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

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	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
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	=	$\dfrac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\dfrac{\mu_0 NI}{2r}$
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.

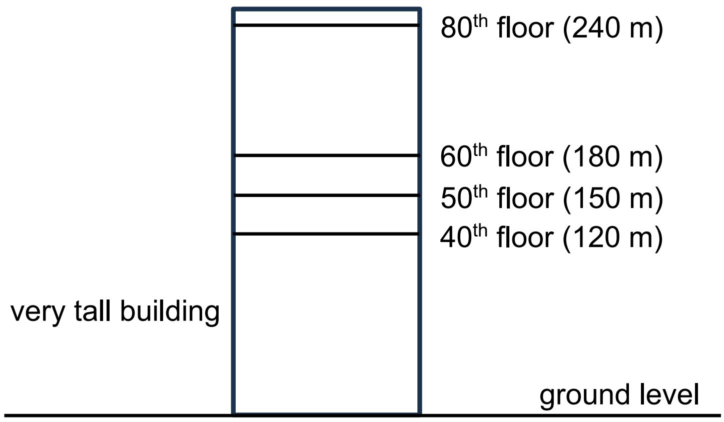

Fig. 1.1

(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.

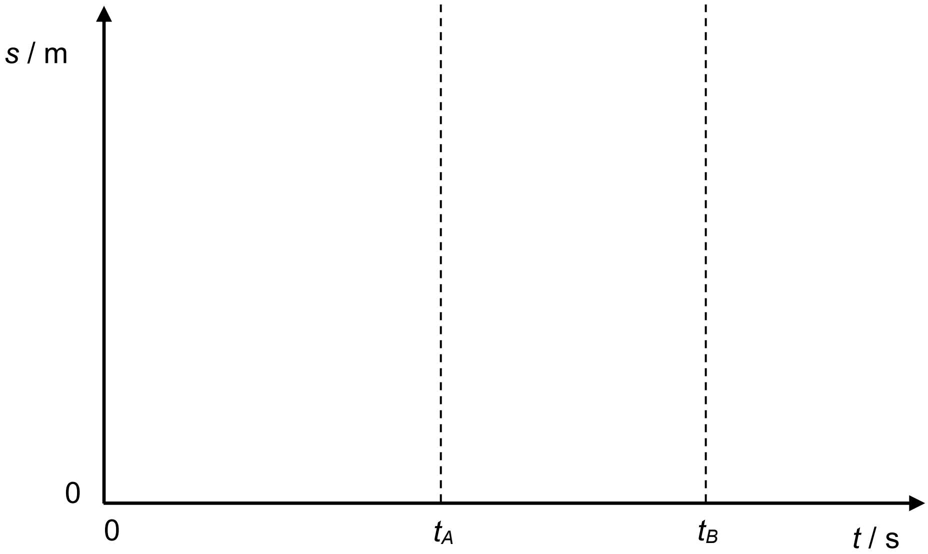

Fig. 1.2

[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.

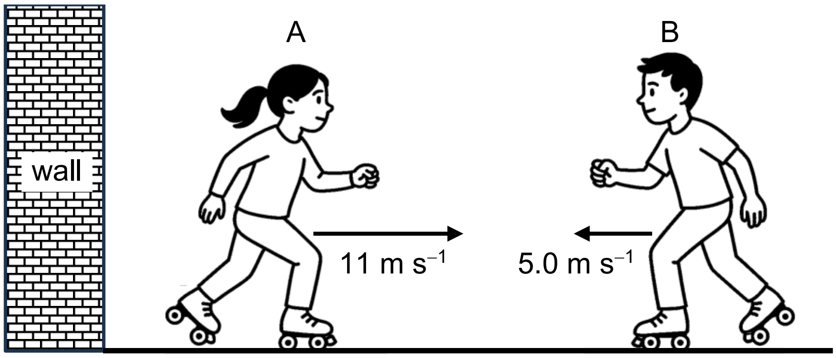

Fig. 2.1

(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.

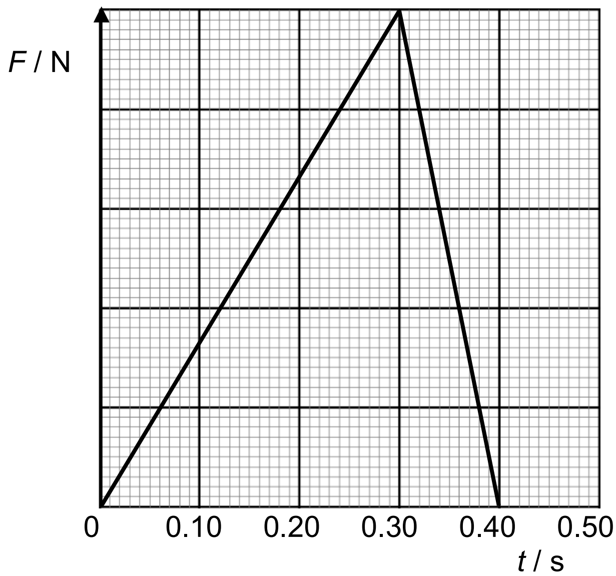

Fig. 2.2

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.

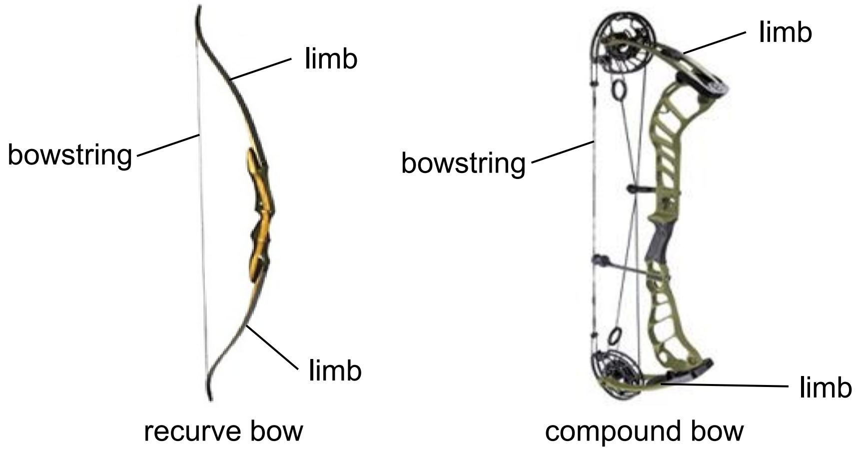

Fig. 3.1

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.

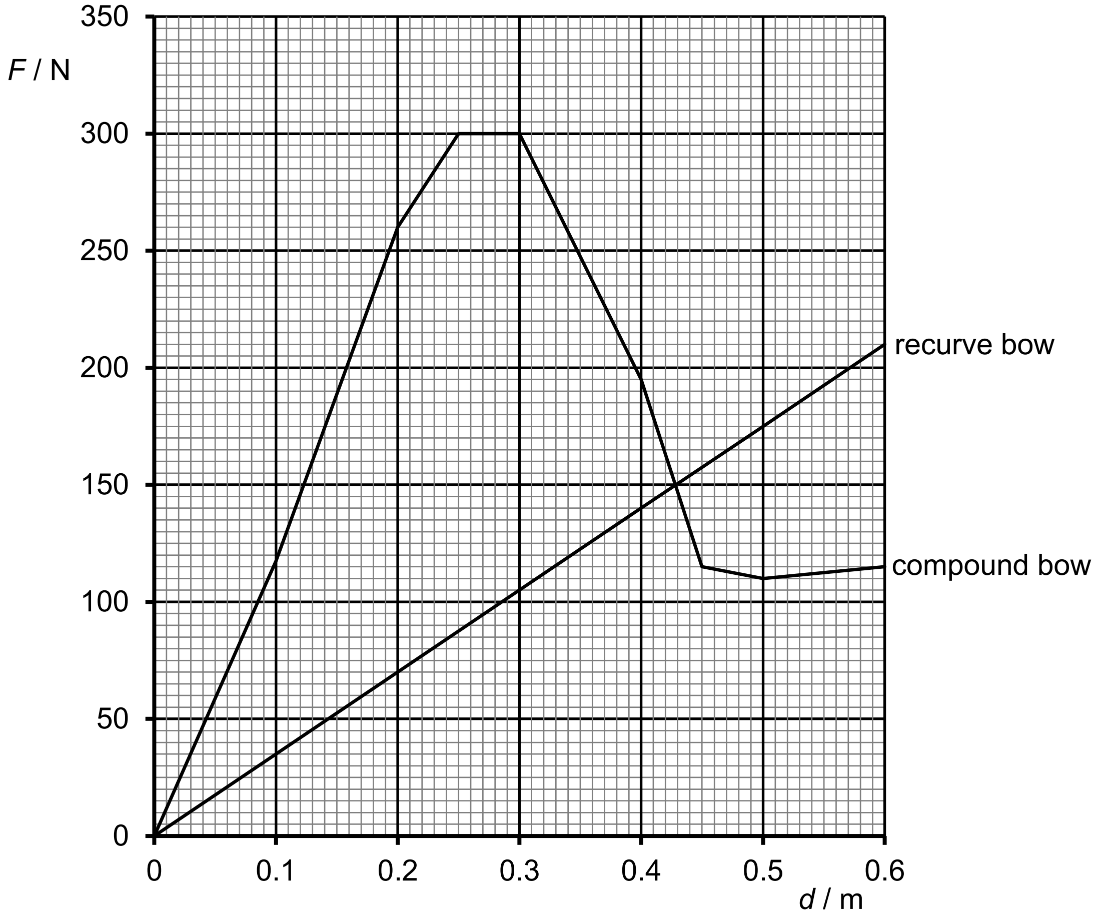

Fig. 3.2

(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.

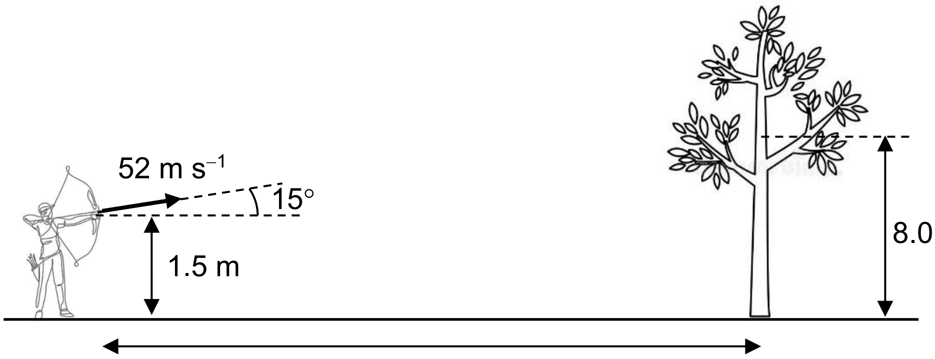

Fig. 3.3

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.

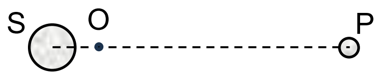

Fig. 4.1

(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.

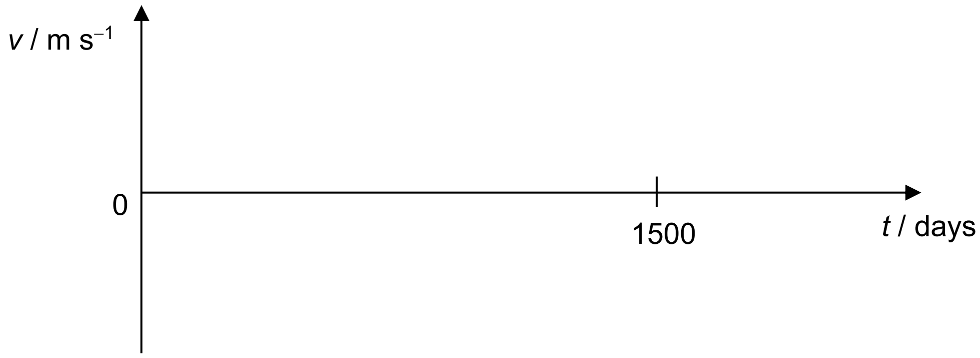

Fig. 4.2 [1]

[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.

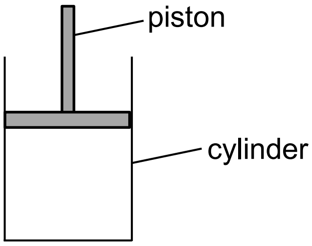

Fig. 5.1

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]

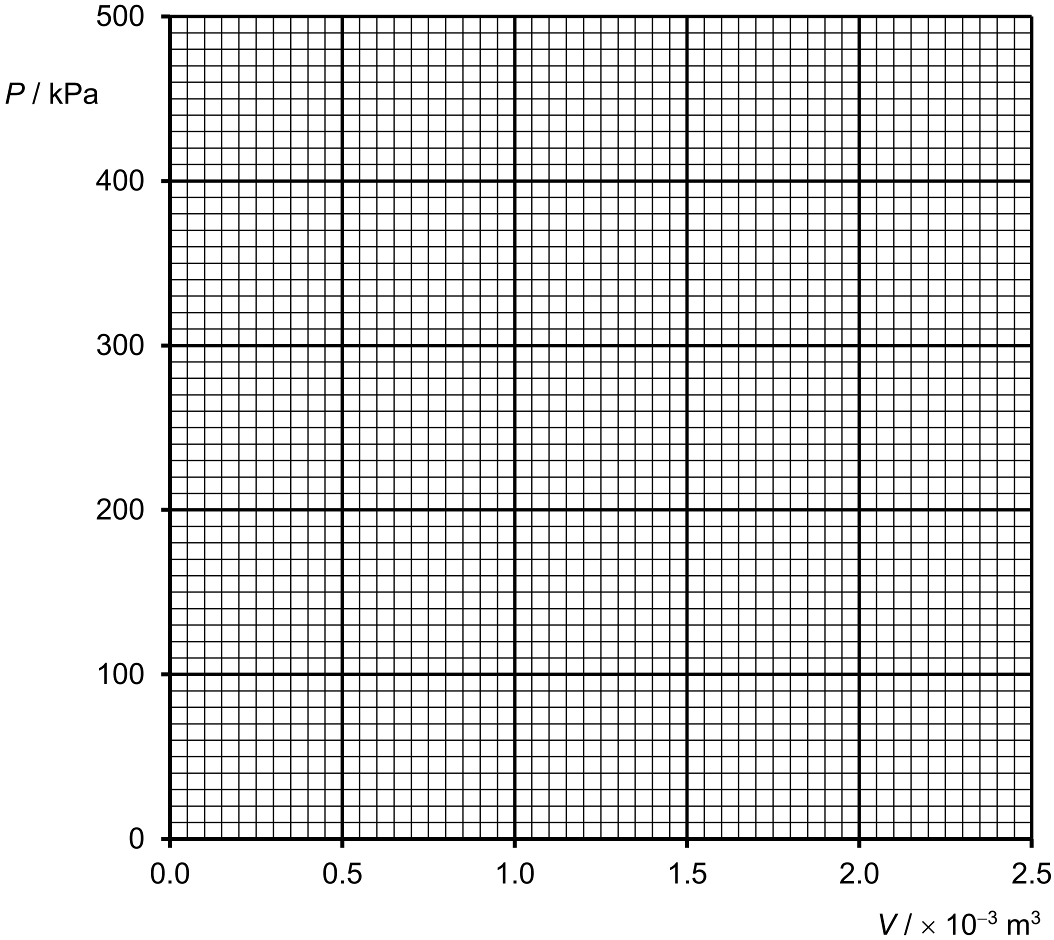

Fig. 5.2

(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.

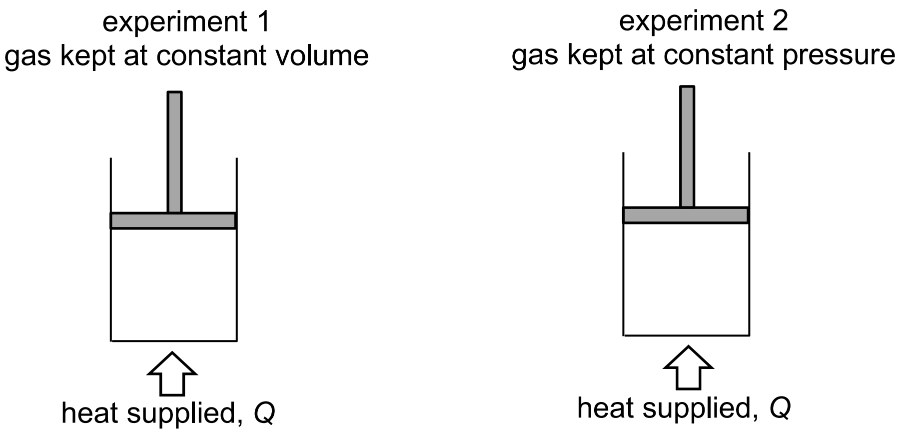

Fig. 5.3

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.

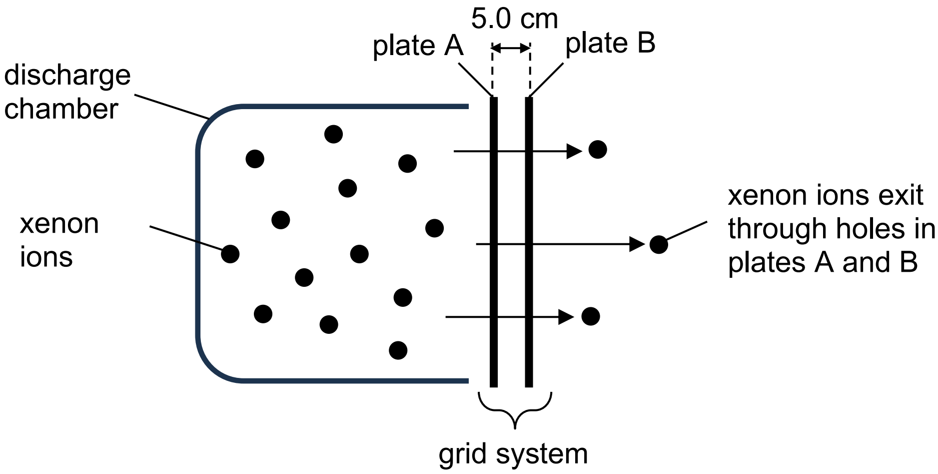

Fig. 6.1

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.

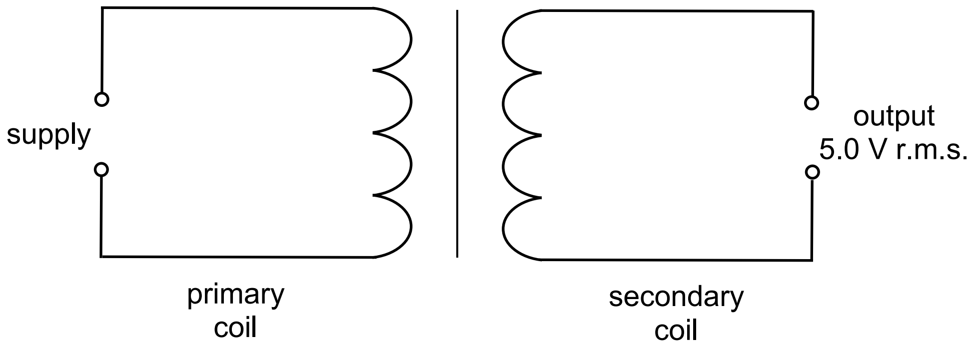

Fig. 7.1

(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.

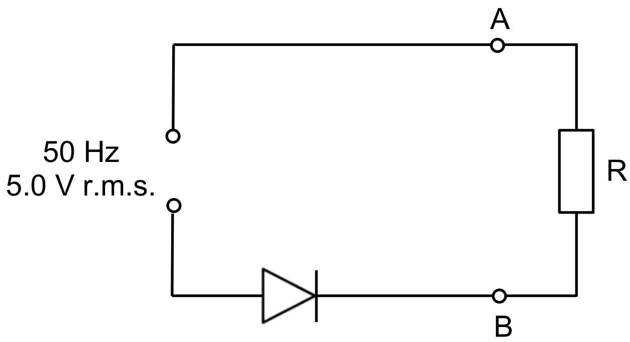

Fig. 7.2

(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]

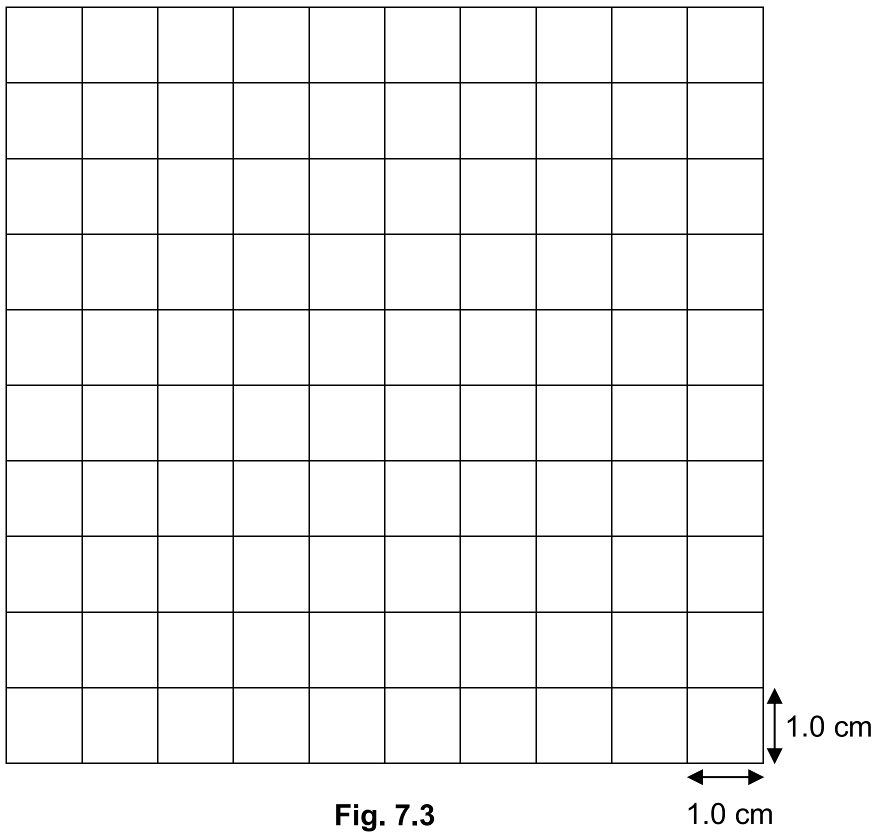

Fig. 7.3

[Total: 8]