Name: ______________________________ (   )   Class: 23 / ______

ANDERSON SERANGOON JUNIOR COLLEGE

2023 JC2 Preliminary Exam

PHYSICS Higher 2 — 9749/03

Paper 3 Longer Structured Questions — **Friday 15 September 2023**

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	

This document consists of **26** printed pages and **2** blank pages.

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_o = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_o = 8.85 \times 10^{-12}$ 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	$\phi = -\dfrac{Gm}{r}$
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	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
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	$\lambda = \dfrac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1 A raindrop falls vertically from rest. The variation with time t of the vertical velocity of the raindrop is shown in Fig. 1.1.

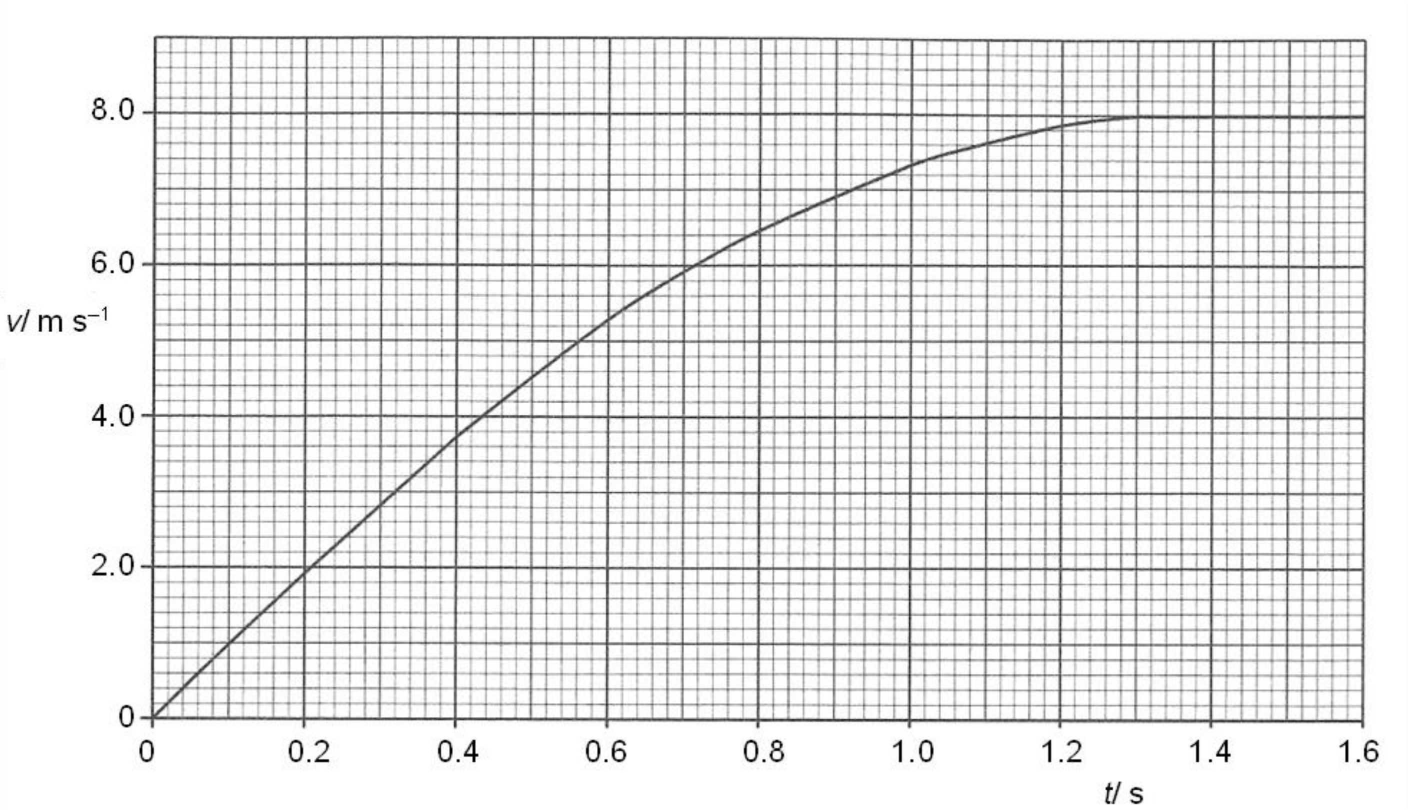

Fig. 1.1

(a) Use Fig. 1.1 to explain how it may be deduced that air resistance varies with speed.

....

....

....

....

....

.... [2]

(b) A student suggests that the drag force D on the raindrop of mass m falling with a speed v is given by the expression

$$D = k\,v^2$$

where k is a constant.

At speed v, the acceleration of the raindrop is a.

(i) Show that, based on the student's suggestion, and without using data from the graph in Fig. 1.1,

$$(g - a) = \frac{kv^2}{m}$$

where g is the acceleration of free fall.

[2]

(ii) Use information from Fig. 1.1 or otherwise, complete Table 1.2. Show your working clearly.

Table 1.2

velocity v / m s^{-1}	acceleration a / m s^{-2}	$(g - a)$ / m s^{-2}
4.0		
8.0	0	9.8

[2]

(iii) Use the completed Table 1.2 to deduce whether the student's suggestion for velocities of 4.0 m s^{-1} and 8.0 m s^{-1} is correct.

[2]

[Total: 8]

[Turn Over

2 **(a)** Define *force*.

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

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

(b) Mechanical power P can be calculated using the formula $P = Fv$.

Use the concept of work and the definition of power to show how this formula is derived.

[2]

(c) The engine of a lorry provides 130 kW of power to the lorry's wheels when it is travelling at a constant speed of 25 m s^{-1} along a straight horizontal road.

(i) Show that the resistive force opposing the forward motion of the lorry is 5200 N. Explain your working clearly.

[2]

(ii) Describe, in terms of Newton's third law, the horizontal forces acting on the tyres of the lorry and on the road.

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

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

(d) The lorry in (c) travels up a straight section of road that is inclined at an angle θ to the horizontal, as shown in Fig. 2.1.

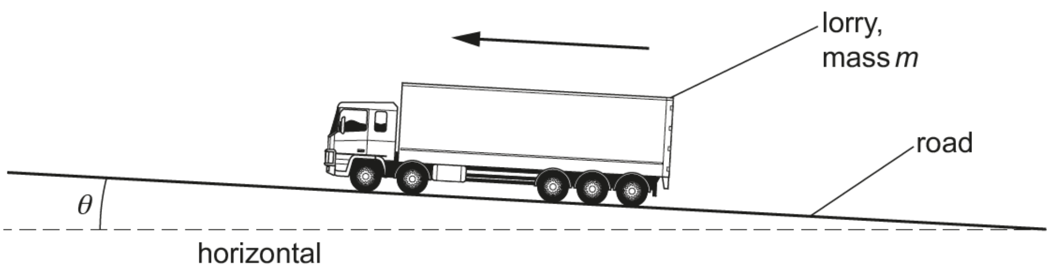

Fig. 2.1 (not to scale)

The total resistive force remains unchanged at 5200 N and the engine now provides greater power to cause an acceleration of 0.15 m s^{-2}. The total mass of the lorry is 36 000 kg. The angle θ is 1.4°.

Determine the total force provided by the engine.

force = …………………………….N [2]

[Total: 9]

3 **(a)** Two identical cars are moving around a horizontal track. One car follows path X and the other follows path Y, as shown in Fig. 3.1.

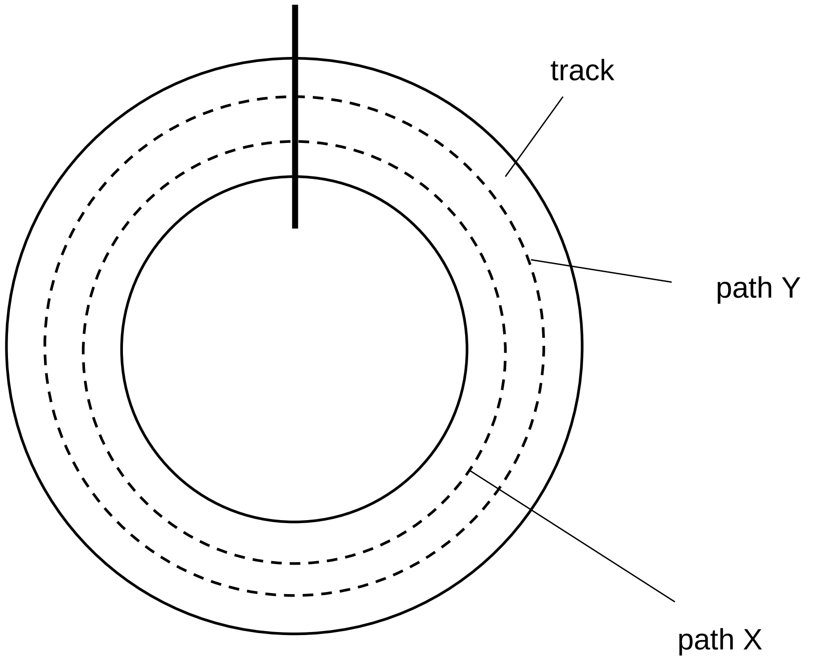

Fig. 3.1

The maximum lateral friction force that the cars can experience without sliding is the same for both cars. Each car is travelling at its maximum speed at which it can move without sliding.

State and explain whether the magnitude of the acceleration and maximum speed of the car on path Y is less than, greater than or same as the car on path X.

acceleration

....

....

....

maximum speed

....

....

....[4]

(b) Jupiter has close to eighty moons, of which eight of them are in approximately circular orbits. Jupiter has a mass M_J, radius R_J and a Jupiter-day is approximately 0.417 Earth-days.

The orbital radii and periods of two of the moons of Jupiter are tabulated in Table 3.1. The orbital radii and the orbital periods of these moons are expressed in units of R_J and Earth-days respectively.

Table 3.1

name of Moon	orbital radius / R_J	orbital period / Earth-days
Amalthea	2.62	....
Thebe	3.18	0.676

(i) Show that the period T of a circular orbit around Jupiter, expressed in terms of the radius of the orbit R is given by

$$T = \sqrt{\frac{4\pi^2 R^3}{GM_J}}\ .$$

[2]

(ii) Using the data provided in Table 3.1, determine the orbital period for Amalthea.

orbital period = …………………………….Earth-days [2]

(iii) A *stationary orbit* refers to a circular orbit around a planet in which a moon would appear stationary to an observer on the planet's surface.

Using the data provided in Table 3.1, explain whether it is possible for the moon Thebe to be in a stationary orbit around Jupiter.

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

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

[Total: 10]

[Turn Over

4 The apparatus shown in Fig. 4.1 may be used to demonstrate a stationary wave.

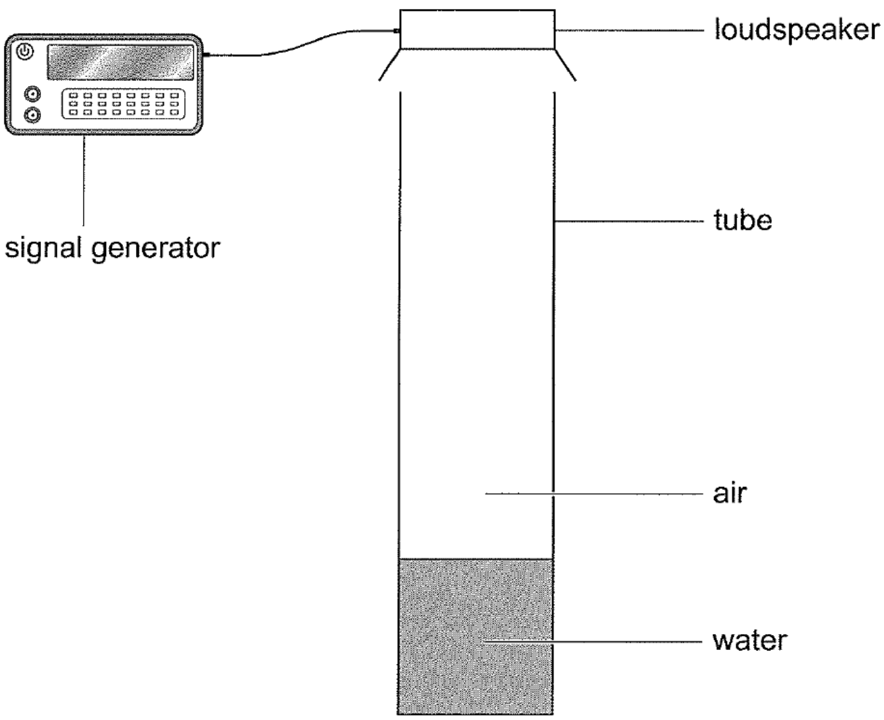

Fig. 4.1

(a) Apart from changing the frequency, state how the apparatus shown in Fig. 4.1 may be adjusted to allow a stationary wave to form.

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

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

(b) When the loudspeaker is emitting sound of frequency 480 Hz, the minimum length of the column of air is 18 cm for a stationary wave to be produced.

Calculate the speed of sound in the air column.

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

(c) The frequency of the sound from the loudspeaker in Fig. 4.1 is increased until the next stationary wave is produced.

(i) On Fig. 4.2, draw a representation of the stationary wave that is produced. Label any nodes N and any antinodes A.

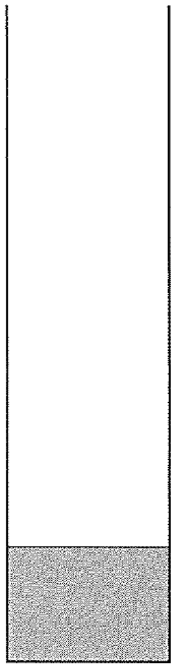

Fig. 4.2

[3]

(ii) Describe the movement of the air particles at the open top of the air column.

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(iii) Determine the frequency of the sound.

frequency = ……………………………Hz [2]

[Total: 10]

5 Fig. 5.1 shows the I–V characteristics for two 12 V filament lamps A and B.

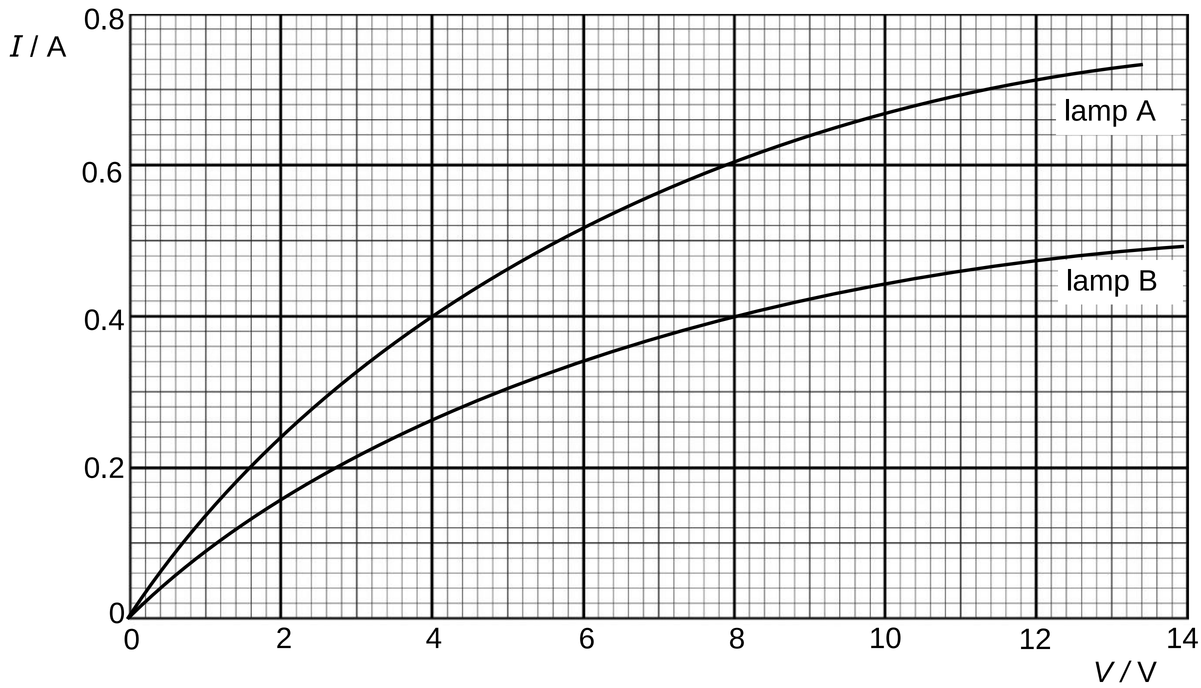

Fig. 5.1

(a) Explain the shape of the graph for filament lamp.

....

....[2]

(b) The two lamps are now connected in series with a 12 V battery with negligible internal resistance as shown in Fig. 5.2.

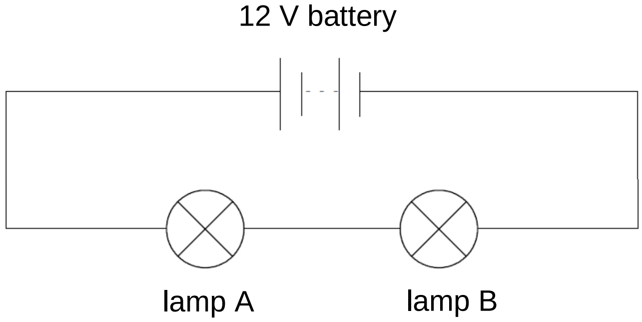

Fig. 5.2

(i) Use Fig. 5.1 to deduce the total current from the battery. Explain your deduction.

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....

....[2]

(ii) Compare the power dissipated by the two lamps.

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

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(c) A uniform resistance wire XY of length 80 cm is connected to the circuit as shown in Fig.5.3.

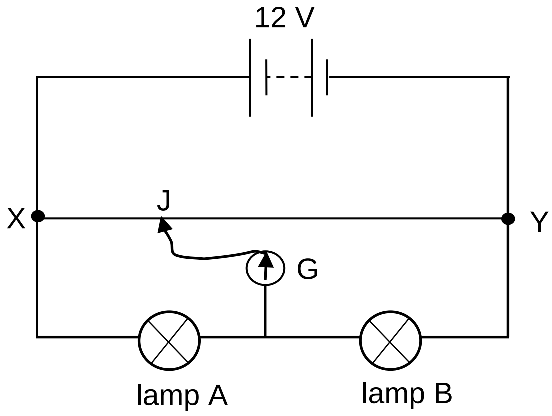

Fig. 5.3

The movable contact J can be connected to any point along the wire XY.

Calculate the length XJ required to produce zero current in the galvanometer G.

XJ = ………………..m [2]

[Total: 8]

6 **(a)** A coil of wire consisting of two loops is suspended from a fixed point as shown in Fig. 6.1.

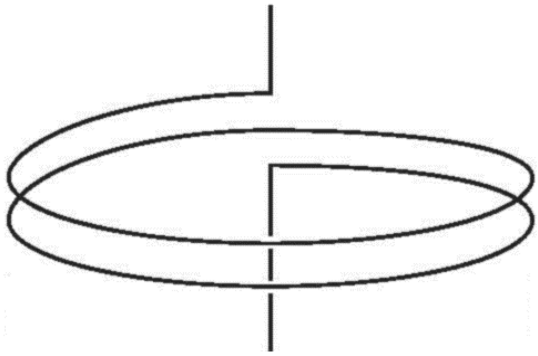

Fig. 6.1

The coil is connected into a circuit such that the lower end of the coil is free to move.

Explain why, when a current is switched on in the coil, the separation of the loops of the coil decreases.

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

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

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

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

(b) Fig. 6.2 shows a current balance in which a frame ABCD rests on conducting pivots. Arm AB is placed between a pair of strong magnets.

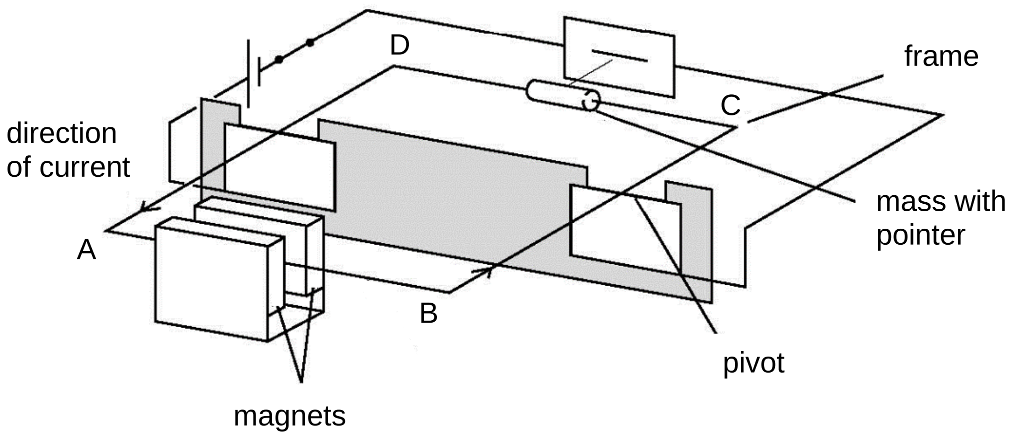

Fig. 6.2

When there is current of 4.5 A in arm AB of the frame, a mass must be added to arm CD to restore balance.

(i) State and explain the direction in which the magnetic force must be acting on the arm AB.

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

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

(ii) Arm AB has a length of 4.6 cm inside the uniform magnetic field. The magnetic force acting on arm AB is 24 mN.

Calculate the magnetic flux density of the uniform magnetic field.

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

[Total: 6]

7 Nuclear fission products are usually radioactive and give rise to a series of radioactive products. Each decay product has its own half life, but eventually a stable nuclide is reached.

One such fission product and its decay products is shown as below:

$$^{143}_{54}\text{Xe} \rightarrow {}^{143}_{55}\text{Cs} \rightarrow {}^{143}_{56}\text{Ba}$$

The half-lives of Xenon-143 and Caesium-143 are 0.511 s and 1.79 s respectively.

(a) Suggest why the number of Caesium-143 nuclei inside the nuclear reactor increases initially and decreases subsequently.

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

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

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

(b) Explain why Xenon-143 does not decay faster when heated.

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

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

(c) Suggest two reasons why a detector placed near to a sample of Xenon-143 would record a count rate much larger than the expected activity of Xenon.

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

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

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

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

(d) Xenon-143 decayed to Caesium-143 through *β*-particle emission. Although a lead container was used to contain Xenon-143 and it provides adequate shielding for the *β*- particle emission, some X-ray radiation can be detected outside the lead container. Explain why.

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

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

[Total: 9]

Section B

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

8 **(a)** A mercury-in-glass thermometer is initially at 23.0 °C. It is used to measure the temperature of an insulated beaker of water that is at 37.4 °C. The bulb of the thermometer is inserted into the water, and the water is stirred until the reading on the thermometer becomes steady.

The mass of water in the beaker is 18.7 g.
The mass of mercury in the thermometer is 6.94 g.
The specific heat capacity of water is 4.18 J g^{-1} K^{-1}.
The specific heat capacity of mercury is 0.140 J g^{-1} K^{-1}.

(i) Calculate, the final steady temperature indicated by the thermometer in the water.

temperature = ... °C [3]

(ii) It may be assumed that negligible heat is lost to the surroundings during the measurement of the temperature of the water, due to sufficient insulation provided by the beaker.

State one other assumption that you have used in your calculations in part **(a)(i)**.

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

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

(iii) Suggest **one** change that could be made to the design of the thermometer that would enable it to give a more accurate measurement of temperature.

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

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

(iv) Explain why the thermometer in **(a)** does **not** provide a direct measurement of thermodynamic temperature.

....

....

.... [2]

(v) Thermodynamic temperature T may be determined by the behaviour of a type of substance for which T is proportional to the product of pressure and volume.

State the name of this type of substance.

.... [1]

(b) A sealed container of fixed volume V contains N molecules, each of mass m, of an ideal gas at pressure p. The gas is supplied with thermal energy Q.

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

....

....

.... [2]

(ii) Explain, with reference to the first law of thermodynamics, why the increase in internal energy of the gas is Q.

....

....

.... [2]

(iii) Use the information in **(b)(ii)** to show that the specific heat capacity c of the gas is given by

$$c = \frac{3k}{2m}.$$

[3]

(iv) The container in **(b)** is now replaced with one that does not have a fixed volume. Instead, it now has a movable frictionless piston.

Suggest, with a reason, how the specific heat capacity of the gas would now compare with the value in **(b)(iii)**.

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

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

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

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

(v) The piston in **(b)(iv)** is now moved so that the gas expands, without supplying thermal energy.

Use kinetic theory to explain whether this will cause a change in the temperature of the gas.

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

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

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

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

[Total: 20]

9 **(a)** Define *magnetic flux linkage*.

....

....

.... [2]

(b) A solenoid of diameter 6.0 cm and 540 turns is placed in a uniform magnetic field as shown in Fig. 9.1.

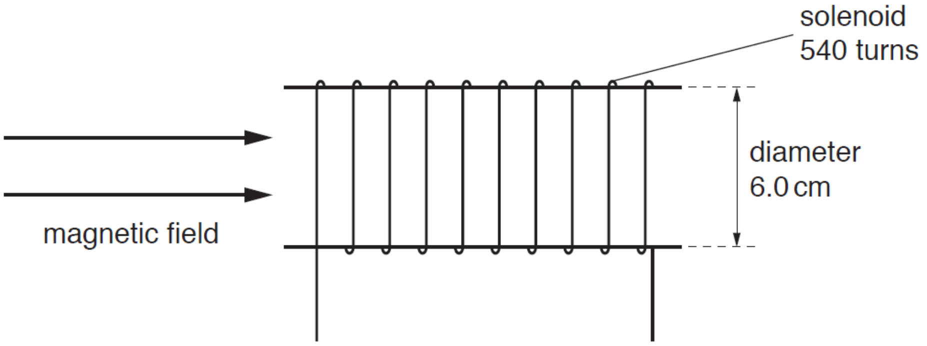

Fig. 9.1

The variation with time t of the magnetic flux density is shown in Fig. 9.2.

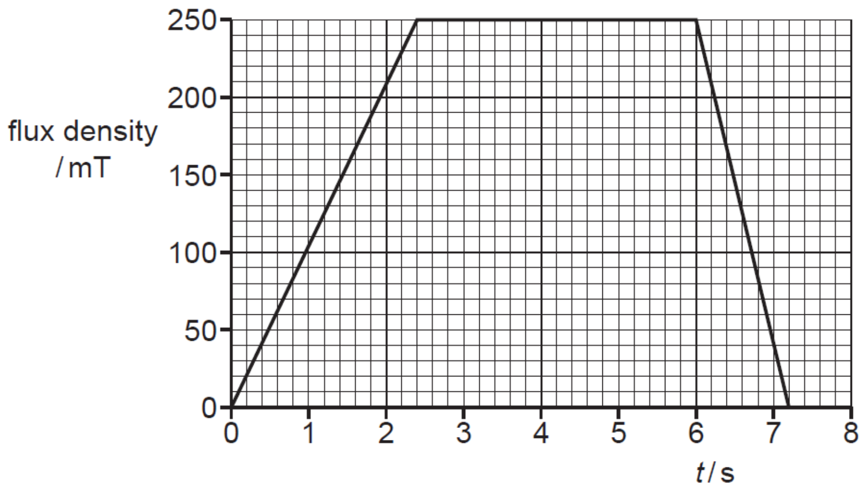

Fig. 9.2

Calculate the maximum magnitude of the induced electromotive force (e.m.f.) in the solenoid.

e.m.f. = ... V [3]

Question 9 continues on the next page.

(c) A thin copper sheet X is supported on a rigid rod so that it hangs between the poles of a magnet as shown in Fig. 9.3.

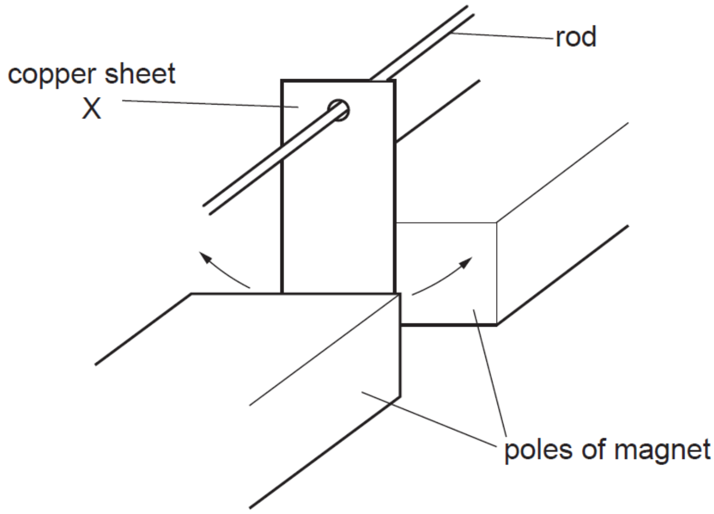

Fig. 9.3

Sheet X is displaced to one side and then released so that it oscillates. A motion sensor is used to record the displacement of X.

A second thin copper sheet Y replaces sheet X. Sheet Y has the same overall dimensions as X but is cut into the shape shown in Fig. 9.4.

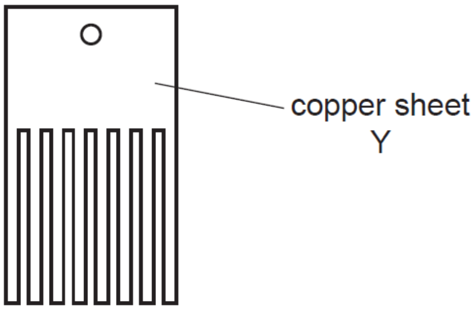

Fig. 9.4

The motion sensor is again used to record the displacement.

The graph in Fig. 9.5 shows the variation with time *t* of the displacement *s* of each copper sheet.

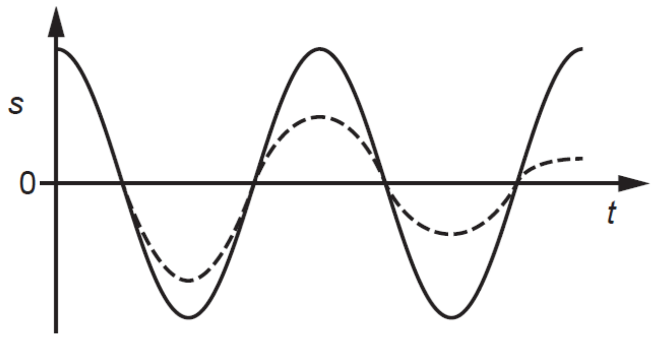

Fig. 9.5

(i) State the name of the phenomenon illustrated by the gradual reduction in the amplitude of the dashed line.

.... [1]

(ii) Deduce which copper sheet is represented by the dashed line. Explain your answer using the principles of electromagnetic induction.

....

....

....

....

....

....

.... [4]

(d) The output potential difference (p.d.) of an alternating power supply is represented by

$$V = 320 \sin(100\pi t)$$

where V is the p.d. in volts and t is the time in seconds.

The power supply is connected to resistor R of resistance 120 Ω and an ideal diode in the circuit shown in Fig. 9.6.

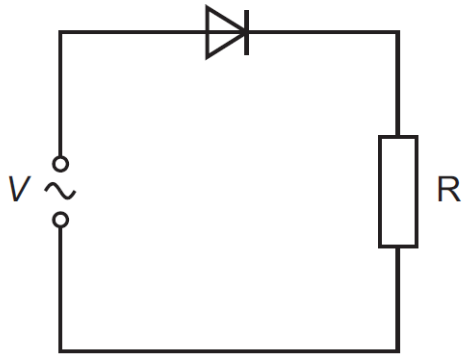

Fig. 9.6

(i) Sketch on Fig. 9.7, from time t = 0 to time t = 40 ms.

1. the variation with time t of the p.d across the source,

2. the variation with time t of the p.d across the R,

3. the variation with time t of the p.d across the diode.

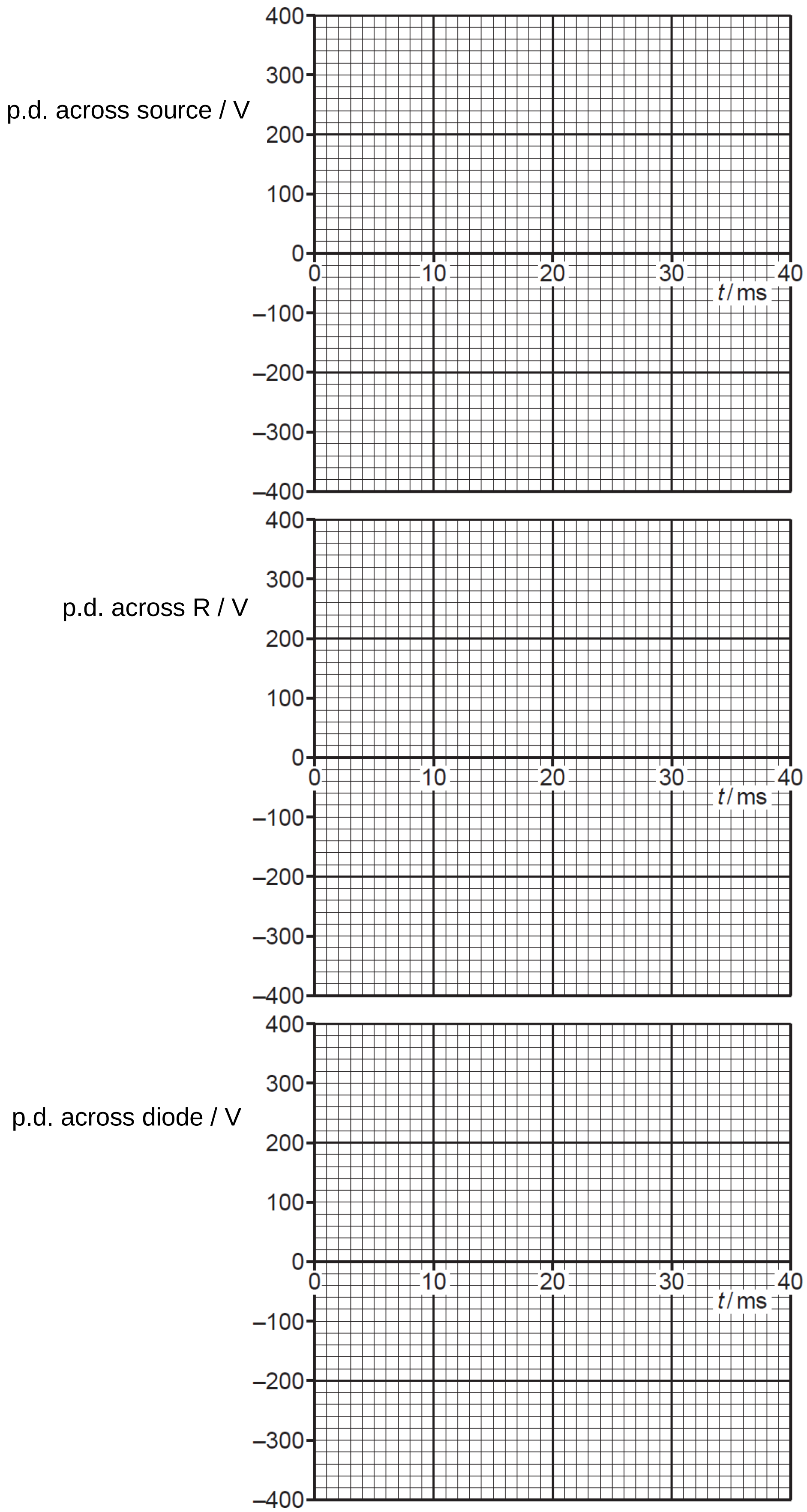
p.d. across source / V
400
300
200
100
0
–100
–200
–300
–400
0
10
20
30
40
t / ms
p.d. across R / V
p.d. across diode / V

Fig. 9.7

[5]

(ii) Determine the average power dissipated in the resistor R.

power = ……………………………W [2]

(iii) Define the *root-mean-square (r.m.s.) current.*

……………………………………………………………………………………………..

……………………………………………………………………………………………..

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

(iv) Determine the r.m.s current in the resistor R.

r.m.s current = …………………………….A [2]

[Total: 20]

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