Name: ______________________________ (   )   Class: 22 / ______

ANDERSON SERANGOON JUNIOR COLLEGE

2022 JC2 Preliminary Examination

PHYSICS Higher 2 — 9749/03

Paper 3 Longer Structured Questions — **Thursday 15 September 2022**

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.

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.

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	/ 8
2	/ 9
3	/ 12
4	/ 11
5	/ 11
6	/ 9
7	/ 20
8	/ 20
Deduct	
Total	

This document consists of **25** printed pages and **3** blank pages.

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	$T/\text{K} = T/{}^\circ\text{C} + 273.15$
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 a 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 in the spaces provided.

1 **(a)** State Newton's second law of motion.

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

(b) Two objects X and Y are attached together by a rope of negligible mass over a frictionless pulley in Fig. 1.1.

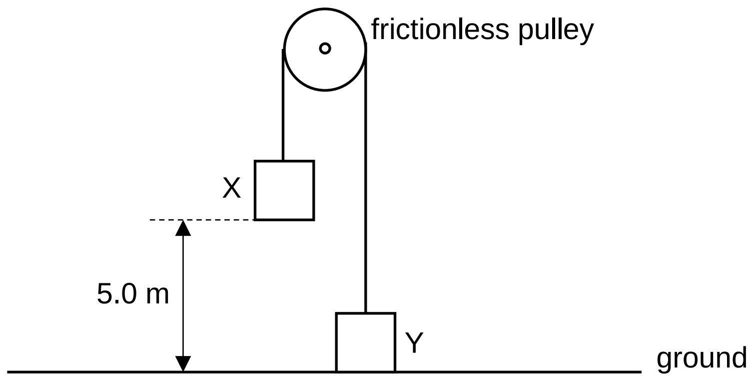

Fig. 1.1

The mass of object X is greater than the mass of object Y. Object Y is held on the ground and object X is at a vertical height of 5.0 m above the ground. Object Y is released. Air resistance is negligible.

(i) Explain why the acceleration of object X is less than the acceleration of free fall *g*.

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

(ii) Show that the acceleration of object Y is given by the relation

$$a = \frac{m_X - m_Y}{m_X + m_Y} g$$

where m_X is the mass of object X, m_Y is the mass of object Y, and g is the acceleration of free fall.

[3]

(iii) The mass of object X is 6.0 kg and the mass of object Y is 3.0 kg. Calculate the time taken by object X to reach the ground.

time taken = …………………………… s [2]

[Total: 8]

2 A mass is suspended from one end of a spring as shown in Fig. 2.1a. The mass is lowered into a beaker of water until it is fully submerged as shown in Fig. 2.1b. The extension of the spring reduces by 4.5 mm when the mass is fully submerged.

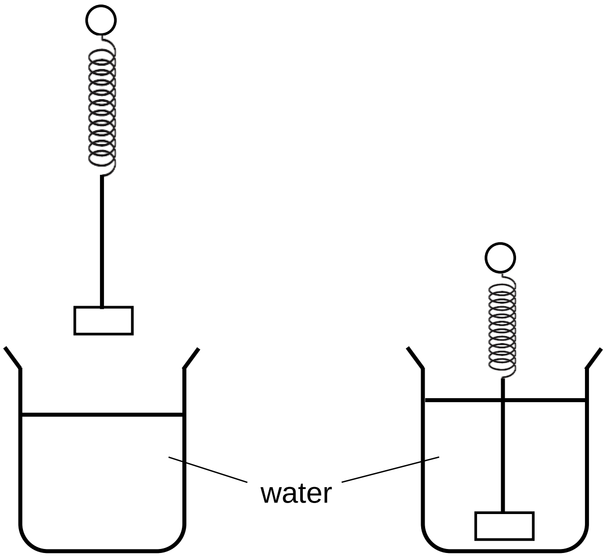

Fig. 2.1a **Fig. 2.1b**

The spring has a spring constant of 42 N m^{-1} and the density of water is 1000 kg m^{-3}.

(a) Show that the upthrust acting on the mass is 0.19 N.

[2]

(b) Determine the volume of the mass.

volume = …………… m^3 [2]

(c) State the magnitude of force that the mass exerts on the water and explain your answer.

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

(d) The mass is slowly raised vertically by lifting the upper end of the spring.

The vertical distance moved by the mass from its original position is s.

The mass reaches constant speed at $s = s_1$ as shown in Fig. 2.2a. It continues to move at a constant speed until it is fully out of the water for a short distance at $s = s_2$ as shown in Fig. 2.2b.

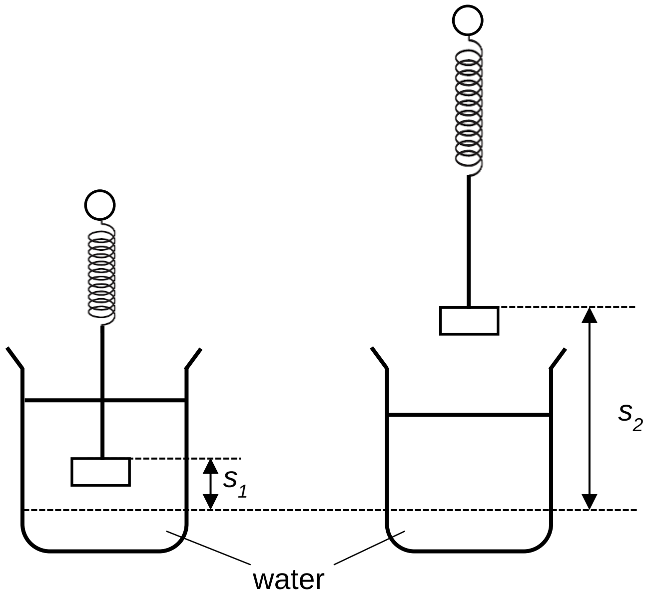

Fig. 2.2a **Fig. 2.2b**

On the axes of Fig. 2.3 below, sketch the variation with s of the extension e of the spring, from s_1 to s_2. Drag force is negligible.

Fig. 2.3

[3]

[Total: 9]

3 **(a)** **(i)** Define *gravitational potential* at a point.

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.... [2]

(ii) Explain why gravitational potential is negative.

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.... [3]

(b) A moon of mass M and radius R orbits a planet of mass $3M$ and radius $2R$.
At a particular time, the distance between their centres is D, as shown in Fig. 3.1.

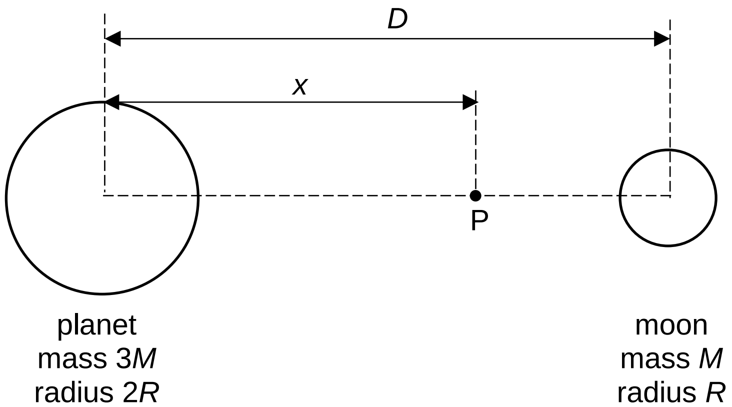

Fig. 3.1

Point P is a point along the line between the centres of the planet and the moon, at a variable distance x from the centre of the planet.

The variation with x of the gravitational potential ϕ at point P, for points between the planet and the moon, is shown in Fig. 3.2.

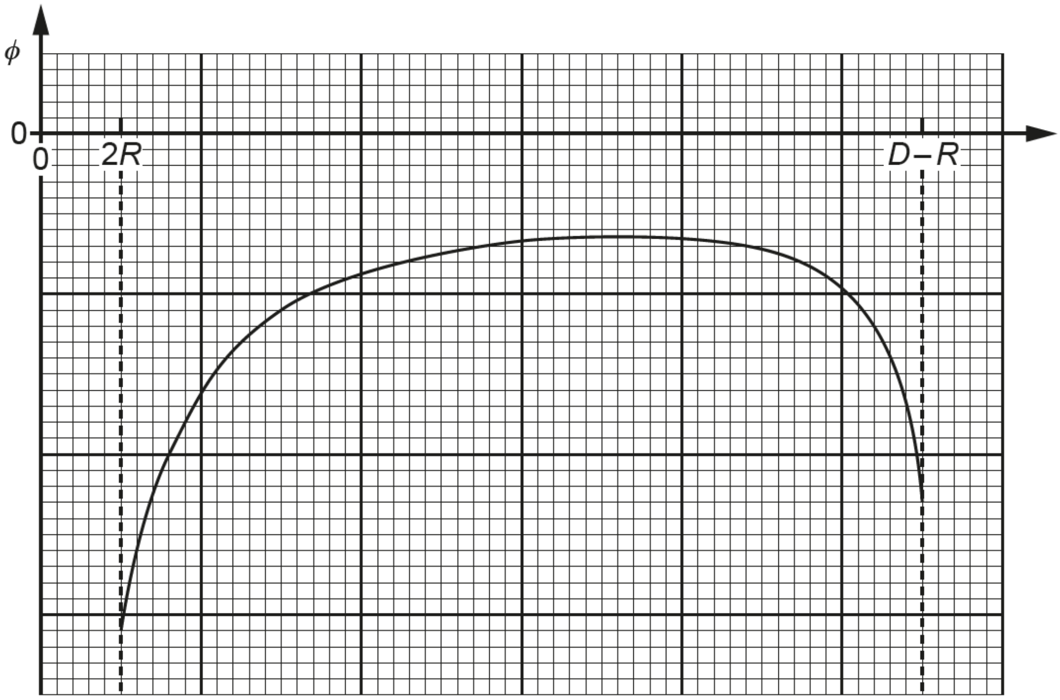

Fig. 3.2

On Fig 3.3, sketch the variation with x of the gravitational field strength g at point P between $x = 2R$ to $x = D - R$.

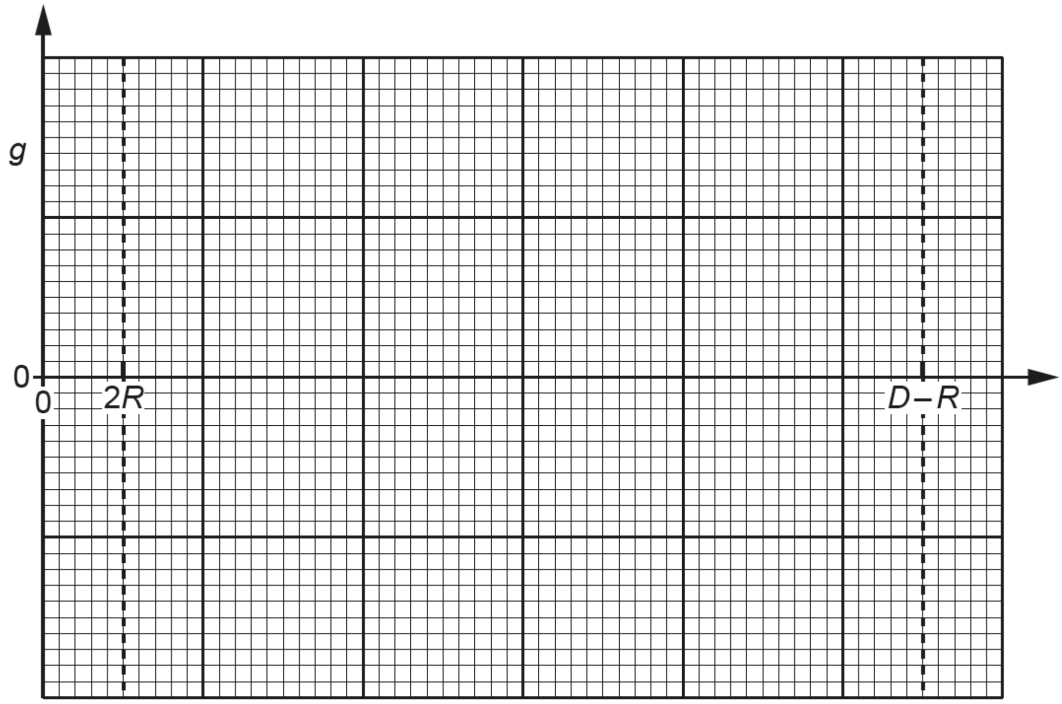

Fig. 3.3

[2]

(c) The Earth and the Moon may be considered to be isolated in space with their masses concentrated at their centres.

The orbit of the Moon around the Earth is circular with a radius of 3.84×10^5 km.
The radius of the Earth is 6.37×10^3 km and the mass of the Moon is 7.35×10^{22} kg.

(i) Given that the gravitational field strength at the Earth's surface is 9.81 N kg^{-1}, show that the gravitational force on the Moon is 1.98×10^{20} N.

[2]

(ii) Tidal action on the Earth's surface causes the radius of the orbit of the Moon to increase by 4.0 cm each year.

Using the answer in **(c)(i)**, calculate the change, in one year, of the gravitational potential energy of the Moon. Explain your working.

energy change = …………………………… J [3]

[Total: 12]

4 **(a)** Define *specific heat capacity*.

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

(b) A container of volume V contains N molecules, each of mass m, of an ideal gas at pressure p. Each molecule travels with a mean-square speed $<c^2>$.

The pressure p of an ideal gas is given by

$$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle .$$

(i) Show that the mean kinetic energy $\langle E_K \rangle$ of a molecule is given by:

$$<E_K> = \frac{3}{2}kT .$$

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

[2]

(ii) Explain why the internal energy of the gas is equal to the total kinetic energy of the molecules.

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

(c) The mass of a hydrogen molecule is 3.34×10^{-27} kg.

Use the expression in **(b)(i)** to determine the root-mean-square (r.m.s) speed of a molecule of hydrogen gas at 25°C.

r.m.s. speed = ……………………… m s^{-1} [2]

(d) Use the first law of thermodynamics to explain the following observations:

(i) The specific heat capacity of an ideal gas measured at constant volume is lower than the specific heat capacity when measured at constant pressure.

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(ii) The internal energy of the water in an ice cube increases when the ice melts, at atmospheric pressure, to form a liquid without any change of temperature.

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

[Total: 11]

5 A battery of electromotive force (e.m.f.) 12 V and negligible internal resistance is connected to a network of two lamps and two resistors, as shown in Fig. 5.1.

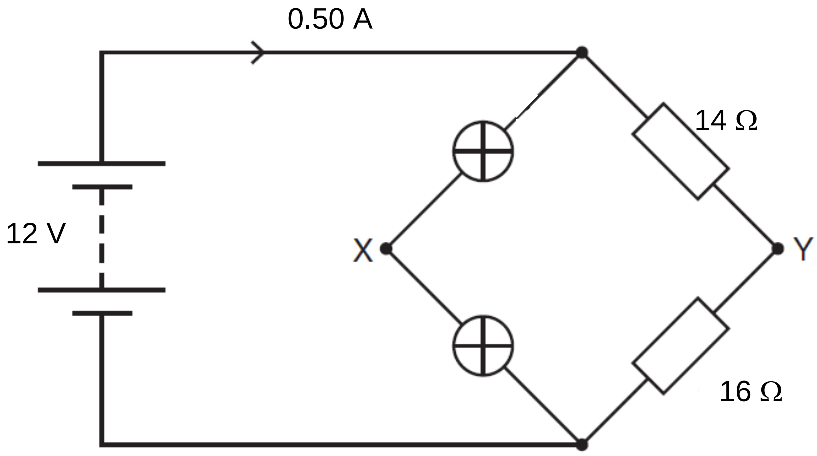

Fig. 5.1

The two lamps in the circuit have equal resistances. The two resistors have resistances 14 Ω and 16 Ω. The lamps are connected at junction X and the resistors are connected at junction Y. The current in the battery is 0.50 A.

(a) The two filament lamps are observed to take a few seconds to achieve their full brightness. Explain why this is so.

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....[2]

(b) Calculate the potential difference across the 16 Ω resistor.

potential difference = ...V [2]

(c) **(i)** Determine the potential difference between points X and Y.

potential difference = ……………………………V [1]

(ii) State whether point X or point Y is at a higher potential.

……………………………………………………………………………………….[1]

(d) Show that the current in the lamps is 0.10 A.

[1]

(e) Calculate the ratio

$$\frac{\text{total power dissipated by the lamps}}{\text{total power produced by battery}}$$

ratio = ………………………………[2]

(f) The 14 Ω is replaced by another resistor of higher resistance.

State and explain the effect, if any, of this change on the ratio in **(e)**.

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

[Total: 11]

6 A resistance wire of uniform cross-sectional area 3.3×10^{-7} m^2 and length 2.0 m is made of metal of resistivity 5.0×10^{-7} Ω m.

(a) Show that the resistance of the wire is 3.0 Ω.

[2]

(b) The ends of the resistance wire in **(a)** are connected to the terminals S and T in the circuit shown in Fig. 6.1.

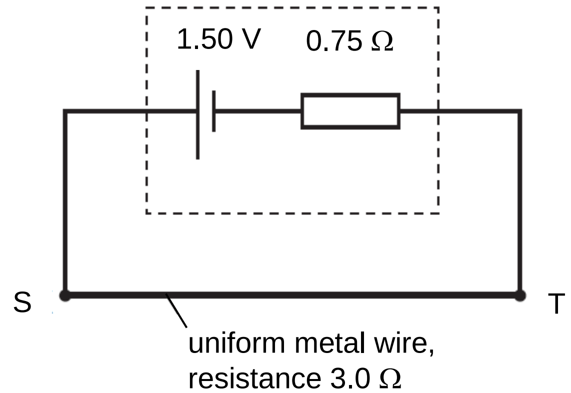

Fig. 6.1

The cell has an e.m.f. of 1.50 V and internal resistance 0.75 Ω.

The resistance wire has 8.5×10^{28} free electrons per m^3.

Calculate the average drift speed of the electrons.

speed = ………………………..m s^{-1} [2]

[Turn Over

(c) A galvanometer and a cell of e.m.f. *E* with negligible internal resistance are connected to the circuit in **(b)**, as shown in Fig. 6.2.

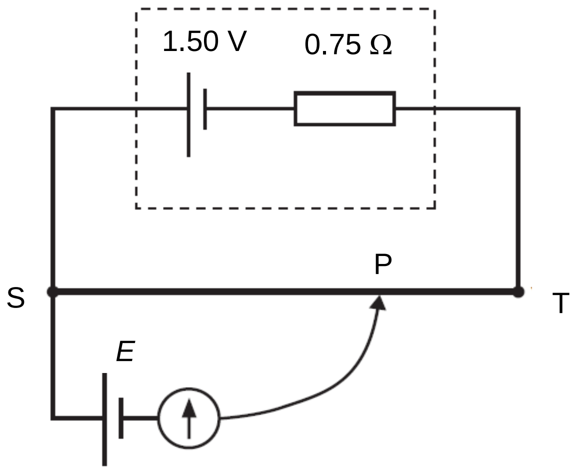

Fig. 6.2

The galvanometer has a reading of zero when the connection P is adjusted so that the length SP is 1.4 m.

(i) Determine the e.m.f. *E* of the cell.

e.m.f = ……………………………V [2]

(ii) The circuit in Fig. 6.2 is modified by replacing the original resistance wire with a second resistance wire. The second wire has the same length as the original wire and is made of the same metal.

The second wire has a smaller cross-sectional area than the original wire. Connection P is adjusted on the second wire so that the galvanometer has a reading of zero.

State and explain whether length SP for the second wire is shorter than, longer than or the same as length SP for the original wire when the galvanometer reading is zero.

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[Total: 9]

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Section B

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

7 **(a)** Fig. 7.1 shows two identical coils mounted next to each other and passing through a horizontal board. The currents in the two coils are equal.

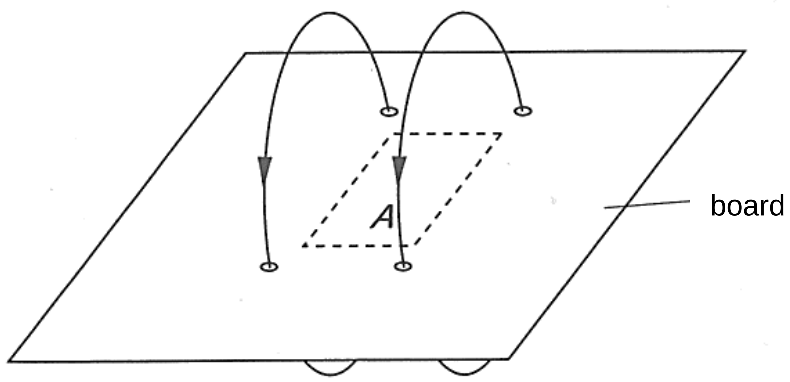

Fig. 7.1

The separation of the two coils is equal to their radii and the magnetic field in the area labelled A is uniform.

On Fig. 7.2 draw the magnetic field pattern due to the currents over the whole area of the board.

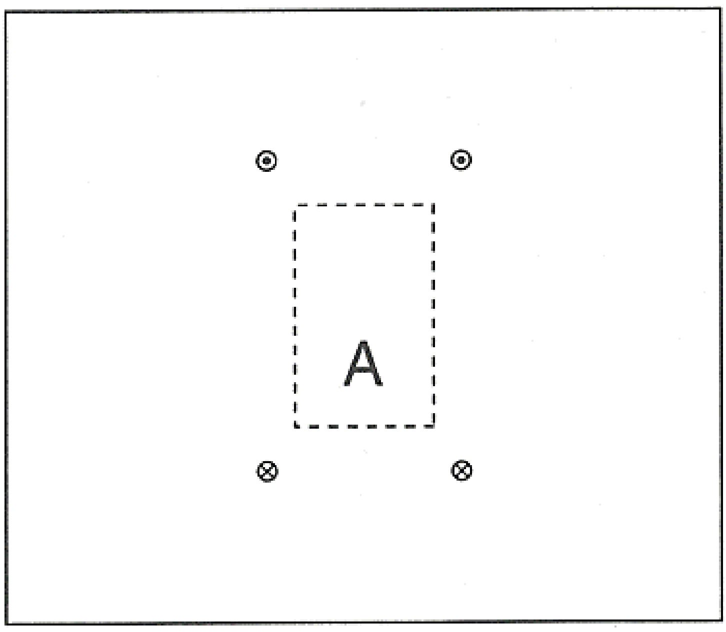

Fig. 7.2 [3]

(b) Two long parallel identical wires, wire X and Y are held with one directly above the other on a table.

The current in wire X is 90 A. The current in wire Y is 60 A and is in opposite direction to the current in wire X. Wire Y is held in suspension magnetically at a distance of 5.0 cm above the wire X as shown in Fig. 7.3.

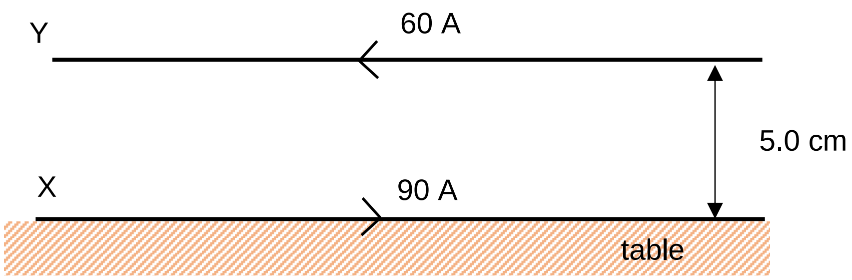

Fig. 7.3

(i) Calculate the magnetic flux density at wire Y due to the current in wire X.

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

(ii) Hence, determine the mass per unit length of the wire.

mass per unit length = ………………… kg m^{-1} [2]

(c) A moving charged particle may experience a force in an electric field and in a magnetic field.

State a difference between the forces experienced in the two types of field.

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

(d) A thin metal foil is placed in a magnetic field.

A negatively charged particle enters the region of the magnetic field. It loses kinetic energy as it passes through the foil. The particle follows the path shown in Fig. 7.4.

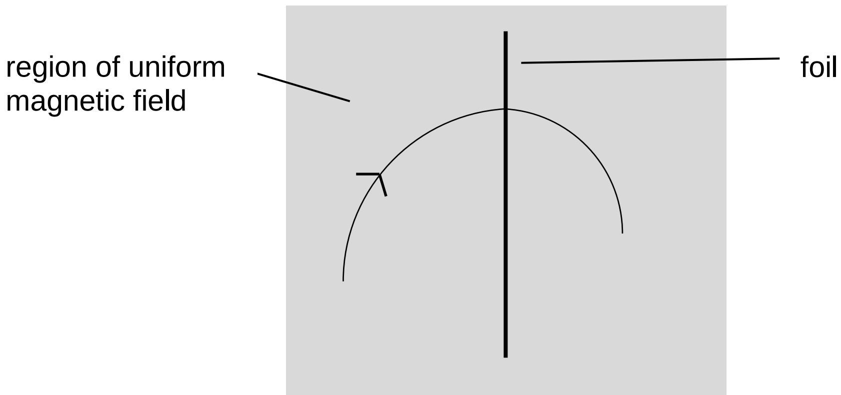

Fig. 7.4

(i) State the direction of the magnetic field.

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

(ii) The path of the particle has different radii on each side of the foil. The radii are 7.4 cm and 5.7 cm.

Determine the ratio $\dfrac{\text{final momentum of particle}}{\text{initial momentum of particle}}$

for the particle as it passes through the foil. Explain your working.

ratio = ……………………………..[3]

(e) A pair of concentric coils is shown in Fig. 7.5.

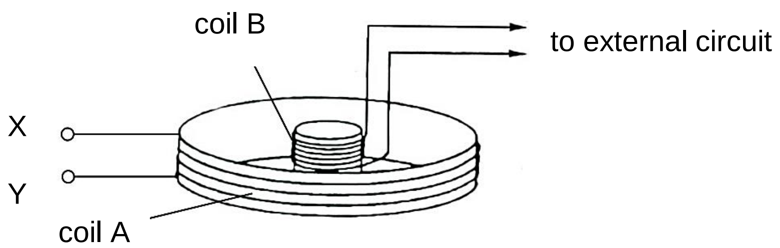

Fig. 7.5

The outer coil A is connected to a variable power supply by the terminals XY. The variation with time t of the current I in coil A is shown in Fig. 7.6.

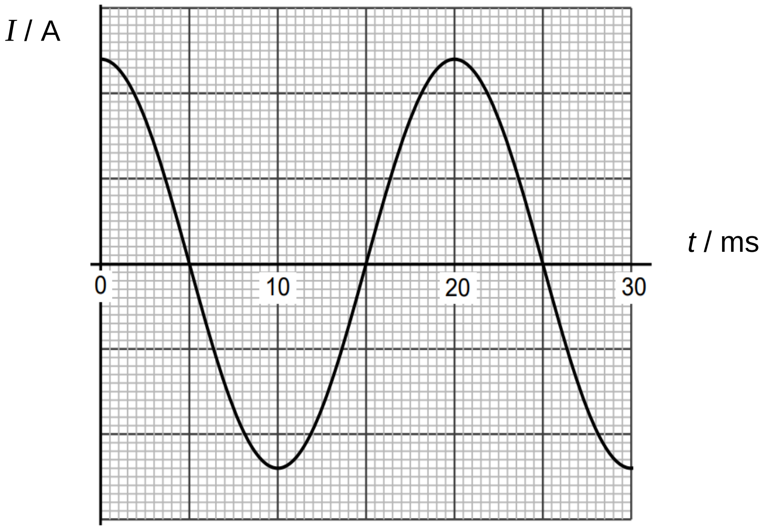

Fig. 7.6

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

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

(ii) Using Faraday's law, explain why an e.m.f. is induced in coil B.

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

(iii) State an instant where the induced e.m.f. in coil B is a maximum value.

t = ……………………………ms [1]

(iv) Explain your choice of answer for **(e)(iii).**

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

(v) State and explain whether the induced current in coil B is in the same or opposite direction as the current in coil A from t = 10 ms to t = 15 ms.

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

[Total: 20]

8 **(a)** Two metal electrodes are placed in an evacuated tube. The collector electrode is at a positive potential with respect to the emitter electrode. Starting from rest, electrons leave the emitter electrode and move towards the collector electrode.

(i) The potential difference between the electrodes is 140 V.

1. Determine, in electron-volts, the kinetic energy of an electron as it reaches the collector electrode.

kinetic energy = …………………………… eV [1]

2. Determine the momentum of the electron as it reaches the collector electrode.

momentum = ……………………………kg m s^{-1} [2]

(ii) An electron diffraction pattern consisting of concentric rings is observed on a fluorescent screen after the accelerated electrons are made to pass through a graphite film.

1. Describe the energy changes of the electrons after emission from the emitter electrode to the formation of concentric rings on the fluorescent screen.

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

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

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

2. State and explain what must be done to the potential difference between the electrodes in order to have the rings of the diffraction pattern closer together.

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

(b) A cool gas is placed in a chamber as shown in Fig. 8.1. To excite the atoms of the gas, a beam of electrons with kinetic energy of 5.0×10^{-19} J each is directed as shown.

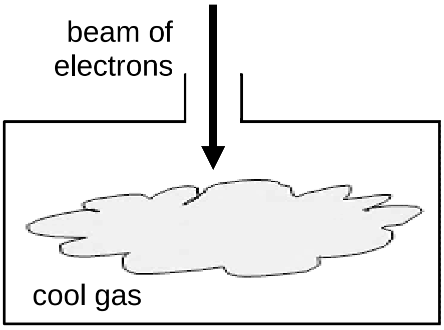

Fig. 8.1

Fig. 8.2 shows the energy states within the atoms of the gas, with level A_1 being the lowest energy state.

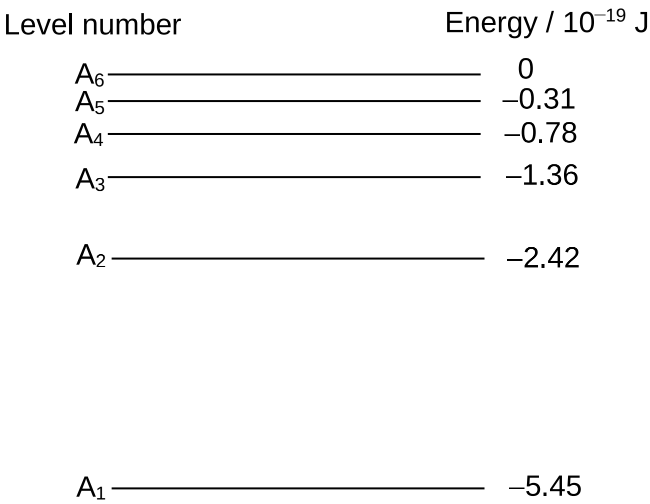

Fig 8.2

(i) State the highest energy level number in which the atoms of the gas can be excited to in this setup.

level number = ……………………………. [1]

(ii) Determine the shortest wavelength of the photons emitted from the gas.

wavelength = …………….…………………..m [2]

(iii) State the region of the electromagnetic spectrum which the radiation in **(b)(ii)** occurs.

region = ………….……………………………… [1]

(c) **(i)** By reference to the photoelectric effect, explain

1. what is meant by *work function energy*,

…………………………………………………………………………………………

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

2. why, even when the incident light is monochromatic, the emitted electrons have a range of kinetic energies up to a maximum value.

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

(ii) In an experiment to investigate the photoelectric effect, a student measures the wavelength λ of the light incident on a metal surface, and the maximum kinetic energy E_{max} of the emitted electrons. The variation with E_{max} of $\frac{1}{\lambda}$ is shown in Fig. 8.3.

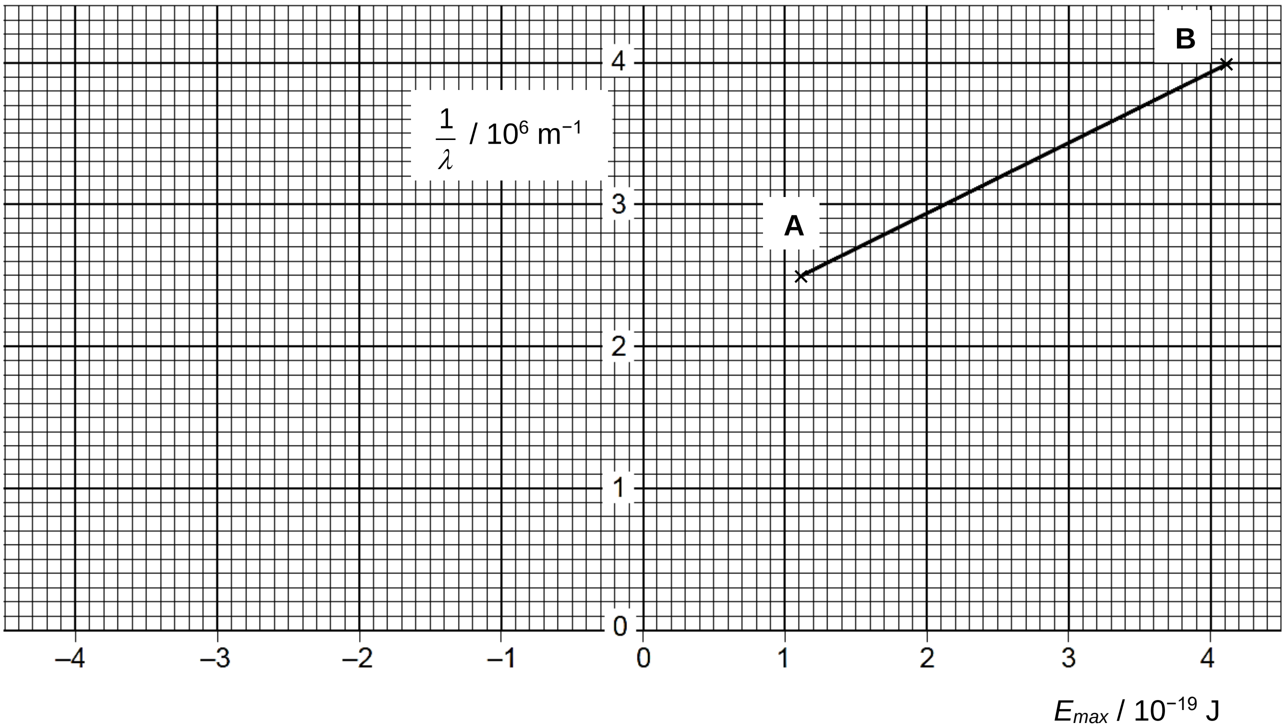

Fig. 8.3

[Turn Over

1. Without using the value of the Planck constant, use Fig. 8.3 to determine the work function energy of the metal surface.

work function energy = ……………………………. J [2]

2. Using points A and B, determine the Planck constant.

Planck constant = ……………………………. J s [3]

[Total: 20]

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