Cambridge Assessment International Education

Cambridge Pre-U

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

5352538571

PHYSICS **9792/02**

Paper 2 Written Paper **May/June 2022**

2 hours

You must answer on the question paper.

You will need: Insert (enclosed)

INSTRUCTIONS

- Section 1: answer **all** questions.
- Section 2: answer **the** question. The question is based on the material in the insert, which is a copy of the pre-release material.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 100.
- The number of marks for each question or part question is shown in brackets [ ].

This syllabus is regulated for use in England, Wales and Northern Ireland as a Cambridge International Level 3 Pre-U Certificate.

This document has **28** pages. Any blank pages are indicated.

DC (PQ/SG) 302920/3

Data

gravitational field strength close to Earth's surface	$g = 9.81\,\mathrm{N\,kg^{-1}}$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
speed of light in vacuum	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
electron mass	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
proton mass	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
unified atomic mass constant	$u = 1.66 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
Stefan-Boltzmann constant	$\sigma = 5.67 \times 10^{-8}\,\mathrm{W\,m^{-2}\,K^{-4}}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
	$s = \left(\frac{u+v}{2}\right)t$
heating	$\Delta E = mc\Delta\theta$
change of state	$\Delta E = mL$
refraction	$n = \frac{\sin\theta_1}{\sin\theta_2}$
	$n = \frac{v_1}{v_2}$

diffraction

single slit, minima $n\lambda = b \sin\theta$

grating, maxima $n\lambda = d \sin\theta$

double slit interference $\lambda = \frac{ax}{D}$

Rayleigh criterion $\theta \approx \frac{\lambda}{b}$

photon energy $E = hf$

de Broglie wavelength $\lambda = \frac{h}{p}$

simple harmonic motion $x = A\cos\omega t$

$v = -A\omega\sin\omega t$

$a = -A\omega^2\cos\omega t$

$F = -m\omega^2 x$

$E = \frac{1}{2}mA^2\omega^2$

energy stored in a capacitor $W = \frac{1}{2}QV$

capacitor discharge $Q = Q_0 e^{-\frac{t}{RC}}$

electric force $F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$

electrostatic potential energy $W = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r}$

gravitational force $F = -\frac{Gm_1 m_2}{r^2}$

gravitational potential energy $E = -\frac{Gm_1 m_2}{r}$

magnetic force $F = BIl\sin\theta$

$F = BQv\sin\theta$

electromagnetic induction $E = -\frac{d(N\Phi)}{dt}$

Hall effect $V = Bvd$

time dilation $t' = \frac{t}{\sqrt{1-\frac{v^2}{c^2}}}$

length contraction $l' = l\sqrt{1-\frac{v^2}{c^2}}$

kinetic theory $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$

work done on/by a gas $W = p\Delta V$

radioactive decay $\frac{dN}{dt} = -\lambda N$

$N = N_0 e^{-\lambda t}$

$t_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$

attenuation losses $I = I_0 e^{-\mu x}$

mass-energy equivalence $\Delta E = c^2\Delta m$

hydrogen energy levels $E_n = \frac{-13.6\,\text{eV}}{n^2}$

Heisenberg uncertainty principle $\Delta p\Delta x \geqslant \frac{h}{2\pi}$

Wien's displacement law $\lambda_{max} \propto \frac{1}{T}$

Stefan's law $L = 4\pi\sigma r^2 T^4$

electromagnetic radiation from a moving source $\frac{\Delta\lambda}{\lambda} \approx \frac{\Delta f}{f} \approx \frac{v}{c}$

Section 1

You are advised to spend about 1 hour 30 minutes on this section.

1 A uniform rectangular beam has negligible thickness and weight 850 N. Its length is 5.000 m and it is in contact with the top of a support at point P. The middle point of the base of the support is Q. The support acts as a pivot at P.

Fig. 1.1 shows that P is 0.800 m from one end of the beam.

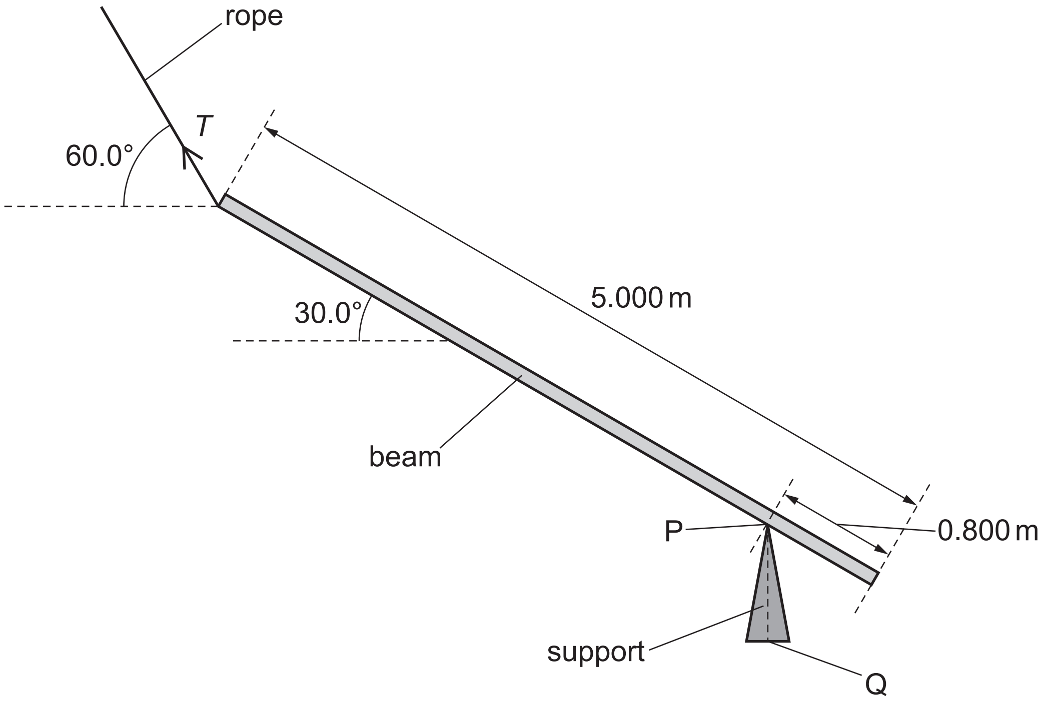

Fig. 1.1 (not to scale)

The beam is held stationary, at an angle of 30.0° to the horizontal, by a rope that is attached to the bottom corner of the other end of the beam.

(a) Calculate the moment of the weight of the beam about point P.

moment = ... N m [2]

(b) The rope is at an angle of 60.0° to the horizontal, as shown in Fig. 1.1.

(i) Show that the perpendicular distance between the line of the rope and P is 2.100 m.

[1]

(ii) Calculate the magnitude of the force T on the beam due to the tension in the rope.

T = ... N [2]

(c) Point Q on the base of the support is vertically below P. The resultant of the weight of the beam and the force on the beam due to the tension in the rope is R.

(i) By drawing, determine the magnitude of R and the angle between R and the vertical line PQ.

magnitude of R = ... N

angle between R and PQ = ... °
[4]

(ii) Hence determine the magnitude of the force exerted by the support on the beam and comment on the direction of this force relative to R.

magnitude of force exerted by the support = ... N

direction of force exerted by support: ....
[1]

[Total: 10]

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2 Copper is a metal that is ductile and tough.

(a) State what is meant by:

(i) ductile

....

.... [1]

(ii) tough.

....

.... [1]

(b) A student is given a piece of copper wire that has a uniform circular cross-section of diameter 3.76×10^{-4} m. The length of the wire is 2.50 m.

The student attaches one end of the wire to the ceiling.

She then suspends a load from the lower end of the wire and measures the extension of the wire.

The extension of the wire remains within the Hooke's law region.

(i) State Hooke's law.

....

.... [1]

(ii) The weight of the load is 1.47 N and the extension of the wire is 0.28 mm.

Calculate the Young modulus of copper.

Young modulus = ... Pa [2]

(iii) Explain, in terms of its microstructure, the behaviour of copper in the region where Hooke's law is obeyed.

....

....

.... [2]

[Total: 7]

3 A capsule containing scientific instruments has a mass of 95.0 kg. At time t = 0, the capsule is dropped from a bridge and it falls vertically downwards through the air and into the sea underneath the bridge.

Fig. 3.1 is the speed–time graph for the capsule.

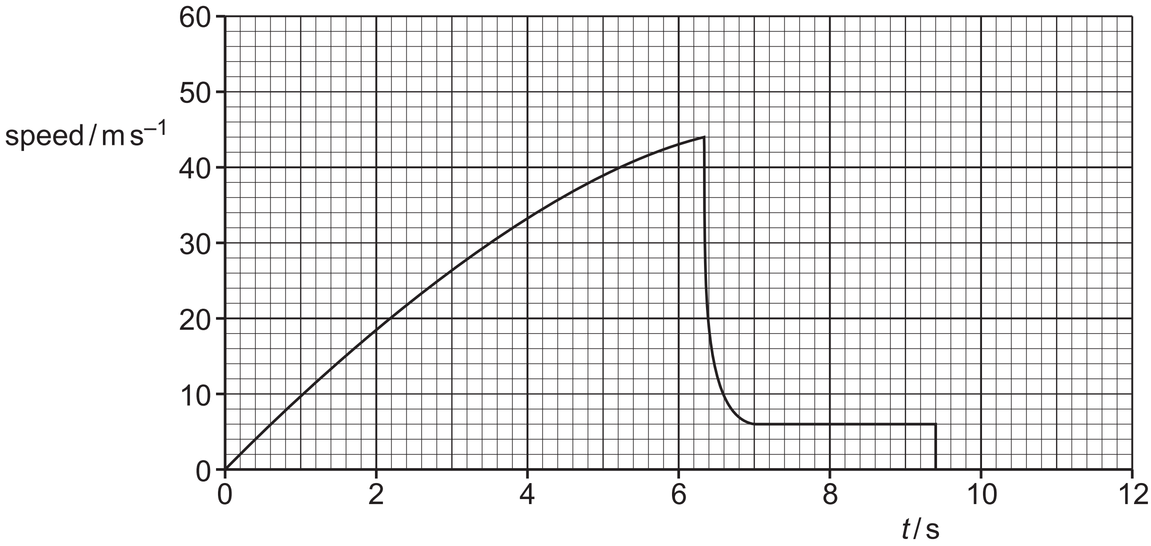

Fig. 3.1

List what can be deduced from this information. Your answer should, where appropriate, include relevant calculations.

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.... [8]

4 During the day, a solar power station uses mirrors to focus solar radiation onto a vessel that contains a molten mixture of chemical salts. The hot molten mixture is a liquid and it is pumped into an insulated storage container.

At sunset, the storage container holds $1.36 \times 10^4\,m^3$ of the molten mixture which has a density of $1.69 \times 10^3\,kg\,m^{-3}$. The specific heat capacity of the molten mixture is $1.52 \times 10^3\,J\,kg^{-1}\,K^{-1}$.

During the night, a heat exchanger is used and thermal energy is transferred from the molten mixture. The temperature of the mixture decreases from 621 °C to 260 °C.

(a) Calculate the thermal energy transferred from the molten mixture during the night.

thermal energy transferred = ... J [2]

(b) The thermal energy transferred is used to power the boiler in a conventional power station. The useful output of the generators in the power station is electrical energy.

The overall efficiency of this stage of the process is 37.6% (0.376).

(i) Define percentage efficiency.

....

.... [1]

(ii) The power station supplies electrical energy to consumers at a constant rate for 8.00 hours.

Calculate the useful output power of the power station.

output power = ... W [2]

(iii) The electrical energy from the power station is transmitted, at a voltage of 275 kV, to a distant town using transmission cables of total resistance 10.4 Ω.

Calculate the rate at which energy is wasted in the transmission cables.

rate of waste of energy = ... $J\,s^{-1}$ [2]

(c) As the molten mixture cools, its density increases. The dimensions of the storage container, which is a vertical cylinder, do not change.

Explain what happens to the pressure due to the molten mixture on the base of the storage container.

....

.... [1]

[Total: 8]

5 A battery of electromotive force (e.m.f.) 18.0 V has an internal resistance of 1.60 Ω.

(a) The battery is connected into a circuit. The terminal potential difference is less than the e.m.f.

(i) State what is meant by potential difference.

....

....

.... [2]

(ii) Explain why the terminal potential difference is less than the e.m.f.

....

....

....

.... [2]

(b) Twelve resistors, each of resistance *R*, are connected into the arrangement shown in Fig. 5.1.

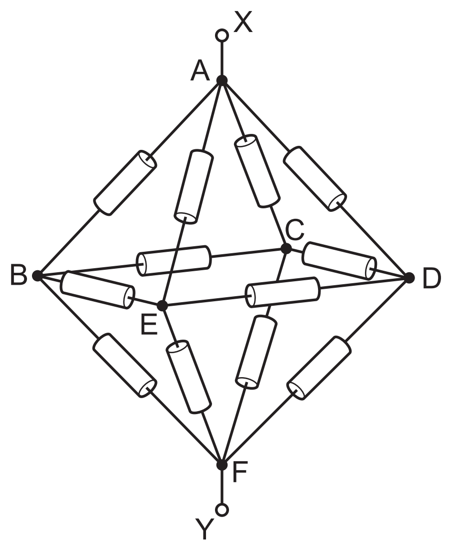

Fig. 5.1

The resistance between terminals X and Y is 13.4 Ω.

(i) Determine the resistance R of a single resistor.

R = ... Ω [3]

(ii) The 18.0 V battery is connected across X and Y in the arrangement of resistors in Fig. 5.1.

Calculate the potential difference between the terminals of the battery.

terminal potential difference = ...V [2]

[Total: 9]

6 Electromagnetic waves can be plane polarised but sound waves cannot.

(a) Explain why electromagnetic waves can be plane polarised.

....

....

.... [2]

(b) Fig. 6.1 shows unpolarised light of intensity I_0 incident, at right angles, on a polarising filter F_1.

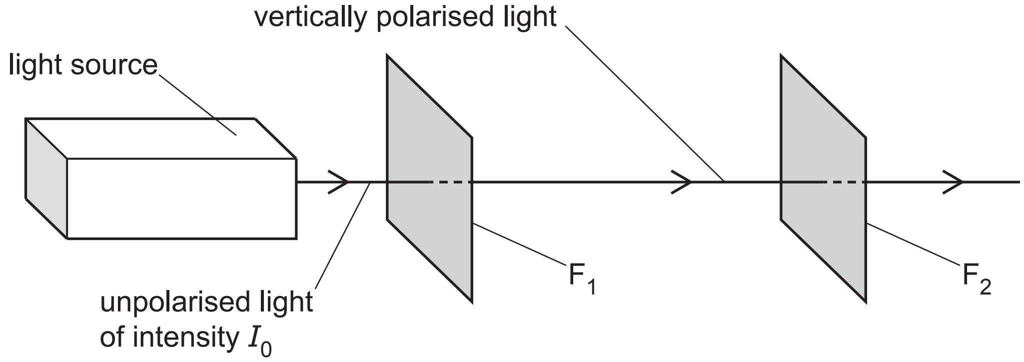

Fig. 6.1

A second polarising filter F_2 is identical to F_1. It is placed parallel to F_1.

The light that emerges from F_1 is completely vertically polarised and strikes F_2 at 90° to its surface.

When F_2 is in this position, the light that emerges from it is equal in intensity to the light that is incident on it.

(i) F_2 is now rotated about an axis perpendicular to its surface, as shown in Fig. 6.2.

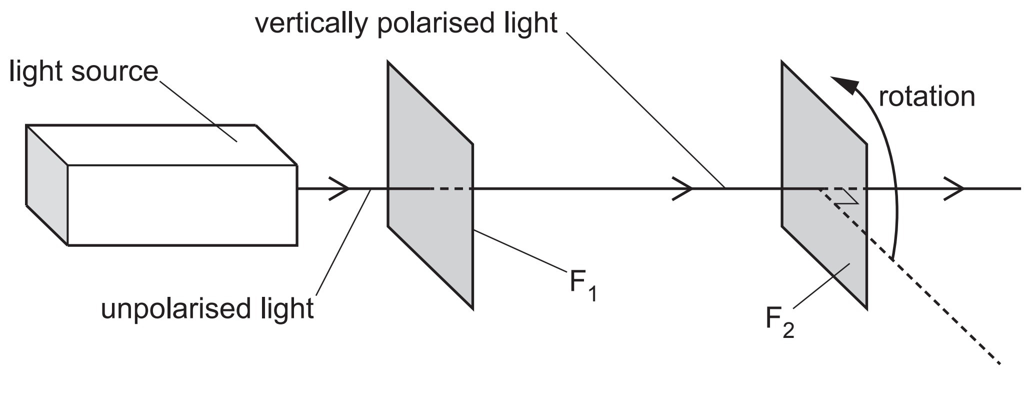

Fig. 6.2

On Fig. 6.3, sketch a graph to show how the intensity of the light emerging from F_2 varies with angle as F_2 is rotated through 360°.

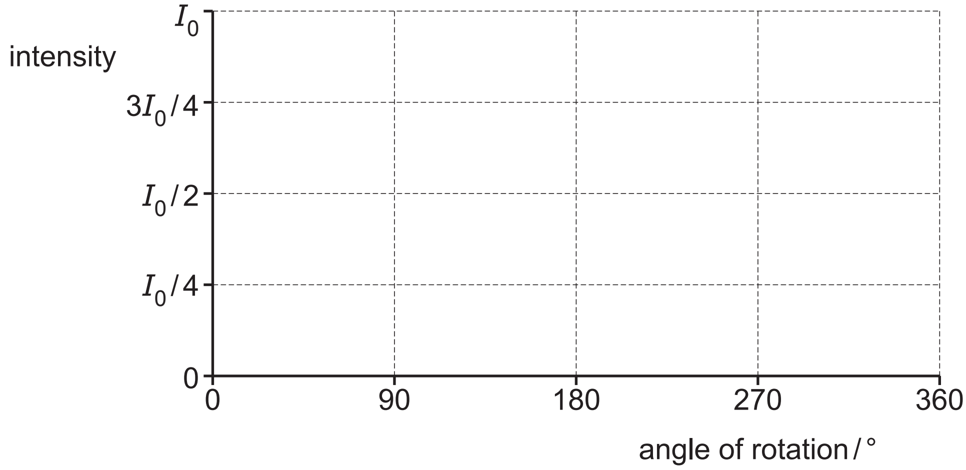

Fig. 6.3

[3]

(ii) F_2 is rotated again until no light emerges from it.

Then, a third identical polarising filter F_3 is placed between F_1 and F_2. Fig. 6.4 shows that F_3 is parallel to both F_1 and F_2.

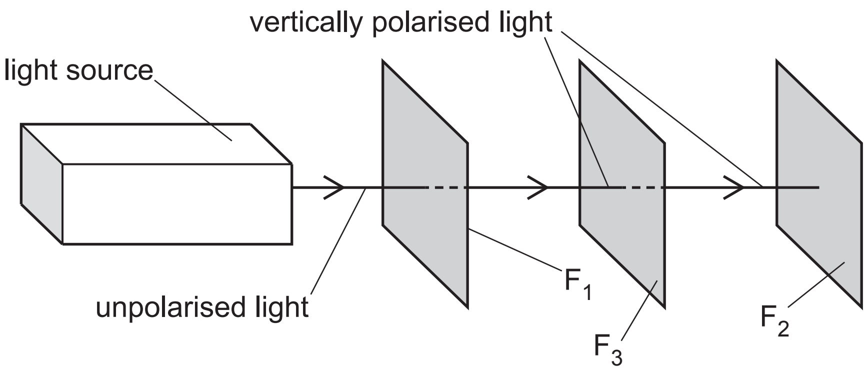

Fig. 6.4

The light that emerges from F_3 is equal in intensity to the light that is incident on it and still no light emerges from F_2.

F_3 is now rotated through 45° about an axis perpendicular to its surface.

Explain why some light now emerges from F_2.

....

....

.... [2]

[Total: 7]

7 A sound wave, travelling in air at a speed of $330\,\mathrm{m\,s^{-1}}$, has a wavelength of 0.600 m.

(a) Sound is a longitudinal wave.

Explain, in terms of air molecules, what is meant by longitudinal.

....

.... [1]

(b) Calculate the frequency of the sound in air.

frequency = ... Hz [2]

(c) Fig. 7.1 shows two loudspeakers, J and K, placed close to each other in an open area.

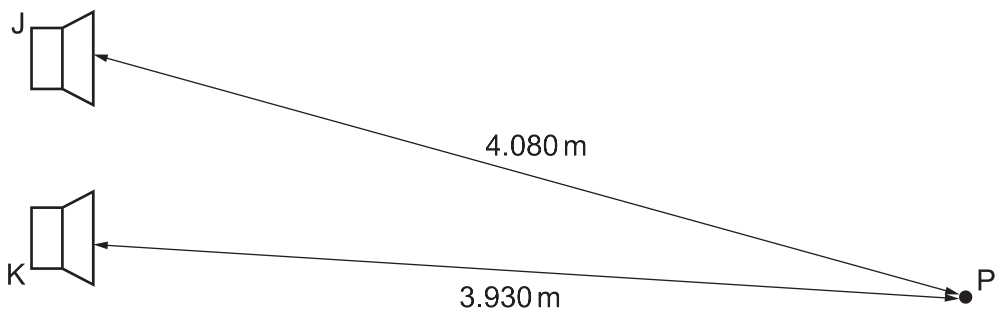

Fig. 7.1 (not to scale)

P is a point that is in front of J and K. The distance from J to P is 4.080 m and the distance from K to P is 3.930 m.

Loudspeakers J and K both produce sound waves of wavelength 0.600 m. The two sound waves are in phase as they leave the loudspeakers.

(i) Explain what is meant by in phase.

....

.... [1]

(ii) Determine, in degrees, the phase difference between the two sound waves at P.

phase difference at P = ...° [3]

(iii) At P, the amplitude of the sound wave from J is 0.0050 Pa and the amplitude of the sound wave from K is 0.0120 Pa. At P, the two waves superpose and produce a combined sound wave.

Using a phasor diagram or otherwise, determine the amplitude of the combined sound wave at P.

amplitude = ... Pa [3]

[Total: 10]

8 Almost all of the mass of an atom is in its nucleus.

(a) It is possible to conclude, from two observations in an experiment, that

- the nucleus has an extremely small volume compared with that of the atom
- the nucleus is electrically charged.

(i) Describe, with the help of a diagram, an experiment in which the two observations are made.

....

....

....

....

.... [3]

(ii) Explain how the observations made in the experiment suggest each of the two conclusions.

....

....

....

.... [2]

(b) In a nuclear reactor, uranium-235 is used as a fuel.

A neutron is absorbed by the nucleus of an atom of uranium-235 ($^{235}_{92}U$) to produce a nucleus of uranium-236. Immediately, the uranium-236 nucleus splits into a nucleus of zirconium-94, a nucleus of tellurium-139 and some neutrons.

(i) Deduce the number of neutrons produced as the uranium-236 nucleus splits.

number of neutrons = ... [1]

(ii) The proton number (atomic number) of zirconium is 40.

Deduce the proton number of tellurium.

proton number of tellurium = ... [1]

(iii) Explain how fission reactions such as this can lead to a chain reaction.

....

....

.... [2]

(iv) The uranium fuel is stored as long, thin rods.

When a stray neutron is absorbed by a uranium-235 nucleus in an isolated fuel rod, a chain reaction does not develop.

Suggest how the shape of the rod prevents a chain reaction.

....

.... [1]

[Total: 10]

9 Fig. 9.1 shows equipment in which a fine beam of high-speed electrons passes through a thin slice of graphite, and strikes a fluorescent screen to produce a pattern of light.

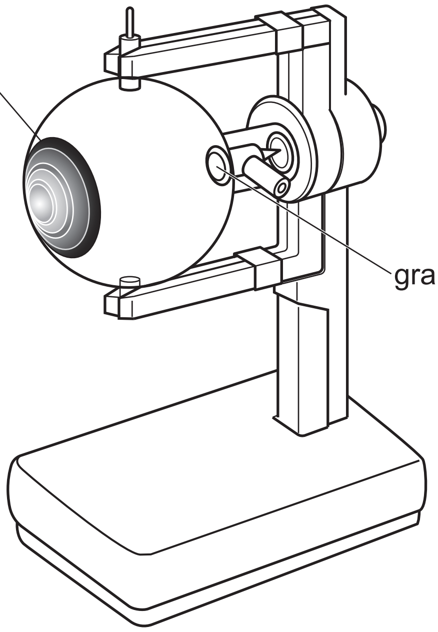

Fig. 9.1

(a) **(i)** State the name of the effect that produces a pattern that is not just a dot at the centre of the screen.

.... [1]

(ii) Some regions of the pattern are dark whilst others are bright.

Explain what this shows about the nature of electrons.

....

....

.... [2]

(b) Describe and explain the effect on the pattern of increasing the speed of the electrons.

....

....

....

.... [3]

[Total: 6]

Section 2

You are advised to spend about 30 minutes on this section.

The questions in this section refer to the pre-release material provided as an insert to the question paper.

Your answers should, where possible, make use of any relevant physics.

10 **(a)** The cloud chamber photograph in Fig. 10.1 shows the first evidence for the existence of the positron.

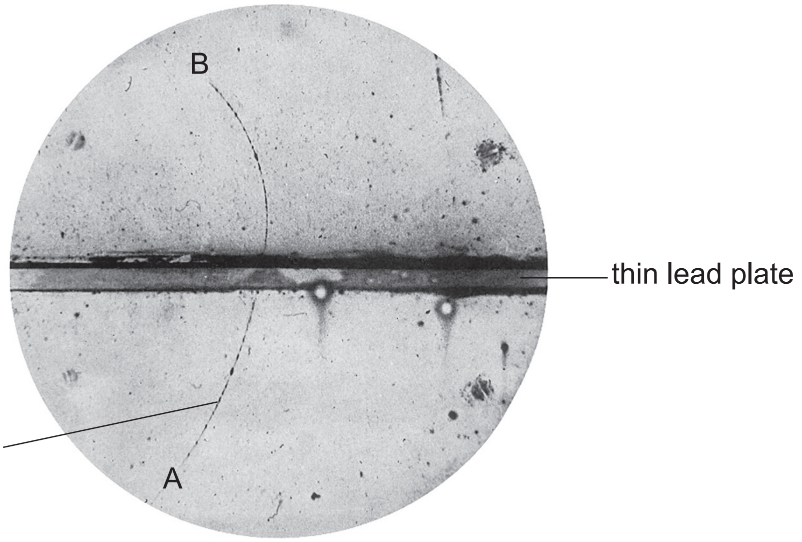

Fig. 10.1

The whole cloud chamber is in a uniform magnetic field at right angles to the plane of the photograph. The track AB is left by a particle passing from A to B through the chamber. The thickness of this track is much less than that produced by an alpha-particle and similar to that produced by a beta-particle.

(i) State how the photograph shows that the particle producing the track AB is electrically charged.

....

.... [1]

(ii) The magnetic field direction is vertically into the plane of the paper.

State how this shows that the particle producing the track AB is a positron, not an electron.

....

.... [1]

(iii) By comparing the track near A with the track near B, explain what happens to the energy of the particle as it passes through the thin lead plate.

....

....

....

....

....

.... [3]

(b) The decay of polonium-210 described in extract 2 produces a daughter nucleus, here called X, and an alpha-particle.

(i) Complete the equation for this decay.

$$^{210}_{84}\text{Po} \longrightarrow \,^{.....}_{.....}\text{X} + \,^{.....}_{.....}.....$$

[2]

(ii) The polonium-210 nucleus is initially stationary. As the alpha-particle is emitted, the nucleus X recoils.

By considering momentum, explain why the magnitude of the recoil velocity (v_X) of this nucleus is less than 2% of the magnitude of the velocity of the alpha-particle (v_α).

....

....

....

.... [2]

(iii) The kinetic energy of the alpha-particle is E_α and the kinetic energy of the nucleus X is E_X.

Show that the ratio $\frac{E_\alpha}{E_X}$ is equal to the ratio of speeds $\frac{v_\alpha}{v_X}$.

[3]

(c) The beta-decay of bismuth-210 was once described by the equation

$$^{210}_{83}\text{Bi} \longrightarrow {}^{210}_{84}\text{Po} + {}^{0}_{-1}\text{e}.$$

(i) Explain how this equation shows that baryon number is conserved.

....

.... [1]

(ii) Explain how conservation of lepton number shows that at least one other particle should feature in the equation.

....

....

....

.... [2]

(iii) Data from Extract 2 suggests that the kinetic energy of alpha-particles is between four and five times greater than the maximum kinetic energy of beta-particles. Despite this, alpha-particles travel much more slowly than beta-particles.

Explain why.

....

....

.... [1]

(d) The antineutrino reaction producing a positron and a neutron described in Extract 3 is shown in Fig. 10.2.

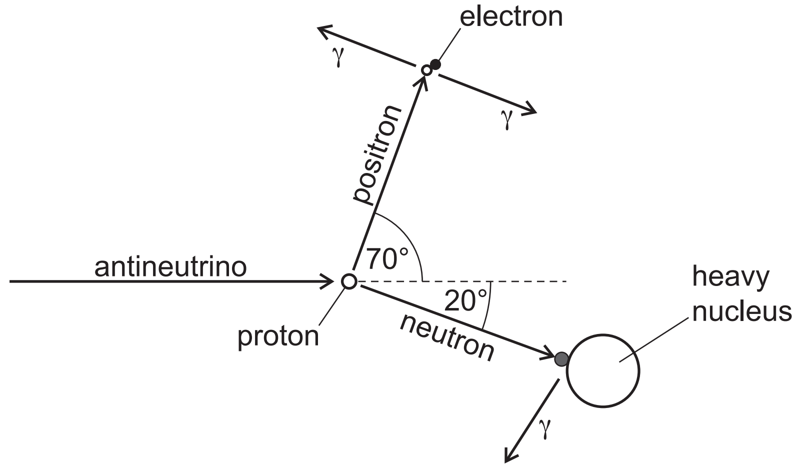

Fig. 10.2 (not to scale)

(i) The positron in Fig. 10.2 is travelling at a speed of $2.2 \times 10^8\,\text{m}\,\text{s}^{-1}$.

mass of positron = 9.11×10^{-31} kg   mass of neutron = 1.67×10^{-27} kg

Use the principle of conservation of momentum to show that the neutron is travelling at approximately $3 \times 10^5\,\text{m}\,\text{s}^{-1}$.

[4]

(ii) Calculate the wavelength λ of each photon emitted in the positron–electron annihilation.

λ = ... m [2]

(e) Extract 4 states that 9.5×10^{12} km of lead would stop half the neutrinos that pass into it.

(i) Neutrino radiation of initial intensity I_0 is reduced to a value I after penetrating a distance x through an absorbing material. I is given by the equation

$$I = I_0 e^{-\mu x}$$

where μ is the absorption coefficient of the material.

The distance through the absorbing material after which the intensity of neutrino radiation is reduced to half of its initial value is $x_{\frac{1}{2}}$.

Show that $x_{\frac{1}{2}}$ is related to the absorption coefficient μ by the equation

$$x_{\frac{1}{2}} = \frac{\ln 2}{\mu}.$$

[2]

(ii) Calculate the absorption coefficient μ for neutrinos in lead.
Express your answer in m^{-1}.

μ = ... m^{-1} [1]

[Total: 25]

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