HWA CHONG INSTITUTION
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME		CT GROUP	18S
CENTRE NUMBER		INDEX NUMBER	

PHYSICS

9749/01

Paper 1 Multiple Choice

26 September 2019

60 minutes

Additional Materials: Optical Mark Sheet

INSTRUCTIONS TO CANDIDATES

Write in soft pencil.

Write your name, CT, NRIC or FIN number on the optical mark sheet (OMS). Shade your NRIC or FIN in the spaces provided.

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 OMS.

Each correct answer will score one mark. A mark will **not** be deducted for a wrong answer.

Any rough working should be done in this booklet.

This paper consists of **18** printed pages.

Data
speed of light in free space, $c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space, $\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space, $\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1} $\approx (1/(36\pi)) \times 10^{-9}$ 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	$\phi = -\frac{Gm}{r}$
temperature	$T/\text{K} = T/°\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean kinetic energy of a molecule of an ideal gas	$E = \frac{3}{2}kT$
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	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

1 The rate of energy transfer H through a conducting slab is given by

$$H = kA\left|\frac{\Delta T}{l}\right|$$

where the proportionality constant k is the thermal conductivity of the material, A is the cross-sectional area of the slab, l is the length of the slab and ΔT is the temperature difference at opposite faces of the slab.

Which of the following is the unit of k in ***base SI units***?

A $\text{W m}^{-1}\text{ K}^{-1}$

B $\text{W m}^{-2}\text{ K}^{-1}$

C $\text{kg m}^{5}\text{ s}^{-2}\text{ K}^{-1}$

D $\text{kg m s}^{-3}\text{ K}^{-1}$

2 A tennis ball travelling at 4.0 m s^{-1} due east strikes a surface and bounces off at 3.0 m s^{-1} due north. The change in velocity of the tennis ball is

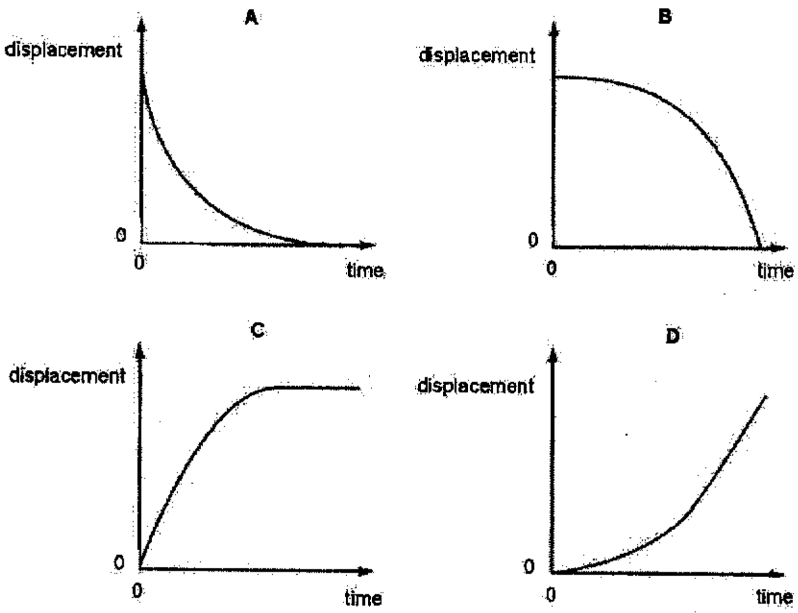
A 1.0 m s^{-1} at 37° east of north

B 1.0 m s^{-1} at 53° west of south

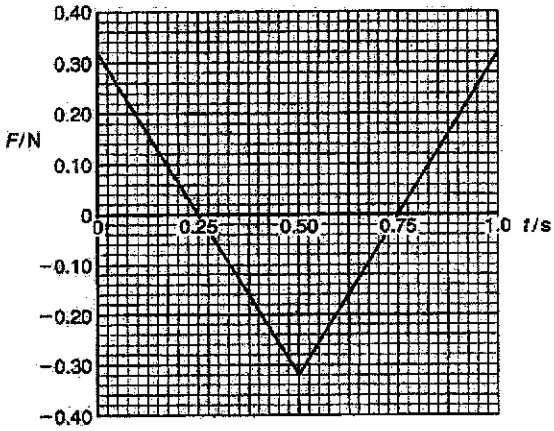
C 5.0 m s^{-1} at 37° east of south

D 5.0 m s^{-1} at 53° west of north

3 An object is released from rest and falls vertically. Eventually it reaches terminal velocity. Which graph best represents how the displacement of the object varies with time?



4 A resultant force F acts on a mass m. The variation with time t of F is as shown.



Mass m is 150 g. At time t = 0, the mass is at rest.

Which of the following statements is ***incorrect***?

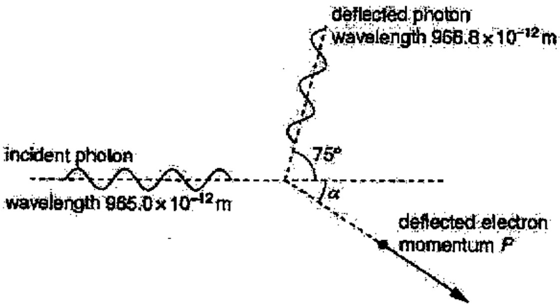
A The mass slowed down at a decreasing rate from t = 0.25 s to t = 0.50 s.

B The mass is momentarily at rest at t = 0.50 s.

C The mass reversed direction at t = 0.50 s and sped up at a decreasing acceleration from t = 0.50 s to t = 0.75 s.

D The magnitude of the change in velocity of the mass from t = 0.25 s to t = 0.75 s is 0.53 m s^{-1}.

5 An X-ray photon of wavelength 965.0×10^{-12} m collides elastically with a stationary electron.

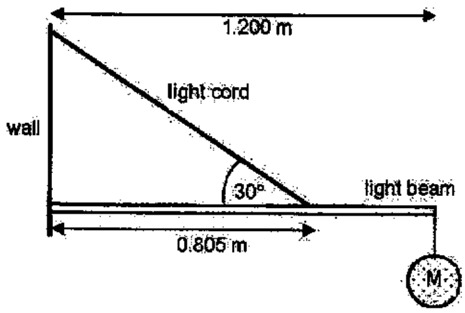


The photon is deflected through an angle of 75° and has a wavelength of 966.8×10^{-12} m. Given that the momentum carried by the deflected electron is 8.362×10^{-25} N s.

What is the deflection angle α of the electron?

A 12° **B** 38° **C** 52° **D** 78°

6 A 1.200 m light beam carries a mass M at one end. A light cord affixed to the wall is supporting the beam at 0.805 m from the wall as shown.



What is the maximum mass M that can be supported if the maximum allowed tension in the cord is 300 N?

A 10.3 kg **B** 17.8 kg **C** 20.5 kg **D** 30.5 kg

7 A helium balloon of volume V carrying a light weather instrument rises into the atmosphere. The total mass of the balloon skin and the weather instrument is M kg. Given the gravitational field strength is g, the density of air is ρ_{air}, and the density of helium is ρ_{He}, the net force acting on the balloon is

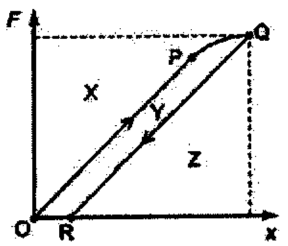
A $(\rho_{air} - \rho_{He})Vg$

B $(\rho_{air})Vg - Mg$

C $(\rho_{air} - \rho_{He})Vg - Mg$

D $(\rho_{He} - \rho_{air})Vg - Mg$

8 A metal wire is stretched by a varying force F, causing its extension x to increase as shown by the line OPQ on the graph. The force is then gradually reduced to zero and the relation between force and extension is indicated by line QR.



Which of the following correctly represents the work done by the force F in stretching the wire to Q and the corresponding elastic potential energy stored in the wire?

	Work done by the force F in stretching the wire to Q	Elastic potential energy stored in the wire
A	Y+X	X
B	Y	Z
C	Y+Z	Z
D	Y+Z	Y+Z

9 A car moves with the same speed over each of the 4 bridges shown below. In which of the bridges is the force which the car exerts on the bridge the smallest?

A

B

C

D

10 An isolated spherical planet has mass *M* and radius *R*. The acceleration of free fall on the surface of the planet is *g*. What is the work done to move a small mass *m* from the surface to a height 2*R* above the surface?

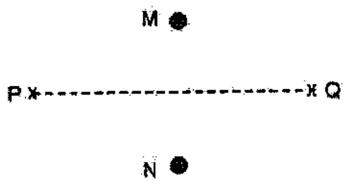
A 0.50 mgR

B 0.67 mgR

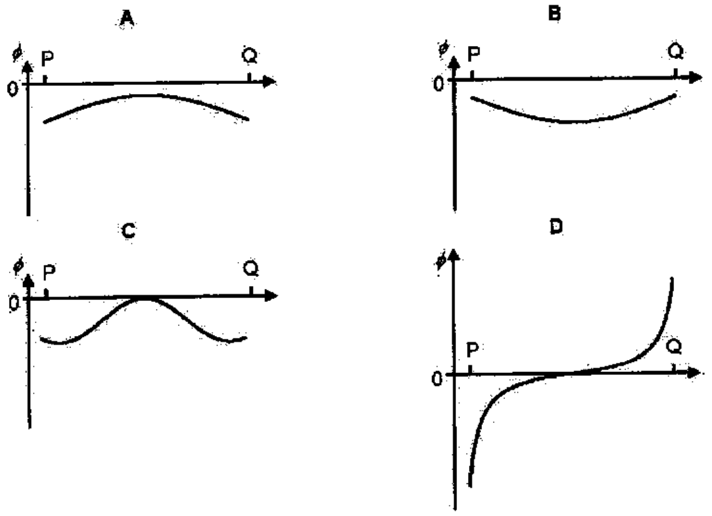
C mgR

D 2.0 mgR

11 M and N are two stars of equal mass. The points P and Q are equidistant from M and N.



Which graph best shows the variation in the gravitational potential ϕ due to the stars between P and Q?



12 A fixed mass of ideal gas has pressure of 1.2×10^5 Pa at 50 °C. After a sudden compression, its pressure increases to 6.0×10^5 Pa at 200 °C.
What is the ratio of the compressed volume to the original volume?

A 0.80 **B** 0.29 **C** 0.14 **D** 0.05

13 Consider the following:

S: 1 kg of ice at 0 °C
L1: 1 kg of water at 20 °C
L2: 1 kg of water at 40 °C
G: 1 kg of steam at 100 °C

Which of the following statements is ***false***?

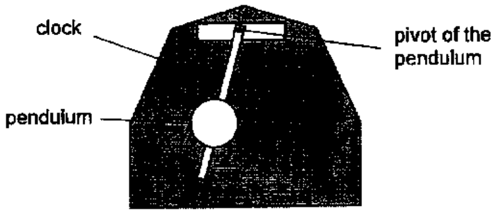
A L2 contains molecules with higher average kinetic energies than L1.

B S has higher potential energy than G.

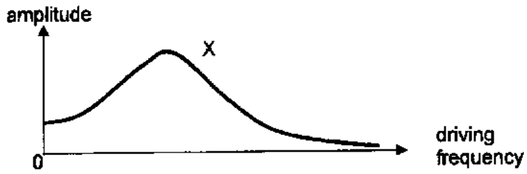
C There is positive work done on G when G condenses.

D The amount of thermal energy S must gain in order to melt is less than the amount of thermal energy G must lose in order to condense.

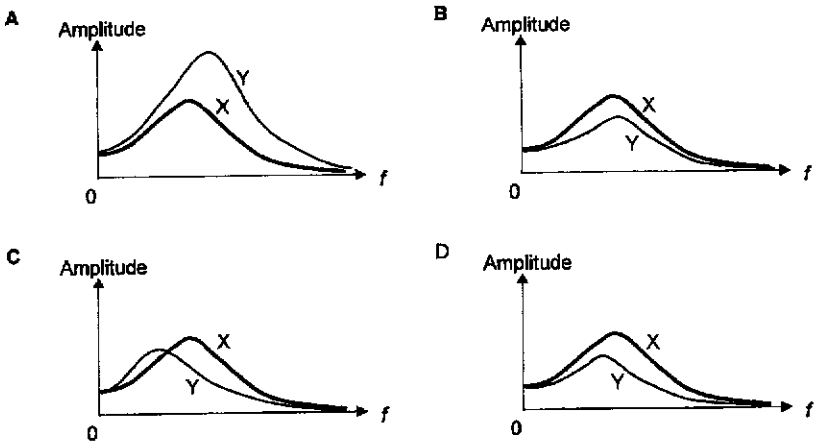
14 The amplitude of oscillations of a pendulum in a clock below is observed to decay with time. To maintain the amplitude, an electric motor is attached to the pivot of the pendulum to drive it periodically.



As the frequency f of the periodic force provided by the motor varies, the amplitude of oscillations vary with f as shown.



Over the years, the friction in the pivot increased.
Which of the following would be the new graph Y showing the variation of amplitude with f?



15 A wave is travelling on a string in the x-direction.

Fig. (a) and Fig. (b) show the variation with distance x of the displacement y of the string.

Fig. (a) corresponds to time t = 0.00 s while Fig. (b) corresponds to time t = 0.20 s.

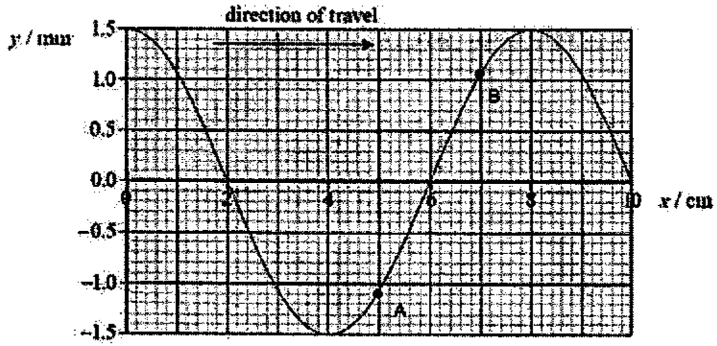


Fig. (a)

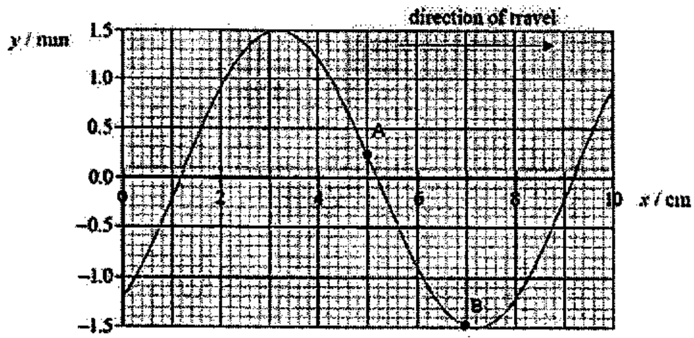


Fig. (b)

Which of the following is correct about the speed of the wave and the phase difference between A and B?

	speed / m s^{-1}	phase difference / radians
A	0.16	0.5π
B	0.16	0.25π
C	6.8	0.5π
D	6.8	0.25π

16 Which region of the electromagnetic spectrum includes waves with a frequency of 10^7 MHz?

A infra-red waves

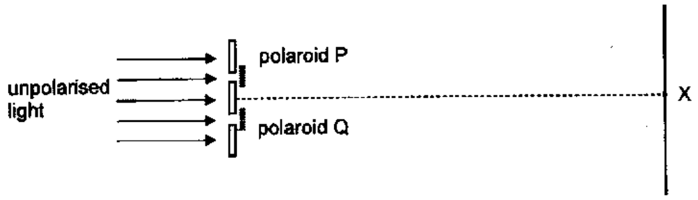
B radio waves

C ultraviolet waves

D X-rays

17 Two sheets of polaroid P and Q are placed in front of a double slit such that their directions of polarization are parallel to each other.

When unpolarised light is incident normally on the double slit, the central bright fringe at X has an amplitude $2A$.



What is the amplitude at X when polaroid P is turned through an angle of 60°?

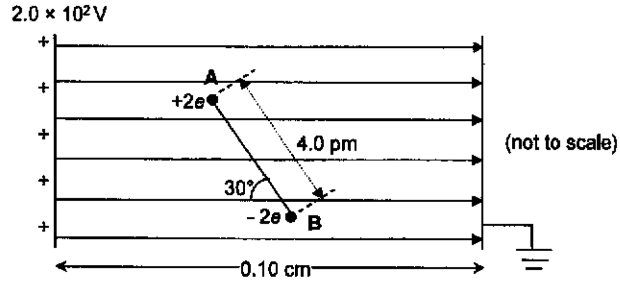
A $0.5A$ **B** $1.5A$ **C** $1.7A$ **D** $2A$

18 A parallel beam of monochromatic light of wavelength λ is incident normally on a diffraction grating. The angle between the directions of the two second-order diffracted beams is θ.

What is the spacing of the lines on the grating?

A $\dfrac{\lambda}{\sin\theta}$ **B** $\dfrac{\lambda}{\sin\left(\frac{\theta}{2}\right)}$ **C** $\dfrac{2\lambda}{\sin\theta}$ **D** $\dfrac{2\lambda}{\sin\left(\frac{\theta}{2}\right)}$

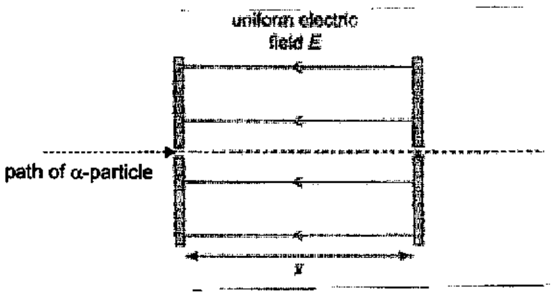
19 Two ions **A** and **B**, at a distance of 4.0 pm apart, are linked to form a molecule. They are situated between a pair of charged parallel plates placed a distance of 0.10 cm apart. The left plate has a potential of 2.0×10^2 V and the right plate is earthed. The line joining **A** and **B** is at an angle of 30° to the direction of the electric field as shown in the diagram below.



What is the torque on the molecule **AB**?

A 1.3×10^{-25} N m **B** 2.2×10^{-25} N m **C** 2.6×10^{-25} N m **D** 5.1×10^{-25} N m

20 An alpha particle travels through a uniform electric field of field strength E. It enters the field with velocity v and then travels a distance x in a direction opposite to the field, as shown.



Given that e is the elementary charge, u is the unified atomic mass constant.
What will be the speed of the alpha particle when it leaves the field?

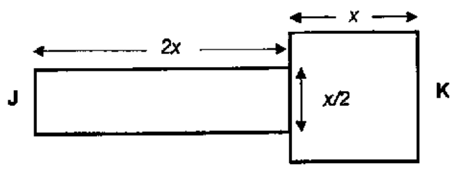
A $v-\sqrt{\dfrac{eEx}{2u}}$

B $\sqrt{v^2-\dfrac{eEx}{2u}}$

C $v-\sqrt{\dfrac{eEx}{u}}$

D $\sqrt{v^2-\dfrac{eEx}{u}}$

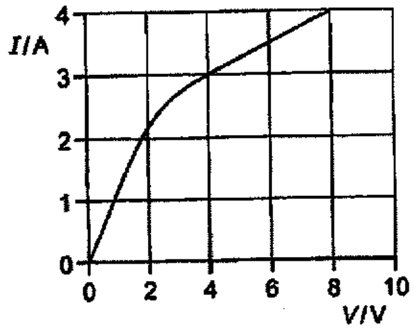
21 A thin rectangular sheet of metal of uniform thickness and of length $2x$ and width $\frac{x}{2}$ is connected to another square sheet of the same metal of the same thickness, which has a resistance of 8.0 Ω measured between opposite edges.



What is the resistance between edges J and K?

A 6.4 Ω **B** 16 Ω **C** 32 Ω **D** 40 Ω

22 The graph plots current I against potential difference V for a filament lamp.



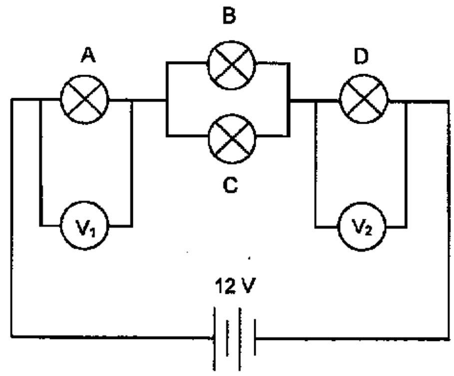
What are the correct resistance values at 1 V and 6 V potential difference?

	resistance at 1 V	resistance at 6 V
A	less than 1.0 Ω	1.7 Ω
B	greater than 1.0 Ω	1.7 Ω
C	less than 1.0 Ω	4.0 Ω
D	greater than 1.0 Ω	4.0 Ω

23 A cell of e.m.f. 12 V is connected across four similar bulbs A, B, C and D.

The bulb D has a broken filament.

Voltmeters V_1 and V_2 of infinite resistance are placed in the circuit as shown below.



Which of the following correctly shows the voltmeter readings?

	Voltmeter V_1 / V	Voltmeter V_2 / V
A	0	0
B	0	12
C	12	0
D	8	4

24

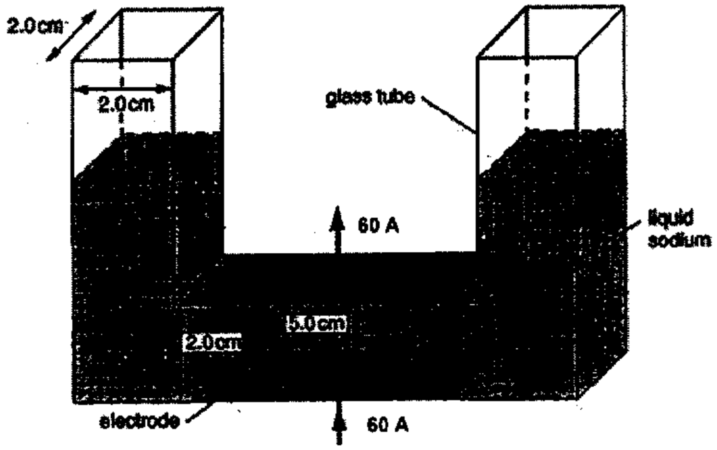


Fig. a

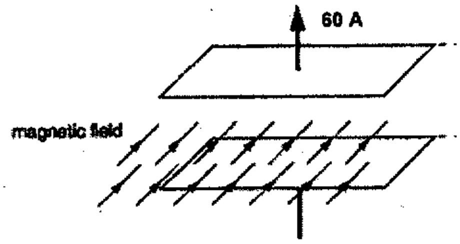


Fig. b

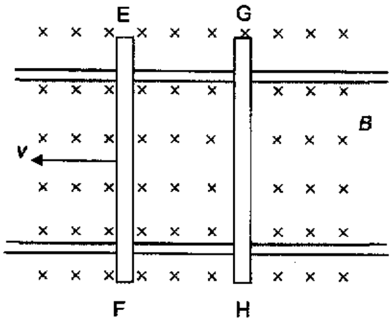
The U-tube shown above contains liquid sodium of density 960 kg m^{-3}. Electrodes are set into the upper and lower faces of the horizontal section and a current of 60 A is sent through the liquid as shown in Fig. a.

When a uniform magnetic field is applied as shown in Fig. b, the liquid in the left arm rises by 1.0 cm while the liquid in the right arm lowers by 1.0 cm.

What is the magnetic flux density of the applied magnetic field?

A 0.013 T **B** 0.025 T **C** 0.031 T **D** 0.063 T

25 Two conducting rods EF and GH can slide along two parallel copper bars in a uniform magnetic field B perpendicular to the plane as shown.



If rod EF is given an initial speed v to move to the left, rod GH will

A move to the right.

B move to the left.

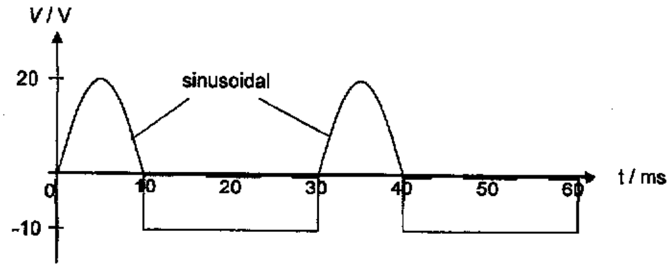
C move to the right first, then to the left.

D move to the left first, then to the right.

26 A rectangle coil of 800 turns has an area of 0.050 m². It is placed at right angles to a magnetic field of flux density 4.0×10^{-5} T. It is then rotated through 180° in 0.20 s. The average emf induced in the coil is

A 0.000 V **B** 0.016 V **C** 0.025 V **D** 0.046 V

27 An alternating voltage is connected to a resistor of resistance 5.0 Ω.



What is the mean power dissipated by the resistor?

A 16 W **B** 27 W **C** 120 W **D** 800 W

28 In an experiment to demonstrate the photoelectric effect, light of intensity L and frequency f is incident on a metal surface. The maximum photoelectric current is I and the stopping potential is V_s.

What change, if any, will occur in the maximum photoelectric current and the stopping potential if light of the same intensity L but of frequency $2f$ is incident on the surface?

	Maximum photoelectric current	**Stopping potential**
A	I	greater than $2V_s$
B	less than I	greater than $2V_s$
C	I	equal to $2V_s$
D	less than I	equal to $2V_s$

29 Which of the following statements is ***incorrect***?

In an alpha decay of a stationary nucleus,

A the daughter nucleus and the alpha particle always move off in opposite directions.

B total kinetic energy is not conserved.

C the parent nucleus has a larger mass defect than the daughter nucleus.

D the parent nucleus has a larger binding energy per nucleon than the daughter nucleus.

30 The table below shows the count-rate recorded by a Geiger-Müller counter at a point in a laboratory at various times, with and without a radioactive source in position.

time / days	count rate / s^{-1}	
	with source	*without source*
10	60	20
30	30	20
90	20	20

From these readings, what is the half-life of the source?

A 10 days **B** 15 days **C** 20 days **D** 30 days

END OF PAPER

HWA CHONG INSTITUTION
JC2 Preliminary Examination
Higher 2

CANDIDATE NAME		CT GROUP	18S
CENTRE NUMBER		INDEX NUMBER	

PHYSICS

9749/02

Paper 2 Structured Questions

19 September 2019

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

INSTRUCTIONS TO CANDIDATES

Write your **name, CT class** and **tutor's name** 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.

Do not use staples, paperclips, highlighters, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Answer **all** questions.

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		
P1 (15%)		30
Paper 2		
1		9
2		10
3		10
4		12
5		10
6		10
7		19
Deductions		
P2 (30%)		80

This paper consists of **21** printed pages.

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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}

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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	$B = \frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_o nI$
radioactive decay	$x = x_o \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

1 A large metal ball is hung from a crane by means of a cable of length 5.8 m as shown in Fig. 1.1.

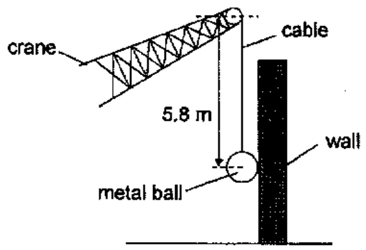


Fig. 1.1

To knock down a wall, the metal ball of mass 350 kg is pulled away from the wall while keeping the cable taut, and then released. The crane does not move. Fig. 1.2 shows the variation with time t of the speed v of the ball after release.

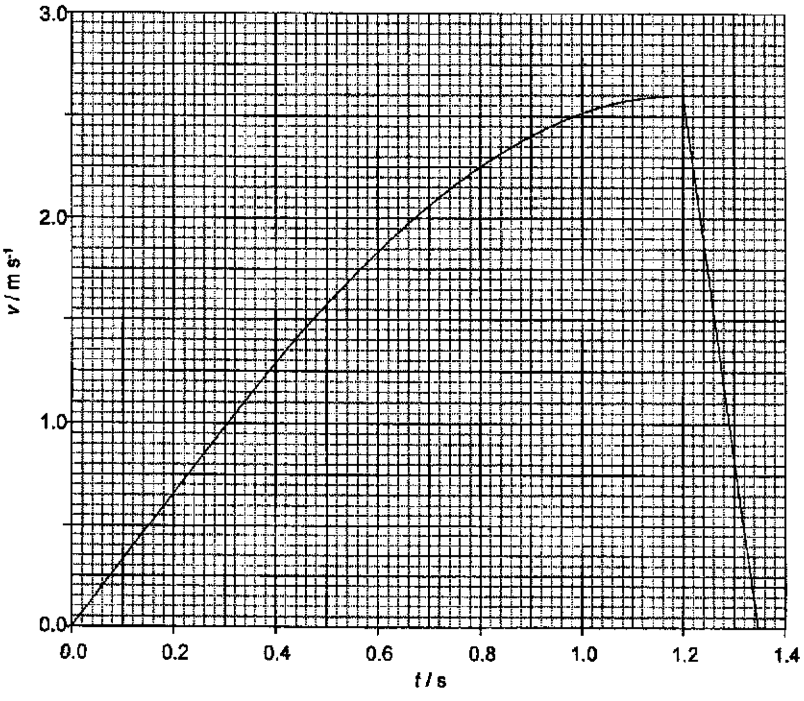


Fig. 1.2

The ball contacts the wall when the cable from the crane is vertical.

(a) At the instant just before the ball hits the wall,

(i) explain why the tension in the cable is not equal to the weight of the ball;

....

.... [1]

(ii) by reference to Fig. 1.2, estimate the tension in the cable.

tension = ... N [2]

(b) For the collision between the ball and the wall, determine the average force exerted by the ball on the wall.

average force exerted by the ball on the wall = ... N [2]

(c) The metal ball has lost momentum.
State the principle of conservation of linear momentum and discuss whether it applies to this situation.

....

....

....

.... [2]

(d) During the impact of the ball with the wall, 12% of the total kinetic energy of the ball is converted into thermal energy in the ball. The metal of the ball has specific heat capacity 450 J kg^{-1} K^{-1}.
Determine the average rise in temperature of the ball as a result of colliding with the wall.

average rise in temperature = ...°C [2]

2 (a) Explain what is meant by *upthrust*.

....

.... [1]

(b) Before a small balloon is inflated, its mass is 1.30 g as recorded on an electronic mass balance. The balloon is inflated with air so that it is spherical in shape with a diameter of 22.0 cm.

(i) The density of air is 1.21 kg m^{-3}. Calculate the mass of air displaced by the balloon.

mass of air displaced = ... g [2]

(ii) The inflated balloon gives reading of 1.55 g when placed on the balance. Calculate the mass of air in the balloon.

mass of air in balloon = ... g [2]

(iii) Explain why the value in **(b)(ii)** is larger than the value in **(b)(i)**.

....

.... [1]

(c) A 2.10 g nut is now tied to the balloon with a light cotton thread. The balloon is dropped from a height of 4.00 m.

(i) Calculate the acceleration of the balloon and nut at the start of their descent.

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

(ii) Explain why the acceleration will approach zero as the balloon descends.

....

....

....

.... [2]

3 (a) Explain what is meant by a *polarised light*.

....

....

....[1]

(b) A beam of polarised light of intensity I_0 incident on polariser A as shown in Fig. 3.1.

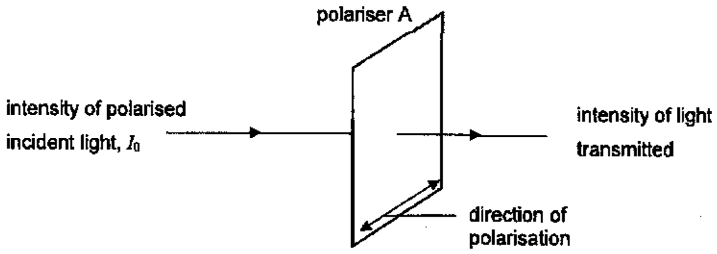


Fig. 3.1

Polariser A is arranged such that the intensity of light transmitted through it is ***zero***.

(i) With reference to the arrangement in Fig. 3.1, by placing another polariser X before polariser A with both planes in parallel, the intensity of light transmitted may now be greater than zero. Explain why this is so.

....

....

....

....

.... [2]

(ii) Initially, the directions of polarisation of polariser X and A are parallel.
Polariser X is then rotated about the axis of the light beam while keeping the planes of the polarisers parallel.

The angle between the direction of polarisation of polariser X and of polariser A is θ.

1. Complete the table below. You may use the space below for your working. [2]

θ	Intensity of light transmitted through polariser A (in terms of I_o)
0°	0
45°	
60°	

2. Polariser X is rotated through 360° about the axis of the light beam.
Sketch on the axes of Fig. 3.2 the variation with the angle of rotation θ of the intensity I of the light after passing through polariser A. [2]

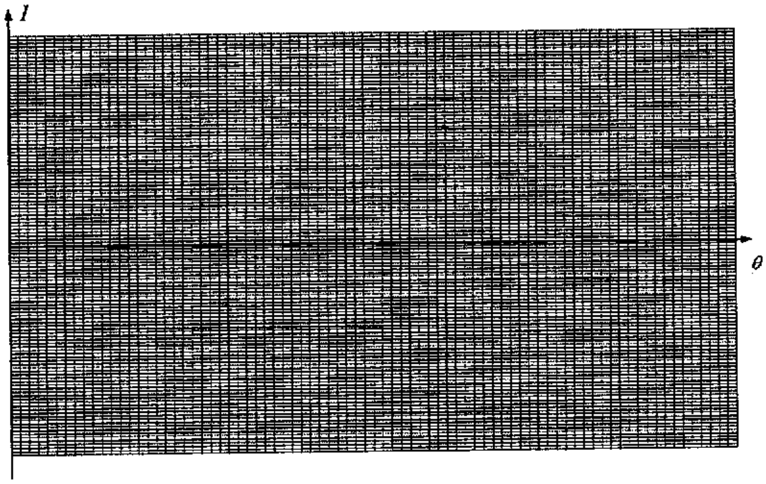


Fig. 3.2

(c) A speaker of a public address system radiates sound uniformly in all directions.
The intensity of the sound wave detected by a microphone located 78.0 m away from the speaker is 0.026 Wm^{-2}.

(i) Determine the detected intensity if the same microphone is moved to a position 300.0 m away from the speaker.

intensity = ... $W m^{-2}$ [2]

(ii) Find the power received at the position 300.0 m by the microphone diaphragm which has an area of 3.20 cm^2.

power = ... W [1]

4 (a) (i) Define the term *electric potential.*

....

....

.... [2]

(ii) Write down the relationship between electric field strength and electric potential.

....

.... [1]

(b) Fig. 4.1 is a map of equipotential lines drawn to scale. The potentials in the region mapped are set up by a system of small stationary charged spheres in a plane, three of which carrying charge of q_1, q_2 and q_3 are shown. All the charged spheres are fixed in their locations.

Potential values are given in volts (V). Note the signs (+/–).

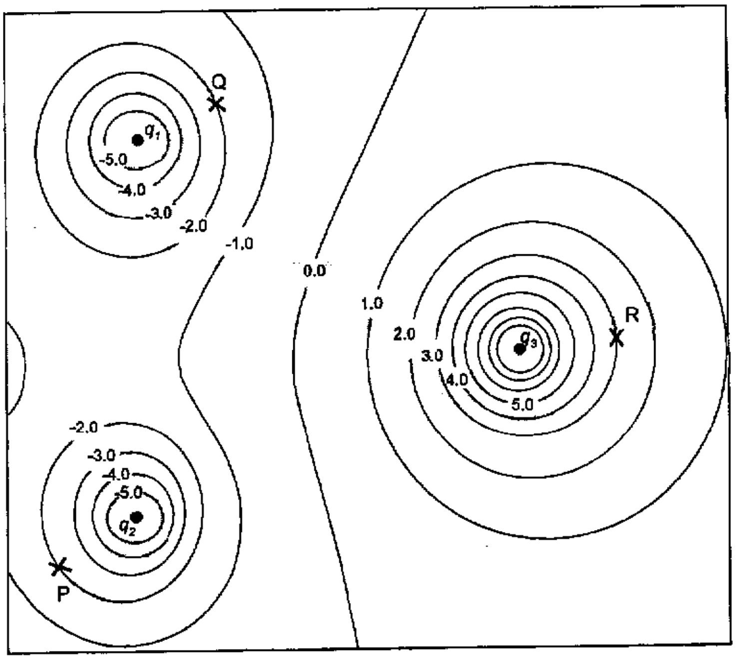


Fig. 4.1

Based on Fig. 4.1, state with reasons whether the charge q_1, q_2 and q_3 are positive or negative.

....

....

....

.... [2]

(c) **(i)** Draw on Fig. 4.1 an arrow at P to indicate the direction of the electric field strength at P. Label the arrow as *E*. [1]

(ii) Estimate the magnitude of electric field strength at point P.

magnitude of electric field strength = ... Vm^{-1} [1]

(d) Calculate the work required to move an electron from point P to point R without a gain in kinetic energy.

work = ... J [2]

(e) Sketch on Fig. 4.2 the variation of the electric field strength E along a straight line from the sphere carrying charge q_1 to the sphere carrying charge q_3.

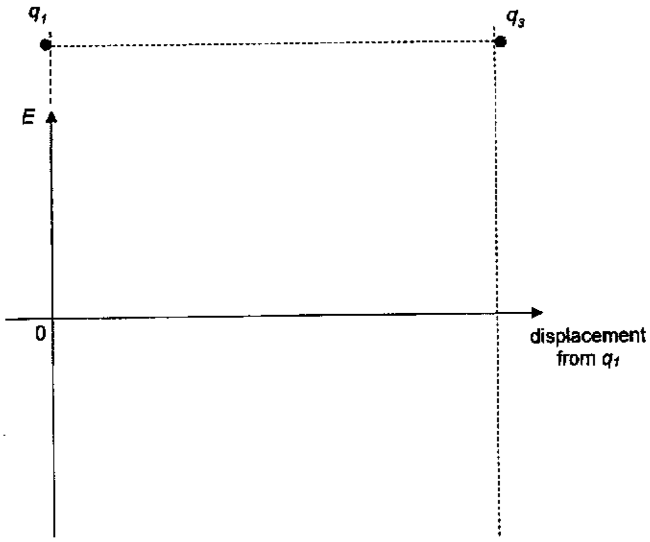


Fig. 4.2

[3]

5 Fig.5 illustrates the connection between the copper and filament wires of a lamp. The diameter of the copper wire is 1.50 mm and the diameter of the filament wire is 0.020 mm.

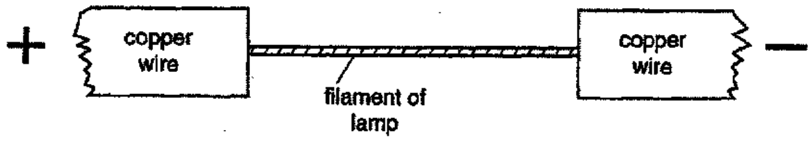


Fig. 5

The number density of charge carriers in copper is 8.49×10^{28} m^{-3}, and the number density of charge carriers in tungsten is 3.40×10^{28} m^{-3}. The uncoiled filament wire is 1.5 m long and has a resistance of 300 Ω.

(a) State and explain whether the current in the copper wire and tungsten filament are the same.

....

....

....[1]

(b) Calculate the resistivity of the filament wire.

resistivity = ... Ω m [2]

(c) **(i)** The drift velocity of electrons in the copper wire is 0.021×10^{-3} m s^{-1}.
Determine the drift velocity of electrons in the tungsten filament.

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

(ii) Use your answers to **(c)(i)** to explain why the filament of the lamp gets hot but the copper leads stay relatively cold.

....

....

....

....

....

.... [2]

(iii) The filament wire is now replaced with another tungsten wire of the same length, but twice its diameter. The potential difference (p.d.) across the wire is unchanged. The temperature of both wires is the same.

Without any calculations, state and explain the change, if any, to the drift velocity of the charge carriers in the second filament wire.

....

....

....

....

....

.... [2]

6 (a) A battery B, a variable resistor R and a uniform resistance wire XY are connected in series, as shown in Fig. 6.1.

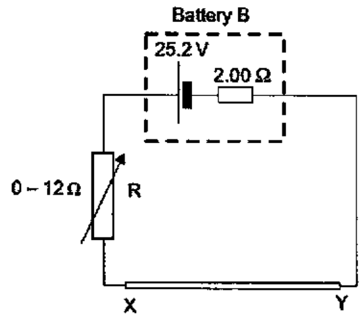


Fig. 6.1

Battery B has electromotive force (e.m.f.) 25.2 V and internal resistance 2.00 Ω. Wire XY is made of constantan and has resistance 40.0 Ω.

(i) The resistance of R is varied from 0.0 to 12.0 Ω.
Describe and explain the variation in the terminal potential difference (p.d.) across B.
Numerical values are not required.

....

....

....

....

.... [3]

(ii) The resistance of R is set at 4.00 Ω. Calculate the terminal p.d. across B.

p.d. = ... V [2]

(b) A thermistor T is connected in series with a resistor of resistance 1.50 kΩ and a battery, as shown in Fig. 6.2. The e.m.f. of the battery is 6.00 V and its internal resistance is negligible.

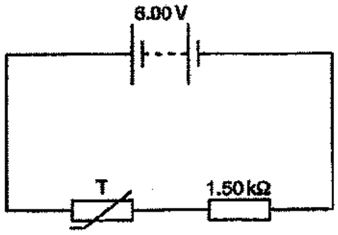


Fig 6.2

The variation with temperature θ of the resistance R of the thermistor is shown in Fig. 6.3.

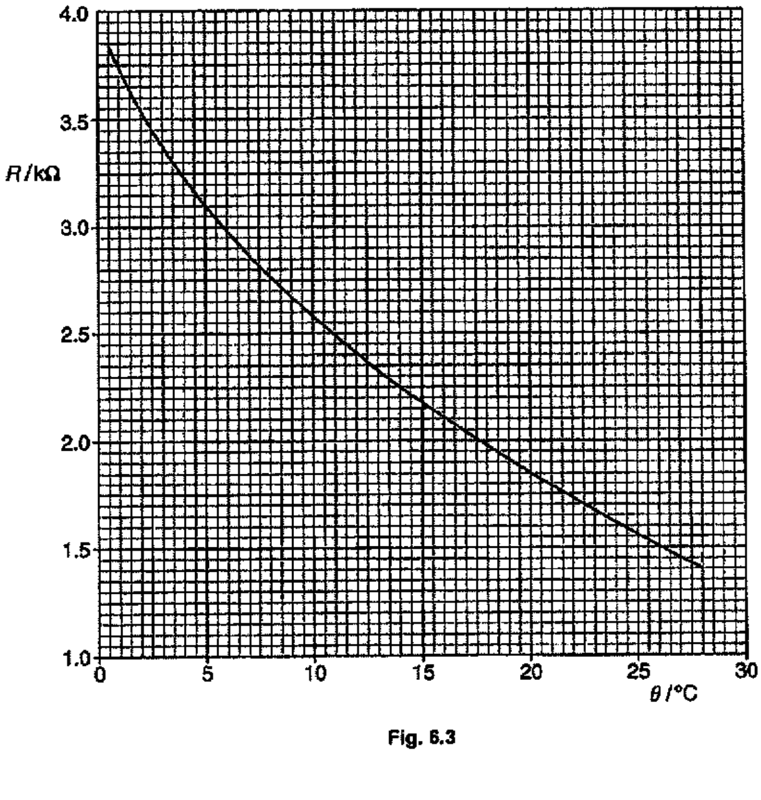


Fig. 6.3

(i) At one temperature *t* of the thermistor, the current in the circuit is 1.60 mA. Determine the temperature *t*.

t = ...°C [3]

(ii) Determine the p.d. across the fixed resistor when the temperature is 5 °C.

p.d. = ...V [2]

7 Read the following article then answer the questions that follow.

Compton Scattering

Besides the photoelectric effect, a number of other experiments were carried out in the early twentieth century which also supported the photon theory. One of these was the Compton effect named after its discoverer. Compton scattered X-rays from various materials. He found that the scattered light had a slightly longer wavelength than the incident light. He was able to explain this result based on the quantum theory of light. Light is seen as particles colliding with the electrons of the material (Fig. 7.1).

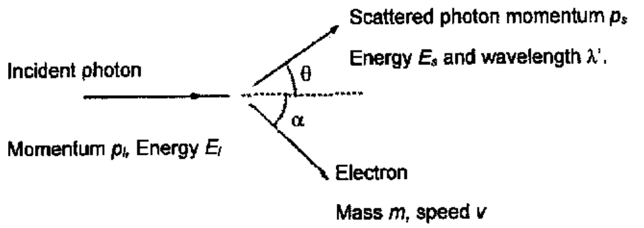


Fig 7.1

The incident photon has momentum p_i and energy E_i The photon is scattered through an angle θ and, after scattering, has momentum p_s and energy E_s. The electron of mass m which was originally stationary, moves off with speed v at an angle α to the original direction of the incident photon.

Compton applied the laws of conservation of energy and momentum to the collision and obtained the following equation for the wavelength of the scattered photons.

$$\lambda' = \lambda + \frac{h}{mc}(1-\cos\theta)$$

where m is the mass of the electron. The quantity $\frac{h}{mc}$ has the dimension of length and is called the Compton wavelength of the electron, whose accepted value is 2.43×10^{-12} m.

The predicted wavelength of the scattered photons depends on the angle θ at which they are detected. Compton's measurements of 1923 were consistent with this formula.

In an experiment to provide evidence to justify Compton's theory, measurements were made of the wavelength λ of the incident photon, the wavelength λ' of the scattered photon and the angle θ of scattering. Some data from this experiment are given in Fig. 7.2.

λ / 10^{-12} m	λ' / 10^{-12} m	θ
191.92	193.27	59°
965.04	966.84	75°

Fig. 7.2

The wave theory of light does not predict such a shift: an incoming EM wave of frequency f should set electrons into oscillation at frequency f, and such oscillating electrons would re-emit EM waves of this same frequency. Hence Compton effect adds to the firm experimental foundation for the photon theory of light.

(a) Explain what is meant by a *photon*.

....

.... [1]

(b) The inelastic collision between a photon and a stationary electron may be represented by Fig. 7.1.

(i) Write down equations (in terms of p_i, p_s E_i, E_s, m, v, θ and α) that represent

1. the conservation of energy. [1]

2. the conservation of momentum along the direction of the incident photon. [1]

(ii) Using quantum theory of light, explain why a scattered photon has a wavelength longer than that of the incident photon.

....

....

....

....

.... [2]

(c) In the Compton scattering experiment, the uncertainty in the measurement of θ is ± 5°. Determine the value of cos θ with its uncertainty, for the angle θ = 75° ± 5°.

cos θ = ... ± .... [2]

(d) Given that $\Delta\lambda = \lambda' - \lambda$, additional data for the variation of $\Delta\lambda$ against cos θ are shown in Fig. 7.3.

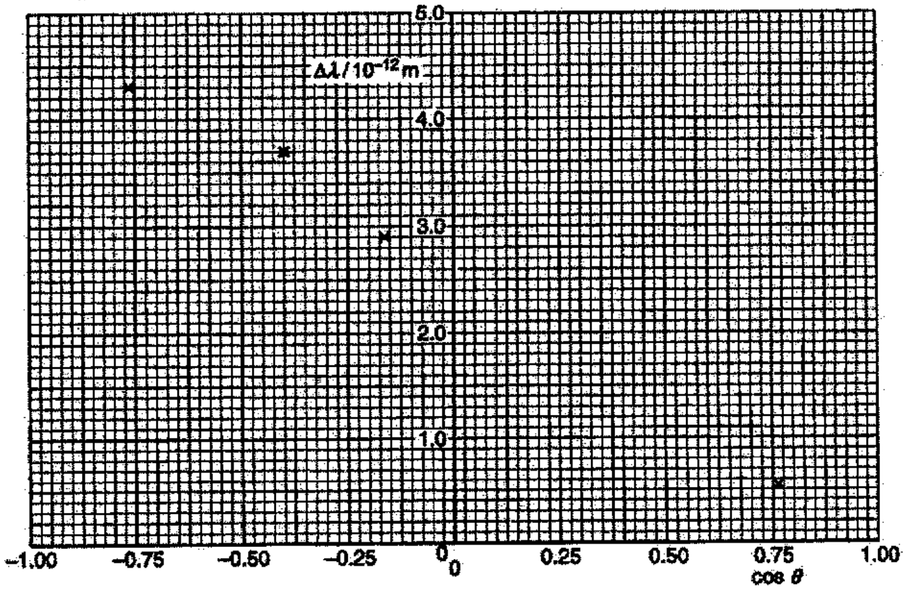


Fig. 7.3

(i) Plot the data given in Fig 7.2 on Fig 7.3. [3]

(ii) Draw the best-fit line for the points on Fig. 7.3. [1]

(iii) State and explain one way to determine the Compton's wavelength from Fig. 7.3.

....

....

....

.... [2]

(iv) Determine the Compton's wavelength using the method described in **d (iii)**.

Compton's wavelength = ... [2]

(e) In another Compton scattering experiment, 19.0 keV X-ray photons scatter off a carbon target.

(i) Find the wavelength of the scattered photon if the scattered angle is 30°.

wavelength = ... [2]

(ii) For a carbon atom, the binding energy of an electron is of the order of a few eV.

Compton's theory assumes that the electrons are not bound in the atoms but are free. Suggest whether this assumption is justified.

....

....

....

.... [2]

HWA CHONG INSTITUTION
JC2 Preliminary Examination
Higher 2

CANDIDATE NAME		**CT GROUP**	18S
CENTRE NUMBER		**INDEX NUMBER**	

PHYSICS

9749/03

Paper 3 Longer Structured Questions

24 September 2019

2 hours

Candidates answer on the Question Paper.
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.
Do not use staples, paperclips, highlighters, glue or correction fluid.

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		11
3		8
4		8
5		8
6		9
7		8
SECTION B		
8		20
9		20
Deductions		
Total (35%)		80

This document consists of 28 printed pages.

Data

speed of light in free space, $c = 3.00 \times 10^{8}$ m s^{-1}

permeability of free space, $\mu_o = 4\pi \times 10^{-7}$ H m^{-1}

permittivity of free space, $\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1} $\approx (1/(36\pi)) \times 10^{-9}$ 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	$\phi = -\frac{Gm}{r}$
temperature	T/K = T/°C + 273.15
pressure of an ideal gas	$P = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean 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	$B = \frac{\mu_o NI}{2r}$
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) A fixed amount of ideal monatomic gas is contained in a cylinder as shown in Fig. 1.1.

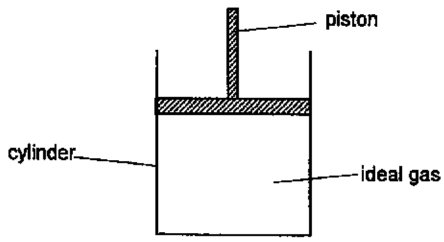


Fig. 1.1

The cylinder is fitted with a movable piston which is light and frictionless. When the piston is moved down to compress the gas, both the temperature and pressure of the gas are observed to increase.

Use the kinetic theory of gases to explain,

(i) the increase in temperature.

....

....

.... [1]

(ii) the increase in pressure.

....

....

....

.... [2]

(b) The gas in the cylinder is made to undergo a cycle of changes A → B → C→ A, as shown in Fig. 1.2.

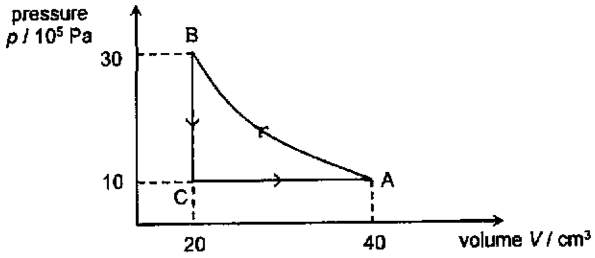


Fig. 1.2

(i) Show that the increase in internal energy of the gas during the change A → B is 30 J.

[2]

(ii) Calculate the heat supplied to the gas during the change B → C → A.

heat supplied = ... J [3]

2 A light spring hangs from a fixed point. A 0.850 kg mass is then attached to the free end of the spring, which eventually comes to a rest at an equilibrium position 0.220 m below its original position, as shown in Fig. 2.1.

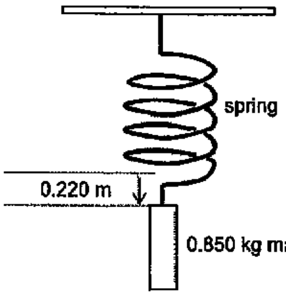


Fig. 2.1

(a) Show that the force constant, k is 37.9 N m^{-1}.

[1]

(b) The mass is pulled vertically down a distance of 0.110 m from its equilibrium position. When the mass is released, it performs a simple harmonic motion.

(i) Calculate the acceleration of the mass just after it is released at the bottom.

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

(ii) Calculate the frequency of oscillation.

frequency = ... Hz [2]

(iii) On the axes of Fig. 2.2, sketch a graph to show the variation of the velocity v of the mass with its vertical displacement x.

Label the axes with appropriate values.

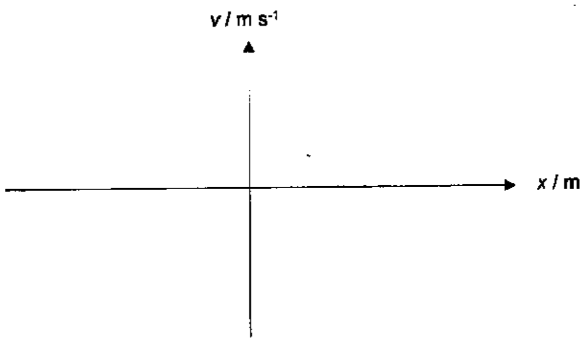
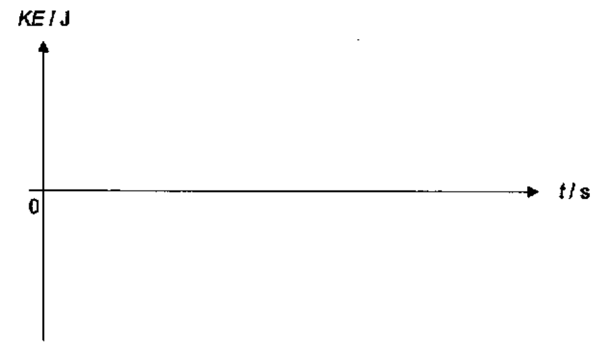


Fig. 2.2

[2]

(iv) On the axes of Fig. 2.3, sketch a graph to show the variation with time of the kinetic energy of the mass for one complete oscillation after the mass was released at the bottom.

Include appropriate values on the axes.



[2]

Fig. 2.3

(v) If the system undergoes light damping, sketch on Fig. 2.2 the velocity-displacement graph expected. Assume the oscillation starts at $x = +x_0$. [2]

3 Fig. 3.1 shows the arrangement of a mass spectrometer, which is an instrument to measure the masses of ions. An ion of mass m and charge $+q$ from the ion source S is accelerated from rest through a potential difference V. The ion then passes through a slit into a region of uniform magnetic field of flux density B, which is directed perpendicularly out of the paper.

In the field, it moves in a semicircle, striking and producing a spot on a photographic plate at a distance x from the entry slit.

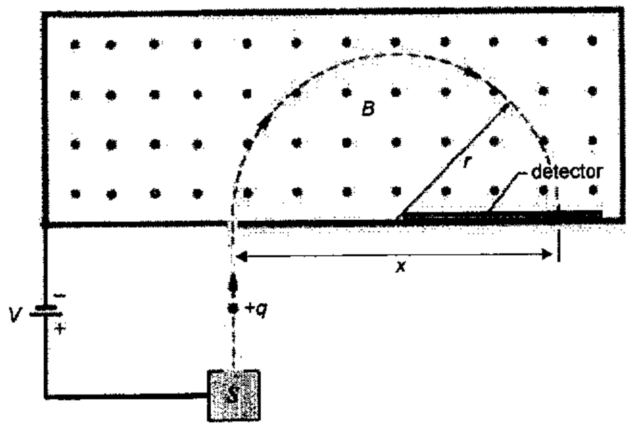


Fig. 3.1

(a) Show that the ion enters the magnetic field with a velocity, $v = \sqrt{\dfrac{2qV}{m}}$.

[1]

(b) Describe and explain the effects of the magnetic field on the velocity of the ion upon its entry into the magnetic field.

....

....

....

.... [2]

(c) Two singly and positively charged ions are accelerated through a potential difference V of 4.0 kV and enter the magnetic field of flux density B of 0.50 T.

If the masses of the ions are 12u and 14u, calculate the distance Δx between the two spots they make on the photographic plate.

Δx = ... m [3]

(d) If an electron were to be introduced into the mass spectrometer, briefly describe and explain, if any, changes to the path if the magnitude of the accelerating potential and the magnetic field remained unchanged.

....

....

....

....

.... [2]

4 Fig. 4.1 shows a large rectangular coil used in a power station generator. The coil, with 38 turns, each 2.0 m long and 1.2 m wide, is rotating at 50 revolutions per second in a magnetic field of flux density 0.29 T.

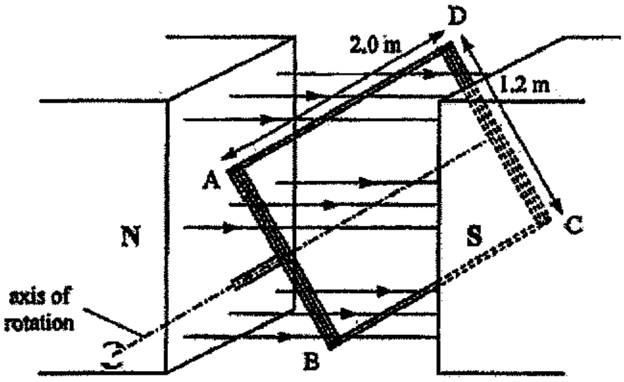


Fig. 4.1

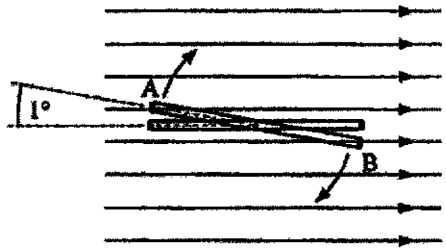


Fig. 4.2

Fig. 4.2 shows the coil from the side view, near the time when maximum e.m.f. occurs.

Consider the coil rotating through an angle of 1°.

(a) Show that the time taken for it to rotate 1.0° is 5.6×10^{-5} s.

[1]

(b) Determine the change in flux linkage of the coil in 5.6×10^{-5} s.

change in flux linkage = ... Wb turns [2]

(c) Hence, determine the e.m.f. generated by the coil during the 5.6×10^{-5} s.

e.m.f. = ... kV [1]

(d) State the direction of the current induced in side AD as a result of this e.m.f. Explain your answer using the laws of electromagnetic induction.

....

....

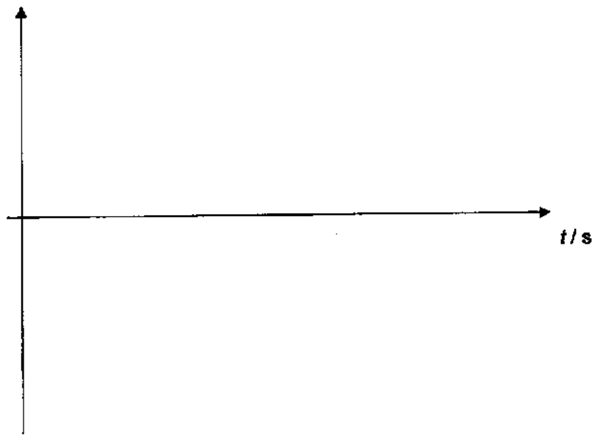
....

.... [2]

(e) Given that at time $t = 0$ the coil is parallel to the plane of the magnetic field, sketch on the same axes, the variation with time in one cycle of the

1. magnetic flux linkage,
2. induced current

Label your graphs (1) and (2) clearly.



[2]

5 **(a)** The variation of an alternating voltage V_P in volts with time t in seconds is given by

$$V_P = 170 \sin(314t)$$

Determine

(i) the r.m.s. potential difference $V_{r.m.s.}$

$V_{r.m.s.}$ = ... V [1]

(ii) the period, T of the voltage supply.

T = ... s [1]

(b) The alternating voltage V_P is connected to the primary coil of a transformer as shown in Fig. 5.1.

An electric heater with resistance 130 Ω is connected to the secondary coil of the transformer.

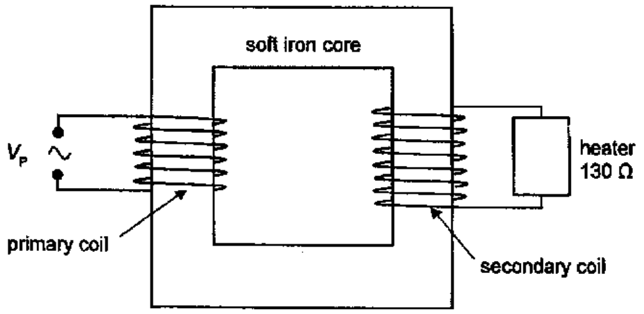


Fig. 5.1

The primary coil consists of 2000 turns and the secondary coil consists of 3500 turns.

(i) Determine peak potential difference, V_S of the secondary coil.

V_S = ... V [2]

(ii) Determine the peak current, I_P in the primary coil.

I_P = ... A [2]

(c) A diode and another identical heater are connected to the secondary coil as shown in Fig. 5.2.

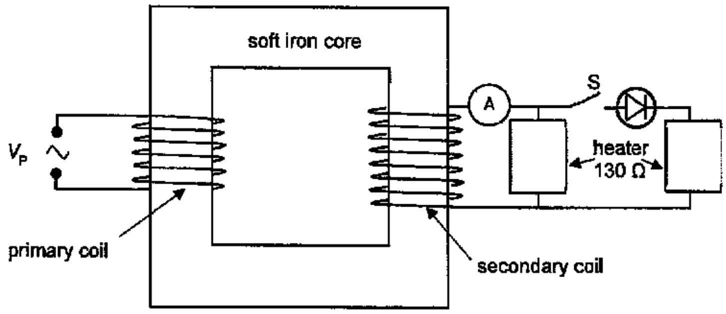


Fig. 5.2

Sketch on the axes of Fig. 5.3, the variation with time of the current I in the secondary coil when switch S is closed. Label the axes with appropriate values, Include on your graph a time equal to two periods of the alternating potential difference.

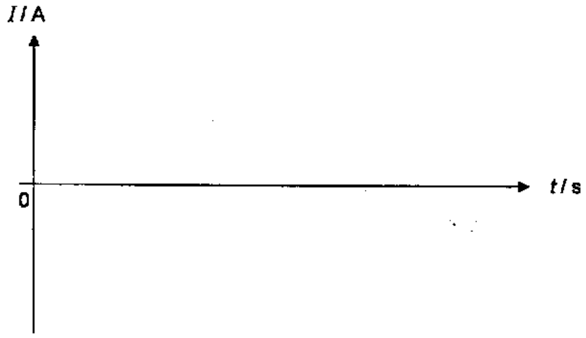


Fig. 5.3

[2]

6 Fig 6.1 shows some of the electron energy levels in an isolated atom of lithium.

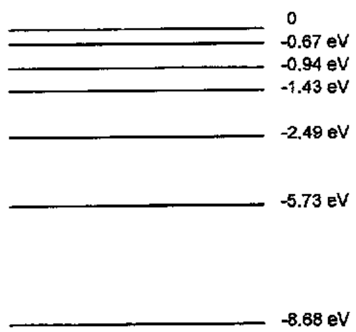


Fig. 6.1

The outer electron of a lithium atom is in the lowest energy level shown.

Electrons of energy 7.50 eV are directed at a discharge tube of lithium gas.

(a) Calculate the de Broglie wavelength of the electrons directed at the gas.

de Broglie wavelength = ... m [2]

(b) State the range of energy of the recoiling electrons.

.... eV ≤ energy ≤ .... eV [1]

(c) Sketch on Fig. 6.1 the transitions that represent the photons produced from the lithium gas, having electrons of 7.50 eV directed at it. [1]

(d) Calculate the wavelength of the most energetic photon produced and state the region of electromagnetic spectrum to which it belongs.

wavelength = ... m

region = ... [3]

(e) The ionization energy of lithium atom is 8.68 eV. Suggest and explain whether the work function of lithium metal is larger or smaller than 8.68 eV.

....

....

....

.... [2]

7 The radioactive isotope strontium-90 decays into yttrium-90, emitting a beta-particle. Strontium-90 has a half-life of 28.0 years and the energy produced in each decay is 0.546 MeV.

(a) The beta-particles produced from the decay of strontium-90 are found to possess a range of kinetic energies as shown in Fig. 7.1.

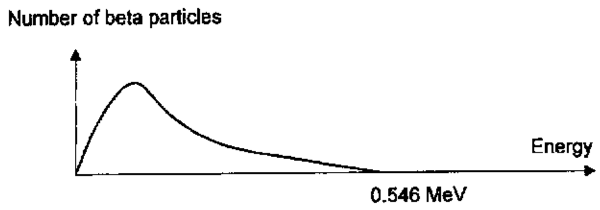


Fig. 7.1

Explain why this suggests an extra particle is emitted.

....

....

....

....

.... [2]

(b) **(i)** Explain what is meant by half-life.

....

.... [1]

(ii) Determine the decay constant, λ of Strontium-90,

λ = ... s^{-1} [2]

(iii) Determine the mass of strontium-90 present, for an activity of 6.40×10^{8} Bq.

mass = ... g [3]

Section B

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

8 **(a)** State Newton's law of gravitation.

....

....

....

.... [2]

(b) A satellite of mass *m* moving at speed *v* in a circular orbit of radius *r* about the Earth (as shown in Fig. 8.1) behaves as though the Earth's mass *M* were concentrated at its centre.

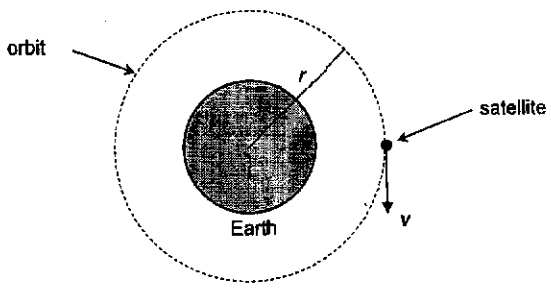


Fig. 8.1 (not drawn to scale)

(i) Show that the satellite's potential energy E_p and kinetic energy E_k are related by the expression $E_p = -2E_k$.

[3]

(ii) Sketch on Fig. 8.2 the variation with orbital radius of the satellite's

1. gravitational potential energy E_p,
2. kinetic energy E_k
3. total energy E_T

[2]

Fig. 8.2

(c) It is given that $r = 6.70\times10^{6}$ m, $m = 1.80\times10^{3}$ kg and $M = 5.98\times10^{24}$ kg.

(i) Calculate the satellite's orbital speed.

orbital speed = ... km h^{-1} [2]

(ii) For the satellite to be geostationary at this orbital radius, it must orbit at a speed of about 487 m s^{-1}. Explain, in terms of centripetal force, why the geostationary orbit is not possible at this orbital radius.

....

....

.... [1]

(d) As a result of atmospheric friction, the radius of the satellite's orbit about the Earth decreases by 0.2% in a week.

(i) State the energy conversion taking place during the orbital decay.

....

....

.... [2]

(ii) Assuming that the orbit remains circular, determine the percentage change in the satellite's total energy in a week. The total energy of the satellite is given by $E_T = -\frac{GMm}{2r}$.

percentage change = ...% [1]

(iii) By considering the satellite's rate of loss of energy and your answer to **(c)(i)**, show that the frictional force acting on the satellite is 0.023 N.

[3]

(e) To counter orbital decay, the satellite carries a small booster motor. The force exerted by the motor is equal to uz where z is the rate at which fuel is burnt (mass per unit time), and u has a value of 2.00×10^3 N s kg^{-1}.

(i) Draw in Fig. 8.3 labelled arrows showing (at this particular instant)

1. the direction of the satellite's change in velocity (label X) and
2. the direction of the force exerted by the booster motor (label Y).

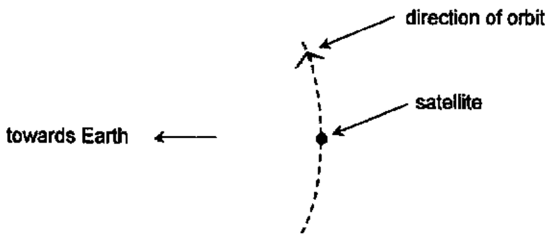


Fig. 8.3

[2]

(ii) Determine the amount of fuel necessary for the satellite to maintain its orbit for 24 hours.

amount of fuel = ...kg [2]

9 (a) State the principle of superposition.

....

....

.... [2]

(b) A stationary wave (in solid line) is produced by the superposition of two progressive waves, P and Q. Fig. 9.1 shows the positions of the stationary wave and one of the two progressive waves, P, at a particular instant in time.

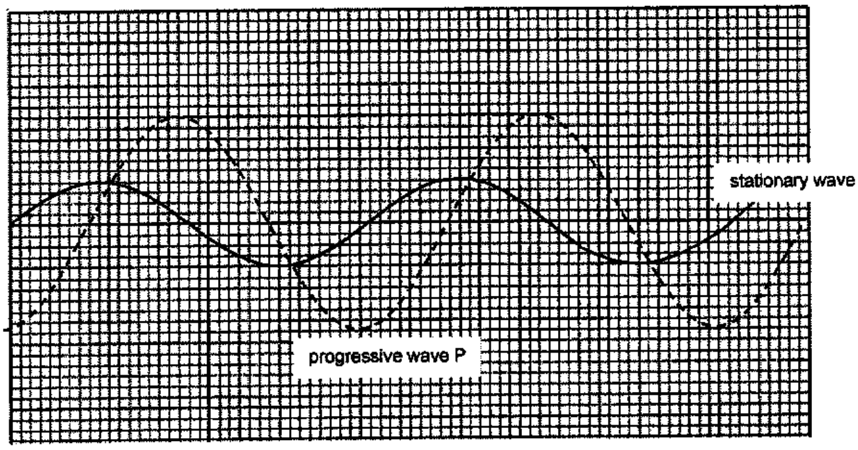


Fig. 9.1

Sketch on Fig. 9.1 progressive wave Q that superposes with progressive wave P to produce the stationary wave shown. You should include at least one complete wavelength in your sketch. [2]

(c) Fig. 9.2 shows an experiment with sound waves.

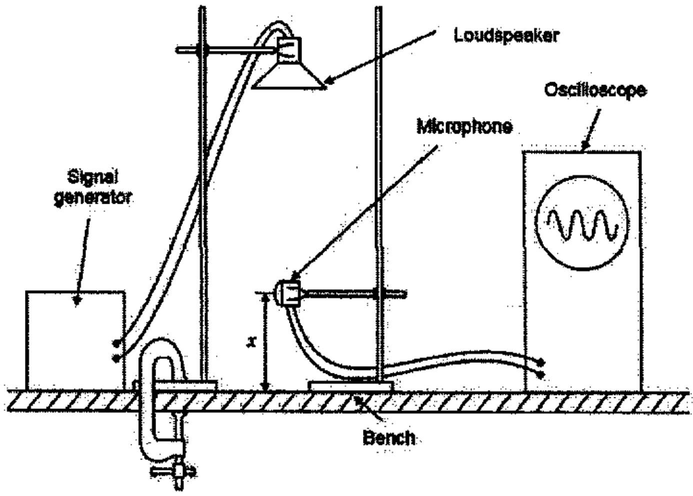


Fig. 9.2

The loudspeaker connected to a signal generator is mounted, pointing towards the bench. The sound is detected by a microphone connected to an oscilloscope. The height of the trace on the oscilloscope is proportional to the amplitude of the sound waves at the microphone.

When the vertical distance x between the microphone and the bench is varied, the amplitude of the sound waves is found to vary as shown in Fig. 9.3.

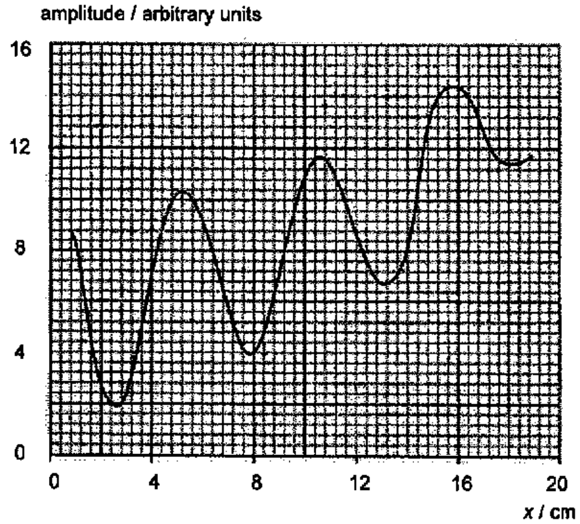


Fig 9.3

(i) Explain the formation of alternating maxima and minima.

....

....

....

....

.... [3]

(ii) Explain why the intensity of the minima increases with *x*.

....

....

....

.... [2]

(iii) The speed of sound is 340 m s^{-1}. Use Fig. 9.3 to calculate the frequency of the waves emitted by the loudspeaker.

frequency = ... Hz [3]

(d) Light of wavelength 650 nm is incident normally on a double slit such that the waves emerge from X and Y in phase, and reach a screen 1.5 m away, as shown in Fig. 9.4.

Fig. 9.4

The variation of intensity with distance along the screen is shown in Fig. 9.5.

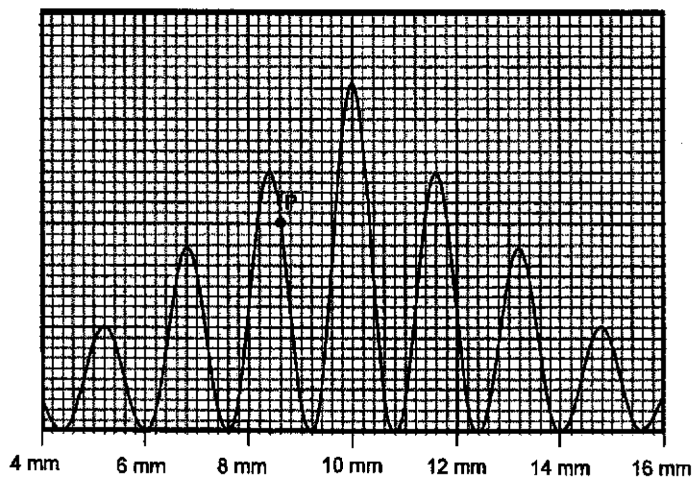


Fig. 9.5

(i) Explain how it can be deduced from Fig. 9.5 that the waves from the two slits are coherent.

.... [1]

(ii) Determine the phase angle between the waves from the slits when the waves meet to produce the intensity at point **P** on the pattern of Fig. 9.5.

phase angle = ... rad [2]

(iii) Calculate the separation *a*, between the slits.

a = ... mm **[2]**

(iv) Given that the 6th order bright fringe is the first missing order due to the diffraction envelope, calculate the width *b*, of each slit.

b = ... mm [3]

END OF PAPER

HWA CHONG INSTITUTION
C2 Preliminary Examination
Higher 2

A

CANDIDATE NAME		CT GROUP	18S
CENTRE NUMBER		INDEX NUMBER	

PHYSICS **9749/04**

Paper 4 Practical **30 August 2019**

Candidates answer on the Question Paper. **2 hours 30 minutes**

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Centre number, index 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 an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions.

You will be allowed a maximum of one hour to work with the apparatus for Questions 1 and 2, and a maximum of one hour for Question 3. You are advised to spend approximately 30 minutes on Question 4.

Write your answers in the spaces provided on the question paper.
The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

Give details of the practical shift and laboratory, where appropriate, in the boxes provided.

At the end of the examination, submit sets A, B and C separately.
The number of marks is given in brackets [ ] at the end of each question or part question.

Shift
Laboratory

For Examiner's Use	
1	/ 13
2	/ 8
3	/ 22
4	/ 12
Total	/ 55

Sets A, B, C consist of **14** printed pages.

1 In this experiment, you will investigate the behaviour of a system in static equilibrium.

(a) (i) Use the weighing balance to determine the mass of one paper clip.

mass of one paper clip = ... [2]

(ii) Connect two mass hangers with a short string and place them on both sides of a pulley as shown in Fig. 1.1. The mass hangers should balance each other's weight and hang in equilibrium.

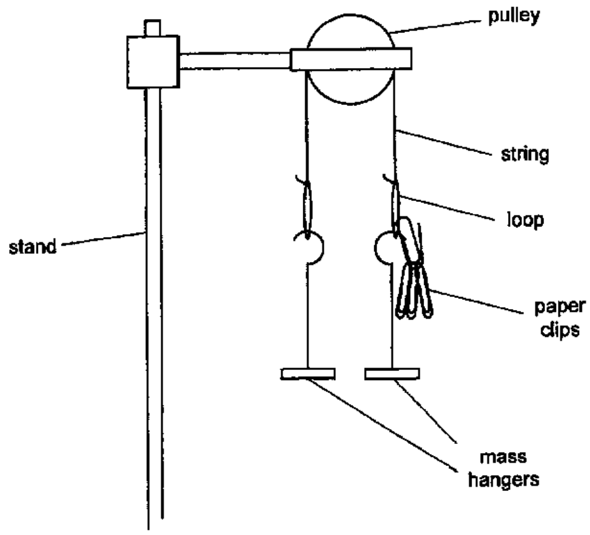


Fig 1.1

Now add paper clips, one by one, to one side until the pulley starts to rotate. Record the maximum number of paper clips that is added before the equilibrium is broken.

number of paper clips = ... [1]

(b) Set up the apparatus as shown in Fig. 1.2. Mass *m* and *M* are provided by a 50 g mass hanger and a pendulum bob, respectively.

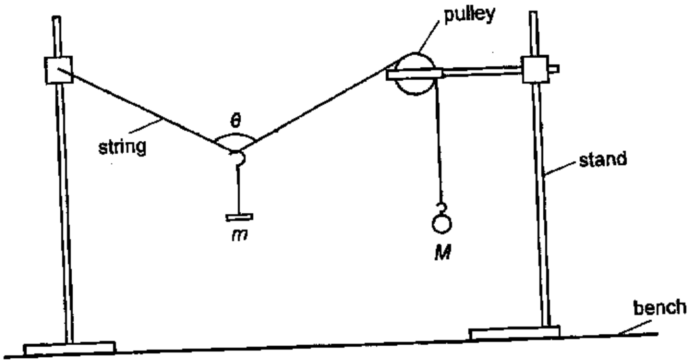


Fig 1.2

(i) Adjust the position of *m* along the string until the angle *θ* is symmetrical about the vertical axis.

Measure and record *θ*.

θ = ...° [1]

(ii) Estimate the uncertainty in your value of *θ*.

uncertainty in θ = ... [1]

(c) Theory suggests that

$$2M\cos\frac{\theta}{2} = m$$

(i) Calculate the value of *M*.

M = ... [1]

(ii) Using your values in **(a)(ii)** and **(b)(ii)**, estimate the maximum value of *M*.

maximum M = ... [1]

(d) **(i)** Repeat **(b)(i)** for m = 100 g.

θ = ... [1]

(ii) If you were to repeat this experiment with more masses, describe the graph that you would plot to determine M.

....

....

....

....[2]

(e) **(i)** Suggest two significant sources of error in the measurement of θ.

1...

....

....

....

2...

....

....

....[2]

(ii) Suggest an improvement that could be made to address one of the errors identified in **(e)(i)**. You may suggest the use of other apparatus or a different procedure.

....

....

....

....[1]

[Total: 13]

2 In this experiment, you are provided with an LED (light emitting diode) that produces light of wavelength 640 nm.

(a) Connect the circuit as shown in Fig. 2.1. You should be able to turn the LED on and off by adjusting the potentiometer. You are reminded that an LED allows current to pass in one direction, but not the other.

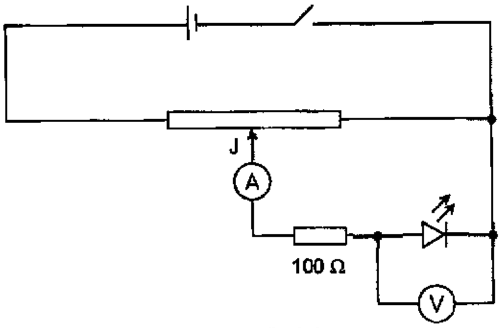


Fig 2.1

Close the switch.

(i) Adjust the potentiometer J until the ammeter reading is 5.0 mA. Record the voltmeter reading V to the nearest 0.001 V.

V = ... [1]

(ii) Calculate the resistance of the LED when it is operated at a current of 5.0 mA.

resistance = ... [1]

(b) The turn-on voltage V_F is defined as the potential difference across the LED that produces a current of 0.10 mA through the LED.

(i) Adjust the potentiometer J to determine the turn-on voltage of the LED you're provided.

V_F = ... [1]

(ii) Estimate the percentage uncertainty in your value of V_F.

percentage uncertainty in V_F = ... [1]

(iii) It is suggested that the turn-on voltage V_F of an LED is inversely proportional to the wavelength λ of the light produced by the LED.

You are told that the turn-on voltage of another LED producing green light of wavelength 565 nm is 1.800 V.

State whether this information and your values from **(b)(i)** support the suggested relationship. Justify your conclusion by referring to your values in **(b)(ii)**.

....

....

....

....[2]

(c) Fig. 2.2 shows another circuit that may be used to control the current through the LED.

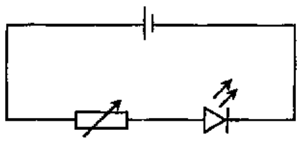


Fig 2.2

Draw lines in Fig. 2.3 to show how the components can be connected to achieve the circuit shown in Fig. 2.2.

[2]

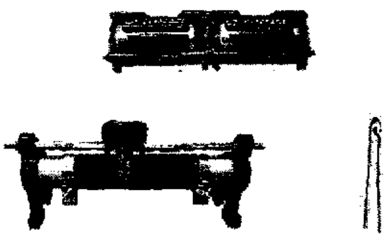


Fig 2.3

[Total: 8]

NAME ______________________ CLASS 18S ( ) SCORE ______ **B**

3 In this experiment, you will investigate the behaviour of an oscillating system.

(a) Measure and record the width *w* and thickness *d* of the half metre ruler, as shown in Fig. 3.1.

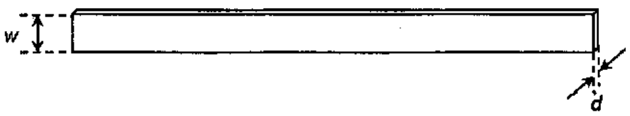


Fig 3.1

w = ... [1]

d = ... [1]

(b) Use rubber bands to attach two 50-g masses separately to about 5 cm away on either side from the centre of a half metre ruler.

Use a bulldog clip to attach the centre of the half metre ruler to the spring and set up the apparatus as shown in Fig. 3.2.

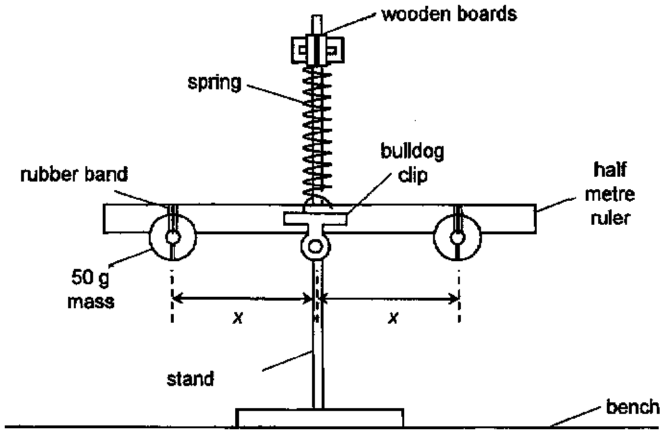


Fig 3.2

(i) Measure and record the distance *x* between the centre of the ruler and the centre of each of the two masses.

x = ...

(ii) Turn the ruler through approximately 45° about a vertical axis. Release the ruler. The ruler will oscillate about a vertical axis. Determine the period *T* of these oscillations.

T = ... [2]

(c) Vary x and repeat **(b)(i)** and **(b)(ii)** for each new distance x. Tabulate all results including previous ones.

[6]

(d) T and x are related by the expression

$$T^2 = P + Qx^2$$

where P and Q are constants.

Plot a suitable graph to determine the values of P and Q.

P = ...

Q = ...

[6]

(e) The relationship between T and x are given in more detail by the expression

$$T^2 = \frac{4\pi^2}{k}(\frac{1}{12}ML^2 + 2mx^2)$$

where k is a constant related to the elasticity of the spring, M and L are the mass and length of the ruler respectively, and m is the mass of each of the 50-gram mass attached to the ruler.

Calculate M.

M = ... [2]

(f) Calculate the density of the ruler.

density = ... [2]

(g) Draw another line to show the graph that would be obtained if the ruler is made of material half the density as the one used.

[2]

[Total: 22]

NAME ____________________ CLASS 18S ( ) SCORE ______ **C**

4 The attenuation of a beam of beta radiation is the reduction in its intensity due to its passage through a material. One way to investigate the attenuation is to measure the half-value thickness τ, the thickness of material that reduces the intensity of the beta radiation to half its original value.

In addition to apparatus which may be commonly found in a school laboratory, you are also provided with the following:

Beta-source
Geiger-Muller tube
Ratemeter
A number of aluminium plates of different thicknesses
A uniform magnetic field of exactly 0.500 mT
Variable high-voltage DC power supply
A pair of parallel metal plates

Design a laboratory experiment to obtain the relationship between the half-value thickness τ for aluminium and the speed of the beta-particles. You should draw a diagram showing the arrangement of your equipment. In your account you should pay particular attention to

(a) the procedure to be followed,
(b) how the speed of the beta particles can be determined or chosen, (You do NOT have to provide any detail on how to generate or monitor the 0.500 mT magnetic field. You are to ignore any relativistic effect)
(c) how the beta radiation would be detected and the measurements that would be made,
(d) how a suggested relationship may be validated,
(e) the safety precautions that you would take,
(f) any precautions that you would take to improve the accuracy of the experiment.

Diagram

....

....

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....

....

....

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....

....

....

....

....[12]

[Total: 12]

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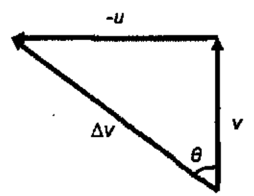
2019 HCI H2 PHYSICS Prelim P1 Suggested Solutions

1 D Transposing the equation: $k = \frac{H}{A\left|\frac{\Delta T}{l}\right|}$

Hence, the units of k are $\frac{J\,s^{-1}}{m^2\,K\,m^{-1}} = \frac{N\,m\,s^{-1}}{m\,K} = \frac{kg\,m\,s^{-2}\,s^{-1}}{K} = \frac{kg\,m\,s^{-3}}{K} = kg\,m\,s^{-3}\,K^{-1}$

[
"Rate of" is considered as "per unit time," so the units of 'rate of energy transfer' are J s^{-1}.]
[Note: answers A and B have the unit 'W,' which is not a base unit; these answers do not have to be considered.

2 D Initial velocity, u = 4.0 m s^{-1} due east.
Final velocity, v = 3.0 m s^{-1} due north.
Change in velocity $\Delta v = v - u = v + (-u)$, where $(-u)$ = 4.0 m s^{-1} due west.
Doing a vector addition:



$|\Delta v| = \sqrt{(-u)^2 + v^2} = \sqrt{4^2 + 3^2} = 5$
$\theta = \tan^{-1}(4/3) = 53°$
Hence, the change in velocity is 53° west of north.

3 D As the object is released, the speed will increase until it reaches a constant value.
As speed is given by the gradient of the graph, the gradient will increase until a constant value.

4 A The mass slowed down at an increasing rate from t = 0.25 s to t = 0.50 s.

5 C $(\Sigma P_i = \Sigma P_f)_y$ ↑+
0 = (h/λ_i) sin75° − p sinα
($6.63 \times 10^{-34}/966.8 \times 10^{-12}$) sin75° − ($8.362 \times 10^{-25}$) sinα
sinα = 0.7922
α = 52.4°

6 A Clockwise moment by weight of M = anticlockwise moment by tension in string
Mg(1.200) = 300 sin30° (0.805)
M = 10.3 kg

7 C Net force
= Upthrust by air – Weight of helium – Weight of balloon skin & instrument.
= Weight of air displaced – $\rho_{He}Vg - Mg$
= $\rho_{air}Vg - \rho_{He}Vg - Mg$
= $(\rho_{air} - \rho_{He})Vg - Mg$

8 C Option A: Student thought that force and extension were reversed.
Option B: Student confused the net work done with work done by the force F.
Option C: Correct.
Option D: Student thought that there is no deformation in the wire.

9 B By drawing the free body diagram of the car for each bridge, realise that for convex bridges

Weight of car – Normal contact force on car by road = mv^2/r

Normal contact force on car by road = Weight of car – mv^2/r (smaller than weight)

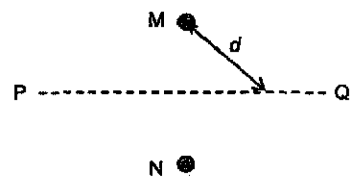
The convex bridge which has the shorter radius will exert the least normal contact force on the car.

By Newton's 3rd Law, force exerted by car has same magnitude as the normal contact force

10 B $g = \frac{GM}{R^2}$

Work done = increase in GPE $= -\frac{GMm}{3R} - \frac{GMm}{R}$
$= \frac{2}{3}\frac{GMm}{R}$
$= \frac{2}{3}\frac{GMm}{R^2}R$
$= \frac{2}{3}mgR$

11 B



Gravitational potential ϕ is a scalar quantity. It is always negative and for point masses follow the formula $\phi = -\frac{GM}{r}$. So in this case, the resultant potential is $-2\frac{GM}{d}$. As such it is most negative (but not infinitely negative) at the midpoint, where it is nearest to both the stars, and less negative along either side as they move further away from the stars.
(modified from 2014 P1 Q13)

12 B $pV = nRT$
$(1.2\times10^5)V_1 = (50+273)$
$(6.0\times10^5)V_2 = (200+273)$
$5\frac{V_2}{V_1} = \frac{473}{323}$
$\frac{V_2}{V_1} = 0.29$

13 B
A At higher temperature, the average KE of molecules are higher. Evaporation occur at a faster rate for this reason.
B S has negative potential energy while G has negligible.
C Water contracts both when melting and condensing, so the atmospheric pressure does positive work.
D The specific latent heat of fusion is a lot less than the specific latent heat of vaporization

14 D Damping force on the forced oscillation increases. Amplitude with added friction is always lower for all frequencies. The resonant frequency at which maximum amplitude occurs would be also be lower.

15 A Wavelength is 8.00 cm.

The wave profile travelled by 3.20 cm in 0.20 seconds, the speed is 0.032/0.2 = 0.16 m s^{-1}.

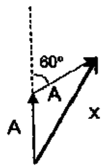
Distance between A and B is 2 cm. Hence, the phase difference must be

$$\frac{\Delta x}{\lambda} = \frac{\Delta\phi}{2\pi} \rightarrow \frac{2.00 \text{ cm}}{8.00 \text{ cm}} = \frac{\Delta\phi}{2\pi} \rightarrow \Delta\phi = \pi/2$$

16 A

The wavelength of the electromagnetic wave is $c = \lambda f \rightarrow \lambda = \frac{3\times10^8}{10^{13}} = 30\ \mu m$, which is longer than the visible light. Hence, the answer is infra-red waves.

17 C



Resultant amplitude x = √(2A²- 2A²cos 120°) = √3 A

18 D

$$d\sin\left(\frac{\theta}{2}\right) = 2\lambda$$

$$d = \frac{2\lambda}{\sin\left(\frac{\theta}{2}\right)}$$

19 A

$$\tau = qE \times d = (2\times1.6\times10^{-19})(\frac{2.0\times10^2}{0.001})(4.0\times10^{-12}\sin30^0)$$

$$= 1.3\times10^{-25} \text{N m}$$

20 D An α-particle has mass $4u$ and carries charge +2e.

Within the plates, constant $E = V/x$

By PCOE,

Loss in KE = Gain EPE

$\frac{1}{2}(4u)(v_i^2 - v_f^2) = qV$

$\frac{1}{2}(4u)(v_i^2 - v_f^2) = 2eEx$

$v_f^2 = v^2 - eEx/u$

$v_f = \sqrt{(v^2 - eEx/u)}$

21 D

$R_{eff} = R_J + R_K = \frac{\rho 2x}{\frac{x}{2}t} + \frac{\rho x}{xt}$, where ρ is resistivity and t is thickness

$$R_{eff} = R + 4R = 8.0 + 4(8.0) = 40\ \Omega$$

Option A: Student thought that J and K are connected in parallel.
Option B: Student thought that the resistance of K is also 8.0 Ω
Option C: Student forgot to add the resistance of J.

22 A

R at *1 V*	R at *6 V*
When I is at 2.0 A, V < 2.0 V	
V/I < 2.0 / 2.0	V/I = 6.0 /3.5
V/I < 1.0 Ω	= 1.7 Ω

23 B Option A: Student thought that no current flows through hence potential drop must be zero across all the bulbs in the circuit.
Option B: Correct.
Option C: Student did not consider the potential difference across A and thought that the potentials across bulb D is the same.
Option D: Student did not consider the potential difference across A.

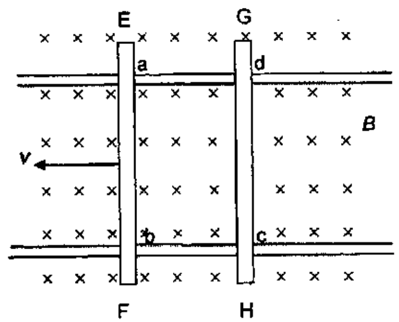
24 D Excess weight in one arm over the other = mg

$= \rho Ahg$

$= 960\times4.0\times10^{-4}\times0.020\times9.81 = 0.07534$ N

Magnetic force = BIL = 0.07534
0.07534 = B(60)(0.020)
B = 0.063 T

25 B

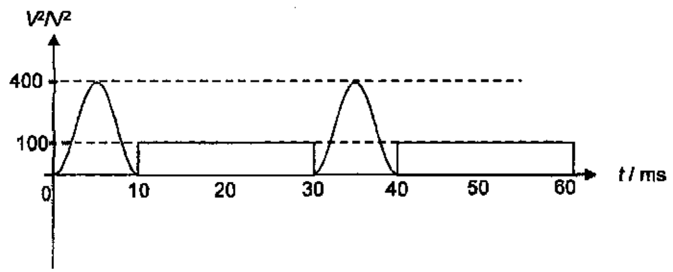


When EF is moved to the left, by FRHR, induced current flow in the direction ab and thus abcd in the closed circuit. By FLHR, induced current in rod GH experiences a magnetic force to the left, causing it to accelerate to the left, while rod EF will experience a magnetic force to the right that slows it down. When both rods achieve the same velocity, there will be no flux change, and no induced current, both rods will continue to move at this constant speed.

26 B

$$\langle E\rangle = \left|-\frac{\Delta\Phi}{\Delta t}\right| = \frac{NBA-(-NBA)}{0.20} = \frac{2(800)(4.0\times10^{-5})(0.050)}{0.20} = 0.016\,V$$

27 B Calculate r.m.s. voltage across the resistor. Then use $P = \frac{V_{rms}^2}{R}$ to find the mean power.



Mean of $V^2 = \frac{(200\times10)+(100\times20)}{30} = 4000/30$ volts^2

Mean power $= \frac{V_{rms}^2}{R} = \frac{4000/30}{5.0} = 26.7$ W

28 B Originally, $eV_s = hf - \Phi$, $V_s = (hf - \Phi)/e$
Intensity L = power/area = nhf/At
Frequency $2f$ implies energy of photon is doubled. Same metal surface used implies work function, Φ remains the same. Thus maximum KE of electron or its PE gained, $eV'_s = (2hf - \Phi)$.
Thus new stopping potential $V'_s = (2hf - \Phi)/e > 2(hf - \Phi)/e$ or $2V_s$

Intensity remains the same, but since frequency of light is now $2f$, number of photons incident on the metal surface is halved.
Thus the number of photoelectrons emitted per unit time will be less; maximum photocurrent will be less than I.

29 D the parent nucleus is less stable and has a smaller binding energy per nucleon than the daughter nucleus.

30 A From the first 2 sets of reading, Corrected count rate, $C_0 = 40$ s^{-1}, $C = 10$ s^{-1}.

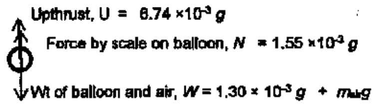
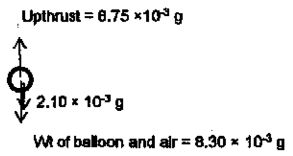
$$\frac{C}{C_0} = \left(\frac{1}{2}\right)^{\frac{20}{T}}$$

$$\frac{10}{40} = \left(\frac{1}{2}\right)^{\frac{20}{T}} \Rightarrow \left(\frac{1}{2}\right)^2 = \left(\frac{1}{2}\right)^{\frac{20}{T}}$$

By comparison, T = 10 days.

HCI H2 PHYSICS Prelim P2 Suggested Solutions

1	(a)	(i)	The tension force must be greater than the weight so that the resultant force provides a **centripetal force** for the ball to moving along the **arc of a circle.**	[1]
	(a)	(ii)	From Fig 1.2, velocity of the ball just before it hits the wall, v = 2.6 m s^{-1} By Newton's 2nd Law, $F_{net} = ma_c$ Tension force – weight = mv^2/r Tension force = $mv^2/r + mg$ = 350 (2.6^2 / 5.8 + 9.81) Tension force = 3840 = 3800 N (2 or 3 s.f.)	 [1] [1]
	(b)		From the graph, the average force exerted by the wall on the ball $\langle F \rangle = \frac{\Delta p}{\Delta t} = \frac{m\Delta v}{\Delta t} = \frac{350\times(0.000-2.600)}{(1.35-1.20)}$ $= -6070$ N By Newton's Third Law, (average force by ball on the wall) = - (average force by wall on the ball) = 6070 = 6100 N (2 or 3 s.f.)	[1] [1]
	(c)		The principle of conservation of linear momentum states that the total momentum remains constant provided there is no **net** external force acting on the system. In this case, external force is acting on the wall as the wall is held by the ground, thus the principle does not apply. OR Considering the system as the ball, the wall and the Earth, the total momentum is constant: momentum loss of ball = momentum gain of wall and Earth.	[1] [1]
	(d)		Thermal energy of ball = 12% of initial KE of ball $mc\Delta T$ = 0.12(½ mv^2) ΔT = 0.12 (½ v^2)/c = 0.12 (½ x 2.6^2) / 450 = 9.0 x 10^{-4} K or °C	[1] [1]

2	(a)		(Net) upward force by a fluid on an object (partially or fully) immersed in the fluid.	1
	(b)	(i)	$M = \rho V = \rho$ x 4/3 (πr^3) = 1.21 x 4/3 (π) (11.0 x 10^{-2})^3 = 0.00675 kg = 6.75 g	 1 1
		(ii)	 Net force = 0 Thus 1.30 × 10^{-3} g + $m_{air}g$ = 6.74 ×10^{-3} g + 1.55 ×10^{-3} g Mass of air in balloon, m_{air} = 6.99 g	 1 1
		(iii)	The air is being compressed by the elastic balloon material so is at a higher pressure and hence denser.	1
	(c)	(i)	At start assume velocity is momentarily zero so drag is zero  a = F_{net}/m = [(8.30 + 2.10 – 6.75) x 10^{-3} x 9.81]/ [(7.00 + 1.30 +2.10) x 10^{-3}] = 3.44 m s^{-2}	 1 1
		(ii)	As speed increases, drag force (upward) increases. Acceleration becomes zero when upthrust + drag force = weight of balloon, air and nut.	1 1

3 (a) The direction of vibration of *electric field* is restricted to one direction in a plane that is normal to the direction of energy transfer (propagation). [1]

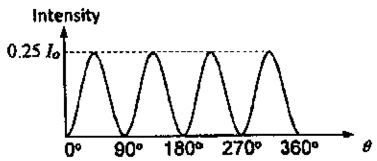
(b) (i) When polariser X is oriented such that its direction of polarisation is not perpendicular to A, a component of the polarised light along the direction of polarization of X passes through X. [1]

The light component passing through X has a component along the direction of polarization of A that can pass through A. Thus the intensity of the transmitted light is not zero. [1]

1.

θ	Intensity of light tranmitted by polariser A (in terms of I_o)
0°	0
45°	$(\cos^2 45°)^2 I_o = I_o / 4 = 0.25\, I_o$ [1]
60°	$(\cos^2 60°)(\cos^2 30°) I_o = 3I_o / 16 = 0.1875\, I_o$ [1]

2. - min intensities are correct at 0°, 90°, 180°, 270° and 360°. [1]
Max intensities (0.25 I_o) at 45°, (90°+ 45°), (180°+ 45°), and (270°+ 45°) [1]
- correct shape



(c) (i) Let P_s = Power emitted by source uniformly in all directions
I_{78} = Intensity at 78.0 m away
I_{300} = Intensity at 300 m away

Power = Intensity x area

$Ps = (I_{78})(4\pi \times 78.0^2) = (I_{300})(4\pi \times 300.0^2)$ [1]

$I_{300} = (0.026)\left(\frac{4\pi \times 78.0^2}{4\pi \times 300.0^2}\right) = 0.00176\ \text{W m}^{-2}$ [1]

(ii) Let P_r = power received by the microphone diaphragm

$P_r = (I_{300})(\textit{area of microphone})$ [1]

$P_r = (0.00176)(3.2 \times 10^{-4}) = 5.63 \times 10^{-7}$ W

4 (a) (i) Electric potential is the work done per unit positive charge by an external force in bringing a test charge from infinity to that point without a change in kinetic energy. 2

(ii) Electric field strength at a point in the electric field is numerically equal to the potential gradient at that point, and directed towards lower potential. (no marks if direction not stated). 1

or $E = -\frac{dV}{dr}$ (where E is the electric field strength at the point, V is the potential and r is the distance from a particular reference point)

(b) q_1, q_2 are negative. Potential around them is negative and increases (ie less negative) with distance from either charge. 1

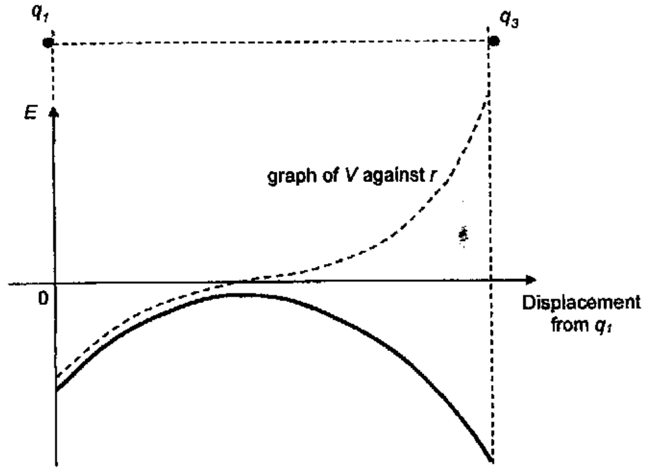
q_3 is positive. The potential around it is positive and decreases (ie less positive) with distance from the charge. 1

(c) (i) Direction of field strength is perpendicular to P, radially towards q_2. 1

(ii) $|E| = \Delta V / \Delta r = [-1 - (-3)] / (1.5 \times 10^{-2}) = 130\ \text{V m}^{-1}$ (2 sf) 1

(d) Work done by external agent
$= q(V_f - V_i) \quad = q(V_R - V_P)$ 1
$= (-1.60 \times 10^{-19})[(+3.0) - (-2.0)]$ 1
$= -8.0 \times 10^{-19}$ J

(e)



- 1 mark for correct shape (having the turning point vs the inflexion point)
- 1 mark for negative and not touching the x-axis
- 1 mark for a larger magnitude of E at q_3 than at q_1

3

			Comments 1. Students should first draw the potential *V*-curve, then use $E = -\frac{dV}{dr}$ to help sketch the *E*-curve. *E* is simply the negative of the potential gradient. 2. The potential gradient near q_3 is steeper and thus the magnitude of *E* at q_3 should be larger than that at q_1.	

5	(a)		The current in the copper and tungsten filament wires is the same because both wires are connected in series.	[1]
	(b)		*Resistivity*, $\rho = \frac{AR}{L}$ $= \frac{\pi(0.020\times10^{-3})^2\times300}{4(1.5)} = 6.28\times10^{-8}\ \Omega$ m	[1] [1]
	(c)	(i)	Since current is the same in both wires, using $I = neAv$ where *I*: current, *n*:number density, *A*: cross-sectional area, *v*: drift velocity of electrons Hence *neAv* for tungsten = *neAv* for copper $v_{tungsten} = \frac{n_{Cu}A_{Cu}v_{Cu}}{n_{tungsten}A_{tungsten}} = \frac{(8.49\times10^{28})(1.5)^2(0.021\times10^{-3})}{(3.4\times10^{28})(0.020)^2}$ $= 0.295$ m s^{-1} OR 0.30 m s^{-1}	[1] [1] [1]
		(ii)	The electrons in the tungsten filament have a significantly higher drift velocity. This implies that they collide with the positive lattice ions at a much higher speed more frequently (more collisions per unit area). They impart more kinetic energy to the lattice ions at the same time, such that the ions vibrate more vigorously and obstruct the flow of electrons. Since the tungsten filament gains thermal energy at a significantly higher rate and subsequently heats up, the filament of the lamp gets hot but the copper leads stay relatively cold.	[1] [1]
		(iii)	If the diameter of the wire is doubled, the cross-sectional area of the wire will be quadrupled. The resistance $\left(R = \frac{\rho l}{A}\right)$ is thus quartered. Current $\left(I = \frac{V}{R}\right)$ will be quadrupled. Electron number density is the same for the same material, the drift velocity of electrons in the tungsten wire ($v = I/nqA$) is unchanged.	[1] [1]

6	(a)	(i)	Increasing R increases the total resistance of the circuit, thus reducing the current in the circuit.	[1]
			Thus the potential drop across the internal resistance is reduced.	[1]
			Since the terminal p.d. is the e.m.f. of the battery minus the p.d. across the internal resistance, terminal p.d. increases with R.	[1]
			OR	
			Increasing R increases the external resistance.	[1]
			This increases the ratio of the external resistance to the total resistance.	[1]
			By the potential divider principle, the terminal p.d. increases with R.	[1]
	(a)	(ii)	$I = \frac{25.2}{2.00+4.00+40.0} = 0.548$ A	
			$V_B = 25.2 - 0.548(2.00)$ $= 24.1$ V	[1] [1]
			OR	
			$V_B = \frac{4.00+40.0}{2.00+4.00+40.0} \times 25.2$ $= 24.1$ V	[1] [1]
	(b)	(i)	$V_R = (1.60\times10^{-3})(1.50\times10^{3}) = 2.40$ V	[1]
			$V_{thermistor} = 6.00 - 2.40 = 3.60$ V and $R_{thermistor} = \frac{3.60}{1.60\times10^{-3}} = 2250\ \Omega$	[1]
			From the graph, $t = 14$°C	[1]
	(b)	(ii)	From the graph, $R_{thermistor} = 3100\ \Omega$ at $t = 5$°C	[1]
			Based on potential divider principle, potential difference across the fixed resistor	
			$V_R = \left(\frac{1500}{1500+3100}\right)6.00 = 1.96$ V	[1]

7	(a)		A photon is a discrete packet of electromagnetic energy. [1]	[1]
	(b)	(i)	1. $E_i = E_s + ½ mv^2$	[1]
		(i)	2. $p_i = p_s \cos\theta + mv \cos\alpha$	[1]
		(ii)	Energy of photon, E = hf. As the scattered photon energy E_s is less than the incident photon energy E_i, the frequency of the scattered photon is smaller than that of incident photon. [1] As the wavelength is inversely proportional to its frequency, the scattered photon will have a wavelength greater than that of the incident photon. [1]	[2]
	(c)		Actual value, cos 75° = 0.2588 Check that cos 80° = 0.1736, cos 70° = 0.3420 Using $\Delta R = (R_{max} - R_{min}) / 2$ Δ(cos θ) = (cos 70° − cos 80°)/ 2 = 0.08 (1 s.f.) Therefore cos θ = 0.26 ± 0.08	[2]
	(d)	(i)	Calculate cos θ Correctly plot the two data points to within half smallest square	[1] [2]
		(ii)	Correct best fit line	[1]
		(iii)	Δλ = k − k cos θ Method 1: gradient of graph gives negative k [1] Method 2: y-intercept of graph gives k [1]	[2]
		(iv)	Correct values for k based on graphs. [1] Correct unit for k. [1]	[2]

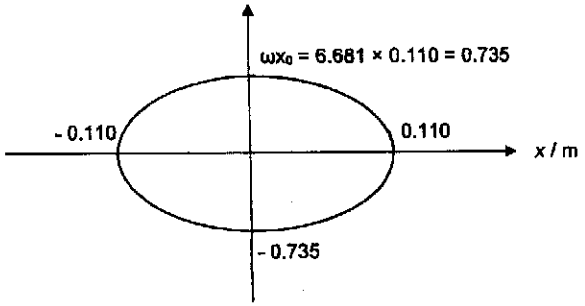
	(e)	(i)	Energy of incident beam 19.0 keV $E = \frac{hc}{\lambda}$ Wavelength, $\lambda = \frac{hc}{E} = \frac{(6.63\times10^{-34})(3\times10^{8})}{(19.0\times10^{3})(1.6\times10^{-19})} = 6.53\times10^{-11}\ m$	[1]
			Using $\lambda' = \lambda + \frac{h}{mc}(1-\cos\theta)$, $\lambda' = 6.56\times10^{-11}\ m$ Alternatively, accept $\Delta\lambda$ = k – k cos θ and using the value of k obtained in (d)(iv).	[1]
		(ii)	As the binding energy of an electron of a carbon atom is negligible compared with the energy of the incident photons (19 keV).	[1]
			Therefore it is justified to assume that the electrons are free.	[1]

2019 HCI H2 PHYSICS Prelim P3 Suggested Solutions

1	(a)	(i)	The gas molecules rebound off the incoming piston at speed higher than before the collisions. The increase in average KE corresponds to an increase in temperature.	B1
		(ii)	The frequency of collisions increases. The change in momentum per collision is higher.	B1 B1
	(b)	(i)	For ideal gas, total internal energy = total number of molecules x mean kinetic energy of a molecule of ideal gas $U = \frac{3}{2}NkT$ $\Delta U = \frac{3}{2}Nk\Delta T$ $\Delta U = \frac{3}{2}\Delta(pV)$ $\Delta U = \frac{3}{2}(30\times20 - 10\times40)(10^5\times10^{-6})$ $= 30$ J	M1 A1
		(ii)	During the change B → C → A, By First Law of Thermodynamics, $W = 0 + (-p\Delta V)$ $= -(10)(40-20)(10^5\times10^{-6})$ $= -20$ J $\Delta U = Q + W_{on}$ $-30 = Q + (-20)$ $Q = -10$ J	M1 M1 A1

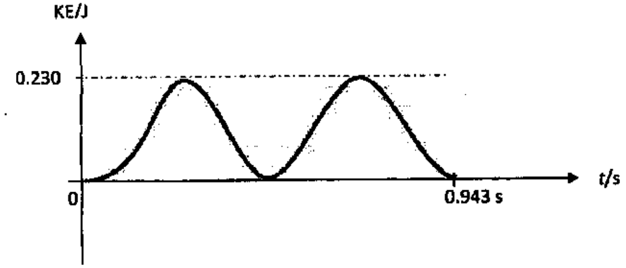
2	(a)		At equilibrium, the net force is zero hence weight = spring force $mg = kx$ $0.850(9.81) = k(0.220)$ [1] $k = \frac{0.850(9.81)}{(0.2200)} = 37.9$ N m^{-1}	
	(b)	(i)	F_{net} = spring force − weight $= ke - mg$ $= 37.9(0.110 + 0.220) - 0.850(9.81)$ $= 4.17$ N $F_{net} = ma$ $a = \frac{F_{net}}{m} = \frac{37.9(0.330)-0.850(9.81)}{0.850}$ [1] $a = 4.91$ m s^{-2} [1]	
		(ii)	$a_0 = \omega^2 x_0$ $4.91 = \omega^2(0.110)$ $\omega^2 = \frac{4.91}{0.110}$ $\omega = 2\pi f$ $f = \frac{\omega}{2\pi} = \frac{\sqrt{\frac{4.91}{0.110}}}{2\pi}$ [1] $f = 1.06$ Hz [1]	

(iii)



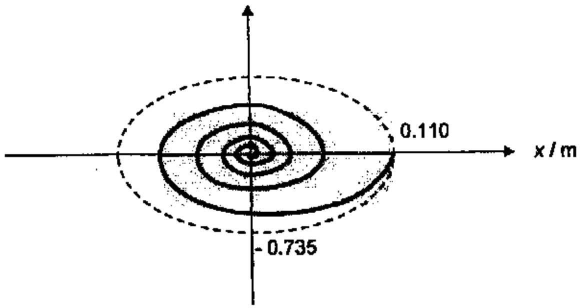
[1] shape must be an ellipse
[1] correct values of x-intercepts and y-intercepts of ellipse.

(iv)



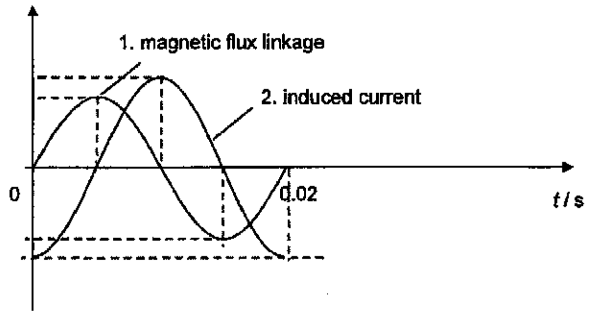
[1] Sine-squared wave in one period
[1] Labels: KE_{max} = ½ $m\omega^2 x_0^2$ = 0.5(0.850)(44.636)(0.110)^2 = 0.230 J and period = 1/f = 1/1.06 = 0.941 s or 0.943 s.

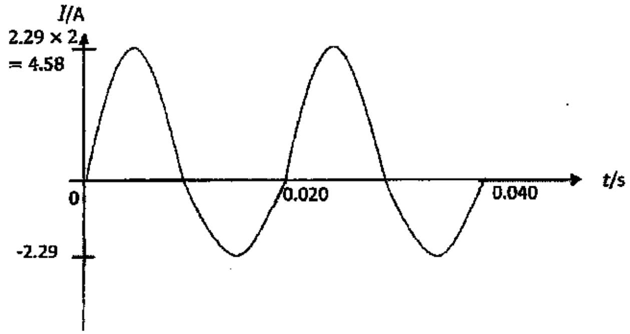
(v)



[1] Spiral clockwise inwards starting from at x_0 = + 0.110 m.
[1] Exponentially decreasing amplitude of oscillation (spacing between x-intercepts become smaller), at least 3 complete spiral rounds

3	(a)	By conservation of energy, Gain in kinetic energy = Loss in electric potential energy $\frac{1}{2}mv^2 - 0 = qV$ $v = \sqrt{\frac{2qV}{m}}$	1
	(b)	The moving ion, upon entering the magnetic field, will experience a constant magnetic force perpendicular to the direction of velocity. This constant magnetic force provides the centripetal acceleration, causes the velocity to change its direction but not the speed (its magnitude). As a result, the ion moves in a uniform circular motion in the magnetic field.	1 1
	(c)	Magnetic force on ion provides the centripetal force. Bqv = mv²/r → r = mv/Bq = $\sqrt{\frac{2mV}{B^2q}}$ $r_{14}= \sqrt{\frac{2\times14\times1.66\times10^{-27}\times4000}{0.50^2(1.60\times10^{-19})}} = 0.068176$ m $r_{12}= \sqrt{\frac{2\times12\times1.66\times10^{-27}\times4000}{0.50^2(1.60\times10^{-19})}} = 0.063119$ m Hence Δx = 2(0.068176 – 0.063119) = 0.0101 m	1 1 1
	(d)	If an electron were to be introduced into the magnetic field, it would be deflected to the left because electron is negatively-charged. The electron will move towards the left in a semicircle in an anticlockwise manner. In addition, the diameter of its semi-circular path would be much smaller since the mass of electrons is only much smaller at 9.11 x 10^{-31} kg.	1 1

4	(a)	Period or time for 1 full cycle = 1/f time to rotate 1° = $\frac{1}{360}\left(\frac{1}{f}\right)=\frac{1}{360}\left(\frac{1}{50}\right)=5.56\times10^{-5}$ s OR since it rotates 50 x 360 = 18000° in 1 s, time taken to rotate 1° = 1/18000 = 5.6 x 10^{-5} s	1
	(b)	Change in flux linkage = $\Delta\Phi$ = $\Delta(NBA)$ = $NA\Delta B_{\perp}$ = 38 (0.29)(2.0)(1.2) sin 1.0° - 0 = 0.46 Wb turns	1 1
	(c)	e.m.f. = $\Delta\Phi/\Delta t$ = 0.46 / 5.6 x 10^{-5} = 8200 V = 8.2 k V	1
	(d)	The direction of the current induced in side AD is **A to D.** As the coil starts turning, induced emf in the coil is proportional to the rate of increase in flux linkage, by Faraday's Law. **By Lenz's Law, induced current in the coil will be in the direction A to D to produce a leftward magnetic field to oppose the increase of flux linkage to the right.** (The direction of current is predicted using right hand grip rule.)	1 1
	(e)	 -1 mark for wrong shape of graph or not labelling the period.	1 1

5	(a)	(i)	$V_{rms}=\frac{V_0}{\sqrt{2}}=\frac{170}{\sqrt{2}}$ = 120 V	1
		(ii)	$\omega=2\pi/T=314$ $T=0.0200$ s	1
	(b)	(i)	$\frac{V_S}{V_P}=\frac{N_S}{N_P}$ $\frac{V_S}{170}=\frac{3500}{2000}$ V_S = 298 V	1 1
		(ii)	$V_S=I_SR$ $298=I_S(130)$ $I_S=2.288$ A $\frac{I_P}{I_S}=\frac{N_S}{N_P}=\frac{3500}{2000}$ For correct working above: I_P = 4.00 A	1 1
	(b)		 Shape of graph: 1 mark. Correct labels: 1 mark	

6	(a)		$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}}$	1
			$\lambda = \frac{6.63\times10^{-34}}{\sqrt{2\times9.11\times10^{-31}\times7.50\times1.60\times10^{-19}}} = 4.48\times10^{-10}\,\text{m}$	1
	(b)		Enough energy to excite atom to -1.43 eV. Hence recoil speeds are 0.25 eV (excited to -1.43 eV), 4.55 eV (excited to -5.73 eV).	1
	(c)		6 transitions shown.	1
	(d)		$\Delta E = \frac{hc}{\lambda}$	1
			$\lambda = \frac{(6.63\times10^{-34})(3\times10^{8})}{(-1.43-(-8.68))(1.6\times10^{-19})} = 1.71\times10^{-7}\,m = 171\,nm$	1
			UV region.	1
	(e)		Work function is smaller. Liberated electron not bound to a specific nucleus/atom	1 1
7	(a)		If it were the only particle produced besides the daughter nucleus, then, **by the principle of conservation of linear momentum, the beta particle and the daughter nucleus would always have the same speed ratio.**	1
			Since the energy released in each decay is fixed, **by the principle of conservation of energy, all the beta particles would** (receive the same fraction of the released energy and therefore) **have the same energy.** Note: Accept any variation that shows *proper understanding* of COLM and COE *in the context.* Do not accept the statement that, if there were no other particle, the energy of the beta-particle would have to be equal to 0.546 MeV without further elaboration.	1
	(b)	(i)	The half-life of a radioactive nuclide is the **average** time taken for half of the original number of nuclei in **a sample of the radioactive nuclide** to decay. OR The half-life of a radioactive nuclide is the **average** time taken for the activity of **a sample of radioactive nuclide** to halve.	1
		(ii)	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}} = \frac{\ln 2}{28.0\times365\times24\times60\times60} = 7.85\times10^{-10}\ s^{-1}$	1 1
		(iii)	$A = \lambda N$ number of nuclei $N = \frac{A}{\lambda} = \frac{6.40\times10^{9}}{7.85\times10^{-10}} = 8.15\times10^{18}$	1
			mass of strontium-90 in the sample = $N \times 90 / N_A$	1

			$= \left(\frac{6.40\times10^{9}}{7.85\times10^{-10}}\right)\times90\times\frac{1}{6.02\times10^{23}}$	1
			OR mass of strontium-90 in the sample = $N \times 90 \times u$ $= \left(\frac{6.40\times10^{9}}{7.85\times10^{-10}}\right)\times90\times(1.66\times10^{-27})$ $= 1.22\times10^{-6}$ kg $= 1.22\times10^{-3}$ g	

8 (a) The force of attraction between two point masses is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

0 mark for nonsensical definition.
1 mark for mostly correct definition.
2 marks for faultless definition.

(b) (i) Gravitational pull provides the required centripetal force.

$$\frac{GMm}{r^2} = m\frac{v^2}{r}$$

$$\frac{1}{2}\frac{GM}{r} = \frac{1}{2}mv^2$$

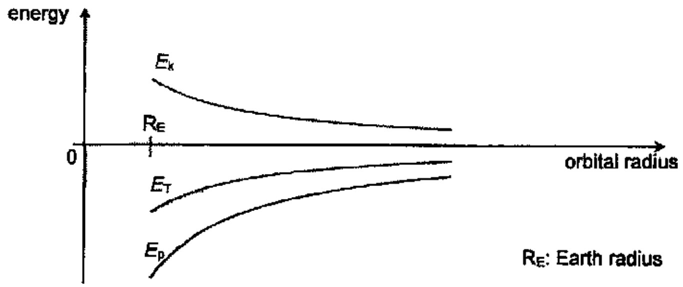
$$-\frac{1}{2}\left(-\frac{GM}{r}\right) = \frac{1}{2}mv^2$$

$$-\frac{1}{2}E_p = E_k$$

$$E_p = -2E_k$$

1 mark for correct GPE or KE.
2 marks for full derivation.

(ii)



1 mark if a least 1 graph is correct.
2 marks for all correct.

(c) (i)

$$\frac{GMm}{r^2} = m\frac{v^2}{r}$$

$$\frac{GM}{r} = v^2$$

$$\frac{(6.67\times10^{-11})(5.98\times10^{24})}{6.7\times10^6} = v^2$$

$$v = 7716 \text{ m s}^{-1}$$

$$= 27800 \text{ km h}^{-1}$$

M1 at correct substitutions.
A1 at correct numerical answer.

(ii) At this altitude, the centripetal force provided by the Earth is larger than the required centripetal force (for circular motion at geostationary speed). **B1**

(d) (i) GPE is converted into KE and heat.
1 mark if KE or heat is omitted.

(ii)

$$\frac{\Delta TE}{TE} = \frac{\Delta r}{r}$$

$$= 0.2\%$$ **B1**

(iii)

$$\Delta TE = -\frac{0.2}{100}\times\left(\frac{1}{2}\frac{GMm}{r}\right)$$ **M1**

$$= -\frac{0.2}{100}\times\frac{1}{2}\frac{(6.67\times10^{-11})(5.98\times10^{24})(1.80\times10^3)}{6.70\times10^6}$$

$$= -\frac{0.2}{100}\times5.3579\times10^{10}$$

$$= 1.072\times10^8 \text{ J}$$

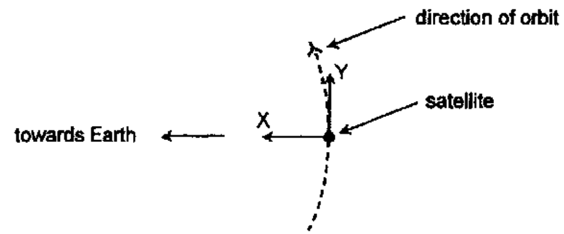
Rate of loss of energy $= \frac{1.072\times10^8}{7\times24\times3600} = 177 \text{ J s}^{-1}$ **M1**

$(P = Fv)$

$177 = f(7716)$ **M1**

$f = 0.0230$ N

(e) (i) **B2**

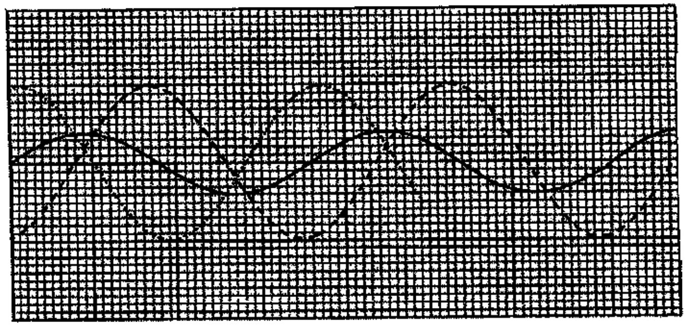


(ii) $F = uz$

$0.0230 = 2.00\times10^3 z$ **M1**

$z = 1.148\times10^{-5}$ kg s^{-1}

Fuel needed $= 24\times3600\times1.148\times10^{-5} = 0.992$ kg **A1**

9	(a)		When two or more waves meet at a point at the same time, the resultant displacement is the vector sum of the individual displacements at that point at that time. [2 marks for flawless definition. 1 mark for somewhat correct definition.]	[2]
	(b)			[2]
	(c)	(i)	The sound wave reflects off the bench. The incident and reflected waves superpose/interfere with each other. Maximum amplitude where the waves interfere constructively; minimum amplitude where they interfere destructively.	[1] [1] [1]
		(ii)	As x increases, the incident wave is stronger and the reflected wave weaker. There is more complete cancellation of the incident and reflected waves at small values of x and less complete cancellation at larger values of x.	[1] [1]
		(iii)	Distance between 2 consecutive nodes = $\lambda/2$ = (18.0 – 2.6)/3 = 5.13 cm λ = 10.26 cm f = 340/0.1026 = 3310 Hz	[1] [1] [1]
	(d)	(i)	An interference pattern is seen on the screen.	[1]
		(ii)	$\Delta\phi = \frac{1.4}{1.6}\times 2\pi$ $= 5.5$ rad	[1] [1]
		(iii)	$x = \frac{14.8-5.2}{6} = 1.6$ mm $a = \frac{\lambda D}{x} = \frac{650\times10^{-9}\times1.5}{1.6\times10^{-3}} = 0.61$ mm	[1] [1]
		(iv)	Distance of 6th order from principal axis = 1.6 × 6 = 9.6 mm $\theta = \tan^{-1}\left(\frac{0.0096}{1.5}\right) = 0.0064$ rad	[1] [1]

			$b = \frac{1\lambda}{\sin\theta} = \frac{650\times10^{-9}}{\sin(0.0064\text{ rad})} = 0.102$ mm	[1]

2019 HCI H2 PHYSICS Prelim P4 Mark Schemes & Suggested Solutions

1 a) i)	Value of mass in the range 0.10 to 0.50 gram (inclusive) Students should weigh the total mass of at least ten paperclips, with working	[1]
	Mass is recorded with unit and to the correct precision Precision is based on raw data and calculation	[1]
1 a) ii)	Number of paperclips in the range 5 to 20 (inclusive)	[1]
1 b) i)	Value of θ in the range 125° to 155° (inclusive) θ is recorded to the correct precision (nearest degree)	[1]
1 b) ii)	Absolute uncertainty in the range 2° to 5° (inclusive) 1 s.f. Degree symbol has to be present	[1]
1 c) i)	Value of M is calculated correctly with appropriate s.f. and units (2 or 3 s.f.)	[1]
1 c) ii)	Clear explanation or method on how the maximum value of M can be obtained Maximum value of M correctly calculated Students have to explicitly use the values of (a) (ii) and (b) (ii) Their calculation must be carried out correctly	[1]
1 d) i)	Value of θ should be smaller than that in (b) (i) θ is recorded with unit and to the correct precision (nearest degree) Check with (b) (i) and do not double penalise incorrect precision	[1]
1 d) ii)	Plot m versus cos (θ/2) or another appropriate graph Log-log graphs are accepted, as long as the mathematics is fine	[1]
	M will be half the gradient *or* 2M is the gradient For other graphs, check that the method to obtain M is correct	[1]

1 e) i)	Two reasonable sources of error should be given.	[2]

Accepted sources of error	***Improvement***
Difficult to measure θ accurately, using a protractor held in one's hand, because of **shaky hands**	**Clamp the protractor** with a retort stand, so that it is stable
Friction present in the ball bearings of the **pulley** causes the setup to be stable over a range of θ	**Lubricate** the axle of the **pulley**
The **hook of the hanger** makes it impossible to place the protractor close to the setup	Tie the hanger to a **piece of string**
Difficult to gauge where the **vertical axis is**	Use a **plumb line** to indicate the vertical axis
The **hook of the hanger** is too thick, making the origin of the angle difficult to judge	Tie the hanger to a **piece of string**
Not accepted sources of error	
Parallax error	
Wind (due to fans)	
Thickness of string	

1 e) ii)	Improvement should address one of the sources of error indicated in (e)(i).	[1]

2 a) i)	Voltage in the range 1.600 to 1.800 volts (inclusive) Voltage is recorded with unit and to the correct precision	[1]
2 a) ii)	Value of resistance calculated correctly and presented with appropriate s.f. and units (2 or 3 s.f.)	[1]
2 b) i)	Voltage in the range 1.480 to 1.560 volts (inclusive) Voltage is recorded with unit and to the correct precision	[1]
2 b) ii)	Percentage uncertainty in V_F **is based on an absolute uncertainty of 0.002 to 0.008 V and correctly calculated** Accept 1, 2 and 3 s.f. % symbol has to be present	[1]
2 b) iii)	Values of proportionality constant k are calculated correctly Percentage difference between values of k is calculated correctly	[1]
	Percentage difference is explicitly compared to the value obtained in (b)(ii) Conclusion is consistent with data obtained	[1]
2 c)	Three wires drawn Rheostat correctly connected	[1]
	LED correctly connected, with short leg connected to negative pole of battery	[1]

Question 3 Suggested Marking Scheme

(a)		Value of w in range of 2.50 to 3.00 cm measured by VC to the correct precision with unit. Value of w in range of 2.5 to 3.0 cm measured by 30-cm ruler to the correct precision with unit.	[1]
		Value of d in range of 0.35 to 0.75 cm measured ONLY by VC to the correct precision with unit. *Student should indicate zero error for VC (annotate).	[1]
(b)	(i)	Value of x should be around 5 cm. Mark cross and annotate if student did not follow instruction but no mark is deducted.	
	(ii)	Correct mode of oscillation, i.e. $T > 3$ s for x around 5 cm (check table if x in b(i) is not 5 cm).	[1]
		Evidence that appropriate number of oscillations (N) has been taken for t ≥ 15 s (check table if x in b(i) is not 5 cm). Correct calculation of T with correct unit given. *T has already been clearly defined in the question as period of oscillations, hence we only give credit to correct usage of this symbol. We do not interpret for student that N =1 in the absence of evidence of t and N in the working or in (c).	[1]
(c)		Data collection Candidate is expected to collect 6 or more sets of data (x, t). - Deduct one mark for collection of 5 sets of data (x, t). - Deduct one mark for not including data in b(ii). - Deduct one mark for no evidence of repeat readings (for time for N oscillations). - Deduct one mark for insufficient range of x values (min. $5 \le x \le 20$ cm) or include x = 25 cm.	[2]
		- Layout: Column headings: The unit must conform to accepted scientific convention e.g. T^2 / s^2 and x^2/ m^2. Annotate if student does not have N column in table or state N clearly. Deduct one mark if N cannot be deduced directly from b(ii) or table.	[1]
		- All raw values of x and t must be given to the correct precision. Credit will be awarded only if both x and t are tabulated.	[1]
		- For each calculated value of e.g. T, x^2 or T^2, the number of s.f. should be the same or one more than the number of s.f. in the raw data.	[1]
		- Correctly calculated values of calculated quantity (max. 1 slip allowed).	[1]
(d)		- Linearizing equation correctly and suitable graph plotted. - Sensible scales must be used. Awkward scales (e.g. 3:10) are not allowed. - Scales must be chosen so that plotted points occupy at least half the graph grid in both x and y directions. - Axes must be labelled with the quantity which is being plotted.	[1]
		- All observations must be plotted. Work to an accuracy of half a small square.	[1]
		- Straight line of best fit – judged by scatter of points about the candidate's line. There must be a fair scatter of points on either side of the line. Deduct this mark if student identified anomaly due to wrong judgement.	[1]
		- Y-intercept must be read off to the nearest half small square or determined from $y = mx + c$ using a point on the line.	[1]
		- Gradient – the hypotenuse of the triangle must be greater than half the length of the drawn line. Read-offs must be accurate to half a small square.	[1]
		- P and Q values are consistent with values of y-intercept and gradient calculated respectively with correct units. Unit of P: s^2 Units of Q: $s^2 m^{-2}$ or $s^2 cm^{-2}$. Check that experimental P & Q values are within range. Accept: $15 \le P \le 30$ s^2 & $1700 \le Q \le 3000$ $m^{-2} s^2$ or $0.17 \le Q \le 0.30$ $cm^{-2} s^2$.	[1]
(e)		Correct method and working for calculation of M. E.c.f. allowed.	[1]
		Final value of M given to the correct s.f. with appropriate unit.	[1]
(f)		Correct method and working for calculation of density. E.c.f. allowed.	[1]
		Final value of density given to the correct s.f. with appropriate unit.	[1]
(g)		Line must have same gradient.	[1]
		Y-intercept value is halved or all y values moved down by half of y-intercept value. Deduct one mark if student has reasoned out the above 2 points but did not draw new line.	[1]

Q4 Mark Scheme

	Marks	Marking Points	Remarks
Diagram	2	Clear labeled diagram showing • Correct setup (D1) • Correct polarity of E-field and B-field of the velocity selector (D2)	D1: Apparatus must include a small slit that allows a straight beam of beta particles to pass through D2: Polarity of the E-field and B-field must be such that the forces acting on the beta particles are in the opposite directions
Variables	5	• Measurement of the thickness of the aluminium using a micrometer screw gauge or vernier caliper (V1). • Measurement of count rate using GM tube connected to counter/any appropriate detector (V2) • Vary thickness to obtain τ (V3) • Method to vary v for 10 sets of readings (V4) • Correct formula to calculate v $\left(= \frac{E}{B} = \frac{V}{dB}\right)$(V5)	If wrong method is used (eg varying v with a constant thickness of aluminum), marks for V3 and V4 will not be awarded. V2: Rate-meter connected to the GM tube is shown in the diagram or stated in the write-up is acceptable. V4: At least 8 sets of readings is acceptable V5: B not substituted with the given value of 0.500 mT is acceptable
Analysis	2	• Propose power law relationship: $\tau = kv^n$ (A1) • Correct linearization, suggest an appropriate graph to plot and comment on how the data will suggest whether the relationship is valid (A2)	A1: Only accepts power law relationship. Either $\tau = kv^n$ or $v = k\tau^n$ is acceptable. A2: Linearisation based on an inappropriate relationship can be accepted provided if all the criteria for A2 are met
Reliability	max. 2	Suggested methods to ensure reliability: • Taking into account background radiation (R1) • Use the count rate vs thickness graph to obtain half-value thickness (R2) • Repeating count rate measurement because of random nature of radioactive decay (R3) • Preliminary trial to identify range of potential difference V corresponding to the range of speed v of the beta source (R4) • Keep distance between the apparatus constant (R5)	R1: Description of how background radiation is taken into account (ie subtract background radiation from measured count-rate) is required R5: Need to state explicitly distance is kept constant or suggest a specific distance. Not acceptable: • Measure thickness at different locations and take average (trivial) • Using a source with a long half life (the source is provided)
safety	max. 1	Relevant safety precaution relating to handling of radioactive source, such as: • Store source in lead lined box when not in use	Reject ridiculous suggestions such as wear lead suits/ lead lined rooms/ lead gloves etc