Name: _____ (   )   Class: 25 / _____

ANDERSON SERANGOON JUNIOR COLLEGE

2025 JC2 Preliminary Examination

PHYSICS Higher 2   **9749/03**

Paper 3 Longer Structured Questions   **Thursday 28 August 2025**

                                                                            2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

___

READ THESE INSTRUCTIONS FIRST

Write your name, class index number and class in the spaces provided above.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** questions.

Section B
Answer **one** question only.

You are advised to spend about one and a half hours on Section A and half an hour on Section B.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Paper 3 (80 marks)	
1	
2	
3	
4	
5	
6	
7	
8	
9	
Deductions	
Total	

Data

speed of light in free space	c	$= 3.00 \times 10^8 \text{ m s}^{-1}$
permeability of free space	μ_0	$= 4\pi \times 10^{-7} \text{ H m}^{-1}$
permittivity of free space	ε_0	$= 8.85 \times 10^{-12} \text{ F m}^{-1}$
		$(1/(36\pi)) \times 10^{-9} \text{ F m}^{-1}$
elementary charge	e	$= 1.60 \times 10^{-19} \text{ C}$
the Planck constant	h	$= 6.63 \times 10^{-34} \text{ J s}$
unified atomic mass constant	u	$= 1.66 \times 10^{-27} \text{ kg}$
rest mass of electron	m_e	$= 9.11 \times 10^{-31} \text{ kg}$
rest mass of proton	m_p	$= 1.67 \times 10^{-27} \text{ kg}$
molar gas constant	R	$= 8.31 \text{ J K}^{-1} \text{mol}^{-1}$
the Avogadro constant	N_A	$= 6.02 \times 10^{23} \text{ mol}^{-1}$
the Boltzmann constant	k	$= 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	G	$= 6.67 \times 10^{-11} \text{ N m}^2 \text{kg}^{-2}$
acceleration of free fall	g	$= 9.81 \text{ m s}^{-2}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -\dfrac{Gm}{r}$
temperature	$T/\text{K} = T/°\text{C} + 273.15$
pressure of an ideal gas	$p = \dfrac{1}{3}\dfrac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{x_o^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \dots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \dots$
electric potential	$V = \dfrac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \dfrac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \dfrac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_o nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \dfrac{\ln 2}{t_{\frac{1}{2}}}$

[Turn Over

Section A

Answer **all** the questions in this section in the spaces provided.

1 A ball is kicked from horizontal ground towards the top of a vertical wall, as shown in Fig. 1.1.
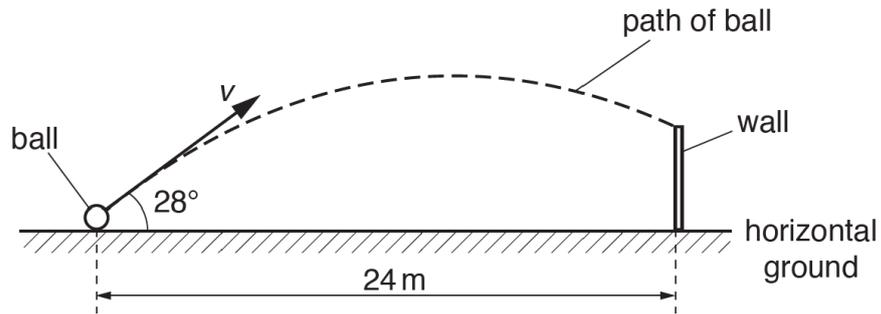

Fig. 1.1

The horizontal distance between the initial position of the ball and the base of the wall is 24 m. The ball is kicked with an initial velocity v at an angle of 28° to the horizontal. The ball hits the top of the wall after a time of 1.5 s. Air resistance may be assumed to be negligible.

(a) Show that the initial vertical component v_Y of the velocity of the ball is 8.5 m s^{-1}.

[2]

(b) Calculate the time taken for the ball to reach its maximum height above the ground.

time = …………………………….s [2]

(c) The ball is kicked at time t = 0. On Fig. 1.2, sketch the variation with time t of the vertical component v_Y of the velocity of the ball until it hits the wall. It may be assumed that velocity is positive when in the upwards direction.
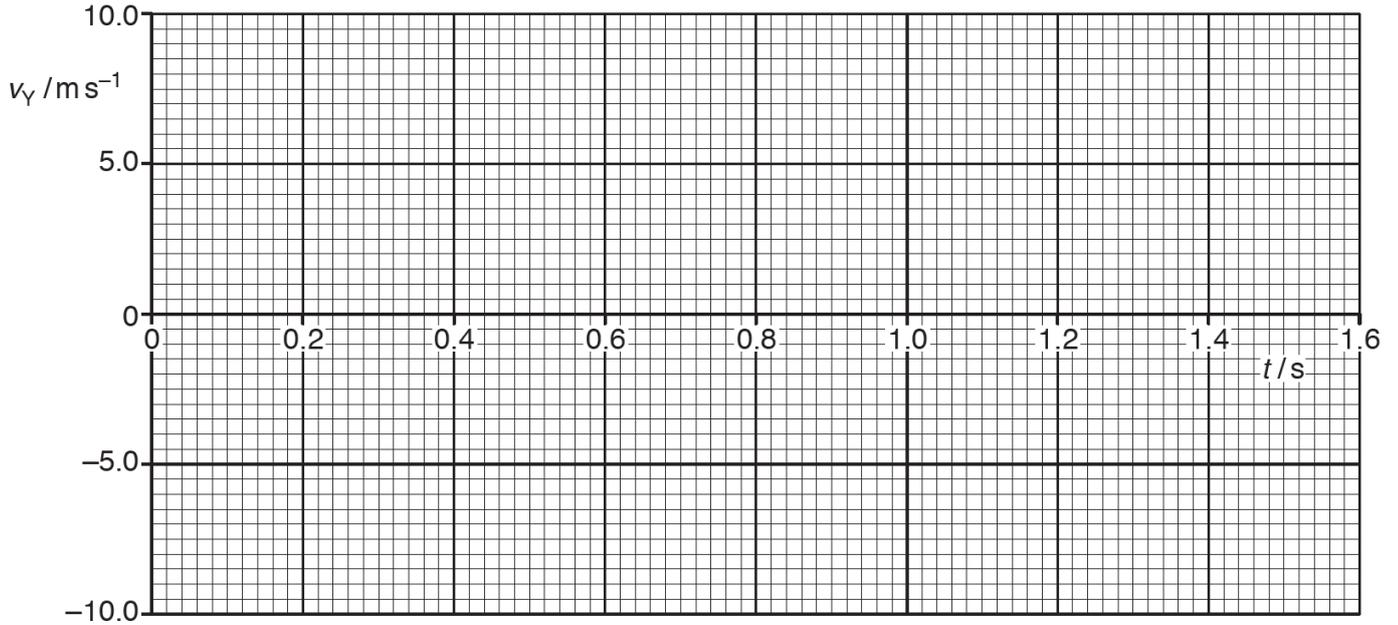

Fig. 1.2

[2]

(d) A ball of greater mass is kicked with the same velocity v and at an angle of 28° to the horizontal.

State and explain the effect, if any, of the increased mass on **(b)**. Air resistance is still assumed to be negligible.

....

....

....[1]

(e) State and explain the effect of air resistance on the answer in **(b)**.

....

....

....[2]

[Total: 9]

2 **(a)** A copper wire of diameter 1.4 mm connects to the tungsten filament wire of a light bulb of diameter 0.020 mm. A current of 0.42 A flows through both of the wires. Copper has 8.0×10^{28} electrons per cubic metre and tungsten can be assumed to have 3.4×10^{28} electrons per cubic metre.

(i) The filament is 2.0 m long when uncoiled and has a resistivity of 5.5×10^{-8} Ω m.

Calculate the power dissipated in the filament bulb.

power dissipated = …………………………….W [2]

(ii) The drift speed of electrons in the copper wire is 0.021×10^{-3} m s^{-1}.

1. Determine the drift speed of electrons in the tungsten filament.

drift speed = …………………………….m s^{-1} [2]

2. Explain, in microscopic terms, why the copper wire stays cool although the tungsten filament reaches a high temperature.

……………………………………………………………………………....................

……………………………………………………………………………....................

……………………………………………………………………………....................

………………………………………………………………………………….... [2]

(b) A thermistor has resistance 3900 Ω at 0 °C and resistance 1250 Ω at 30 °C. The thermistor is connected into the circuit of Fig. 2.1 in order to monitor temperature changes.
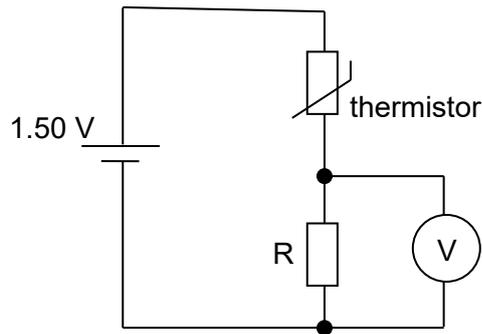
Fig. 2.1

The battery of e.m.f. 1.50 V has negligible resistance and the voltmeter has infinite resistance.

The reading on the voltmeter is 1.00 V at 0 °C.

(i) The temperature of the thermistor is increased to 30 °C. Determine the reading on the voltmeter.

reading = ……………………………V [2]

(ii) The voltmeter in Fig. 2.1 is replaced with one having a resistance of 7800 Ω. Calculate the reading on this voltmeter for the thermistor at a temperature of 0 °C.

reading = ……………………………V [2]

[Total: 10]

[Turn Over

3 The Earth may be assumed to be an isolated uniform sphere with its mass M concentrated at its centre. A satellite of mass m orbits the Earth in a circular path of radius R.

For the satellite in its orbit, show that

(a) (i) its kinetic energy E_K is given by

$$E_K = \frac{GMm}{2R}$$

where G is the gravitational constant.

[3]

(ii) its total energy E_T is given by

$$E_T = -\frac{GMm}{2R}$$

[2]

(b) The satellite in **(a)** gradually loses energy due to small resistive forces.
Suggest why many such satellites eventually "burn up" in the Earth's atmosphere.

....

....

....

....

....

.... [3]

(c) Polar orbiting satellites have orbits over the poles of the Earth. Geostationary satellites are in equatorial orbits.

State one advantage and one disadvantage of the use of a geostationary satellite as compared with a polar orbiting satellite.

(i) advantage:

…..

.... [1]

(ii) disadvantage:

…..

.... [1]

[Total: 10]

[Turn Over

4 A sphere floats in equilibrium on the surface of sea water of density 1050 kg m⁻³, as shown in Fig. 4.1.
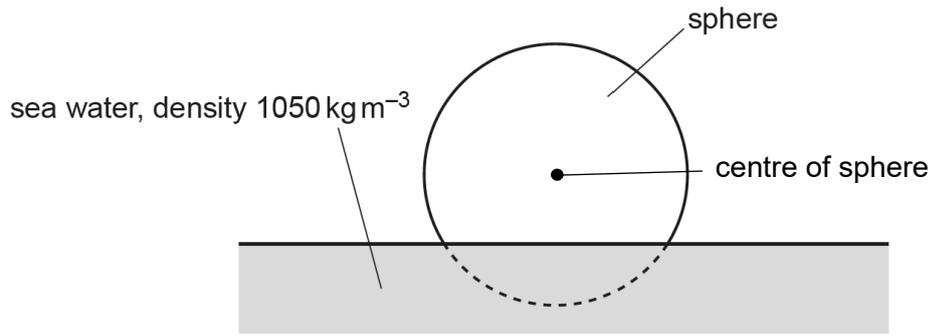

Fig. 4.1

(a) On Fig 4.1, draw an arrow to represent the force exerted on the sphere due to the seawater. [2]

(b) Explain the origin of the force in **(a)**.

....

....[1]

(c) Explain how the force in **(a)** helps the sphere to stay in equilibrium.

....

....

....[2]

(d) 21% of the volume of the sphere is below the surface of the water.
Calculate the density of the sphere.

density = ...kg m⁻³ [2]

(e) The sphere is now held stationary by a force of 2000 N so that its entire volume is below the surface of the water.

Calculate the diameter of the sphere.

diameter = ...m [2]
[Total: 9]

5 A pinball machine uses a spring to launch a small metal ball of mass 4.5×10^{-2} kg up a ramp. The spring is compressed by 8.0×10^{-2} m and held in equilibrium, as shown in Fig. 5.1.
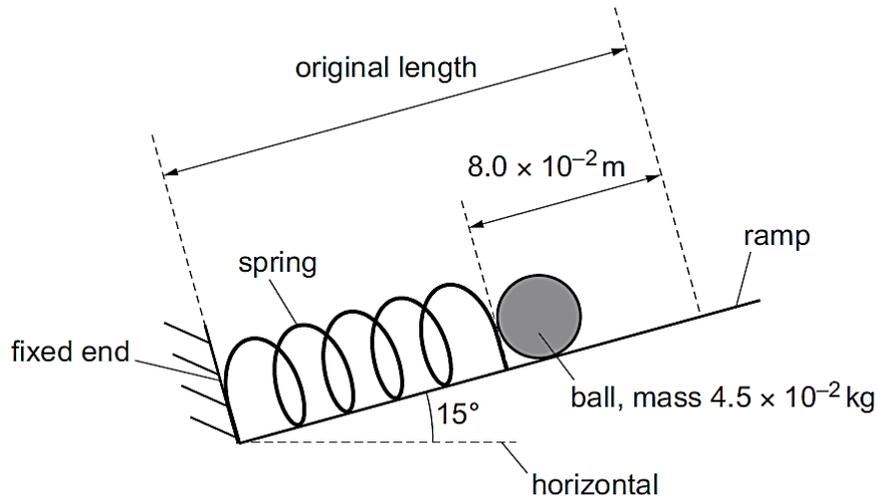

Fig. 5.1 (not to scale)

The ramp is at an angle of 15° to the horizontal.

(a) The spring obeys Hooke's law and has a spring constant of 29 N m^{-1}.

Calculate the elastic potential energy in the compressed spring.

elastic potential energy = ……………………………..J [2]

(b) The spring is released and expands quickly back to its original length.

The ball leaves the spring when the spring reaches its original length. Assume that all the elastic potential energy of the spring is transferred to the ball.

Calculate the speed of the ball as it leaves the spring.

speed = ……………………………..m s^{-1} [3]

[Turn Over

(c) State and explain the effect on the speed in **(b)** when the mass of the spring cannot be neglected.

……………………………………………………………………………………………………..

……………………………………………………………………………………….........[1]

[Total: 6]

6 A transformer has a turns ratio of N_p/N_s = 1/20 and the sinusoidal input signal voltage has a value of 9.0 V r.m.s. The mean power input to the transformer is 30 W. A graph of the power input is shown in Fig. 6.1.
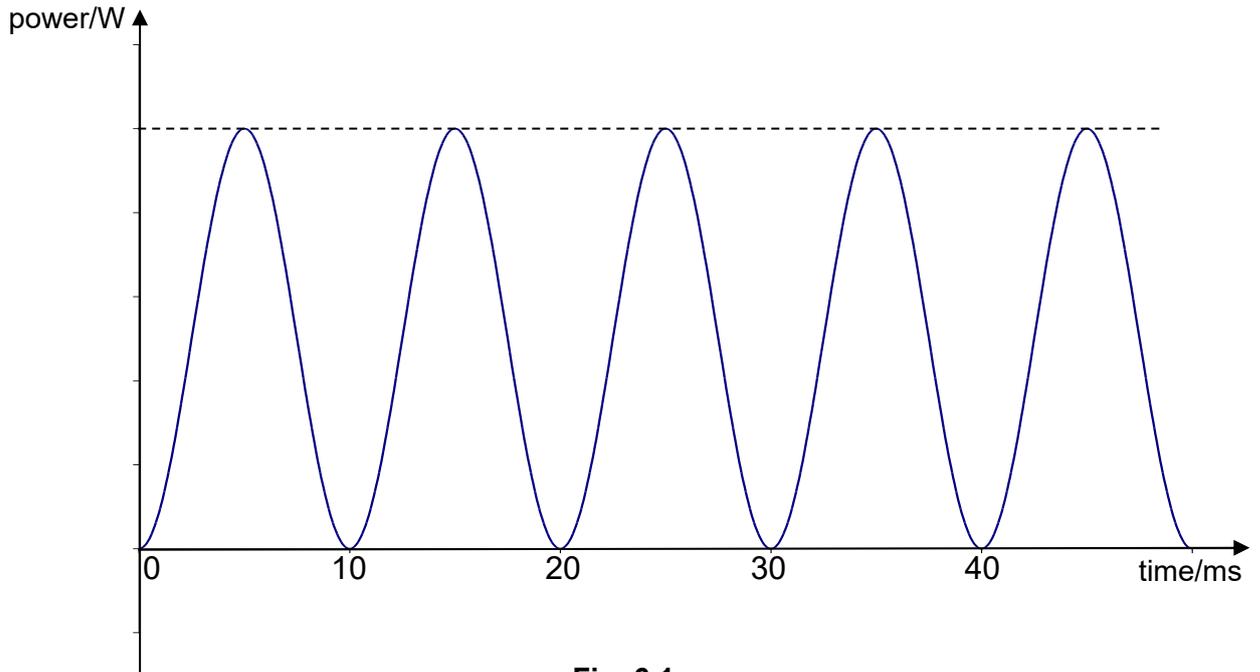

Fig. 6.1

The output of the transformer is connected across a resistor R.

(a) For the transformer, assumed to be ideal, calculate

(i) the r.m.s. value of the output voltage,

r.m.s. output voltage = …………………………..V [1]

(ii) the r.m.s. value of the input current,

r.m.s. input current = …………………………..A [1]

[Turn Over

(iii) State the equation of the variation with time *t* of the output voltage *V*.

[2]

(b) A diode is inserted in series with the resistor R.

State

(i) the peak power dissipated in R,

peak power = …………………………W [1]

(ii) the mean power dissipated in R.

mean power = ………………………….W [1]

(c) **(i)** Explain why thermal energy is generated in the core when the transformer is in use.

…………………………………………………………………………….................

…………………………………………………………………………….................

…………………………………………………………………………….................

…………………………………………………………………………………....... [2]

(ii) State a typical feature in the design of the iron core to reduce power loss.

…………………………………………………………………………………....... [1]

[Total: 9]

7 (a) State what is meant by the *diffraction* of a wave.

………………………………………………………………………………………………..

………………………………………………………………………………………………..

………………………………………………………………………………………..........[2]

(b) A pair of distant stars is being observed through a telescope with an aperture of 12.0 cm. The stars emit light with a wavelength of 550 nm.

(i) Explain what is meant by the *Rayleigh criterion* for the resolution of the two stars as observed through the telescope.

………………………………………………………………………….....................

………………………………………………………………………….....................

………………………………………………………………………….....................

………………………………………………………………………………………..... [2]

(ii) State and explain the effect of having a smaller aperture on the resolving power of the telescope.

………………………………………………………………………….....................

…………………………………………………………………………………………... [1]

(iii) Calculate the minimum angular separation θ, between the stars that allows them to be just resolved by the telescope.

θ = …………………………….rad [2]

[Total: 7]

[Turn Over

Section B

Answer **one** question from this Section in the spaces provided.

8 **(a)** A long straight vertical wire A carries a current in an upward direction.
The wire passes through the centre of a horizontal card, as illustrated in Fig. 8.1.
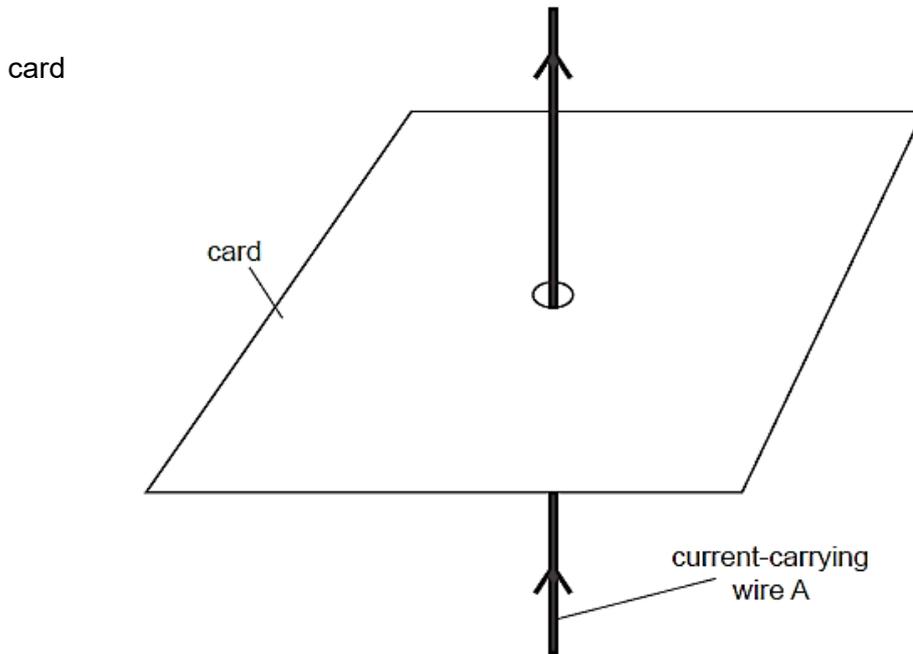
card

Fig. 8.1

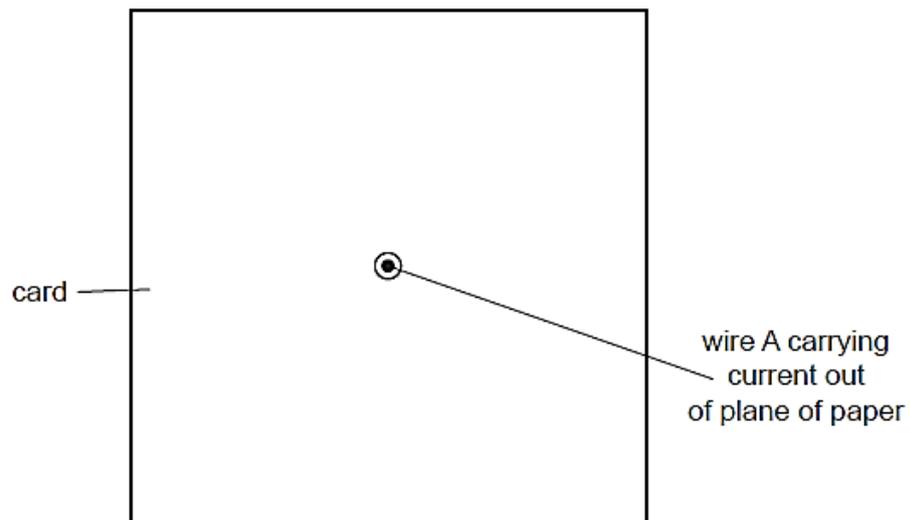The card is viewed from above. The card is shown from above in Fig. 8.2.

Fig. 8.2

(i) On Fig. 8.2, draw lines to represent the magnetic field produced by the current-carrying wire.

[2]

(ii) Two wires A and B are now placed through a card. The two wires are parallel and carrying currents in the same direction, as illustrated in Fig. 8.3.
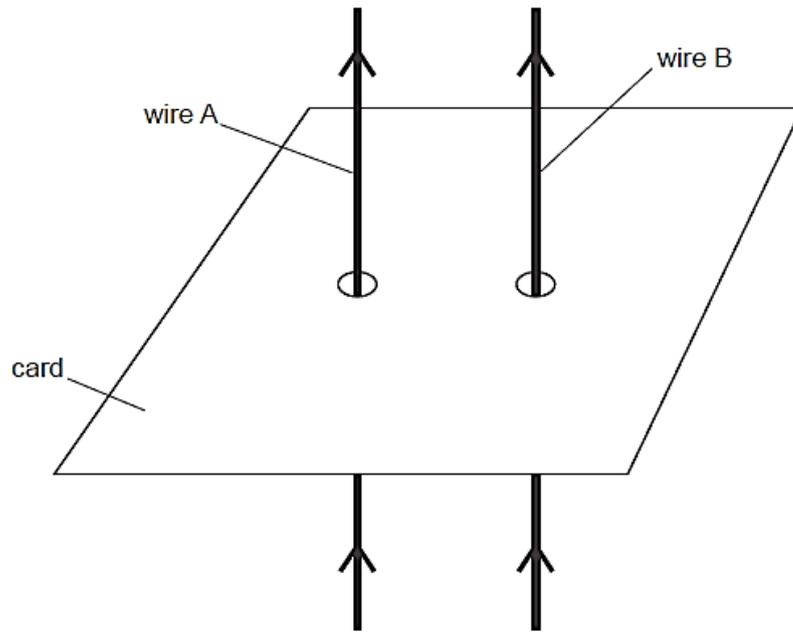

Fig. 8.3

1. Explain why a magnetic force is exerted on each wire.

   ....

   ....

   ....

   .... [2]

2. The currents in the two wires are not equal.
   Explain whether the magnetic forces on the two wires are equal in magnitude.

   ....

   ....

   .... [1]

(b) Electrons are moving in a vacuum with speed 1.70×10^7 m s^{-1}. The electrons enter a uniform magnetic field of flux density 4.80 mT.
Fig. 8.4 shows the path of the electrons.

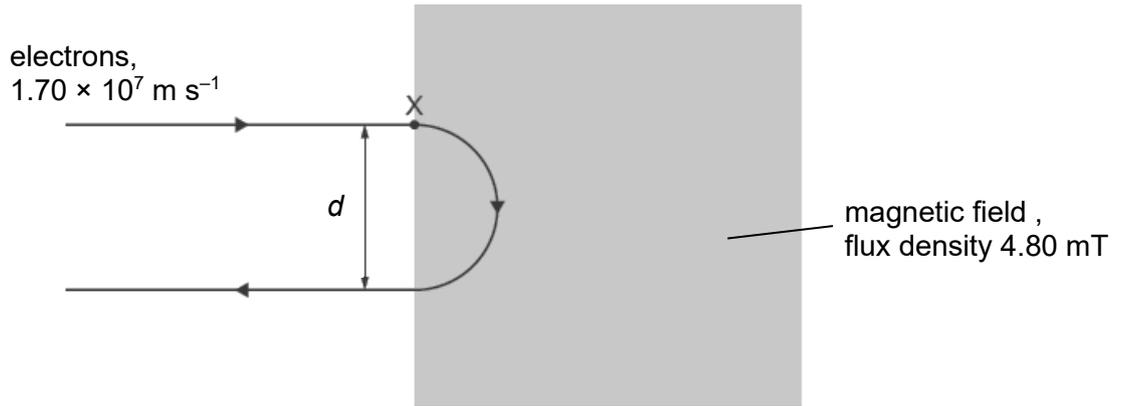electrons,
1.70×10^7 m s^{-1}

X

d

magnetic field ,
flux density 4.80 mT

Fig 8.4

The path of the electrons remains in the plane of the page.

(i) Define magnetic flux density.

....

....

....

.... [2]

(ii) State the direction of the magnetic field.

....

.... [1]

(iii) Explain why the path of the electron in the magnetic field is the arc of a circle.

....

....

....

.... [2]

(iv) Calculate the distance *d* between the path of the electrons entering the magnetic field and the path of the electrons leaving it.

d = …………………………cm [3]

(v) Show that the duration which the electron is inside the magnetic field is approximately 3.7×10^{-9} s.

[1]

(vi) A uniform electric field of magnitude 18.0 kV m^{-1} is directed into the page in the same region as the magnetic field.

Use your answer in **(b)(v)** to determine the final speed of the electron as it leaves the fields.

final speed = …………………………. m s^{-1} [4]

[Turn Over

(c) The magnitude and direction of the uniform electric field in part **(b)(vi)** is adjusted so that electrons with speed 1.7×10^7 m s^{-1} now travel in a straight path in the region of uniform fields, as shown in Fig. 8.5.

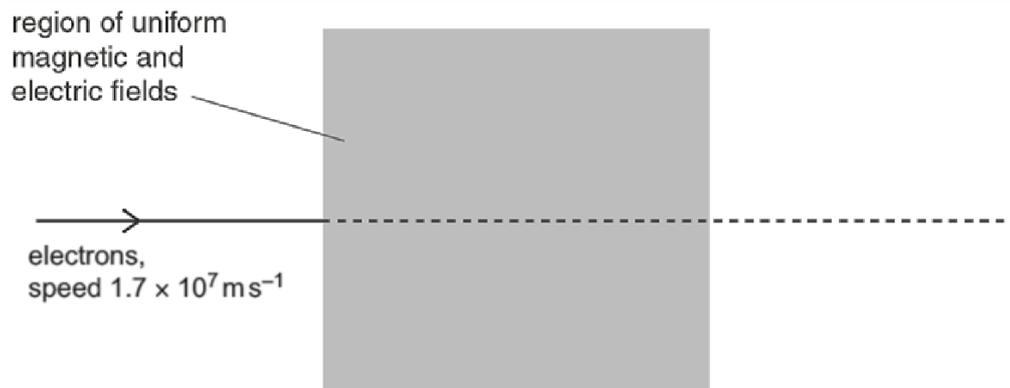region of uniform
magnetic and
electric fields

electrons,
speed 1.7×10^7 m s^{-1}

Fig 8.5

If the electrons are replaced with protons moving with speed 2.0×10^7 m s^{-1}, sketch the path of the protons on Fig. 8.5.

[2]

[Total: 20]

9 **(a)** For a particular metal surface, it is observed that there is a minimum frequency of light below which photoelectric emission does not occur. This observation provides evidence for a particulate nature of electromagnetic radiation.

(i) State two further observations from photoelectric emission that provide evidence for a particulate nature of electromagnetic radiation.

1. ……………………………………………………………………………………………….......................

…………………………………………………………………………………………….......................

2. ……………………………………………………………………………………………….......................

………………………………………………………………………………………………….... [2]

(ii) When electromagnetic radiation of wavelength λ is incident on a metal surface, electrons of maximum kinetic energy E_{MAX} are emitted.

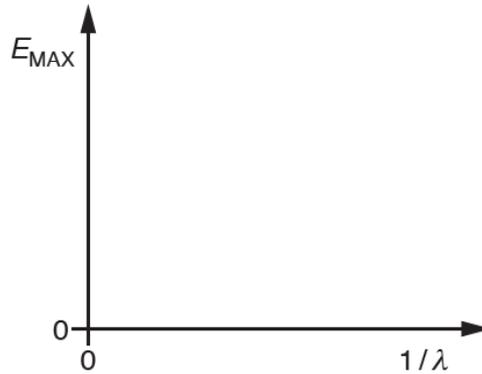**1.** On Fig. 9.1, sketch the variation with $1/\lambda$ of E_{MAX}.

Fig. 9.1

[2]

2. State an equation relating the gradient of the graph drawn on Fig. 9.1 to the Planck constant h.
Explain any symbols you use.

……………………………………………………………………………………………….......................

………………………………………………………………………………………………….... [1]

[Turn Over

3. Light of a particular wavelength is incident on a metal surface and gives rise to a photoelectric current.

The wavelength is reduced. The intensity of the light is kept constant.

State and explain the effect, if any, on the photoelectric current.

…………………………………………………………………………………….......................

…………………………………………………………………………………….......................

…………………………………………………………………………………….......................

…………………………………………………………………………………….......................

………………………………………………………………………………………….... [3]

(b) Fig. 9.2 shows the visible part of the emission spectrum from hydrogen gas in a laboratory on the Earth. The numbers indicate the wavelength, in nm, represented by each line.
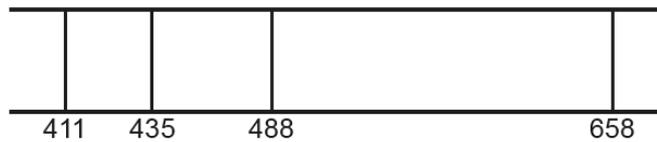

Fig. 9.2

(i) Explain how the emission spectrum provides evidence for the existence of discrete energy levels for the electron in a hydrogen atom.

…………………………………………………………………………………….......................

…………………………………………………………………………………….......................

…………………………………………………………………………………….......................

…………………………………………………………………………………….......................

…………………………………………………………………………………….......................

………………………………………………………………………………………….... [3]

(ii) Fig. 9.3 shows five of the energy levels in the hydrogen atom. The wavelengths of radiation shown in Fig. 9.2 relate to transitions to the − 3.400 eV level in Fig. 9.3.
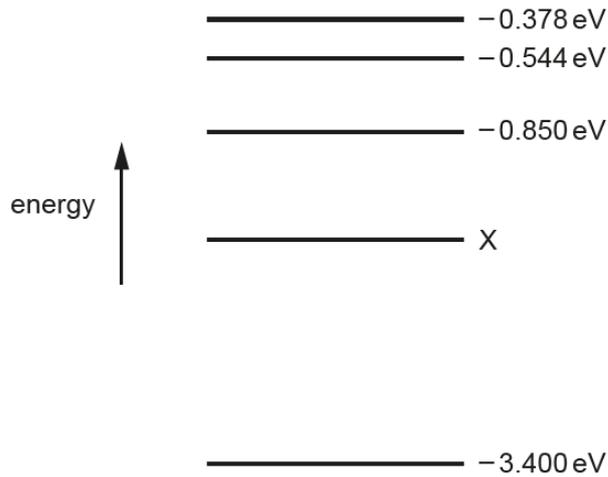

energy

−0.378 eV
−0.544 eV
−0.850 eV
X
−3.400 eV

Fig. 9.3 (not to scale)

Show that the energy level X is −1.51 eV.

[3]

(c) Electrons are accelerated through a potential difference of 15 kV. The electrons collide with a metal target and a spectrum of X-rays is produced.

(i) Calculate the wavelength of the highest energy X-ray photon produced.

wavelength = …………………………..m [2]

[Turn Over

(ii) Describe and explain the changes, if any, in the x-ray spectrum if the accelerating potential is increased.

……………………………………………………………………….....................

……………………………………………………………………….....................

……………………………………………………………………….....................

……………………………………………………………………….....................

…………………………………………………………………………….... [4]

[Total: 20]