Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

0123456789

PHYSICS **9702/04**

Paper 4 A Level Structured Questions **For examination from 2022**

SPECIMEN PAPER **2 hours**

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- 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 document has **26** pages. Blank pages are indicated.

Data

acceleration of free fall	$g = 9.81\ \text{m s}^{-2}$
speed of light in free space	$c = 3.00 \times 10^{8}\ \text{m s}^{-1}$
elementary charge	$e = 1.60 \times 10^{-19}\ \text{C}$
unified atomic mass unit	$1\ \text{u} = 1.66 \times 10^{-27}\ \text{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\ \text{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\ \text{kg}$
Avogadro constant	$N_A = 6.02 \times 10^{23}\ \text{mol}^{-1}$
molar gas constant	$R = 8.31\ \text{J K}^{-1}\ \text{mol}^{-1}$
Boltzmann constant	$k = 1.38 \times 10^{-23}\ \text{J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11}\ \text{N m}^{2}\ \text{kg}^{-2}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \text{m F}^{-1})$
Planck constant	$h = 6.63 \times 10^{-34}\ \text{J s}$
Stefan–Boltzmann constant	$\sigma = 5.67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
hydrostatic pressure	$\Delta p = \rho g \Delta h$
upthrust	$F = \rho g V$
Doppler effect for sound waves	$f_o = \frac{f_s v}{v \pm v_s}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$

gravitational potential	$\phi = -\dfrac{GM}{r}$
gravitational potential energy	$E_P = -\dfrac{GMm}{r}$
pressure of an ideal gas	$p = \frac{1}{3}\dfrac{Nm}{V}\langle c^2\rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm\omega\sqrt{(x_0^{\,2} - x^2)}$
electric potential	$V = \dfrac{Q}{4\pi\varepsilon_0 r}$
electrical potential energy	$E_P = \dfrac{Qq}{4\pi\varepsilon_0 r}$
capacitors in series	$\dfrac{1}{C} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
discharge of a capacitor	$x = x_0 e^{-\frac{t}{RC}}$
Hall voltage	$V_H = \dfrac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 e^{-\lambda t}$
decay constant	$\lambda = \dfrac{0.693}{t_{\frac{1}{2}}}$
intensity reflection coefficient	$\dfrac{I_R}{I_0} = \dfrac{(Z_1 - Z_2)^2}{(Z_1 + Z_2)^2}$
Stefan–Boltzmann law	$L = 4\pi\sigma r^2 T^4$
Doppler redshift	$\dfrac{\Delta\lambda}{\lambda} \approx \dfrac{\Delta f}{f} \approx \dfrac{v}{c}$

1 **(a)** Explain how the force(s) on a satellite can result in the satellite being in a circular orbit around a planet.

....

....

.... [2]

(b) The Earth and the Moon may be considered to be uniform spheres that are isolated in space. The Earth has mass M, radius R and mean density ρ. The Moon, mass m, is in a circular orbit about the Earth with radius nR, as illustrated in Fig. 1.1.

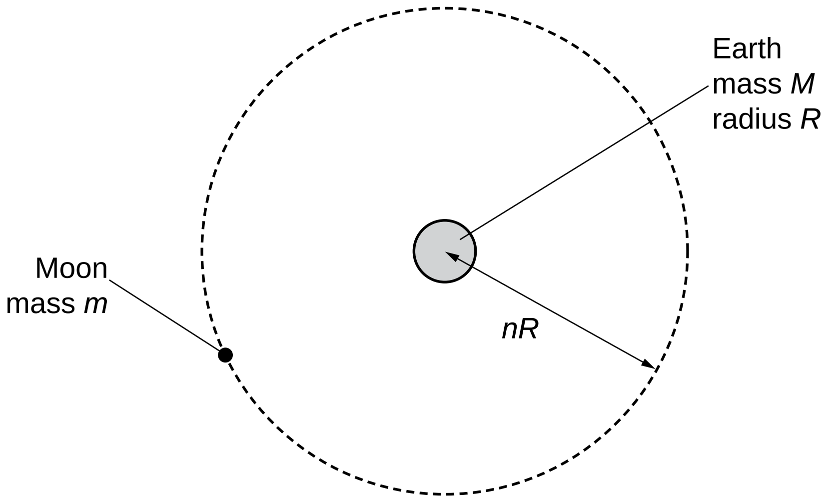

Fig. 1.1

The Moon makes one complete orbit of the Earth in time T.
Show that the mean density ρ of the Earth is given by the expression

$$\rho = \frac{3\pi n^3}{GT^2}$$

where G is the gravitational constant.

[4]

(c) The radius R of the Earth is 6.38×10^6 m and the distance between the centre of the Earth and the centre of the Moon is 3.84×10^8 m.
The period T of the orbit of the Moon about the Earth is 27.3 days.

Use the expression in **(b)** to calculate ρ.

ρ = ... kg m^{-3} [3]

[Total: 9]

2 A cylinder contains 5.12 mol of an ideal gas at pressure 5.60×10^5 Pa and volume 3.80×10^{-2} m^3.

(a) Calculate the thermodynamic temperature of the gas.

temperature = ... K [2]

(b) The average kinetic energy E_K of a molecule of the gas is given by the expression

$$E_K = \frac{3}{2} kT$$

where k is the Boltzmann constant and T is the thermodynamic temperature.

The gas is heated at constant pressure so that its temperature rises by 125 K.

(i) Show that the new volume of the gas is 4.75×10^{-2} m^3.

[1]

(ii) Calculate the increase in internal energy of the gas. Explain your working.

increase in internal energy = ... J [3]

(c) (i) Use the information in **(b)(i)** to calculate the external work done during the expansion of the gas.

work done = ... J [2]

(ii) Use the first law of thermodynamics to determine the total thermal energy transferred to the gas in **(b)**. Explain your reasoning.

energy = ... J [2]

[Total: 10]

3 A bar magnet of mass 250 g is suspended from the free end of a spring, as illustrated in Fig. 3.1.

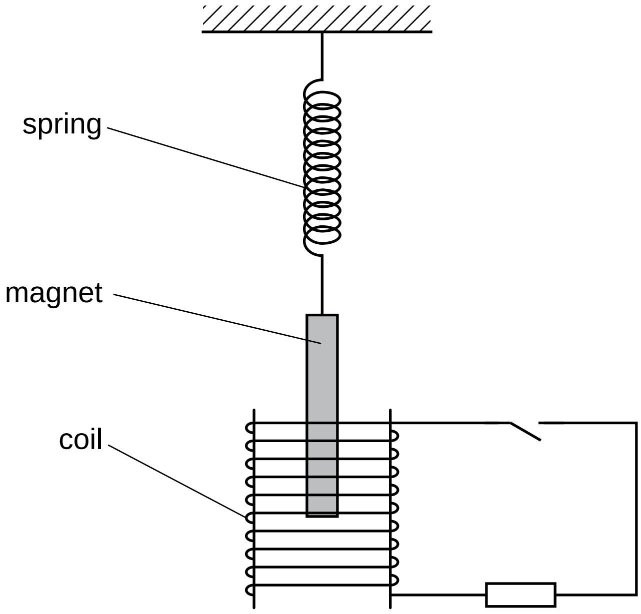

Fig. 3.1

The magnet hangs so that one pole is near the centre of a coil of wire.
The coil is connected in series with a resistor and a switch. The switch is open.

The magnet is displaced vertically and then allowed to oscillate.

At time t = 0, the magnet is oscillating freely. At time t = 6.0 s, the switch in the circuit is closed.

The variation with time t of the vertical displacement y of the magnet is shown in Fig. 3.2.

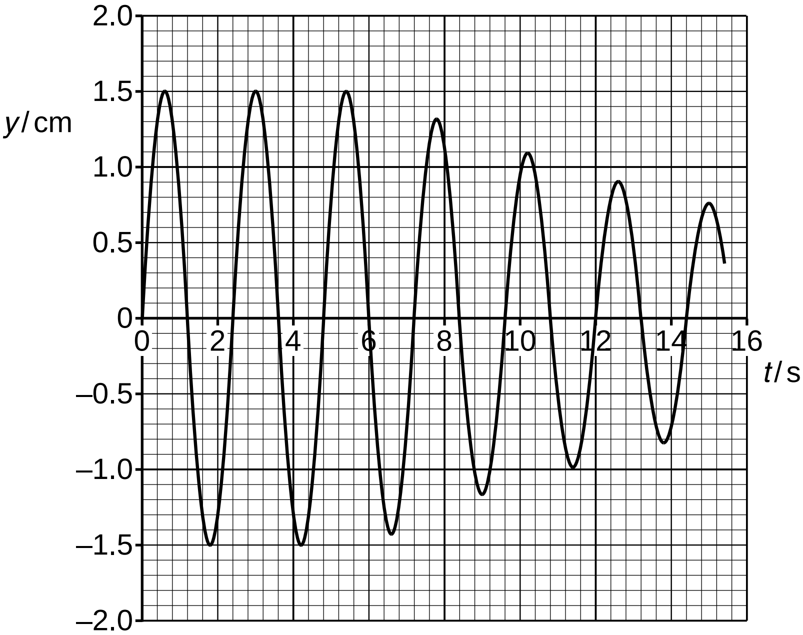

Fig. 3.2

(a) For the oscillating magnet, use data from Fig. 3.2 to determine, to two significant figures:

(i) the frequency f

f = ... Hz [2]

(ii) the energy of the oscillations during the time interval t = 0 to t = 6.0 s.

energy = ... J [3]

(b) When the switch is closed, the oscillations are damped.

Explain, with reference to Fig. 3.2, whether this damping is light, critical or heavy.

....

....

.... [1]

[Total: 6]

4 **(a)** State Coulomb's law.

....

....

.... [2]

(b) Two charged metal spheres A and B are situated in a vacuum, as illustrated in Fig. 4.1.

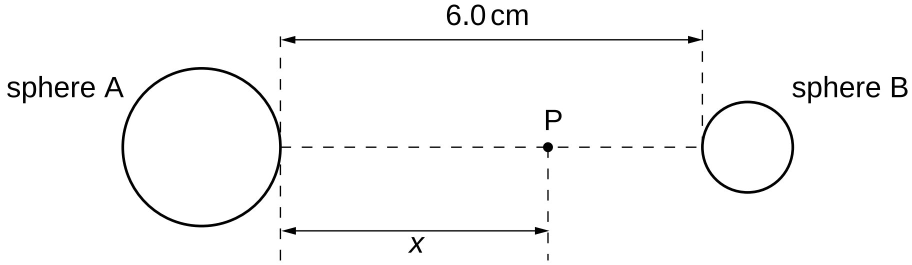

Fig. 4.1

The shortest distance between the surfaces of the spheres is 6.0 cm.

A movable point P lies along the line joining the centres of the two spheres, a distance x from the surface of sphere A.

The variation with distance x of the electric field E at point P is shown in Fig. 4.2.

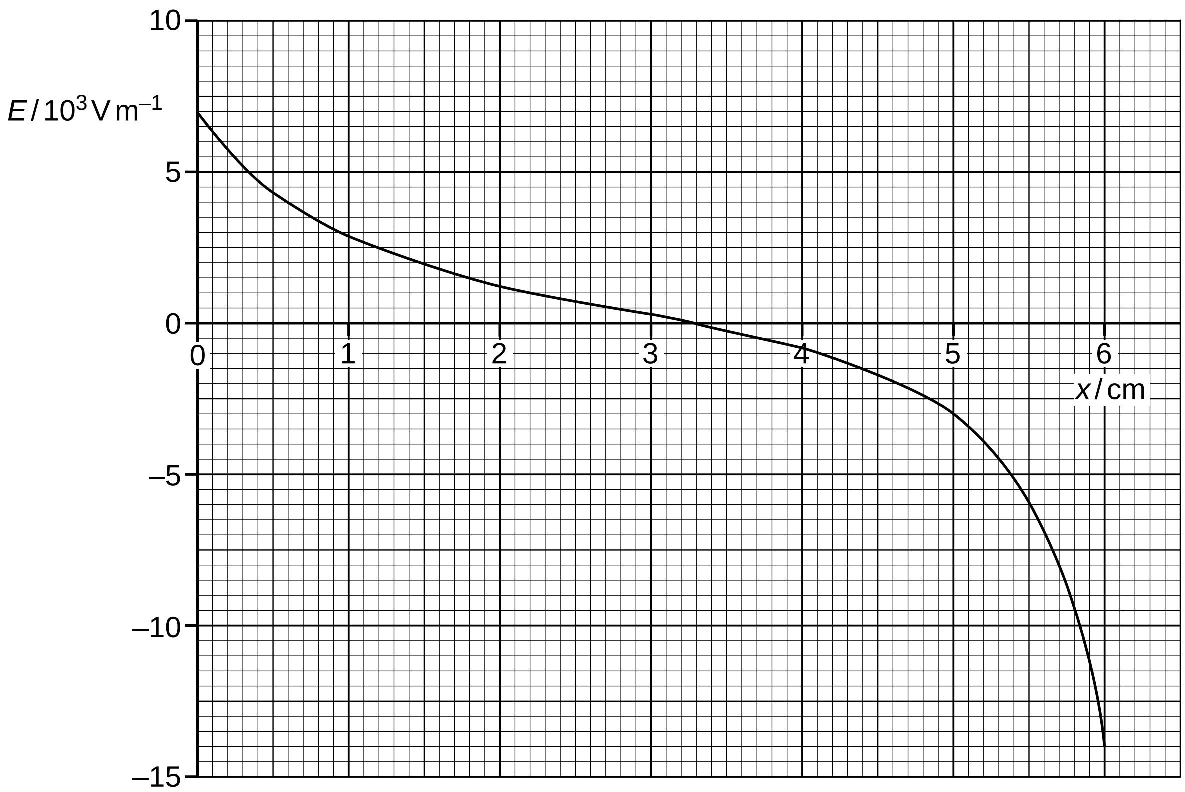

Fig. 4.2

(i) Use Fig. 4.2 to explain whether the two spheres have charges of the same, or opposite, sign.

....

....

....

.... [2]

(ii) A proton is at point P where $x = 5.0\,\text{cm}$.
Use data from Fig. 4.2 to determine the magnitude of the acceleration of the proton.

acceleration = ... $\text{m}\,\text{s}^{-2}$ [3]

(c) The electric potential gradient is related to the electric field.

Use data from Fig. 4.2 to state the value of x at which the magnitude of the electric potential gradient is maximum. Give a reason for the value you have chosen.

....

....

.... [2]

[Total: 9]

5 A sinusoidal alternating potential difference (p.d.) from a supply is rectified using a single diode. The variation with time *t* of the rectified potential difference *V* is shown in Fig. 5.1.

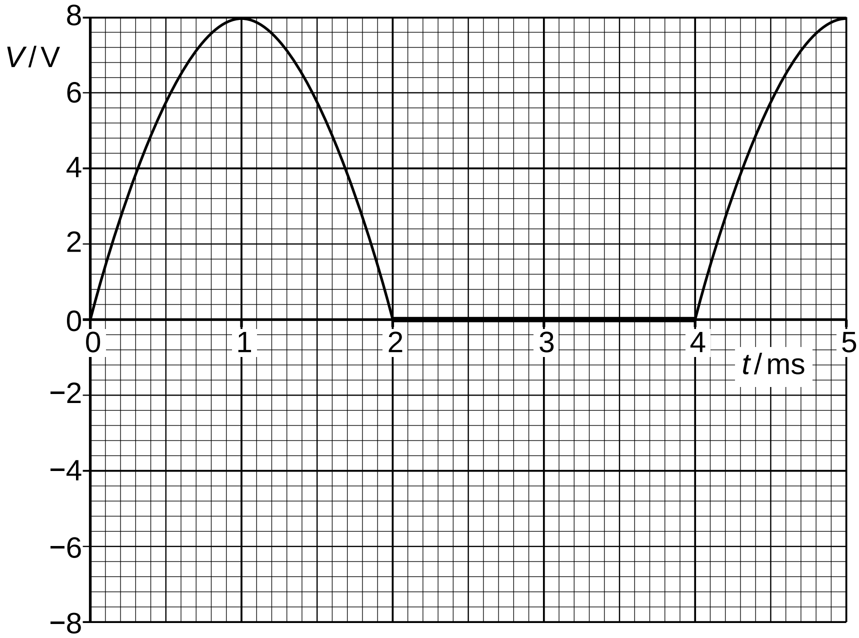

Fig. 5.1

(a) (i) Determine the root-mean-square (r.m.s.) value of the supply potential difference before rectification.

r.m.s. potential difference = ... V [2]

(ii) State the type of rectification shown in Fig. 5.1.

.... [1]

(b) The alternating potential difference is rectified and smoothed using the circuit in Fig. 5.2.

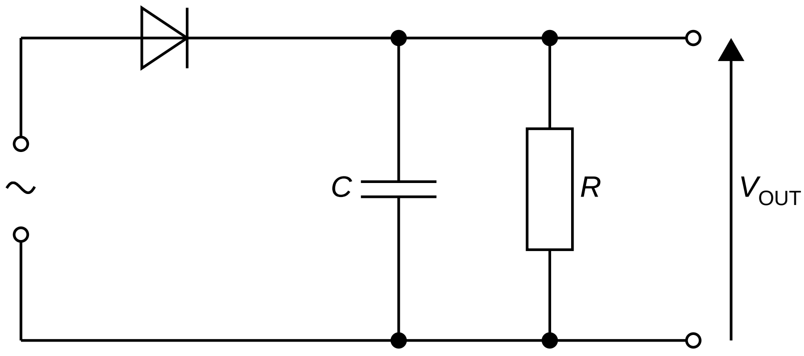

Fig. 5.2

The capacitor has capacitance C of 85 μF and the resistor has resistance R.

The effect of the capacitor and the resistor is to produce a smoothed output potential difference V_{OUT}. The difference between maximum and minimum values of V_{OUT} is 2.0 V.

(i) On Fig. 5.1, draw a line to show V_{OUT} between times t = 1.0 ms and t = 5.0 ms. [3]

(ii) Determine the time, in s, for which the capacitor is discharging between times t = 1.0 ms and t = 5.0 ms.

time = ... s [1]

(iii) Use your answers in **(b)(i)** and **(b)(ii)** to calculate the resistance R.

R = ... Ω [2]

[Total: 9]

6 A thin slice of conducting material has its faces PQRS and VWXY normal to a uniform magnetic field of flux density B, as shown in Fig. 6.1.

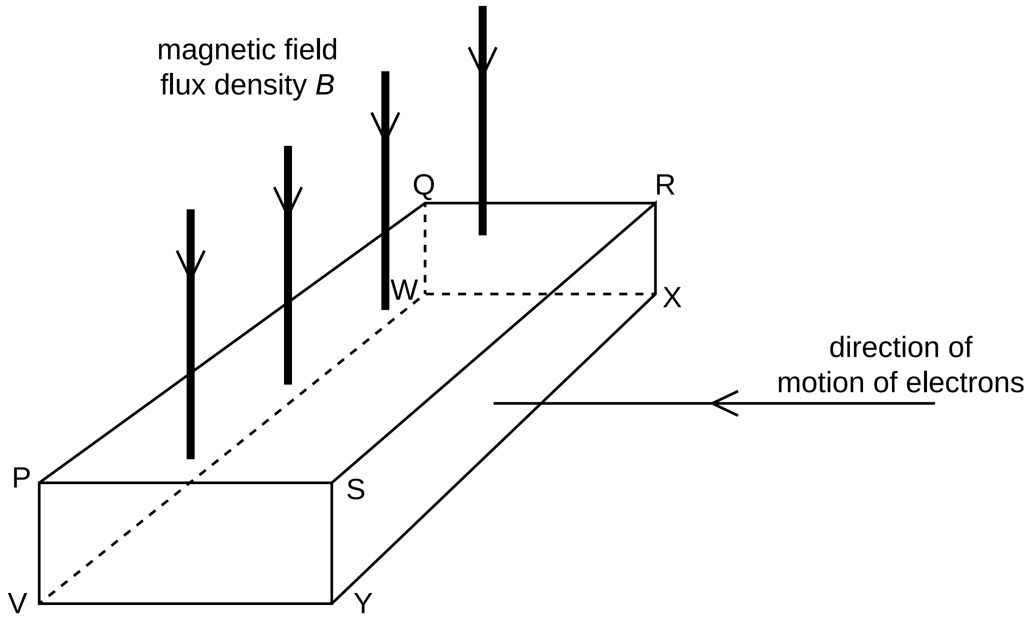

Fig. 6.1

Electrons enter the slice at right-angles to face SRXY.

A potential difference, the Hall voltage V_H, is produced between two faces of the slice.

(a) **(i)** Use letters from Fig. 6.1 to identify the two faces between which the Hall voltage is produced.

.... and .... [1]

(ii) State and explain which of the two faces named in **(a)(i)** is the more positive.

....

.... [2]

(b) The Hall voltage V_H is given by the expression

$$V_H = \frac{BI}{ntq}.$$

(i) Use the letters in Fig. 6.1 to identify the distance t.

.... [1]

(ii) The negative charge carriers (electrons) are replaced by positive charge carriers moving in the same direction towards the slice.

State and explain the effect, if any, of this change on the polarity of the Hall voltage.

....

....

.... [2]

[Total: 6]

7 **(a)** **(i)** Define magnetic flux.

....

....

.... [2]

(ii) State Faraday's law of electromagnetic induction.

....

....

....

.... [2]

(b) A solenoid has a coil C of wire wound tightly about its centre, as shown in Fig. 7.1.

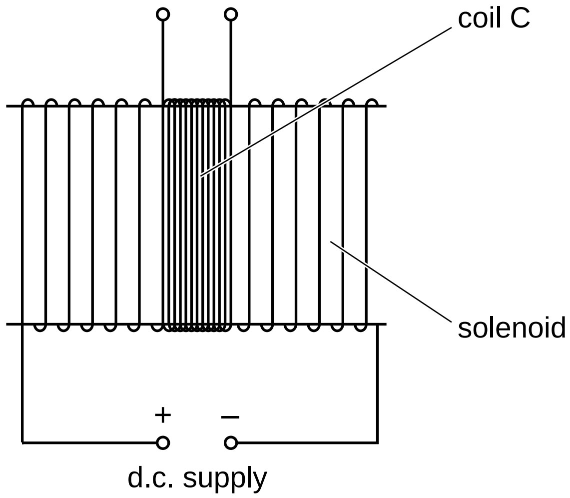

Fig. 7.1

The coil C has 96 turns.
The uniform magnetic flux Φ, in Wb, in the solenoid is given by the expression

$$\Phi = 6.8 \times 10^{-6} \times I$$

where I is the current, in A, in the solenoid.

Calculate the average electromotive force (e.m.f.) induced in coil C when a current of 3.5 A is reversed in the solenoid in a time of 2.4 ms.

e.m.f. = ... V [2]

(c) The d.c. supply in Fig. 7.1 is now replaced with a sinusoidal alternating supply.

Describe qualitatively the e.m.f. that is now induced in coil C.

....

....

.... [2]

[Total: 8]

8 **(a)** Describe **two** phenomena associated with the photoelectric effect that cannot be explained using a wave theory of light.

1 ....

....

2 ....

.... [2]

(b) The maximum energy E_{max} of electrons emitted from a metal surface when illuminated by light of wavelength λ is given by the expression

$$E_{max} = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right)$$

where h is the Planck constant and c is the speed of light.

(i) Identify the symbol λ_0.

.... [1]

(ii) The variation with $\frac{1}{\lambda}$ of E_{max} for the metal surface is shown in Fig. 8.1.

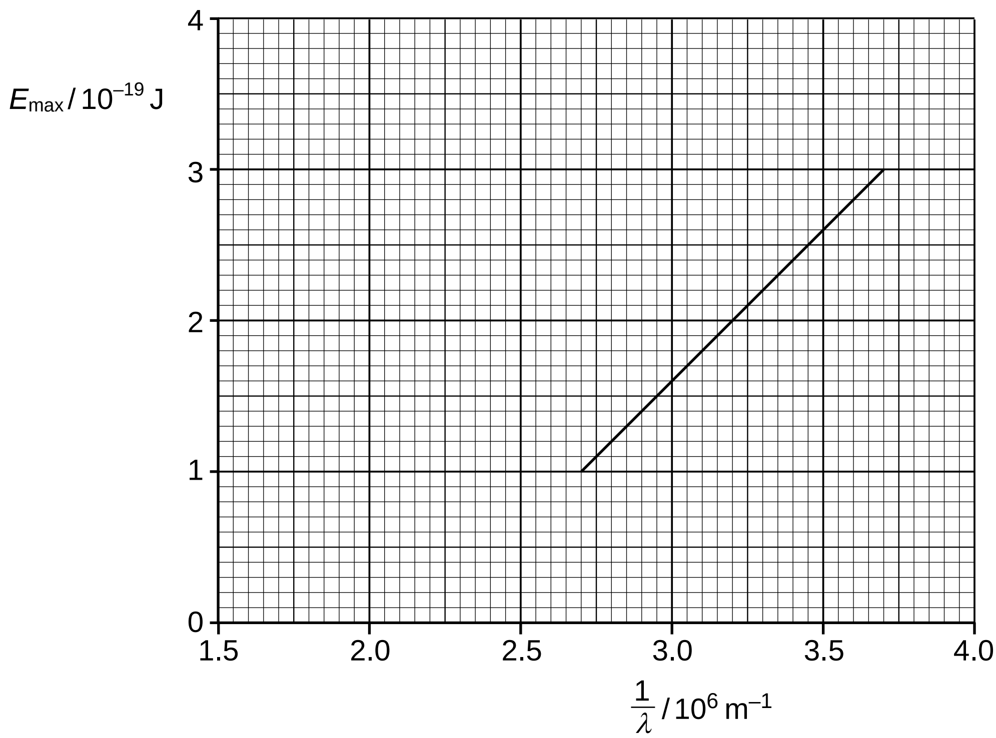

Fig. 8.1

Use Fig. 8.1 to determine the magnitude of λ_0.

λ_0 = ... m [1]

(iii) Use the gradient of Fig. 8.1 to determine a value for the Planck constant h. Show your working.

h = ... J s [3]

(c) The metal surface in **(b)** becomes oxidised.
Photoelectric emission is still observed but the work function energy is increased.

On Fig. 8.1, draw a line to show the variation with $\frac{1}{\lambda}$ of E_{max} for the oxidised surface. [2]

[Total: 9]

9 Data for a nucleus and some particles are given in Table 9.1.

Table 9.1

nucleus or particle	mass / u
$^{139}_{57}\text{La}$	138.955
$^{1}_{0}\text{n}$	1.00863
$^{1}_{1}\text{p}$	1.00728
$^{0}_{-1}\text{e}$	5.49×10^{-4}

(a) One nuclear reaction that can take place in a nuclear reactor may be represented, in part, by the equation shown below.

Complete the equation.

$$^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \longrightarrow {}^{95}_{42}\text{Mo} + {}^{139}_{57}\text{La} + 2\,^{1}_{0}\text{n} + \text{..................} + \text{energy}.$$ [1]

(b) **(i)** Show that the energy equivalent to 1.00 u is 934 MeV.

[3]

(ii) Calculate the binding energy per nucleon, in MeV, of lanthanum-139 ($^{139}_{57}\text{La}$).

binding energy per nucleon = ... MeV [3]

(c) State and explain whether the binding energy per nucleon of uranium-235 ($^{235}_{92}U$) is greater, equal to or less than the binding energy per nucleon of lanthanum-139 ($^{139}_{57}La$).

....

....

....

.... [2]

[Total: 9]

10 (a) (i) State what is meant by contrast in an X-ray image.

....

....

.... [1]

(ii) A parallel beam of X-ray radiation is incident, separately, on samples of bone and of muscle.

Data for the thickness x of the samples of bone and of muscle, together with the linear attenuation coefficients μ of the radiation in bone and in muscle, are given in Table 10.1.

Table 10.1

	x / cm	μ / cm^{-1}
bone	1.5	2.9
muscle	4.0	0.95

Calculate the ratio

$$\frac{\text{intensity of radiation transmitted through the bone}}{\text{intensity of radiation transmitted through the muscle}}.$$

ratio = ... [2]

(b) **(i)** Explain how ultrasound pulses are used to obtain diagnostic information about internal body structures in medical diagnosis.

....

....

....

....

.... [3]

(ii) Define specific acoustic impedance.

....

....

.... [2]

(iii) Two media have specific acoustic impedances Z_1 and Z_2.

State the approximate value of the intensity reflection coefficient at the boundary between the two media when:

- Z_1 is almost equal to Z_2

intensity reflection coefficient = ...

- Z_1 is very different from Z_2.

intensity reflection coefficient = ...
[2]

[Total: 10]

11 **(a)** Positron emission tomography (PET scanning) makes use of a tracer containing a radioactive material that decays by positron emission.

(i) State what is meant by a tracer.

....

....

.... [2]

(ii) State the name of the particles that are emitted from the body and detected by the detectors during PET scanning.

.... [1]

(b) Explain how the particles in **(a)(ii)** are created from positrons.

....

....

....

....

.... [3]

(c) Positrons can be artificially created by a process in the laboratory that is the reverse of the process in **(b)**. This process creates both a positron and an electron moving at the same speed in opposite directions.

Suggest why two of the particles in **(a)(ii)** are needed to create one positron.

....

....

....

.... [2]

[Total: 8]

12 **(a)** A star has a luminosity that is known to be 4.8×10^{29} W. A scientist observing this star finds that the radiant flux intensity of light received on Earth from the star is $2.6\,\text{nW}\,\text{m}^{-2}$.

(i) Name the term used to describe an astronomical object that has known luminosity.

.... [1]

(ii) Determine the distance of the star from Earth.

distance = ... m [2]

(b) The Sun has a surface temperature of 5800 K. The wavelength λ_{max} of light for which the maximum rate of emission occurs from the Sun is 500 nm.

The scientist observing the star in **(a)** finds that the wavelength for which the maximum rate of emission occurs from the star is 430 nm.

(i) Show that the surface temperature of the star in **(a)** is approximately 6700 K. Explain your reasoning.

[2]

(ii) Use the information in **(a)** and **(b)(i)** to determine the radius of the star.

radius = ... m [2]

[Total: 7]

BLANK PAGE