Name: ______________________________ (   )   PDG: ______/ 16

ANDERSON JUNIOR COLLEGE

2017 JC2 Preliminary Examination

PHYSICS Higher 2
9749/03

Paper 3 Longer Structured Questions **Thursday 14 September 2017**

2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name, class index number and PDG 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, graphs or rough working.
Do not use 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 one and half hours on Section A and half an hour on Section B.

At the end of the examination, fasten all your work securely together.
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	
Significant Figure	
Total (80 marks)	

This document consists of **21** printed pages and **1** blank page.

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
acceleration of free fall	$g = 9.81$ 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	$\phi = -\frac{Gm}{r}$
temperature	$T/\text{K} = T/°\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
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	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to long straight wire	$B = \frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_o nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1 Fig. 1.1 shows a trolley of mass 0.80 kg, on a bench surface, connected to a mass M by a string. The mass M is released and the trolley moves along the surface. Fig. 1.2 shows the variation of the velocity v of the trolley with time t for the motion from A to B.

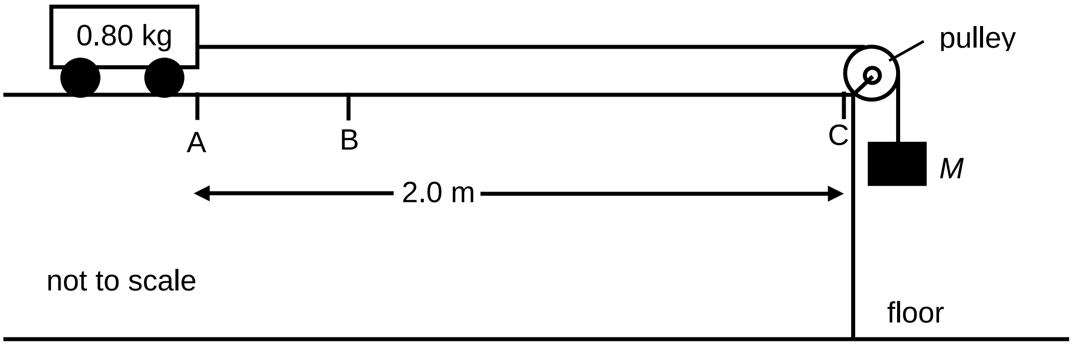


Fig. 1.1

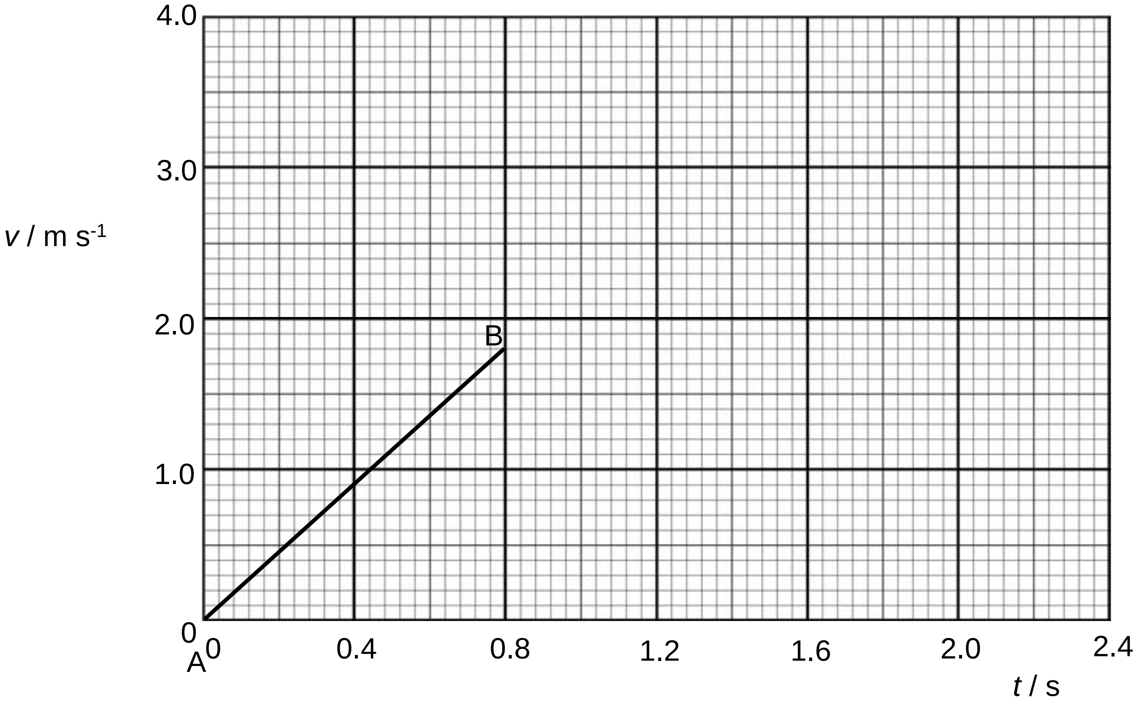


Fig. 1.2

(a) Calculate the acceleration of the trolley between A and B.

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

(b) Show that the distance from A to B is 0.72 m.

[1]

(c) When the trolley reaches B the mass *M* has just reached the floor.

(i) Ignoring any resistive forces, calculate the time it takes the trolley to travel from B to C.

time = …………………………………..s [2]

(ii) On Fig. 1.1, complete the graph for the trolley moving from B and coming to rest at the pulley at C. [2]

(iii) Using energy considerations, determine the mass *M*.

M = …………………………………..kg [2]

2 Bodies A and B of mass *2M* each are located at a distance *D* from one other as shown in Fig. 2.1.

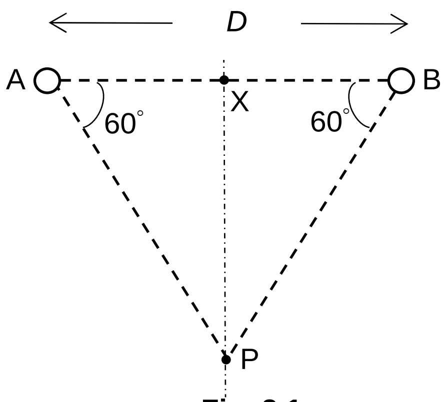


Fig. 2.1

(a) (i) Determine the net gravitational potential ϕ_P at P, in terms of *M, D* and the gravitational constant *G*, due to masses A and B.

ϕ_P = ………………………….. [2]

(ii) A stationary mass m is released at P and it moves to point X under the influence of gravitational field by A and B. Determine the speed of the mass, v_x, when it reaches X in terms of m, G, M and D.

v_x = ……………………….. [2]

(b) Electrical charges of $+2Q$ and $-Q$ were induced in bodies A and B respectively and it was assumed that the electrical charges were evenly distributed on the surfaces of A and B.

Taking direction towards B as positive, sketch on the axes provided below,

(i) the variation with distance from A of the gravitational field strength and gravitational potential between AB.

Label your graphs g for gravitational field strength and ϕ for gravitational potential respectively.

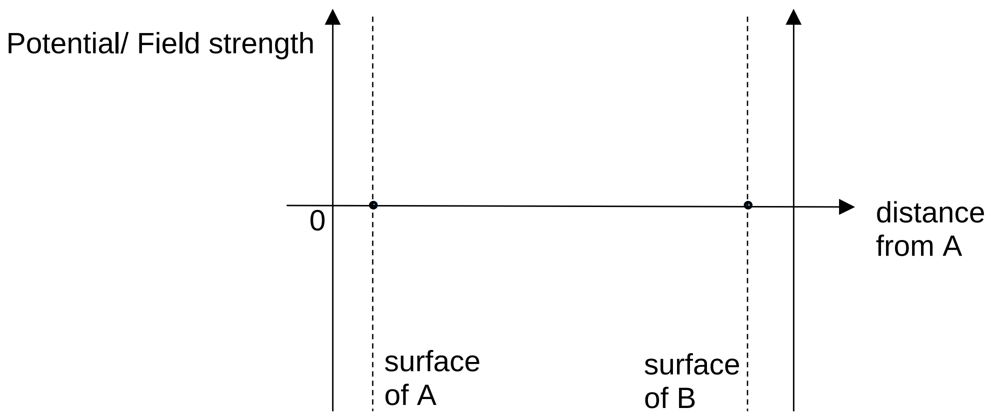


Fig 2.2

[2]

(ii) the variation with distance from A of the electric field strength and electric potential between AB.

Label your graphs *E* for electric field strength and *V* for electric potential respectively.

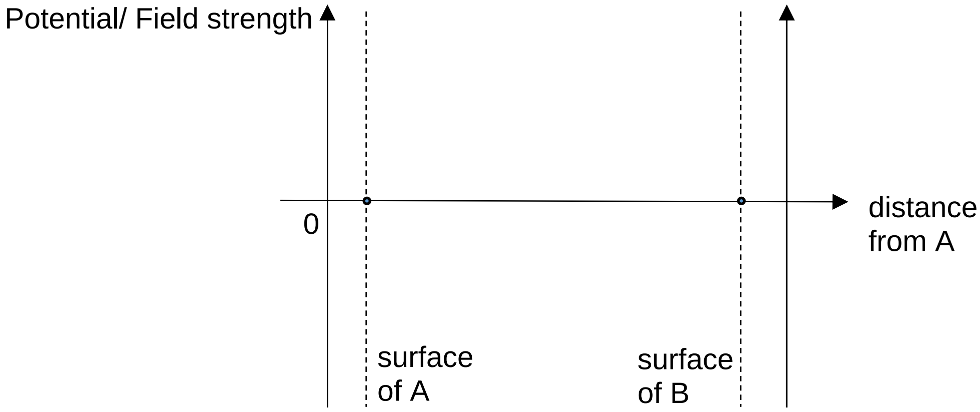


Fig 2.3

[2]

(iii) At point R in Fig 2.4 below, a body of mass *M* and charge +*Q* is being released from rest.

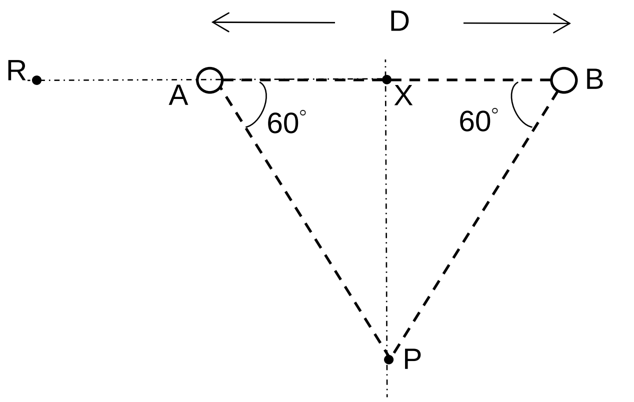


Fig 2.4

Suggest with a reason the direction of the body's subsequent motion.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

3 In a heat engine, the working substance is an ideal monatomic gas with 3.0 moles of molecules. The gas undergoes a cycle of thermodynamic processes ABCDA as it drives the engine as shown in Fig 3.1.

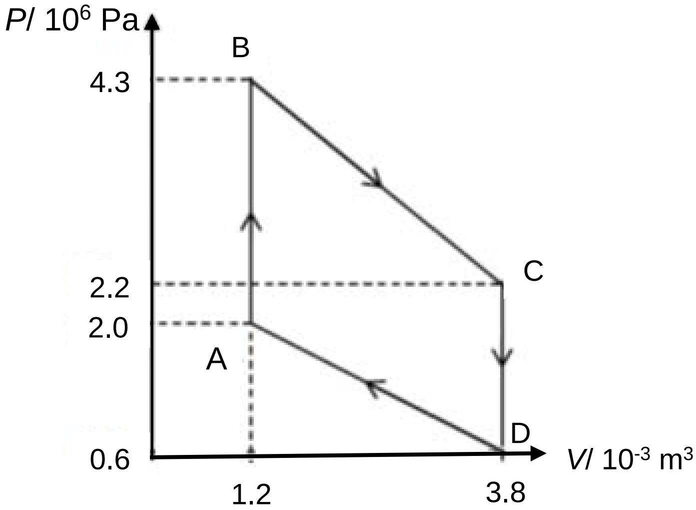


Fig 3.1

(a) Determine the thermodynamic temperature of the gas at B.

temperature = ………………………………. K [2]

(b) Determine the change in internal energy of the gas in process BC.

change in internal energy = ………………………………... J [2]

(c) Determine the work done by the gas in process BC.

work done by gas = ……………………………….. J [2]

(d) Determine the heat absorbed by the gas in process BC.

heat absorbed = ……………………………….. J [2]

4 **(a)** Light is an example of transverse electromagnetic wave.

Light can be polarized. Explain how this gives evidence for light being a transverse wave.

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

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

(b) Fig. 4.1 shows an ideal polarizer A arranged so that its polarizing direction is vertical. Polariser B is oriented with its plane parallel to that of A and with its polarizing direction at 45° to the vertical.

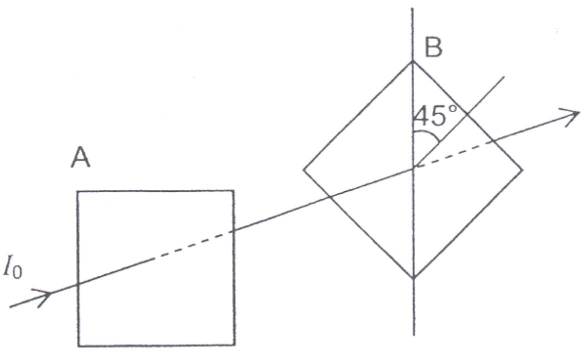


Fig. 4.1 a

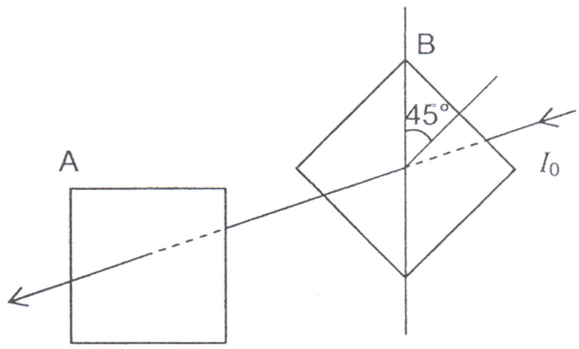


Fig. 4.1b

A beam of vertically-polarised light, of initial intensity I_o, passes through the polarisers in turn. Determine the intensity and the orientation of the emergent beam when the beam passes through the polarizer system

(i) in the direction from A to B (Fig. 4.1a),

intensity = ……………………………………….

orientation =……………………………………….

[3]

(ii) in the direction from B to A (Fig. 4.1b).

intensity = ……………………………………….

orientation = ……………………………………….

[2]

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

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

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

(b) Two identical point sources of monochromatic light of wavelength 600 nm are placed at a distance of 40 m from a slit and at a separation of 10 mm, as shown in Fig 5.1. The images of the point sources of monochromatic light are formed on a screen situated 25 mm away from the slit.

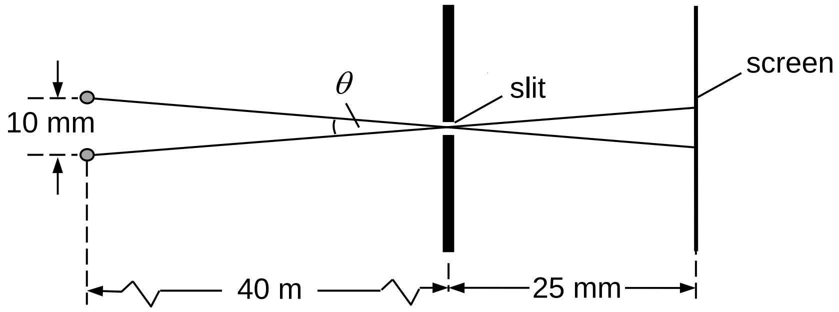


Fig. 5.1

(i) Calculate the angle subtended θ at the slit by the two sources.

θ = ……………………rad [1]

(ii) If the slit has a width of 1.5 mm, discuss whether or not the two images will be resolved.

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

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

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

(c) An arrangement for demonstrating the interference of light is shown in Fig. 5.2.

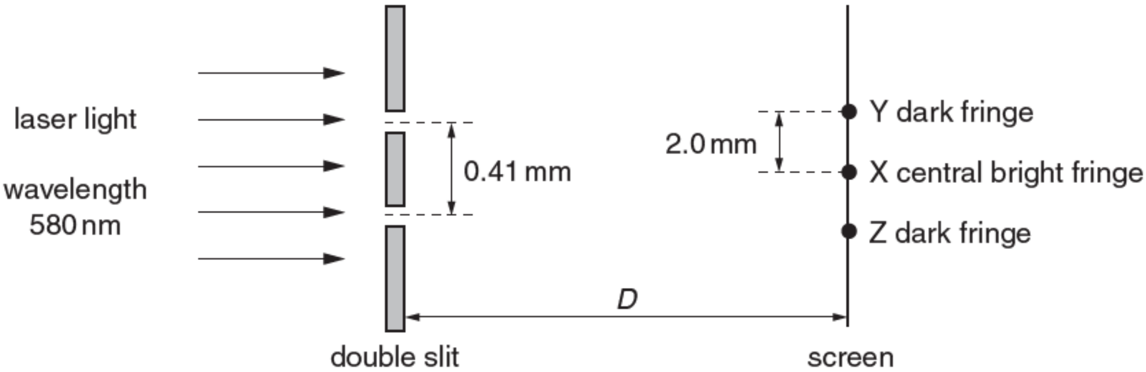


Fig. 5.2 (not to scale)

The wavelength of the light from the laser is 580 nm. The separation of the slits is 0.41 mm. The perpendicular distance between the double slit and the screen is *D*.

Coherent light emerges from the slits and an interference pattern is observed on the screen. The central bright fringe is produced at point X. The closest dark fringes to point X are produced at points Y and Z. The distance XY is 2.0 mm.

(i) Explain why a bright fringe is produced at point X.

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

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

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

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

(ii) State the difference in the distances, in nm, from each slit to point Y.

distance = ……………………. nm [1]

(iii) Calculate the distance *D*.

D = ……………………. m [2]

6 A long, straight wire Z carrying a direct current of 2.0 A flows in the direction as shown in Fig. 6.1.

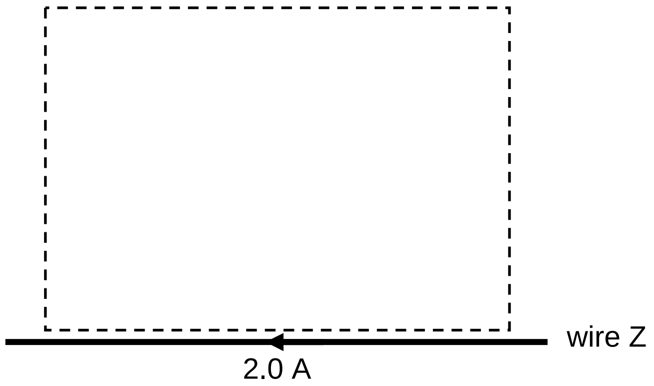


Fig. 6.1

(a) Using symbols X or ⊙ to represent the direction of magnetic field into or out of the paper respectively, draw on Fig. 6.1 the pattern of magnetic field produced by wire Z in the region indicated by the dotted box.

[2]

(b) A positive ion is projected from point P with an initial velocity *v* in a direction perpendicular to wire Z as shown in Fig. 6.2.

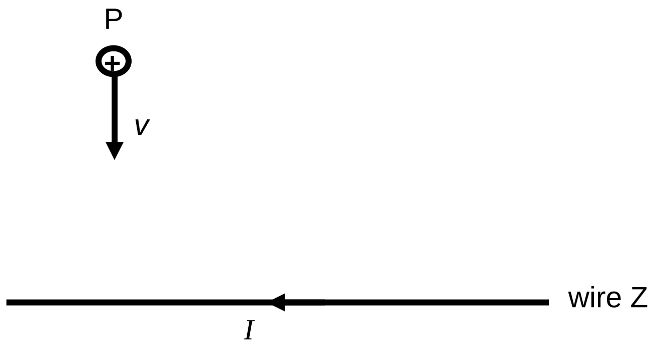


Fig. 6.2

Describe and explain the subsequent path of the ion, shortly after leaving P, due to the effect of the wire's magnetic field.

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

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

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

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

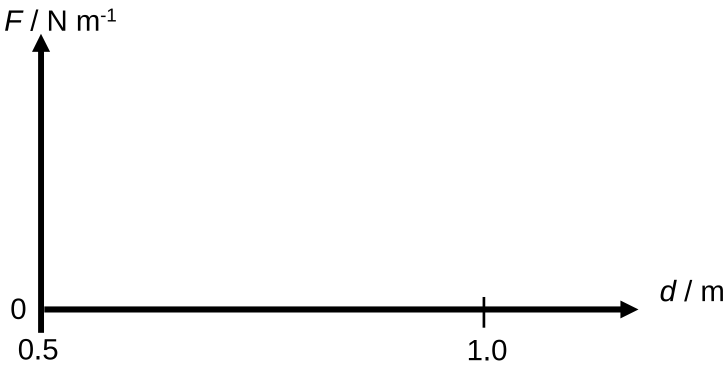
……………………………………………………………………………………………........[3]

(c) A similar wire Y is placed parallel to wire Z. The separation *d* between the two wires is 1.0 m. Wire Y is carrying a current of 1.0 A in the same direction as wire Z.

(i) Calculate the resultant magnetic flux density at the mid-point between the two wires.

magnetic flux density = …………………………….T [2]

(ii) Wire Y moves towards wire Z such that the separation *d* of the two wires decreases from 1.0 m to 0.5 m. Wire Y is maintained parallel to wire Z throughout the motion. Sketch the variation with separation *d* of the force per unit length *F* experienced by wire Y due to the magnetic field of wire Z.



[2]

7 A π^0 meson is a sub-atomic particle.
A stationary π^0 meson, which has mass 2.4×10^{-28} kg, decays to form two γ-ray photons.
The nuclear equation for this decay is

$$\pi^0 \rightarrow \gamma + \gamma.$$

(a) Explain why the two γ-ray photons will move off in opposite directions with equal energies.

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

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

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

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

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

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

(b) Determine, for each γ-ray photon,

(i) the energy,

energy = ... J [2]

(ii) the wavelength,

wavelength = ... m [2]

(iii) the momentum.

momentum = ... N s [2]

Section B

Answer **one** question in this section.

8 **(a)** Define

(i) resistance

…………………………………………………………………………………………

……………………………………………………………………………………… [1]

(ii) the ohm

…………………………………………………………………………………………

……………………………………………………………………………………… [1]

(b) Sketch the I–V characteristics of a metallic conductor at constant temperature on Fig. 8.1 and a filament lamp on Fig. 8.2. [2]

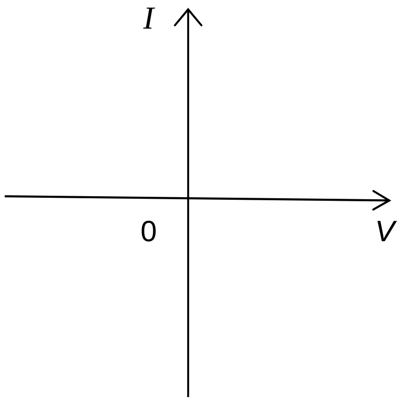


Fig. 8.1

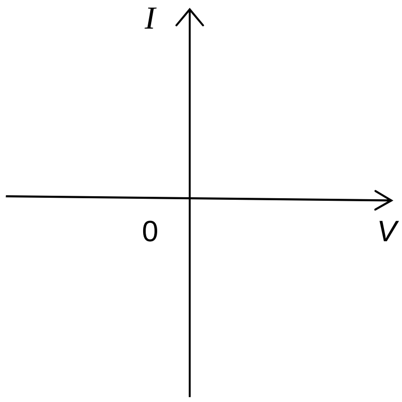


Fig. 8.2

(c) State and explain the difference between how the resistance of a filament lamp and the resistance of a semiconductor vary with temperature.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

………………………………………………………………………………………[3]

(d) 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 $5.5 \times 10^{-8}\ \Omega$ 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.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(iii) State one important property of a conductor used to make heating elements.

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

(e) 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. 8.3 in order to monitor temperature changes.

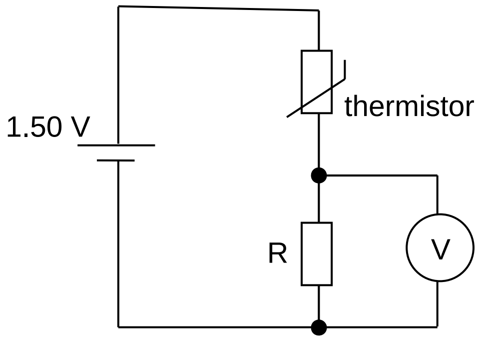


Fig. 8.3

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

(i) The voltmeter is to read 1.00 V at 0 °C. Show that the resistance of resistor R is 7800 Ω.

[1]

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

reading = …………………………….V [2]

(iii) The voltmeter in Fig. 8.3 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]

9 **(a)** State and explain two relations in which the Planck constant h is the constant of proportionality.

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

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

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

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

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

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

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

…………………………………………………………………………………………..........[4]

(b) Experiments are conducted to investigate the photoelectric effect.

(i) It is found that, on exposure of a metal surface to light, either electrons are emitted immediately or they are not emitted at all.

Suggest why this observation does not support a wave theory of light.

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

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

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

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

(ii) Data for the wavelength λ of the radiation incident on the metal surface and the maximum kinetic energy E_k of the emitted electrons are shown in Fig. 9.1.

λ /nm	E_k /10^{-19} J
650	-
240	4.44

Fig. 9.1

1. Without any calculation, suggest why no value is given for E_k for radiation of wavelength 650 nm.

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

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

2. Use data from Fig. 9.1 to determine the work function energy of the surface.

work function energy = ... J [2]

(iii) Radiation of wavelength 240 nm gives rise to a maximum photoelectric current I. The intensity of the incident radiation is maintained constant and the wavelength is now reduced.

State and explain the effect of this change on

1. the maximum kinetic energy of the photoelectrons,

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

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

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

2. the maximum photoelectric current I.

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

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

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

(c) Some electron energy levels in atomic hydrogen are illustrated in Fig. 9.2.

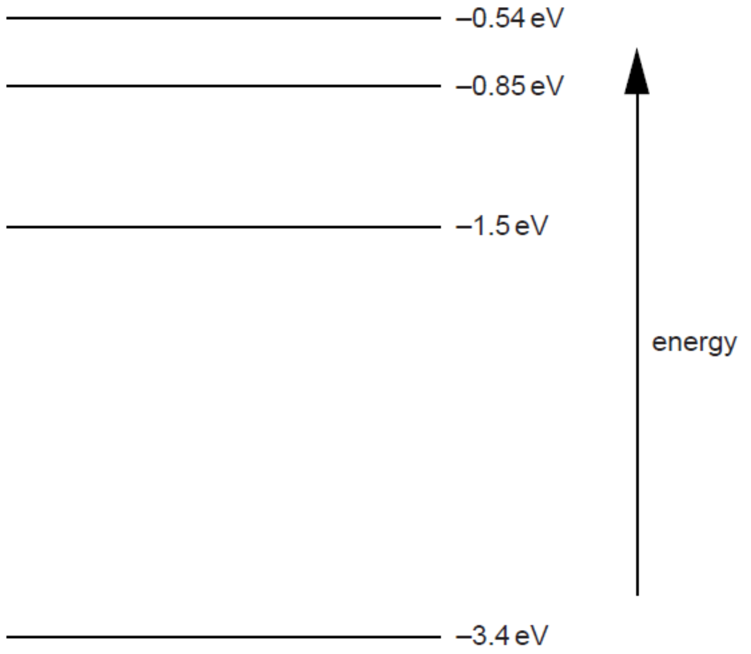


Fig. 9.2

The longest wavelength produced as a result of electron transitions between two of the energy levels shown in Fig. 9.2 is 4.0×10^{-6} m.

(i) On Fig. 9.2,

1. draw, and mark with the letter L, the transition giving rise to the wavelength of 4.0×10^{-6} m, [1]

2. draw, and mark with the letter S, the transition giving rise to the shortest wavelength. [1]

(ii) Calculate the wavelength for the transition you have shown in **(i) part 2**.

wavelength = …………………………….m [2]

(iii) Photon energies in the visible spectrum vary between approximately 3.66 eV and 1.83 eV.

Determine the energies, in eV, of photons in the visible spectrum that are produced by transitions between the energy levels shown in Fig. 9.2.

photon energies = …………………………….eV [2]

BLANK PAGE