RAFFLES INSTITUTION
PRELIMINARY EXAMINATION 2025
Higher 2

CANDIDATE NAME | | CLASS INDEX NUMBER | |

CLASS | 2 | 5 | S | 0 | | |

PHYSICS

9749/01

Paper 1 Multiple Choice

25 September 2025

1 hour

You must answer on the multiple choice answer sheet

You will need: Multiple choice answer paper
Soft clean eraser
Soft pencil (type 2B is recommended)

INSTRUCTIONS

- 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 multiple choice answer sheet.
- Follow the instructions on the multiple choice answer sheet.
- Write in soft pencil.
- Write your name, class and index number on the multiple choice answer sheet in the spaces provided.
- Do **not** use correction fluid or tape.
- You may use an approved calculator.

INFORMATION

- The total mark for this paper is 30.
- Each correct answer will score one mark.
- Any rough working should be done on this question paper.

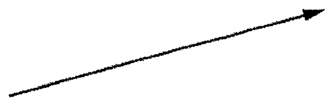
Data

speed of light in free space	c	$= 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	μ_0	$= 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	$= 8.85 \times 10^{-12}$ 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}

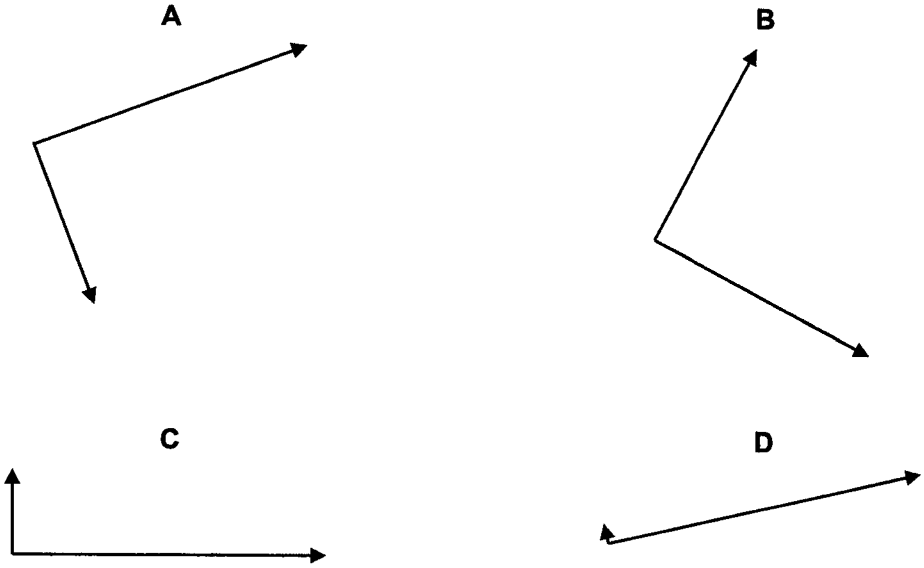
Formulae

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	ϕ	$= -Gm/r$
temperature	T/K	$= T/{}^\circ\text{C} + 273.15$
pressure of an ideal gas	p	$= \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	E	$= \frac{3}{2}kT$
displacement of particle in s.h.m.	x	$= x_0 \sin \omega t$
velocity of particle in s.h.m.	v	$= v_0 \cos \omega t = \pm\omega\sqrt{x_0^2 - x^2}$
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	$= \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	x	$= x_0 \sin \omega t$
magnetic flux density due to a long straight wire	B	$= \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	$= \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	$= \mu_0 nI$
radioactive decay	x	$= x_0 \exp(-\lambda t)$
decay constant	λ	$= \ln 2 / t_{1/2}$

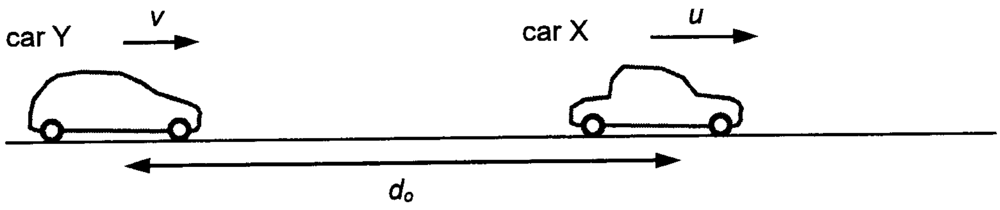
1 The arrow represents a vector R.



Which diagram does **not** represent R as two perpendicular components?



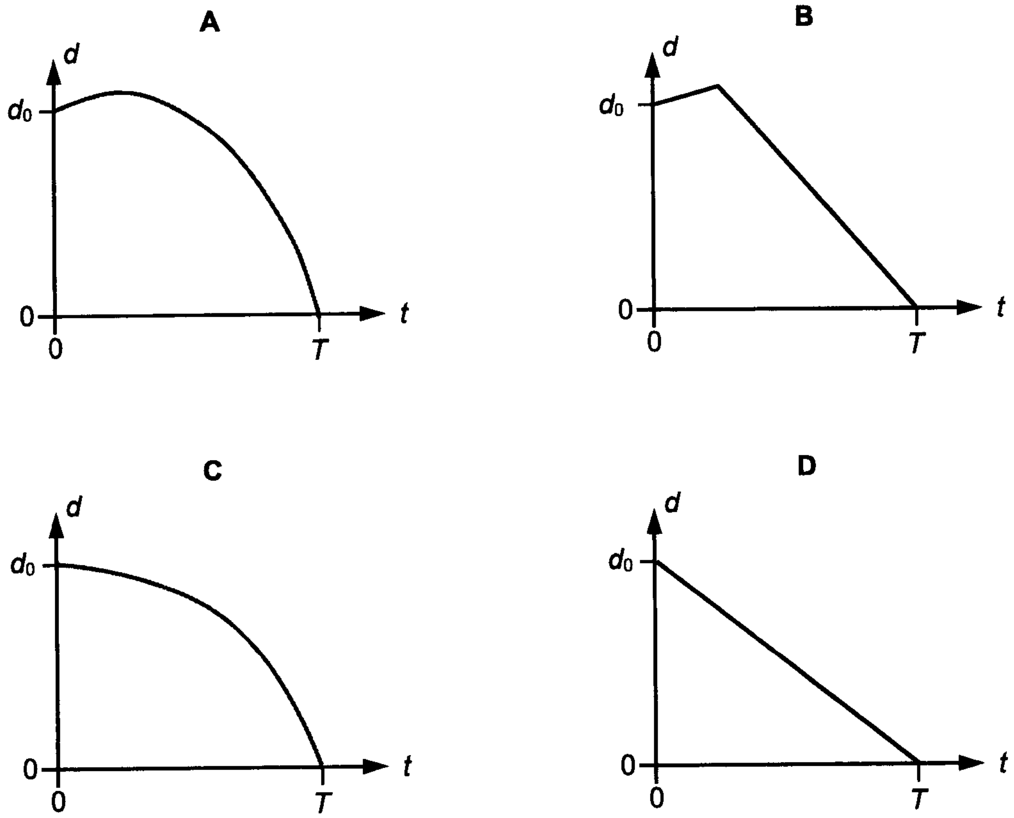
2 A car X travels at constant speed u along a straight road. At time t = 0, a second car Y is a distance d_0 behind car X and travels at a speed v in the same direction. Speed v is less than speed u.



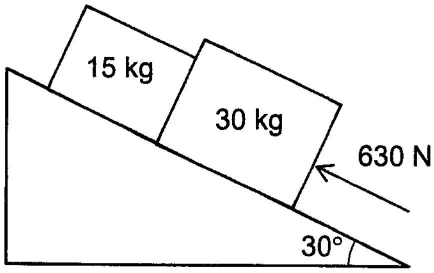
At time t = 0, car Y begins to accelerate with constant acceleration.

Car Y overtakes car X at time t = T.

Which graph best shows the variation with time t of the distance d between the cars?



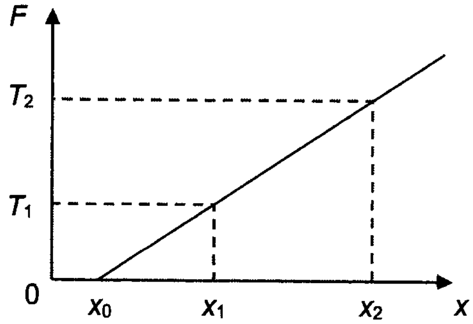
3 Two crates, of masses 15 kg and 30 kg, are in contact and placed on a frictionless incline that makes an angle of 30° to the horizontal. A constant force of 630 N parallel to the surface of the incline is applied to the 30 kg crate.



What is the force that each crate exerts on the other?

A 63 N **B** 140 N **C** 210 N **D** 420 N

4 The force F required to extend a spring of unstretched length x_0 to a length x is measured. When the tension in the spring is T_1, the length of the spring is x_1. When the tension in the spring is T_2, the length of the spring is x_2.



What is the work done to stretch the spring from length x_1 to length x_2?

A $\frac{1}{2}(T_2)(x_2 - x_0)$

B $\frac{1}{2}(T_1 + T_2)(x_2 - x_1)$

C $\frac{1}{2}(T_1 + T_2)(x_2 + x_1 - 2x_0)$

D $\frac{1}{2}(T_1 + T_2)(x_2 - x_1 - 2x_0)$

5 Which statement is correct?

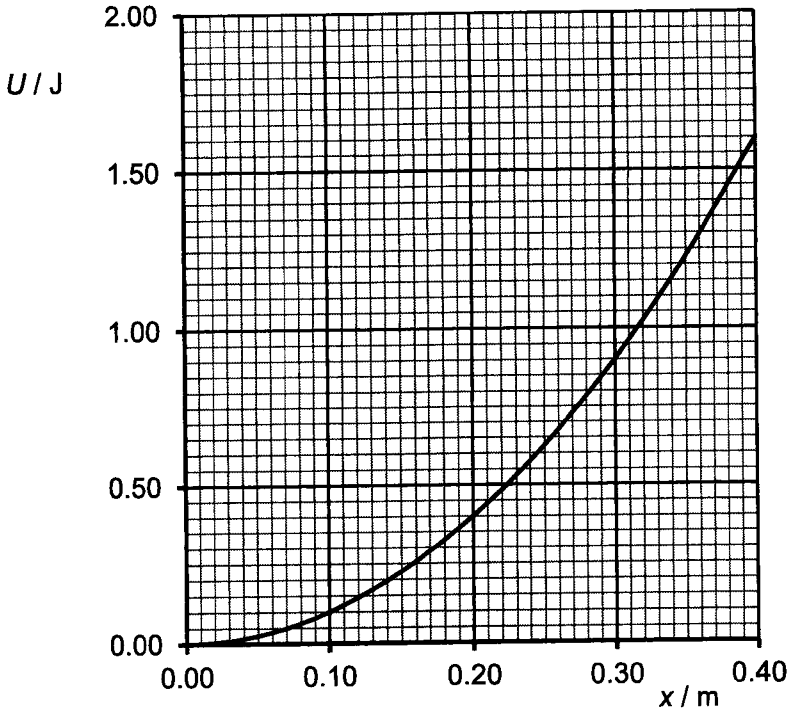
A An object with only a couple acting on it is in translational equilibrium.

B An object with only a couple acting on it is in equilibrium.

C The direction of the torque of a couple depends on where the pivot is.

D A couple is an action-reaction pair of forces.

6 The variation with displacement x of the potential energy U of a body is shown.



What is the magnitude of the force acting on the body at x = 0.30 m?

A 0.090 N **B** 0.17 N **C** 3.0 N **D** 6.0 N

7 A driving force of 250 N is needed for a car of mass 900 kg to travel along a level road at a constant speed of 24 m s^{-1}.

What power is required to maintain the car at this speed when it is moving up a slope that rises 1.0 m for every 12 m of travel along the road?

A 6.8 kW **B** 12 kW **C** 18 kW **D** 24 kW

8 A ball of mass 0.10 kg is attached to a string and swung in a vertical circle of radius 0.50 m. The speed of the ball at the top of the circle is 6.0 m s^{-1}.

What is the tension in the string at this instant?

A 0.98 N **B** 6.2 N **C** 7.2 N **D** 8.2 N

9 A spherical body of radius r has uniform density ρ.

What is the gravitational potential on its surface?

A $-4\pi G\rho r^2$ **B** $-\frac{4}{3}\pi G\rho r^2$ **C** $-\frac{4}{3}\pi G\rho r$ **D** $\frac{4}{3}\pi G\rho r^2$

10 Two planets X and Y travel anticlockwise in circular orbits about a star. The radii of their orbits are in the ratio 3:1.

Diagram 1 shows the positions of X and Y at time $t = 0$. They are aligned such that they make a straight line with the star.

Diagram 2 shows the position of X at a later time $t = t_1$. The angular displacement of planet X is 90° from its initial position.

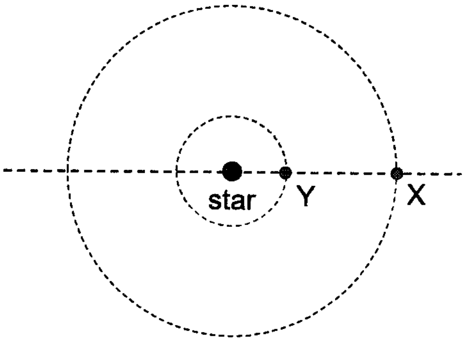


diagram 1

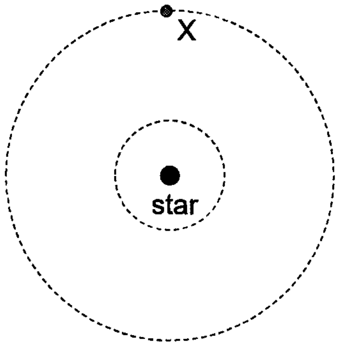
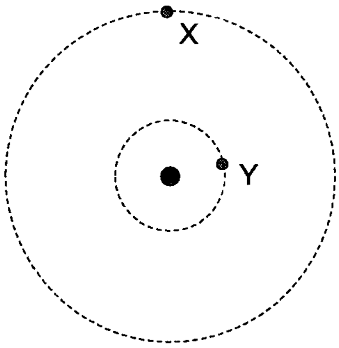


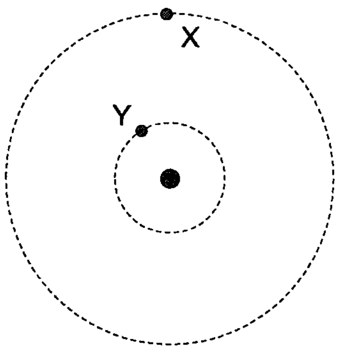
diagram 2

Which diagram shows the position of planet Y at time $t = t_1$?

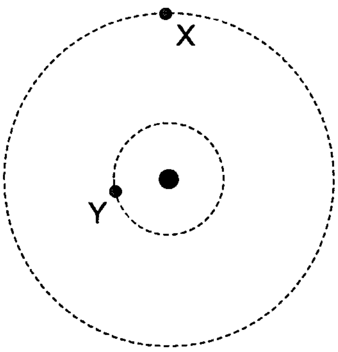
A



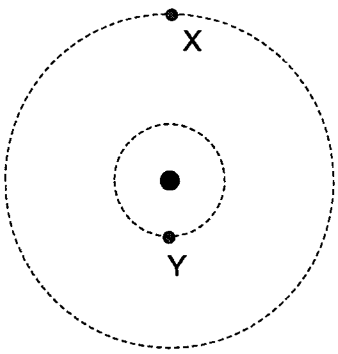
B



C



D



11 A particle oscillating horizontally with simple harmonic motion has a displacement given by the equation:

$$x = 3.0 \sin(20t),$$

where x is the displacement in metres and t is the time in seconds.

What is the displacement of the particle when the kinetic energy of the particle is equal to the potential energy?

A 0 m **B** 1.5 m **C** 2.1 m **D** 3.0 m

12 Which of the following is an example of resonance?

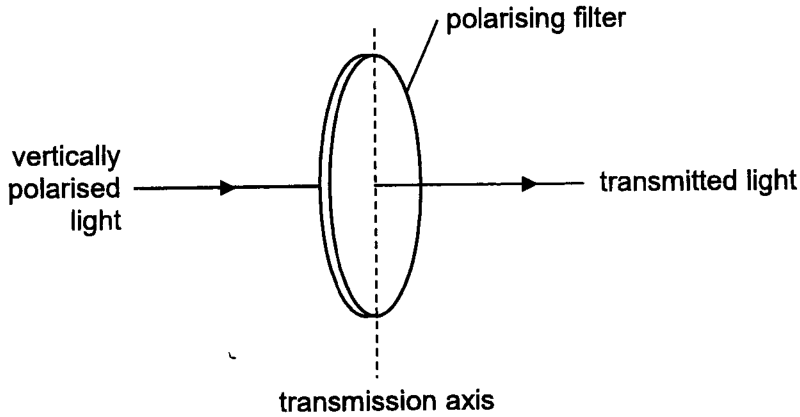
A A car oscillates with a large amplitude after going over a hump.

B A string that is fixed on both ends is plucked in the middle and it starts to vibrate.

C Increasing the initial displacement of a pendulum such that it oscillates at a larger amplitude.

D A child on a swing is given a push whenever he is about to move forward such that the amplitude of the swing increases.

13 A beam of vertically polarised light is incident normally on a polarising filter. The filter is rotated such that it is always in a plane perpendicular to the beam of light. The polarising axis of the filter is initially vertical as shown.

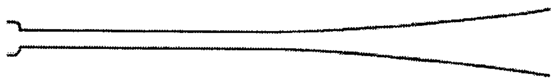


The filter is first rotated clockwise by an angle of 30° and the transmitted light waves have intensity I. The filter is then rotated anticlockwise by an angle of 45° from its current position.

What is the new intensity of the transmitted light waves?

A $0.089I$ **B** $0.67I$ **C** $1.2I$ **D** $24I$

14 A musical instrument is made using a long tube with a mouthpiece at one end. The other end is open as shown.



A musician maintains stationary sound waves with a node at the mouthpiece and an antinode at the other end. The lowest frequency of sound that the instrument can produce is 92 Hz.

Which different frequencies of sound can be produced by the instrument?

A 92 Hz, 184 Hz, 276 Hz, 368 Hz

B 92 Hz, 184 Hz, 368 Hz, 736 Hz

C 92 Hz, 276 Hz, 460 Hz, 644 Hz

D 92 Hz, 276 Hz, 552 Hz, 828 Hz

15 A beam of monochromatic light falls on a diffraction grating at normal incidence. The third order diffracted beam occurs at an angle of 50.8° to the normal.

What is the highest order visible with this grating at this wavelength?

A 3 **B** 4 **C** 5 **D** 6

16 Which of the following is **not** a basic assumption of the kinetic theory of gases?

A All molecules are in random motion.

B All collisions between molecules are perfectly elastic.

C All molecules are point particles with negligible volume.

D All molecules move with the same speed at a certain temperature.

17 Which of the following statements regarding internal energy is correct?

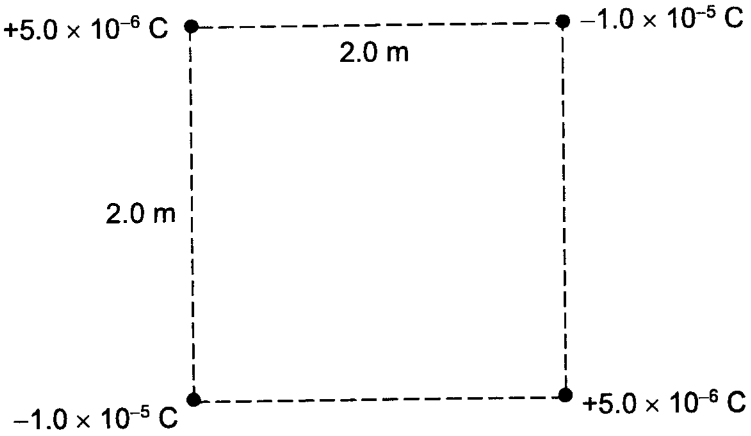
A Shaking a bottle of water will increase its internal energy.

B An expanding gas with an increase in temperature leads to a fall in internal energy.

C The internal energy of a gas always increases when heat is supplied to the gas.

D Compressing a gas will always increase its internal energy.

18 Two point charges of $+5.0 \times 10^{-6}$ C and two point charges of -1.0×10^{-5} C are fixed at the corners of a rigid square as shown. The length of each side of the square is 2.0 m.



What is the total electric potential energy of the system?

A −0.90 J **B** −0.50 J **C** −0.45 J **D** 1.1 J

19 Which statement is **not** correct?

A The electric potential at a point can be zero even though the electric field at that point is not zero.

B The electric field at a point can be zero even though the electric potential at that point is not zero

C As the distance from a positive point charge increases, the electric potential gradient decreases.

D A charged particle under the action of an electric force will always move from a region of higher electric potential to a region of lower electric potential.

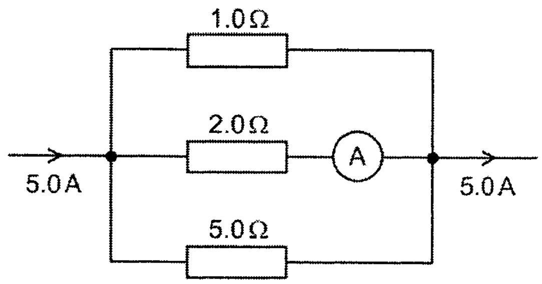
20 A metal wire of length 20 cm and uniform cross-sectional area contains 4.8×10^{22} free electrons.

When a potential difference is applied across the ends of the wire, the free electrons move with an average drift speed of 3.2×10^{-5} m s^{-1}.

What is the current in the wire?

A 0.0098 A **B** 0.050 A **C** 1.2 A **D** 6.1 A

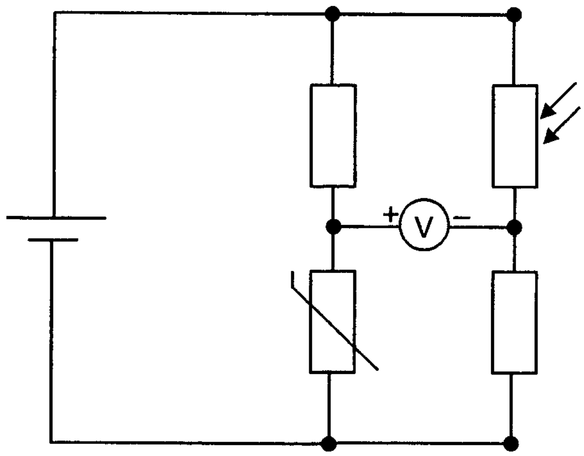
21 The diagram shows part of a current-carrying circuit. The ammeter has negligible resistance.



What is the reading on the ammeter?

A 1.3 A **B** 1.5 A **C** 3.8 A **D** 4.3 A

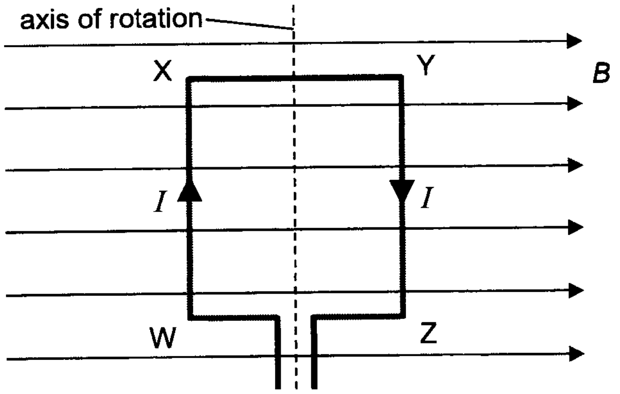
22 A student conducts an experiment by setting up a circuit as shown in the diagram. The diagram shows how the positive and negative terminals of a voltmeter are connected to the circuit. The initial reading on the voltmeter is positive.



Which changes, if any, in temperature and light intensity would cause the voltmeter reading to decrease?

	temperature	light intensity
A	increase	increase
B	no change	decrease
C	decrease	no change
D	decrease	decrease

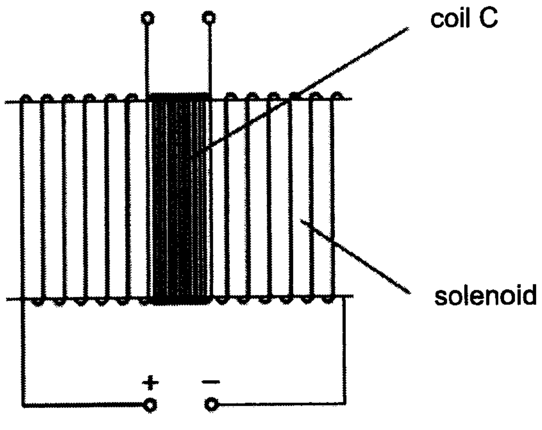
23 A rectangular loop WXYZ carries a current I and rotates in a magnetic field of flux density B. The axis of rotation is perpendicular to the magnetic field.



Which row correctly describes the variation of the magnitude of the magnetic force acting on WX and torque on the loop?

	magnetic force	torque
A	constant	constant
B	constant	not constant
C	not constant	constant
D	not constant	not constant

24 A solenoid has a coil C of wire wound tightly about its centre as shown.

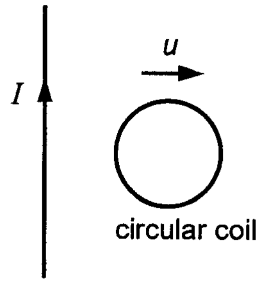


The coil C has 96 turns of area 1.6×10^{-3} m^2. The solenoid has 950 turns in 80 cm and carries a current of 2.0 A. The current is reversed in a duration of 0.24 s.

What is the average induced e.m.f. in coil C when the current is reversed?

A 0 V **B** 1.9 mV **C** 3.1 mV **D** 3.8 mV

25 A fixed long straight wire carrying current I is placed close to a circular conducting coil. The circular coil is moving away from the wire with an initial speed u.



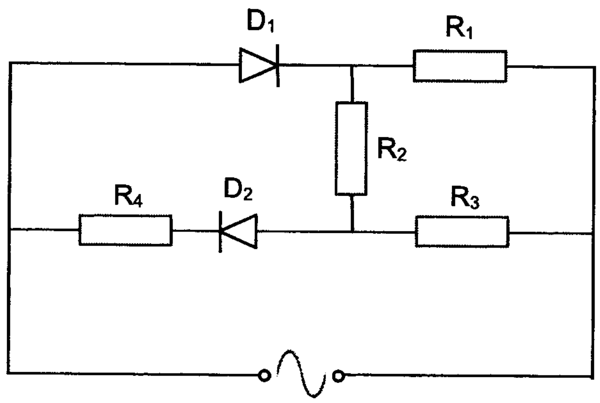
Which row correctly describes the direction of the induced current and the speed of the circular coil as the coil moves away from the wire?

	direction of induced current	speed
A	clockwise	no change
B	clockwise	decrease
C	anticlockwise	no change
D	anticlockwise	decrease

26 In the circuit shown, D_1 and D_2 are ideal diodes. Resistor R_1 has a resistance of $2R$. Resistors R_2, R_3 and R_4 are identical and have the same resistance R.

The input voltage to the circuit is a sinusoidal alternating voltage of peak value V_0.

What is the average power delivered to the circuit?



A $0.25\dfrac{V_0^2}{R}$ **B** $0.36\dfrac{V_0^2}{R}$ **C** $0.39\dfrac{V_0^2}{R}$ **D** $0.79\dfrac{V_0^2}{R}$

27 According to Bohr's model for the hydrogen atom, the electron at the ground state moves in an orbit of specific radius *r* with specific tangential velocity *v* around a positively charged nucleus.

Which of the following statements correctly explains why the Bohr's model is wrong?

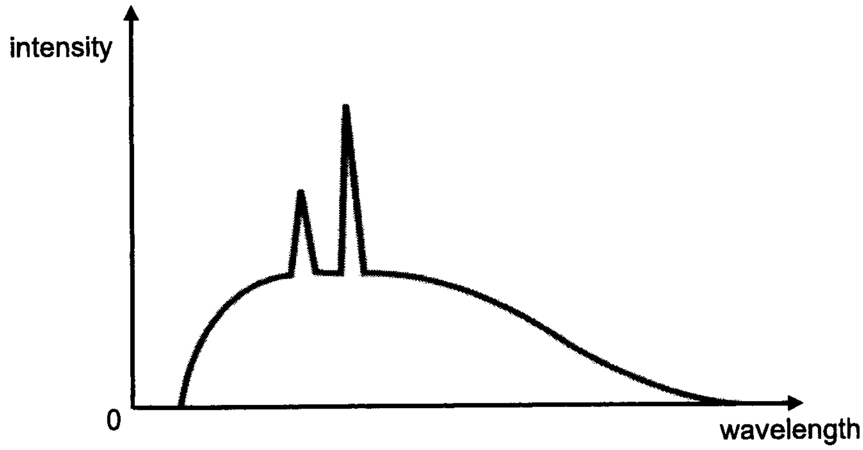
A Bohr's model implies that the uncertainties in *r* and *v* are both zero simultaneously and thus violating the Heisenberg uncertainty principle.

B Bohr's model implies that the uncertainty in *r* and the uncertainty in the momentum of the electron in the radial direction are both zero simultaneously and thus violating the Heisenberg uncertainty principle.

C Based on the Heisenberg uncertainty principle, an electron confined to such a small space will be moving faster than the speed of light.

D Based on the Heisenberg uncertainty principle, the electron will eventually escape, and the atom will not be stable.

28 An X-ray spectrum is shown in the figure below.



Which of the following best explains the origin of the sharp peaks in the X-ray spectrum?

A They are caused by transitions of electrons between energy levels in the atoms of the target.

B They are produced when high-energy electrons slow down in the electric fields of nuclei.

C They result from scattering of X-rays off electrons in the target.

D They are due to diffraction of X-rays by atoms in the crystal lattice of the target.

29 A positron and an electron, each of mass 9.11×10^{-31} kg moving with negligible kinetic energy, meet and annihilate each other, producing two gamma photons of the same frequency.

What is the energy of each of the two gamma photons produced?

A 5.5×10^{-22} J **B** 4.1×10^{-14} J **C** 8.2×10^{-14} J **D** 1.6×10^{-13} J

30 During a particular fission process, a uranium-235 nucleus absorbs a slow-moving neutron. This initiates the fission reaction, creating a xenon-144 nucleus, a strontium-90 nucleus and two neutrons.

The binding energies per nucleon are:

Uranium-235	7.6 MeV
Xenon-144	8.4 MeV
Strontium-90	8.5 MeV

What is the energy released or absorbed in the reaction?

A 1.5×10^{-12} J of energy is absorbed

B 1.5×10^{-12} J of energy is released

C 3.0×10^{-11} J of energy is absorbed

D 3.0×10^{-11} J of energy is released

RAFFLES INSTITUTION
PRELIMINARY EXAMINATION 2025
Higher 2

CANDIDATE NAME		CLASS INDEX NUMBER	

CLASS	2	5	S	0		

PHYSICS

9749/02

Paper 2 Structured Questions

17 September 2025

2 hours

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS
- Answer **all** questions.
- Use a black or dark blue pen. You may use an 2B pencil for any diagrams or graphs.
- Write your name, index number and class in the spaces at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen. Do **not** use correction fluid or tape.
- You may use an approved calculator.

INFORMATION
- The total mark for this paper is 80.
- The number of marks for each question or part question is shown in brackets [ ].

For Examiner's Use	
1	/ 6
2	/ 6
3	/ 9
4	/ 10
5	/ 8
6	/ 9
7	/ 12
8	/ 20
Deduction	
Total	/ 80

This document has **23** 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}

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	=	ρgh
gravitational potential	ϕ	=	$-Gm/r$
temperature	T/K	=	$T/{}^\circ\text{C} + 273.15$
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
mean translational kinetic energy of an ideal gas molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_0 \cos \omega t = \pm\omega\sqrt{x_0^2 - x^2}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \dots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \dots$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\ln 2/t_{1/2}$

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

1 Fig. 1.1 shows a cuboid made of glass.

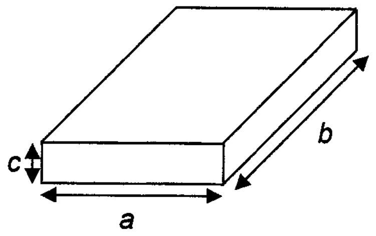


Fig. 1.1

A student measures the mass *m* of the cuboid and the side lengths *a*, *b* and *c*. The measurements are shown in Table 1.1.

Table 1.1

quantity	measurement
m	(0.234 ± 0.002) kg
a	(5.13 ± 0.01) cm
b	(11.38 ± 0.01) cm
c	(1.72 ± 0.01) cm

(a) Determine the density ρ of the glass.

ρ = ... kg m^{-3} [1]

(b) Determine the value of ρ together with its actual uncertainty.
Give your answer to an appropriate number of significant figures.

ρ = ...±.............................. kg m^{-3} [3]

(c) The true value of the density of the glass is different from the answer in **(a)** because of a systematic error in the measurements.

Suggest **one** possible cause of this systematic error.

....

....

....

.... [2]

[Total: 6]

2 A cantilever is set up on a rough table using a rigid uniform metre rule of mass 0.11 kg, a 1.5 kg block and a 5.0 g mass as shown in Fig. 2.1.

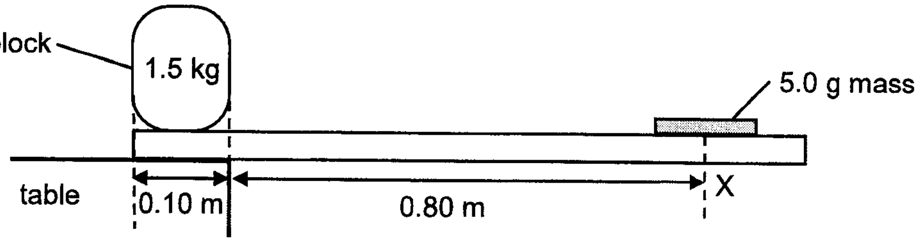


Fig. 2.1

(a) Determine the maximum number of 5.0 g masses that can be stacked above point X such that the cantilever does not topple.

maximum number = ... [3]

(b) The structure in Fig. 2.1 is modified by adding an inextensible string that passes over a frictionless pulley with its ends tied to the 1.5 kg block and to the centre of the metre rule as shown in Fig. 2.2. The string remains taut.

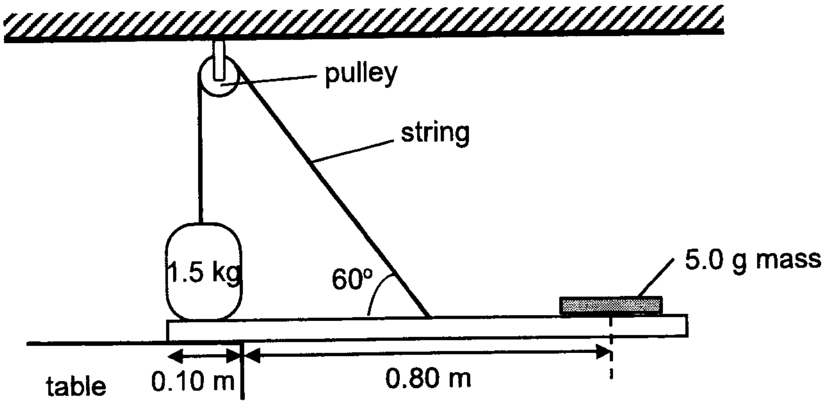


Fig. 2.2

State and explain how this modification will affect your answer in **(a)**.

....

....

....

....

....

.... [3]

[Total: 6]

3 In a machine, a peg that is fixed to a wheel rotates in a vertical circle of radius r. Both the peg and the wheel rotate with a constant angular velocity ω and period T about the centre of wheel O. The peg is in contact with a horizontal slot in a yoke. As the peg undergoes uniform circular motion, the yoke of mass m moves vertically up and down within a well.

Fig. 3.1 shows the positions of the peg and yoke at different times t.

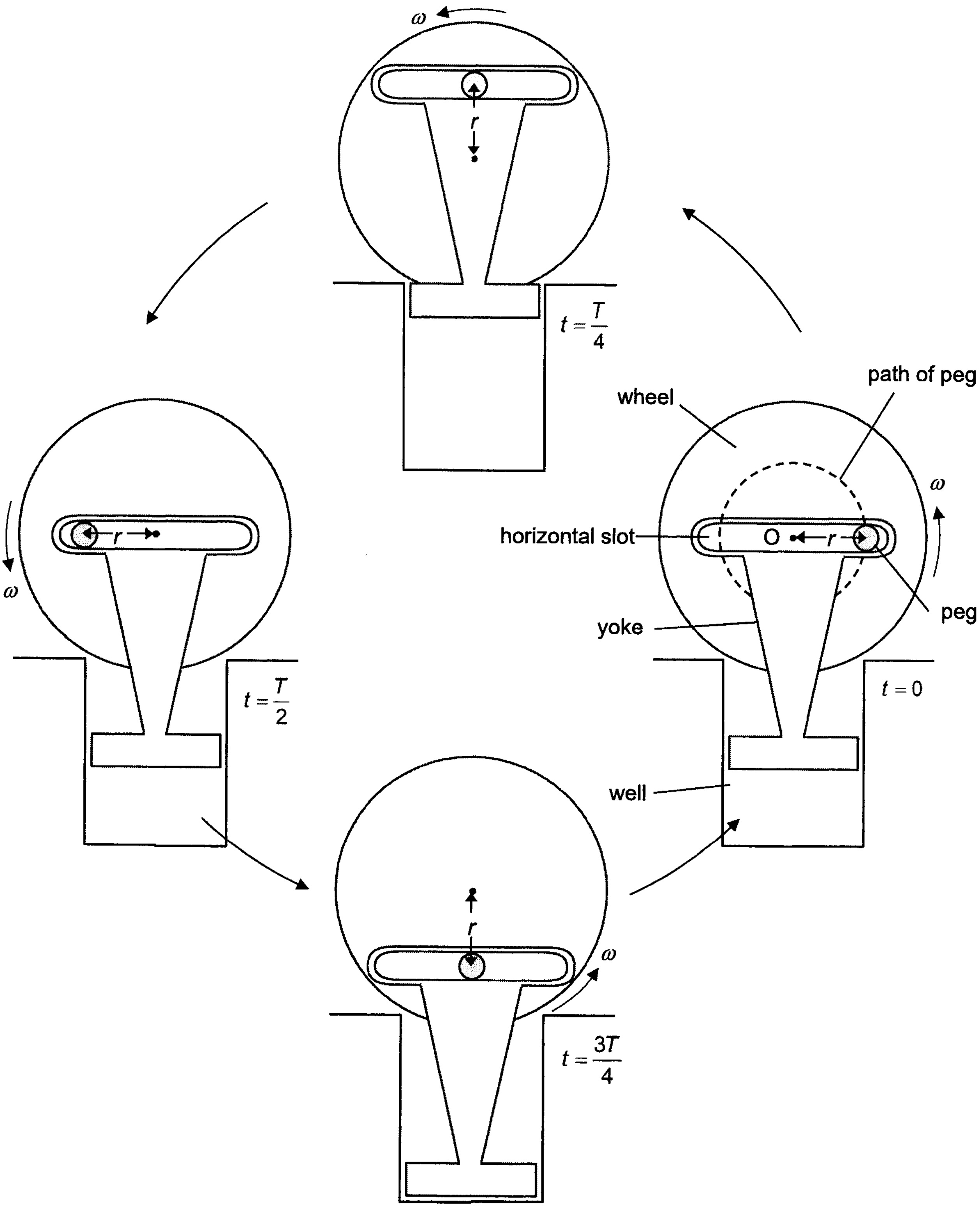


Fig. 3.1

(a) State and explain the motion of the yoke.

....

....

....

.... [2]

(b) Given that $r = 0.080$ m, $T = 0.40$ s and $m = 0.30$ kg, determine:

(i) **1.** the maximum speed v_0 of the yoke

v_0 = ... m s^{-1} [2]

2. the maximum acceleration a_0 of the yoke.

a_0 = ... m s^{-2} [2]

(ii) On Fig. 3.2, sketch a line to show the variation of net force F on the yoke with time t. Take the equilibrium position of the yoke as the zero of displacement and the upwards direction as positive.

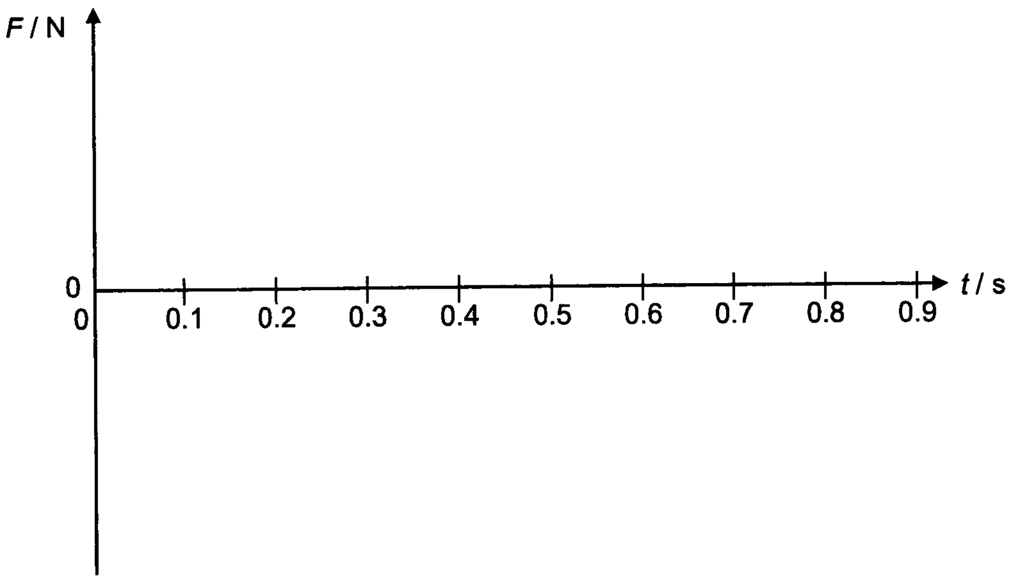


Fig. 3.2

[3]

[Total: 9]

4 Polarised light of wavelength 590 nm is incident normally on a double slit, as shown in Fig. 4.1.

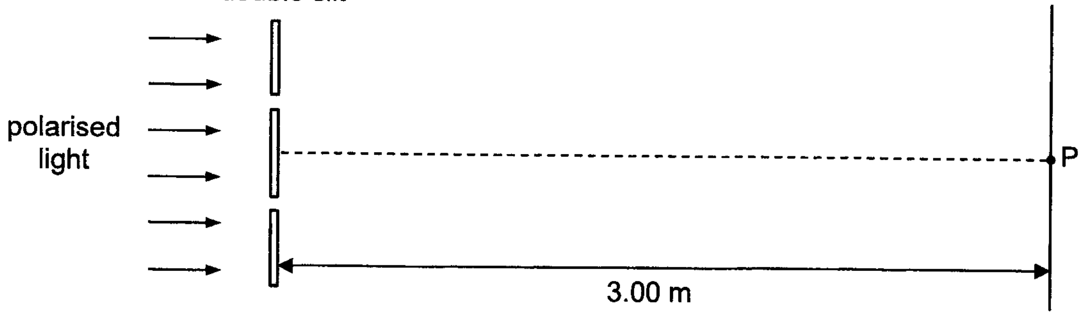


Fig. 4.1 (not to scale)

The separation of the two slits of equal width is very small compared to the distance of 3.00 m between the slits and the screen. The double slit and the screen are parallel.

An interference pattern consisting of bright and dark fringes is observed on the screen. Point P is equidistant from both slits.

(a) **(i)** Explain how the bright and dark fringes are formed.

....

....

....

....

....

.... [3]

(ii) Explain why some bright fringes are observed to be missing from the interference pattern.

....

.... [1]

(b) One of the two slits is covered.

(i) The distance between the first dark fringes on either side of point P on the screen is 35.4 mm. Determine the width of each slit.

width = ... mm [3]

(ii) Parallel light from a second source of the same wavelength of 590 nm is also incident on the uncovered slit. The angle between the two beams of light is 0.0040 rad, as shown in Fig. 4.2.

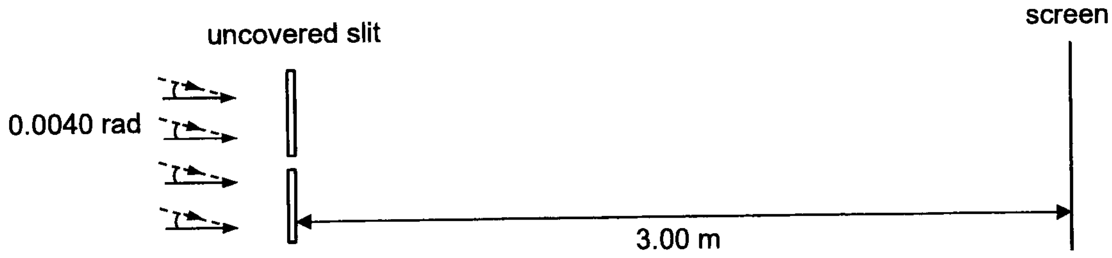


Fig. 4.2 (not to scale)

Each beam forms a separate diffraction pattern on the screen.

With reference to the Rayleigh criterion, explain whether the two diffraction patterns formed on the screen are seen as being separate.

....

....

....

....

....

.... [3]

[Total: 10]

5 An ideal gas at a temperature of 22 °C is trapped in a metal cylinder of volume $0.20\ m^3$ at a pressure of 1.6×10^6 Pa.

(a) State what is meant by an ideal gas.

....

....

....

.... [2]

(b) Calculate the amount of gas contained in the cylinder.

amount = ... mol [2]

(c) The gas has a molar mass of $4.2 \times 10^{-2}\ kg\ mol^{-1}$.

Calculate the root-mean-square speed of the gas molecules in the cylinder.

root-mean-square speed = ... $m\ s^{-1}$ [2]

(d) The cylinder is taken to high altitude where the temperature is –50 °C and the pressure is 3.6×10^4 Pa. A valve on the cylinder is opened to allow gas to escape.

Calculate the mass of gas remaining in the cylinder when it reaches equilibrium with its surroundings.

mass of gas remaining = ... kg [2]

[Total: 8]

6 A potentiometer wire PR, mounted on a metre rule (not shown), is used to measure the electromotive force (e.m.f.) *E* of a solar cell with internal resistance as shown in Fig. 6.1.

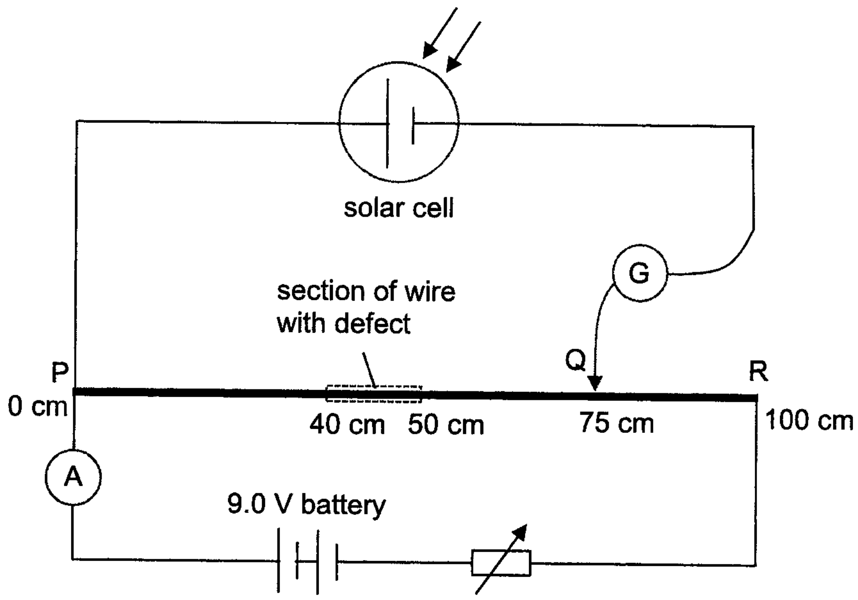


Fig. 6.1

Points P and R of the wire are at the 0 cm and 100 cm marks on the metre rule respectively. The 9.0 V battery has negligible internal resistance.

The potentiometer wire has a resistivity of $5.0 \times 10^{-7}\ \Omega$ m. It is found that there is defect in a small section of the wire, from 40 cm to 50 cm marks, where the cross-sectional area is 20% smaller than the rest of the wire which has a cross-sectional area of 5.7×10^{-8} m^2.

(a) State what is meant by e.m.f. of a battery.

....

.... [1]

(b) Calculate the resistance of the potentiometer wire PR.

resistance = ... Ω [2]

(c) When the variable resistor is set to a resistance of 25 Ω, the galvanometer shows no deflection when the jockey Q is in contact with the wire at the 75 cm mark.

(i) Calculate the current I shown on the ammeter.

I = ... A [2]

(ii) Calculate E.

E = ... V [2]

(d) **(i)** Explain why the internal resistance of the solar cell does not have to be considered in the calculation in **(c)(ii)**.

....

.... [1]

(ii) Explain, without calculation, how the balance length would change if the cross-sectional area of the potentiometer wire is uniform throughout with a value of 5.7×10^{-8} m^2 and the resistance of the variable resistor is unchanged.

....

.... [1]

[Total: 9]

7 Potassium-40 ($^{40}_{19}K$) is an isotope of potassium with a half-life of 1.25×10^9 years.

(a) (i) Explain the term isotopes.

....

.... [1]

(ii) Define half-life of a radioactive isotope.

....

.... [1]

(b) Most of the isotope potassium-40 undergoes beta decay to form the stable isotope calcium-40 ($^{40}_{20}Ca$).

(i) Complete the nuclear decay equation. Include all the decay products.

$^{40}_{19}K \rightarrow$

[3]

(ii) Data for the atomic masses are given in Table 7.1.

Table 7.1

	mass / u
$^{40}_{19}K$	39.963998
$^{40}_{20}Ca$	39.962591

Determine the energy released in each decay of potassium-40 to calcium-40.

energy released = ... MeV [4]

(c) 90% of the potassium-40 decays to form calcium-40 while the remaining 10% decays to form the stable isotope argon-40.

In a particular sample of rock, the ratio of the number of potassium atoms to the number of argon atoms is found to be 2:1.

Estimate the age of the rock. Assume that originally there was no argon present.

age of rock = ... years [3]

[Total: 12]

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

Skiing is a popular recreational activity involving using skis to move across snow. Ski resorts in snowy mountain regions have ski lifts to transport skiers uphill. The chairs in ski lifts move on a continuously circulating wire rope. Fig. 8.1 shows a two-person chair that is commonly used in ski lifts.

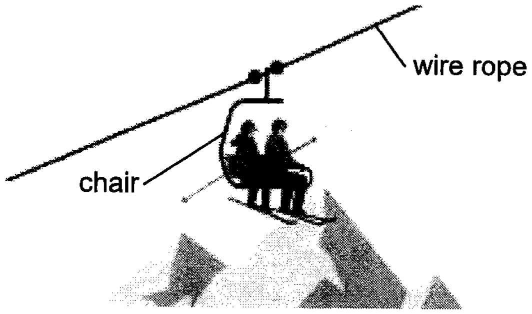


Fig. 8.1

A particular ski lift uses 48 two-person chairs, evenly spaced along the wire rope, to transport skiers up a height of 300 m from the lower station to the upper station. Each chair has a mass of 80 kg and moves at a constant speed of 2.5 m s^{-1}. The distance between the two stations is 900 m as shown in Fig. 8.2.

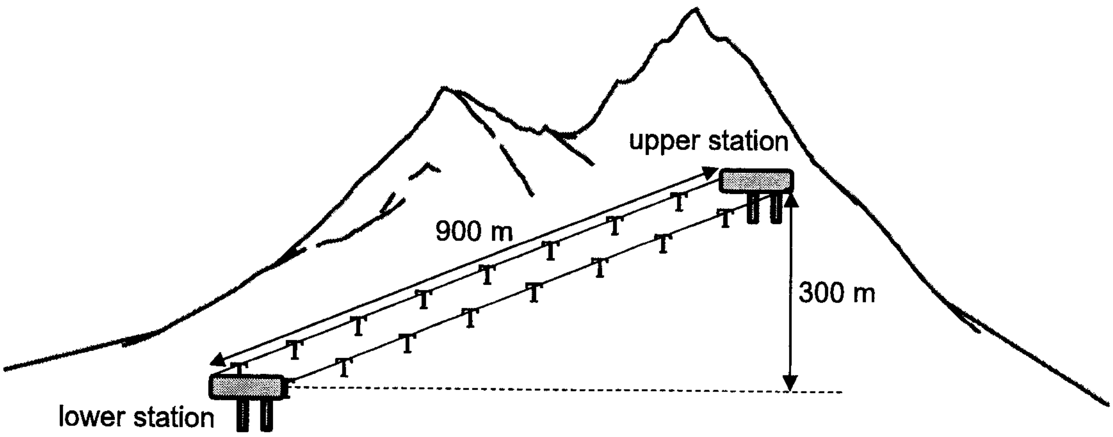


Fig. 8.2 (not to scale)

Ski resorts offer ski lessons where skiers new to skiing can learn the two basic techniques: sliding and carving.

Sliding occurs when a skier moves down a slope in a straight path. This movement results from the interaction between two forces: the skier's weight and the friction between the skier and snow surface.

When skis press against snow, the increased pressure beneath the skis causes localised melting, creating a microscopic layer of water. This water layer significantly reduces friction, facilitating smoother ski movements. The type of snow plays a crucial role in this process, directly affecting both the skier's control and velocity.

The friction f between the skis and the snow is related to the normal contact force N acting on the skier due to the snow by the equation:

$$f = \mu N$$

where μ is the coefficient of friction.

(a) **(i)** On a crowded day, each chair carries two skiers uphill and no skiers downhill. The average mass of a skier is 75 kg.

Calculate the mechanical power required to drive the ski lift.

power = ... W [3]

(ii) Suggest a reason why your answer in **(a)(i)** is an underestimation.

....

.... [1]

(b) Table 8.1 shows the values of μ for various types of snow.

Table 8.1

type of snow	μ
hard snow	0.050
medium snow	0.080
soft snow	0.12
wet / icy snow	0.030

To maintain control and regulate speed while sliding, skiers will adjust their direction of motion relative to the downhill direction. The angle between the direction of motion and the downhill direction, known as the ski angle α, is shown on Fig. 8.3.

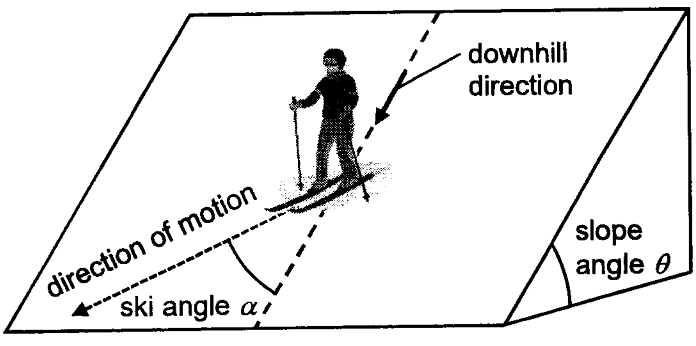


Fig. 8.3

Skiers typically ski across the face of the slope in a zig-zag pattern for optimal control. The acceleration a_g in the direction of motion due to gravity varies depending on the slope angle θ and ski angle α.

Fig. 8.4 shows the variation with α of a_g at various values of θ.

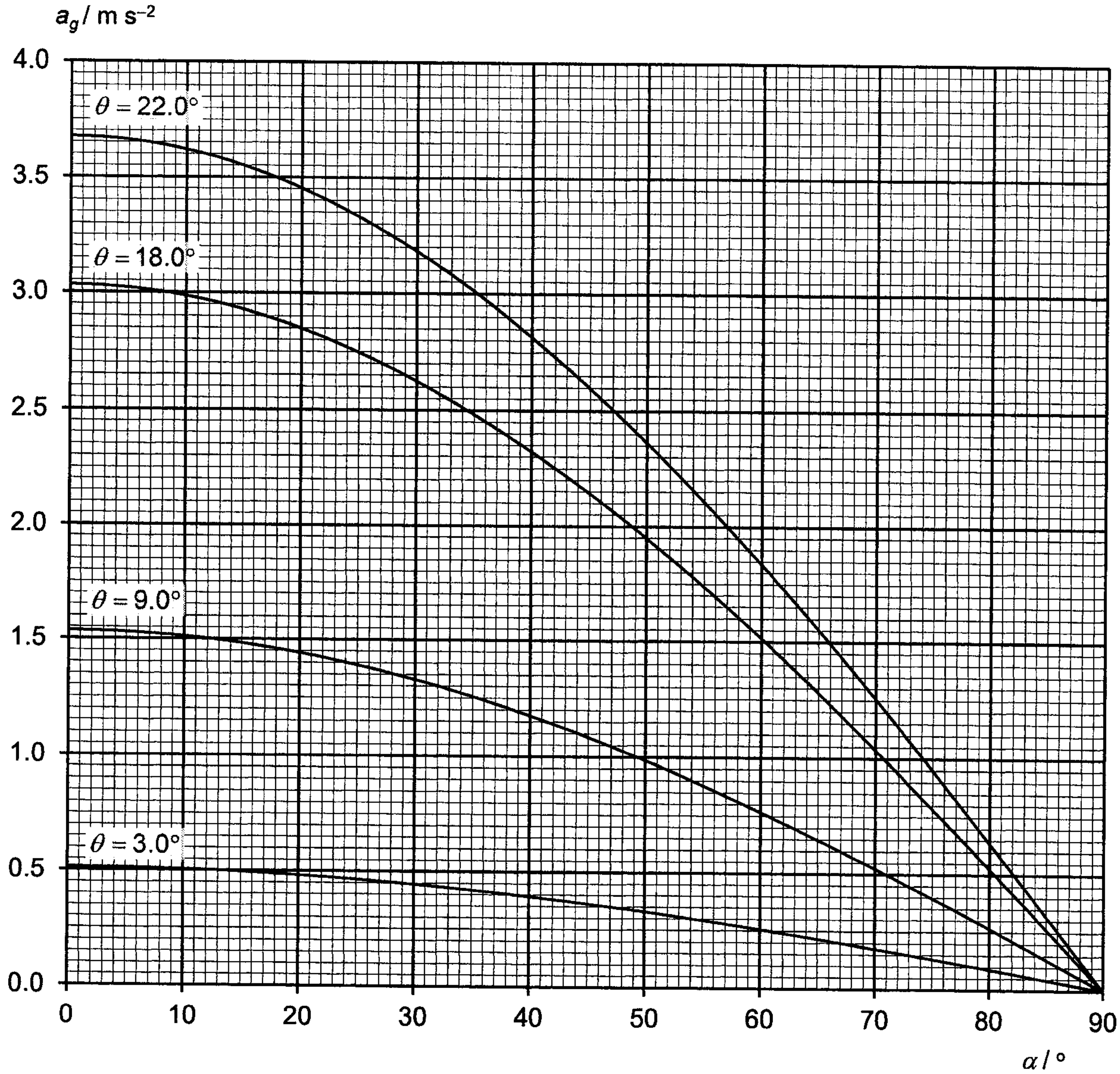


Fig. 8.4

A skier of mass 75 kg moves down the slope with slope angle $\theta = 9.0°$ and ski angle $\alpha = 0°$. The slope is covered with medium snow. Assume that air resistance is negligible.

(i) Show that the normal contact force N acting on the skier is 730 N.

[1]

(ii) Determine the friction acting on the skier.

friction = ... N [2]

(iii) Determine the acceleration of the skier.

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

(c) The skier moves down a new slope of slope angle $\theta = 22.0°$. The new slope is covered with soft snow. To maintain a constant speed, the skier adjusts his direction of motion to a ski angle α.

(i) Determine the friction acting on the skier on the new slope.

friction = ... N [1]

(ii) Use Fig. 8.4 to determine the ski angle α.

α = ... ° [3]

(iii) State how the skier can increase his speed.

....

.... [1]

(d) Carving occurs when skiers tilt their skis to execute controlled turns as shown in Fig. 8.5.

Fig. 8.5

The angle between the skis and the snow surface known as the edge angle β is shown in Fig. 8.6.

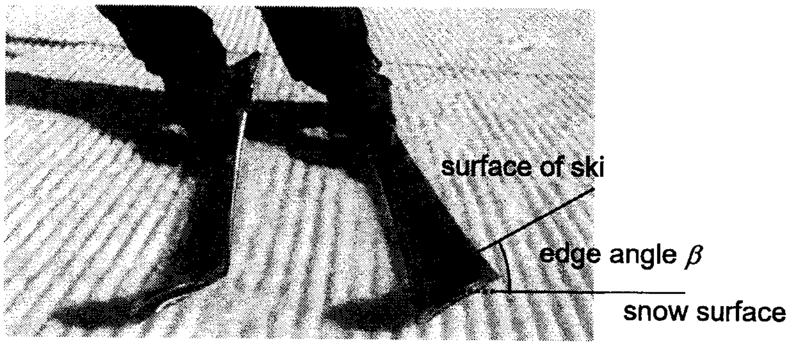


Fig. 8.6

Unlike sliding, carving involves following a circular arc in the plane of the slope. The edge angle β determines the turn radius r.

Fig. 8.7 shows the variation with β of r for different types of snow when the skier moves at a speed of 5.0 m s^{-1} and a ski angle $\alpha = 0°$.

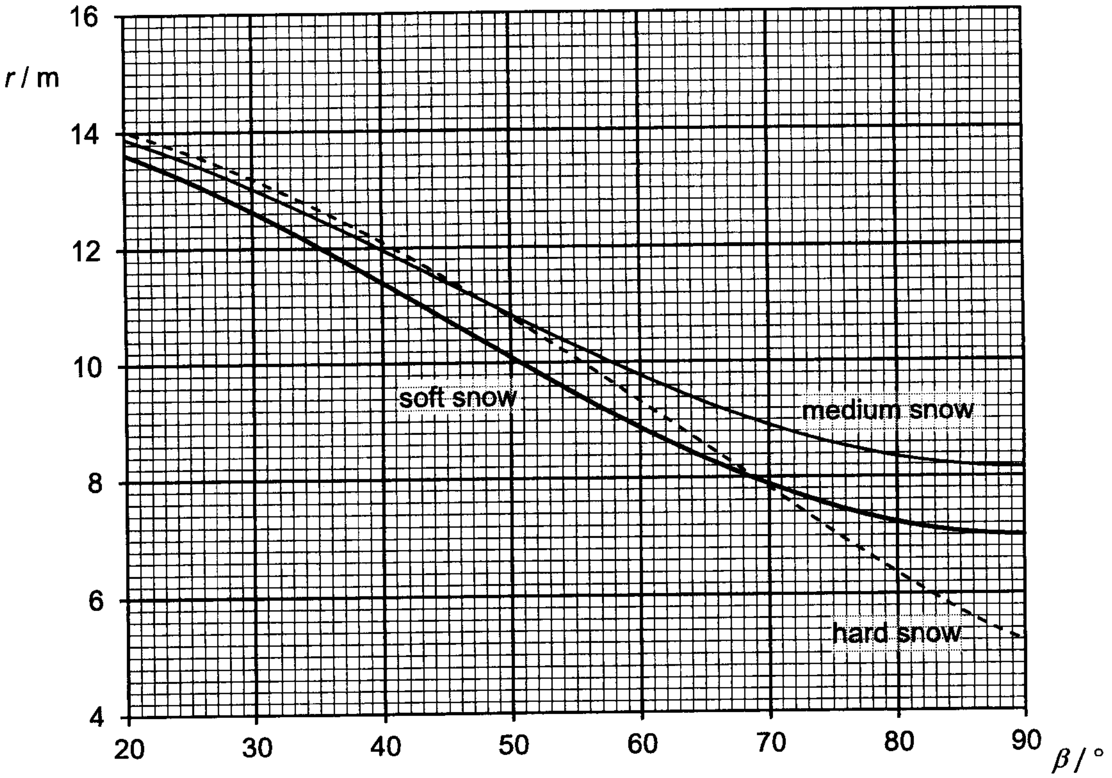


Fig. 8.7

(i) Determine the centripetal force acting on the skier for edge angle of 61° on hard snow.

centripetal force = ... N [3]

(ii) With reference to the forces acting on the skier and the stability of the skier, explain why a larger edge angle is required to generate a higher centripetal force.

....

....

....

....

....

.... [3]

[Total: 20]

RAFFLES INSTITUTION
PRELIMINARY EXAMINATION 2025
Higher 2

CANDIDATE NAME		CLASS INDEX NUMBER	

CLASS: 2 5 S 0 _ _

PHYSICS

9749/03

Paper 3 Longer Structured Questions

24 September 2025

Section A

2 hours

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Use a black or dark blue pen. You may use an 2B pencil for any diagrams or graphs.
- Write your name, index number and class in the spaces at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen. Do **not** use correction fluid or tape.
- You may use an approved calculator.

Section A
Answer **all** questions.

Section B
Answer **one** question only.

You are advised to spend one and a half hours on Section A and half an hour on Section B.

The number of marks for each question or part question is shown in brackets [ ].

For Examiner's Use	
1	/ 7
2	/ 7
3	/ 10
4	/ 10
5	/ 8
6	/ 10
7	/ 8
8	/ 20
9	/ 20
Deduction	
Total	/ 80

This document has **18** 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}

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	=	ρgh
gravitational potential	ϕ	=	$-Gm/r$
temperature	T/K	=	$T/°\text{C} + 273.15$
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
mean translational kinetic energy of an ideal gas molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_0 \sin\omega t$
velocity of particle in s.h.m.	v	=	$v_0 \cos\omega t = \pm\omega\sqrt{x_0^2 - x^2}$
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	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	x	=	$x_0 \sin\omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\ln 2 / t_{1/2}$

Section A

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

1 A ball is released from rest at the 80th floor of a very tall building. The height of each floor of the building is 3.0 m and the point of release is 240 m from the ground level as shown in Fig. 1.1.

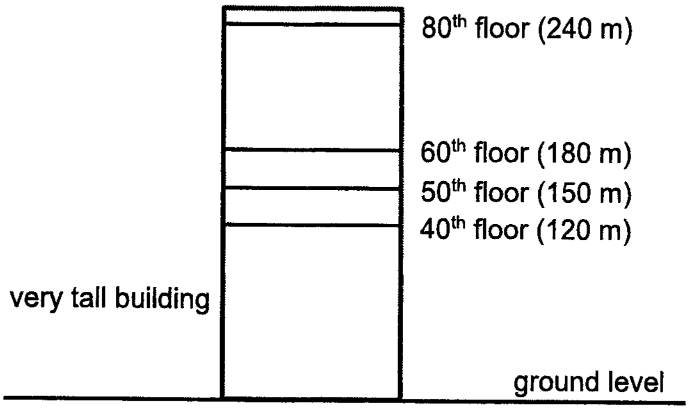


Fig. 1.1

(a) You can assume that air resistance is negligible.

(i) Determine the time taken for the ball to fall from the 60th floor to the 50th floor.

time = ... s [2]

(ii) Explain why the time taken to fall from the 50th floor to the 40th floor is shorter than your answer in **(i)**.

....

.... [1]

(iii) Determine the speed of the ball when it reaches the ground.

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

(b) In practice, air resistance is not negligible. The ball is released from rest at the 80th floor at time t = 0. It reaches terminal velocity at $t = t_A$ and hits the ground at $t = t_B$.

On the axes of Fig. 1.2, sketch a graph to show the variation with time t of displacement s from the 80th floor of the ball. Numerical values are not required.

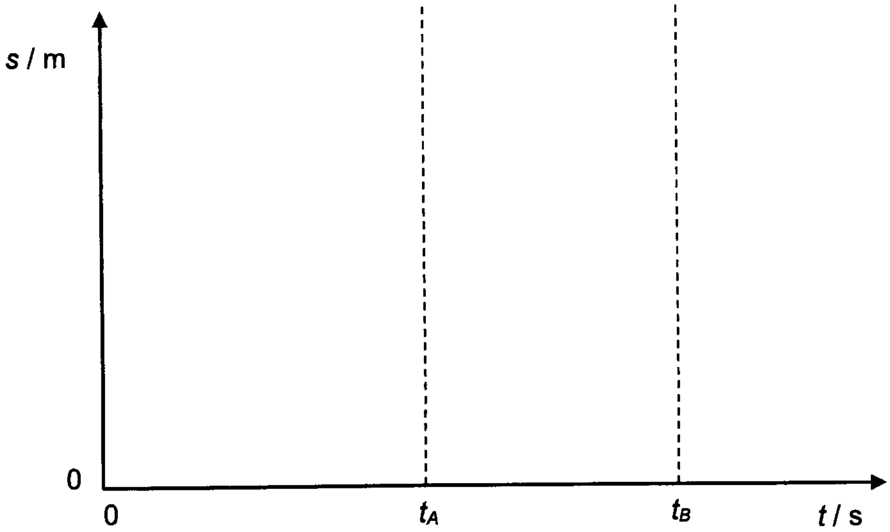


Fig. 1.2

[2]

[Total: 7]

2 Fig. 2.1 shows two skaters A and B moving along the same straight line towards each other in an amusement park with speeds of 11 m s^{-1} and 5.0 m s^{-1} respectively just before they collide. The masses of skaters A and B are 60 kg and 90 kg, respectively.

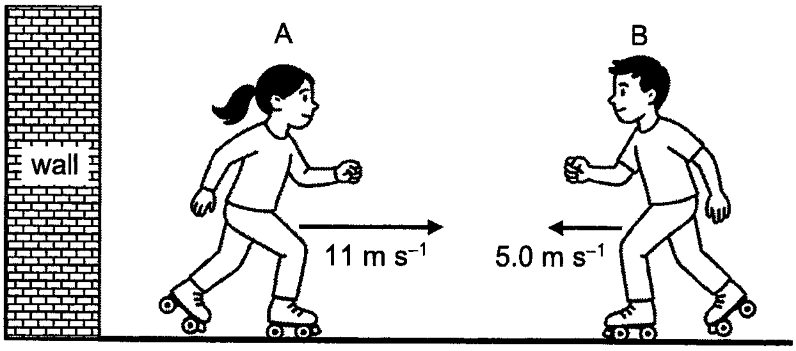


Fig. 2.1

(a) State the *principle of conservation of momentum.*

....

.... [1]

(b) Assuming that the collision is elastic, show that skater A moves towards the left with a speed of 8.2 m s^{-1} after the collision.

[2]

(c) After the collision, skater A hits the wall and bounces off the wall with a speed of 1.0 m s^{-1}.

(i) The variation with time *t* of the force *F* that the wall exerts on skater A is shown in Fig. 2.2.

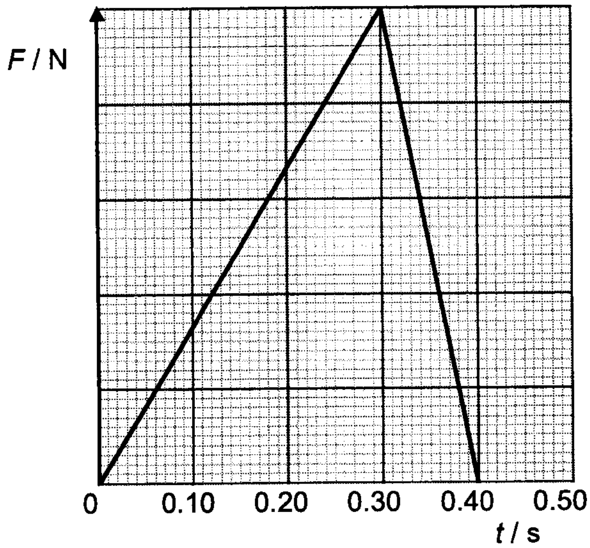


Fig. 2.2

Determine the maximum force exerted by the wall on skater A.

maximum force = ... N [2]

(ii) Explain how the walls in the amusement park can be made safer so that the maximum force exerted on the skater is reduced.

....

....

....

.... [2]

[Total: 7]

3 A bow works by storing potential energy in its bent limbs when the bowstring is pulled back, and then converting that potential energy into kinetic energy when the string is released, propelling the arrow forward. Two types of bows, the recurve bow and compound bow are shown in Fig. 3.1.

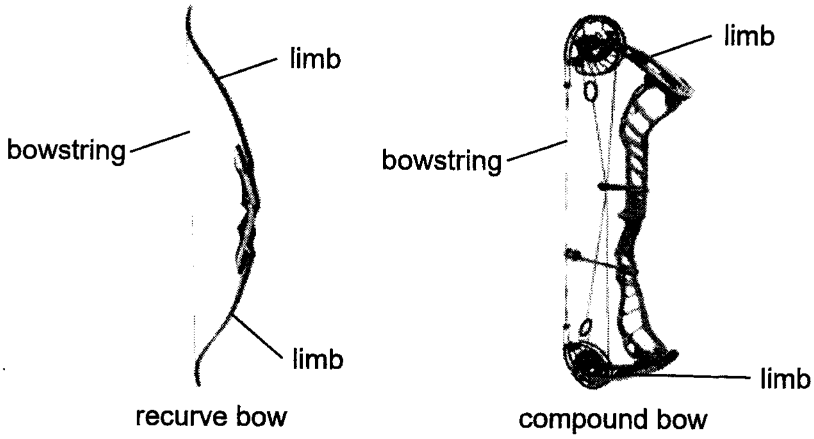


Fig. 3.1

The draw d refers to the distance a bowstring is pulled back. Fig. 3.2 shows the variation with d of the force F required to pull the bowstring of a recurve bow and a compound bow. The maximum draw of both bows is 0.60 m.

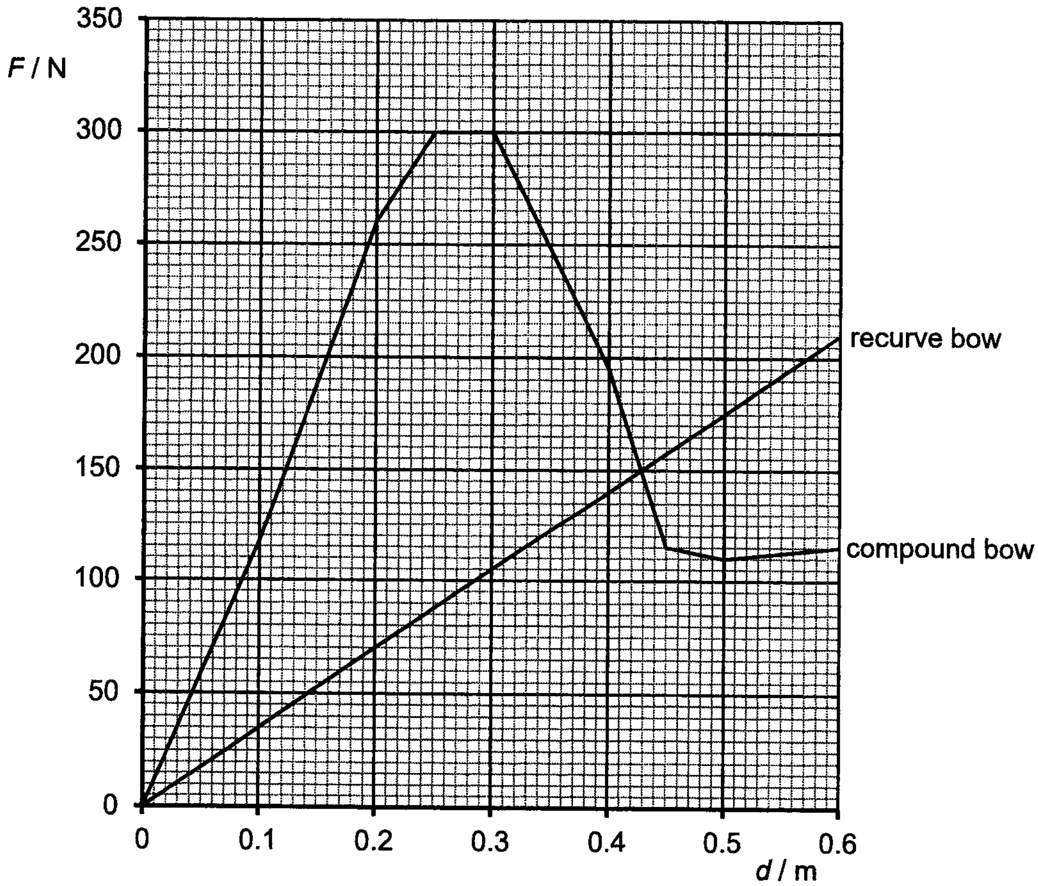


Fig. 3.2

(a) An arrow of mass 32 g is shot from the recurve bow when bow is at maximum draw of $d = 0.60$ m.

(i) Use Fig. 3.2 to determine the speed of the arrow as it leaves the recurve bow.

State any assumption made.

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

(ii) Use Fig. 3.2 to explain an advantage of the compound bow over the recurve bow at maximum draw.

....

.... [1]

(b) Explain why the bowstring of any fully drawn bow should not be released without an arrow.

....

.... [1]

(c) An archer is at a distance of less than 50 m away from a tree as shown in Fig. 3.3.

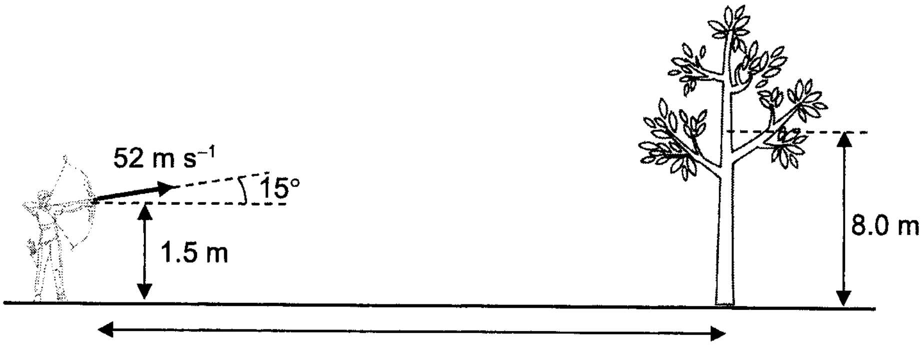


Fig. 3.3

The archer fires an arrow with a speed of 52 m s^{-1} at an angle of 15° above the horizontal from a height of 1.5 m above the ground. The arrow hits the tree at a height of 8.0 m above the ground. The mass of the arrow is 32 g.

The length of the arrow and air resistance are negligible.

(i) Determine the kinetic energy of the arrow just before it hits the tree.

kinetic energy = ... J [2]

(ii) Calculate the distance of the tree from the archer.

distance = ... m [3]

[Total: 10]

4 A distant star S of mass M and its planet P of mass $0.12M$ orbit in circular orbits about a fixed point O with angular velocity ω as shown in Fig. 4.1.

Fig. 4.1

(a) **(i)** On Fig 4.1, draw circles that represent the orbits of star S and planet P. [1]

(ii) Explain why the centripetal forces acting on star S and planet P are equal in magnitude.

....

....

....

.... [2]

(iii) Show that the ratio of the radius r_S, of the orbit of star S to the radius r_P of the orbit of planet P is

$$\frac{r_S}{r_P} = 0.12.$$

[1]

(b) The period of star S is 1500 days and its speed is 70 m s^{-1}. Determine

(i) the angular velocity ω of star S,

ω = ... rad s^{-1} [1]

(ii) the radius r_S of the orbit of star S,

r_S = ... m [1]

(iii) the separation between the centers of star S and planet P,

separation = ... m [1]

(iv) the mass M.

M = ... kg [2]

(c) The plane of orbits of star S and planet P is parallel to the line of sight from Earth.

On the axes of Fig. 4.2, sketch the variation with time *t* of the apparent speed *v* of star S as viewed from the Earth.

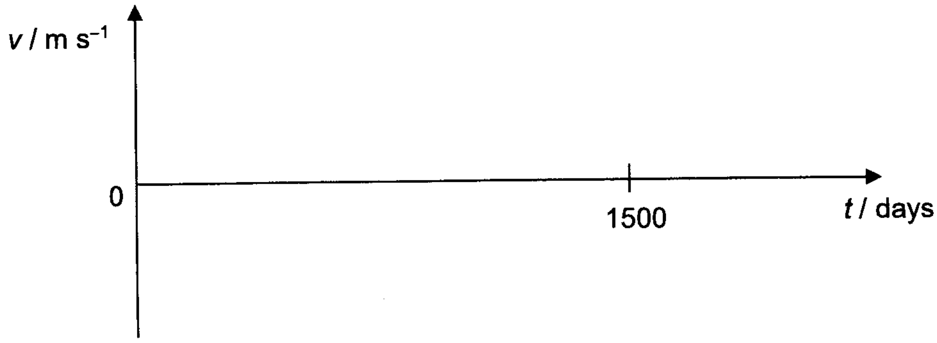


Fig. 4.2 [1]

[Total: 10]

5 (a) State the first law of thermodynamics.

....

....

.... [1]

(b) Fig. 5.1 shows a fixed mass of an ideal gas in a cylinder with a freely moving piston. The gas has an initial pressure of 400 kPa and an initial volume of 0.50×10^{-3} m^3.

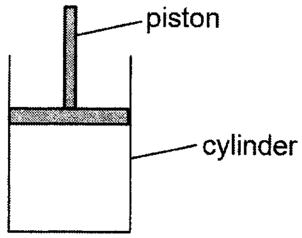


Fig. 5.1

When heat is supplied to the gas, it expands at a constant temperature to a final volume of 2.00×10^{-3} m^3.

(i) On Fig. 5.2, draw the variation with volume V of the pressure P of the gas from the initial volume to the final volume. [2]

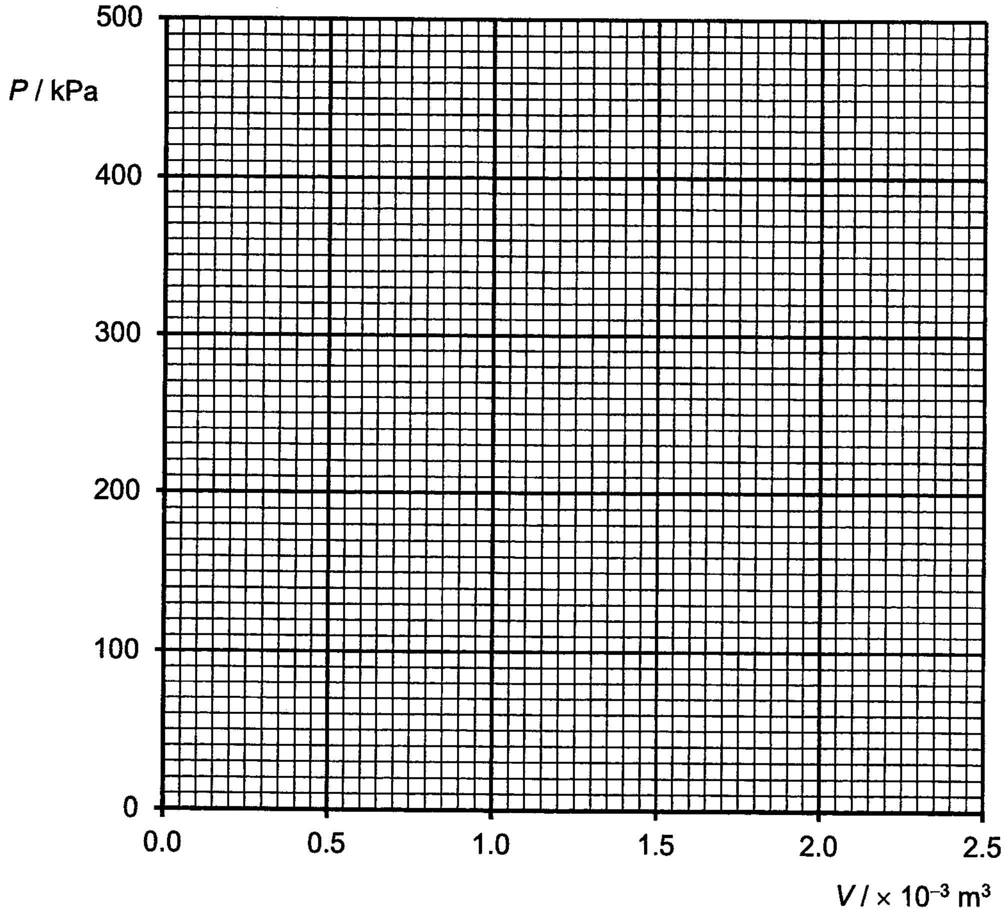


Fig. 5.2

(ii) Explain why the amount of heat supplied to the gas is numerically equal to the area under the graph you have drawn in **(i)**.

....

....

....

.... [2]

(c) Two experiments are carried out using two identical sets of cylinders with freely moving pistons as shown in Fig. 5.3.

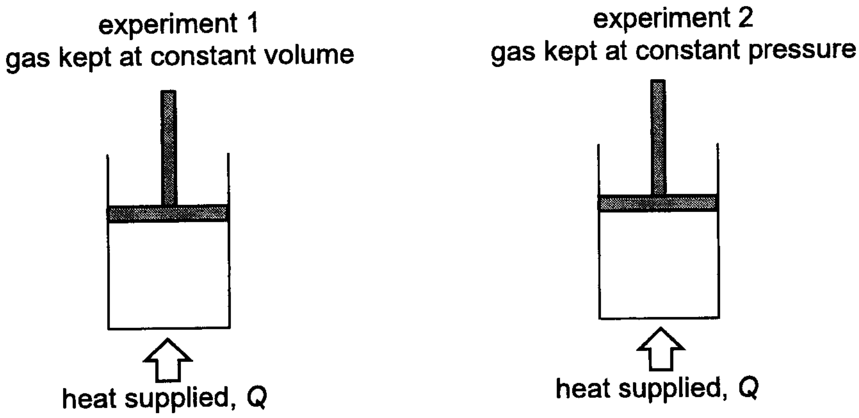


Fig. 5.3

Both cylinders contain ideal gas with the same initial temperature, pressure and volume.

In experiment 1, an amount of heat Q is supplied to the gas kept at constant volume.
In experiment 2, the same amount of heat Q is supplied to the gas kept at constant pressure.

State and explain which gas will have a higher final temperature.

....

....

....

....

....

.... [3]

[Total: 8]

6 An ion thruster is a device used in spacecraft propulsion in space. It uses an accelerated beam of ions to create thrust for the spacecraft.

Fig. 6.1 shows a common design for an ion thruster. Xenon ions, with a positive charge of +e, initially inside a discharge chamber, are accelerated through a uniform electric field within a grid system.

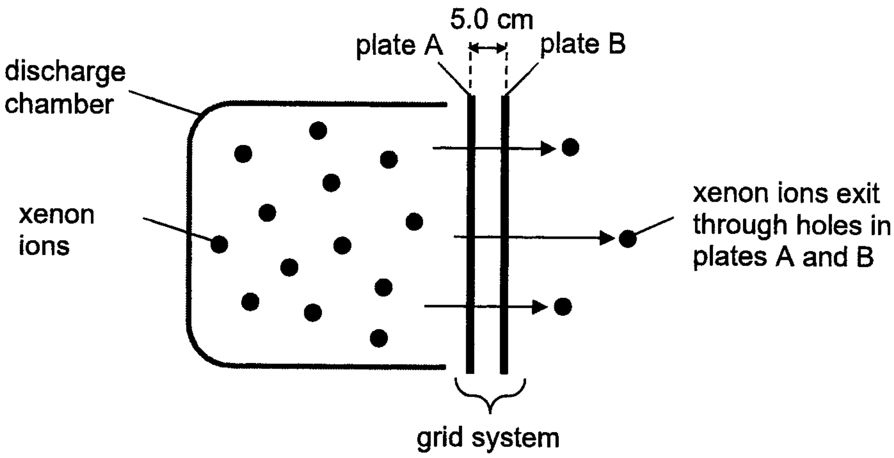


Fig. 6.1

The grid system consists of two parallel plates, A and B, with many tiny holes in them to allow the xenon ions to pass through. They are 5.0 cm apart with a potential difference of 1300 V between them.

(a) Define *electric potential* at a point.

....

....

.... [1]

(b) **(i)** Plate A has a potential of 100 V.

On the axes of Fig. 6.2, sketch the variation with distance *x* from plate A to B of the electric potential *V*. Label the axes with appropriate values.

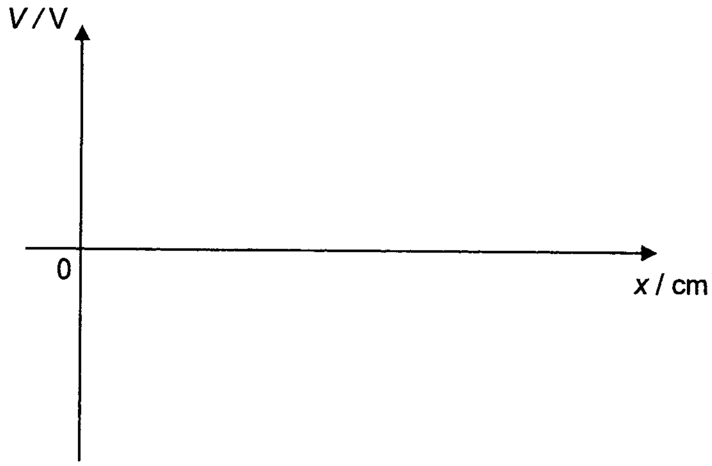


Fig. 6.2 [2]

(ii) Determine the electric field strength between plates A and B.

electric field strength = ... $N\ C^{-1}$ [2]

(iii) Hence, or otherwise, assuming a xenon ion of mass 131 *u* was released from rest near plate A, determine the speed of the xenon ion when it exits the grid system. Explain your working clearly.

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

(c) As the xenon ions exit the grid system as a beam, a device near the ion thruster injects electrons into the ion beam in order to neutralise the ions.

Suggest why the ion beam needs to be neutralised as it exits the grid system.

....

....

....

.... [2]

[Total:10]

7 A step-down transformer is used to change a supply voltage to 5.0 V r.m.s. for use in a home appliance, as shown in Fig. 7.1. The primary and secondary coils are wound around the same iron core. Assume that the transformer is ideal.

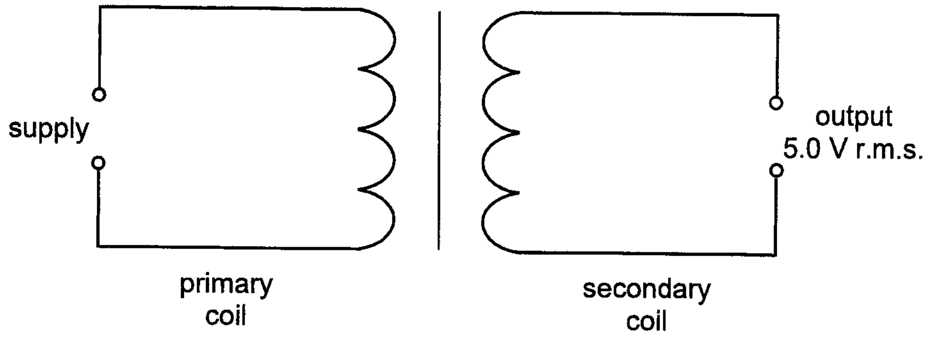


Fig. 7.1

(a) Explain why the current in the primary coil must be an alternating current.

....

.... [1]

(b) The transformer has a turns ratio of 0.022.

Determine the r.m.s. value of the supply voltage.

supply voltage = ... V r.m.s. [2]

(c) The output in Fig. 7.1 has a frequency of 50 Hz and is connected to an ideal diode and a resistor R as shown in Fig. 7.2.

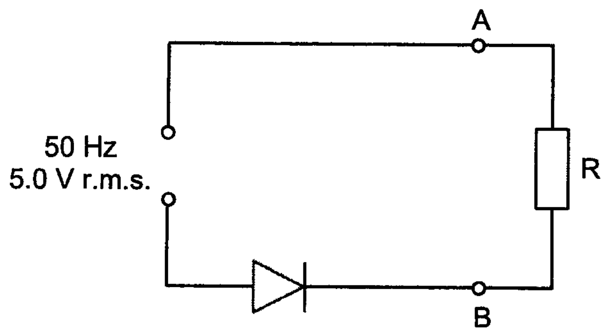


Fig. 7.2

(i) Calculate the maximum potential difference across the diode during one cycle.

potential difference = ... V [1]

(ii) State and explain the potential difference across R when the diode has maximum potential difference across it.

....

....

....

.... [2]

(iii) The Y-plates of a cathode-ray oscilloscope (c.r.o.) are connected to points A and B.

Fig. 7.3 shows the screen of the c.r.o., which is used to display the variation with time of the potential difference across R. On the vertical scale, 1.0 cm represents 2.0 V. On the horizontal scale, 1.0 cm represents 5.0 ms.

On Fig. 7.3, draw the waveform that is seen on the screen of the c.r.o. [2]

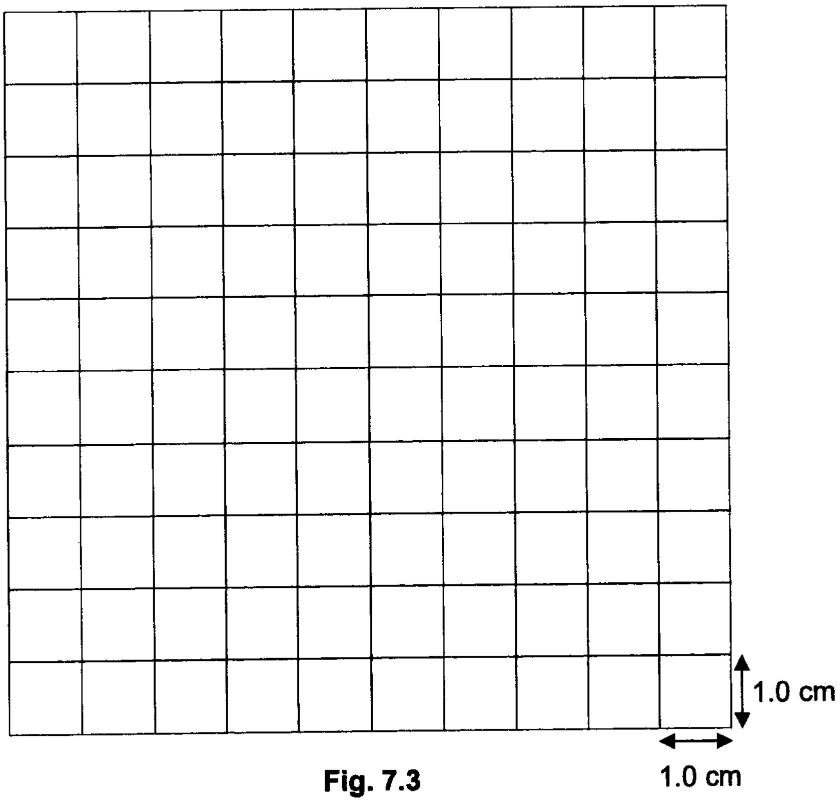


Fig. 7.3

[Total: 8]

RAFFLES INSTITUTION
PRELIMINARY EXAMINATION 2025
Higher 2

CANDIDATE NAME		CLASS INDEX NUMBER	

CLASS	2	5	S	0		

PHYSICS

9749/03

Paper 3 Longer Structured Questions

24 September 2025

Section B

2 hours

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Use a black or dark blue pen. You may use an 2B pencil for any diagrams or graphs.
- Write your name, index number and class in the spaces at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen. Do **not** use correction fluid or tape.
- You may use an approved calculator.

Section B
Answer **one** question only.

You are advised to spend one and a half hours on Section A and half an hour on Section B.

The number of marks for each question or part question is shown in brackets [ ].

For Examiner's Use	
8	/ 20
9	/ 20
Deduction	

Section B

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

8 **(a)** Define *magnetic flux density*.

....

....

....

.... [2]

(b) A metal rod PQ of mass m and resistance 5.0 Ω is placed on top of two smooth parallel metal rails of negligible resistance. The rails are 1.5 m apart. A source of e.m.f. 6.0 V and negligible internal resistance is connected across the rails as shown in Fig. 8.1.

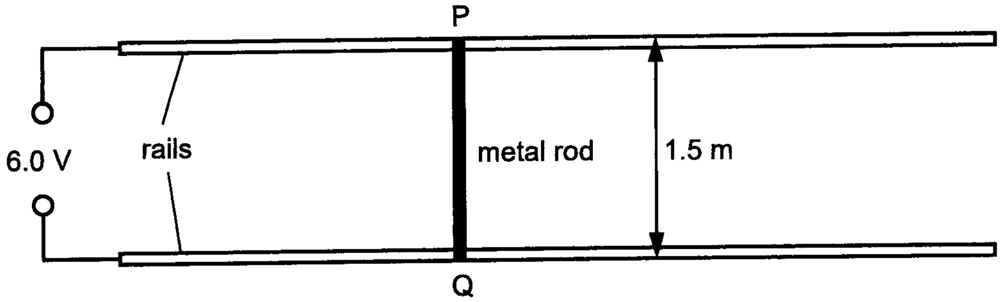


Fig. 8.1 (top view)

The rails are inclined at an angle of 30° to the horizontal and located in a region with a uniform magnetic field of flux density 0.021 T directed vertically downwards as shown in Fig. 8.2.

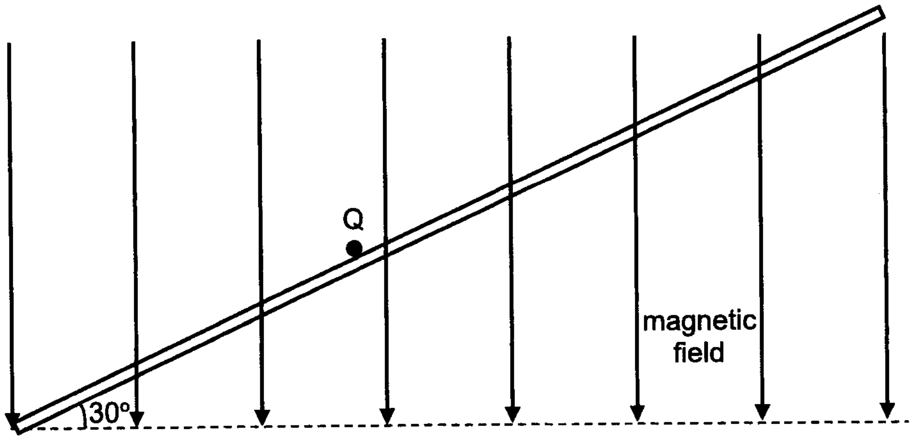


Fig. 8.2 (front view)

Rod PQ remains stationary on the rails.

(i) On Fig. 8.2, draw and label arrows to show all the forces acting on rod PQ. [2]

(ii) Calculate the current through rod PQ.

current = ... A [1]

(iii) Determine the mass m of rod PQ.

m = ... kg [3]

(iv) Rod PQ is replaced by another rod XY of the same length and material but with double the cross-sectional area. Rod XY is now placed on the rails.

State and explain what happens to the rod XY.

....

....

....

....

....

.... [3]

(c) The source of e.m.f. is replaced with resistor R and switch S as shown in Fig. 8.3.

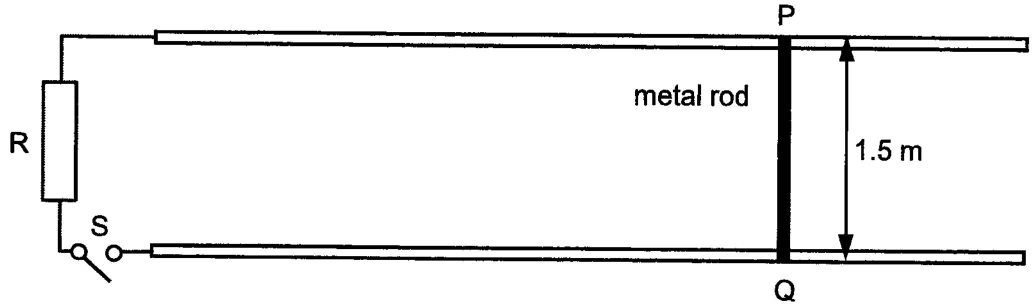


Fig. 8.3

Switch S is open. Rod PQ is released from rest and moves down the rails.

(i) Explain why an e.m.f. is induced across rod PQ.

....

.... [1]

(ii) Determine the e.m.f. induced across rod PQ when it is at a distance of 2.0 cm down the slope from the point of release.

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

(iii) Switch S is now closed and rod PQ is released from rest at the same initial position.

1. Using Lenz's law, state and explain the direction of the induced current in rod PQ.

....

....

....

.... [2]

2. Without further calculation, state and explain the change, if any, this would make to your answer in **(c)(ii)**.

....

....

....

....

....

.... [3]

[Total: 20]

9 (a) State the name of a phenomenon that gives evidence that light behaves like

(i) a wave

....

.... [1]

(ii) a stream of particles (photons)

....

.... [1]

(b) A hydrogen lamp is found to produce red light and blue light. The wavelengths of the lights are 6.56×10^{-7} m and 4.86×10^{-7} m.

(i) Explain why the lamp produces lights of specific wavelengths.

....

....

....

....

....

.... [3]

(ii) The blue light from the hydrogen lamp is incident normally on a metal surface with work function energy of 2.00 eV.

Show, by appropriate calculations, that photoelectric emission will be observed.

[3]

(iii) The intensity of the blue light is 6.80×10^3 W m^{-2}. The area of the metal surface is 3.00 cm^2.

1. Show that the power of the blue light that is incident on the metal surface is 2.04 W.

[1]

2. Calculate the force exerted by the photons of the blue light on the metal surface, assuming that all the photons are absorbed.

force = ... N [4]

(c) The red and blue lights of **(b)** are part of the Balmer series of light emitted by the hydrogen atom. The wavelengths λ_n of the Balmer series are given by:

$$\frac{1}{\lambda_n} = R\left(\frac{1}{4} - \frac{1}{n^2}\right)$$

where R is a constant and has the value of 1.097×10^7 m^{-1} and n is an integer greater than 2. That is, n = 3, 4, 5, ..., etc.

(i) Determine:

1. the value of n that gives the red light

n for red light = ... [1]

2. the value of n that gives the blue light.

n for blue light = ... [1]

(ii) Calculate the shortest wavelength in the Balmer series.

wavelength = ... m [2]

(iii) Use your answers in **(c)(i)** and **(c)(ii)**, sketch a partial energy level diagram for the Balmer series. Label the energy levels with their respective values of energy.

[3]

[Total: 20]