YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAM
Higher 2

CANDIDATE NAME	

CG		INDEX NO	

PHYSICS

9749/01

Paper 1 Multiple Choice

19 September 2025

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid/tape.
Write your name, class and index number on the Answer Sheet in the spaces provided unless this has been done for you.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

The document consists of **16** printed pages.

2

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} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

3

Formulae

uniformly accelerated motion,	s =	$ut + \dfrac{1}{2}at^2$
	v^2 =	$u^2 + 2as$
work done on/by a gas,	W =	$p\Delta V$
hydrostatic pressure,	p =	ρgh
gravitational potential,	ϕ =	$-\dfrac{Gm}{r}$
temperature,	T/K =	$T/°C + 273.15$
pressure of an ideal gas,	p =	$\dfrac{1}{3}\dfrac{Nm}{V}<c^2>$
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 =	$v_0 \cos \omega t$
	=	$\pm \omega \sqrt{\left(x_0^2 - x^2\right)}$
electric current,	I =	$Anvq$
resistors in series,	R =	$R_1 + R_2 + ...$
resistors in parallel,	$1/R$ =	$1/R_1 + 1/R_2 + ...$
electric potential,	V =	$\dfrac{Q}{4\pi \varepsilon_0 r}$
alternating current/voltage,	x =	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire,	B =	$\dfrac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil,	B =	$\dfrac{\mu_0 I}{2r}$
magnetic flux density due to a long solenoid,	B =	$\mu_0 nI$
radioactive decay,	x =	$x_0 \exp\left(-\lambda t\right)$
decay constant,	λ =	$\dfrac{\ln 2}{t_{\frac{1}{2}}}$

4

1 What is the best estimate for the density of an average adult male?

   A 10^{-3} g cm^{-3} **B** 10^0 g cm^{-3} **C** 10^3 g cm^{-3} **D** 10^6 g cm^{-3}

2 An aeroplane is stationary at one end of a runway. It accelerates uniformly and takes off 35 s later, having travelled a distance of 560 m.

   What are the acceleration and take-off speed of the aeroplane?

	acceleration / m s^{-2}	take-off speed / m s^{-1}
A	0.46	16
B	0.46	32
C	0.91	16
D	0.91	32

3 A tennis ball is hit at point X and then follows the path shown.
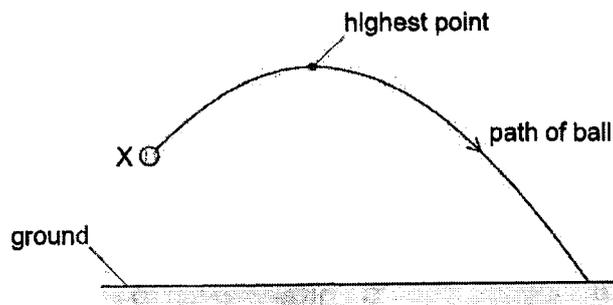

   The air resistance on the ball is negligible.

   How is the ball moving at its highest point?

   A It has zero velocity both vertically and horizontally.

   B It has zero acceleration vertically and non-zero velocity horizontally.

   C It is accelerating vertically and has zero velocity horizontally.

   D It is accelerating vertically and has non-zero velocity horizontally.

5

4 The figure below shows a uniform block resting on a smooth inclined plane, supported by a force F to prevent it from moving.
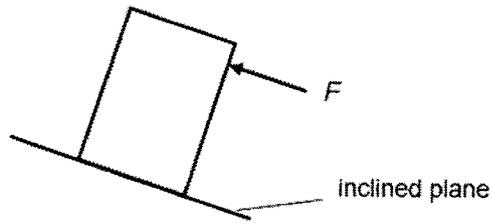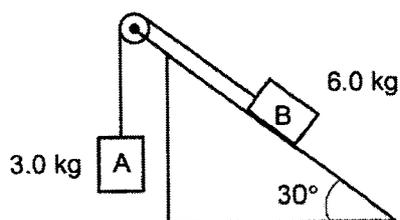

Which one of the following diagrams correctly shows the force R exerted by the inclined plane on the block?

A

B

C

D
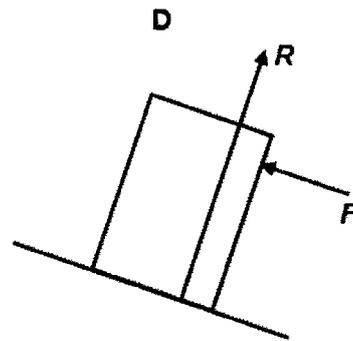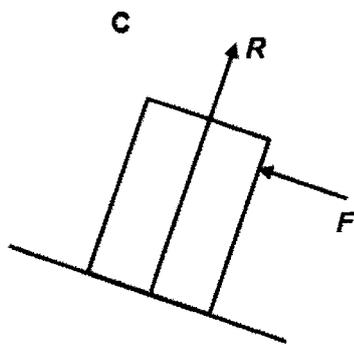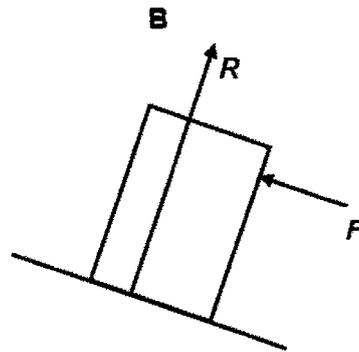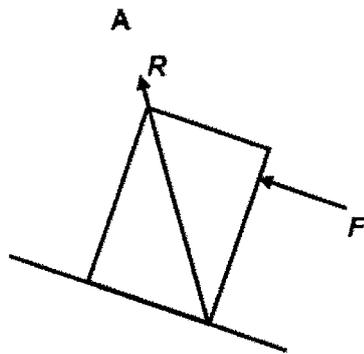
5 Blocks A and B are connected by a light cord running over a frictionless, light pulley as shown below.

3.0 kg A

6.0 kg
B

30°

Which of the following statements is correct?

A Block A moves down with an acceleration of 9.81 m s^{-2}.

B Block A moves up with an acceleration of 3.27 m s^{-2}.

C Block B moves up the slope with an acceleration of 3.27 m s^{-2}.

D Blocks A and B do not experience any acceleration.

6 A car travels along a road at a constant speed of 25 m s^{-1}. Its power output is 30 kW. The total resistive force on the car is proportional to the square of its speed.

What power will be required for the car to travel at a constant speed of 40 m s^{-1}?

A 48 kW   B 77 kW   C 120 kW   D 200 kW

7 A small wind turbine contains a generator that is used to generate electricity. Every second, 10.7 kg of air arrives at its blades with a speed of 5.0 m s^{-1} and leaves the blades with a speed of 2.5 m s^{-1}.

The efficiency of the generator is 70%.

What could be the output potential difference (p.d.) and current of the turbine?

	p.d. / V	current / A
A	8.0	3.0
B	25	2.8
C	25	4.0
D	36	4.0

8   A disc of radius 6.0 cm rotates about its centre O. P is a point on the circumference and Q is halfway between O and P.
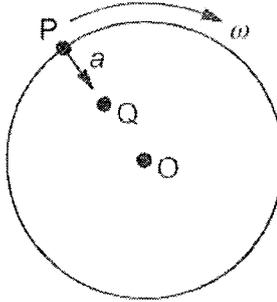
At Q, the angular velocity ω is 3.0 rad s^{-1} and the centripetal acceleration a is 27 cm s^{-2}.

Which row gives the values of these quantities at P?

	ω / rad s^{-1}	a / cm s^{-2}
A	3.0	27
B	3.0	54
C	6.0	110
D	6.0	220

9   A stationary object is released from a point P a distance 3R from the centre of the Moon which has a radius R and mass M.
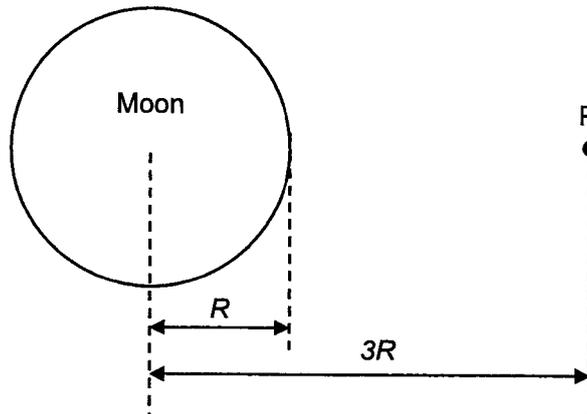
Which one of the following expressions gives the speed of the object hitting the Moon?

A $\sqrt{\dfrac{4GM}{3R}}$ B $\sqrt{\dfrac{2GM}{R}}$ C $\sqrt{\dfrac{4GM}{R}}$ D $\sqrt{\dfrac{GM}{R}}$

8

10 The acceleration of free fall on the surface of the Earth is 6 times its value on the surface of the Moon. The mean density of the Earth is $\frac{5}{3}$ times the mean density of the Moon.

What is the ratio of the radius of Earth to the radius of the Moon?

A 1.9   B 3.6   C 6.0   D 10

11 A container filled with an ideal gas is at a temperature of 100 °C. The root-mean-square (r.m.s.) speed of the gas molecules is 350 m s^{-1}.

The temperature of the gas is increased to 200 °C.

What is the new r.m.s. speed of the gas molecules?

A 394 m s^{-1} B 444 m s^{-1} C 495 m s^{-1} D 700 m s^{-1}

12 A sample of an ideal gas is taken through the cycle (P → Q → R → S → P) as shown below.
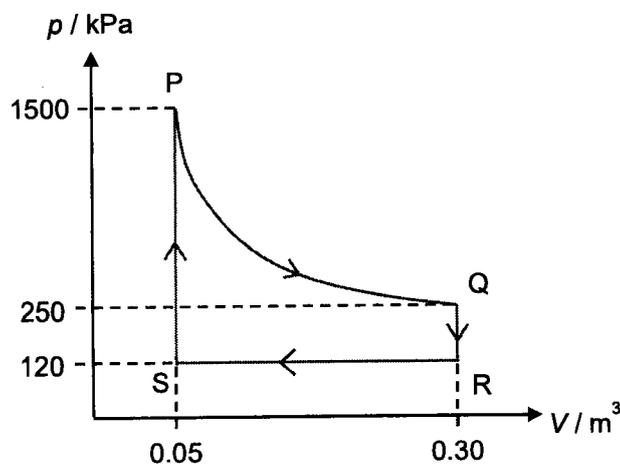
Given that the work done by the gas in process P → Q is 120 kJ, what is the net heat supplied to the gas in one cycle?

A −90 kJ   B 0 J   C 30 kJ   D 90 kJ

13 The diagram below shows a displacement – time graph of a body performing simple harmonic motion.
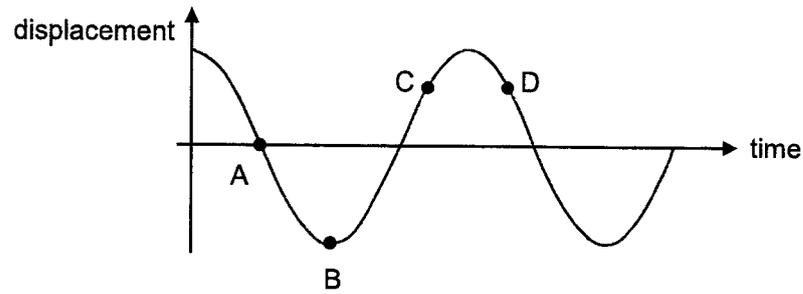
At which one of the points **A**, **B**, **C** or **D**, is the body travelling and accelerating in the same direction?

14 A transverse wave moves to the right.

X and Y are points in the path of the wave.
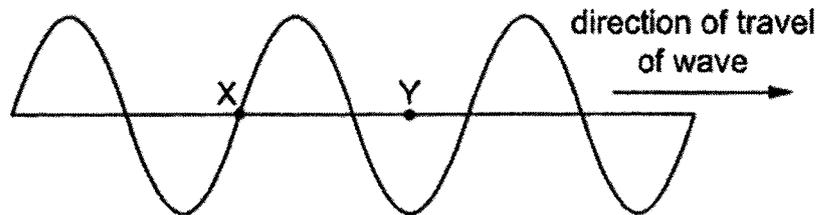
Which statement about the oscillations at X and at Y is correct?

A The oscillations at X and Y are in phase.

B The frequency of oscillations at X is greater than the frequency of oscillations at Y.

C The oscillations at X and Y have a phase difference of π rad.

D The oscillations at X and Y have the same period.

15 Water ripples on a ripple tank approach a narrow gap in a barrier. The width of the gap is equal to the wavelength.

Which diagram shows a possible pattern of the ripples after passing through the barrier?

A

B

C

D
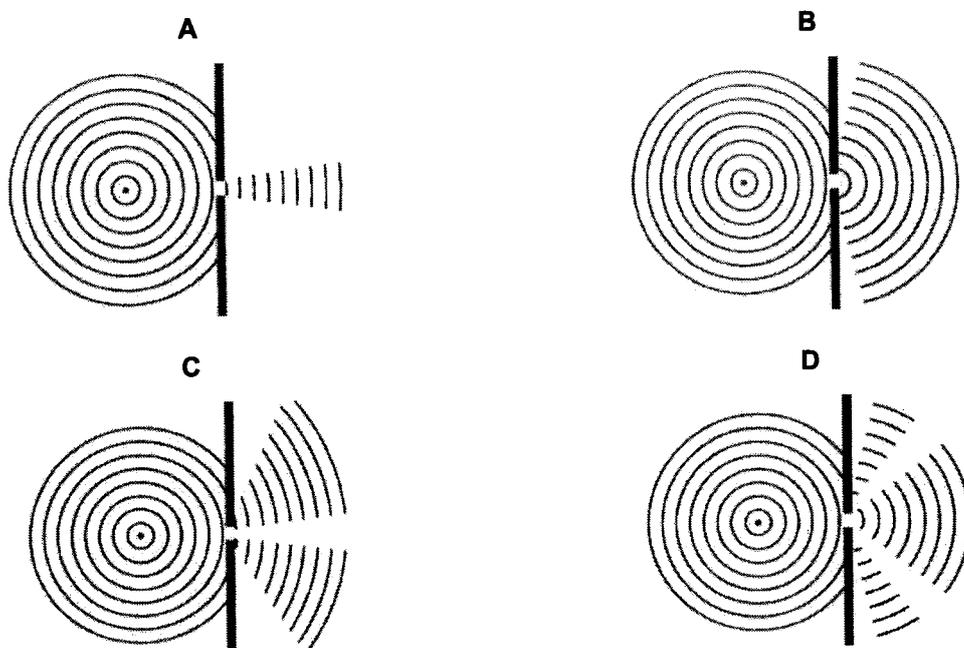
16 A beam of monochromatic light of wavelength 600 nm is incident normally on a diffraction grating that has 3.0×10^3 lines per centimetre.

What is the maximum number of bright fringes produced by light transmitted through this grating?

A 5   B 10   C 11   D 13

17 The diagram shows a stationary wave formed on a wire PQ at a given instant in time.

The phase difference is measured between point X and different points on the wire.

Which graph represents the variation of this phase difference with distance along the wire?
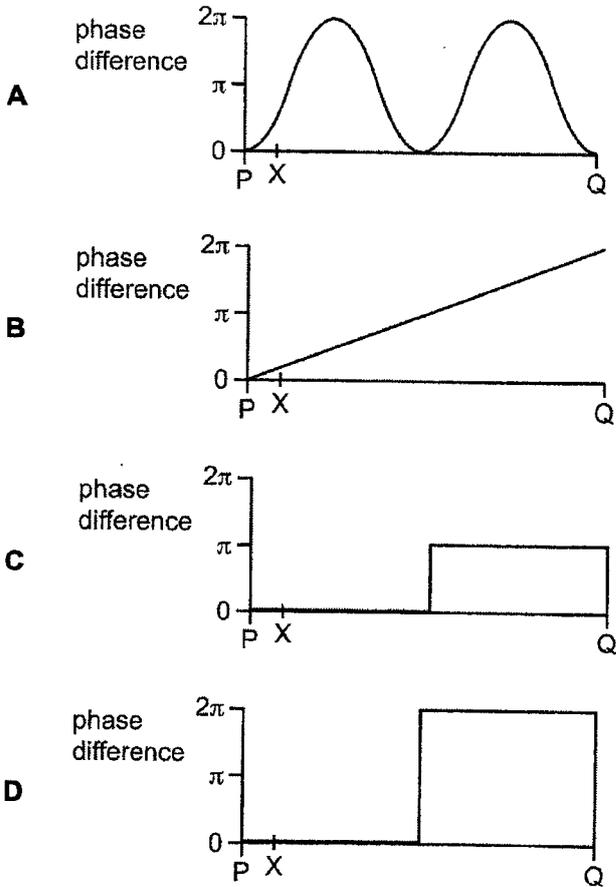
18 Electric field strength is defined as force per unit positive charge on a small test charge.

Why is it necessary for the test charge to be small?

A   So that the test charge does not distort the electric field

B   So that the force on the test charge is small

C   So that the test charge does not create any forces on nearby charges

D   So that Coulomb's law for point charges is obeyed

19 The diagram below shows three points X, Y and Z forming an equilateral triangle of side s in a uniform electric field of strength E. A unit positive test charge is moved from X to Y, from Y to Z and from Z back to X.
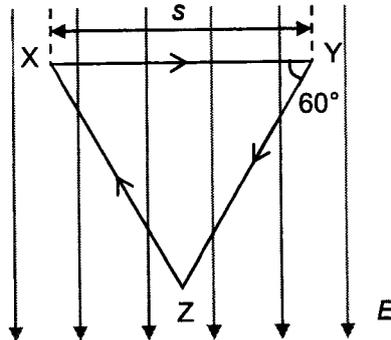
Which of the following correctly gives the work done against electrical forces in moving the charge along the various parts of this path?

	X to Y	Y to Z	Z to X
A	0	$-Es\cos 60°$	$+Es\cos 60°$
B	$+Es$	$+Es\sin 60°$	$-Es\sin 60°$
C	0	$+Es\sin 60°$	$-Es\sin 60°$
D	0	$-Es\sin 60°$	$+Es\sin 60°$

20 A current of 30 mA passes through a slice of semi-conducting material of dimensions as shown.
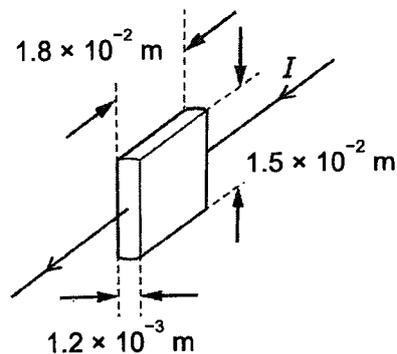
The slice dissipates 300 mW of heat energy.

What is the resistivity of the semiconductor under these conditions?

A 0.010 Ω m   B 0.33 Ω m   C 75 Ω m   D 380 Ω m

21   A NTC thermistor, a LDR and a fixed resistor are connected in series to a power supply. A voltmeter is placed across the thermistor-LDR combination.
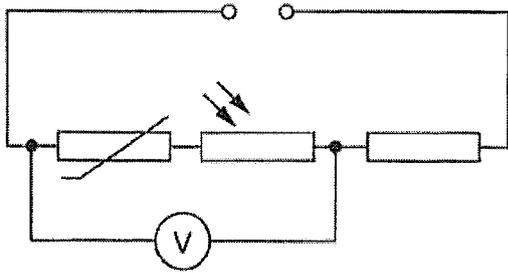
Which conditions of brightness and temperature will produce the smallest reading on the voltmeter?

	temperature	brightness
A	high	high
B	high	low
C	low	high
D	low	low

22   Two resistors, P and Q, are connected in series to a 9.0 V battery with negligible internal resistance.
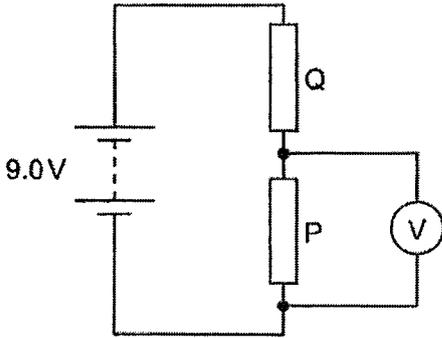
The resistance of the voltmeter is equal to the resistance of P.

The reading on the voltmeter is 6.0 V.

What is the value of the ratio $\dfrac{\text{resistance of the voltmeter}}{\text{resistance of Q}}$?

A   0.50   B   0.25   C   2.0   D   4.0

                   [Turn over

23 In each diagram, two wires are shown, each carrying a constant current I.

In which diagram will the force between the wires, due to the currents, be zero?

A

B

C

D
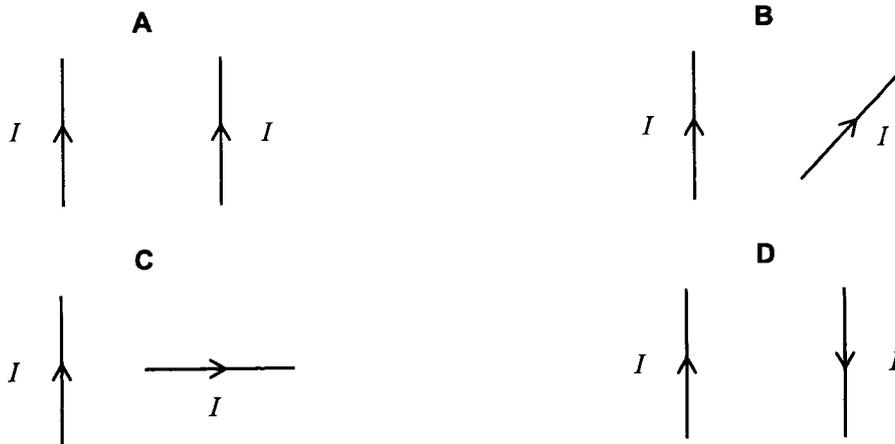
24 A beam of electrons enters a region in which there are magnetic and electric fields directed at right angles. It passes straight through without deviation.

magnetic field B directed into the plane of the page

electrons

electric field E
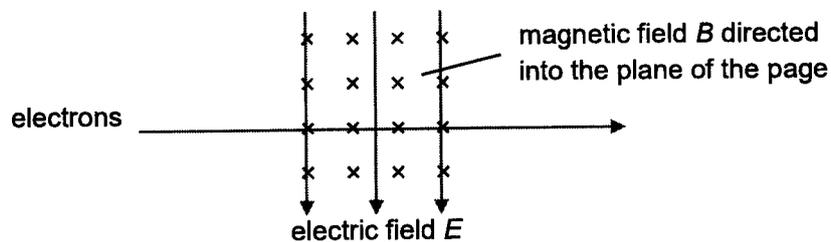
A second beam of electrons travelling twice as fast as the first is directed along the same line.

How is this second beam deviated?

A downwards in the plane of the paper

B upwards in the plane of the paper

C out of the plane of the paper

D into the plane of the paper

25 A plane coil of wire containing N turns each of area A is placed so that the plane of the coil makes an angle θ with the direction of a uniform magnetic field of flux density B. The coil is now moved with a velocity v downwards as shown.

plane of coil

v

θ

plan view of uniform field

B
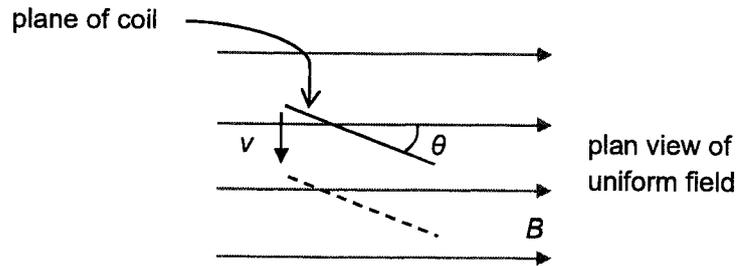
What is the e.m.f. induced in the coil?

A zero **B** $NABv$ **C** $NABv \cos \theta$ **D** $NABv \sin \theta$

26 Half-wave rectification of an alternating sinusoidal voltage of amplitude 200 V gives the waveform as shown.

V / V

200

0

t
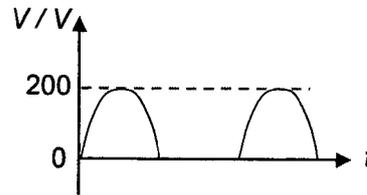
What is the r.m.s voltage?

A 70.7 V **B** 100 V **C** 141 V **D** 200 V

27 A source of electromagnetic radiation emits photons. The intensity is measured at a fixed point near the source. The wavelength of the radiation is then gradually increased but the rate at which photons are emitted remains constant.

Which statement explains the effect this has on the measured intensity?

A Photon energy decreases and intensity decreases.

B Photon energy decreases and intensity increases.

C Photon energy decreases and intensity remains constant.

D Photon energy increases and intensity increases.

28 In a X-ray tube operating at 20 kV, the accelerating electrons hit the target material to produce X-rays.

What is the ratio of the de Broglie wavelength of the incident electrons to the cut-off wavelength of the X-rays produced?

  A 0.0044   **B** 0.14   **C** 7.1   **D** 230

29 Antimony-124 undergoes radioactive decay, with a half-life of 60 days, to become tin-124, which is stable.

Initially a sample of antimony-124 contains no tin-124.

How long would have passed for the ratio of number of tin-124 nuclei to number of antimony-124 nuclei to be 5?

  A Between 60 days and 120 days

  B 120 days

  C Between 120 days and 180 days

  D More than 180 days

30 During a single fission event of uranium-235 in a nuclear reactor, the total mass lost is 0.231 u.

The reactor is 25% efficient.

How many events per second are required to generate 900 MW of power?

  A 1.0×10^{14} **B** 2.6×10^{19} **C** 1.0×10^{20} **D** 4.4×10^{20}

YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE
NAME

CG

INDEX NO

PHYSICS

Paper 2 Structured Questions

9749/02

3 September 2025

2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number 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, highlighters, glue or correction fluid/tape.

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	
Paper 2	
1	/ 8
2	/ 6
3	/ 6
4	/ 12
5	/ 9
6	/ 7
7	/ 11
8	/ 21
Penalty	
Paper 2 Total	
	/80

Data

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elementary charge,	e	=	$1.60 \times 10^{-19} \text{ C}$
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pressure of an ideal gas,	p =	$\dfrac{1}{3}\dfrac{Nm}{V}<c^2>$
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 =	$R_1 + R_2 + \ldots\ldots$
resistors in parallel,	$\dfrac{1}{R}$ =	$\dfrac{1}{R_1} + \dfrac{1}{R_2} + \ldots\ldots$
electric potential,	V =	$\dfrac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	x =	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire,	B =	$\dfrac{\mu_0 I}{2\pi d}$
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magnetic flux density due to a long solenoid,	B =	$\mu_0 nI$
radioactive decay,	x =	$x_0 \exp(-\lambda t)$
decay constant,	λ =	$\dfrac{\ln 2}{t_{\frac{1}{2}}}$

4

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

1   Fig. 1.1 shows a velocity-time graph for a 150 kg rocket moving vertically.
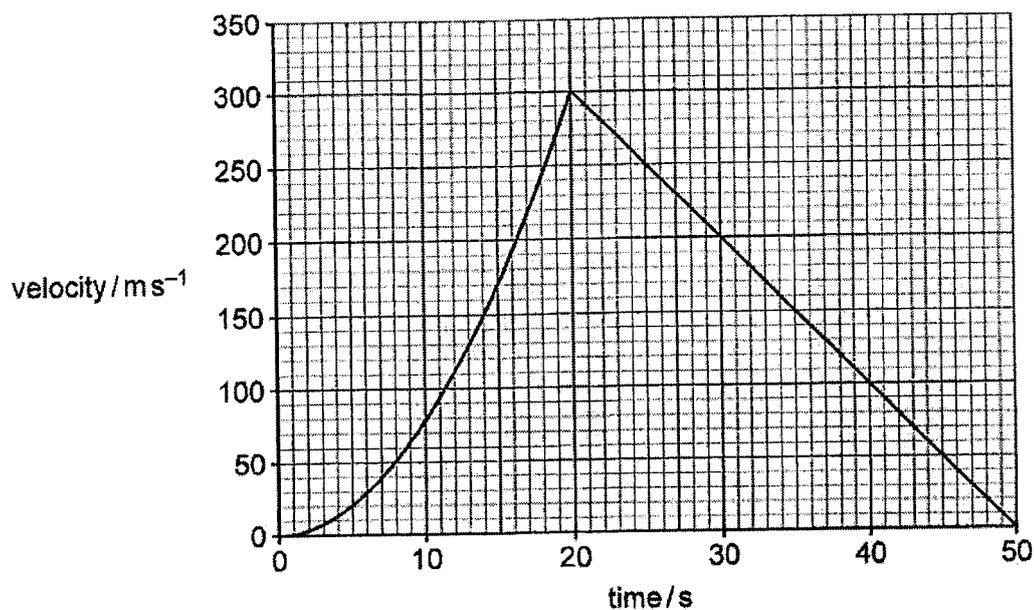
Fig. 1.1

(a)   **(i)**   Use Fig. 1.1 to determine the maximum acceleration of the rocket. Show your construction in Fig 1.1.

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

(ii)   Hence, determine the maximum thrust experienced by the rocket. You may assume that the mass of the fuel is negligible compared to the mass of the rocket.

maximum thrust = ... N [2]

(b) Suggest and explain what happens to the rocket from time = 20 s to 50 s.

....

....

.... [2]

(c) On Fig. 1.2, sketch the variation with time of the vertical displacement s of the rocket from its starting position when t = 0 s.

Fig. 1.2

[2]
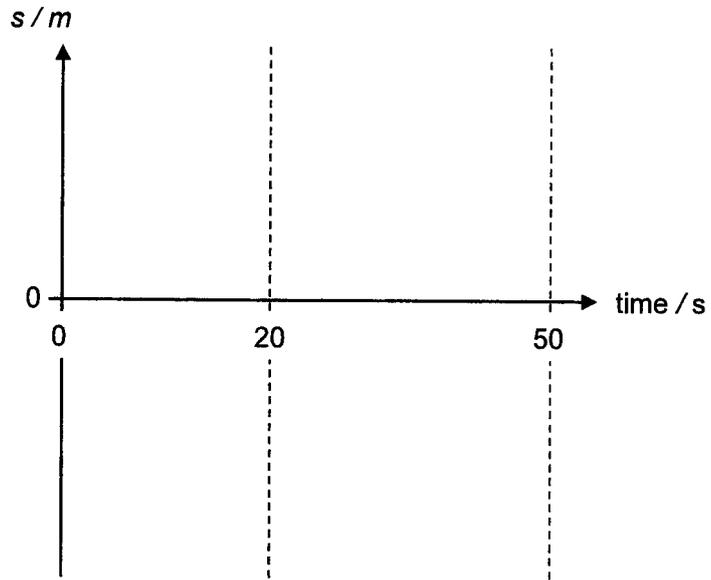
[Total: 8]

2 (a) State the origin of the upthrust acting on a body in a fluid.

....

.... [1]

(b) (i) A deflated balloon has a mass of 12 g. It is then inflated with helium until it forms a spherical balloon of diameter of 30 cm.

The helium-filled ballon is attached by a light string to the bottom of an empty tank as shown in Fig 2.1.
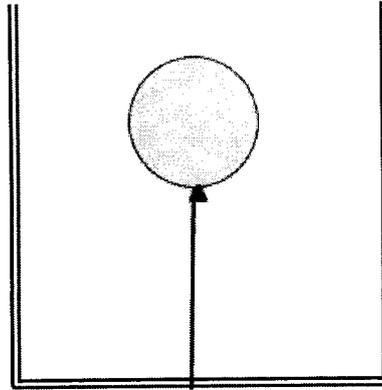
Fig. 2.1

The density of air is 1.29 kg m⁻³ while the density of helium is 0.18 kg m⁻³.

Calculate the tension in the string.

tension = ... N [3]

(ii) The tank is gradually filled with water until the balloon is fully submerged as shown in Fig. 2.2.
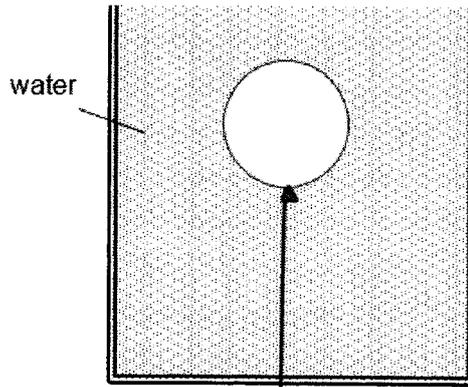
Fig. 2.2

State and explain whether the tension in the string increases, decreases or stays the same when the balloon is fully submerged.

....

....

.... [2]

[Total: 6]

3   In a theme park ride, passengers ride a cart which completes a vertical circle, as shown in Fig 3.1. The loop has a radius of 7.0 m and a passenger of mass 60 kg is travelling at 12 m s⁻¹ when the cart is at the highest point of the loop.
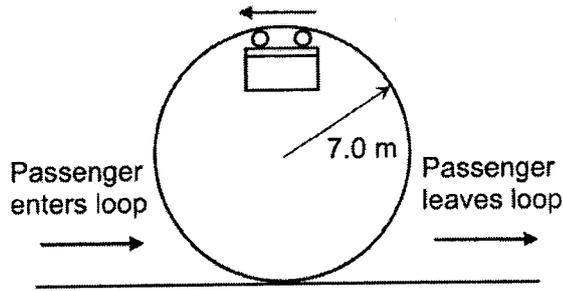
Fig 3.1

(a) Calculate for the passenger:

(i)   the normal contact force acting on him due to the cart at the highest point

normal reaction force = ... N [2]

(ii)   his velocity at the lowest point.

velocity = ... m s⁻¹ [2]

(b) Operators of this ride must ensure that the speed at which the passengers reach the top of the loop is above a certain minimum value.

Explain the need for this minimum speed.

....

....

.... [2]

[Total: 6]

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10

4 **(a)** A fixed mass of an ideal gas has volume 1.5×10^{-2} m^3 at pressure 4.4×10^5 Pa and temperature of 65 °C.

    (i) Using energy considerations, explain what is meant by an *ideal gas*.

....

....

.... [2]

    (ii) Determine the number of molecules in the gas sample.

number of molecules = ... [2]

    (iii) Determine the total internal energy of the gas sample.

total internal energy = ... J [2]

(b) The gas in **(a)** is now heated to 150 °C while maintaining constant pressure. The volume of the gas after heating is 1.9×10^{-2} m^3.

    (i) Calculate the work done by the gas during this process.

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

(ii) The molar heat capacity is the amount of heat supplied to one mole of gas to raise its temperature by one kelvin.

Determine the molar heat capacity for this gas.

molar heat capacity = ... J mol^{-1} K^{-1} [4]

[Total: 12]

5   A metal block hangs vertically from one end of a spring. The other end of the spring is tied to a thread that passes over a pulley and is attached to a vibrator that is fixed in position, as shown in Fig. 5.1.
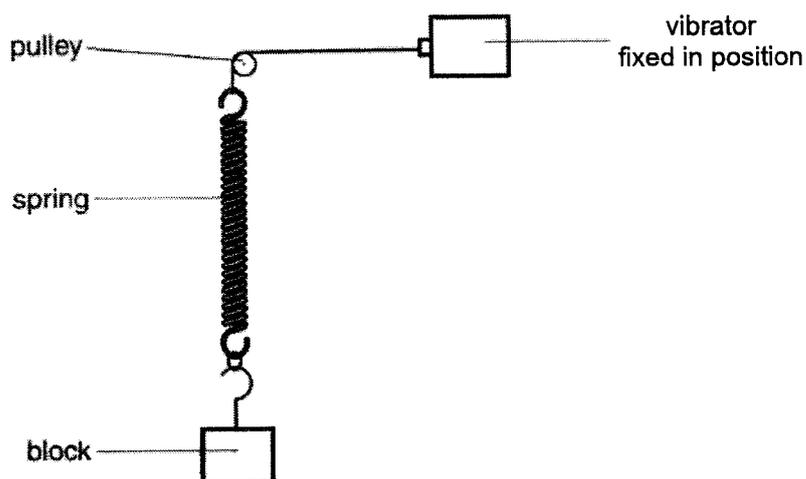
Fig. 5.1

(a)   The vibrator is switched off.

The metal block of mass 120 g is displaced vertically and then released. The variation with time t of the displacement y of the block from its equilibrium position is shown in Fig. 5.2.
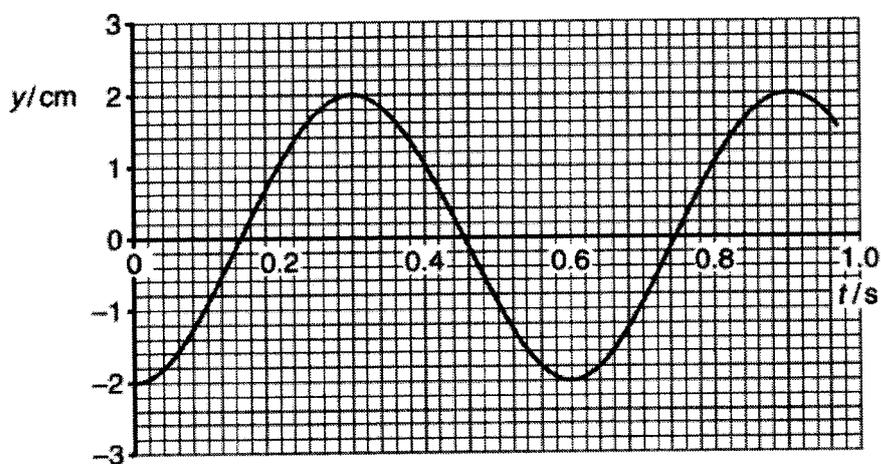
Fig. 5.2

For the oscillation of the block, calculate:

(i)   the angular frequency ω

ω = ... rad s^{-1} [2]

(ii) the total energy.

energy = ... J [2]

(b) State what is meant by resonance.

....

.... [1]

(c) The vibrator is now switched on.

The frequency of the vibrator is varied from 0.7*f* to 1.3*f* where *f* is the frequency of oscillation of the block in **(a)**.

For the block, complete Fig. 5.3 to show the variation with frequency of the amplitude of oscillation. Label this line A. [2]
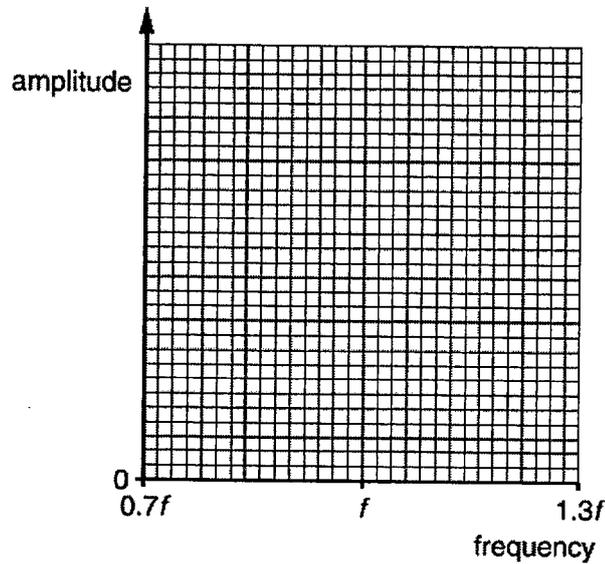
Fig. 5.3

(d) Light feathers are now attached to the block in **(c)**, increasing the effective cross-sectional area.

The frequency of vibrator is once again varied from 0.7*f* to 1.3*f*. The new amplitude of oscillation is measured for each frequency.

On Fig. 5.3, draw a line to show the variation with frequency of the amplitude of oscillation. Label this line B. [2]

[Total: 9]

BP-690

14

6 An ideal transformer is illustrated in Fig. 6.1.
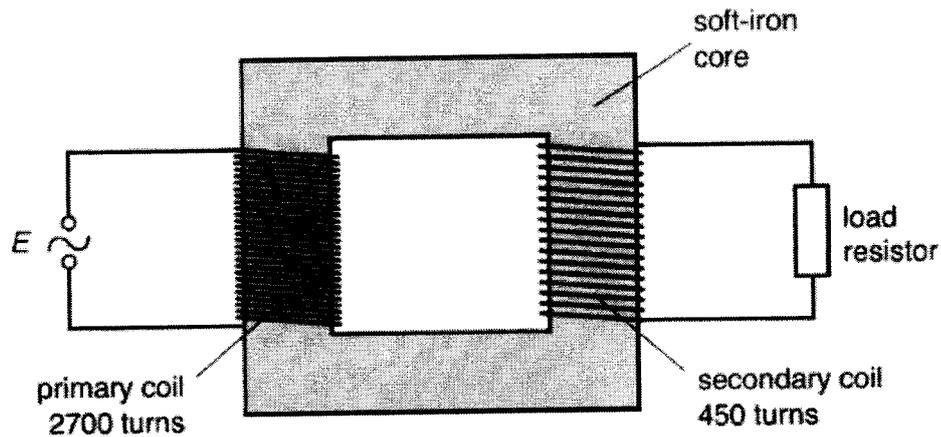
Fig. 6.1

(a) Explain why the input voltage to the transformer is alternating, rather than constant.

....

....

....

....

.... [2]

(b) The primary coil of the transformer has 2700 turns. The secondary coil has 450 turns.

The e.m.f. E applied across the primary coil is given by the expression

$$E = 220\sin(100\pi t)$$

where E is measured in volts and t is the time in seconds.

Calculate the root-mean-square (r.m.s.) e.m.f. induced in the secondary coil.

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

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(c) The average current in the load resistor is zero.

Explain why there is a heating effect in the resistor.

....

....

....

.... [2]

[Total: 7]

7   The electron in the hydrogen atom absorbs or emits electromagnetic radiation when it moves between different energy levels. The visible part of the spectrum emitted by the hydrogen atom can be seen in the laboratory by applying a high voltage to a hydrogen gas discharge tube.

(a)   Describe the difference in appearance between the emission line spectrum and absorption line spectrum for the hydrogen gas.

....

....

.... [1]

(b)   Some electron energy levels of the hydrogen atom are illustrated in Fig. 7.1.

```
                                    _____  -0.55 eV
                                    _____  -0.85 eV

                                    _____  -1.51 eV

        energy  ↑                   _____  -3.40 eV




                |
                |                   _____  -13.6 eV
```
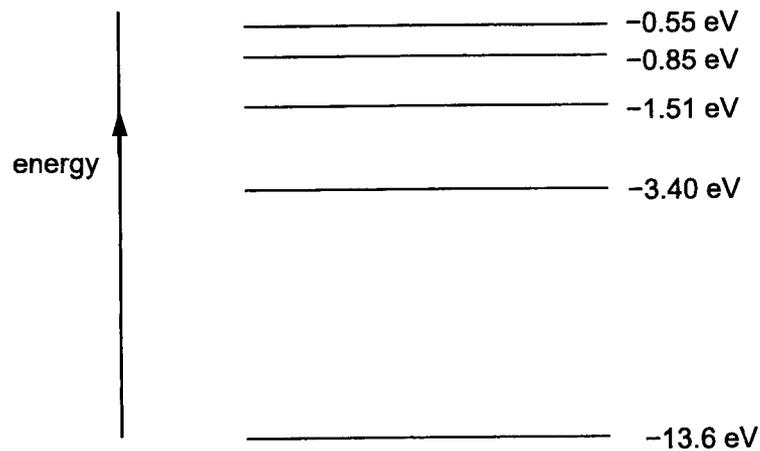
Fig. 7.1 (not to scale)

(i)   The wavelength of violet light is approximately 400 nm.

By calculating the energy, in eV, of a photon of violet light, explain why electron transitions to energy level -13.6 eV do not result in emission in the visible spectrum.

....

....

....

....

.... [4]

(ii) The minimum energy of a photon of visible light is 1.6 eV.

Use Fig. 7.1 to determine, for the electron energy levels shown:

1.   the number of lines that lie in the visible spectrum

number = ... [1]

2.   the longest wavelength of photons in this visible spectrum.

wavelength = ... m [2]

(c) The radiation emitted from the transitions between level -3.40 eV to -13.6 eV as shown in Fig. 7.1 is incident on the surface of a sheet of tungsten.

Tungsten has a work function energy of 4.5 eV.

Calculate the maximum energy of an electron emitted from the tungsten by this radiation.

energy = ... eV [2]

(d) Explain why it is not possible for X-ray radiation to be emitted from a hydrogen atom.

....

.... [1]

[Total: 11]

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

Battey Electric Vehicles: The Power Revolution

Battery Electric Vehicles (BEVs) represent a revolutionary shift in transportation technology, operating solely on electrical energy stored in their onboard battery packs to power their electric motors for propulsion.

The heart of every BEV lies in its sophisticated battery system. These batteries are monitored through a battery management system that measures the open circuit voltage (OCV) to determine the state of charge (SOC), which is the amount of electrical energy left in the battery as a percentage of the total capacity. The relationship between OCV and SOC for two prevalent lithium-ion variants — the lithium-iron-phosphate (LFP) cell and the lithium nickel manganese cobalt (Li-NMC) cell — is illustrated in Fig 8.1.
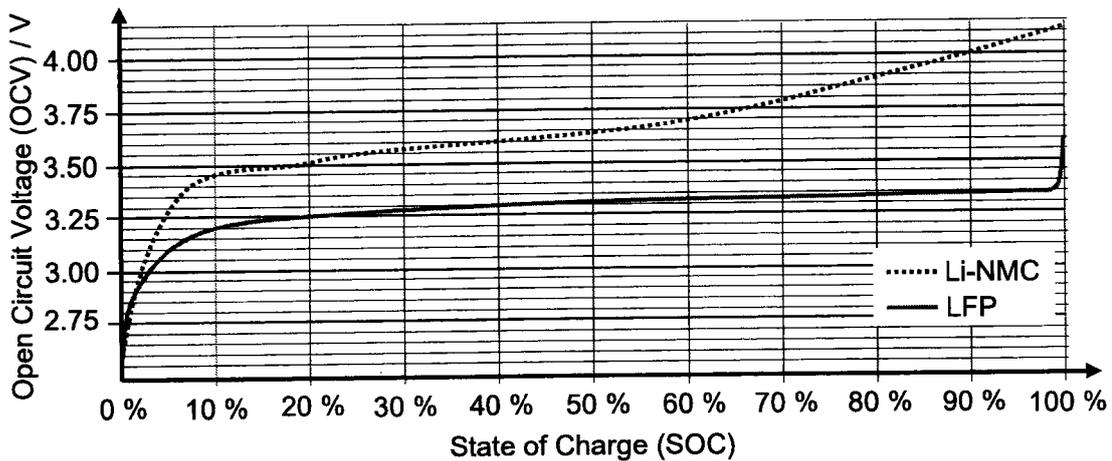
Fig. 8.1

The technological leap from traditional lead-acid batteries to modern lithium-ion systems has been remarkable. Contemporary lithium-ion batteries boast an impressive energy density ranging from 0.90 to 2.63 GJ m^{-3}, dwarfing the 0.36 GJ m^{-3} capacity of their lead-acid predecessors. However, when compared to conventional fuels like petroleum (34 GJ m^{-3}) and ethanol (24 GJ m^{-3}), there remains significant room for advancement.

Yet, the seemingly lower energy density of electric batteries is substantially compensated by their superior efficiency. BEVs demonstrate remarkable energy conversion capabilities, transforming over 77% of electrical energy from the grid into mechanical power at the wheels. This stands in stark contrast to conventional petrol internal combustion engine (ICE) vehicles, which convert merely 25% of petroleum's stored energy into usable power.

The popularity of BEVs in Singapore has been rising such that in 2024, an electric vehicle became the bestselling car. This market-leading electric vehicle combines sporty aesthetics with practical dimensions of 4.46 m length, 1.62 m height, and 1.88 m width. Despite its substantial fully loaded mass of 2100 kg, it achieves remarkable performance metrics, accelerating from 0 to 100 km h^{-1} in 10.1 seconds, thanks to its low drag coefficient of 0.29 and robust maximum power of 100 kW.

(a) An average internal combustion engine (ICE) car using petroleum as its fuel can carry about 0.055 m³ of petroleum.

(i) Calculate:

1. the total energy stored in the petroleum

total energy stored = ... GJ [2]

2. the range of the car if it needs an average of 0.086 GJ of useful energy to cover 100 km

range = ... km [3]

3. the fuel efficiency of the car, which is the average distance covered per unit volume of petroleum consumed.

fuel efficiency = ... km m⁻³ [2]

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(ii) Show that the smallest volume of lithium-ion battery required to cover the same range as the ICE car is 0.23 m³.

You may assume that the rate of energy consumption per distance travelled for the electric car is the same as that as for an ICE car.

[2]

(iii) Hence, suggest why cars powered by lithium-ion batteries have significantly smaller average range compared to ICE cars.

....

.... [1]

(b) **(i)** Using Fig. 8.1, determine the average change in open circuit voltage (OCV) per 1% change in state of charge (SOC) for both types of batteries in the range of 10% to 90 %.

average change in OCV for Li-NMC battery = ... V per 1%

average change in OCV for LFP battery = ... V per 1%

[3]

(ii) Hence, explain whether it is more accurate to monitor the capacity of an Li-NMC battery or an LFP battery using the Open Circuit Voltage (OCV).

....

....

.... [1]

21

(c) The drag force F_D on a car can be calculated using the equation

$$F_D = \frac{1}{2}\rho v^2 C A$$

where ρ is the density of air, v is the speed of the car, A is the cross-sectional area and C is the drag coefficient.

(i) Given that the drag coefficient C is unitless, use SI base units to show that the equation is homogeneous.

[2]

(ii) Given that the density of air is 1.29 kg m^{-3}, determine the speed of the market-leading electric car when its motor is operating at maximum power.

speed = ... m s^{-1} [3]

(iii) Suggest why it is difficult for the car to obtain the top speed.

....

....

.... [2]

[Total: 21]

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YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE
NAME

CG

INDEX NO

PHYSICS

9749/03

Paper 3 Longer Structured Questions

15 September 2025

2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number 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, highlighters,
glue or correction fluid/tape.

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

Section A
Answer **all** questions.
Section B
Answer **one** question only.

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

For Examiner's Use	
Paper 3	
Section A	
1	/ 4
2	/ 9
3	/ 7
4	/ 10
5	/ 11
6	/ 11
7	/ 8
Section B	
8	/ 20
9	/ 20
Penalty	
Paper 3 Total	
	/80

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

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} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

3

Formulae

uniformly accelerated motion, $\quad s \quad = \quad ut + \frac{1}{2}at^2$

$\quad v^2 \quad = \quad u^2 + 2as$

work done on/by a gas, $\quad W \quad = \quad p\Delta V$

hydrostatic pressure, $\quad p \quad = \quad \rho g h$

gravitational potential, $\quad \phi \quad = \quad -\frac{Gm}{r}$

temperature, $\quad T/K \quad = \quad T/^{\circ}C + 273.15$

pressure of an ideal gas, $\quad p \quad = \quad \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$

mean translational kinetic energy of an ideal gas molecule, $\quad E \quad = \quad \frac{3}{2}kT$

displacement of particle in s.h.m. $\quad x \quad = \quad x_0 \sin \omega t$

velocity of particle in s.h.m., $\quad v \quad = \quad v_0 \cos \omega t$

$\quad = \quad \pm \omega \sqrt{(x_o^2 - x^2)}$

electric current, $\quad I \quad = \quad A n v q$

resistors in series, $\quad R \quad = \quad R_1 + R_2 + \ldots\ldots\ldots$

resistors in parallel, $\quad \frac{1}{R} \quad = \quad \frac{1}{R_1} + \frac{1}{R_2} + \ldots\ldots$

electric potential, $\quad V \quad = \quad \frac{Q}{4\pi\varepsilon_0 r}$

alternating current/voltage, $\quad x \quad = \quad x_0 \sin \omega t$

magnetic flux density due to a long straight wire, $\quad B \quad = \quad \frac{\mu_0 I}{2\pi d}$

magnetic flux density due to a flat circular coil, $\quad B \quad = \quad \frac{\mu_0 N I}{2r}$

magnetic flux density due to a long solenoid, $\quad B \quad = \quad \mu_0 n I$

radioactive decay, $\quad x \quad = \quad x_0 \exp(-\lambda t)$

decay constant, $\quad \lambda \quad = \quad \frac{\ln 2}{t_{\frac{1}{2}}}$

4
Section A

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

1   One end of a wire is connected to a fixed point. A load is attached to the other end so that the wire hangs vertically. The diameter d of the wire and the load F are measured as

$$d = 0.40 \pm 0.02\,\text{mm},$$

$$F = 25.0 \pm 0.5\,\text{N}.$$

The stress σ in the wire is calculated by using the expression

$$\sigma = \frac{4F}{\pi d^2}$$

Determine the value of σ and its associated uncertainty.

$\sigma + \Delta\sigma =$ .... ± .... N m^{-2} [4]

[Total: 4]

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6

2 A particle A of mass $5u$ and velocity 2000 m s^{-1} collides head-on with another particle B of mass $32u$ and velocity 500 m s^{-1} as shown in Fig. 2.1. During the collision, the particles stay in contact for 2.5×10^{-12} s. After the collision, particle B moves rightwards with velocity 56 m s^{-1}.
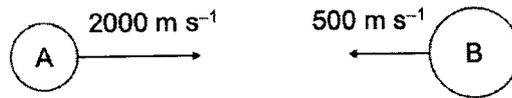
Fig. 2.1

(a) Determine the magnitude and direction of velocity of particle A after the collision.

magnitude of velocity = ... m s^{-1}

direction = ... [3]

(b) For the time during collision,

(i) state and explain whether both particles could be stationary at the same time,

....

....

.... [2]

(ii) calculate the average force F between the particles.

$F =$ .... N [2]

(c) By considering quantitatively the relative speeds of approach and of separation of the two particles, deduce whether the collision is elastic or inelastic.

....

.... [2]

[Total: 9]

3 **(a)** Define the moment of a force about a point.

....

.... [1]

(b) A uniform fishing rod AB of length 2.40 m and weight 5.2 N is shown in Fig. 3.1.
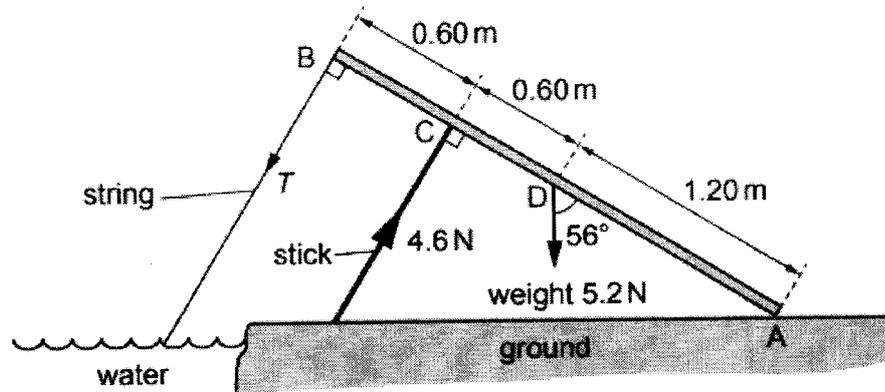
Fig. 3.1 (not to scale)

End A of the rod rests on the ground and a string is attached to the other end B. A support stick exerts a force of 4.6 N perpendicular to the rod at point C. The weight of the rod acts at point D. The tension *T* in the string is in a direction perpendicular to the rod.

The rod is in equilibrium and inclined at an angle of 56° to the vertical.

(i) By taking moments about end A of the rod, calculate the tension *T*.

T = ... N [2]

(ii) Determine the magnitude and the direction of the resultant force acting at the end A.

magnitude of the resultant force = ... N

direction of the resultant force = ...° above the horizontal

[4]

[Total: 7]

4 A binary star consists of two stars A and B that orbits one another, as illustrated in Fig. 4.1.
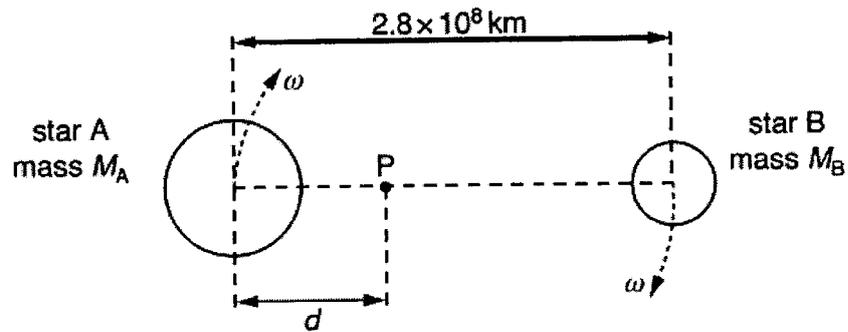
Fig. 4.1

The stars are in circular orbits with the centres of both orbits at point P, a distance d from the centre of star A.

(a) (i) Explain why the centripetal force acting on both stars has the same magnitude.

....

....

.... [2]

(ii) The period of the orbit of the stars about point P is 4.0 years.

Calculate the angular speed ω of the stars.

ω = ... rad s^{-1} [2]

(b) The separation of the centres of the stars is 2.8×10^8 km.

The mass of star A is M_A. The mass of star B is M_B. The ratio $\dfrac{M_A}{M_B}$ is 3.0.

(i) Determine the distance d.

$d =$ .... km [3]

(ii) Use the answers in **(a)(ii)** and **(b)(i)** to determine the mass M_B of star B.

$M_B =$ .... kg [3]

[Total: 10]

5 (a) Define electric field strength.

....

.... [1]

(b) Two small solid metal spheres A and B are in a vacuum. They have equal radii and their centres are 15 cm apart as shown in Fig. 5.1. Sphere A has charge +3.0 pC and sphere B has charge +12 pC.

sphere A charge +3.0 pC   P   sphere B charge +12 pC

5.0 cm

15 cm
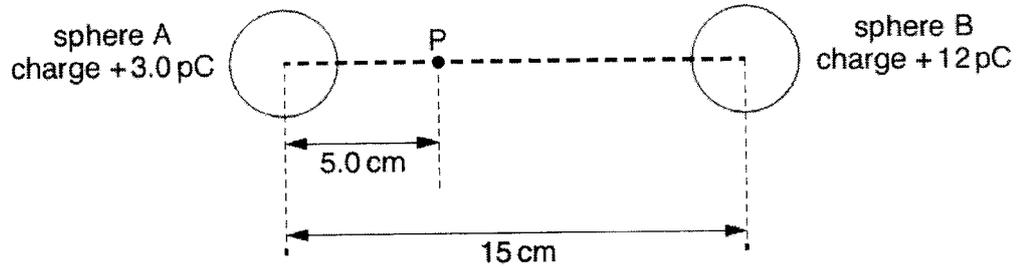
Fig. 5.1

Point P lies on the line joining the centres of the spheres and is a distance of 5.0 cm from the centre of sphere A.

(i) Suggest why the electric field strength in both spheres is zero.

....

....

.... [2]

(ii) Show that the electric field strength is zero at point P. Explain your working.

[3]

(iii) Calculate the electric potential at point P.

electric potential = ... V [2]

(iv) A silver-107 nucleus ($^{107}_{47}\text{Ag}$) has speed v when it is a long distance from point P.

Use your answer in **(b)(iii)** to calculate the minimum value of speed v such that the nucleus can reach point P. Explain your answer.

v = ... m s^{-1} [3]

[Total: 11]

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6 **(a)** A cell of e.m.f. 1.5 V and internal resistance 0.25 Ω is connected in series with a metal wire that has resistance 6.0 Ω, as shown in Fig. 6.1. The resulting current I passes through the metal wire for a time of 5.0 minutes.
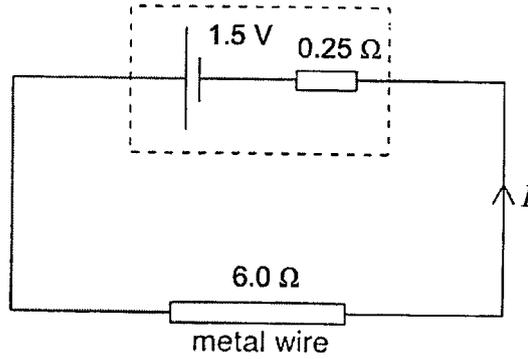
Fig. 6.1

(i) Calculate current I passing through the metal wire.

I = ... A [2]

(ii) Calculate the total energy transferred to the metal wire.

energy = ... J [2]

(iii) A second similar cell is now connected in series with the cell in **(a)** and the metal wire. This causes the current in the metal wire to increase.

By considering the atomic structure of a metal conductor, explain why the resistance of the metal wire increases.

....

....

.... [1]

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(b) An ideal cell of e.m.f. 3.0 V is connected in series with a fixed resistor of resistance 1.0 kΩ and a thermistor, as shown in Fig. 6.2.

3.0 V

1.0 kΩ
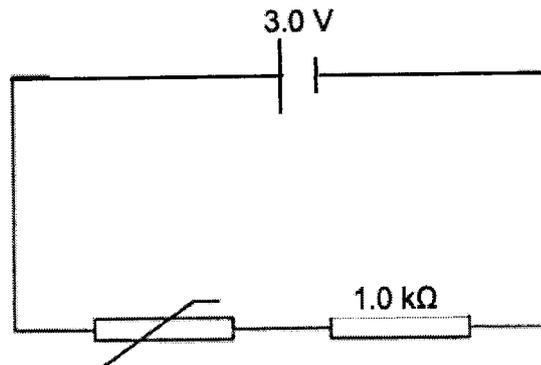
Fig. 6.2

The thermistor has resistance 10 kΩ at 0 °C and 100 Ω at 150 °C, and the internal resistance of the cell may be considered negligible.

(i) Define potential difference.

....

....

.... [1]

(ii) On the same set of axes in Fig. 6.3, sketch the following graphs:

1. The potential difference (p.d.) across the thermistor vs temperature of the thermistor. Label the graph as **T**.
2. The p.d. across the 1.0 kΩ resistor vs temperature of the thermistor. Label the graph as **R**.

[2]

p.d. / V

3.0

0   Temperature / °C
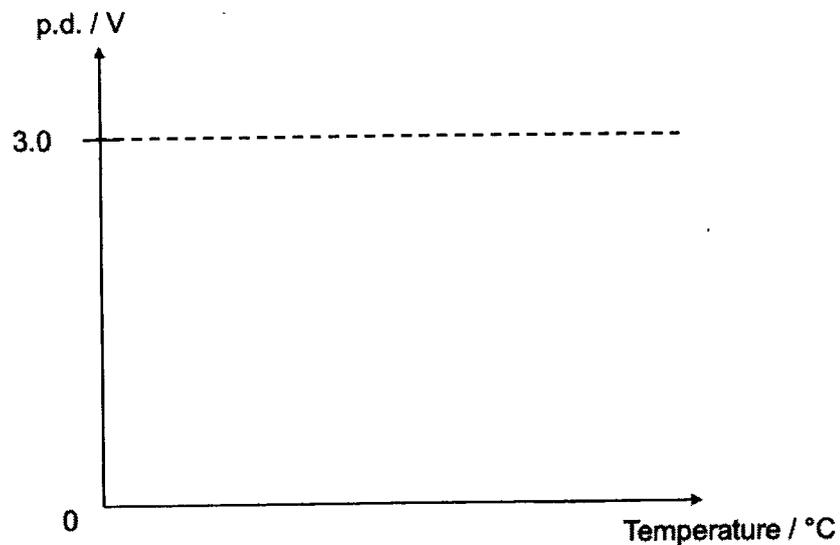
Fig. 6.3

(iii) In one application of the circuit in Fig. 6.2, the user wishes for the potential difference across the fixed resistor to range from 1.2 V at 0 °C to 2.4 V at 150 °C.

Determine whether, by substituting a different fixed resistor in the circuit of Fig. 6.2, it is possible to achieve this range of potential differences.

....

.... [3]

[Total: 11]

7 **(a)** **(i)** Smoke alarms are installed in buildings and homes to warn people of smoke, likely from fires. Once smoke is detected, the alarms will create very loud sounds.

Fig. 7.1 shows part of the inside of a smoke alarm, that contains an α-radiation source and a radiation detector.

Fig. 7.1

When α-particles arrive at the detector, the smoke alarm stays off.

Suggest why the alarm turns on when smoke particles enter the plastic casing.

....

....

.... [2]

(ii) State and explain whether the source should have a long or short half-life when used in smoke alarms.

....

....

.... [2]

(b) **(i)** α-particles are released when Plutonium-239 decays to form an isotope of uranium, U.

Complete the equation below for the above decay.

$$^{239}_{\ldots}Pu \rightarrow \,^{\ldots}_{92}U + \,^{\ldots}_{\ldots}\alpha$$

[2]

(ii) The binding energies per nucleon of the three nuclides above are shown below.

Nuclide	Binding energy per nucleon / MeV
Plutonium-239	7.560
Isotope of uranium	7.591
α-particle	7.062

Determine the energy released when a Plutonium-239 nucleus decays.

energy released = ... MeV [2]

[Total: 8]

Section B

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

8 **(a)** State the meaning of the following terms associated with wave motion.

(i) *intensity* of a wave.

....

.... [1]

(ii) *plane polarisation* of a wave.

....

....

.... [2]

(b) A small loudspeaker is rated 2.5 W. The amplitude of an emitted sound wave from the loudspeaker of intensity 1.0 W m^{-2} is 4.0 μm.

Determine the amplitude of the sound wave at a distance of 2.0 m from the loudspeaker.

amplitude = ... μm [2]

(c) Two waves are shown in Fig. 8.1.
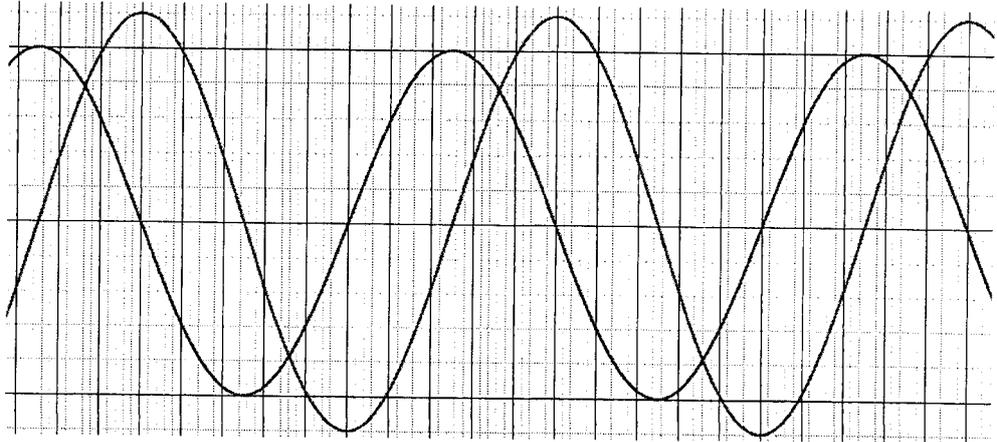

Fig. 8.1

(i) Deduce the phase difference between the two waves.

phase difference = ...° [2]

(ii) Explain why the two waves in Fig. 8.1 are coherent.

....

....

.... [2]

(d) A two-source interference pattern is set up using light of wavelength 546 nm. The light passes through two slits 1.13 mm apart as shown in Fig. 8.2. A pattern of light is formed on a screen at a distance 1.25 m from the slits. A graph of the intensity of light in the pattern is shown in Fig. 8.2.
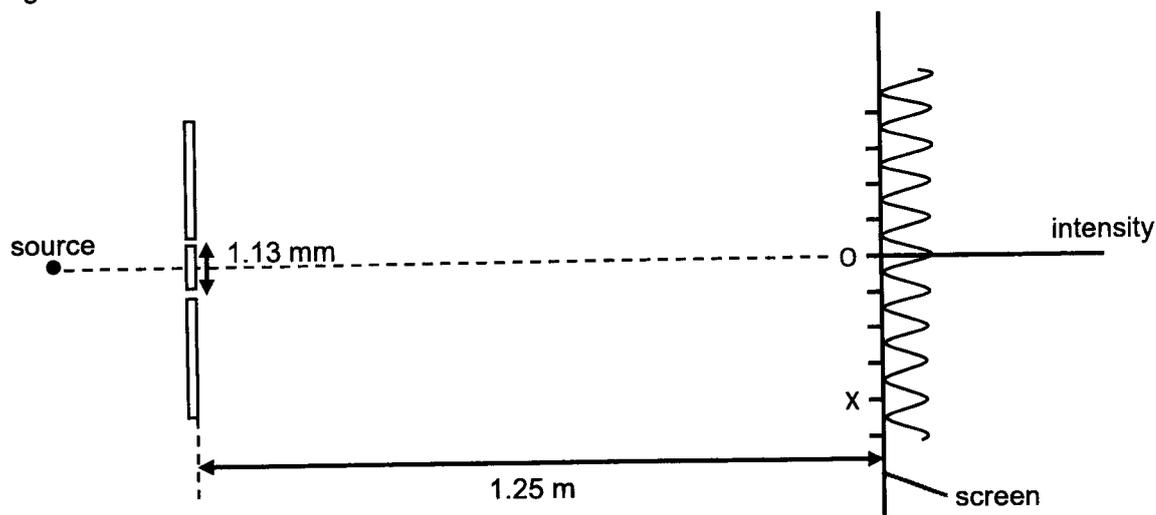

Fig. 8.2

(i) Calculate the distance OX.

OX = ... m [2]

(ii) Suggest how the appearance of the fringes changes when each of the following adjustments is made separately.

1. The width of both slits is reduced without altering their separation.

....

....

.... [1]

2. The screen is rotated so that it is no longer parallel to the plane of the two slits.

....

....

.... [2]

(e) A stationary microwave is formed between a microwave source at A and a reflector at B, as shown in Fig. 8.3.
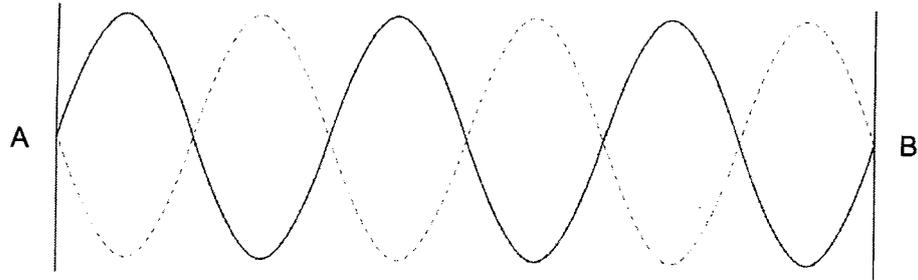

Fig. 8.3

The solid line represents the wave at time $t = 0$ and the dotted line represents the wave at time $t = \dfrac{T}{2}$, where T, the period of the wave, is 40 picoseconds.

(i) Calculate the distance between A and B.

distance = ... m [3]

(ii) Sketch, on Fig. 8.3, the shape of the wave when:

1. $t = \dfrac{T}{4}$. Label this wave shape **X**.

2. $t = \dfrac{7T}{8}$. Label this wave shape **Y**.

[3]

[Total: 20]

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

....

.... [1]

(ii) State Lenz's law of electromagnetic induction.

....

.... [1]

(b) A solenoid is connected in series with a battery and a switch, as illustrated in Fig. 9.1.
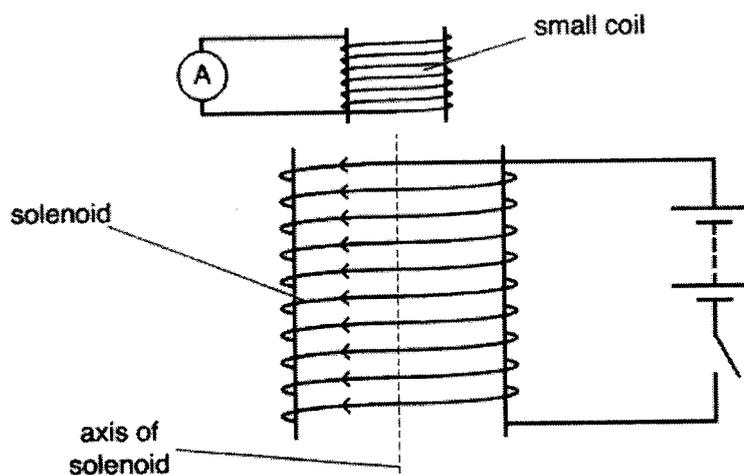

Fig. 9.1

A small coil, connected to a sensitive ammeter, is situated near one end of the solenoid.

(i) On Fig. 9.1, draw an arrow on the axis of the solenoid to show the direction of the magnetic field inside the solenoid when the current in the solenoid is switched on. Label this arrow **P**. [1]

(ii) As the current in the solenoid is switched off, the magnetic flux density inside the solenoid is reduced from 7.5 mT to 0 mT in a time of 0.15 s, inducing an average e.m.f. of 3.6 mV across the solenoid.

1. Use Lenz's law of electromagnetic induction to explain the direction of the induced magnetic field due to the induced current in the small coil when the current is switched off.

On Fig. 9.1, mark the direction of this induced magnetic field with an arrow inside the small coil. Label this arrow **Q**.

....

....

....

.... [3]

2. The battery is now replaced with a variable power supply, which is used to vary the magnetic flux density *B* in the small coil with time *t* as shown in Fig. 9.2.
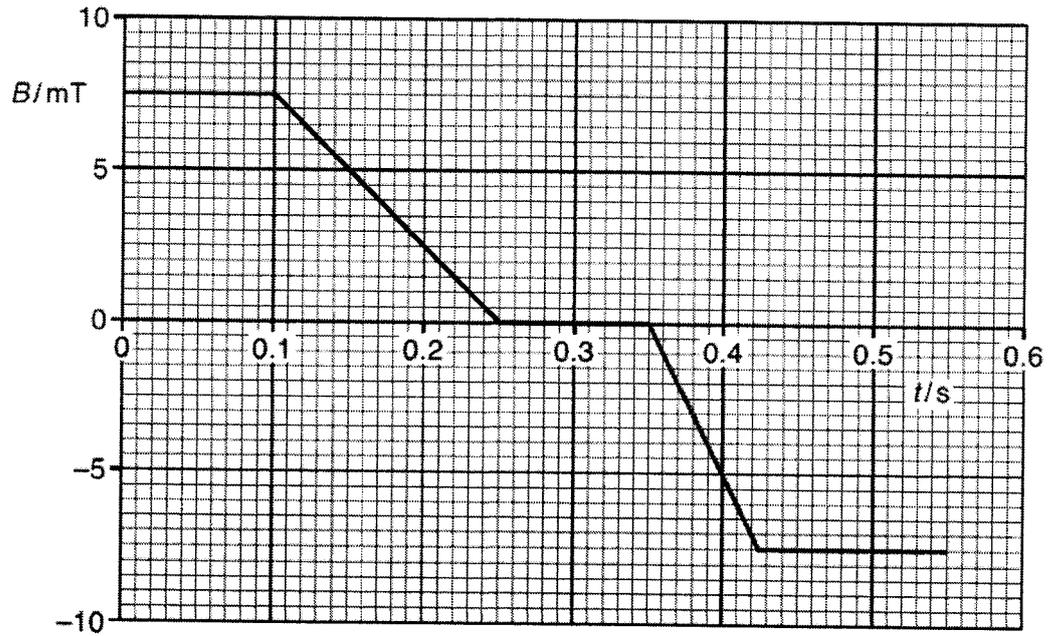

Fig. 9.2

On Fig 9.3, sketch the variation with time *t* of the e.m.f. *E* induced in the small coil.
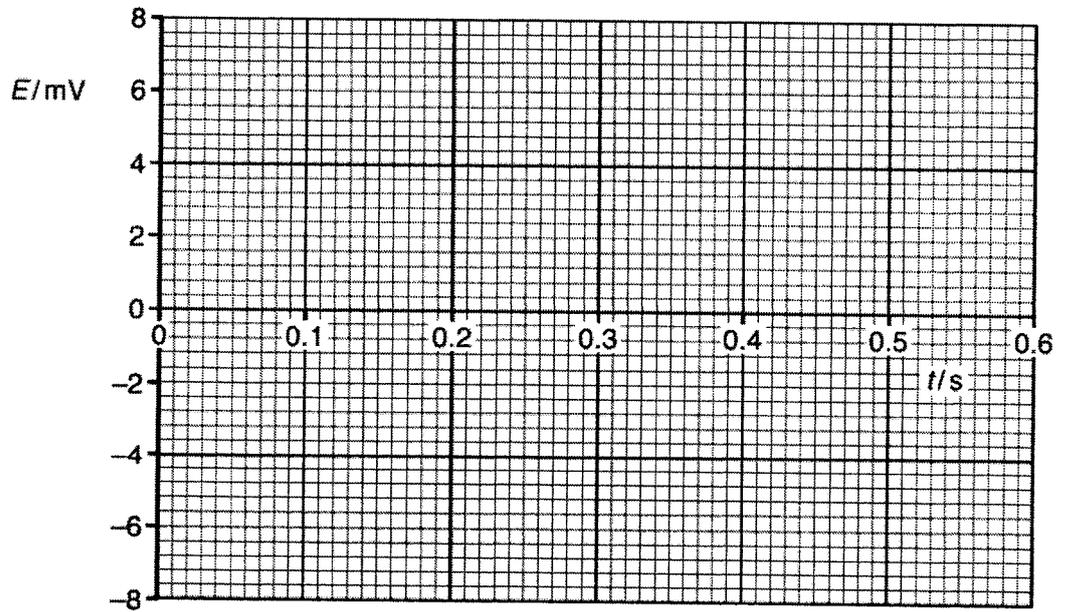

Fig. 9.3

[3]

(c) An electromagnetic braking system is connected to the wheels of a vehicle.

(i) In order to activate the electromagnetic braking system, a uniform magnetic field of flux density 0.017 T is produced by two similar flat coils, as shown in Fig. 9.4. The two flat coils are fixed so that their planes are parallel.
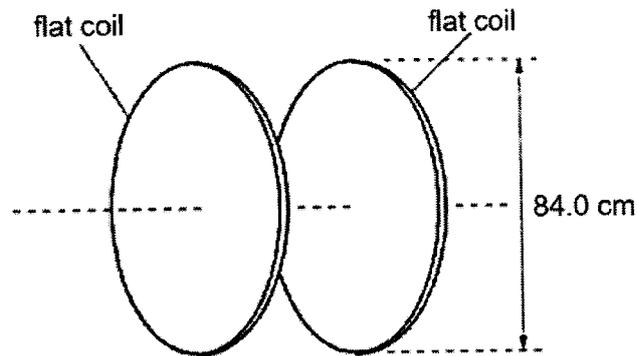
flat coil   flat coil

84.0 cm

Fig. 9.4

The current I in both coils is 12 A.

The magnetic flux density B in the region between the two coils is uniform and given by the expression

$$B = 0.72\mu_o \frac{NI}{r}$$

where N is the number of turns on each of the flat coils of radius r and μ_0 is the permeability of free space.

Determine the number of turns N needed to produce a magnetic flux density of 0.017 T.

$N = $ .... [2]

(ii) A heavy aluminium disc is connected to the wheels of a vehicle. The magnetic field produced in **(c)(i)** is perpendicular to the plane of the rotation of the aluminium disc, as shown in Fig. 9.5. The disc has a diameter of 0.72 m.
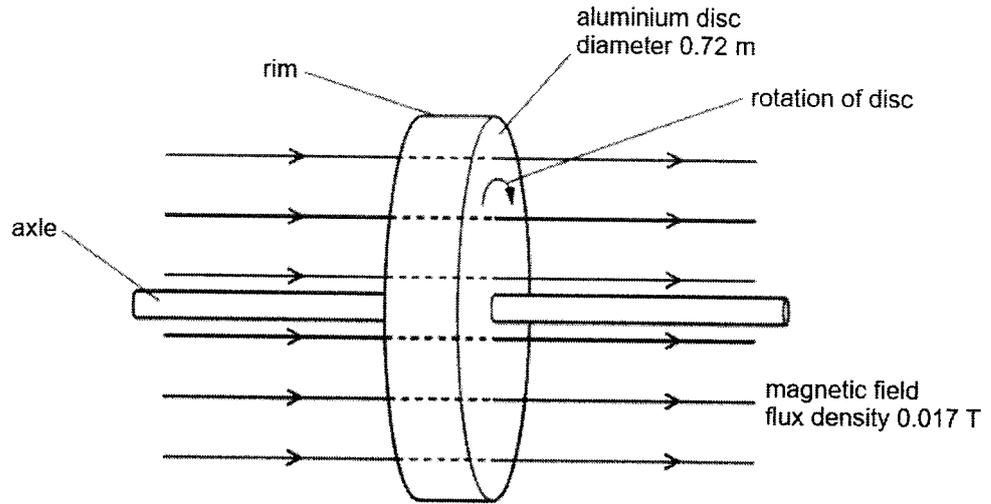

Fig. 9.5

An e.m.f. is induced between the centre and the rim of the rotating disc when a magnetic field of 0.017 T is directed into it. The rotation of the disc can be modelled as a radial wire OP between the axle and the rim cutting the magnetic field as shown in Fig. 9.6.
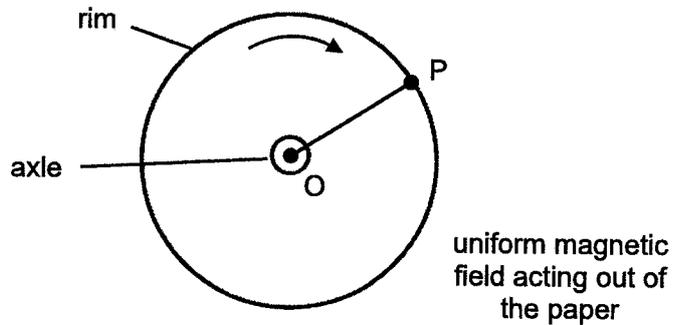

Fig. 9.6

1. Calculate the total magnetic flux cut by the radial wire when the disc rotates one round.

Give a unit for your answer.

magnetic flux = ... unit .... [3]

28

2. The disc is rotating at a rate of 25 revolutions per second.

   Calculate the magnitude of the electromotive force (e.m.f.) induced between the axle and the rim of the disc.

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

3. The axle and the rim are connected to an external circuit that enables the energy of the rotation of the disc to be stored. The direction of rotation is shown in Fig. 9.6.

   Use Lenz's law to determine whether the direction of current in the disc is from the rim to the axle or from the axle to the rim. Explain your reasoning.

   ....

   ....

   ....

   ....

   .... [3]

   [Total: 20]