Cambridge Assessment International Education

Example Responses – Paper 2

Cambridge International AS & A Level Physics 9702

For examination from 2022

Cambridge Pathway

Contents

Introduction

The main aim of this booklet is to exemplify standards for those teaching Cambridge International AS & A Level Physics 9702.

This booklet contains responses to all questions from June 2022 Paper 22, which have been written by a Cambridge examiner. Responses are accompanied by a brief commentary highlighting common errors and misconceptions where they are relevant.

The question papers and mark schemes are available to download from the School Support Hub.

9702 June 2022 Question Paper 22

9702 June 2022 Mark Scheme 22

Past exam resources and other teaching and learning resources are available from the School Support Hub.

Question 1

1 (a) In the following list, underline all units that are SI base units.

<u>ampere</u>   degree Celsius   <u>kilogram</u>   newton   [1]

Examiner comment

Candidates were expected to underline the SI base units in the list and avoid any other method of indication such as ringing or ticking.

(b) Fig. 1.1 shows a horizontal beam clamped at one end with a block attached to the other end.

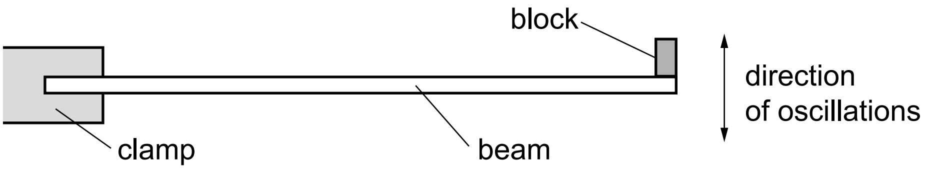

Fig. 1.1

The block is made to oscillate vertically.

The Young modulus E of the material of the beam is given by

$$E = \frac{kM}{T^2}$$

where M is the mass of the block,
T is the period of the oscillations
and k is a constant.

A student determines the values and percentage uncertainties of k, M and T.
Table 1.1 lists the percentage uncertainties.

Table 1.1

quantity	percentage uncertainty
k	±2.1%
M	±0.6%
T	±1.5%

The student uses the values of k, M and T to calculate the value of E as 8.245×10^9 Pa.

(i) Calculate the percentage uncertainty in the value of *E*.

percentage uncertainty in E = 2.1% + 0.6% + (1.5% × 2)

percentage uncertainty = 5.7 % [2]

Examiner comment

- Candidates needed to remember to double the percentage uncertainty in the period of the oscillations.
- Some candidates confused the percentage uncertainty with the absolute uncertainty.

(ii) Use your answer in **(b)(i)** to determine the value of *E*, with its absolute uncertainty, to an appropriate number of significant figures.

absolute uncertainty in E = (5.7 / 100) × 8.245 × 10^9 = 4.7 × 10^8 Pa

E = (8.2 ± 0.5) × 10^9 Pa [2]

Examiner comment

- Candidates who confused percentage uncertainty with fractional uncertainty tended to introduce a power of ten error into the value of the absolute uncertainty.
- The final answer was sometimes expressed incorrectly. Only the strongest responses realised that the answer inside the brackets on the answer line needed to have the value of *E* expressed to a number of decimal places that is consistent with the absolute uncertainty.

Question 2

2 A sphere is attached by a metal wire to the horizontal surface at the bottom of a river, as shown in Fig. 2.1.

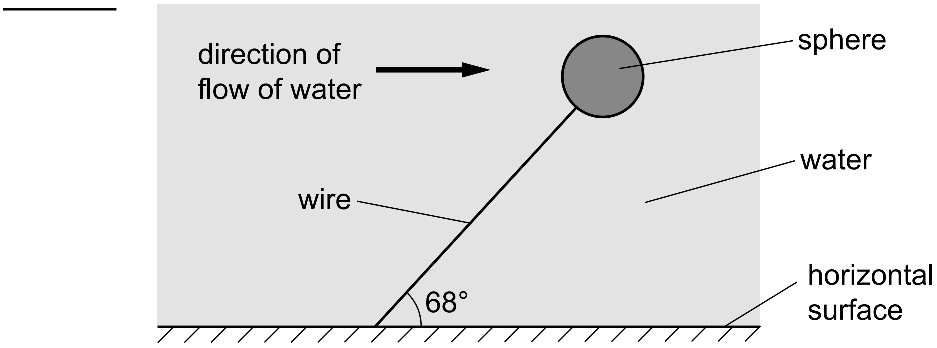

Fig. 2.1 (not to scale)

The sphere is fully submerged and in equilibrium, with the wire at an angle of 68° to the horizontal surface. The weight of the sphere is 32 N. The upthrust acting on the sphere is 280 N. The density of the water is $1.0 \times 10^3\,\text{kg}\,\text{m}^{-3}$.

Assume that the force on the sphere due to the water flow is in a horizontal direction.

(a) By considering the components of force in the vertical direction, determine the tension in the wire.

Considering the components in the vertical direction of the forces on the sphere:

$T \sin 68° + 32 = 280$ where T is the tension in the wire

$T = (280 - 32) / \sin 68°$

tension = ...*270*...... N [2]

Examiner comment

A common mistake was to use cos 68 ° instead of sin 68 ° or to completely omit sin 68° from the calculation.

(b) For the sphere, calculate:

(i) the volume

$F = \rho g V$ where F is the upthrust acting on the sphere

$V = 280 / (1.0 \times 10^3 \times 9.81)$

volume = ...0.029.... m^3 [1]

Examiner comment

- Most candidates realised that they should use the symbol formula that is listed on the Formulae Sheet at the front of the examination paper.
- A common mistake was to substitute the weight of the sphere instead of the upthrust acting on the sphere.
- Some candidates rounded their final answer to one significant figure (0.03 m^3) instead of expressing it to two significant figures.

(ii) the density.

$\rho = m / V$ and $m = W / g$

so $\rho = (32 / 9.81) / 0.029$

density = ...110.... $kg\,m^{-3}$ [2]

Examiner comment

Some candidates confused the mass of the sphere with its weight.

(c) The centre of the sphere is initially at a height of 6.2 m above the horizontal surface. The speed of the water then increases, causing the sphere to move to a different position. This movement of the sphere causes its gravitational potential energy to decrease by 77 J.

Calculate the final height of the centre of the sphere above the horizontal surface.

$\Delta E_p = W \times \Delta h$

$\Delta h = -77 / 32 = -2.4$

$h = 6.2 - 2.4$

height = ...3.8...................................... m [3]

Examiner comment

- Almost all candidates could recall the relevant symbol formula for the change in gravitational potential energy.
- Some candidates confused the weight of the sphere with its mass.
- Less successful responses often gave the change in height as their final answer.
- A significant number of candidates made the mistake of adding the change in height of the sphere to the original height.

(d) The extension of the wire increases when the sphere changes position as described in **(c)**. The wire obeys Hooke's law.

(i) State a symbol equation that gives the relationship between the tension *T* in the wire and its extension *x*. Identify any other symbol that you use.

$T = k\,x$, where k is a constant ....

.... [1]

Examiner comment

- It was essential that the stated equation contained the symbols *T* and *x*.
- Candidates needed to remember to identify the symbol *k*.

(ii) Before the sphere changed position, the initial elastic potential energy of the wire was 0.65 J. The change in position of the sphere causes the extension of the wire to double.

Calculate the final elastic potential energy of the wire after the sphere has changed position.

$E_p = ½kx^2$ where k is a constant

so (final E_p/initial E_p) = (final x/initial x)^2

final $E_p = 0.65 \times 2^2$

final elastic potential energy = 2.6 J [2]

Examiner comment

A common misconception was that doubling the extension of the wire would double, instead of quadruple, its elastic potential energy. This misconception stemmed from the incorrect assumption that $E_p \alpha$ x because $E_p = ½Fx$. This wrongly assumed that the tension of the wire remains constant as the extension doubles, when in fact the tension also doubles.

Question 3

3 A man standing on a wall throws a small ball vertically upwards with a velocity of 5.6 m s^{-1}. The ball leaves his hand when it is at a height of 3.1 m above the ground, as shown in Fig. 3.1.

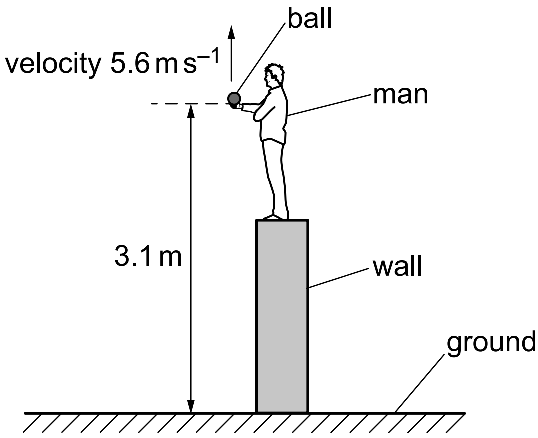

Fig. 3.1 (not to scale)

Assume that air resistance is negligible.

(a) Show that the ball reaches a maximum height above the ground of 4.7 m.

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

Taking upwards direction as positive:

$u = +5.6$, $a = -9.81$ and s is the displacement of the ball at maximum height where $v = 0$

$0^2 = 5.6^2 + (2 \times -9.81 \times s)$

$s = 1.6$

maximum height = 3.1 + 1.6 = 4.7 m [2]

Examiner comment

- This question used the command word ‘show’. Questions that use this command word require the candidate to explicitly present each interim step of the calculation. The subject of any equation must be explicitly stated and the substitution of all values must be clearly shown. When an equation was rearranged, candidates needed to remember to give the new subject of the equation.
- Candidates needed to choose either the upwards or downwards direction as positive and then ensure that each value in the equation had the appropriate sign.
- Some candidates successfully used an alternative method to find the displacement of the ball. They first calculated the time taken for the ball to move to its maximum height. They were then able to substitute the value of this time into an alternative equation representing uniform acceleration.

(b) The man does not catch the ball as it falls.

Calculate the time taken for the ball to fall from its maximum height to the ground.

$s = ut + \frac{1}{2}at^2$

Taking downwards direction as positive:

$s = +4.7$, $a = +9.81$, $u = 0$ and t is the time taken for the ball to fall to the ground from max height.

$4.7 = (0 \times t) + (\frac{1}{2} \times 9.81 \times t^2)$

time taken = 0.98 s [2]

Examiner comment

- Some candidates successfully used an alternative method to determine the answer. They first calculated the final velocity of the ball as it hit the ground. They were then able to substitute this value of the final velocity into an alternative equation representing uniform acceleration.
- A common error was to assume that the ball had a velocity of $5.6\,m\,s^{-1}$ at its maximum height.
- In general, candidates should use $g = 9.81\,m\,s^{-2}$ in their calculations and avoid using $g = 10\,m\,s^{-2}$. Substituting the value of g with only one significant figure can lead to an inaccurate final answer.
- Less successful responses sometimes gave the value of t^2 as their final answer, forgetting that they needed to take the square root of that value to obtain t.

(c) The ball leaves the man's hand at time $t = 0$ and hits the ground at time $t = T$.

On Fig. 3.2, sketch a graph to show the variation of the velocity v of the ball with time t from $t = 0$ to $t = T$. Numerical values of v and t are not required. Assume that v is positive in the upward direction.

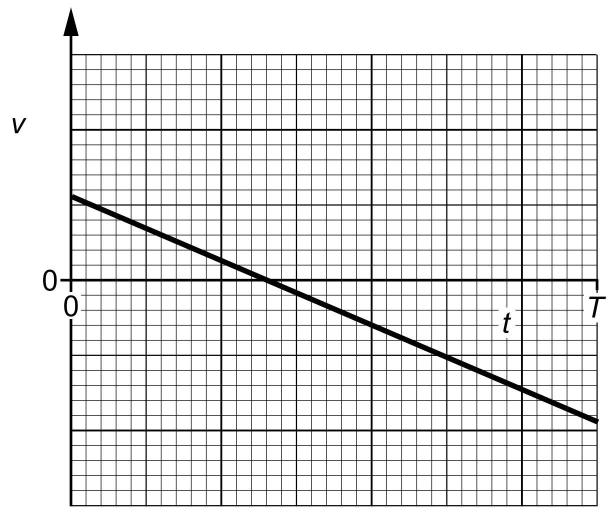

Fig. 3.2

[3]

Examiner comment

- Most candidates realised that the sign of the velocity would change from positive to negative.
- Less successful responses sometimes drew a curved line and did not appreciate that the constant acceleration of the ball meant that the line must have a constant gradient.
- A common mistake was to draw the line with the final speed equal to the initial speed.
- Candidates needed to ensure that the graph line was drawn over the full range of time so that it continued all the way to $t = T$.

(d) State what is represented by the gradient of the graph in **(c)**.

The gradient represents the ball's acceleration which is also the acceleration of free fall. [1]

Examiner comment

It was also acceptable to refer to 'acceleration due to gravity'.

(e) The man now throws a second ball with the same velocity and from the same height as the first ball. The mass of the second ball is greater than that of the first ball. Assume that air resistance is still negligible.

For the first and second balls, compare:

(i) the magnitudes of their accelerations

The balls have equal magnitudes of acceleration. [1]

Examiner comment

- It was generally understood that both objects would fall with the same acceleration due to the absence of air resistance.
- A common misconception was that the second ball would have less acceleration than the first ball (because the second ball has a greater mass).

(ii) the speeds with which they hit the ground.

The balls hit the ground with equal speeds. [1]

[Total: 10]

Examiner comment

A common misconception was that the second ball would hit the ground with a greater speed than the first ball (because the second ball has a greater mass).

Question 4

4 **(a)** State the principle of conservation of momentum.

When no external force acts on a system, the total momentum

remains constant.

.... [2]

Examiner comment

- Candidates needed to refer to the total momentum remaining constant.
- It was acceptable to refer to a closed system or an isolated system instead of no external force acting on the system.
- Some of the less successful responses confused 'momentum' with 'moment'.

(b) Two balls, X and Y, move along a horizontal frictionless surface, as shown from above in Fig. 4.1.

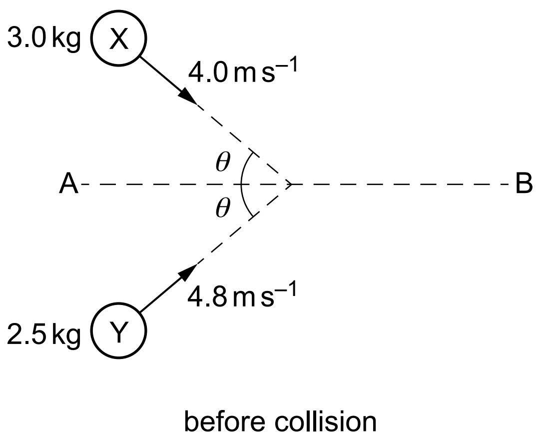

Fig. 4.1 (not to scale)

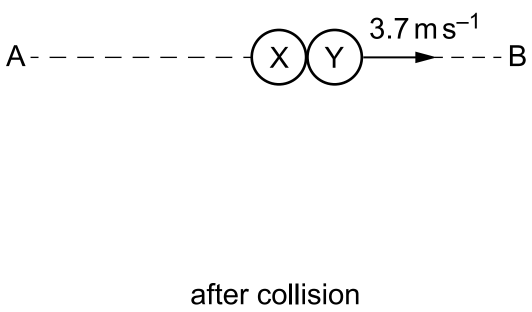

Fig. 4.2 (not to scale)

Ball X has a mass of 3.0 kg and a velocity of 4.0 m s^{-1} in a direction at angle θ to a line AB. Ball Y has a mass of 2.5 kg and a velocity of 4.8 m s^{-1} in a direction at angle θ to the line AB.

The balls collide and stick together. After colliding, the balls have a velocity of 3.7 m s^{-1} along the line AB on the horizontal surface, as shown in Fig. 4.2.

(i) By considering the components of the momenta along the line AB, calculate θ.

p = mv

total momentum along line AB before collision = total momentum along line AB after collision

$(3.0 \times 4.0 \times \cos\theta) + (2.5 \times 4.8 \times \cos\theta) = (5.5 \times 3.7)$

θ = ...32...... ° [3]

Examiner comment

- A common mistake was to use sin θ instead of cos θ or to completely omit cos θ from the calculation.
- A small minority of candidates incorrectly believed that the total velocity in the direction of the line AB would be conserved (instead of the total momentum).

(ii) By calculation of kinetic energies, state and explain whether the collision of the balls is inelastic or perfectly elastic.

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

total EK before the collision $= (\frac{1}{2} \times 3.0 \times 4.0^2) + (\frac{1}{2} \times 2.5 \times 4.8^2) =$ *53 J*

total EK after the collision $= \frac{1}{2} \times 5.5 \times 3.7^2 = 38$ *J*

the total EK after the collision is less than the total EK before the collision and so it is an inelastic collision. [2]

[Total: 7]

Examiner comment

- Most candidates were able to calculate the total kinetic energy after the collision.
- A common mistake was to calculate the initial kinetic energies of the balls by using the components of the velocities in the direction of the line AB (instead of by using the 'full' velocities).

Question 5

5 Light from a laser is used to produce an interference pattern on a screen, as shown in Fig. 5.1.

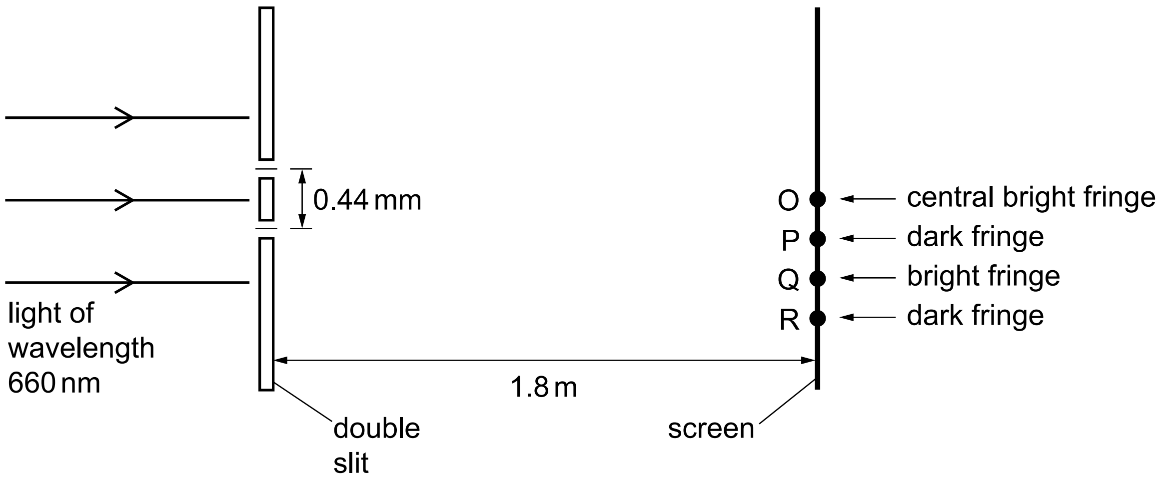

Fig. 5.1 (not to scale)

The light of wavelength 660 nm is incident normally on two slits that have a separation of 0.44 mm. The double slit is parallel to the screen. The perpendicular distance between the double slit and the screen is 1.8 m.

The central bright fringe on the screen is formed at point O. The next dark fringe below point O is formed at point P. The next bright fringe and the next dark fringe below point P are formed at points Q and R respectively.

(a) The light waves from the two slits are coherent.

State what is meant by coherent.

The waves have a constant phase difference. ....

.... [1]

Examiner comment

- It was insufficient to state only that the waves have a constant frequency.
- Some candidates inappropriately stated that the waves have the 'same phase difference'. This wrongly implies that the phase difference is a property of each of the waves (rather than something that is derived from a comparison of the two waves).

(b) For the two light waves superposing at R, calculate:

(i) the difference in their path lengths, in nm, from the slits

path difference = 1.5λ

= 1.5 × 660 nm

path difference = 990 nm [1]

Examiner comment

- It was incorrect to give a final answer of 9.9×10^{-7} m because the question contained a specific instruction to give the path difference in units of nm.
- A common incorrect answer was 330 nm.
- Some of the less successful responses thought that they were being asked to calculate the separation of the fringes on the screen.

(ii) their phase difference.

phase difference = 1.5 × 360°

phase difference = 540 ° [1]

Examiner comment

It was also acceptable to give the phase difference as 180º.

(c) Calculate the distance OQ.

$\lambda = ax / D$

$x = (660 \times 10^{-9} \times 1.8) / 0.44 \times 10^{-3}$

distance OQ = 2.7×10^{-3} m [3]

Examiner comment

- The symbol equation was recalled correctly by the vast majority of the candidates.
- Candidates needed to ensure that each numerical value had the correct power of ten when it was substituted into the symbol equation. Sometimes candidates struggled converting nm to m.
- A common mistake was to think that the symbol x in the equation represented the distance between adjacent bright and dark fringes. This mistake caused candidates to give an incorrect final answer of 5.4×10^{-3} m.

(d) The intensity of the light incident on the double slit is increased without changing the frequency.

Describe how the appearance of the fringes after this change is different from, and similar to, their appearance before the change.

After the intensity of the light incident on the double slit is increased, the bright fringes will appear brighter. There will be no change to the dark fringes. The fringe separation will also be unchanged.

[3]

Examiner comment

- The candidates were asked only to compare the appearance of the fringes before and after the increase in the intensity of the incident light on the double slit. Therefore, they were not required to explain the reasons for any differences or similarities.
- Most candidates realised that the bright fringes would get brighter. A common misconception was that the dark fringes would become darker. Candidates sometimes vaguely referred only to ‘fringes’ without making explicit reference to either ‘bright fringes’ or ‘dark fringes’.
- Some candidates did not realise that a full comparison of the appearance of the fringes included describing things that have stayed the same as well as things that have changed. Only the more successful responses stated that there would be no change to the fringe separation.

(e) The light of wavelength 660 nm is now replaced by blue light from a laser.

State and explain the change, if any, that must be made to the separation of the two slits so that the fringe separation on the screen is the same as it was for light of wavelength 660 nm.

The wavelength of blue light is shorter than 660 nm. When the fringe separation remains constant, the wavelength of the light is proportional to the slit separation. Therefore, the separation of the two slits must be decreased.

[2]

[Total: 11]

Examiner comment

Some candidates stated the change to the slit separation without giving a supporting explanation. It was important not to overlook the command word ‘explain’ given in the question.

Question 6

6 **(a)** A network of three resistors of resistances R_1, R_2 and R_3 is shown in Fig. 6.1.

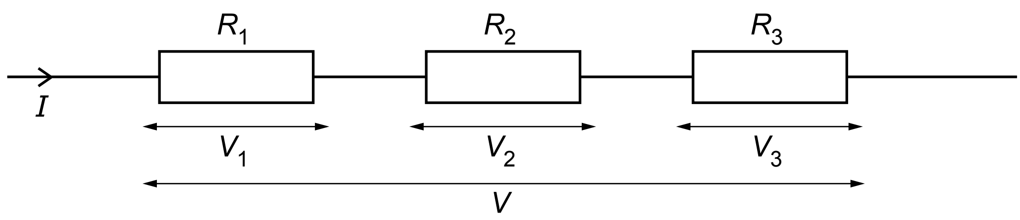

Fig. 6.1

The individual potential differences across the resistors are V_1, V_2 and V_3. The current in the combination of resistors is I and the total potential difference across the combination is V.

Show that the combined resistance R of the network is given by

$$R = R_1 + R_2 + R_3.$$

$V = V_1 + V_2 + V_3$

$V = IR$ and I is the same for all three resistors

$IR = IR_1 + IR_2 + IR_3$

divide each term by I

$R = R_1 + R_2 + R_3$

[2]

Examiner comment

- This question used the command word ‘show’. Therefore, candidates needed to explicitly show all the interim steps in the derivation in a logical order. The subject of any interim equation needed to be explicitly stated.
- The most common mistake was to omit the first step of equating the sum of the individual potential differences to the total potential difference across the combination of resistors.

(b) A battery of electromotive force (e.m.f.) 8.0 V and negligible internal resistance is connected to a thermistor, a switch X and two fixed resistors, as shown in Fig. 6.2.

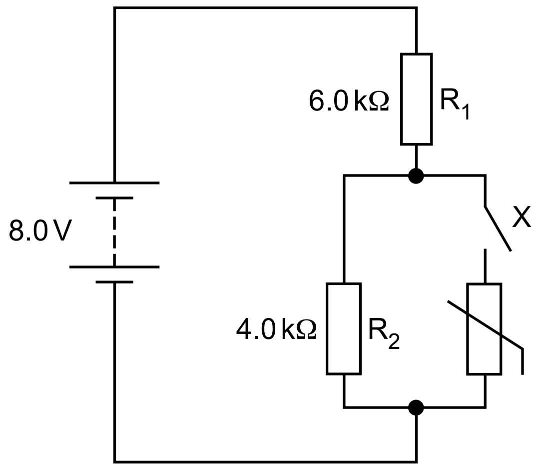

Fig. 6.2

Resistor R_1 has resistance 6.0 kΩ and resistor R_2 has resistance 4.0 kΩ.

(i) Switch X is open.

Calculate the potential difference across R_1.

Let I be the current in R_1

$I = 8.0 / (4.0 \times 10^3 + 6.0 \times 10^3) = 8.0 \times 10^{-4}$

$V = 8.0 \times 10^{-4} \times 6.0 \times 10^3$

potential difference = 4.8 V [2]

Examiner comment

The vast majority of candidates found this to be a straightforward calculation.

(ii) Switch X is now closed. The resistance of the thermistor is 12.0 kΩ.

Calculate the current in the battery.

For the thermistor in parallel with R_2, let the total resistance be R

$(1 / R) = (1 / 4.0 \times 10^3) + (1 / 12.0 \times 10^3)$

$R = 3.0 \times 10^3$

current in battery = $8.0 / (3.0 \times 10^3 + 6.0 \times 10^3)$

current = 8.9×10^{-4} A [2]

Examiner comment

- Candidates needed to ensure that they converted the units of the resistances from kΩ to Ω to avoid the introduction of a power of ten error.
- Some candidates attempted to use the formula for calculating the combined resistance of two resistors in parallel, but then forgot to invert the value for 1/*R* at the end of that part of the calculation.

(c) The switch X in the circuit in **(b)** remains closed. The temperature of the thermistor decreases.

By reference to the current in the battery, state and explain the effect, if any, of the decrease in temperature on the power produced by the battery.

As the temperature decreases, the resistance of the thermistor increases. This causes the total resistance of the whole circuit to increase. Therefore, the current in the battery decreases. The electromotive force (e.m.f.) of the battery is constant and so the power produced by the battery is proportional to the current in it. Therefore, the power produced by the battery decreases. [3]

[Total: 9]

Examiner comment

- Most candidates knew that the resistance of the thermistor would increase. Candidates needed to be clear which resistances they were referring to in their explanations. A vague reference to 'resistance' could mean the resistance of the thermistor, the resistance of a fixed resistor, the combined resistance of the resistors in parallel or the total resistance of the entire circuit.
- Some candidates did not comment on the current in the battery even though the question specifically instructed the candidates to refer to that current in their explanations.

Question 7

7 **(a)** A nucleus of caesium-137 ($^{137}_{55}Cs$) decays by emitting a β^- particle to produce a nucleus of an element X and an antineutrino. The decay is represented by

$$^{137}_{55}Cs \rightarrow {}^{Q}_{S}X + {}^{P}_{R}\beta^- + {}^{0}_{0}\overline{\nu}.$$

(i) State the number represented by each of the following letters.

P ....0........

Q ....137........

R ....−1........

S ....56........

[2]

Examiner comment

- Most candidates realised that the nucleon number would be conserved for the decay process and so the numbers for P and Q were usually given correctly.
- Some of the weaker candidates were unable to recall the number for R and were therefore unable to determine the number for S.

(ii) State the name of the class (group) of particles that includes the β^- particle and the antineutrino.

..Leptons.. [1]

Examiner comment

An answer of ‘fundamental particles’ was accepted although this is a less specific answer.

(b) A particle Y has a quark composition of ddd where d represents a down quark.

A particle Z has a quark composition of $\bar{u}$d where $\bar{u}$ represents an up antiquark.

(i) Show that the charges of particles Y and Z are equal.

$\bar{u}$ has a charge of $-^2/_3$ e and d has a charge of $^1/_3$ e, where e is the elementary charge

charge of particle Y = $(-^1/_3 e) + (-^1/_3 e) + (-^1/_3 e) = -1 e$

charge of particle Z = $(-^1/_3 e) + (-^2/_3 e) = -1 e$

The change of particle Y is equal to the charge of particle Z as both have a charge of -1 e

[2]

Examiner comment

The question used the command word 'show', so it was essential that the candidates clearly and explicitly presented all the steps of their working in a logical order.

(ii) State and explain which particle is a meson and which particle is a baryon.

meson: Particle Z because it consists of a quark and an antiquark.

baryon: Particle Y because it consists of three quarks.

[2]

[Total: 7]

Examiner comment

- Some candidates identified which particle was a meson and which was a baryon, but did not give the required supporting explanations.
- Other candidates gave a general description of a meson and of a baryon, but did not explicitly state which group Y or Z belonged to.
- A common misconception was that a baryon can only contain three quarks that are the same type.

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