HWA CHONG INSTITUTION
JC2 Preliminary Examination
Higher 2

Booklet 1

CANDIDATE NAME		**CT GROUP**	24S
CENTRE NUMBER		**INDEX NUMBER**	

PHYSICS — 9749/03

Paper 3 Longer Structured Questions — **19 September 2025**

Candidates answer on the Question Paper. — **2 hours**

No Additional Materials are required.

INSTRUCTIONS TO CANDIDATES

Write your **Centre number**, **index number, name** and **CT class** clearly on all work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs or rough working.
Do not use staples, paperclips, 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. **Circle** the question number on the cover page.

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.

You are reminded of the need for good English and clear presentation in your answers.

For Examiner's Use		
Section A		
1		8
2		6
3		8
4		8
5		10
6		10
7		10
Section B (choose ONE)		
8		20
9		20
Deductions		
Total		80

Data	Formulae	
speed of light in free space, $c = 3.00 \times 10^{8}$ m s^{-1}	uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
permeability of free space, $\mu_o = 4\pi \times 10^{-7}$ H m^{-1}	work done on / by a gas	$W = p\Delta V$
permittivity of free space, $\varepsilon_o = 8.85 \times 10^{-12}$ F m^{-1} $\approx (1/(36\pi)) \times 10^{-9}$ F m^{-1}	hydrostatic pressure	$p = \rho gh$
elementary charge, $e = 1.60 \times 10^{-19}$ C	gravitational potential	$\phi = -\frac{Gm}{r}$
the Planck constant, $h = 6.63 \times 10^{-34}$ J s	temperature	T/K = T/ °C + 273.15
unified atomic mass constant, $u = 1.66 \times 10^{-27}$ kg	pressure of an ideal gas	$P = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
rest mass of electron, $m_e = 9.11 \times 10^{-31}$ kg	mean kinetic energy of a molecule of an ideal gas	$E = \frac{3}{2}kT$
rest mass of proton, $m_p = 1.67 \times 10^{-27}$ kg	displacement of particle in s.h.m.	$x = x_o \sin \omega t$
molar gas constant, $R = 8.31$ J K^{-1} mol^{-1}	velocity of particle in s.h.m.	$v = v_o \cos \omega t$ $= \pm\omega\sqrt{(x_o^2 - x^2)}$
the Avogadro constant, $N_A = 6.02 \times 10^{23}$ mol^{-1}	electric current	$I = Anvq$
the Boltzmann constant, $k = 1.38 \times 10^{-23}$ J K^{-1}	resistors in series	$R = R_1 + R_2 + \ldots$
gravitational constant, $G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}	resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
acceleration of free fall, $g = 9.81$ m s^{-2}	electric potential	$V = \frac{Q}{4\pi\varepsilon_o r}$
	alternating current / voltage	$x = x_o \sin \omega t$
	magnetic flux density due to a long straight wire	$B = \frac{\mu_o I}{2\pi d}$
	magnetic flux density due to a flat circular coil	$B = \frac{\mu_o NI}{2r}$
	magnetic flux density due to a long solenoid	$B = \mu_o nI$
	radioactive decay	$x = x_o \exp(-\lambda t)$
	decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1 A ball is thrown from point S, as shown in Fig. 1.1.

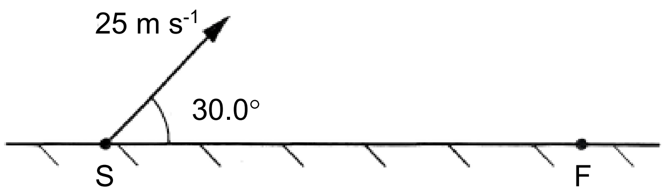

Fig. 1.1

The initial velocity of the ball is 25 m s^{-1} at an angle to the horizontal of 30.0°.

The ball lands at point F. The points S and F are at the same horizontal level.

(a) **(i)** Calculate the vertical component of the ball's initial velocity.

vertical component = ……………………… m s^{-1} [1]

(ii) Show that the maximum height reached by the ball is 8.0 m, assuming air resistance is negligible.

[1]

(iii) The kinetic energy of the ball at S is K. Calculate the kinetic energy and the potential energy of the ball in terms of K at a height of 8.0 m,

kinetic energy = …………………………

potential energy = …..……………………..

[3]

(b) The horizontal distance from S to F is x.

On Fig. 1.2, sketch the variation with the horizontal distance of

(i) the potential energy of the ball and label the graph as E_p.

(ii) the kinetic energy of the ball and label the graph as E_k. [3]

Fig. 1.2

[Total: 8 marks]

2 **(a)** The drag force F_d on a car moving through air is given by the formula:

$$F_d = \frac{1}{2}\rho C_d A v^2$$

where ρ is the air density,

C_d is the unitless drag coefficient,

A is the frontal area of the car, and

v is the velocity of the car.

Table 2.1 shows the data measured for car A.

Table 2.1

ρ / kg m^{-3}	1.20 ± 0.05
C_d	0.30 ± 0.02
A / m^2	2.50 ± 0.05
v / km h^{-1}	108 ± 2

Use this data to calculate the drag force F_d on car A and its associated uncertainty.

$F_d \pm \Delta F_d$ = ... N [3]

(b) Cars A and B approach a junction as shown in Fig. 2.2.

Car A travels east at a constant speed of 40.0 km h^{-1} while car B travels northwest at a constant speed of 50.0 km h^{-1}.

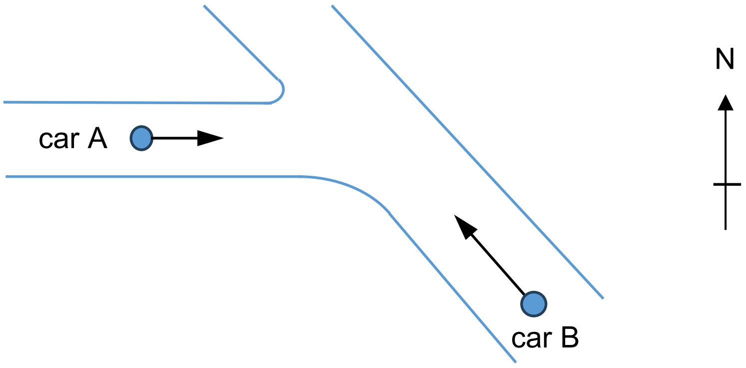

Fig. 2.2

With the aid of a vector diagram, determine the velocity of car A relative to car B.

velocity of car A relative to car B = …………………………… km h^{-1}

direction: ……………………………………………………………………………………………

[3]

[Total: 6 marks]

3 Planet Z is spherical and has a uniform density. It has only argon in its atmosphere.

(a) The escape velocity is the minimum velocity required to escape the gravitational pull of a celestial body.

Show that the escape velocity v of Planet Z is given by

$$v = \sqrt{\frac{8}{3} G \pi \rho r^2}$$

where r is the radius, and ρ is the density of Planet Z.

[2]

(b) Given that Planet Z has a mean density of 5500 kg m^{-3} and radius of 413 km, calculate the escape velocity of the argon gas molecules at its surface.

v = ………………………….. m s^{-1} [1]

(c) Argon gas behaves as an ideal monatomic gas on Planet *Z*, and it has a molar mass of 40 g mol^{-1}.

Assume that the root-mean-square speed of the argon molecules is equal to the escape velocity.

Using Kinetic Theory, determine the absolute temperature of the atmosphere on Planet *Z*.

absolute temperature = ………………… K [3]

(d) Suppose the atmosphere of Planet Z is 100 K lower than the temperature calculated in **(c)**. Suggest a reason whether argon gas molecules would be able to escape from the atmosphere of Planet Z.

……

……

…… [2]

[Total: 8 marks]

4 A beam of monochromatic light of wavelength 633 nm is incident normally on a double slit. A screen is placed parallel to the plane of the double slit at a distance 98.0 cm from the slits. P is the point on the screen that is equidistant from the two slits, as illustrated in Fig. 4.1.

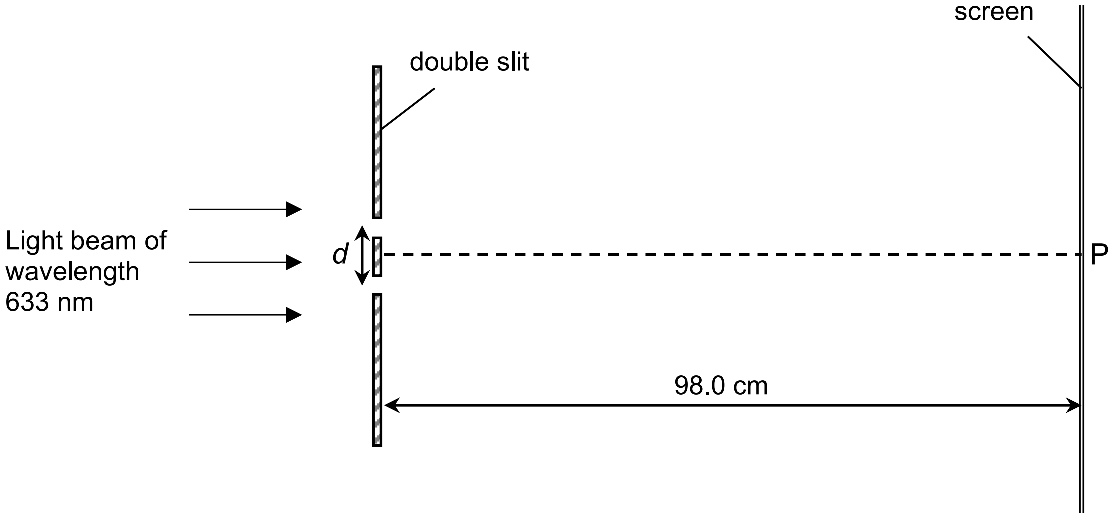

Fig. 4.1 (not to scale)

Fig. 4.2 shows the variation with distance from P of the intensity I of the light on the screen.

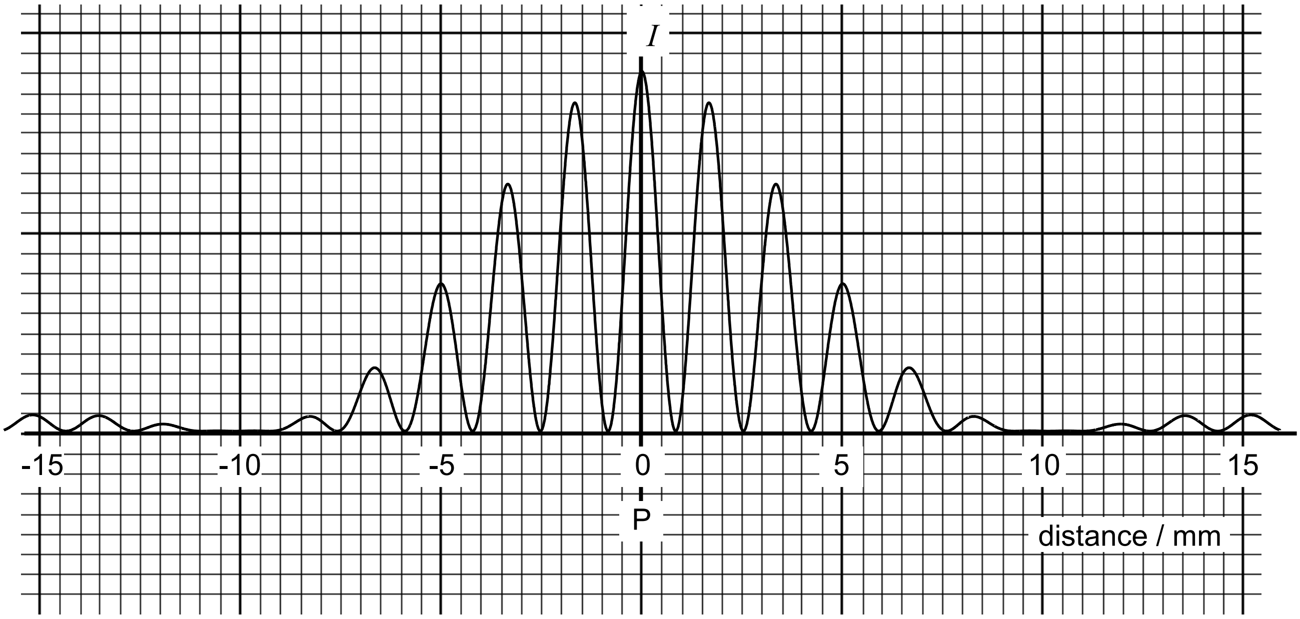

Fig. 4.2

(a) Using Fig. 4.2, show that the slit separation *d* is 3.7×10^{-4} m.

[2]

(b) Estimate the slit width *b* of each slit.

b = ………………………..… m [2]

(c) State with a reason the change to be made to the double slit to achieve each of the following interference patterns on the screen.

(i) The interference pattern spreads out more on the screen.

……………………………………………………………………………………………..

……………………………………………………………………………………………..

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

(ii) The bright fringes have nearly uniform intensity across the pattern.

……………………………………………………………………………………………..

……………………………………………………………………………………………..

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

[Total: 8 marks]

5 (a) An electron moves in a vacuum at an angle of 20° to a magnetic field of magnetic flux density 0.088 T, as shown in Fig. 5.1.

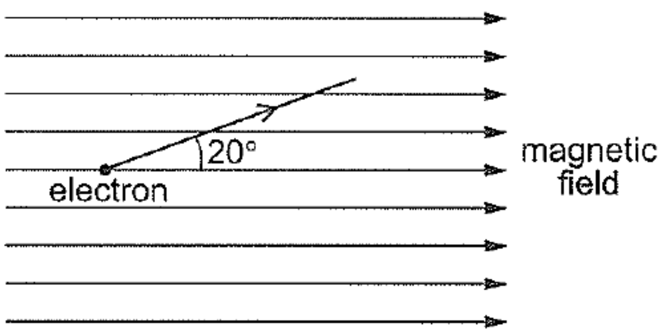

Fig. 5.1

The force on the electron is 4.3×10^{-14} N.

(i) Explain why the electron follows a helical path in the magnetic field.

....

....

....

....

.... [2]

(ii) Calculate the speed of the electron.

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

(iii)

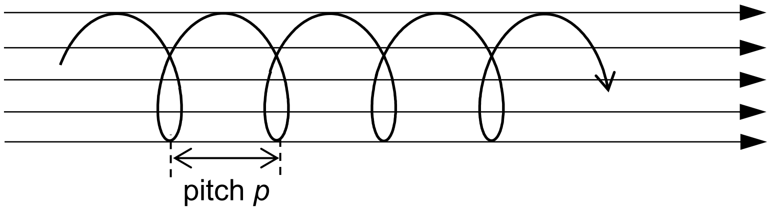

Fig. 5.2

Fig. 5.2 shows the pitch p of the helical path taken by the electron, which is given by the product of the period of the circular motion and the velocity component of the electron parallel to the magnetic field.

Calculate the pitch p.

p = ... m [4]

(b) Fig. 5.3 shows the coil of a simple electric motor between the poles of a magnet.

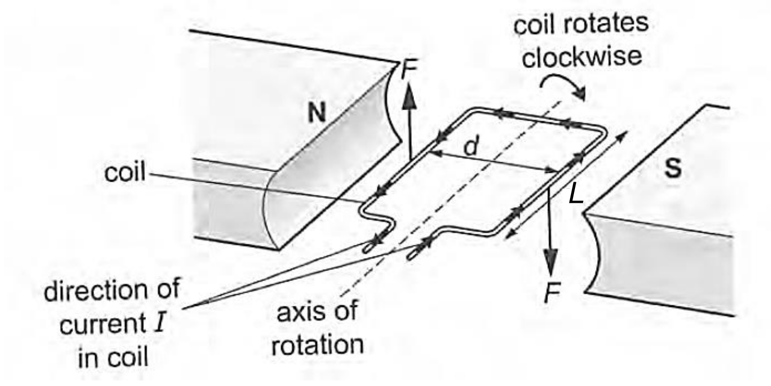

Fig. 5.3

The coil has length *L* and width *d*. The entire coil lies within the magnetic field. The magnetic flux density between the poles of the magnet is *B*. There is a current *I* in the coil.

Two forces, each of magnitude *F*, act in opposite directions on the two sides of the coil, as shown in Fig. 5.3. This produces a torque that causes the coil to rotate.

The current *I* in the coil is 96 A. The area of the rectangular coil in the magnetic field of the magnet is 6.1×10^{-3} m^2 and the coil contains 1200 turns. The maximum output torque given to the coil is 395 Nm.

Calculate the magnetic flux density *B* needed to produce the maximum output torque.

B = ………………….. T [2]

[Total: 10 marks]

6 Light of frequency f and wavelength λ is incident on a metal surface of work function energy Φ. Electrons are emitted from the surface with maximum kinetic energy E_{MAX}.

Conservation of energy for this effect may be expressed as

$$E_{MAX} = hf - \Phi$$

where h is the Plank constant.

(a) **(i)** Explain what is meant by threshold frequency.

....

.... [1]

(ii) Light at the threshold frequency for the metal surface has a wavelength λ_o.

Show that

$$E_{MAX} = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_o}\right)$$

where c is the speed of light.

[1]

(b) The variation with $\frac{1}{\lambda}$ of E_{MAX} is shown in Fig. 6.1.

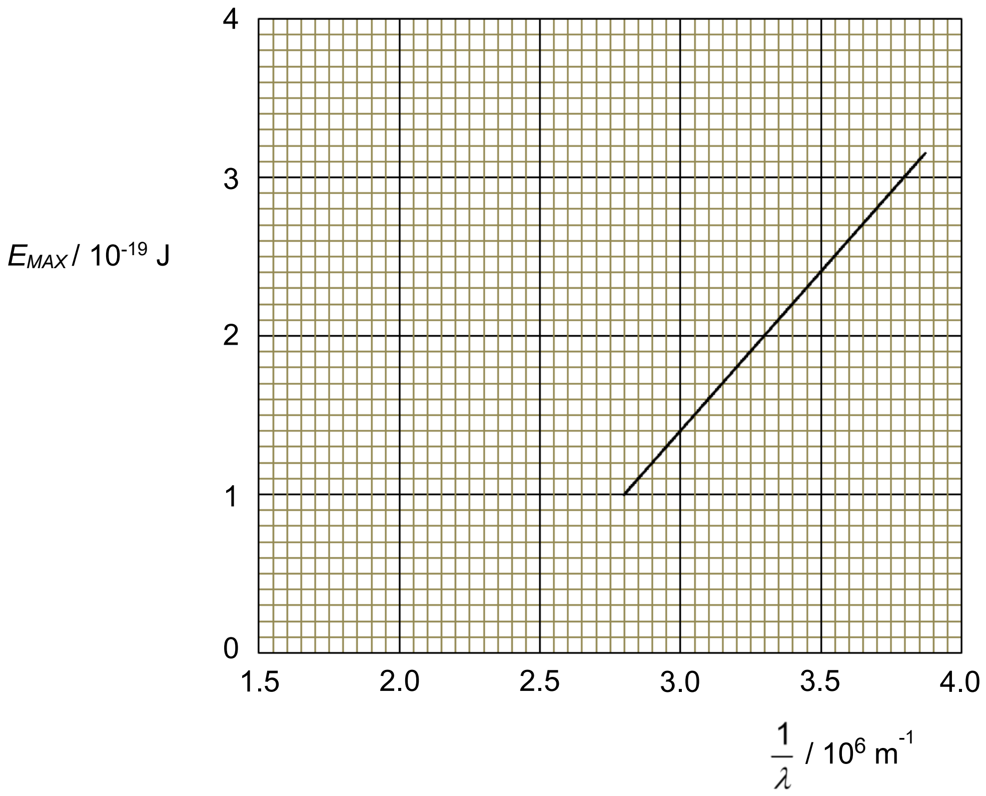

Fig. 6.1

Use Fig 6.1 and the expression in **(a)(ii)** to determine

(i) the maximum wavelength λ_o at which emission of electrons occurs, without using any value of h,

λ_o = ………………………….. m [2]

(ii) the Plank constant *h* using data in Fig. 6.1.

h = ………………………….. J s [2]

(c) The metal is replaced with one that has a smaller work function.

On Fig. 6.1, draw a line to show the variation with $\frac{1}{\lambda}$ of E_{MAX} for this new metal surface. [1]

(d) An isolated sphere of radius *r* made of this material is illuminated by the light of wavelength λ.

By energy consideration, derive an expression of the final charge induced on the sphere in terms of λ, λ_o and *r*.

[3]

[Total: 10 marks]

7 The discovery of the proton was credited to Ernest Rutherford. In 1917, he fired a beam of α particles into pure nitrogen gas which resulted in the production of oxygen and protons. The nuclear reaction is given by the equation

$$^{14}_{7}N + ^{4}_{2}He \rightarrow ^{17}_{8}O + ^{1}_{1}H$$

(a) State what is meant by the binding energy of a nucleus and how it is related to the mass defect.

....

....

....

....

.... [2]

(b) Data for some masses are given in Table 7.1.

		mass / u
proton	$^{1}_{1}H$	1.007 276
neutron	$^{1}_{0}n$	1.008 665
nitrogen-14	$^{14}_{7}N$	14.003 074

Table 7.1

(i) Show that the energy equivalent of 1.00 *u* is 934 MeV.

[2]

(ii) Using data from Table 7.1, show that the binding energy per nucleon of nitrogen-14 is 7.24 MeV.

[2]

(c) The binding energy per nucleon for the other nuclides is shown in Table 7.2.

		binding energy per nucleon / MeV
helium	${}^{4}_{2}He$	6.836
oxygen-17	${}^{17}_{8}O$	7.530

Table 7.2

(i) Use data from Table 7.2 to determine, to three significant figures, the energy released in this reaction associated with the change in mass.

energy released = ………………….. MeV [2]

(ii) State and explain whether the reaction will take place if the incident α-particle has a kinetic energy of 0.300 MeV. You may assume that the nitrogen-14 nucleus is at rest.

……………………………………………………………………………………………………..

……………………………………………………………………………………………………..

……………………………………………………………………………………………………..

……………………………………………………………………………………………………..

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

[Total: 10 marks]

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JC2 Preliminary Examination
Higher 2

Booklet 2

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PHYSICS 9749/03

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Section B (Choose ONE)		
8		20
9		20
Deductions		
Total		80

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permeability of free space, $\mu_o = 4\pi \times 10^{-7}$ H m^{-1}
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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	$\phi = -\frac{Gm}{r}$
temperature	T/K = T/ °C + 273.15
pressure of an ideal gas	$P = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean kinetic energy of a molecule of an ideal gas	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_o \sin \omega t$
velocity of particle in s.h.m.	$v = v_o \cos \omega t$ $= \pm \omega \sqrt{(x_o^2 - x^2)}$
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	$V = \frac{Q}{4\pi\varepsilon_o r}$
alternating current / voltage	$x = x_o \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_o n I$
radioactive decay	$x = x_o \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

Section B

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

8 **(a)** State the conditions required for a body to be in equilibrium.

....

....

.... [2]

(b) A pendulum bob of mass m is held in static equilibrium by a light inelastic string and a horizontal spring with an extension of 5.0 cm. The string makes an angle of 36° with the vertical as shown in Fig. 8.1.

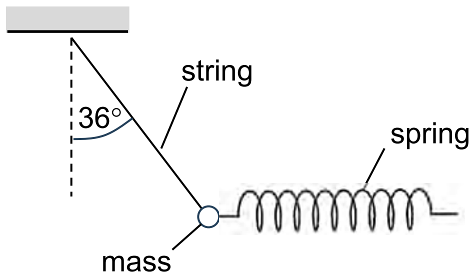

Fig. 8.1

(i) The tension T in the string is measured to be 2.5 N.

Calculate the force constant k of the spring.

force constant k = ... N m^{-1} [2]

(ii) Determine the mass *m* of the bob.

mass *m* = ………………………. kg [2]

(iii) Calculate the elastic potential energy stored in the spring.

elastic potential energy = ……………………….. J [2]

(c) The spring is detached from the pendulum bob.

The bob is then slightly displaced to an angular displacement θ of 10.0° and released to undergo simple harmonic motion as shown in Fig. 8.2. The inelastic string is 15.0 cm in length.

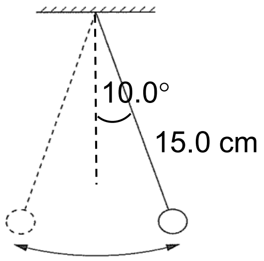

Fig. 8.2

(i) Define simple harmonic motion.

……………………………………………………………………………………………………..

……………………………………………………………………………………………………..

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

(ii) Assuming air resistance is negligible, when the bob is at the bottom of its swing,

1. show that the speed of the bob is 0.21 m s^{-1},

[2]

2. compare the tension T in the string with the weight W of the bob. Explain your reasoning qualitatively.

……………………………………………………………………………………………………..

……………………………………………………………………………………………………..

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

3. Hence or otherwise, calculate the tension in the string at the bottom of its swing.

tension = …………………………….. N [2]

(d) Assuming **air resistance is not negligible.**

(i) Sketch in Fig. 8.3, the variation with displacement x of the velocity v of the bob for 1 period of oscillation.

Label the axes with appropriate values.

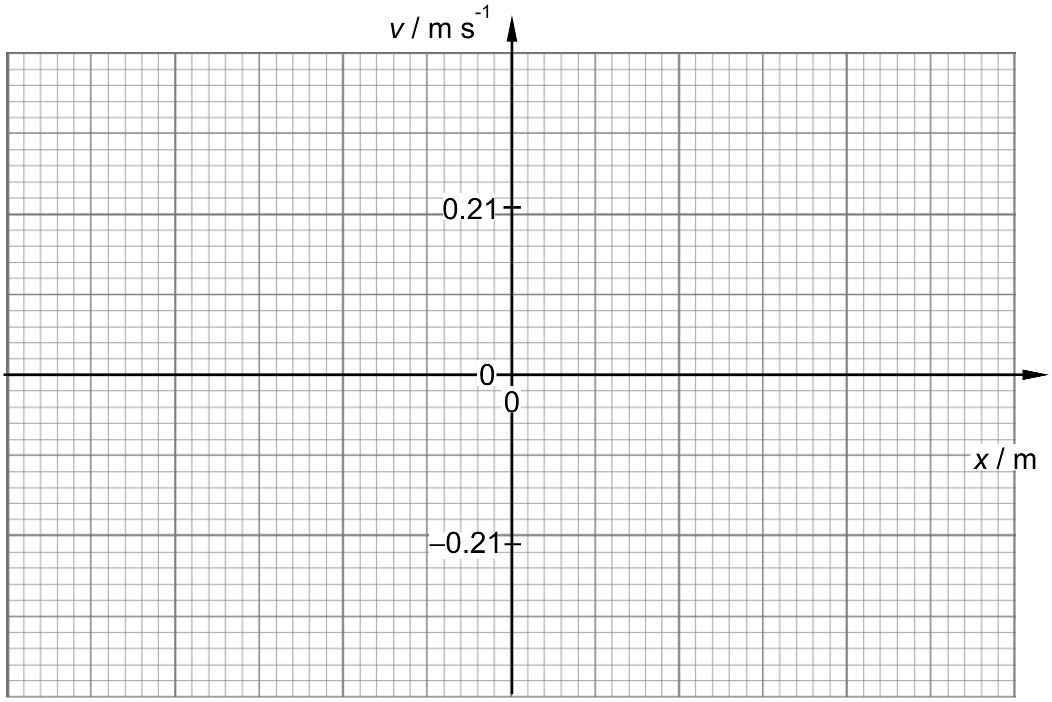

Fig. 8.3

[2]

(ii) Sketch in Fig. 8.4, the variation with time *t* of

1. the potential energy (label the graph *U*) and

2. the kinetic energy (label the graph *K*) of the pendulum bob for 1 period of oscillation.

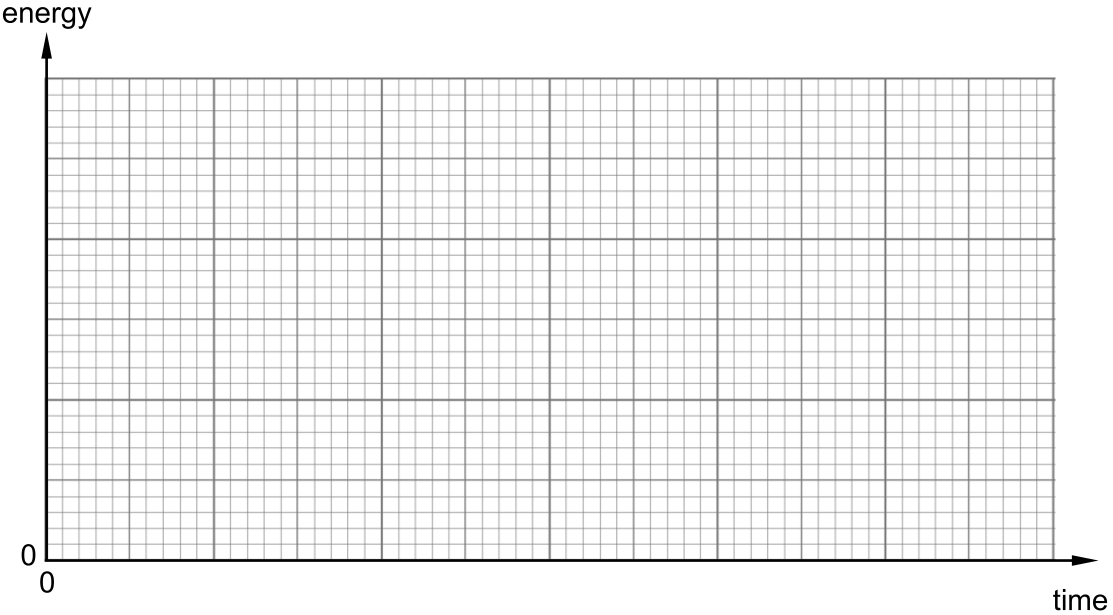

Fig. 8.4

[3]

[Total: 20 marks]

9 **(a)** The coil in a generator is situated in a uniform magnetic field as shown in Fig. 9.1.

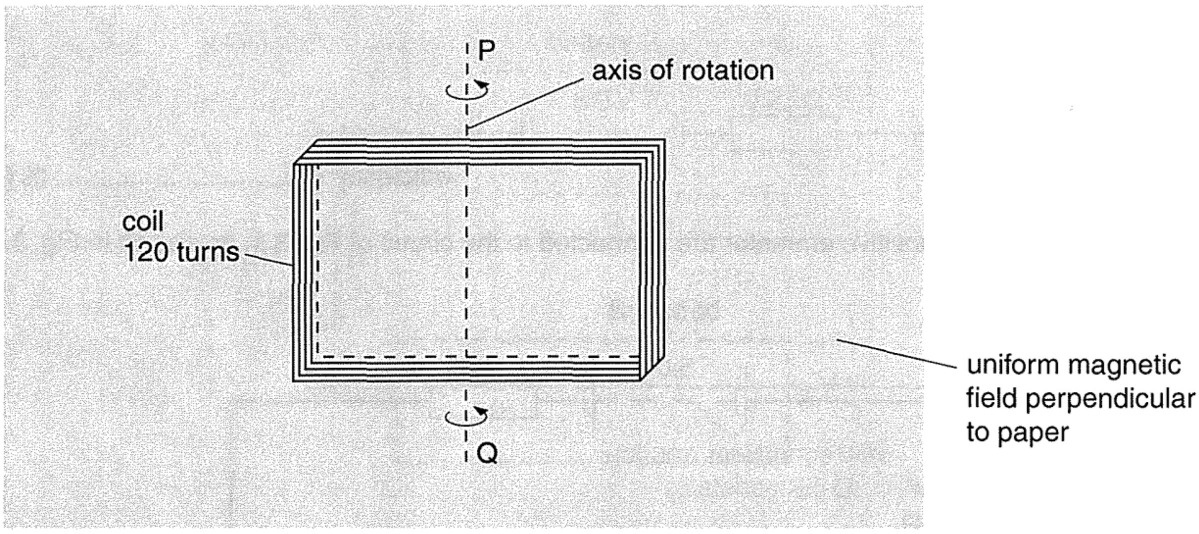

Fig. 9.1

The coil is rotated about the axis PQ as shown in Fig. 9.1. An electromotive force (e.m.f.) is induced in the coil. The e.m.f. is measured with a cathode-ray oscilloscope (c.r.o.).

The Y-plates sensitivity of the c.r.o. is 0.050 V cm^{-1} and the time-base setting is 8.0 ms cm^{-1}.

The waveform displayed on the c.r.o. is shown in Fig. 9.2.

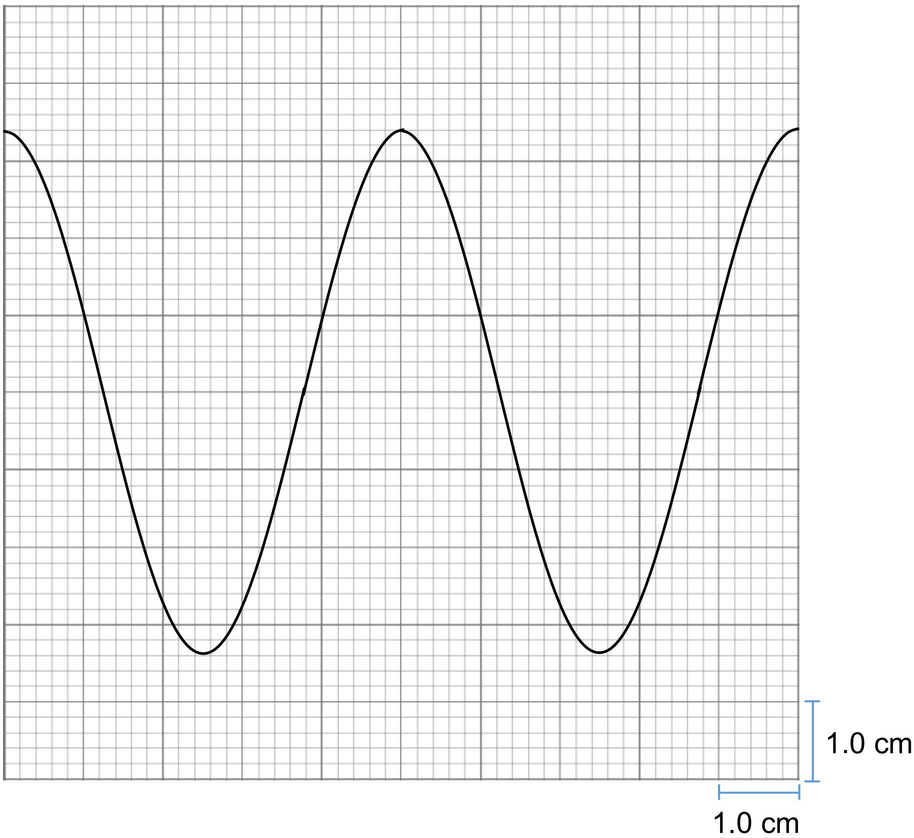

Fig. 9.2

(i) Use Faraday's law of electromagnetic induction to explain the variation of the e.m.f. induced in the coil.

…………………………………………………………………………………………………….....

…………………………………………………………………………………………………….....

…………………………………………………………………………………………………….....

…………………………………………………………………………………………………….....

…………………………………………………………………………………………………….....

…………………………………………………………………………………………………….....

………………………………………………………………………………………………..….. [3]

(ii) Using Fig. 9.2, calculate

1. the maximum induced e.m.f.

maximum e.m.f. = ……………………………………….. V [2]

2. the frequency.

frequency = ………………………………. Hz [2]

(iii) With reference to Fig. 9.1, state how the coil is positioned relative to the magnetic field when the induced e.m.f. in the coil is maximum.

…………………………………………………………………………………………………….....

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

(iv) The coil has 120 turns and a cross-sectional area of 1.3×10^{-3} m^2.

The maximum induced e.m.f. E_0 is given by the expression

E_0 = maximum magnetic flux linkage $\times$ angular speed of the coil.

Use this expression and your answers in **(a)(ii)** to calculate the magnetic flux density of the field.

magnetic flux density = ……………………………. T [2]

(b) An electric heater has a resistance of 38 Ω at its working temperature. The variation with time *t* of the supply voltage *V* connected between the terminals of the heater is given by

$$V = 240 \sin 377t$$

where *V* is measured in volts and *t* is in seconds.

(i) By reference to heating effect, explain what is meant by the *root-mean-square* (r.m.s.) value of an alternating current.

…………………………………………………………………………………………………….....

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

(ii) Determine the frequency *f* of the supply voltage

f = …………………………… Hz [2]

(iii) Determine the power dissipation of the heater.

power = ……………………….. W [3]

(iv) On Fig. 9.3, show the variation with time *t* of the power *P* dissipated in the heater for two periods of the alternating voltage. The alternating voltage has period *T*.

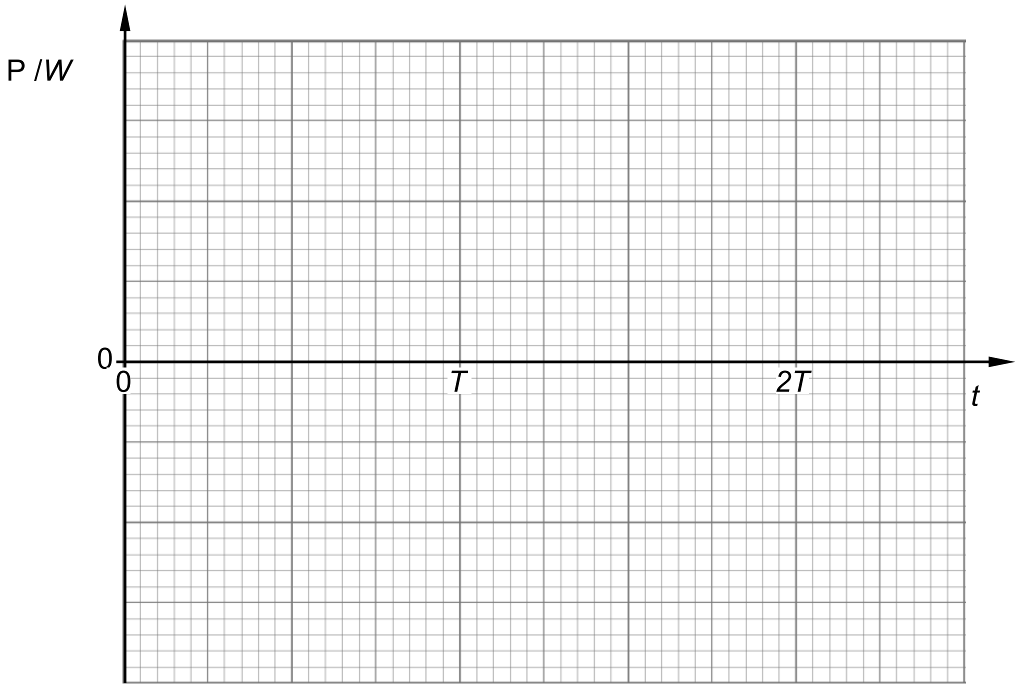

Fig. 9.3

[3]

[Total: 20 marks]

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