Catholic Junior College
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME	
CLASS	2T

PHYSICS
9749/02

Paper 2 Structured Questions

23 August 2024

2 hours

Candidates answer on the Question Paper.

READ THESE INSTRUCTIONS FIRST

Write your name and class in the spaces at the top of this page.
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.
Answer **all** questions.

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

FOR EXAMINER'S USE		
Q1		/ 6
Q2		/ 12
Q3		/ 5
Q4		/ 5
Q5		/ 7
Q6		/ 11
Q7		/ 8
Q8		/ 6
Q9		/ 20
PAPER 2		/ 80

DATA

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
			$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_P	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} mol^{-1}
gravitational constant	G	=	6.67×10^{-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	$p = \rho g h$
gravitational potential	$\phi = -\dfrac{Gm}{r}$
temperature	$T/K = T/{}^\circ C + 273.15$
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	$E = \dfrac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm\omega\sqrt{x_0^{\,2} - x^2}$
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	$B = \dfrac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_o n I$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \dfrac{\ln 2}{t_{\frac{1}{2}}}$

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

1 A car of mass 1700 kg travels over a curved hump in the road as shown in Fig. 1.1. The radius of curvature of the hump is 45 m.

Fig. 1.1

(a) The speed of the car at the top of the hump is 19 m s^{-1}.

Determine, for the car at the top of the hump,

(i) the magnitude of the centripetal force acting on the car,

centripetal force = …………………..……………… N [1]

(ii) the magnitude of the normal contact force exerted by the road on the car.

normal contact force = ……………………………… N [2]

(b) Determine the maximum speed v_{max} that the car can travel at without losing contact with the top of the hump. Explain your working.

v_{max} = ………………………………. m s^{-1} [3]

[Total: 6]

2 A long, straight wire W carrying a direct current of 3.0 A flows in the direction as shown in Fig. 2.1.

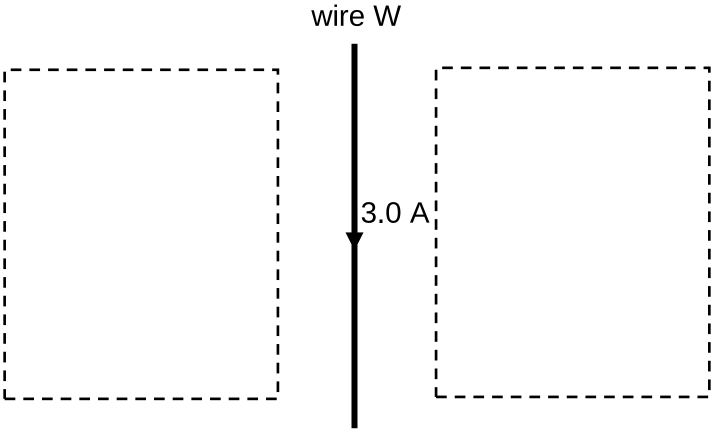

Fig. 2.1

(a) Draw on Fig. 2.1, the pattern of the magnetic field produced by wire W in the regions indicated by the dotted boxes. Use the symbol x to represent magnetic field directed into the page and use the symbol • to represent magnetic field directed out of the page. [3]

(b) A similar wire Y is placed parallel to wire W, separated by a distance of 40.0 cm as shown in Fig. 2.2. Initially, there is no current in wire Y.

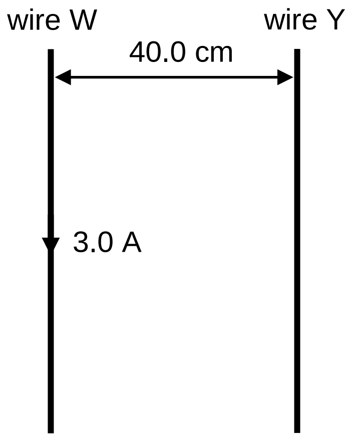

Fig. 2.2

(i) Show that the magnetic flux density at wire Y due to the current in wire W is 1.5×10^{-6} T.

[1]

(ii) A current of 1.0 A is now switched on in wire Y and flows in the opposite direction as the direction of current flow in wire W.

Use your answer in **(b)(i)** to calculate the force per unit length acting on wire Y.

force per unit length = ………………………..…….. N m^{-1} [2]

(iii) Explain why the force that the two wires exert on each other is repulsive.

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

(iv) Determine a possible position, other than at infinity, where the resultant magnetic flux density due to the magnetic fields of both wires is zero.

position: ……………………………………….…………………………… [3]

[Total: 12]

3 A uniform spherical star has a mass of 6.0 x 10^{30} kg. The mass of the star may be assumed to be a point mass at the centre of the star.

The star may be considered to be isolated in space.

(a) Show that the gravitational field strength at a point 3.0 x 10^9 m from the centre of the spherical star is 44.5 N kg^{-1}.

[1]

(b) The radius of the star is 1.0 x 10^9 m.

On the axes of Fig. 3.1, sketch a graph to show the variation with distance x from the centre of the star of the gravitational field strength g of the star for values of x from x = 1.0 x 10^9 m to x = 4.0 x 10^9 m.

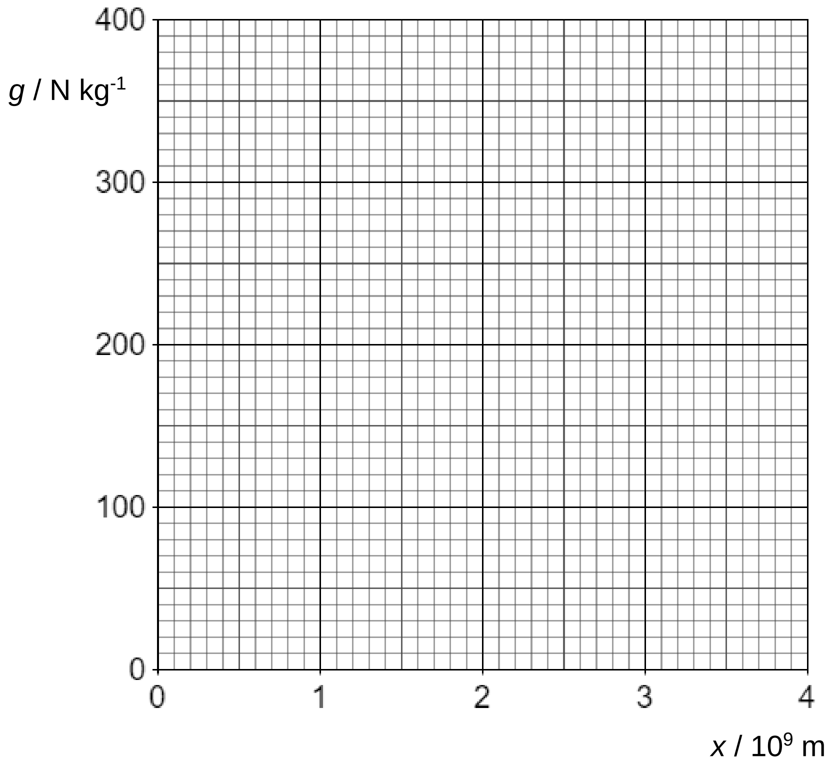

Fig. 3.1 [3]

(c) State what the area under the graph in Fig. 3.1 represents.

……..

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

[Total: 5]

4 Two parallel plates are in a vacuum. One plate is positively charged and the other plate is earthed.

A rectangular conductor of width x is placed in between the plates so that one of its faces is at a distance $0.5x$ from the positively charged plate and the opposite face is at $1.5x$ from the earthed plate as shown in Fig. 4.1.

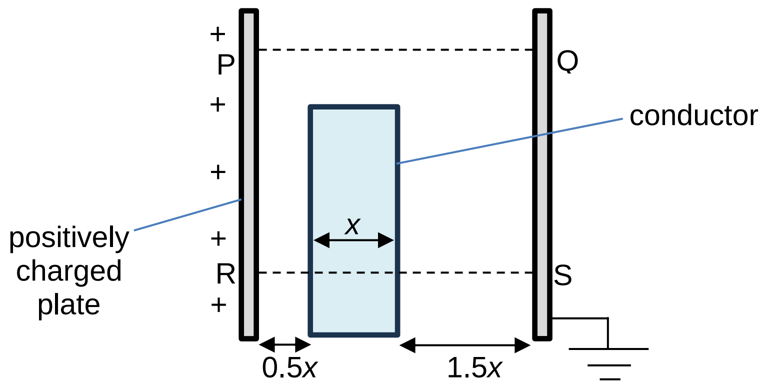

Fig. 4.1

The electric potential difference across the parallel plates is 3.00 V.

(a) The variation with distance from P to Q of the electric potential along line PQ is shown in Fig. 4.2.

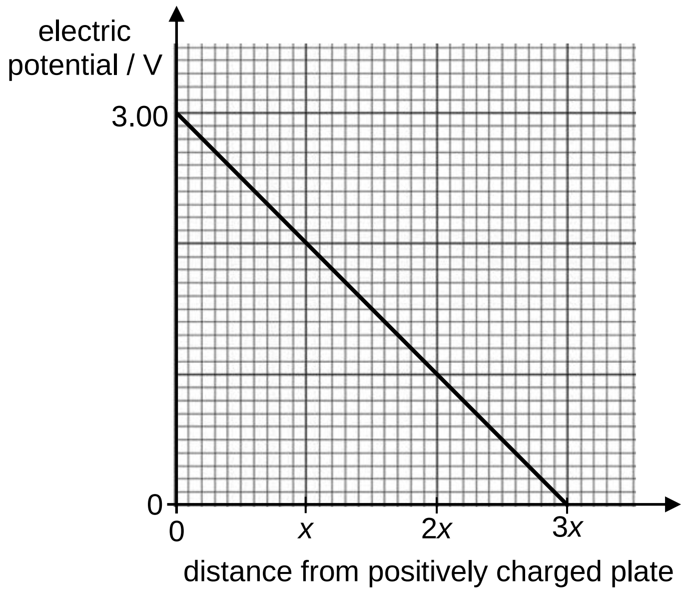

Fig. 4.2

On Fig. 4.2, draw a line to show the variation with distance from R to S of the electric potential along the line RS. [2]

(b) The variation with distance from P to Q of the electric field strength along line PQ is shown in Fig. 4.3.

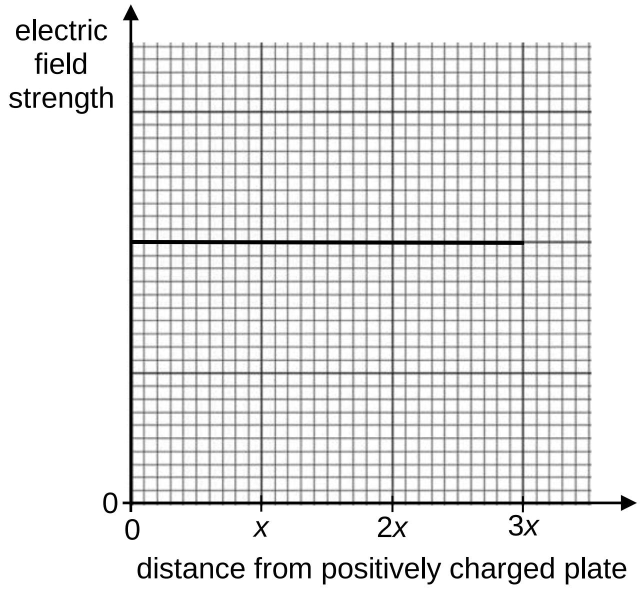

Fig. 4.3

On Fig. 4.3, draw a line to show the variation with distance from R to S of the electric field strength along the line RS. [3]

[Total: 5]

5 Fig. 5.1 shows a circular coil of 500 turns and radius 0.12 m.

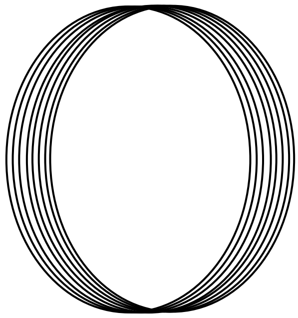

Fig. 5.1

A uniform magnetic field of flux density B is applied at right angles to the plane of the coil.

The magnetic flux density B changes with time t as shown in Fig. 5.2.

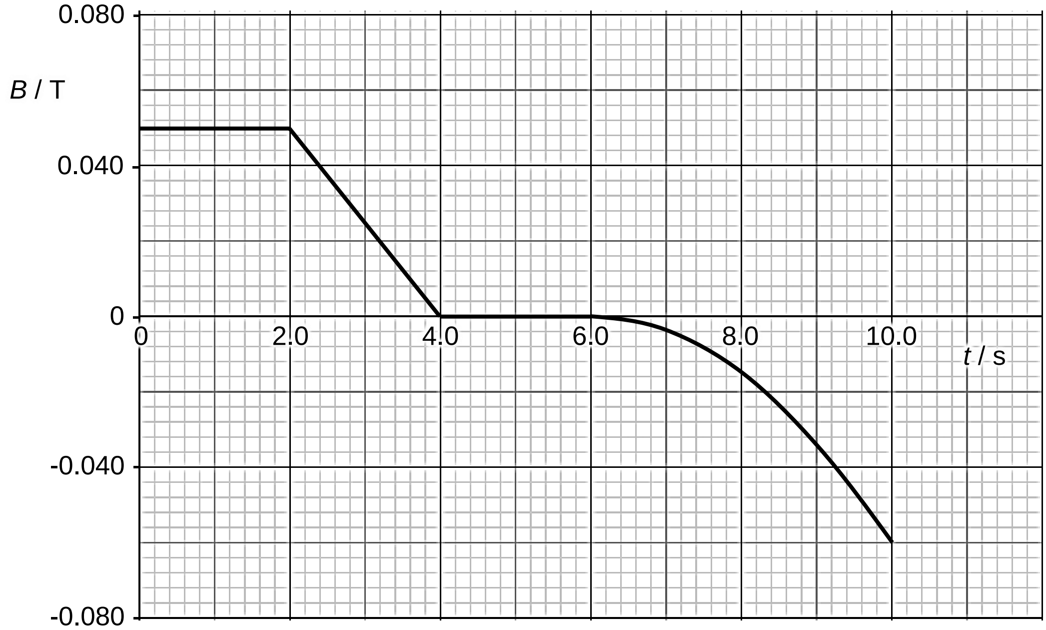

Fig. 5.2

From t = 6.0 s to t = 10.0 s, the gradient of the graph of B against t changes at a constant rate.

(a) Calculate the magnetic flux linkage of the coil at t = 10.0 s.

magnetic flux linkage = ……………………………………. Wb [2]

(b) Show that the magnitude of the induced e.m.f. in the coil between t = 2.0 s and t = 4.0 s is 0.57 V.

[2]

(c) On Fig. 5.3, sketch a graph to show the variation with time t of the induced e.m.f. E in the coil for time t = 0 to t = 10.0 s.

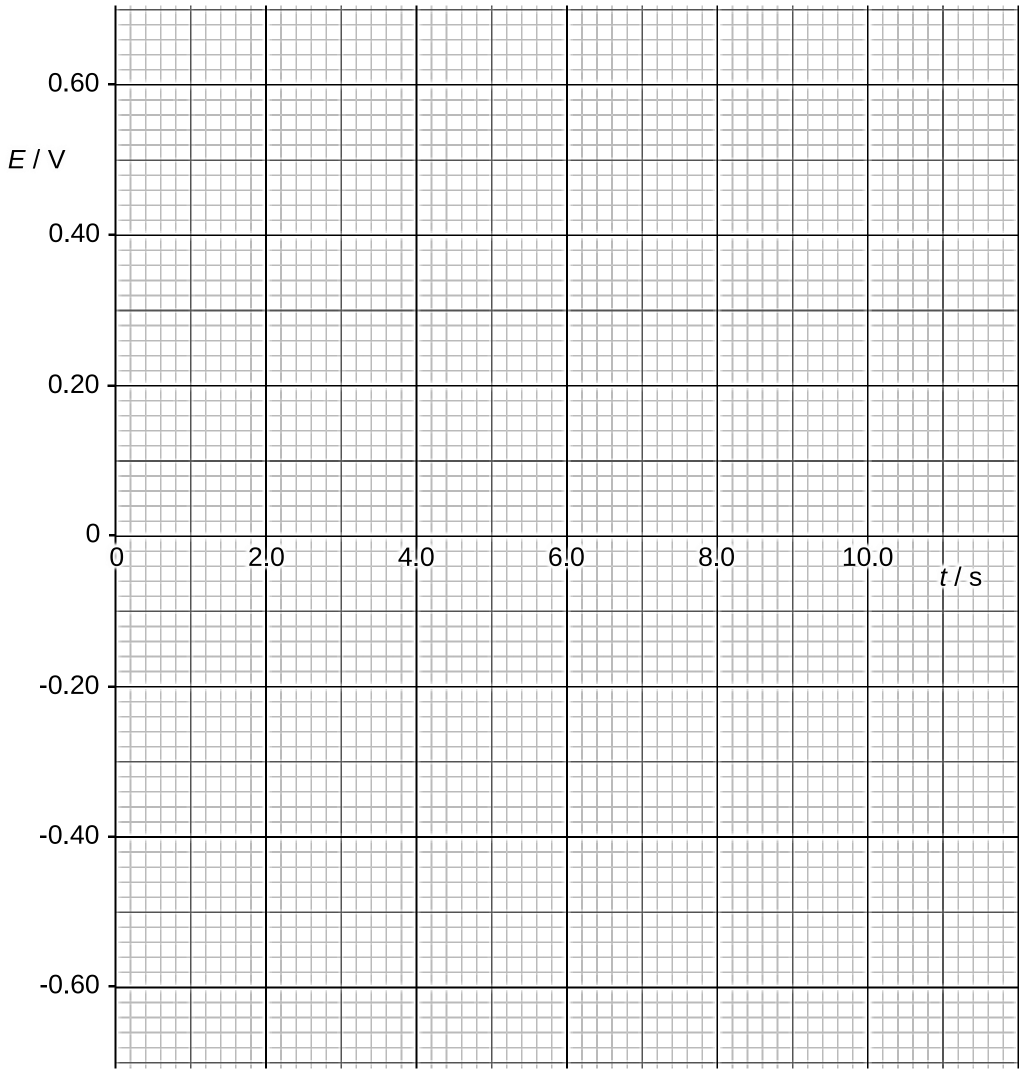

Fig. 5.3

[3]

[Total: 7]

6 A cylinder that contains a fixed amount of an ideal gas is shown in Fig. 6.1.

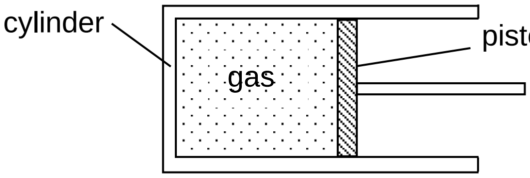

Fig. 6.1

The cylinder is fitted with a piston that moves freely.

(a) Use the kinetic theory of gases to explain

(i) the origin of the pressure of the gas in the cylinder,

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.... [3]

(ii) why the mean velocity of the atoms of the gas is zero.

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.... [2]

(b) Fig. 6.2 shows the variation of pressure and volume of the monoatomic ideal gas in the cylinder. The gas is initially at state W.

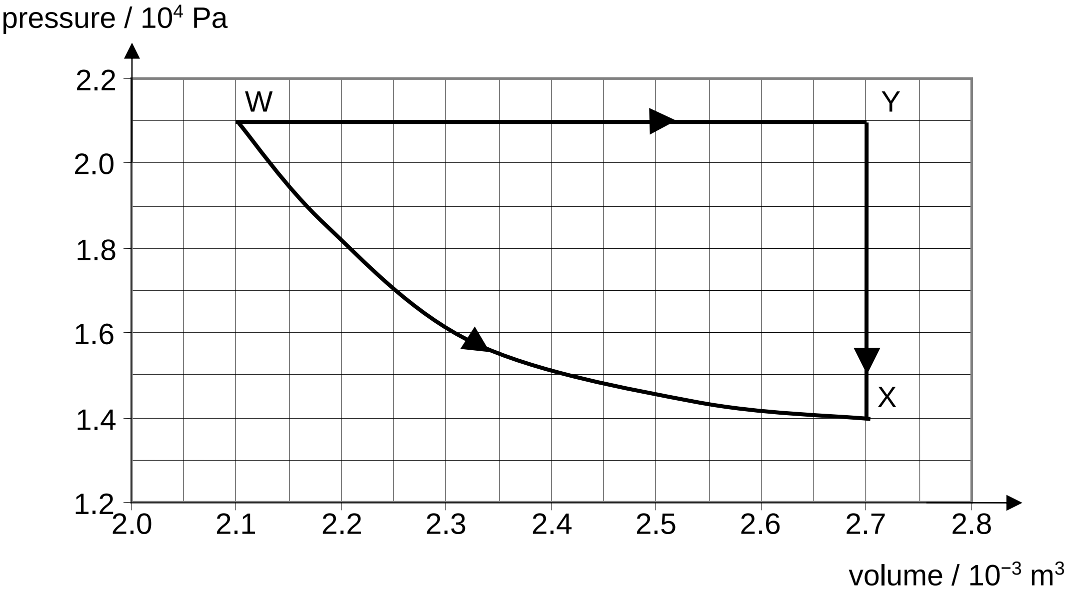

Fig. 6.2

(i) Determine the change in internal energy of the gas when it is taken from state W to state X along the curved path.

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

(ii) The same resultant change in state of the gas may be achieved by stages WY and YX.

Determine the net heat supplied to the gas during the change from W to Y to X.

heat supplied =.................................... J [4]

[Total: 11]

7 **(a)** Fig. 7.1 shows the variation with potential difference V of the current I for a filament lamp X rated at 6.0 V and 1.5 W.

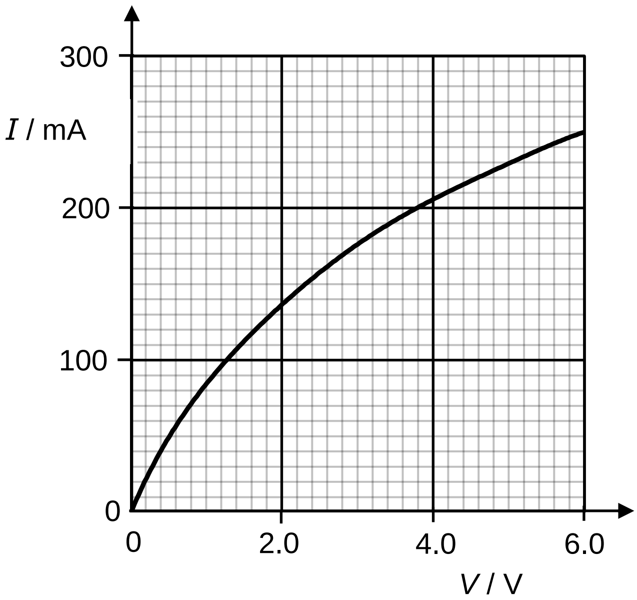

Fig. 7.1

(i) Calculate the resistance of the filament lamp at 6.0 V.

resistance = ………………..…...………….. Ω [2]

(ii) Explain how Fig. 7.1 shows that the resistance of the filament lamp increases as the potential difference across the filament lamp increases.

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

(iii) The filament lamp X is connected in series with a battery B and a variable resistor R, and, in parallel with a voltmeter, as shown in Fig. 7.2.

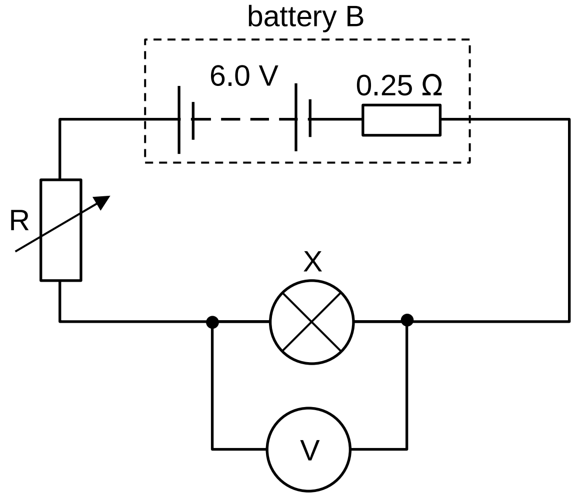

Fig. 7.2

Battery B has electromotive force 6.0 V and internal resistance 0.25 Ω.

The resistance of R is adjusted such that the voltmeter reads 5.0 V.

Calculate the terminal potential difference (p.d.) across B. Show your working.

terminal p.d. across B = ………………..…..………….. V [3]

(b) Fig. 7.3(a) and Fig. 7.3(b) show two circuits which can be used to act as a dimmer switch for a lamp.

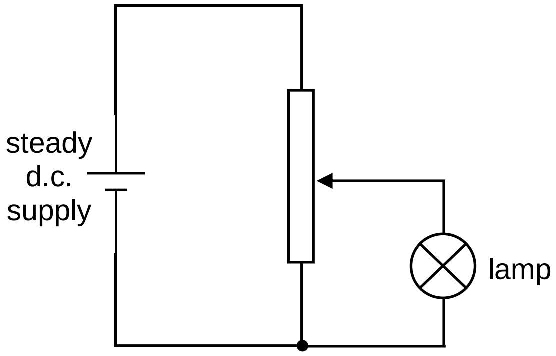

Fig. 7.3(a)

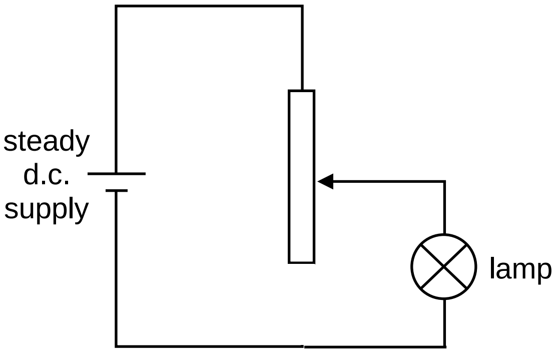

Fig. 7.3(b)

State and explain one advantage the circuit in Fig. 7.3(a) has over the circuit in Fig. 7.3(b) in varying the brightness of the lamp.

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

[Total: 8]

8 A long horizontal tube, containing fine powder, is closed at one end. A loudspeaker connected to a signal generator is positioned at the other of the tube. At a particular frequency, a stationary wave is set up inside the tube and the powder forms heaps as shown in Fig. 8.1.

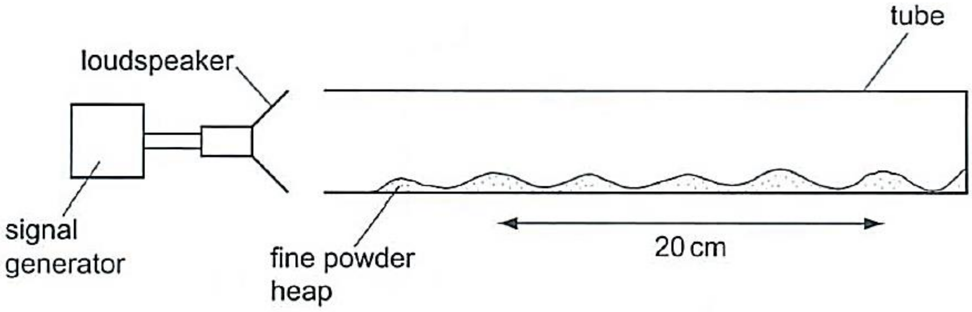

Fig. 8.1

The speed of sound is 330 m s^{-1}.

(a) Explain why, for a stationary wave to form inside the tube, it is usually necessary to adjust either the frequency of the signal generator or the length of the tube.

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

(b) With reference to the motion of the air molecules in the tube, explain why the powder heaps form at the displacement nodes.

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

(c) Using Fig. 8.1, calculate the frequency of the sound wave in the tube.

frequency = ………………………………….. Hz [2]

[Total: 6]

9 Read the passage below and answer the questions that follow.

When an object is moving in a fluid such as air and water, it experiences a force known as drag force which always opposes the motion of the object. The drag force on an object is dependent on a few factors such as the velocity of the object relative to the fluid, the drag coefficient, the frontal area of the object and the density of the fluid. When taking into accounts these factors, the drag force is given by

$$D = kC\rho Av^2$$

where k is a constant;
C is the drag coefficient;
ρ is the density of the fluid;
A is the frontal area of the object;
v is the velocity of the object relative to the fluid.

The frontal area A is the cross-sectional area of the object that passes through the fluid.

The drag coefficient C is a dimensionless quantity with no unit. It is dependent largely on shape of the object and to a small extent on the velocity of the object relative to the fluid. In most cases, the drag coefficient may be considered to be independent of the speed of the object relative to the fluid.

A parachute is an inflatable device which is used to slow down the speed of an object. Parachutes come in different shapes and sizes. Parachutes are made from strong and light weight nylon that has been treated to be less porous so that it does not let as much air through especially at high speeds. This allows the open parachute to create more air resistance and to achieve a lower terminal speed just before reaching the ground.

The parachute is packed into a single backpack called the container. In a particular parachuting jumping, a parachutist with his parachute in the container leaps off from a helicopter. We may consider he falls straight down from rest when his initial horizontal speed is small and there is no wind which causes a horizontal motion.

During the first few seconds of the fall, the parachutist falls under the action of gravity with his parachute in the container. His velocity increases from zero to a constant value known as the terminal velocity. The terminal velocity is dependent on the total mass of the parachutist and the parachute, the drag coefficient, the density of the air and the frontal area of the falling parachutist with his parachute.

The parachutist may fall with his body vertical (known as feet first position) or with his body horizontal (known as spread eagle position). The frontal area of the parachutist depends on whether the parachutist is falling with feet first position or spread eagle position. In the feet first position, the frontal area is approximately 0.18 m^2 while the frontal area in the spread eagle position is about 4 times that of the feet first position.

At a suitable altitude, he triggers the parachute to open by pulling on the ripcord and the velocity decreases rapidly. The parachutist will reach a lower terminal velocity before reaching the ground.

[Turn over

Fig. 9.1 shows the arrangement of the parachute with the parachute fully open.

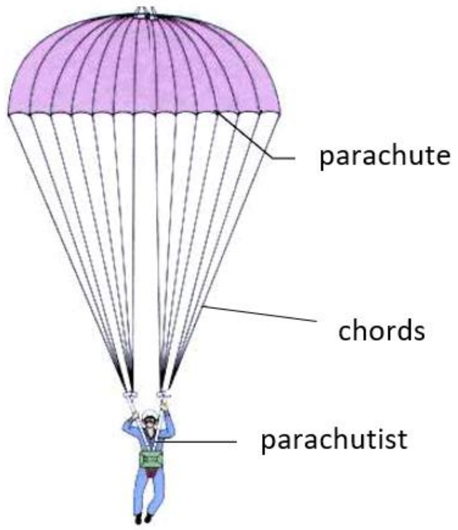

Fig. 9.1

Fig. 9.2 shows the variation with speed of the drag force per unit frontal area acting on a body with different drag coefficients.

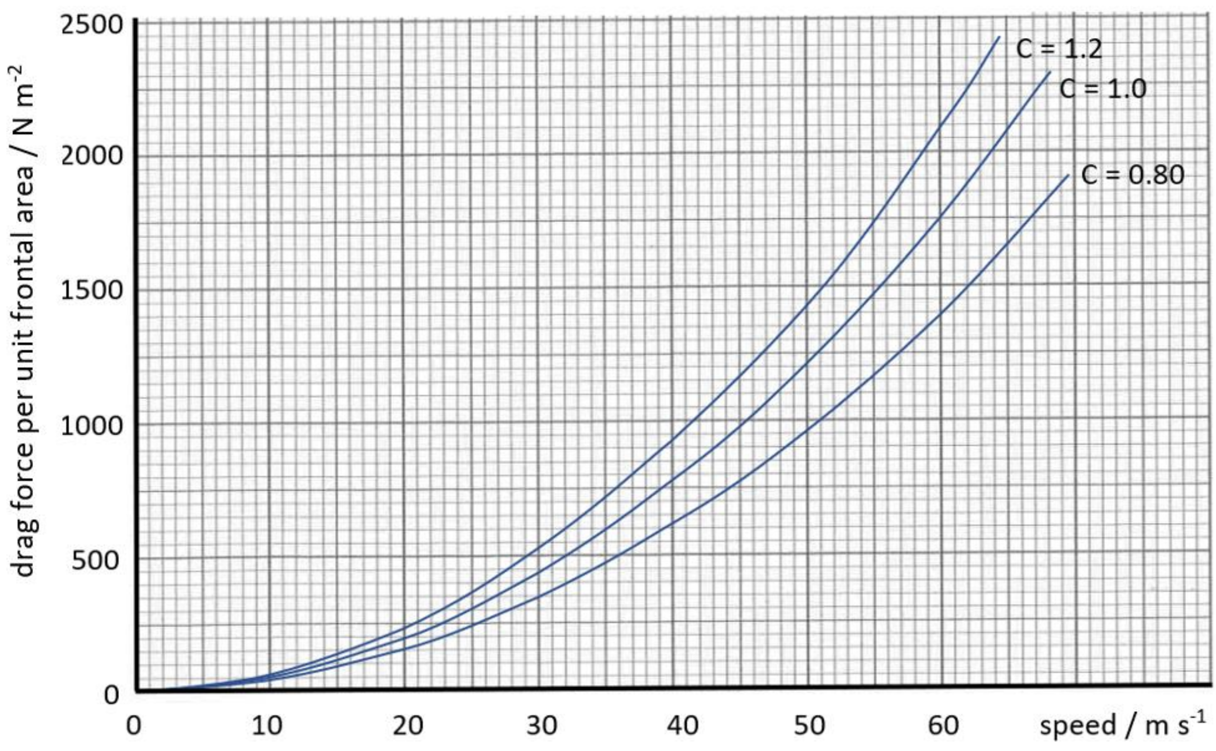

Fig. 9.2

Typical values of the drag coefficient *C* for a parachutist are as shown below:

Parachutist with parachute closed in feet first position	$C = 0.80$
Parachutist with parachute closed in spread eagle position	$C = 1.0$
Parachutist with parachute fully open	$C = 1.2$

The density of air may be assumed to be constant at 1.02 kg m^{-3} throughout the fall.

For safety reason, the terminal velocity of the parachutist must not be more than 7.5 m s^{-1} before reaching the ground. During a parachuting landing when the parachutist falls vertically, the parachutist must slightly bend his knees and clutch his body upon touching the ground, with the elbows tucked into the sides to prevent injury. The parachutist then allows his body to land on the ground before rolling his body.

Fig. 9.3 shows the variation with time of the velocity of a parachutist who falls with parachute closed in spread eagle position. The parachutist reaches a terminal velocity at time 10 s. At 19 s, the parachutist opens the parachute and reaches a new terminal velocity of 7.5 m s^{-1} at 22 s.

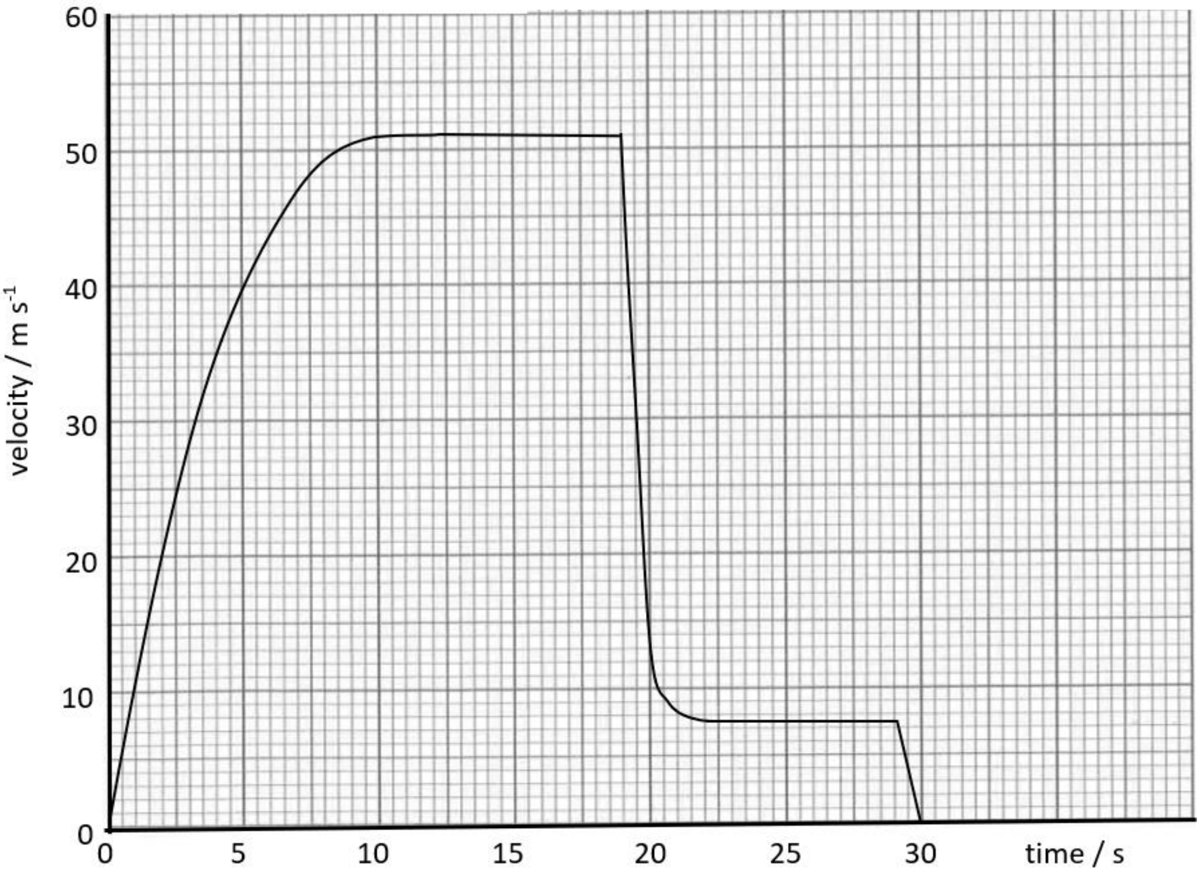

Fig. 9.3

(a) From Fig. 9.2, using the curve for the situation when the parachute is closed with the parachutist in the feet first position, show that the drag force is proportional to the square of the velocity.

[4]

(b) Explain why the acceleration of the parachutist is approximately 10 m s^{-2} when t = 0.

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

(c) Explain how Fig. 9.3 shows that the drag force increases with the velocity during the first 10 s of the motion.

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

(d) A parachutist falls with parachute closed from spread eagle position.

Calculate the total mass of the parachutist and the parachute.

total mass = ……………………………. kg [5]

(e) From time 19 s to 20 s, when the parachute is opened but before it is fully open, the velocity changes linearly with time and the acceleration is constant.

(i) Using Fig. 9.3, calculate the acceleration during this motion.

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

(ii) Explain why drag force remains constant from 19 s to 20 s.

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

(f) For safety reasons, when the parachutist falls vertically,

(i) suggest a modification to the design of the parachute if the parachutist carries a heavy load,

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

(ii) explain why the parachutist needs to bend his knee and body upon touching the ground during landing and then roll his body.

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

(g) The same parachutist with the parachute attempts to trigger the parachute to open immediately after he leaps off the hovering helicopter.

On Fig. 9.3, sketch a graph to show the expected variation with time of the velocity of the parachutist. [1]

[Total: 20]

END OF PAPER