Centre Number	Index Number	Name	Class
S3016			

RAFFLES INSTITUTION
2024 Preliminary Examination

PHYSICS **9749/03**
Higher 2

18 September 2024
Paper 3 Longer Structured Questions **2 hours**

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

READ THESE INSTRUCTIONS FIRST

Write your index number, name and class in the spaces at the top of this page.
Write in dark blue or black pen in the spaces provided in this booklet.
You may use pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** questions.

Section B
Answer **one** question only and **circle the question number** on the cover pages.

You are advised to spend one and a half hours on Section A and half an hour on Section B.
The number of marks is given in brackets [ ] at the end of each question or part question.

***This booklet only contains Section A.**

For Examiner's Use		
Section A	**1**	/ 10
	2	/ 11
	3	/ 12
	4	/ 10
	5	/ 6
	6	/ 5
	7	/ 6
Section B (circle 1 question)	**8**	/ 20
	9	/ 20
Deduction		
Total		/ 80

This document consists of **20** printed 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	=	$T/°C + 273.15$
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	=	$\frac{\mu_0 N I}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 n I$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\ln 2 / t_{1/2}$

Section A

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

1 **(a)** State what is meant by the *internal energy* of an *ideal gas*.

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.... [2]

(b) A fixed mass of an ideal monatomic gas has a volume of 2.0×10^{-2} m^3 at a pressure 1.0×10^5 Pa.

(i) To determine the specific heat capacity of the gas at constant volume, the gas is heated so that its pressure increases to 1.5×10^5 Pa without any change in volume.

1. Show that the heat supplied to the gas is 1500 J.

[1]

2. Determine the increase in temperature of the gas if the average translational kinetic energy of a gas molecule is 6.2×10^{-21} J just before the gas is heated.

increase in temperature = ... °C [3]

(ii) To determine the specific heat capacity of the gas at constant pressure, the gas is heated from its initial state without any change in pressure.

State the first law of thermodynamics and use it to explain why the specific heat capacity of the ideal gas determined at constant volume is different to the specific heat capacity when determined at constant pressure.

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.... [4]

[Total: 10]

2 A light spring of force constant k hangs vertically from a fixed point. A block of mass m is attached to the free end of the spring, as shown in Fig. 2.1.

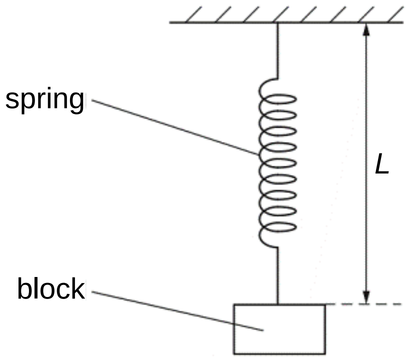

Fig. 2.1

The block is displaced downwards from its equilibrium position and then released at time $t = 0$ s.

(a) The acceleration a of the block is related to its displacement x from the equilibrium position by the equation

$$a = -\frac{k}{m}x.$$

Explain why the equation leads to the conclusion that the block is performing simple harmonic motion.

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.... [2]

(b) The variation with time t of the length L of the spring is shown in Fig. 2.2.

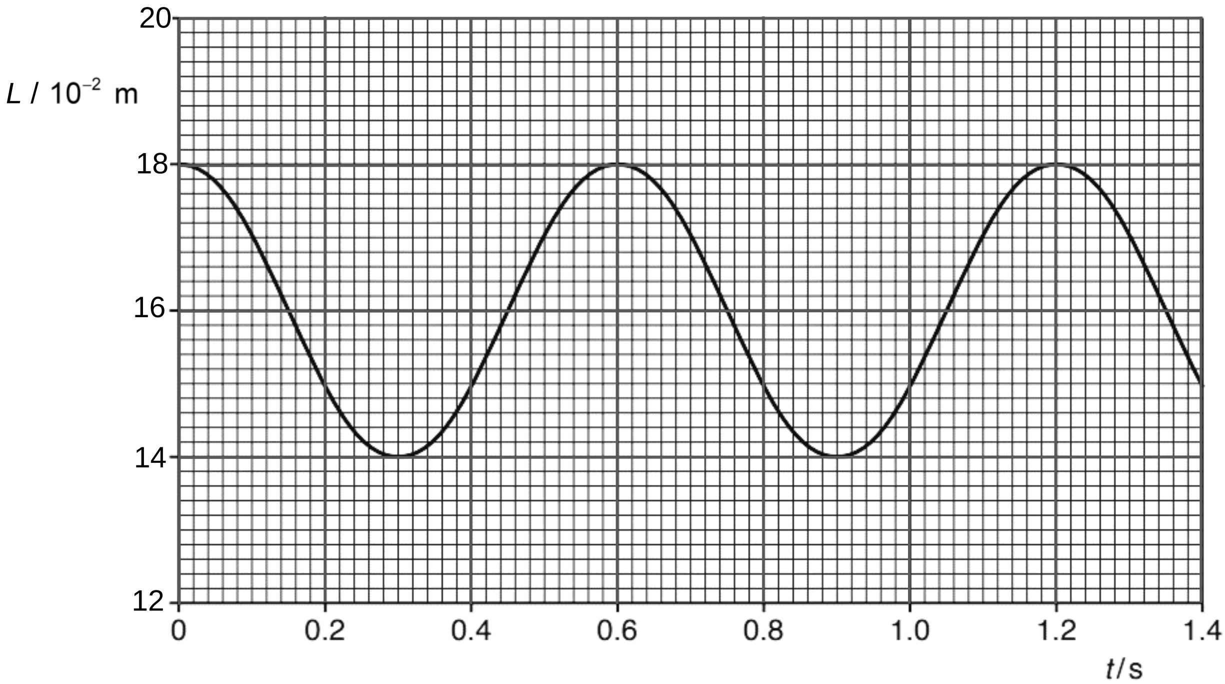

Fig. 2.2

(i) Determine the maximum speed of the block.

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

(ii) On Fig. 2.3, show the variation with time t of the velocity v of the block from $t = 0$ s to $t = 1.4$ s.

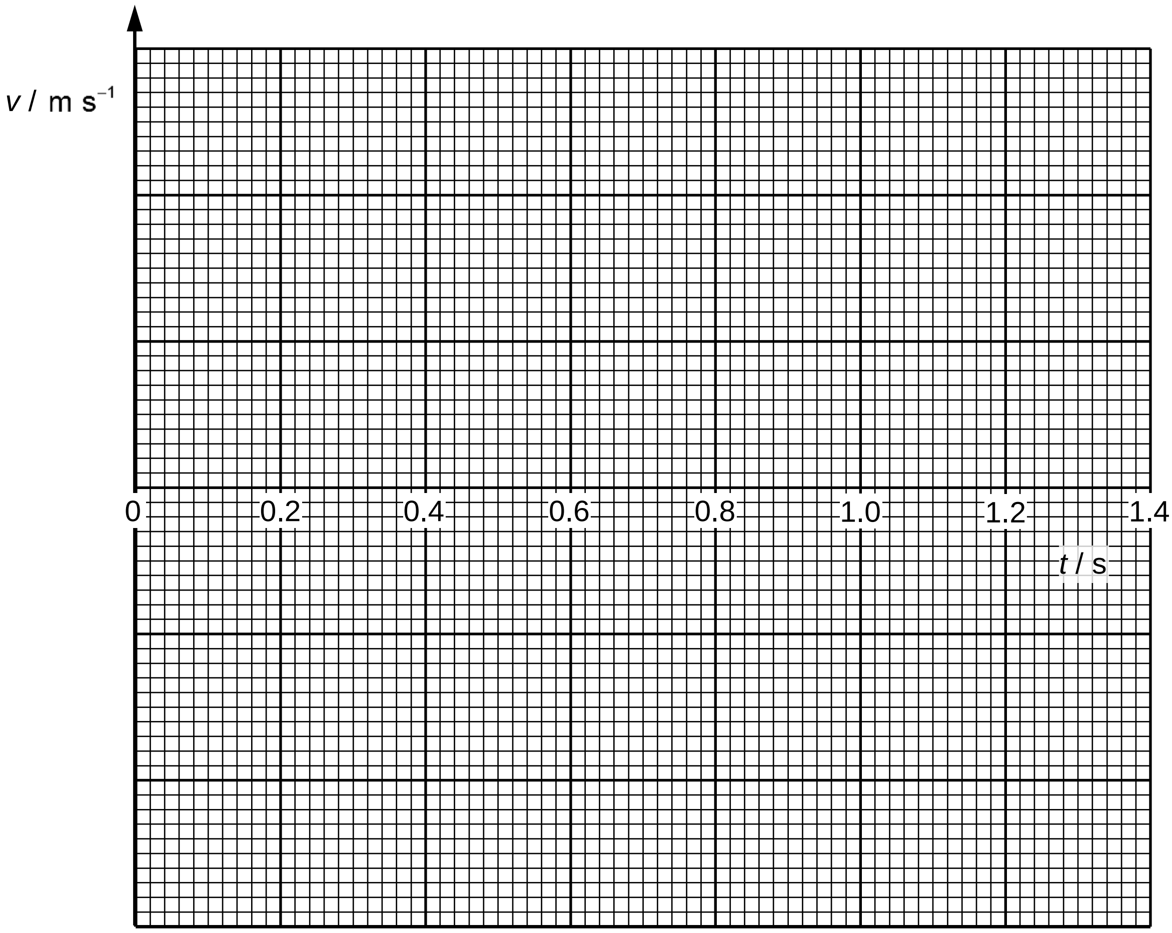

Fig. 2.3

[2]

(iii) Determine a value of L at which the potential energy and kinetic energy of the oscillating system are equal.

The total potential energy of the oscillating system at equilibrium is taken to be zero.

L = ... cm [2]

(c) The same block is suspended from two springs as shown in Fig. 2.4. Both springs are identical to that used in Fig. 2.1.

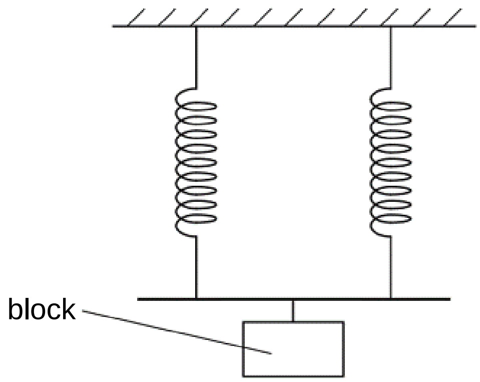

Fig. 2.4

The block is pulled down a small distance and released so that it oscillates.

By considering the extension at equilibrium of the spring combination in Fig. 2.4, state and explain how the period of these oscillations compares with the period of oscillations in **(a)**.

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.... [3]

[Total: 11]

3 Fig. 3.1 shows, at time t_0, the positions x of the air particles where a progressive sound wave passes through the air towards a reflector.

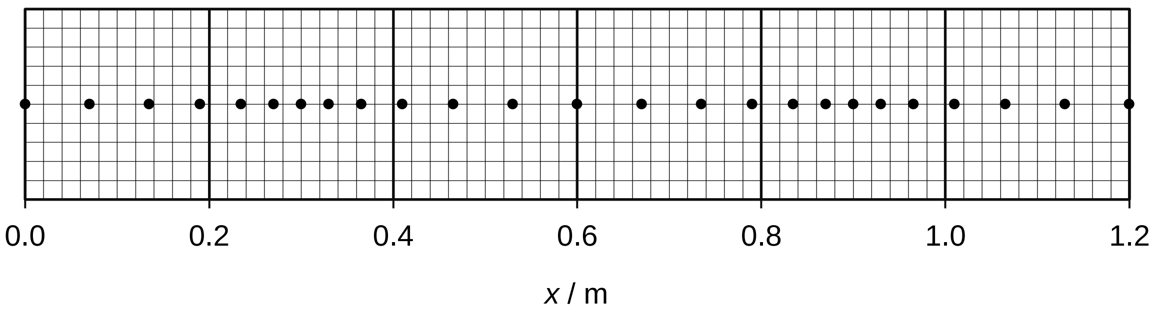

Fig. 3.1

Fig. 3.2 shows, at a later time t_1, the positions x of the same air particles when the reflected sound wave is superposed with the original sound wave to form a stationary wave.

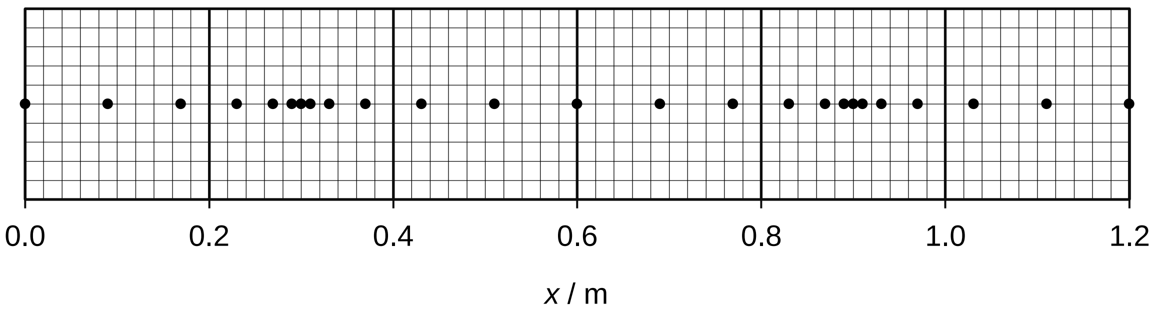

Fig. 3.2

(a) Distinguish between progressive and stationary waves in terms of the amplitudes and the phases of oscillations of the particles.

amplitudes: ....

....

....

....

phases: ....

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.... [2]

(b) Use Fig. 3.1 to deduce, with an explanation,

(i) the wavelength of the sound wave,

wavelength = ... m

....

....

.... [1]

(ii) the amplitude of the oscillations of the particles.

amplitude = ... m

....

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.... [2]

(c) **(i)** On Fig. 3.2, indicate all the positions of the displacement nodes (label as N) and displacement antinodes (label as A).

[1]

(ii) By considering the positions of the particles in Fig. 3.2, draw on Fig. 3.3, the variation with position x of the pressure p of the air when a stationary wave is set up

1. at time t_1 (label as Y), [1]

2. at time $t_1 + \frac{T}{8}$ (label as Z), where T is the period of the wave. [1]

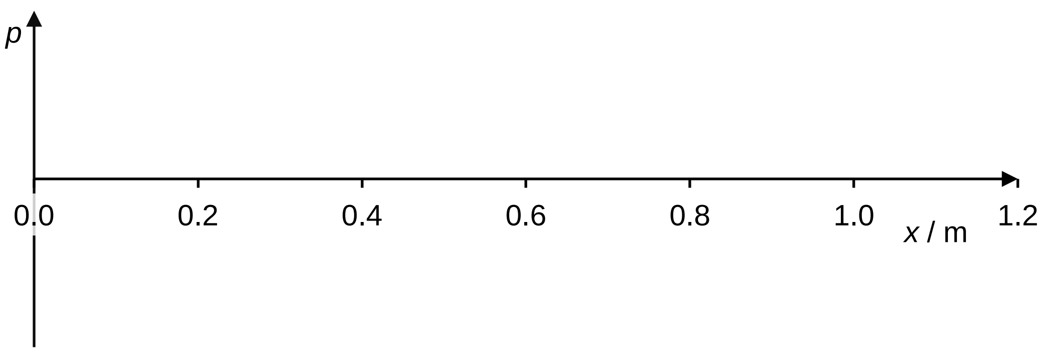

Fig. 3.3

(d) The sound wave represented in Fig. 3.1 is now continuously projected along a vertical tube that is initially fully immersed in water.

As the tube is raised vertically, it was found that the first loud note was heard when the air column has a length of 14.4 cm.

Determine

(i) the end correction of the tube,

end correction = ... m [2]

(ii) the length of the air column when the next loud note is heard.

length = ... m [2]

[Total: 12]

4 **(a)** Two charged particles, A and B, are isolated in space and separated by a distance *x*, as shown in Fig. 4.1.

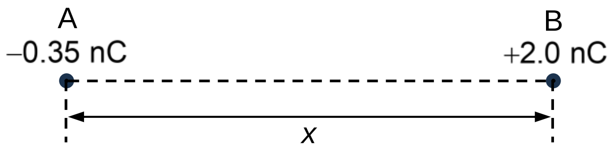

Fig. 4.1

Particle A has a charge of -0.35 nC and particle B has a charge of $+2.0$ nC.

(i) Explain whether the electric field strength is zero at any point along the straight line between the two charged particles.

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.... [1]

(ii) Explain whether the electric potential is zero at any point along the straight line between the two charged particles.

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.... [1]

(b) Two long parallel metal plates, X and Y, are separated by a distance 3.6 cm in a vacuum. Plate X is at potential *V* and plate Y is earthed. The potential difference between the plates gives rise to a uniform electric field in the region between the plates.

A particle of charge -3.2×10^{-19} C and mass 6.6×10^{-27} kg is projected into the uniform electric field midway between plates. It enters the electric field with speed 4.1×10^{5} m s^{-1} at an angle 32° from the vertical and hits plate Y at point P with speed 6.5×10^{5} m s^{-1}. Point P is a vertical distance *d* from the top of the plate.

Fig. 4.2 shows the path of the particle. Ignore gravitational effects.

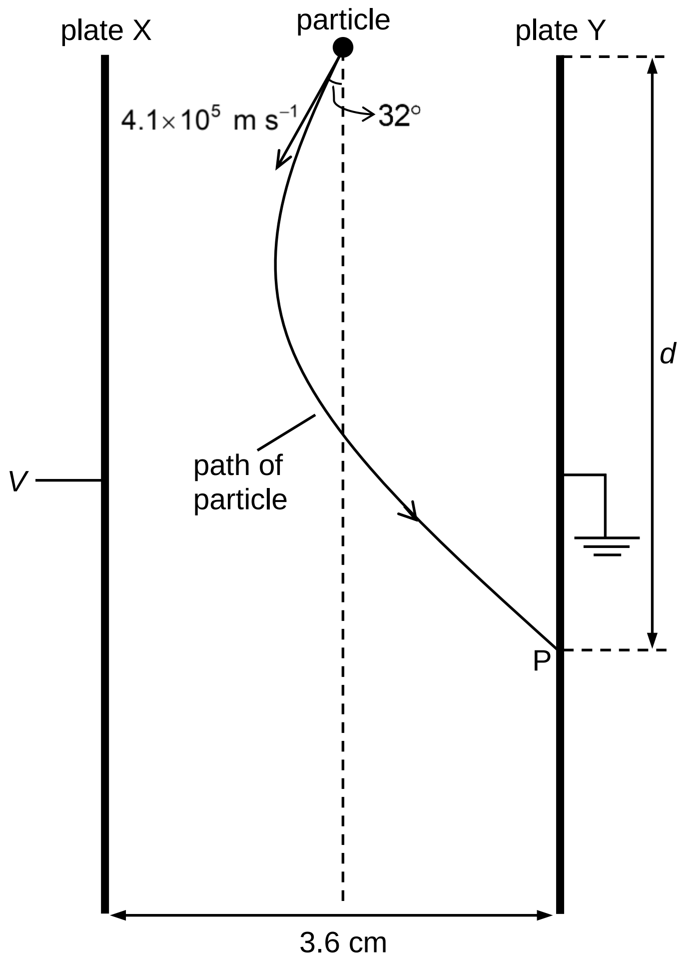

Fig. 4.2

Determine

(i) the potential V,

$V =$ .... V [3]

(ii) the magnitude of the acceleration a of the particle,

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

(iii) the distance d.

$d =$ .... m [3]

[Total: 10]

5 A model for a braking system is shown in Fig. 5.1. A large thin horizontal aluminium disc spinning about a vertical axle through its centre slows down as the poles of two magnets are brought near to it.

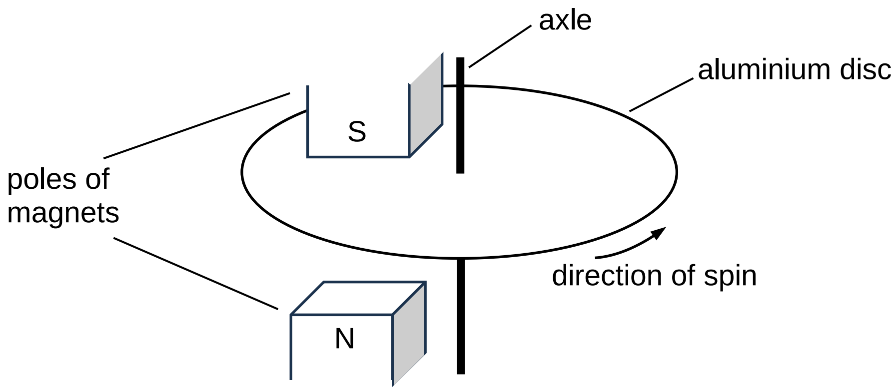

Fig. 5.1

(a) Explain how the model of the braking system shows that Lenz's law is an example of the law of conservation of energy.

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.... [2]

(b) Fig. 5.2 shows the top view of the disc.

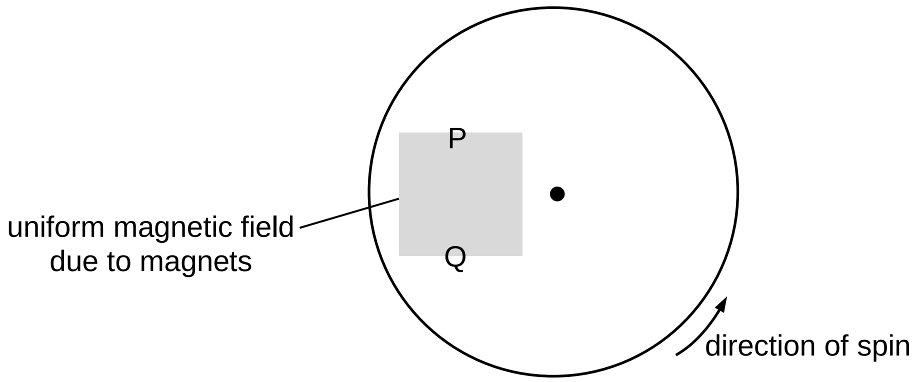

Fig. 5.2

On Fig. 5.2, draw the directions of the eddy currents induced at regions P and Q of the disc.

[1]

(c) Explain why the angular velocity of the disc does not decrease linearly with time.

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....

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.... [3]

[Total: 6]

6 **(a)** By reference to heating effect, state what is meant by the *root-mean-square* value of an alternating current.

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.... [1]

(b) An alternating power supply is connected to a switch S, an ideal diode and two identical resistors R_1 and R_2, as shown in Fig. 6.1. Each resistor has a resistance of $18\ \Omega$.

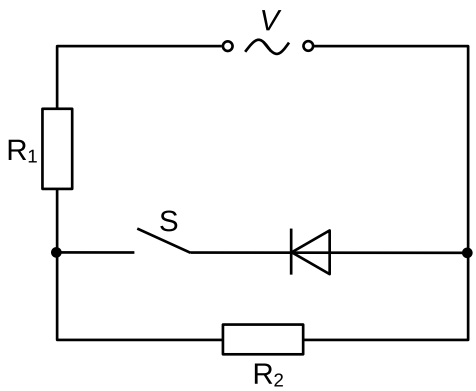

Fig. 6.1

The variation with time t of the potential difference V of the alternating supply is given by the expression

$$V = 24 \sin 314\, t$$

where V is in volts and t is in seconds.

(i) Switch S is closed.

On Fig. 6.2, show the variation with time t of the potential difference V_1 across R_1 for two periods of the alternating voltage.

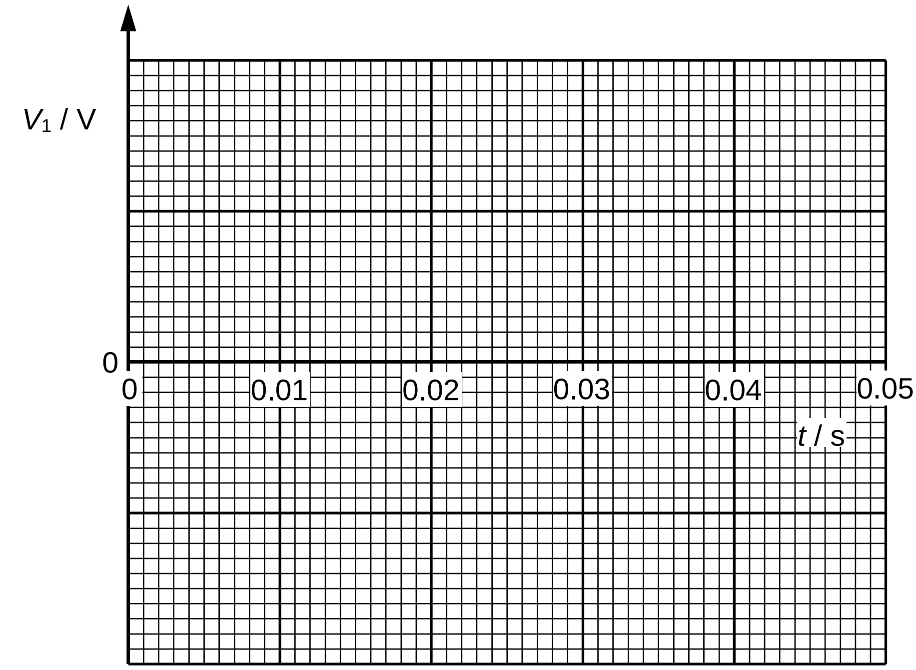

Fig. 6.2

[2]

(ii) Switch S is opened.

On Fig. 6.3, draw the variation with time t of the power P_1 transferred in R_1 for two periods of the alternating voltage.

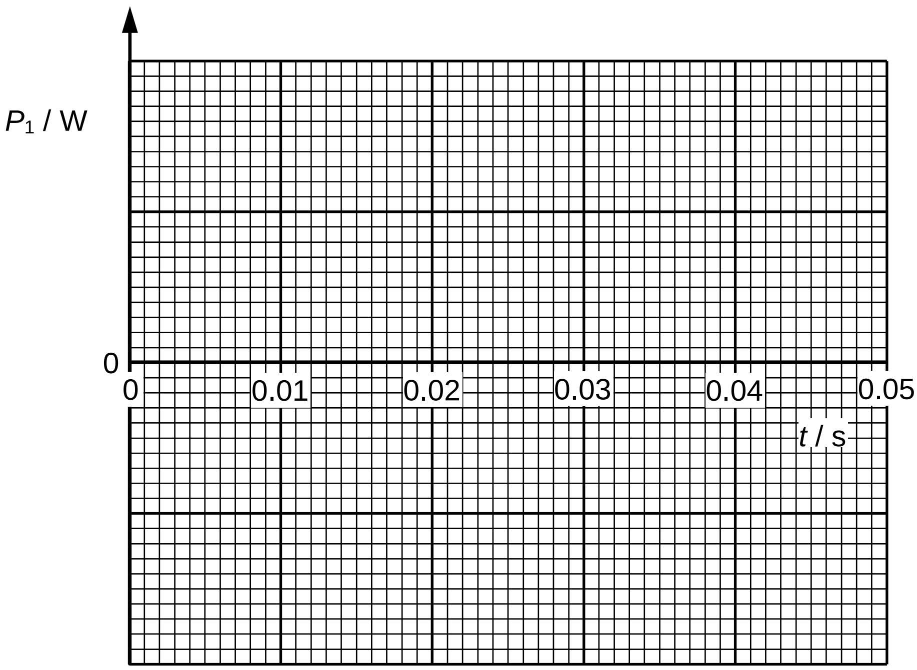

Fig. 6.3

[2]

[Total: 5]

7 **(a)** Explain how emission line spectra provide evidence for discrete electron energy levels in isolated atoms.

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.... [2]

(b) X-rays are produced when high speed electrons collide with a metal target.

Fig. 7.1 shows how the intensity of the X-rays varies with their wavelength.

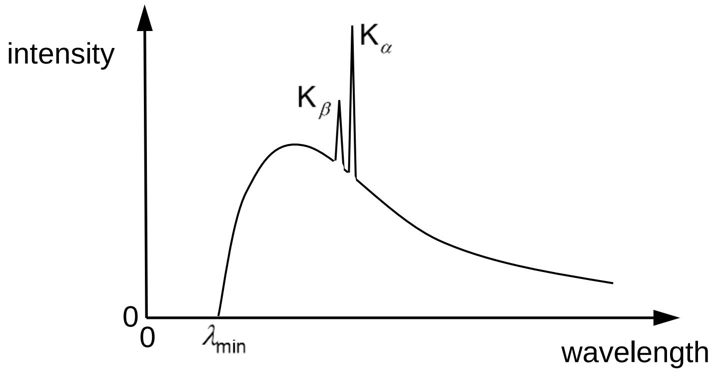

Fig. 7.1

Explain the origins of the following features in Fig. 7.1:

(i) The wavelength of the characteristic line K_α is greater than the wavelength of K_β.

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.... [2]

(ii) There is a minimum wavelength λ_{min} for the X-rays.

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.... [2]

[Total: 6]

End of Paper 3 Section A