope of the graph. **(3 × 3)**

(v) Choose any one from the following:
- Increase distance of free-fall drop
- Increase length of pendulum
- Increase number of oscillations to get better average for *T*
- Make sure pendulum swings through an angle less than 5 degrees
- Use the smallest value of time (*t*) for the free-fall drop **(4)**

2. (i)



(4 × 3)

TIP: You may also mention insulation in the calorimeter, a stirrer for the water and a balance for measuring mass.

(ii) Measurements required were:
- Mass of calorimeter
- Mass of calorimeter and warm water
- Mass of calorimeter, warm water and ice
- Initial temperature of water
- Final temperature of water after ice is added and melted **(6 + 2 × 3)**

(iii) The ice should be crushed, dried and melting. **(4)**

TIP: There is often a question about the correct form of added ice. You need to ensure the ice is melting and as close to 0˚C as possible for a latent change only. You also need to crush it to have a large surface area and equilibrium of temperature. It should be dried so as only ice is added and not liquid water.

(iv) Ice that is melting is at 0˚C. **(6)**

TIP: A thermometer may also be added in here to ensure the ice is at 0˚C.

(v) If warm water is used, heat is given away to the environment at the beginning of the experiment. However, because the final temperature of the water is below room temperature at the end of the experiment, heat energy is taken in from the environment. By using warm water, heat losses at the beginning of the experiment are balanced out by heat gains at the end of the experiment and therefore errors are minimised. **(6)**

TIP: In addition to this, the ice will melt more quickly in warm water.

3. (i)

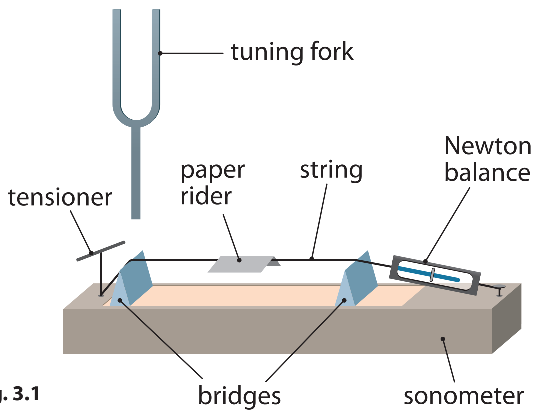


Fig. 3.1

1. Set up the equipment as shown in Fig. 3.1.
2. Adjust the bridges on the sonometer until the string is as long as is practically possible.
3. Strike the lowest frequency tuning fork and place the base of its handle on one of the bridges.
4. While holding the tuning fork on the bridge, adjust the tensioner until resonance occurs and the paper rider falls off the string.
5. The paper rider should be on the middle of the string (antinode). (Keep tension constant from here.)
6. Record the value of length *l* between the bridges and the tuning fork frequency.

(4 × 3)

TIP: A signal generator may also be used instead of a tuning fork and a horseshoe magnet around the current in the wire.

(ii) Because frequency depends on tension, length and mass per unit length, we need to keep everything else constant and only have one independent variable when conducting the experiment. Because this experiment is concerned with the variation of frequency versus length, tension must be kept constant. **(6)**

TIP: Mass per unit length is constant as long as the string is not replaced. Because only the bridges are moved and tension is kept constant, only length is changing here.

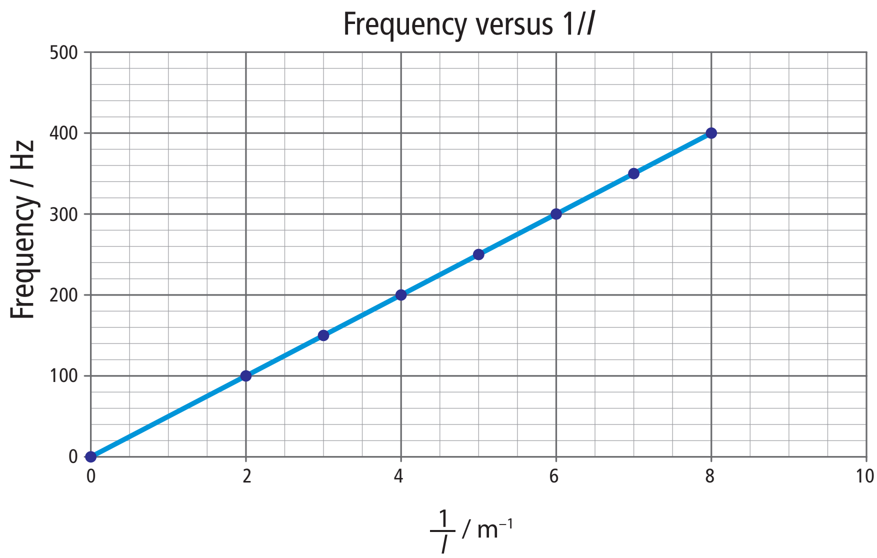
(iii)

f/Hz	100	150	200	250	300	350	400
l/m	0.0	0.33	0.25	0.0	0.166	0.142	0.125
$\frac{1}{l}$ / m^{-1}	**2.00**	**3.03**	**4.00**	**5.00**	**6.02**	7.04	**8.00**

(6 × 1)

TIP: Always check that the units are in metres for length before filling in the table. In this case they are, but if they were in cm or mm, you would need to convert them to metres before getting the reciprocal for 1/*l*.

(iv)



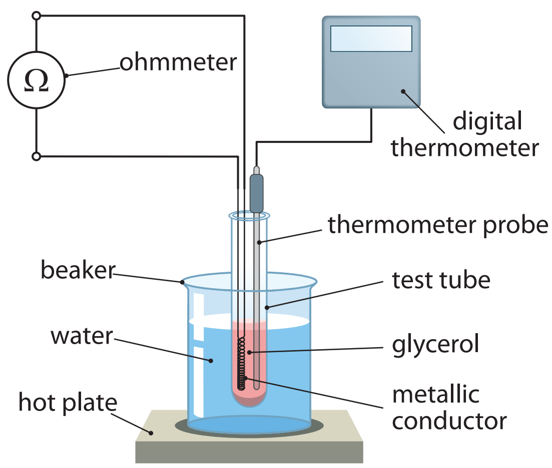
(4 × 3)

TIP: Make sure your graph is a best-fit smooth line that goes through the origin. The graph should take up at least three-quarters of the graph page and have clearly labelled axes.

(v) Fundamental frequency is inversely proportional to length. **(4)**

TIP: You may also show this as a relationship $f \alpha = \frac{1}{l}$, with the letters explained, or you may have stated the relationship in your own words saying that as frequency increased, length decreased.
It is important not to leave a blank if you cannot remember the exact answer. Even if you have to state the answer in a roundabout way, it is better than not saying anything.

4. (i)

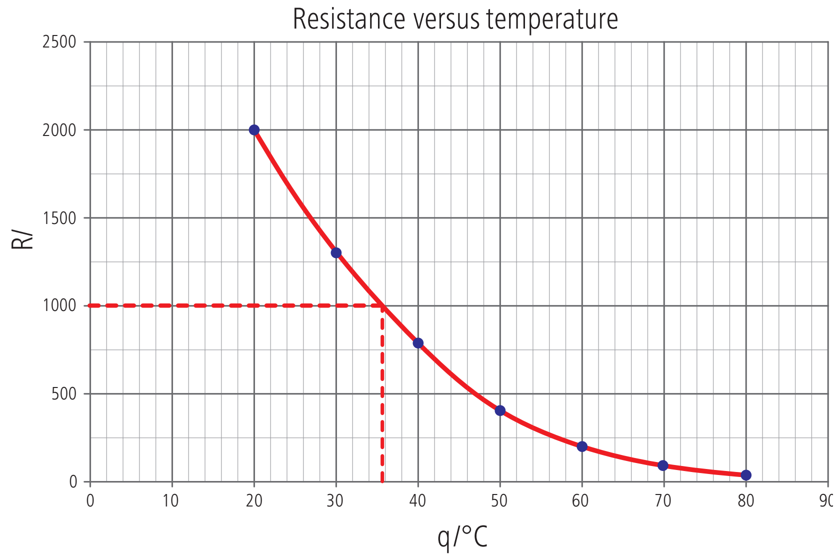


(4 × 3)

(ii) The resistance was measured with an ohmmeter. **(6)**

TIP: You may also say that resistance was measured with a multimeter. It is also acceptable to say that you used a voltmeter and ammeter to measure voltage and current. From these, resistance could have been calculated with Ohm's Law.

(iii)



TIP: It is important to draw a smooth curve joining most or all of the points. The values for temperature must be on the x-axis as you were asked to draw a graph of *R* versus *T*. The graph should take up at least three-quarters of the graph page and have clearly labelled axes.

(4 × 3)

(iv) At 1000Ω, the corresponding temperature is between 35˚C and 36.5˚C. **(4)**

TIP: Where resistance is 1000Ω, draw a horizontal line over to the curve until it intersects it. Then drop a line straight down to find a value for temperature from the x-axis. It is acceptable to be in or around the exact temperature but you must show your work with dotted lines on the graph, so the examiner can see how you achieved the results.

(v) Resistance decreases with temperature for a thermistor. **(6)**

TIP: You may also say that it is not linear or not directly proportional.

SECTION B

5. (a) The total momentum of a system before an interaction is equal to the total momentum of the system after an interaction, as long as no external force acts on it.

TIP: You may also state this as the formula but make sure to explain each variable and what it stands for.

(b) $M = Fd \Rightarrow M = (5\text{N})(1.2\text{m}) \Rightarrow M = 6\text{Nm}$

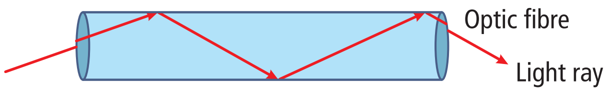
TIP: When calculating questions like this, make sure to convert all quantities into standard units, i.e. 120cm = 1.2m.

(c) The Joule is the unit of energy.

(d) $c = f\lambda \Rightarrow c/f = \lambda \Rightarrow \dfrac{3 \times 10^8}{252 \times 10^3} = 1.19 \times 10^3\text{m}$

TIP: You can see here the importance of knowing your prefixes. You need to know that kHz means 1000s of Hz.

(e)



TIP: You need to make sure that there is some total internal reflection showing here when the ray bounces in the fibre.

(f) Pitch depends on frequency.

TIP: Frequency is the best answer but it should be also said that by varying pressure, amplitude or temperature, pitch can also change.

(g) Gold leaf electroscope.

(h) Isotopes are elements with the same atomic number but differing mass numbers.

(i) Choose any one from the following:
- Burglar alarms
- Automatic door sensors
- On/off sensors for street lights
- Soundtracks for films
- Photocells

(j) Choose any two from the following:
- High energy
- High frequency
- EM waves
- Cause fluorescence
- Expose photographic emulsions
- Ionising
- Very penetrating
- No mass
- No charge

6. (i) Velocity is the rate of change of displacement. **(3)**

TIP: Velocity can also be given as change in displacement divided by time taken.

(ii) Friction is the opposing force which resists motion. **(3)**

TIP: Friction can also be described as a resistive force between moving surfaces.

(i) $v = u + at \Rightarrow 50 = 0 + 0.5t \Rightarrow 50 = 0.5t \Rightarrow 50/0.5 = t \Rightarrow 100\text{s} = t$ **(4)**

(ii) $s = ut + \frac{1}{2}at^2 \Rightarrow s = (50)(90 \times 60) + \frac{1}{2}(0)t^2 \Rightarrow s = 270000\text{m} = 270\text{km}$ **(6)**

TIP: Make sure to convert 90 minutes into (90 × 60) seconds for the time the train is moving at constant velocity. Also, constant velocity means zero acceleration. Therefore $a = 0$ in the equation.

(iii) $v^2 = u^2 + 2as \Rightarrow (0)^2 = (50)^2 + 2(a)(500) \Rightarrow 0 = 2500 + 1000a \Rightarrow -2500 = 1000a \Rightarrow -2500/1000 = a \Rightarrow -2.5\text{m.s}^{-2} = a$ **(6)**

TIP: Note from this answer that a is a negative number. This is because the train is slowing from 50m.s^{-1} to 0m.s^{-1}. It is important to state the variables at the beginning of the question and then substitute them correctly and carefully into the equation.
It is also important to spot the clues in questions like these: Rest means zero velocity. Maximum velocity means no further positive acceleration. Constant speed means no acceleration.

(iv) $F = ma \Rightarrow F = (3000\text{N})(-2.5\text{m.s}^{-2}) \Rightarrow F = -75000\text{N} = -75\text{kN}$ **(6)**

TIP: Again, the force is negative here as it is the retarding force slowing the train down. It is not important to include the negative in the answer but it helps a great deal if you understand what it means when you get the answer.

(v) $E_K = \frac{1}{2}mv^2 \Rightarrow E_K = \frac{1}{2}(30000\text{kg})(50)^2 \Rightarrow E_K = 37500000\text{J} = 37.5\text{MJ}$ **(6)**

TIP: When an object goes from constant velocity to a stop, as here, all of its kinetic energy converts to other energy forms such as heat and noise. Therefore, we can calculate its moving kinetic energy, which is the amount of energy that it has converted (or lost).

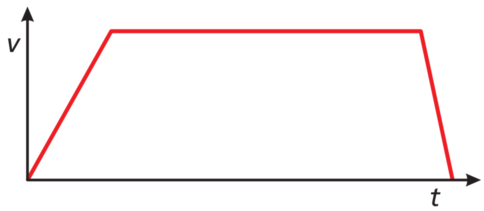
(vi) The kinetic energy was converted into heat, sound and light (sparks). **(6)**

(vii) A = Friction **(2)**
B = Weight (this is the force caused by gravity $W = mg$) **(2)**

(viii) If the tractive force T equalled the frictional force A, then they would cancel and the train would neither positively accelerate nor slow down. Therefore, it would move with constant velocity. **(4)**

TIP: This is an important concept and relates directly to Newton's First Law of Motion. Unless an external force acts, a body will remain at rest at constant velocity. This is the reason a vehicle will accelerate to a maximum velocity and then apply just enough force to counteract the frictional force, so as to keep moving with constant velocity.

(ix)



(8)

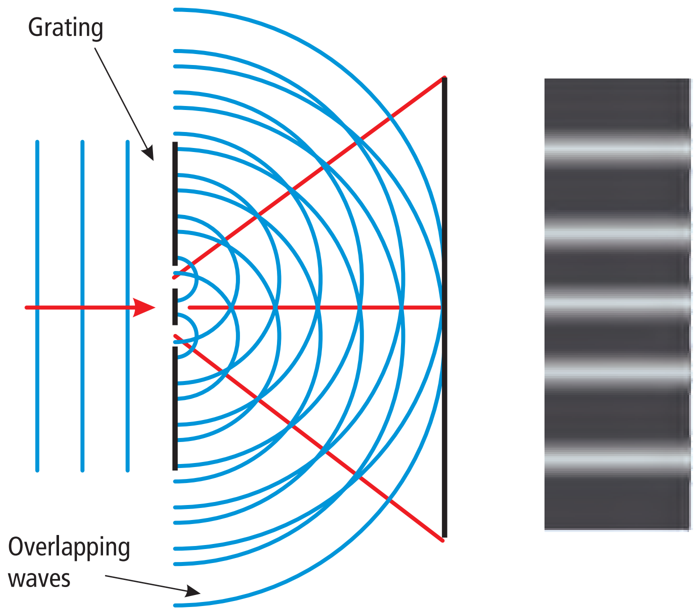
TIP: The graph must show the three stages of motion: uniform acceleration to a maximum velocity; then a horizontal flat line of constant velocity; then a much sharper retardation to rest.

7. (i) Monochromatic light is of one colour. A diffraction grating is a transparent piece of glass or plastic with parallel transparent lines or slits etched into it. **(6 + 6)**

TIP: This also means it is of one wavelength or one frequency.

(ii) There will be a series of bright fringes or dots on the screen. **(6)**

(iii)



As can be seen, the two waves, in phase, constructively and destructively interfere to produce bright fringes (constructive) and dark areas (destructive). **(5 + 3 × 3)**

(iv) This constructive and destructive interference demonstrates that light is a wave. **(6)**

TIP: The presence of interference or any other phenomena of waves such as reflection, refraction or diffraction prove the existence of waves.

(v) The wavelength of light can be determined from the experiment here. **(6)**

TIP: It is also acceptable to say that you can find frequency, since wavelength and frequency are linked.

(vi) In order to calculate the value for wavelength, you would need to find the angle of diffraction from the zero order, along with the grating constant and the order of fringe you are looking at. **(2 × 6)**

TIP: If you used a spectrometer for this, you would read the angle from the scale on the spectrometer. However, if you used the laser method, you would need the distance from grating to screen and from zero order to fringe, to be able to calculate the angle of deviation.

8. (i) Brown. **(6)**

TIP: The live is always connected to the fuse and this is the red or brown wire. However, in Ireland it is predominantly brown and this is the expected answer here.

(ii) The fuse is there as a safety device to prevent too much current flowing and thereby prevent overheating or a fire hazard. **(6)**

(iii) When too much current flows, the fuse heats to a point where it melts and thereby stops the current flowing as the circuit has now broken. **(6 + 3)**

TIP: It can also be said that the fuse is a very thin wire that is designed to heat up and melt before the rest of the circuit.

(iv) Choose any one from the following:

- MCB (miniature circuit breaker)
- RCD (residual current device)
- Circuit breaker
- Trip switch **(4)**

(v) $P = VI \Rightarrow P/V = I \Rightarrow 800/230 = I \Rightarrow 3.48\text{A} = I$

Therefore, a 5A fuse would be the most suitable, as it has to be slightly above the current flowing to allow normal current but still be close enough to be able to break the circuit if the current exceeds the safe normal value. **(3 × 3)**

(vi) If the fuse had too high a rating, the current would cause too much heating before the fuse melted. This could cause a fire before the fuse did its job. **(6)**

(vii) $P = W/t \Rightarrow P \times t = W \Rightarrow (0.8\text{kW})(2.5\text{hrs}) = W \Rightarrow 2\text{kWh}$ **(10)**

TIP: The catch in this question is making sure the values are in the correct form before working out the energy (or work (W)) that is being asked for. Electrical units are measured in kilowatt hours. Therefore, the values for power should be in kilowatts (800W = 0.8kW) and the values for time should be in hours (150 mins = 2.5 hours).

(viii) 2kWh = 2 units
2 units × 15c = 30c **(6)**

TIP: Whatever answer you received for part (vii), make sure you use it in this part, as you will not be penalised twice for the same wrong answer.

9. A magnetic field is a region in which the force of attractive/repulsive magnetic forces can be felt. **(6)**

Method 1:
Iron filings: By placing a sheet of paper over the magnet and sprinkling iron filings over it, you can see the shape of the magnetic field around the poles and between them.

Method 2:
Plotting compasses: By placing a number of plotting compasses around the magnet, you can see the direction in which the needles are pointing to illustrate the magnetic field present around the poles and between them. **(4 × 3)**

(i) When the switch is closed, the needle deflects or twitches. **(6)**

TIP: The needle moves because of current causing a magnetic effect. This is also to do with electromagnetic induction.

(ii) Current causes magnetism and magnetism affects a compass. **(6)**

(iii) The needle will return to its original position as the interfering current-induced magnetism has gone now. **(6)**

(iv) The wire will move when the current is flowing. **(6)**

TIP: This is to do with the force on a current carrying conductor in a magnetic field.

(v) If the current was reversed, the wire would move the other way because of a reversal of the magnetic field. **(6)**

(vi) Choose any two from the following:
- DC motor
- Moving coil loudspeaker
- Galvanometer **(2 × 4)**

10. Radiation can be detected by any of the following:
- G–M tube (Geiger–Müller tube)
- Cloud chamber
- Solid state detector
- Electroscope
- Photographic film
- Scintillation screen **(6)**

Alpha (α), beta (β) and gamma (γ) are the three types of radiation. **(3 × 2)**

(i) Beta is negatively charged. **(2)**

TIP: Beta consists of a fast-moving electron, therefore is it negative.

(ii) Alpha has the shortest range. **(2)**

TIP: Alpha is the biggest radiation since it is made of 2 protons and 2 neutrons, therefore it is the one that moves the least.

(iii) Gamma is unaffected by EM fields. **(2)**

TIP: Gamma is unaffected because it has no mass and no charge.

(iv) Nuclear fission is the splitting of a large nucleus into two similar smaller nuclei with the release of energy. **(6)**

(v) Neutrons cause further fission by splitting the nucleus. **(6)**

TIP: When fission occurs, neutrons are also emitted which then split more nuclei and cause further fission. This is the basis for a chain reaction, where one reaction can trigger more.

(vi) Choose any one from the following:
- Uranium
- Plutonium
- Thorium **(6)**

(vii) The control rods slow down or stop the reaction when they are lowered. **(6)**

TIP: If the control rods are raised, they expose more of the fuel rods and enable more fission to occur and the rate of reaction increases. The control rods are more cylindrical covers than rods.

(viii) The energy produced by fission is carried by a coolant to a heat exchanger. It heats water here and converts the liquid water to steam. This steam then drives the turbines by making them turn in a magnetic field, where they produce electricity. **(6 + 3)**

(ix) Advantages (choose any one from the following):
- Cheap to run
- Abundant fuel source
- No CO_2 emissions or greenhouse gases
- Very low accident rate

Disadvantages (choose any one from the following):
- Cost of disposing of waste
- Risk of nuclear explosion or fallout
- Dangerous to deal with uranium mining **(5)**

11. (a) Stars twinkle because of atmospheric turbulence. **(8 × 7)**

(b) Stellar scintillation.

(c) Refraction is the bending of light as it passes from one medium to another.

(d) Refractive index, temperature and density.

(e) Because of heat rising from buildings and populated areas.

(f) Only stars twinkle. Planets do not twinkle.

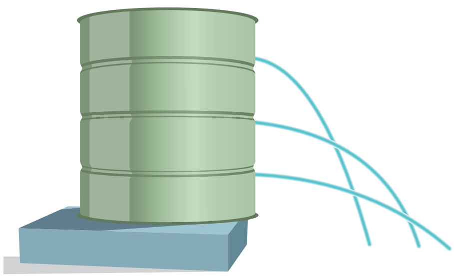
(g) Because the light from these stars has to travel through more air than those higher up, there is more chance of refraction being noticed.

(h) The light comes from nuclear fusion.

TIP: It can be seen that many of these answers come from the paragraph. This shows that it is worth taking time to read the passage for important information. If you cannot find the exact answer, make a logical answer based on what you have learned. In this case, just think about nuclear energy and the refraction of light. As long as the answers are reasonably based on your material, you will gain some, or all, of the marks.

12. (a) Pressure is the force per unit area. **(6)**

TIP: You may also use the formula $P = F/A$ with explanations for the letters to answer this.



Set up a can with holes at varying heights. When it is filled to the top with water, you will notice that the water flows out further from the holes at the bottom, with the water flowing furthest from the lowest hole. This shows that the water pressure increases with depth. **(4 × 3)**

Pressure at 5m: $P = \rho gh \Rightarrow P = (1000)(9.8)(5) \Rightarrow P = 0.49 \times 10^5$Pa

Pressure at 30m: $P = \rho gh \Rightarrow P = (1000)(9.8)(30) \Rightarrow P = 2.49 \times 10^5$Pa

TIP: Make sure to clearly state the pressure at each depth using the correct units of metres in the calculation. Then subtract one from the other. By doing this, even if a slight mistake happens, it will most likely only be an arithmetical one.

Therefore, increase in pressure = 2.94×10^5Pa $- 0.49 \times 10^5$Pa $= 2.45 \times 10^5$Pa **(10)**

(b) Temperature is a measure of the hotness or coldness of a body. **(6)**

Temperature can be measured in Celsius (˚C) or Kelvin (K). **(6)**

TIP: It can also be measured in Fahrenheit (˚F) but this is rarely used in international physics.

$100^\circ C = (273 + 100)K \Rightarrow 100^\circ C = 373K$ **(3)**

TIP: 0˚C = 273K and every Celsius degree change corresponds to a Kelvin degree change, therefore just add 100 to 273. If you were to use Fahrenheit, it would be a harder conversion. The formula is 9/5 ˚C + 32 = F. Therefore, 9/5(100) + 32 = 212˚F.

The thermometric property in a thermometer is length of column. **(3)**

Choose any one from the following:

- Fever strip (liquid crystal)
- Thermocouple
- Thermistor
- Pressure at constant volume
- Volume at constant pressure

The following measurements go with the following thermometric properties:

- Fever strip: Colour – different colours correspond to different temperature ranges
- Thermocouple: Emf – measured with voltmeter/multimeter
- Thermistor: Resistance – measured with ohmmeter/multimeter
- Pressure at constant volume: Masses applied to piston
- Volume at constant pressure: Graduated volume on piston **(2 × 3)**

Different thermometers have different thermometric properties and therefore give different proportional readings. To ensure consistency of reproducible measurements, you need a standard thermometer. **(4)**

(c) Doping is the addition of controlled amounts of impurity to increase extrinsic conduction. A semiconductor is a material whose resistivity is between that of a good conductor and a good insulator. **(6 + 3)**

The electrons and positive holes cross the junction and meet. This causes an area of no free charge carriers, which forms the depletion layer, with a junction voltage on each side of it. **(6)**

TIP: Extrinsic conduction is just conduction caused by an external factor. In this case, extra electrons or positive holes are introduced into the pure semiconductor by doping with other materials.

When the switch is closed, diode A lights the bulb and diode B does not. **(6)**

This occurs because diode A is forward biased and allows current to flow, whereas diode B is reverse biased and does not allow current to flow through the bulb. **(7)**

(d) (i) Thermionic emission is the emission of electrons from the surface of a hot metal. **(6)**

TIP: Just think of the word 'thermionic': 'Therm' is to do with heat and 'ion' for charged particles such as electrons.

(ii) Cathode rays are high speed electrons. **(6)**

TIP: They are called cathode rays because they are emitted from the cathode by thermionic emission.

(iii) The high voltage is there to accelerate the electrons from the cathode to the anode. **(6)**

(iv) The high velocity cathode rays are converted to a scintillation (bright spot of light). **(6)**

(v) Choose any one from the following:

- Television
- Oscilloscope
- Monitor **(4)**

SECTION A

1. (i)

1. Set up the equipment as shown in Fig. 1.1, making sure to raise the track *just enough* so that the trolley will move with constant velocity when pushed. (This means that the trolley will not move unless it is pushed. It also means that the trolley will not speed up or slow down after being pushed.)
2. Feed the ticker tape through the ticker timer and attach the ticker tape to the trolley with Sellotape or putty.

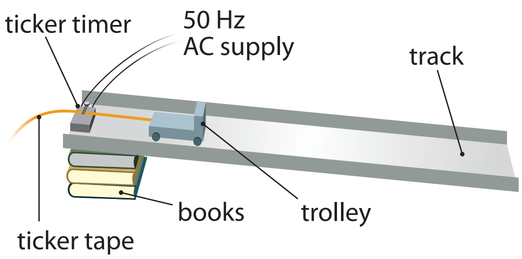


Fig. 1.1

3. Move the timer so that the tape can run freely through it to the trolley.
4. Connect the ticker timer to the a.c. power supply and set it to the stated recommended voltage for the timer (usually around 12V).
5. Switch the timer on and give the trolley a gentle push to initiate movement.
6. If the trolley moves with constant velocity, stop the trolley at the end of the track and turn off the timer.
7. Remove the tape and label.
8. Repeat for a number of different strength pushes (velocities).
9. Ignoring the dots at the beginning and end of the ticker tape, count the number of spaces (each space = 1/50 of a second).
10. Measure the physical distance between the first and last dot being counted.
11. Put this information in your table and calculate velocity by dividing distance by time.

OR

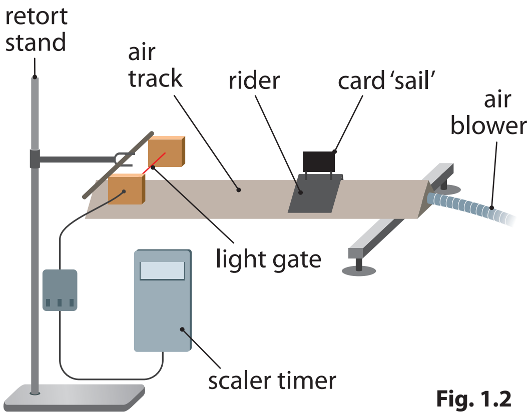


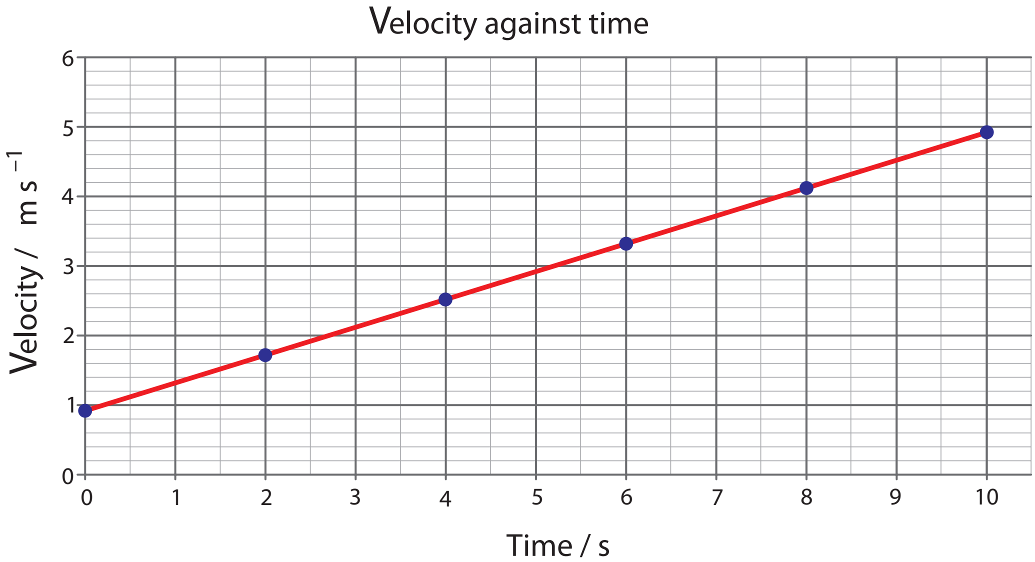
Fig. 1.2

TIP: In the case of the ticker timer and tape, you will need to mention the distance between the dots on the tape and the number of dots present to gain distance and time for velocity.
In the case of the air track, you will need to measure the length of sail and time it took to pass through the light gate, in order to gain distance and time for velocity.

1. Set up the equipment as shown in Fig. 1.2, making sure to adjust the levelling screws on the air track until the rider stays in one place, with the blower turned on. At this point, it should move with constant velocity when pushed.
2. Attach the sail to the rider, making sure that it is parallel to the direction of motion.
3. The light gate should be placed in a retort stand to register the sail passing through its light beam.
4. Connect the scalar timer to the light gate.
5. Push the rider along the track. Its sail should move through the light gate beam.
6. The time it takes for the sail to pass through the beam should register on the scalar timer.
7. Measure the length of sail that passed through the light gate. This is your displacement measurement.
8. Repeat for a number of different strength pushes (velocities).
9. Put this information in your table and calculate velocity by dividing distance by time. (This is distance of sail divided by the time the light beam was interrupted.)

(5 × 3)

(ii)



(5 × 3)

TIP: The graph should be a best-fit line through the given data points. Make sure to clearly label the axes and use at least three-quarters of the graph page to present a clear graph.

(iii) slope = $\frac{y_2 - y_1}{x_2 - x_1} \Rightarrow$ slope = $\frac{(4.9) - (0.9)}{(10) - (0)} \Rightarrow$ slope = $\frac{4}{10}$ slope = $0.4 m.s^{-2}$ **(10)**

TIP: Since slope = the change in *y* divided by the change in *x*, this equates to the change in velocity (y-axis) divided by the change in time (x-axis). This is what is being calculated here. You could just as easily take any two points from the graph and calculate the slope to gain acceleration but because the question did not ask you to use your graph, you can take the first and last data figures given in the question. However, if you are asked to use your graph, you need to take your own values from the graph and get the slope to calculate acceleration.
It is a common for a question to ask you to use your graph to find an answer. Remember that slope is the y-axis divided by the x-axis and in this case velocity divided by time = acceleration.

2. (i)

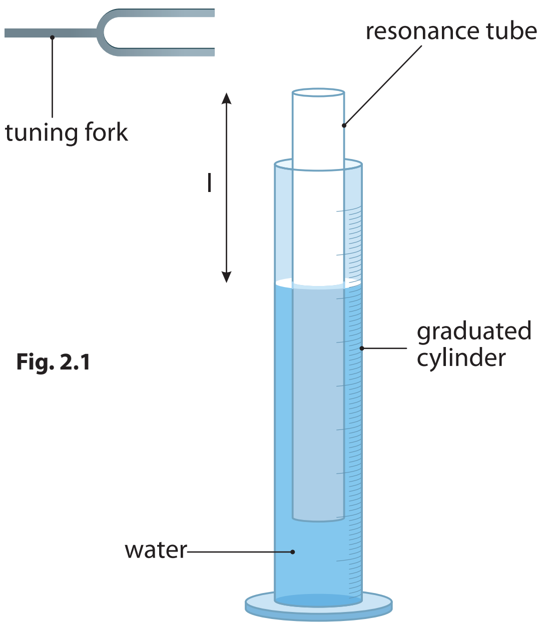


Fig. 2.1

1. Adjust the resonance tube in the water, so that the shortest column of air is between the top of the tube and the water, as in Fig. 2.1.
2. Strike the highest frequency tuning fork. Hold this just above the tube.
3. Keeping the fork above the tube, adjust the length of the air column by raising the tube slowly.
4. Resonance will occur when you hear maximum amplitude (loudness). To achieve this, you may need to make a few fine adjustments of length while holding the vibrating fork above the tube.
5. When the point of resonance has been found, measure the length of the air column with the metre stick, from the top of the tube to the water level.

(2 × 3 + 6)

TIP: Alternatively, you may have used a frequency signal generator instead of tuning forks.

(ii) The frequency of the sound wave was read from the tuning fork. **(6)**

TIP: If a signal generator was used as mentioned in part (i), this would have displayed the frequency at resonance.

(iii) To calculate wavelength, you need to measure the length of the column of air in the tube (l), as well as the diameter of the tube (d). You would then use the formula:

$c = 4f(l + 0.3d)$ to calculate the speed of sound.

Then using $c = f\lambda$, you could calculate wavelength by substituting in the values for c and f, which you now have, and working out λ (wavelength). **(3 × 3)**

TIP: If you wish to skip the first formula – $c = 4f(l + 0.3d)$ – and calculate wavelength directly, you could gain the values for l and d and use the following formula $\lambda = 4(l + 0.3d)$ to work out wavelength in one move.

(iv) The speed of sound in air could be calculated by the above formula with all relevant quantities substituted into it:

$c = 4f(l + 0.3d)$ **(3 × 3)**

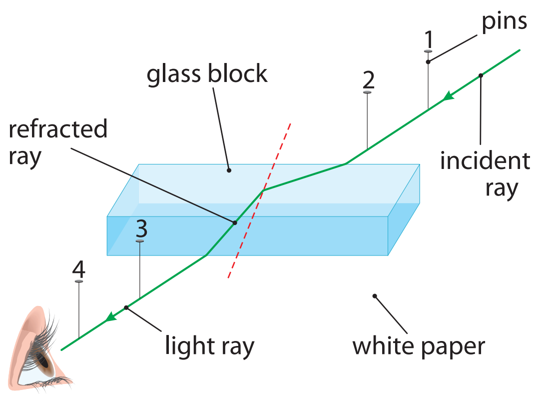
TIP: If you used this formula to calculate wavelength in part (iii), you only need to repeat the procedure here to show speed (c) being worked out again. You cannot leave an answer required in another part of the question when it is specifically asked for here; so it must be restated to show it each time it is asked for.

(v) Choose any one from the following:

- Use a number of different frequencies and work out the speed for each. Then average the answers.
- Average a number of diameter readings for end correction d.
- Take an average of length measurements based on a number of students' perception of where resonance occurs. **(4)**

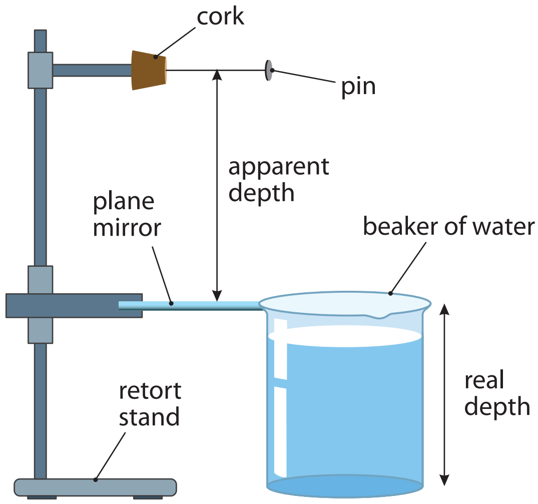
TIP: Since resonance is a difficult thing to find exactly, it is always best to take a number of readings as to where the maximum amplitude of sound occurred. Then use the average length to calculate the speed of sound. It is also wise to take a number of length readings to minimise parallax error in measurement.

3. (i)



TIP: You may have done this experiment using a ray box and, in this case, you need to still show the glass block, paper and lines drawn for incident/refracted rays. It is also a good idea to show a ruler and protractor, since these are needed for measurement.

OR



(6 + 2 × 3)

TIP: If using the real depth/apparent depth method, you need to mention using a ruler as well. This is considered a more difficult experiment to explain as it involves the method of no parallax for locating the virtual image. If you are more familiar with this experiment, use this set-up but make sure to read ahead so as to see you can easily answer the questions that follow.

(ii) The measurements taken were:

Snell's Law method:

- Angle of incidence (*i*)
- Angle of refraction (*r*)

OR

Refractive index of a liquid method:

- Real depth
- Apparent depth **(2 × 6)**

(iii) Snell's Law method:

- *n* = Sin*i*/Sin*r*

Liquid method:

- *n* = Real depth/Apparent depth **(10)**

(iv) Experiments are always repeated to reduce percentage error in measurements and increase accuracy. **(6)**

TIP: Whenever you are answering question on errors and precautions, always keep the concept of reducing percentage error in mind. This is one of the main aims of conducting an experiment successfully.

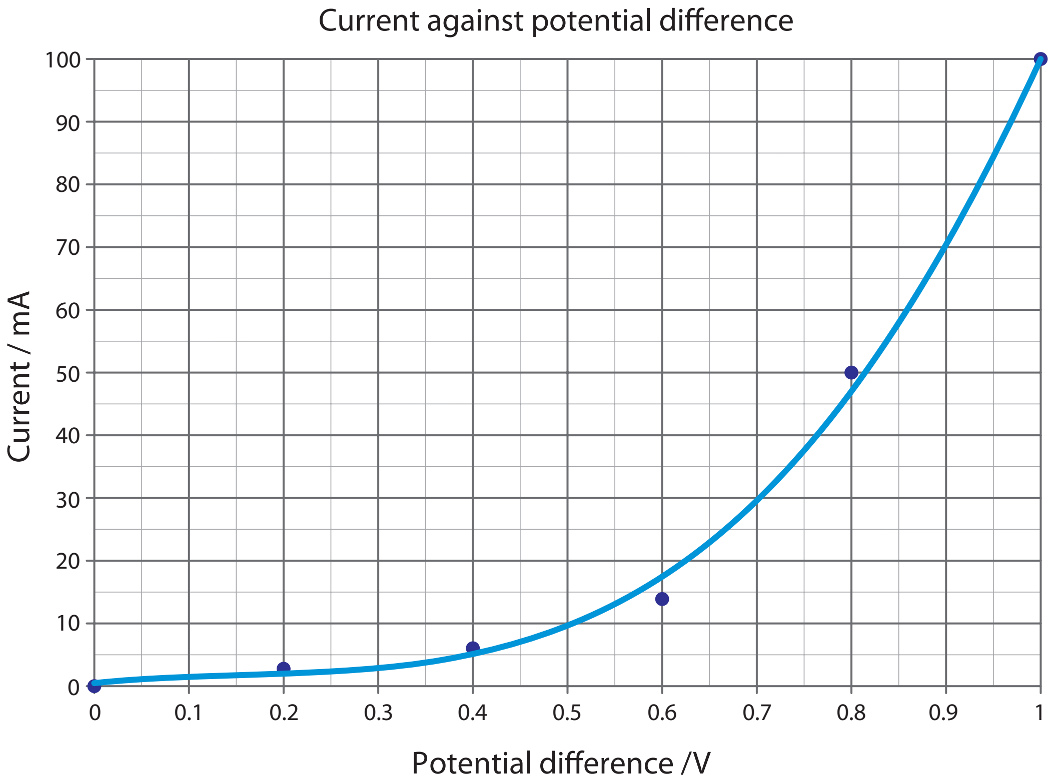
4. (i) X = Milliammeter, measuring current **(2 × 3)**

TIP: The ammeter is always placed in series in the circuit. As you are measuring current, you could also list a galvanometer or ammeter or multimeter.

(ii) Y = Variable resistor, which allows you to change the value of resistance in the circuit, which then also will change the voltage and current in the experiment. **(2 × 3)**

TIP: This could also be named as a rheostat or potential divider.

(iii) The 330Ω resistor is used to protect the diode. **(6)**



TIP: The graph needs to be a smooth curve joining the points given with clear, labelled axes. The graph should also take up at least three-quarters of the graph page in order to be big enough to answer any questions that follow concerning it.

(4 × 3)

The graph shows that current remains almost zero until the potential difference reaches the junction voltage of 0.6V, where current rises sharply. This shows that the variation of current with voltage is not linear and the diode does not have ohmic conduction (does not adhere to Ohm's Law of $V = IR$, at constant temperature). **(10)**

SECTION B

5. (a) The total momentum of a system before an interaction is equal to the total momentum of the system after an interaction, so long as no external force acts on it. **(8 × 7)**

TIP: You may also state this as the formula but make sure to explain each variable and what it stands for.

(b) $P = \frac{F}{A} \Rightarrow P = \frac{25\text{N}}{(1.2\text{m} \times 1.2\text{m})} \Rightarrow 17.4 \text{ Nm}^{-1}$

TIP: You need to make sure that the force is in newtons and the area is in metres squared for this question. Since the block is a cube, you just need to multiply any side by itself to gain the area of one face.

(c) Energy is measured in Joules (J).

(d) Sound is measured in decibels (dB).

(e) $P = 1/f \Rightarrow 1/P = f \Rightarrow 1/0.1 = f \Rightarrow 10\text{cm} = f$

TIP: In this question watch the units. Because the power is given in cm^{-1}, then the answer will be in cm. If the power was given in m^{-1}, the answer would be in m.

(f) Choose any one from the following:
- Lightning
- Static shocks from materials or equipment
- Sparking
- Electrostatic precipitation
- Xerography (photocopying)
- Hair standing up

(g) This is a multimeter. It can be used to measure (choose any two from the following):
- Current (ammeter)
- Voltage (voltmeter)
- Resistance (ohmmeter)
- Capacitance
- Temperature
- Frequency

(h) The live wire is red or brown.

TIP: Brown is the colour of the live wire in Ireland but red is used in other countries. Given that you may be using an appliance from abroad, red should be known as well.

(i) Choose any two from the following:
- High energy
- High frequency
- Small wavelength
- Ionising
- Penetrating
- No mass
- No charge
- Expose photographic film
- Cause certain materials to fluoresce

(j) Nuclear fusion is the joining of two small nuclei to create a larger nucleus with the release of energy.

6. Force is anything that causes a body to move or change velocity. Its unit is the Newton (N). **(3 × 3)**

TIP: You may also say that force causes acceleration. This can be shown with the formula $F = ma$, where a force (F) causes a mass (m) to accelerate (a).

Every mass in the universe attracts every other mass with a force that is proportional to the product of their masses and inversely proportional to the square of the distance between them. **(3 × 3)**

$$g_{moon} = \frac{GM}{R^2} \Rightarrow g_{moon} = \frac{(6.7 \times 10^{-11})(7 \times 10^{22})}{(1.7 \times 10^{6})} \Rightarrow g_{moon} = 1.6\text{m.s}^{-2}$$

(4 × 3 + 4)

TIP: The best way to calculate these questions is to state the variables first, then write the formula and then substitute the variables in. You can also make a reasonable guesstimate of the answer, since gravity on earth is 9.8m.s^{-2} and the moon is 1/6th of the mass of the earth. Therefore, the gravity on the moon should be roughly 1/6 of 9.8m.s^{-2} (1.6 m.s^{-2}).

(i) $W = mg \Rightarrow W = (2000kg)(9.8 \Rightarrow W = 19600N$ **(6)**

TIP: The weight of an object is always calculated as the mass by the gravity of where it currently is. It is for this reason that objects weigh less on the moon than on earth.

(ii) 2000kg **(6)**

TIP: Mass does not change regardless of where the body is. It is the weight that is dependent on gravity.

(iii) $W = mg \Rightarrow W = (2000kg)(1.6) \Rightarrow W = 3200N$ **(4)**

TIP: You need to use the value for gravity here that was calculated earlier.

Since the gravitational pull on the moon is less than on earth, a less powerful rocket is required to lift the same mass. This is because the rocket does not need to have the same escape velocity to break free of the moon's gravity. **(6)**

7. (i) Temperature is the measure of hotness or coldness of a body. **(6)**

(ii) ˚C /K **(6)**

(iii) Choose any one from the following:

- Colour
- Length of column
- Emf
- Resistance
- Pressure at a constant volume
- Volume at a constant pressure **(6)**

(iv) Heat is a form of energy. **(6)**

(v) Conduction, convection, radiation. **(3 × 3)**

(vi) Specific heat capacity is the amount of heat energy required to change 1kg of a substance by 1K (1˚C). **(6)**

TIP: You may also define SHC (specific heat capacity) in terms of the formula: $c = \frac{Q}{m\Delta\theta^1}$, but you should also explain each letter used.

(i) The rise in temperature is from 20˚C to 100˚C. Therefore, $\Delta\theta = 80˚C$ **(3)**

(ii) $Q = mc\Delta\theta \Rightarrow Q = (0.5)(4200)(80) \Rightarrow Q = 168000J$ (168kJ) **(6)**

TIP: Make sure to put all units in the correct form. Mass is always given in kg.

(iii) Energy supplied per second means power. Therefore, with a power of 2kW, the ring supplies 2kJ every second, i.e. 2000J. **(3)**

(iv) $P = \frac{W}{t} \Rightarrow t = \frac{W}{p} \Rightarrow t = \frac{168000}{2000} \Rightarrow 84s$ **(5)**

TIP: As you can see, each answer moves smoothly on to the next question. You need to know the energy required to heat the water from $Q = mc\Delta\theta$. Then you need to know how much energy is being supplied each second. Then you calculate the time it takes to do this.

Remember there are not many formulae in the heat section and they all revolve around energy in Joules. Try to work out the energy required for a task and the energy being supplied and it will work out quickly. Also, watch out for when efficiency is not 100 per cent. In these cases, you need to work out the actual energy being supplied before you use it.

8. (i) The person will notice the sound getting louder and fainter as they move from A to B. **(7)**

(ii) Since the two speakers are emitting the same note, their waves are constructively interfering (louder) and destructively interfering (fainter) as they meet. **(7)**

TIP: Whenever a question is involved with something reflecting, refracting, diffracting, interfering or being polarised, this is evidence of a wave being present.

(iii) As mentioned above, this occurs with waves, showing that sound is a wave. **(7)**

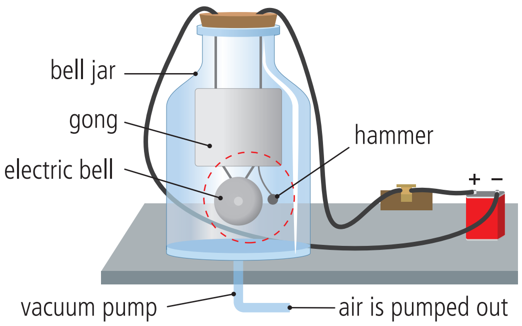


Fig. 8.1

1. Set up the equipment as in Fig. 8.1.
2. Remove the air to achieve a vacuum.
3. With the bell ringing, allow the air to re-enter the bell jar and you will hear the sound amplitude increasing. This demonstrates that sound requires a medium to travel. **(4 × 3 + 2)**

(i) The apparent change in pitch is the Doppler effect. **(7)**

(ii) As sound waves are emitted from a moving source, wavefronts get bunched up as the source approaches you. This gives the effect of lower wavelength and higher frequency (pitch). However, as the source is moving away from you, the wavefronts are stretched out and give the effect of longer wavelength and lower frequency (pitch). **(7)**

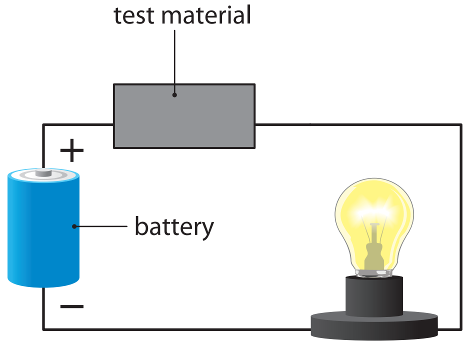
(iii) Choose any one from the following:
- Speed guns
- Red shift/blue shift of star motion
- Radar
- Medical blood flow measurement **(7)**

9. (i) Electric current is a flow of electrons. **(6)**

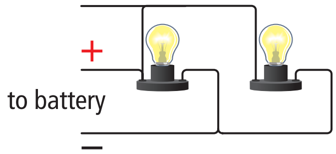
TIP: You can also refer to current as a movement of charge.

(ii) Choose any two from the following:
- Heating
- Magnetic
- Chemical **(6)**

(iii) Choose any one from the following:
- Simple cell
- Secondary cell
- Mains
- Thermocouple **(4)**



Place different test materials between the wire contacts on each side. If the bulb lights, the material is a conductor. If it does not, it is an insulator. **(4 + 2 × 3)**

(i) 

(6)

(ii) Parallel circuits enable all components to work even if one breaks. They also supply full voltage to each component, making them brighter than a series circuit. **(6)**

(iii) Fuses are included to prevent fire, overheating or too much current. **(6)**

(iv) $\frac{1}{R_{tot}} = \frac{1}{R_1} + \frac{1}{R_2} \Rightarrow \frac{1}{R_{tot}} = \frac{1}{20} + \frac{1}{20} \Rightarrow \frac{1}{R_{tot}} = \frac{2}{20} = \frac{1}{R_{tot}} = \frac{1}{10} = R_{tot} = 10\Omega$ **(6)**

TIP: Make sure to carefully calculate parallel resistance as it can sometimes seem wrong when you gain a smaller resistance after adding total resistances. However, resistance decreases when more than one resistor is in parallel.

(v) $V = IR \Rightarrow V/R = I \Rightarrow 24/10 = I \Rightarrow 2.4\text{A} = I$ **(6)**

10. Choose any two from the following:

- Fundamental particles
- Charge of 1.6×10^{-19}C
- Negative charge
- Orbit nucleus
- Deflected by EM fields
- Very small mass **(9)**

(i) Alpha particles are helium nuclei with two protons and two neutrons. **(9)**

(ii) The following was observed:
- Most alpha particles passed straight through the foil.
- Some alpha particles were deflected off course.
- Very few alpha particles bounced straight back. **(9)**

(iii) From the previous results, Rutherford concluded that the atom is mainly empty space, with a small dense positive nucleus. **(9)**

(iv) The electrons orbit the nucleus in different energy levels. **(9)**

(v) Choose one from the following:
- G–M tube (Geiger–Müller tube)
- Cloud chamber
- Solid state detector
- Electroscope
- Photographic film
- Scintillation screen **(6)**

(vi) Alpha particles are big particles that do not have good penetration depth. As such, air particles would get in their way and stop them very quickly. **(5)**

11. (a) Choose any two from the following: **(8 × 7)**
- Cooking
- Heating
- Lighting
- Radio
- TV
- Washing machine, etc.

(b) Choose two from the following:
- Insulation
- Double/triple glazing
- Energy-efficient devices and appliances
- Closing doors/windows

(c)
- Wind
- Wave
- Solar
- Geothermal
- Biomass
- Hydro
- Tidal

(d) In order of operation:
1. Solar panel (solar tubes)
2. Water pipes
3. Water storage cylinder tank

(e) The panel receives more of the sun's energy facing south.

(f) In case of low solar energy, the backup heater can be used to supply heat. This may occur due to weather or night use.

(g) Black is a better absorber of heat and a worse reflector of heat than silvered surfaces.

(h) Convection.

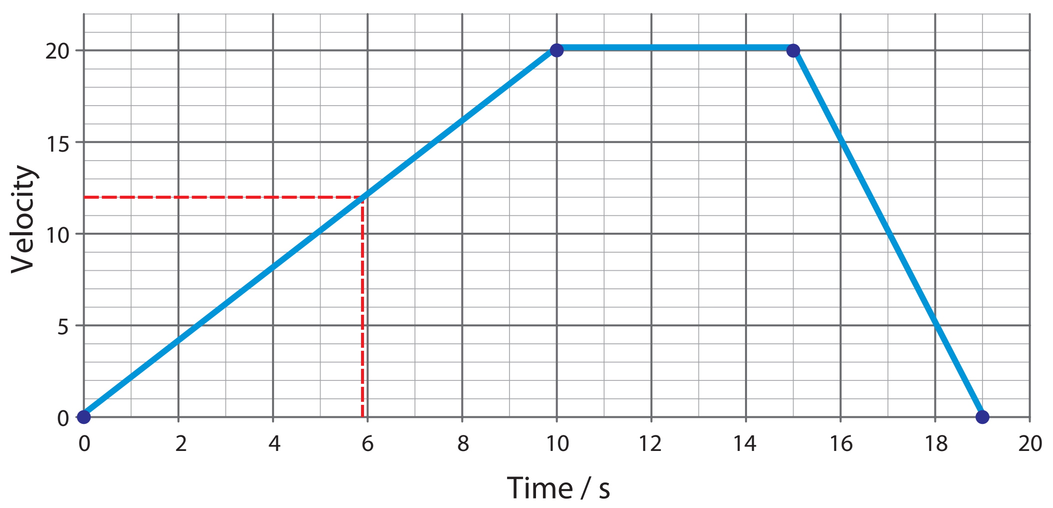
12. (a) (i) Velocity is the change in displacement with respect to time.

TIP: This can also be stated as $v = s/t$, with the letters explained.

(ii) Acceleration is the change in velocity with respect to time. **(6 × 3)**

TIP: This can also be stated as $a = \frac{v-u}{t}$,

(i)



(6)

TIP: Make sure to show clearly where the velocity changes happen and double-check the times they occur at.

(ii) 12m.s^{-1} **(3)**

TIP: Draw a line upwards from 6s until it intersects the graph and then a line across to the velocity axis to read the velocity at that time. A range of answers will be accepted but if you have drawn a good clear graph as above, the answer should be simple to read.

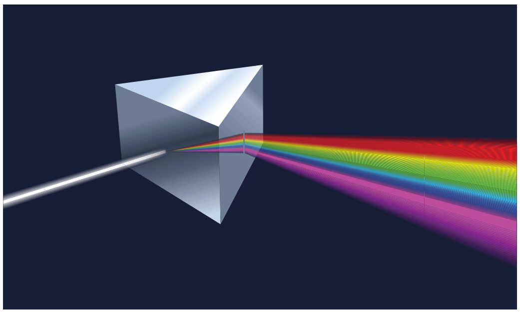
(iii) $a = \frac{v-u}{t} \Rightarrow a = \frac{20-0}{10} \Rightarrow a = \frac{20}{10} \Rightarrow a = 2\text{m.s}^{-2}$ **(6)**

(iv) Distance = velocity × time $\Rightarrow s = (20)(5) \Rightarrow s = 100\text{m}$ **(4)**

TIP: This can also be worked out from the area under the constant velocity part of the graph. The area is $20 \times 5 = 100$m.

TIP: As you can see, being able to draw a good simple graph using most of the graph page is very important for gaining answers later.

(b) (i)



You could use a prism to disperse light into its constituent colours or you could use a diffraction grating to split the light into a spectrum. You would need to use white light for this to work. **(3 × 3)**

(ii) Infrared (IR) and ultraviolet (UV) radiation. **(2 × 3)**

(iii) Choose one from the following options:
To detect IR in the EM spectrum, do the following:
- Shine white light through a quartz prism or grating to disperse it onto a screen.
- Place a thermometer just outside the red end of the spectrum and you should notice a heating effect, showing the presence of invisible IR.

To detect UV in the EM spectrum, do the following:
- Shine white light through a quartz prism or grating to disperse it onto a screen.
- Place a piece of paper with Vaseline on it just outside the violet side of the spectrum and you should begin to see it glow, thereby showing the presence of invisible UV light. **(3 × 3)**

(iv) Choose either IR or UV:
Use of IR (choose one from the following):
- Heat source
- Suntan lamps
- Incubation lights
- Restaurant heating lamps
- Communication remote control

Use of UV (choose one from the following):
- Sterilisation of instruments
- Insect removal
- Disco lights
- Detection of forged currency **(4)**

(c) The photoelectric effect is the emission of electrons from the surface of a metal when EM radiation of a suitable frequency is incident on it. **(6)**

(i) A = Photocathode
B = Photoanode **(2 × 3)**

(ii) By changing the distance between the light source and photocell, you can vary the amount of brightness on the photocell. **(6)**

(iii) The brightness affects the photocurrent. The more brightness, the more current produced; the less brightness, the less current flowing in the photocell. **(4)**

(iv) Choose any one from the following:
- Burglar alarms
- Light meters
- Solar cells
- Automatic door mechanism
- Soundtrack on films
- On/off switch on street lights **(6)**

(d) Electromagnetic induction occurs when a changing magnetic field induces an emf, which in turn produces a current. **(6)**

To demonstrate Faraday's Law of Electromagnetic Induction, do the following:

1. Set up the experiment as shown in Fig. 12.1.
2. As the north pole approaches the coil, the galvanometer needle twitches one way.

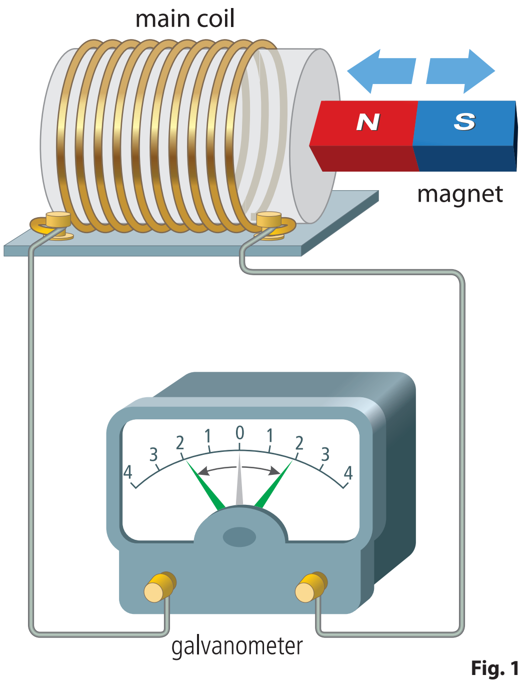


Fig. 12.1

3. As the north pole moves away from the coil, the galvanometer needle twitches the other way.
4. Reversing the magnet shows the opposite effects.
5. If the magnet and coil are kept stationary, no movement takes place on the galvanometer. **(4 × 3 + 4)**

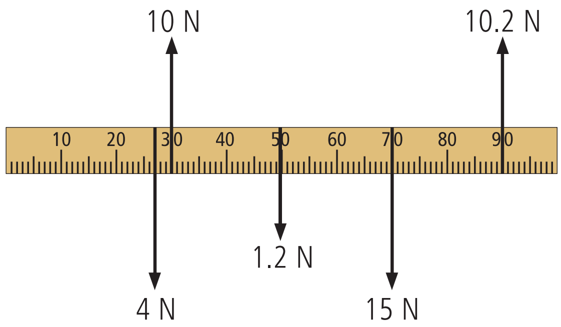
a.c. means alternating current. **(6)**

SECTION A

1. (i) The metre stick would be in equilibrium if it was horizontal and balanced with no movement. **(4)**

TIP: It is also safe to state the Law of Equilibrium about the forces and moments being balanced.

(ii)



(3 + 3)

TIP: The extra downward force of 1.2N was calculated by allowing the upward and downward forces to balance as per the Law of Equilibrium.
(10N + 10.2N) = (4N + 15N + 1.2N) (weight of metre stick acting through 50cm mark.)

It is common to be asked to find a missing force or moment, and you need to allow them to balance to find them. One of the most common mistakes is to forget about the weight of the metre stick acting through the centre of gravity.

(iii) (a) Total upward force = 20.2N (10N + 10.2N) **(6)**
(b) Total downward force = 20.2N (4N + 15N + 1.2N) **(6)**
(c) The sum of the upward forces equals the sum of the downward forces. **(3)**

TIP: It is also acceptable to state the Law of Equilibrium where the sum of the forces is zero or resultant forces are zero.

(iv) (a) Anticlockwise moments = $F \times$ perpendicular distance = (10N × 0.3m) + (10.2N × 0.9m) = 12.18Nm **(6)**

TIP: Remember when calculating moments that the main point is to know the point from which distance is measured. The measurement here is 0cm, so all perpendicular measurements are in metres from 0cm.

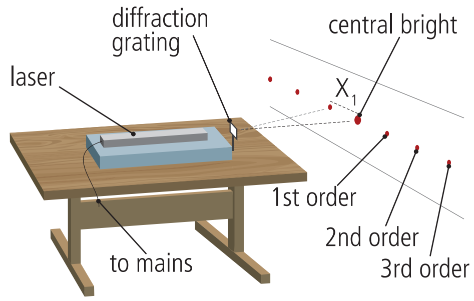
The other point to remember is how to work out which moments are clockwise and which are anticlockwise. Try to imagine holding the metre stick at the 0cm mark and being able to turn about it. If you apply any of the forces, which way will it turn?

(b) Clockwise moments
= $F \times$ perpendicular distance = (4N × 0.27m) + (1.2N × 0.5m + 15N × 0.7m) = 12.18Nm **(6)**

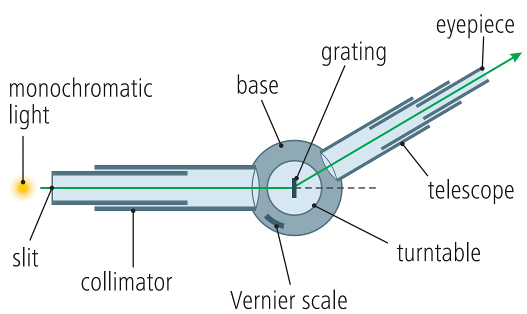
(c) The sum of the moments about any point is zero. **(3)**

TIP: It is also acceptable to state that the sum of the clockwise moments equals the sum of the anticlockwise moments. Sometimes, the moments, or forces, will not balance exactly but will be very close. This can be explained by a parallax error in measurement or inaccuracies in mass measurement.

2. (i)



OR



(12)

TIP: 3 marks for the diagram and 3 marks for the list of extra equipment.

TIP: When asked to describe the equipment used, choose the set-up you are familiar with. Either of these experiments use monochromatic (single colour) light and a grating. The only other piece of equipment to mention is the Vernier scale for the spectrometer, or a ruler for the laser and screen. Remember when listing apparatus to mention all the basic equipment that will give you the values you need (i.e. diffraction constant d and angle for $n\lambda = d\text{Sin}\theta$).

(ii) Choose any one from the following:

- Sodium vapour lamp
- Laser **(4)**

TIP: Any gaseous vapour that produces a line spectrum is appropriate to use.

(iii) If using the laser method:

- Distance from grating to screen
- Distance from zero order to required orders

If using the spectrometer:

- Angle off vernier scale for zero order
- Angle off vernier scale for required orders **(3 + 3)**

TIP: You may also mention adjusting the laser and grating or spectrometer set-up, but these are not vital measurements for calculating the wavelength of light.

(iv) $d = \dfrac{1 \times 10^{-2}\text{m}}{\text{number of lines per mm}} \Rightarrow d = \dfrac{1 \times 10^{-2}\text{m}}{600} \Rightarrow d = 1.66 \times 10^{-6}\text{m}$ **(6)**

TIP: If you are given so many lines per mm, it can a be a lot easier to write 1mm (1×10^{-3}m) on the top of the equation and divide this by the number of lines per mm. By doing this, you can calculate the value for *d* directly and your answer will be in metres.

(v) $n\lambda = d\text{Sin}\theta$ **(6)**

TIP: If you are using the laser method, you may be asked to state how you reached the answer for θ. This is achieved by using trigonometry where

$$\theta = \text{Tan}^{-1}\left(\frac{\text{distance between zero order and required order}}{\text{distance between grating and screen}}\right)$$

However, in this question, you are not given the values and so it is not necessary to work this out here.

(vi) Choose any one from the following:

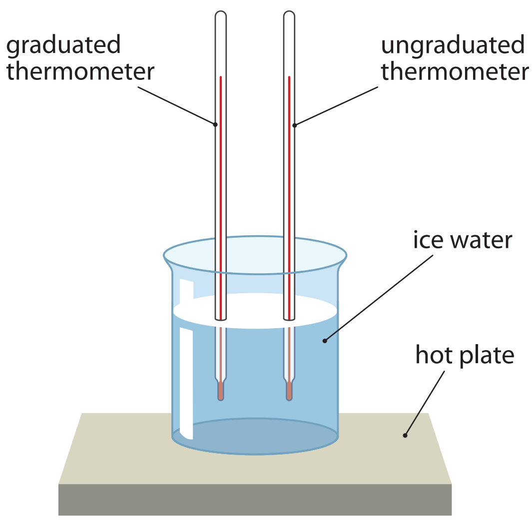
Spectrometer method:

- Slit not too wide/narrow
- Crosshairs on the centre of fringe
- Perpendicular grating and level table
- Focused telescope and adjusted collimator
- Use a grating with a large number of lines

Laser method:

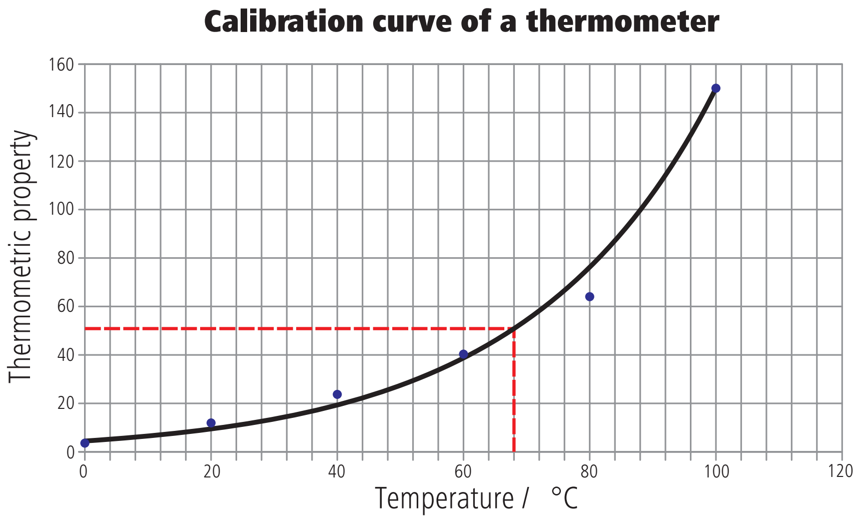
- Perpendicular grating and table
- Average distance to reduce parallax from ruler measurements
- Make the distance between grating and screen very big to reduce percentage error of distance measurement
- Use a grating with a large number of lines **(6)**

3. (i)



(4 × 3)

(ii)



TIP: Make sure to label the axes correctly and draw a smooth curve between the points.

TIP: It is always a good idea to use at least three-quarters of the graph page for the graph and carefully draw a smooth line, allowing for space to extend the graph if required.

(4 × 3)

(iii) 68˚C–72˚C **(6)**

TIP: As seen from the graph above, draw a dotted line from the thermometric property axis at *50*, until it intersects the graph line. Then drop the dotted line down to the temperature axis and read the temperature at this point. It is very important to show this work on your own graph because the examiner needs to see the method, in case of a slight numerical mistake.

(iv) Choose any one from the following:

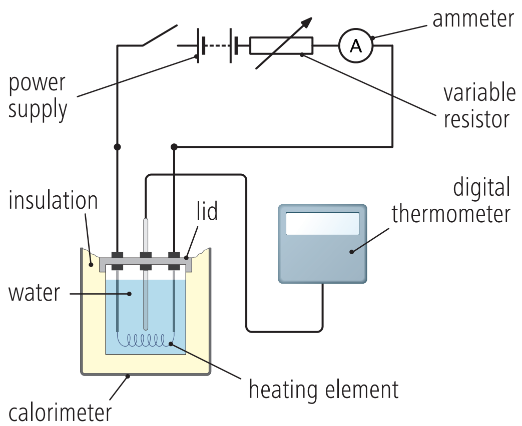
- Colour
- Emf
- Resistance
- Length of column
- Pressure at constant volume
- Volume at constant pressure **(6)**

TIP: Make sure to read ahead and give an answer for part (iv) that you can explain easily in part (v). There are only a few marks and all that is needed is a simple answer about how you would measure this thermometric property. If a diagram is needed, choose the one you can picture and draw best.

(v) The following measurements go with the following thermometric properties:

- Colour: different colours correspond to different temperature ranges
- Emf: voltmeter/multimeter
- Resistance: ohmmeter/multimeter
- Length of column: ruler/metre stick
- Pressure at constant volume: masses applied to piston
- Volume at constant pressure: graduated volume on piston **(4)**

4. (i)



TIP: You may also mention a stopwatch for ensuring that time is kept constant, but the main pieces of equipment to be shown and labelled are those that give you the data (i.e. ammeter, thermometer, variable resistance and heating element).

(4 × 3)

(ii) You can change the current throughout the experiment either by varying the power supply to change voltage or by adjusting the variable resistor to change resistance. Either of these will vary current. The advantage of the variable resistor is that, as the heating coil heats up, its resistance changes and you can use either variable resistor to keep current constant in each experiment. **(4)**

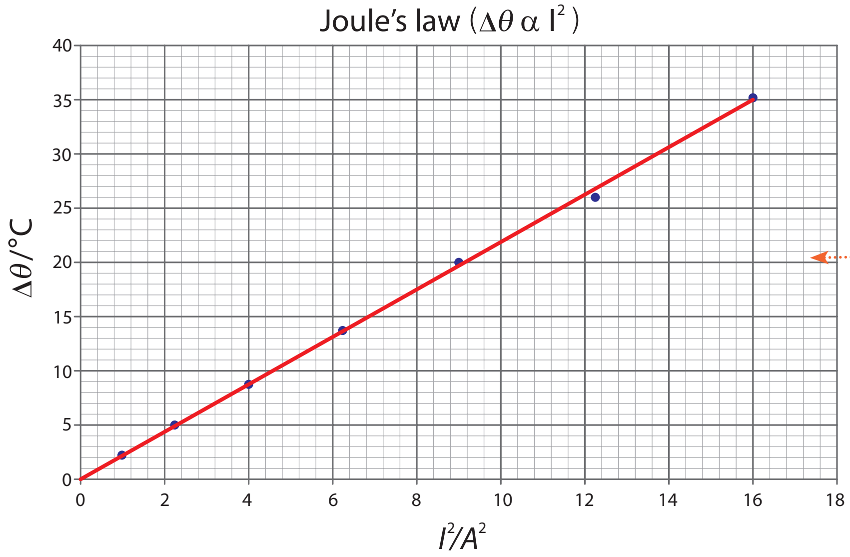
(iii)

I/A	1.0	1.5	2.0	2.5	3.0	3.5	4.0
I^2/A^2	**1.0**	**2.25**	4	**6.25**	**9.0**	**12.25**	**16.0**
Δθ/°C	2.2	5.0	8.8	13.8	20.0	26.0	35.2

(6)

TIP: You should know that current needs to be squared for this experiment as Joule's Law shows a relationship between the square of the current and heat generated.

(iv)



(4 × 3)

TIP: Make sure to label the axes correctly and draw a smooth best-fit line between the points.

It is always a good idea to use at least three-quarters of the graph page for the graph and carefully draw a smooth line, allowing for space to extend the graph if required. In the case of this graph, it must pass through the origin as a current of 0A will give you no heating effect.

(v) The graph verifies Joule's Law as it is a straight line through the origin. This shows the relationship of Δθ I^2. **(2 × 3)**

TIP: When you get a straight-line graph through the origin, a very common question that is asked is how your graph verifies a law. The above answer, stating that a straight line through the origin, is usually correct.

SECTION B

5. **(8 × 7)**

(a) The rate of change of a body's momentum is proportional to the net force applied and will act in the direction of the force.

(b) Nuclear

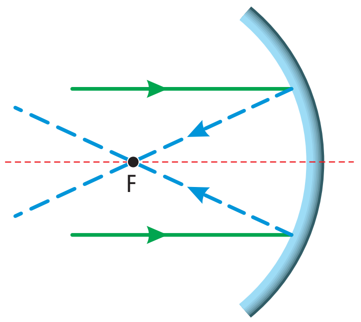
(c) 307K

TIP: You can use your tables to see that 0˚C = 273K. Therefore, by adding 34 to 273, you reach this answer.

(d) Choose any two from the following:

- Conduction
- Convection
- Radiation

(e)



TIP: Any ray coming in parallel to the principal axis will reflect back through the focal point. This is the reason you use parallel distant light to find the approximate focal length in the mandatory experiment on a concave mirror.

(f) Choose any one from the following:

- Red shift
- Blue shift for star motion
- Speed cameras
- Hospital scans

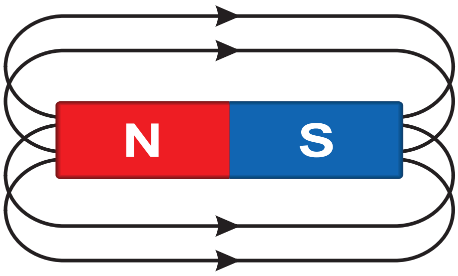
(g) Choose any two from the following:

- MCB (miniature circuit breaker)
- RCD (residual current device)
- Fuse
- Earthing
- Bonding

(h) LDR (light-dependent resistor)

TIP: Since you can see the arrows coming in to show light, this tells you that the device requires (depends on) light.

(i)



TIP: Make sure to show multiple lines and show direction, which should always go from the north to south pole of the magnet.

(j) 9 days divided by 3 days = 3 half-lives.
Therefore $\frac{1}{2}^3$ of sample remains = $\frac{1}{8}$ of sample remaining.

TIP: Every 3 days, the radioactive element decreases activity by half. Therefore, work out how many 3-day periods have elapsed and half for each one. This can be done quickly by using $\frac{1}{2}^n$ of the sample left, where n = a half-life.

6. (i) Work is done when a force moves a body through a displacement. Its unit is the Joule. **(9)**

TIP: You may also give the unit of work as Nm, since it is a force (N) moving a distance (m).

(ii) Power is the rate at which work is done. Its unit is the Watt. **(9)**

TIP: You may also give the unit of power as the $J.s^{-1}$, since it is the amount of work (J) done every second (s).

Potential energy is the energy a body has because of its position or state. **(3)**

TIP: The formula for potential energy is mgh, showing how the height is involved (h).

Kinetic energy is the energy a body has due to movement. **(3)**

TIP: The formula for kinetic energy is $\frac{1}{2}mv^2$, showing how velocity is involved (v).

(i) Total weight = 7200N (lift) + 800N (person) = 8000N **(4)**

(ii) Work = force × distance ⇒ 8000N × 25m = 200 × 10^3 J (or 200kJ) **(6)**

TIP: Make sure you only add weights or forces when asked. If only mass is given, you need to multiply it by gravity to convert mass to weight.

(iii) Power = work/time ⇒ $P = 200 \times 10^3 J/40s$ ⇒ $P = 5000W$ (or 5kW) **(6)**

(iv) Energy gained = person's weight × distance moved = 800N × 25m = 20kJ **(6)**

TIP: This can also be seen as the work the person has done on their own mass.

Power = work/time ⇒ $P = 20kJ/120s$ ⇒ $P = 166.67W$ **(5)**

TIP: Make sure to convert time into seconds for any of the work/power measurements.

Two disadvantages of using a lift may be:

- More energy is required to move the lift as well.
- The costs of installing and running the lift are considerable.
- The person receives no health benefits from losing out on exercise.
- The lift may break down or need repair. **(5)**

7. Resonance is the transfer of energy between two bodies when the applied frequency from one body is the same as or near the natural frequency of the other body. **(6)**

Natural frequency is the frequency at which a body naturally oscillates at when set in motion. **(6)**

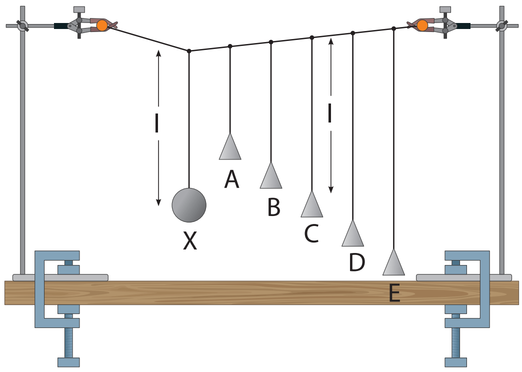


Fig. 7.1

1. Set up equipment as in Fig. 7.1, with pendulums of various lengths.
2. Attach a mass X of the same length string *(l)* as one of the pendulums.
3. When you swing the mass, the pendulum of similar length *l* (in this case pendulum C) will begin to swing as well. This demonstrates the resonance caused by the natural frequency applied from the swinging mass.

OR

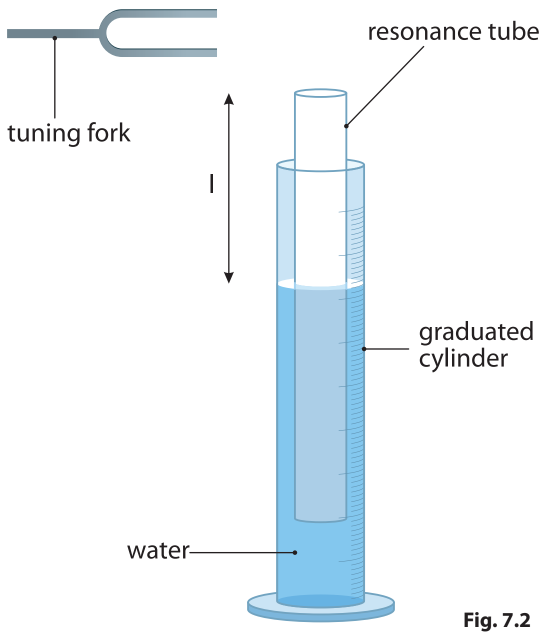


Fig. 7.2

1. Set up equipment as in Fig. 7.2.
2. Adjust the resonance tube in the water, so as to have the shortest column of air between the top of the tube and the water.
3. Strike the highest frequency tuning fork. Hold this just above the tube.
4. Keeping the fork above the tube, adjust the length of air column by raising the tube slowly.
5. Resonance will occur when you hear maximum amplitude (loudness). To achieve this, you may need to make a few fine adjustments of length while holding the vibrating fork above the tube.

OR

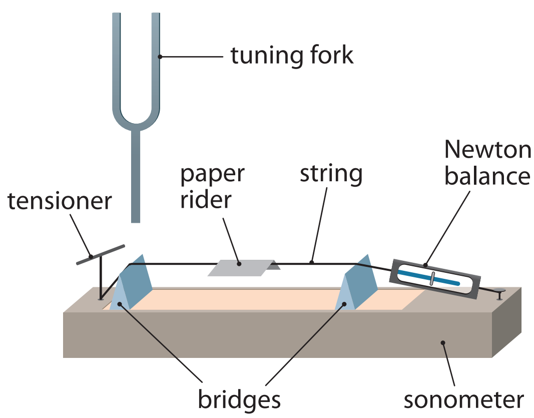


Fig. 7.3

1. Set up equipment as in Fig. 7.3, with pendulums of various lengths.
2. Adjust the bridges on the sonometer until the string is as long as is practically possible.
3. Strike the lowest frequency tuning fork and place the base of its handle on one of the bridges.
4. While holding the tuning fork on the bridge, adjust the tensioner until resonance occurs and the paper rider falls off the string.

(4 × 3)

TIP: Since this is a Section B question, you need only describe briefly how resonance occurred and show a basic diagram. Choose the one that you can describe in the simplest way and list steps in bullet points.

(i) A = Wavelength

(ii) B = Amplitude (or loudness/intensity) **(6 + 3)**

Frequency is the number of waves/cycles passing a point per second. **(6)**

(i) Loudness depends on amplitude. **(4)**

(ii) Pitch depends on frequency. **(4)**

> **TIP:** Loudness may also depend on frequency as certain animals hear different frequencies at different levels because of resonance. Humans hear 2000Hz–4000Hz louder than other frequencies at the same volume. This is the reason we use dBA meters to weight certain frequencies more than others.
>
> Also pitch can be said to depend on wavelength, because wavelength and frequency are inversely proportional.

$$c = f\lambda \Rightarrow \frac{c}{f} = \lambda \Rightarrow \frac{340}{256}\ \lambda \Rightarrow 1.33\text{m} = \lambda \qquad \textbf{(9)}$$

8. (a) (i) Dispersion is the separation of light into its constituent colours.
Spectrum is the range of colours present in a light source. **(3 × 3 + 1)**

> **TIP:** You may also refer to individual frequencies or wavelengths instead of colours and you may refer to the light source as white light.

(ii) When white light enters the prism at Z, it will refract and undergo dispersion as the light splits into constituent colours. **(6)**

> **TIP:** It is easy to remember which range goes with which colour because the colour is included in the part of the spectrum shown. Red is next to infrared (IR) and violet is next to ultraviolet (UV).

(iii) X = Infrared range
Y = Ultraviolet range **(6 + 3)**

(iv) Choose any one from the following:
To detect IR in the EM spectrum, do the following:

- Shine white light through a quartz prism or grating to disperse it onto a screen.
- Place a thermometer just outside the red end of the spectrum and you should notice a heating effect, showing the presence of invisible IR.

To detect UV in the EM spectrum, do the following:

- Shine white light through a quartz prism or grating to disperse it onto a screen.
- Place a piece of paper with Vaseline on it just outside the violet side of the spectrum and you should begin to see it glow, thereby showing the presence of invisible UV light. **(6 + 2 × 3)**

> **TIP:** You may also show the equipment mentioned to further illustrate your method of detection.

(v) For IR uses, choose any one from the following:

- Heat source
- Hot lamps in restaurants
- Incubation lights for chickens
- Muscle heat treatment
- Communication for remote controls

For UV uses, choose one of the following:

- Sterilisation of instruments
- Suntan
- Disco lights
- Forged currency detection
- Insect control **(3 + 3)**

(b) (i) Red, green and blue. **(6 + 3)**

TIP: Tip: You may sometimes see the letters RGB on TV/computer monitors or as types of graphics. This stands for the primary colours. Remember that the primary colours in physics do not correspond to those in art used as pigments.

(ii) When you mix any two primary colours, you create a secondary colour. For yellow, you need to mix red and green. **(4)**

TIP: Since the question asks for any secondary colour and only mentions yellow as an example, only give the primary colours necessary to make yellow, if you are sure. Otherwise, just give what is asked.

9. (a) The electrostatic force between any two point charges is proportional to the product of their charges and inversely proportional to the square of the distance between them. **(9)**

TIP: You may also give Coulomb's Law as a formula but you will also need to give a legend of what the letters stand for.

(i) You will need to follow these steps to positively charge an electroscope:

- Bring a negatively charged rod near the cap of the electroscope.
- The leaf will diverge from the rod, at which point touch the cap and earth the electroscope.
- The leaf will drop after you have earthed the electroscope.
- Remove your hand and then remove the charged rod.
- The leaf will move up again because it is now positively charged. **(9)**

TIP: You can also show these steps with individual – but simple – diagrams to show the leaf moving up and down as you bring the rod near and earth it, respectively.

The important thing with an experiment like this is to state simple bullet points with logical information in order. Do not make long detailed statements.

(ii) The leaf drops back to the rod. This occurs because the excess negative charges move from the electroscope to the earth. **(6 + 3)**

TIP: If you have previously drawn simple diagrams for part (i), you can always refer back to them for the answer to (ii) as well.

(iii) The cap can be earthed by touching it as you create the contact to ground. **(6)**

(b) (i) The capacitor will charge up and store the energy as the switch is at A. **(6)**

TIP: Remember that a capacitor needs to be charged by a power source (position A) before it can discharge through a component such as a bulb (position B).

(ii) When the switch is at position B, the current flows back through the capacitor and through the bulb, thereby lighting it. **(6)**

(iii) $C = Q/V \Rightarrow C = 0.6C/6V \Rightarrow C = 0.1\text{F}$ **(6)**

(iv) Choose any one from the following:

- Tuning radio circuits
- Charging a camera flash
- Flash gun
- Filtering
- Smoothing fluctuations
- Phone charger **(5)**

10. X-rays are high-frequency electromagnetic radiation. **(6)**

- Choose any one from the following:
- Medical imaging
- Medical treatments
- Structural integrity measurements **(6)**

TIP: As long as you refer to X-rays from the high frequency (high energy) end of the EM spectrum, you will be fine. For uses, choose the most obvious, and if asked for two uses, remember that if you can X-ray a bone, you can also X-ray building materials for structural integrity or pipelines.

A = Cathode (You may also mention heated filament.)
B = Anode (You may also mention tungsten target.)
C = Shielding (You may also mention lead safety shielding.) **(6 + 3 + 3)**

(i) When the cathode filament is heated, thermionic emission occurs and electrons are emitted. **(2 × 6)**

(ii) A high voltage supply is required to accelerate the electrons from the cathode to the anode at such a rate as to cause X-ray production when they hit the anode. **(2 × 3)**

TIP: X-rays can only occur if the electrons are moving with sufficient velocity when they hit the anode. This requires a very high voltage to quickly accelerate them from rest to very high velocity.

(iii) X-rays are produced and emitted when the fast-moving electrons hit part B. **(4)**

(iv) The anode target may be made from tungsten or titanium (or any other high-melting-point metal). **(6)**

TIP: All the questions that follow the introduction are only asking you to elaborate on the previous answers about the parts of X-ray production.

(v) Choose any one from the following:
- Use a lead protection barrier.
- Wear lead-lined clothing or aprons.
- Restrict access to X-ray area.
- Limit the number of X-rays a person is exposed to in a certain timeframe. **(4)**

11. (a) Radioactivity is the spontaneous decay of radioactive nuclei with the emission of alpha, beta or gamma radiation. **(8 × 7)**

(b) Radon originates from the decay of uranium in the soil and rocks.

(c) The GM tube (Geiger–Müller tube) can be used for ionisation or the solid state detector can also be used.

(d) Radon can enter buildings through the floor or cracks/gaps in the building.

(e) Radon only becomes dangerous when it is highly concentrated. Therefore, by having good ventilation, sealing cracks/gaps or having a radon barrier membrane to stop the radon entering a building, you can reduce the amount of radon in that building.

(f) Radon can cause damage to the lungs and tissue and eventually lead to cancer.

(g) Once radon is diluted, it is not as dangerous.

(h) Choose any one from the following:
- Radium
- Plutonium
- Uranium
- Carbon-14

TIP: This type of STS question requires a careful reading of the passage to take all of the information required from it. The remaining information needed to answer the question is based on the topic and does not require long or detailed answers. As long as you make a logical guess, you will gain some marks.

12. (a) The total momentum of a system before an interaction is equal to the total momentum of the system after an interaction, as long as no external force acts on it. **(7)**

TIP: You may also state this as a formula but make sure to explain each variable and what it stands for.

As the gas is expelled one way, the momentum is balanced out by the rocket moving the other way. This is why a rocket fires gas downwards with huge momentum to make it rise upwards with equal momentum. **(6 + 3)**

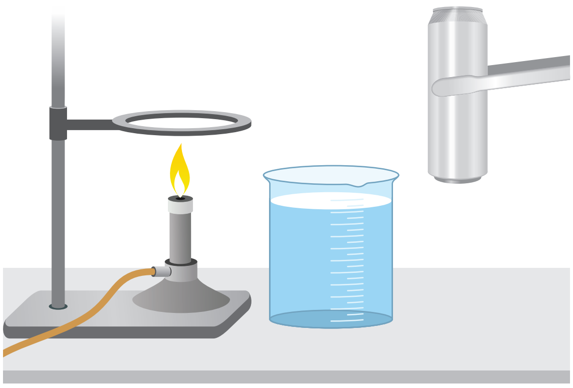
TIP: Because the rocket is of a very large mass, it needs to fire a lot of gas at very high velocity to create a momentum that will force the mass of the rocket up with less velocity. It is for this reason that rockets seem to take off very slowly, as their mass tends to make them move slowly at the start.

(i) Initial momentum: $\rho = mu \Rightarrow \rho = (12\text{kg})(3.5) \Rightarrow \rho = 42\text{kg m.s}^{-1}$ **(6)**

(ii) $42\text{kg m.s}^{-1} = (m_1 + m_2)v \Rightarrow 42 = (12\text{kg} + 12\text{kg})v \Rightarrow 42 = 24v \Rightarrow 42/24 = v \Rightarrow 1.75\text{m.s}^{-1} = v$ **(6)**

TIP: Because trolley B was at rest, all of the momentum from trolley A has to equal the momentum of trolley A and B when they move off together. This is because the momentum before must equal the momentum afterwards. Therefore 42 (momentum before) = 24*v* (mass × velocity afterwards).

(b) (i) Pressure is the force per unit area. **(6)**



TIP: You may define pressure as a formula: $P = F/A$ but you must explain the notation as well.

Fig. 12.1

1. Place a small amount of water in an empty clean aluminium can (see Fig. 12.1).
2. Carefully heat the can over a Bunsen burner, using tongs and making sure the top opening is unobstructed.
3. When you hear the water boiling and see steam, remove the can from the heat.
4. Immediately invert the can in a beaker of cold water.
5. The water seals the can. The absence of air inside the can is unable to counteract the atmospheric pressure pushing from the outside.
6. The can immediately collapses. **(2 × 3 + 2)**

TIP: You may describe any other experiment to show atmospheric pressure, such as a card over a glass of water and then invert it. A diagram is not required here but it may help your explanation.

(ii) Boyle's Law states that the volume of a fixed mass of gas is inversely proportional to its pressure, as long as the temperature is constant. **(6)**

$P_1V_1 = P_2V_2 \Rightarrow (1000)(2) = (500)(V_2) \Rightarrow 2000 = 500V_2 \Rightarrow 2000/500 = V_2 \Rightarrow 4\text{m}^3 = V_2$ **(6)**

TIP: There is another way of showing Boyle's Law. Since the temperature is constant, we can say that as volume goes up, pressure will drop proportionally. Therefore, by getting the product of pressure by volume before (P_1V_1), we can let it equal the product of pressure by volume at the end (P_2V_2). Then it is just a matter of finding the missing volume (V_2). Another way of looking at it is to see how much the pressure changed and getting the reciprocal of this change for volume. i.e. pressure halved. Therefore, volume doubles.

The balloon will continue to increase in volume as pressure lowers until it bursts. **(2)**

(c) Ohm's Law states that the ratio of current to voltage in a metallic conductor is constant, so long as temperature is constant. **(6)**

TIP: You may also use $V=IR$ or $V \propto I$, but explain the letters as well.

(i) Total resistance: $R_{tot} = R_1 + R_2 \Rightarrow R_{tot} = (3\Omega) + (6\Omega) \Rightarrow R_{tot} = 12\Omega$ **(6)**

TIP: Resistors in series are just added to get the total resistance in the circuit.

(ii) $V = IR \Rightarrow V/R = I \Rightarrow 6V/12\Omega = I \Rightarrow 0.5A = I$ **(6)**

TIP: Because Ohm's Law was asked for at the beginning of the question, it should still be fresh in your mind here for this part.

(iii) $V = IR \Rightarrow V = (0.5A)(9\Omega) \Rightarrow V = 4.5V$ **(6)**

TIP: This is another use of Ohm's Law, but be careful and only work out the voltage (potential difference) through the single resistor of 9Ω.

A voltmeter or multimeter set for voltage is used to measure voltage. **(4)**

(d) Electromagnetic induction occurs when a changing magnetic field induces an emf, which, in turn, produces a current. **(6 + 4)**

(i) A = Soft iron core **(3)**

TIP: You may also mention how it is a laminated core or 'former'.

B = Primary coil **(3)**

TIP: You may also call this primary coil the input coil.

(ii) $$\frac{V_i}{V_o} = \frac{N_p}{N_s} \Rightarrow \frac{230}{V_o} = \frac{4600}{120} \Rightarrow \frac{(230)(4600)}{120} = V_o \Rightarrow 6V = V_o$$ **(6)**

TIP: By allowing the ratio of (input voltage to output voltage) to equal the ratio of (primary turns to secondary turns), you can substitute in all the figures you have and calculate the missing value for output voltage. It is a good idea to write all the figures you have first and then substitute them in.

(iii) Choose one from the following:

- Mobile phone charger
- Microwave
- TV
- Domestic electricity transformers **(6)**