H

NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAMINATION

Higher 2

CANDIDATE NAME

SUBJECT CLASS

REGISTRATION NUMBER

PHYSICS **9749/03**

Paper 3 Longer Structured Questions **(Section A)**

19 Sep 2025
2 hours

Candidate answers on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your subject class, registration number and name 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 a HB pencil for any diagrams, graphs or rough working.
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.

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.

For Examiner's Use	
Section A	
1	/ 10
2	/ 10
3	/ 9
4	/ 11
5	/ 10
6	/ 10
Sub-Total	/ 60
Section B	/ 20
Total	/ 80

This document contains **19** printed pages and **1** blank pages.

Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(1/(36\pi)) \times 10^{-9}\,\mathrm{F\,m^{-1}}$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
unified atomic mass constant	$u = 1.66 \times 10^{-27}\,\mathrm{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

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	$\phi = -Gm/r$
temperature	$T/\text{K} = T/°\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
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	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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

1 **(a)** Define *gravitational potential at a point*.

....

.... [1]

(b) The Earth may be considered to be an isolated sphere of radius *R* with its mass *M* concentrated at its centre.

The variation of gravitational potential φ with distance *x* from the centre of the Earth is shown in Fig. 1.1.

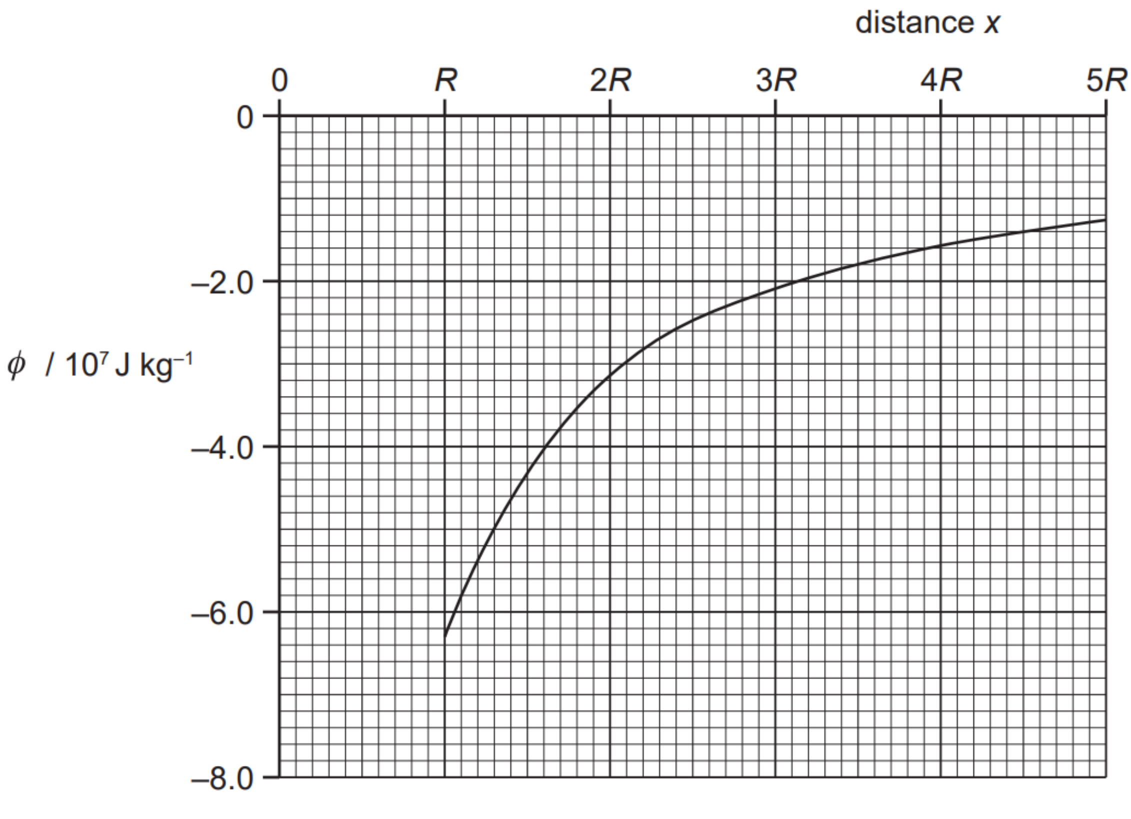


Fig. 1.1

The radius *R* of the Earth is 6.4×10^6 m.

(i) Show that the mass *M* of the Earth is 6.0×10^{24} kg.

[2]

(ii) A meteorite is at rest at infinity. The meteorite travels from infinity towards the Earth.

When the meteorite at a distance $2R$ above the Earth's surface, calculate

1. the speed of the meteorite,

speed = ………………………… m s^{-1} [3]

2. the acceleration of the meteorite.

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

(iii) In practice, the Earth is not an isolated sphere because it is orbited by the Moon.

Suggest how the speed calculated in **(ii)1.** will change.

……………………………………………………………………………………………

……………………………………………………………………………………………

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

[Total: 10]

2 A cylinder that contains a fixed amount of an ideal gas is shown in Fig. 2.1.

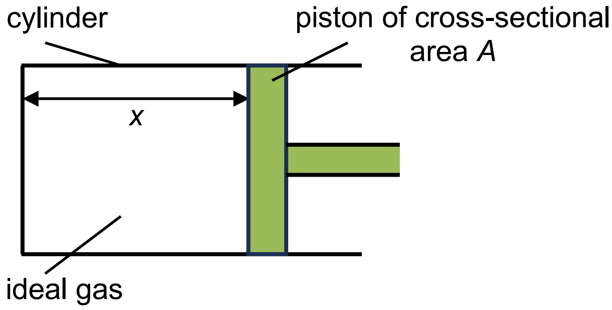


Fig. 2.1

The cylinder is tightly fitted with a piston, of cross-sectional area A. The piston moves freely in the horizontal direction, trapping the gas within a length x.

(a) A gas molecule of mass m travels at a speed of u in the horizontal direction and collides elastically with the piston and the walls of the container.

(i) State an expression, in terms of some or all of the symbols defined above, for the magnitude of the change in momentum during each collision.

change in momentum = ... [1]

(ii) Hence, show that the average force exerted on the piston by the molecule is $\dfrac{mu^2}{x}$.

[1]

(b) The gas in the cylinder undergoes a cycle of changes A → B → C → A, as shown in Fig. 2.2.

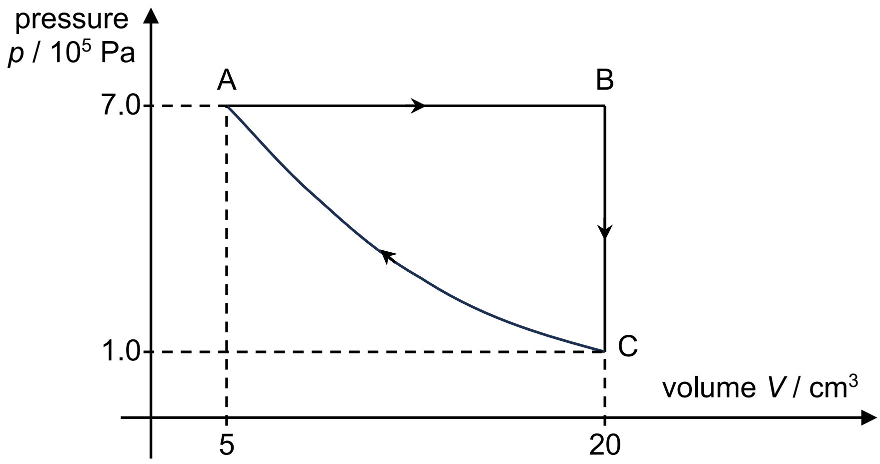


Fig. 2.2

(i) Calculate the work done by the gas during the change A → B.

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

(ii) Fig. 2.3 is a table of energy changes during one cycle. Complete Fig. 2.3.

section of cycle	heating supplied to gas / J	work done on gas / J	increase in internal energy of gas / J
A → B			
B → C	−30		
C → A	zero	3.7	

Fig. 4.2

[4]

(iii) The net work done by the gas is considered the useful work done of the cycle.

The efficiency of this cycle is given by

$$efficiency = \frac{useful\ work\ done}{total\ energy\ input} \times 100\%$$

Determine the efficiency of the cycle.

efficiency = ... % [2]

[Total: 10]

3 **(a)** State the *principle of superposition*.

....

....

.... [2]

(b) Two coherent microwave sources X and Y of frequency 2.5×10^{10} Hz are a distance of 0.18 m apart in a vacuum, as shown in Fig. 3.1.

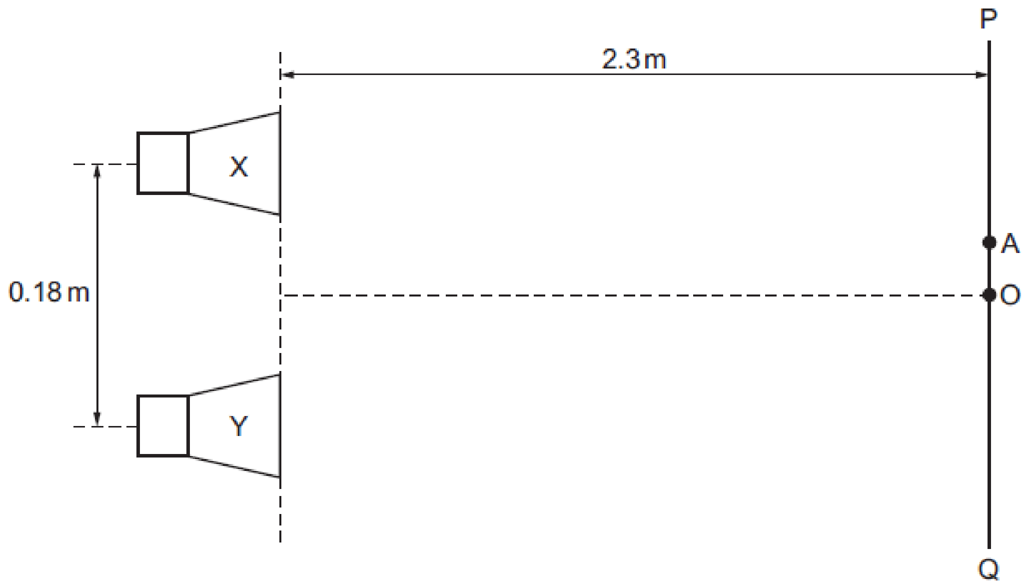


Fig. 3.1 (not to scale)

There is a phase difference of 180° between the waves emitted by the two sources.

A microwave detector moves along line PQ, which is parallel to the line joining the two sources and 2.3 m away from it.

Point O is along line PQ at a position that is equidistant from the two sources.
Point A is the first maximum intensity detected when the detector moves from O to A.

(i) Show that the wavelength of the microwaves is 0.012 m.

[1]

(ii) **1.** Explain why zero intensity is detected at point O.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

2. Determine the difference in the distances travelled by the microwaves from X to A and from Y to A.

difference = ……………………………… m [1]

(iii) Use the formula for the double-slit interference of light to calculate the distance between adjacent intensity maxima on line PQ.

distance = ……………………………… m [2]

(iv) On Fig. 3.1, draw a cross (×) to show the position of a point along line PQ closest to point O where the waves meet with a phase difference of 90°. Label this point B. [1]

[Total: 9]

4 **(a)** Define *electric field strength at a point*.

....

.... [1]

(b) Two isolated non-conducting charged spheres X and Y are placed near to each other, as shown in Fig. 4.1.

Fig. 4.1

P is a point on the line joining the centres of the spheres where the electric potential is zero.

(i) Explain why it is **not** possible for the resultant electric field to be zero at point P.

....

....

....

.... [2]

(ii) The magnitudes of the charges on spheres X and Y in Fig. 4.1 are Q and $2Q$ respectively. The spheres may be considered as point charges at their centres.

Point P is at a distance x from the centre of sphere X.

1. Show that the distance of point P from the centre of sphere Y is equal to $2x$.

[1]

2. Determine an expression, in terms of Q, x, π and the permittivity of free space ε_0, for the resultant electric field strength E at point P due to the two spheres.

E = ... [2]

(c) Fig. 4.2 shows a spark detector used to detect alpha particles.

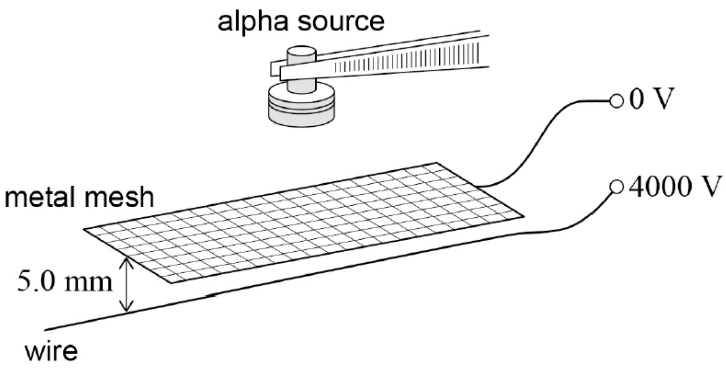


Fig. 4.2

The detector consists of a metal mesh placed 5.0 mm above a wire.
A potential difference of 4000 V is applied between the mesh and the wire.

Molecules in the air between the mesh and the wire are ionised by an alpha particle and a spark is produced.

(i) Fig. 4.3 shows equipotential surfaces between the mesh and the wire.

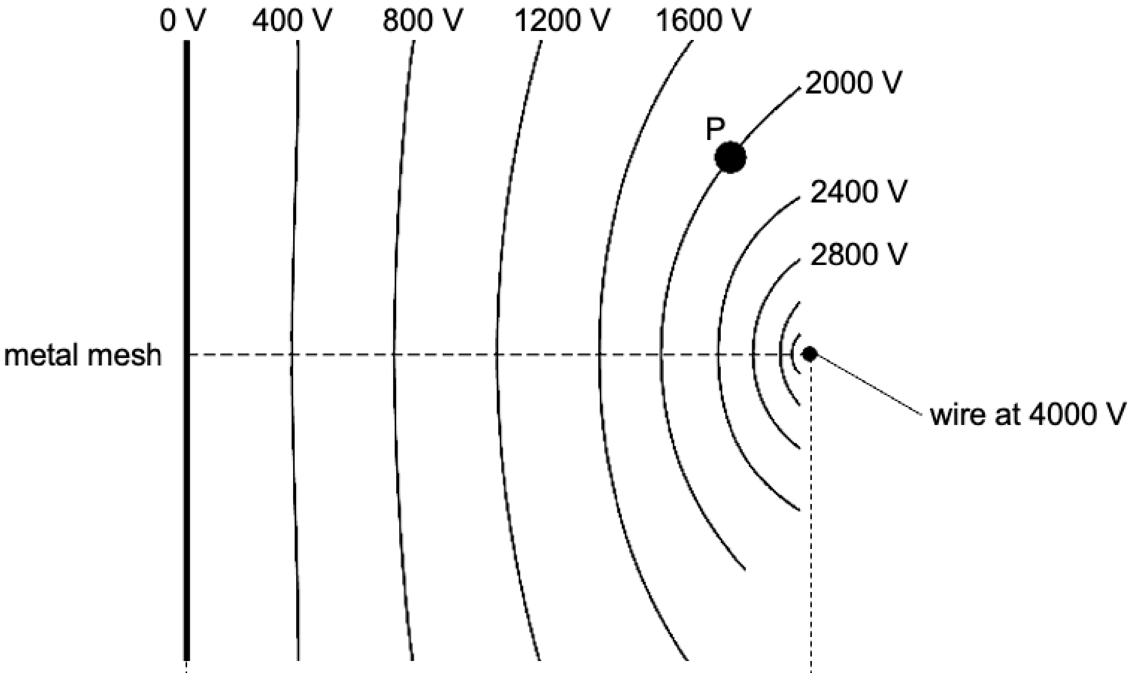


Fig. 4.3

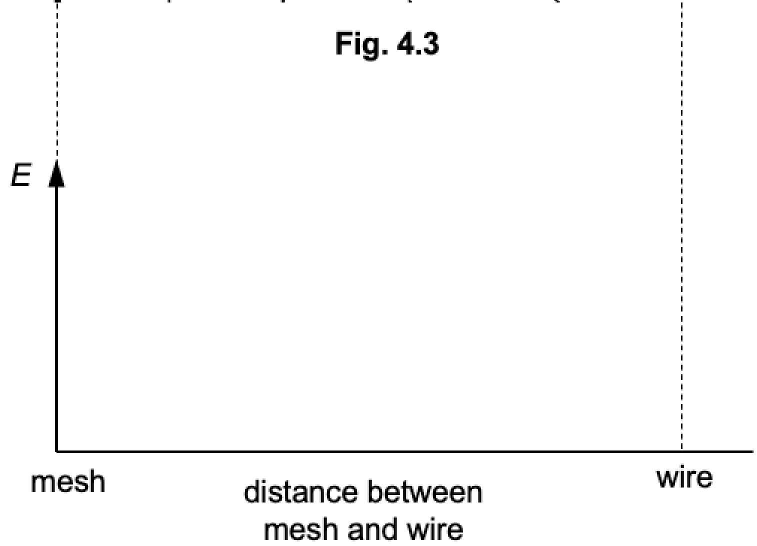


Fig. 4.4

Sketch on Fig. 4.4 the variation of the magnitude of the electric field strength E along the dashed line between the mesh and the wire in Fig. 4.3.

Values are not required on the E-axis. [2]

(ii) An alpha particle passes through the mesh. The alpha particle ionises an argon atom at point **P** on Fig. 4.3, releasing one electron.

The electron and the argon ion have no kinetic energy at point **P.**

The electron then travels to the wire and the argon ion (mass = 6.64×10^{-26} kg) travels to the mesh.

Calculate the ratio $\frac{speed\ of\ electron\ when\ it\ reaches\ the\ wire}{speed\ of\ argon\ ion\ when\ it\ reaches\ the\ mesh}$.

Assume that the air does not affect the motion of the electron or the argon ion.

ratio = ... [2]

(iii) In practice, the air **does** affect the motion of the electron and the motion of argon ion.

Suggest qualitatively how the presence of the air between the mesh and the wire affects the ratio in **(b)(ii).**

....

....

.... [1]

[Total: 11]

5 **(a)** A metal rod is accelerated uniformly from rest in a uniform magnetic field as shown in Fig. 5.1.

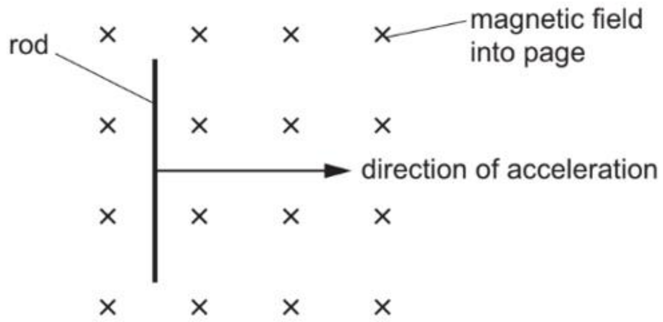


Fig. 5.1

The rod has length l and the flux density of the magnetic field is B.

An electromotive force (e.m.f.) is induced in the rod. The variation with time t of the induced e.m.f. E is shown in Fig. 5.2.

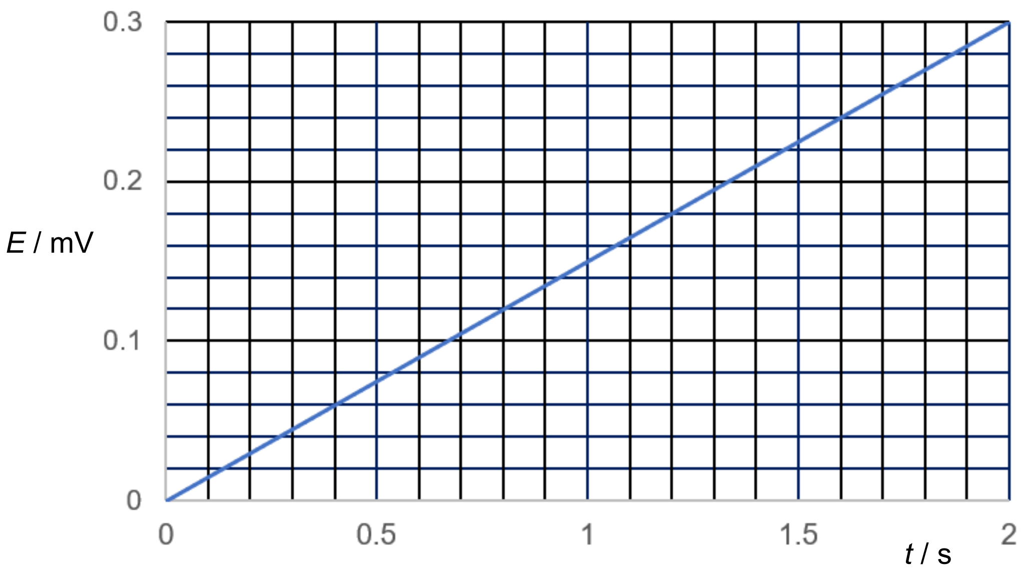


Fig. 5.2

(i) Explain how Fig. 5.2 shows that the acceleration of the rod is uniform.

....

....

.... [2]

(ii) The same metal rod in **(a)** is now placed on a pair of smooth conducting rails with a resistor *R* connected to the rails on a flat surface as shown in Fig. 5.3. The rod is pulled on the rails at a steady speed *v* from the left to the right.

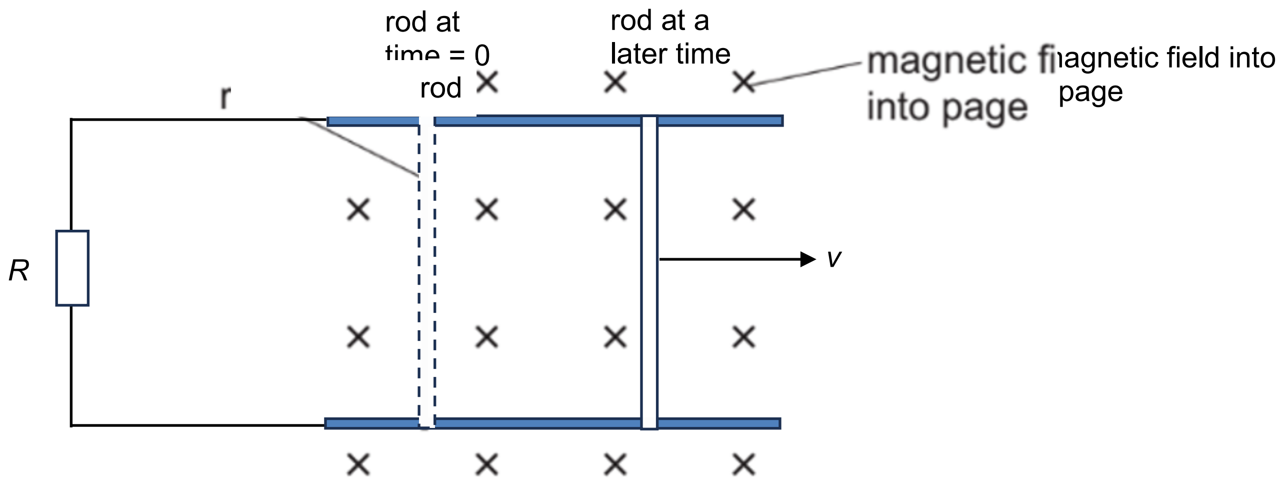


Fig. 5.3

Explain in terms of energy changes, why external work is needed to keep the speed of the rod constant.

....

....

....

....

.... [2]

(b) An alternating current I in a resistor of resistance 400 Ω varies with time t according to

$$I = 3.5 \sin(40\pi t)$$

where I is in A and t is in s.

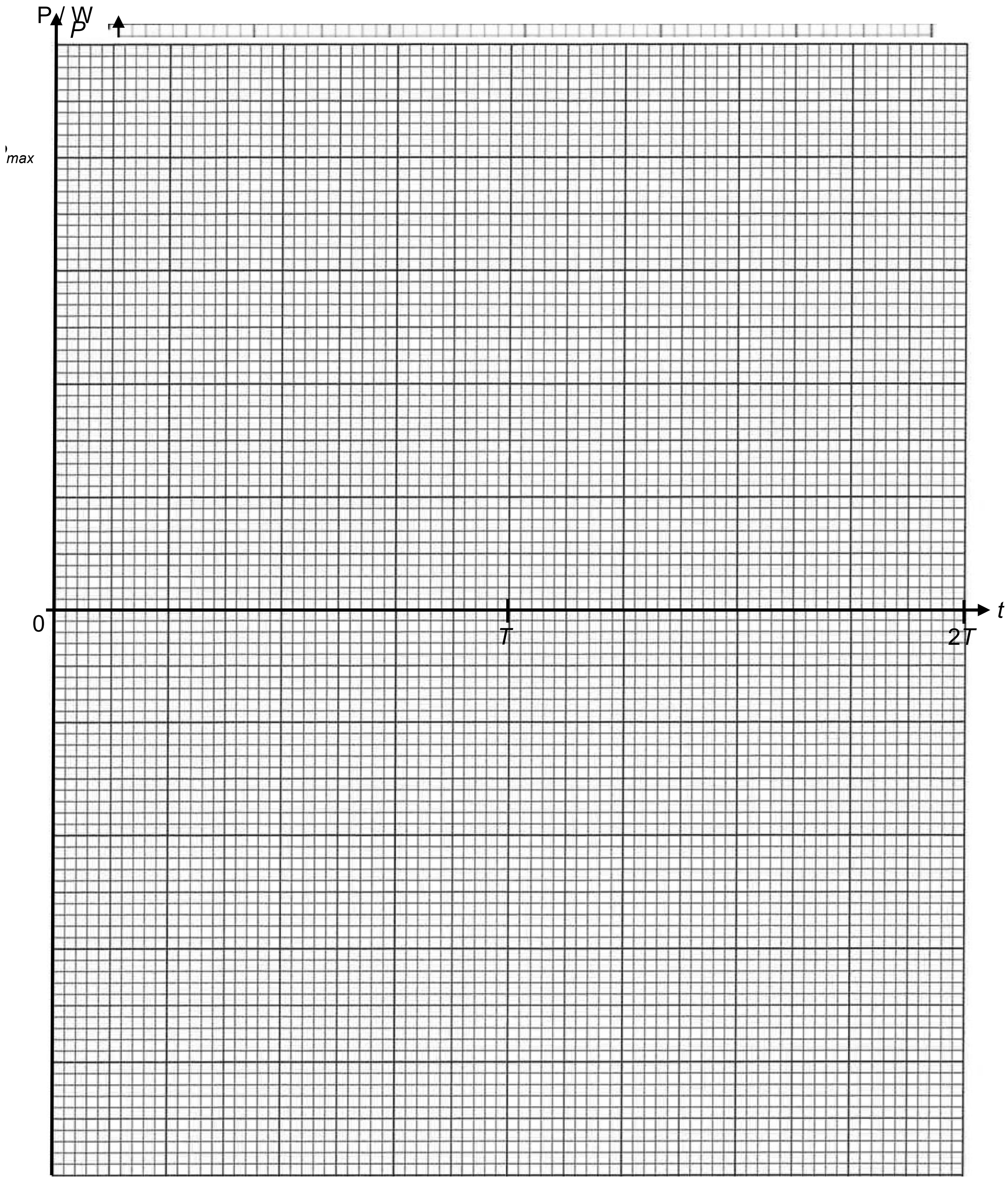
(i) Calculate the period T period of the alternating current.

T = ………………………………. s [1]

(ii) Calculate the mean power P transferred in the 400 Ω resistor.

P = ………………………………. W [2]

(iii) On Fig. 5.4, show the variation with time *t* of the power *P* transferred in the resistor for two periods of the alternating current. P_{max} is the maximum power transferred in the resistor.



[3]

[Total: 10]

6 The energy E, in eV, of the electron energy levels in a hydrogen atom may be determined using the expression

$$E = -\frac{13.6}{n^2}$$

where n is the energy level.

(a) **(i)** Calculate the energy, in eV, of energy level n = 2.

energy = ... eV [1]

(ii) Explain why the energy of each energy level is negative.

....

.... [1]

(b) A sample of low-pressure cool hydrogen gas is illuminated with monochromatic electromagnetic radiation of 103 nm. Some of the atoms are excited from the n = 1 level to the n = 3 level.

A spectrometer is placed near the sample of hydrogen gas, as shown in Fig. 6.1.

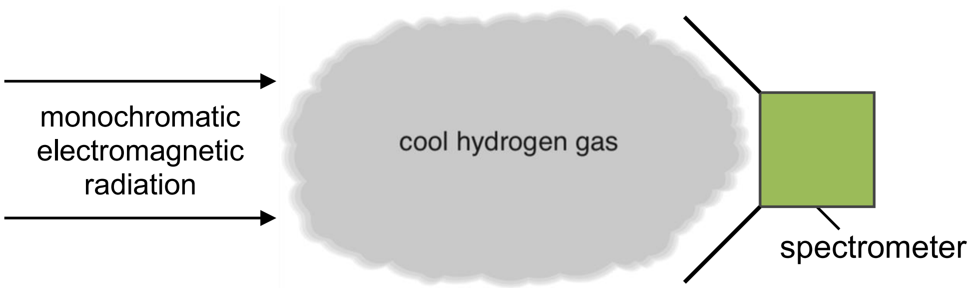


Fig. 6.1

Three wavelengths are detected by the spectrometer. One of the wavelengths is the incident radiation.

(i) The hydrogen glows faintly. Only transitions from n = 3 level to the n = 2 level lead to emission of visible light photons.

Determine the wavelength of the visible light photons and state the colour of the glow.

wavelength = ... m

[Turn over

colour: ……………………………… [2]

(ii) Determine the third wavelength detected.

wavelength = ……………………………… m [2]

(iii) Explain why the number of photons measured over a duration for the wavelengths in **(i)** and **(ii)** is equal.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(iv) On Fig. 6.2, sketch the number of photons against wavelength graph of the spectrum detected over a duration.

Fig. 6.2

[3]

[Total: 10]

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