HWA CHONG INSTITUTION
JC2 Preliminary Examination
Higher 2

CANDIDATE NAME		**CT GROUP**	16S
CENTRE NUMBER		**INDEX NUMBER**	

PHYSICS **9749/01**

Paper 1 Multiple Choice

21 September 2017

1 hour

Additional Materials: Optical Mark Sheet

READ THESE INSTRUCTIONS FIRST

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.

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,
$\varepsilon_o = 8.85 \times 10^{-12}$ 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, $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

1 Which of the following is equivalent to the quantity, 37.86×10^{-4} MJ cm^{-4}?

A 37.86×10^{-18} J m^{-4}

B 37.86 μJ m^{-4}

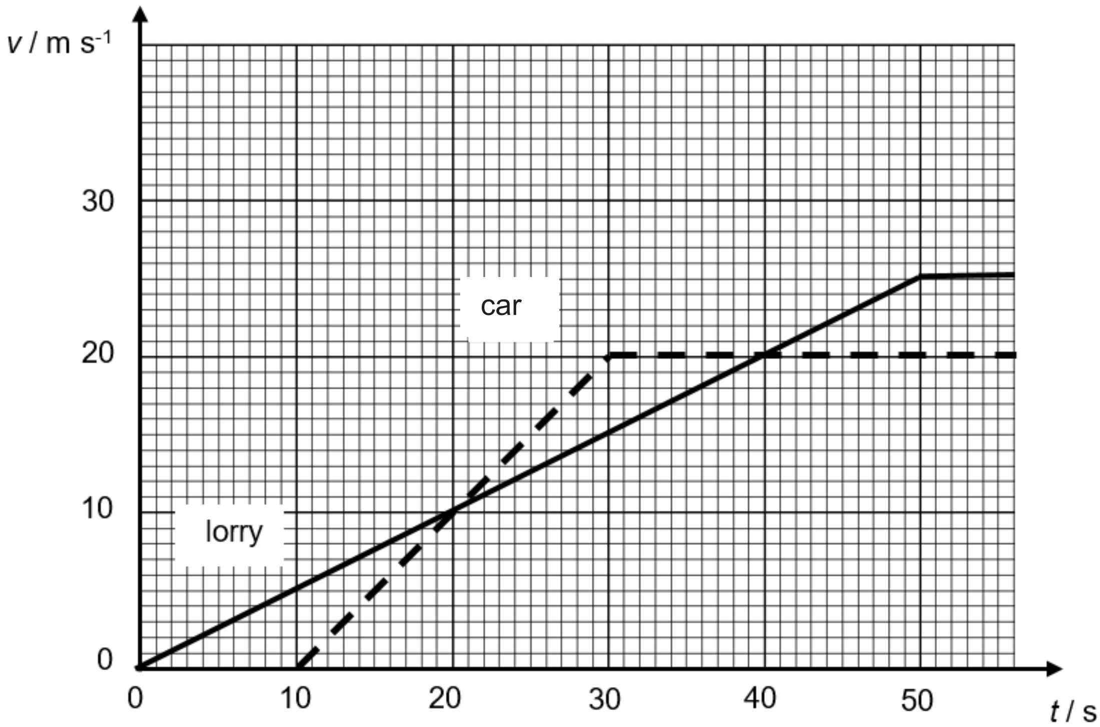
C 378.6 TJ m^{-4}

D 378.6 GJ m^{-4}

2 Which of the following is the best estimate of the population density (population per unit area) in Singapore?

A 10^0 km^{-2} **B** 10^2 km^{-2} **C** 10^4 km^{-2} **D** 10^6 km^{-2}

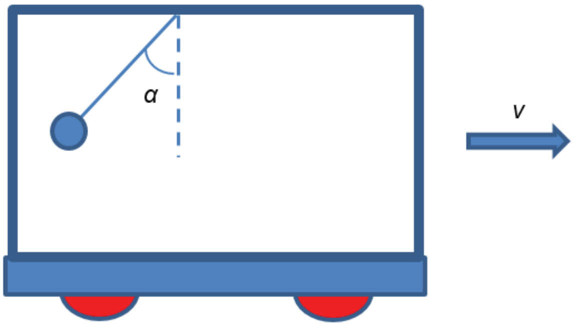
3 The variation with time *t* of the speed *v* of a lorry after leaving a petrol station is as shown in the graph below. A car leaves the petrol station 10.0 s later and its speed-time graph is also shown.



At which of the following times would the distance between the lorry and car be the least?

A 20.0 s **B** 30.0 s **C** 40.0 s **D** 50.0 s

4 A mass m hangs at the end of a rope which is attached to a support fixed on a trolley moving to the right with a speed v on a horizontal track, as shown. The angle, α, is the angle the rope makes with the vertical.



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

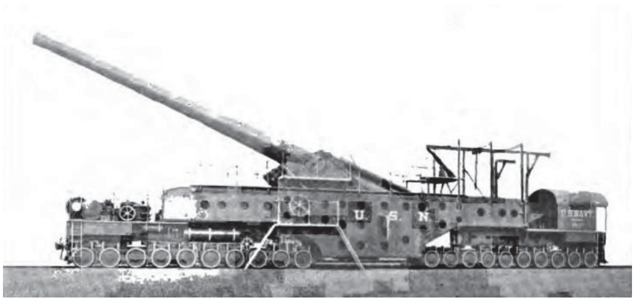
A The angle α is zero when the trolley moves with a uniform speed.

B When the trolley moves with a constant acceleration a, the magnitude of angle α is only determined by a and g.

C The tension T in the rope is larger when the trolley moves with a uniform speed than when it moves with a constant acceleration.

D The ball swings to the right when the trolley decelerates.

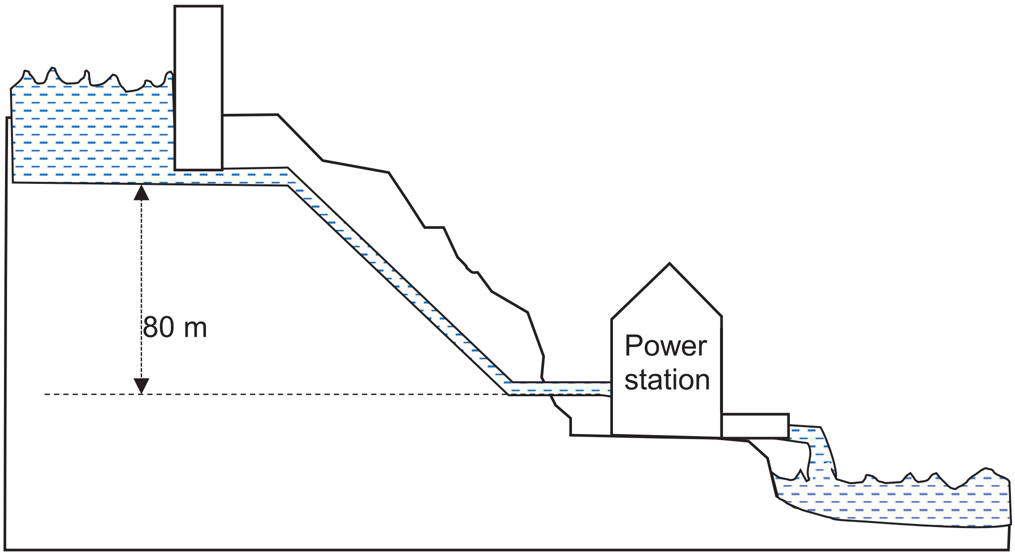
5 A 70 000 kg railway gun sitting on the railway platform in contact with the Earth is as shown.



It fires a 500 kg artillery shell at an angle of 45° and with a muzzle velocity of 200 m s^{-1}. What is the magnitude of the recoil velocity of the gun?

A 0.5 m s^{-1} **B** 1.0 m s^{-1} **C** 1.4 m s^{-1} **D** 2.8 m s^{-1}

6 A hydroelectric power station is shown in the figure below.



Water is supplied from a reservoir which is 80 m above the power station. The water passes through its turbines at a rate of 6.0 m^3 s^{-1}.

Assume that the density of water is 1000 kg m^{-3}.

If the efficiency of the power station is 60%, the electrical power output is

A 0.29 MW **B** 1.9 MW **C** 2.8 MW **D** 4.7 MW

7 The engine of a boat delivers 30.0 kW to the propeller while the boat is moving at a constant speed of 15.0 m s^{-1}. The total drag on the boat is proportional to the square of the speed of the boat. If the boat is being towed at 5.0 m s^{-1} after its engine has broken down, the average tension in the towline will be

A 44.4 N **B** 220 N **C** 2000 N **D** 3330 N

8 A light string can bear up to 3.7 kg of mass. A stone of mass 500 g is tied at its end and revolved in vertical circular path of radius 4.00 m. Taking g = 10 m s^{-2}, the maximum angular velocity of the stone is

A 3.0 rad s^{-1} **B** 4.0 rad s^{-1} **C** 5.0 rad s^{-1} **D** 6.0 rad s^{-1}

9 Given that the mass of Earth is M_E, the radius of Earth is R_E, the mass of Mars is M_M and the radius of Mars is R_M, the ratio of the escape speed on the surface of the Earth to the escape speed on the surface of Mars is

A $\sqrt{\frac{M_E}{M_M}\frac{R_E}{R_M}}$ **B** $\sqrt{\frac{M_E}{M_M}\frac{R_M}{R_E}}$ **C** $\sqrt{\frac{M_M}{M_E}\frac{R_E}{R_M}}$ **D** $\sqrt{\frac{M_M}{M_E}\frac{R_M}{R_E}}$

10 The radius of planet X is twice the radius of planet Y and both planets have the same density. The ratio of the acceleration due to gravity at the surface of X to that at the surface of Y is

A 1 : 4 **B** 1 : 2 **C** 2 : 1 **D** 4 : 1

11 A 2.0 kg chunk of ice at -20 °C is placed in 4.0 kg of water at an initial temperature. Assuming that there is no heat loss to the surrounding, what is the initial temperature of the water that will allow all the ice to just melt?

Specific heat capacity of water = 4200 J kg^{-1} K^{-1}
Specific heat capacity of ice = 2100 J kg^{-1} K^{-1}
Specific latent heat of fusion = 3.35×10^5 J kg^{-1}

A 20 °C **B** 40 °C **C** 45 °C **D** 90 °C

12 The density of a sample of helium gas at the pressure of 100 kPa is 0.178 kg m^{-3}. The root-mean-square speed of the helium molecules is

A 41 m s^{-1} **B** 1300 m s^{-1} **C** 561 km s^{-1} **D** 1685 km s^{-1}

13 A mole of a monatomic ideal gas is contained in a cylinder with a movable piston. The temperature of the gas is 200 K and the volume of the gas is 25 x 10^{-3} m^3.

The gas now expands at constant pressure such that the volume of the cylinder increases by 75 x 10^{-3} m^3. The change in internal energy of the gas is

A 7500 J **B** -7500 J **C** 10000 J **D** -10000 J

14 The first law of thermodynamics may be expressed as

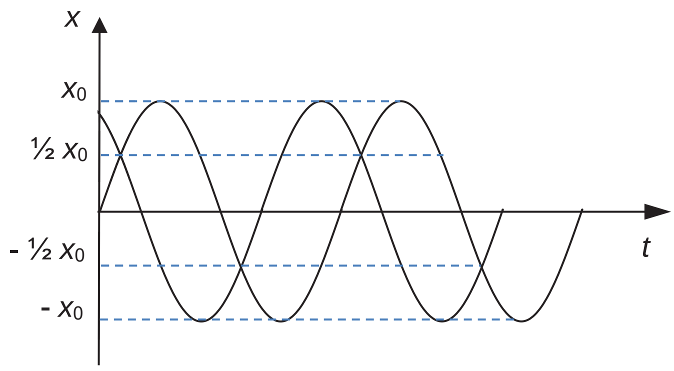
$$\Delta U = q + w$$

where ΔU is the increase in internal energy of the system,
q is the thermal energy supplied to the system,
w is the work done on the system.

Some liquid at its freezing point contracts as it turns to a solid.
What are the changes in ΔU, q and w as the liquid freezes?

	ΔU	q	w
A	negative	negative	positive
B	negative	zero	positive
C	positive	zero	negative
D	zero	negative	positive

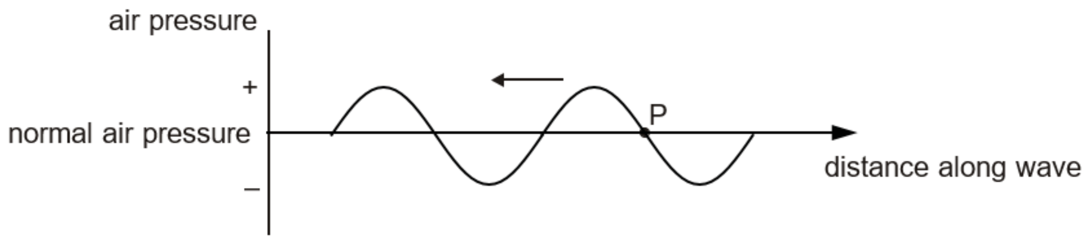
15 Two identical vertical spring mass systems hung at the same height execute simple harmonic motion of the same amplitude and frequency. The graph below shows the variation of the displacements of the masses with time. The masses pass one another at half the amplitude when they are going in opposite directions.



The phase difference between them is

A 90° **B** 120° **C** 135° **D** 150°

16 The graph below shows the variation of air pressure with distance along a wave at one given time. The arrow indicates the direction of travel of the wave.



The air pressure at point P is

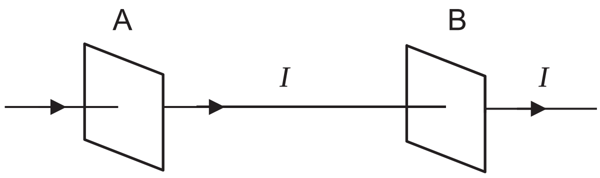
A increasing

B decreasing

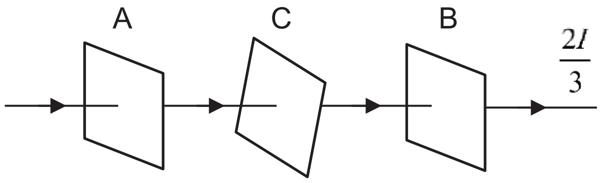
C constant

D zero

17 When a narrow beam of plane-polarised light passes through an ideal polariser A, the light intensity is observed to be I. When an identical polariser B is placed behind A, it is observed that the light intensity beyond B is still I.



A third identical polariser C is now inserted between A and B, causing the light intensity emerging from B to become $\frac{2I}{3}$.



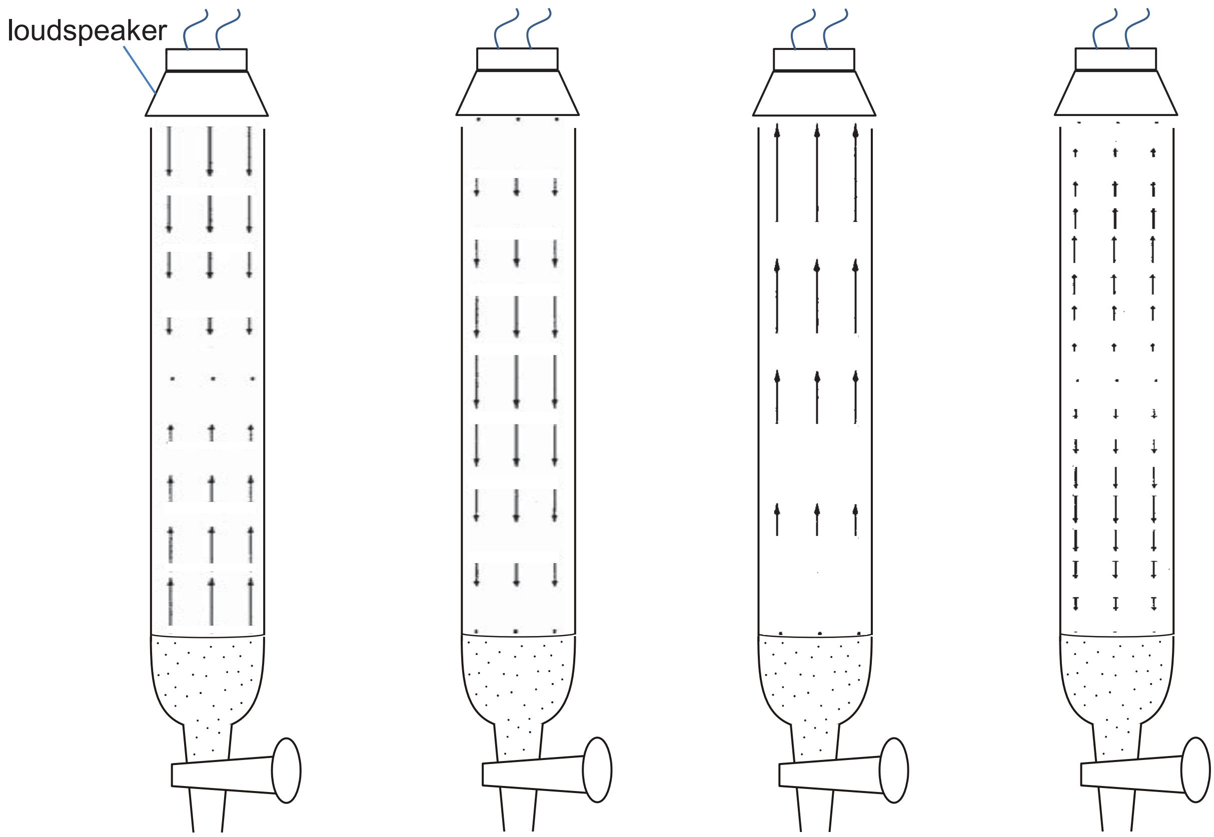
What is the angle between the axes of polarisation of the polarisers A and C?

A 25.4º **B** 35.3º **C** 48.2º **D** 55.6º

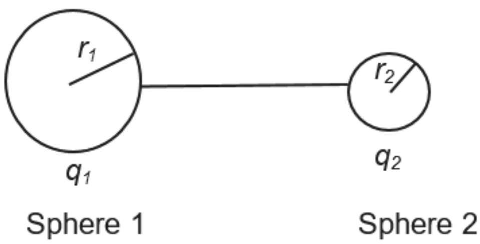
18 A loudspeaker generating a sound of a fixed frequency is held above the top of a burette filled with water. The water gradually runs out of the burette until a maximum loudness of the sound is heard.

Which of the following best shows a possible standing wave pattern set up by air molecules in the burette at this position?

A **B** **C** **D**



19 Two spherical conductors of radii r_1 and r_2 are separated by a distance much greater than the radius of either sphere. The spheres are connected by a conducting wire as shown below. The charges on the spheres in equilibrium are q_1 and q_2 respectively. Find the ratio of the electric field at the surface of sphere 1 to the electric field at the surface of sphere 2.

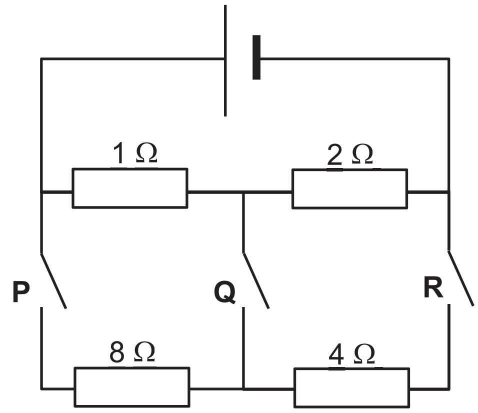


A $\sqrt{\dfrac{r_2}{r_1}}$ **B** $\dfrac{r_2}{r_1}$ **C** $\dfrac{r_2^{\,2}}{r_1^{\,2}}$ **D** 1

20 A copper wire of length l and diameter d has potential difference V applied at its two ends. The drift velocity of the electrons is v_d. If the diameter of copper wire is changed to $\frac{d}{3}$, the drift velocity becomes

A $9\ v_d$ **B** $v_d / 9$ **C** $v_d / 3$ **D** v_d

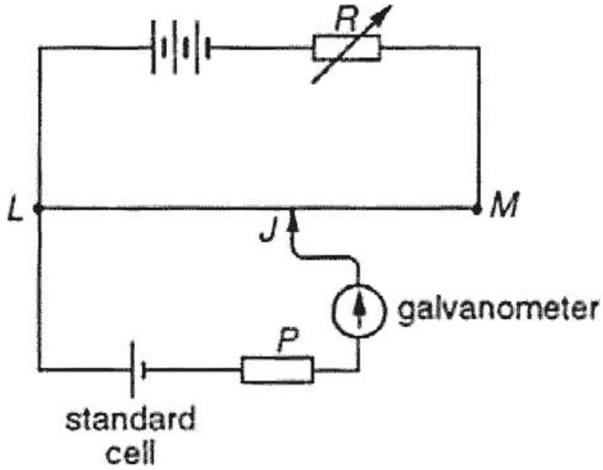
21 The figure below shows the arrangement of four resistors, each with a different resistance.



Which of the following switch settings will produce the greatest current in the circuit?

	P	Q	R
A	Open	Open	Open
B	Open	Closed	Closed
C	Closed	Open	Closed
D	Closed	Closed	Closed

22 A potentiometer is to be calibrated with a standard cell using the circuit as shown.



The balance point is found to be near *L*. To reduce the percentage uncertainty, the balance point should be nearer *M*. This may be achieved by

A replacing the galvanometer with one of lower resistance.

B replacing the potentiometer wire with one of higher resistance per unit length.

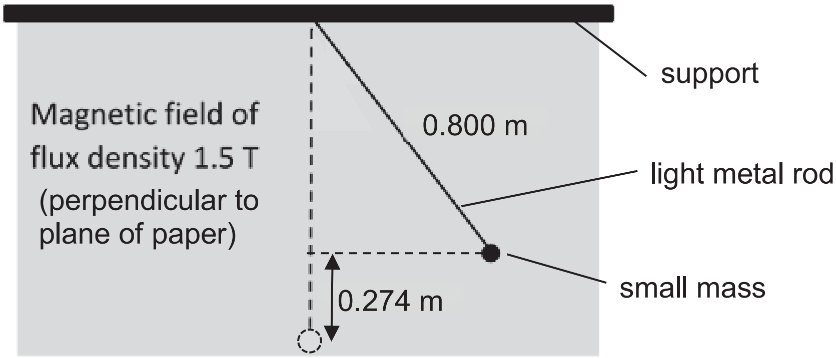
C increasing the resistance *R*.

D removing the resistor *P*.

23 Two very long, straight, parallel wires carry equal steady current I in opposite directions. The distance between the wires is *d*. At a certain instant of time, a point charge *q* is at a point equidistant from the two wires, in the plane of the wires. Its instantaneous velocity *v* is perpendicular to this plane. The magnitude of the force due to the magnetic field acting on the charge at this instant is

A 0 N **B** $\dfrac{\mu_0 Iqv}{2\pi d}$ **C** $\dfrac{\mu_0 Iqv}{\pi d}$ **D** $\dfrac{2\mu_0 Iqv}{\pi d}$

24 A small mass hangs at the end of a thin light metal rod of length 0.800 m hinged at one end to a support. The mass is brought to a height of 0.274 m. It is then released from rest to oscillate in a uniform magnetic field of magnetic flux density 1.5 T as shown.



Which of the following gives the average speed of the rod and the instantaneous e.m.f. induced in the rod at its lowest point of oscillation?

	average speed of the rod / m s^{-1}	induced e.m.f. / V
A	2.32	1.4
B	2.32	2.8
C	1.16	1.4
D	1.16	2.8

25 Fig. 25 (a) shows two concentric circular conductors lying in the same plane. The current in the outer loop is clockwise and changes with time as shown in Fig. 25 (b).

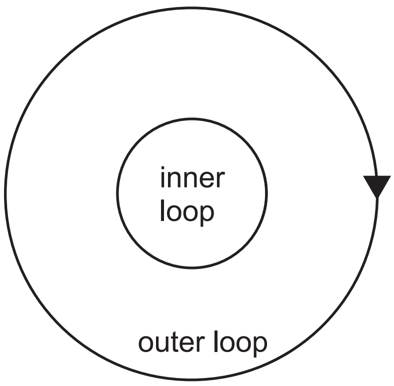


Fig. 25 (a)

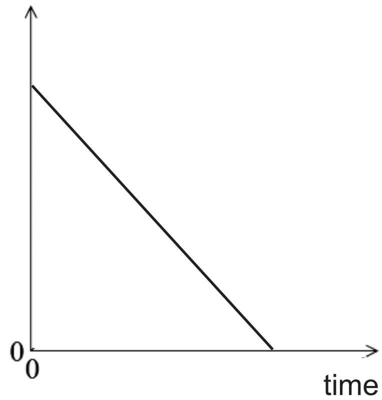


Fig. 25 (b)

The induced current in the inner loop is

A constant in the clockwise direction.
B variable in the clockwise direction.
C constant in the anticlockwise direction.
D variable in the anticlockwise direction.

26 Fig. 26 (a) and (b) shows two separate types of alternating potential difference with the same peak voltage (V_p) applied across a load resistor R.

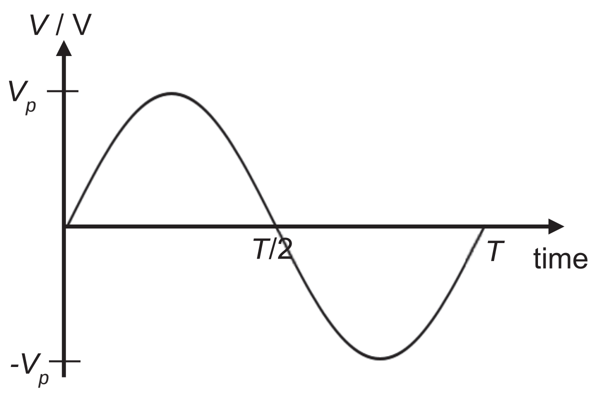


Fig. 26 (a)

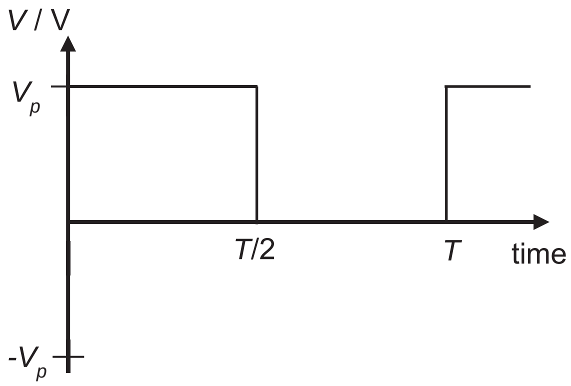


Fig. 26 (b)

What is the ratio $\dfrac{\text{root-mean-square potential difference for (a)}}{\text{root-mean-square potential difference for (b)}}$?

A 0.5 **B** 0.7 **C** 1 **D** 1.4

27 The continuous optical spectrum of light from the Sun, observed from the Earth is crossed by dark lines at particular wavelengths. The photosphere is the outer layer of gas around the Sun's core. Which one of the following statements correctly accounts for these dark lines?

A The elements that exist in the photosphere which are hotter than the Sun's inner regions, absorb the photons emitted from the Sun.

B The elements that exist in the solar interior absorb the photons emitted from the Sun.

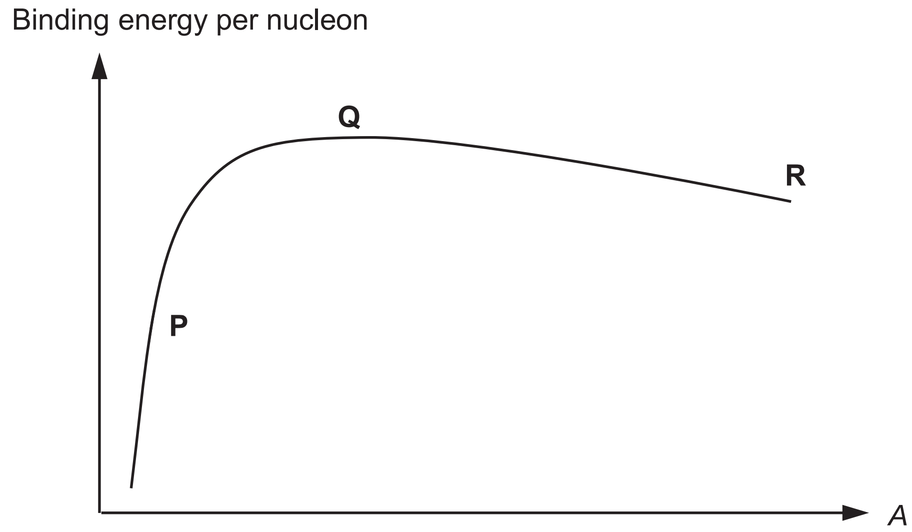
C The elements found in the Earth's atmosphere absorb the photons emitted from the Sun.

D The elements that exist in the cooler photosphere absorb the photons emitted from the Sun.

28 Electrons in a cathode ray tube are accelerated from rest through a potential difference V. What percentage change in the de Broglie wavelength associated with these electrons will occur if the potential difference through which these electrons are accelerated is doubled?

A 29% decrease
B 50% decrease
C No change
D 29% increase

29 The graph below shows how the binding energy per nucleon of a nucleus varies with nucleon number *A*.



Which one of the following statements is **not** true?

A Nuclear fusion reactions bring nuclei closer to region Q.

B Nuclei in region Q are more stable than nuclei in region R.

C Energy is released in nuclear fission reactions from nuclei in region P.

D The binding energy per nucleon increases most significantly at lower nucleon numbers.

30 The grid shows a number of nuclides arranged according to the number of protons and the number of neutrons in each. A nucleus of the nuclide ${}^{8}_{3}Li$ decays by emitting a β particle. What is the resulting nuclide?

number of protons \ number of neutrons	0	1	2	3	4	5	6
4					**A**	**B**	
3				${}^{6}_{3}Li$	${}^{7}_{3}Li$	${}^{8}_{3}Li$	
2		${}^{3}_{2}He$	${}^{4}_{2}He$			**C**	**D**
1	${}^{1}_{1}H$	${}^{2}_{1}H$					

End of Paper

HWA CHONG INSTITUTION
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME		**CT GROUP**	16S
TUTOR NAME			

PHYSICS — 9749/02

Paper 2 Structured Questions — **13 September 2017**

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your **name, CT class** and **subject tutor's name** in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
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		
Paper 1		**30**
Paper 2		
1		**10**
2		**11**
3		**10**
4		**10**
5		**10**
6		**10**
7		**19**
Deductions		
Total		**80**

Data

speed of light in free space,
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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, $V = \frac{Q}{4\pi\varepsilon_0 r}$

alternating current / voltage, $x = x_o \sin \omega t$

magnetic flux density due to a long straight wire
$B = \frac{\mu_o I}{2\pi d}$

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magnetic flux density due to a long solenoid
$B = \mu_o n I$

radioactive decay, $x = x_o \exp(-\lambda t)$

decay constant, $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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1 a) Explain two conditions required for a body to be in a state of equilibrium.

1………………………………………………………………………………………………………

………………………………………………………………………………………………………

2………………………………………………………………………………………………………

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

b) Two smooth spheres M_1 and M_2, both of mass 2.0 kg, are connected by an inextensible bar of negligible mass to form a rigid body. The spheres rest on smooth 45° inclines as shown in Fig. 1.1.

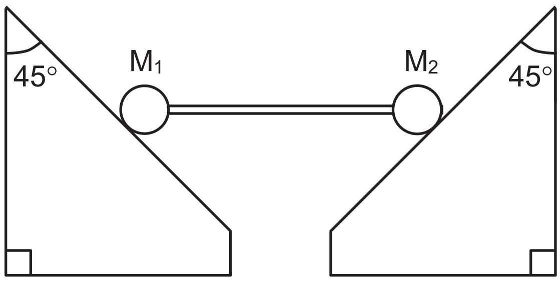

Fig. 1.1

(i) The system (2 spheres and the bar as one rigid body) is in a state of equilibrium when the bar is horizontal. Draw and label clearly the forces acting on the system in Fig 1.1.

[2]

(ii) Calculate the contact force that the incline exerts on M_1.

force = ……………………………… N [2]

(c) M_2 is now replaced by M_3, a sphere with mass of 4 kg.

(i) Explain why the contact forces that the inclines exert on M_1 and M_3 must be equal in magnitude, for the system to be in a state of equilibrium.

………………………………………………………………………………………………………

………………………………………………………………………………………………………

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

(ii) Explain why, for the system to be in a state of equilibrium, the bar cannot be horizontal.

……

……

……

……[2]

(iii) Hence, sketch in Fig. 1.2 how the system should be placed on the inclines so that the system is in a state of equilibrium. (Label M_1 and M_3)

[1]

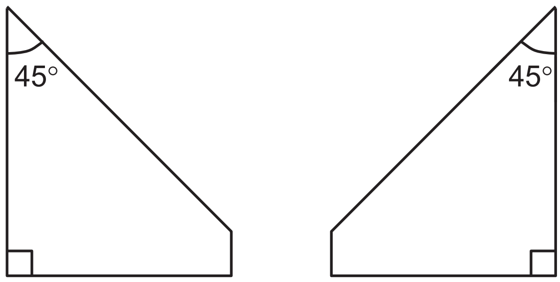

Fig. 1.2

2 **(a)** Define gravitational field strength.

………

………

…… [1]

(b) Consider a satellite of mass m, orbiting the Earth of mass M_E, in a circular path of radius r, with an orbital period of T.

(i) Write down an expression for the acceleration of the satellite in terms of M_E, r and G (the gravitational constant).

[1]

(ii) Show that T^2 is proportional to r^3, and obtain an expression for the constant of proportionality.

constant of proportionality = ………………………………… [3]

Raduga 5 is a Russian-owned geostationary satellite launched in April 1979.

(iii) Determine the angular velocity of Raduga 5.

angular velocity = ……………………………..rad s^{-1} [1]

(iv) Given that the radius of the Earth $= 6.4 \times 10^{6}$ m and the mass of the Earth $= 6.0 \times 10^{24}$ kg, determine the altitude that Raduga 5 maintains above the surface of the Earth.

altitude = ……………………………..m [3]

(v) Suggest, with a reason, a possible use of the Raduga 5 geostationary satellite.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

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

3 One end of a spring is fixed to a support. A mass is attached to the other end of the spring. The arrangement is shown in Fig. 3.1.

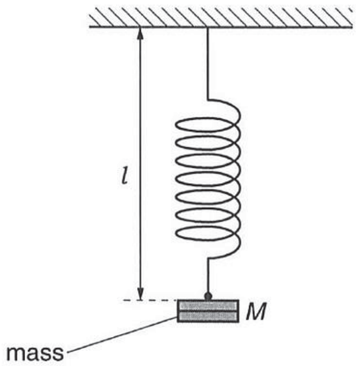

Fig. 3.1

This arrangement is used to determine the length l of the spring when mass M is attached to the spring. The procedure is repeated for different values of M. The variation of mass M with length l is shown in Fig. 3.2.

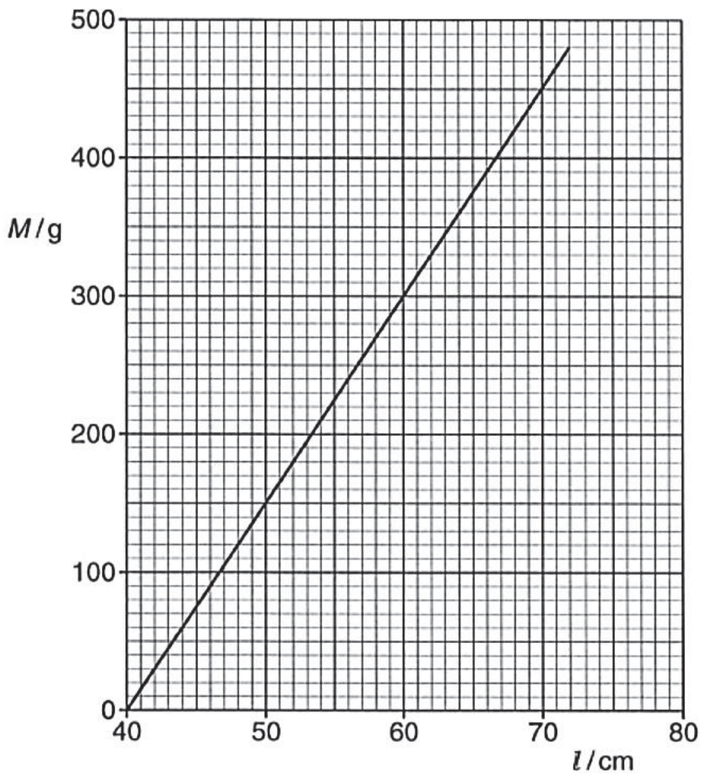

Fig. 3.2

(a) Show that the spring constant k of the spring is 14.7 N m^{-1}. [2]

(b) A mass of 450 g is attached to the spring and is held at rest with length l of 50.0 cm. The mass is then released and the mass oscillates freely. The angular frequency of the spring-mass system is given by the formula

$$\omega = \sqrt{\frac{k}{m}}$$

(i) Calculate the frequency of the system.

frequency = ……………..………...……..Hz [2]

(ii) Calculate the speed of the mass during its oscillation when the spring is extended to a length l of 80.0 cm.

speed = ……………...………...…….. m s^{-1} [4]

(c) The spring is assumed to be light. In practice, the spring will have some mass. Assuming that the spring constant k is unchanged, suggest and explain the effect on the frequency of oscillation of having a spring with mass.

……

……

……

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

4 **(a)** State what is meant by *diffraction* and *destructive interference*.

diffraction:……………………………………………………………………………………………..

……

destructive interference: ……………………………………………………………………………

……

……

……
[3]

(b) In Fig. 4.1, a red laser with a frequency of 4.69×10^{14} Hz is incident on a diffraction grating of 3000 lines per cm. The screen 2.30 m from the grating captures the whole interference pattern.

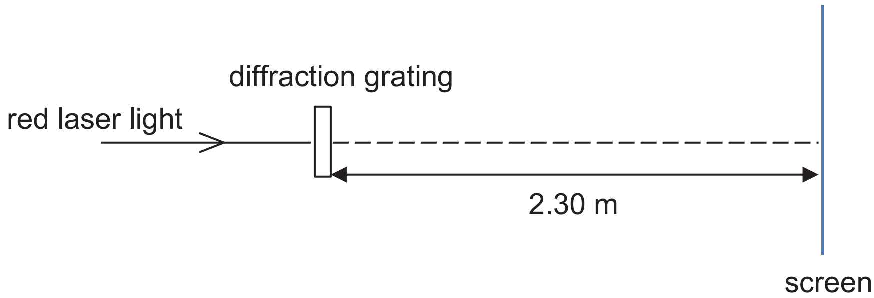

Fig. 4.1

(i) Determine the possible number of intensity maxima on the screen.

possible number of intensity maxima = ………………………………. [3]

(ii) Determine the distance of the furthest maximum away from the central maximum on the screen.

distance = ……………..…………..…….. m [2]

(c) The red laser is replaced with a green laser. How would this affect the pattern on the screen? Explain your answer.

………

………

……[1]

(d) Suggest why it is better to use a diffraction grating than a double slit to determine the wavelength of the laser.

………

………

……[1]

5 In order to investigate the photoelectric effect, a student varied the wavelength of the radiation incident on the metal surface. For each value of wavelength λ, the stopping voltage V_s required just to prevent electrons from reaching the electrode was measured. Two such data are shown in Fig. 5.1.

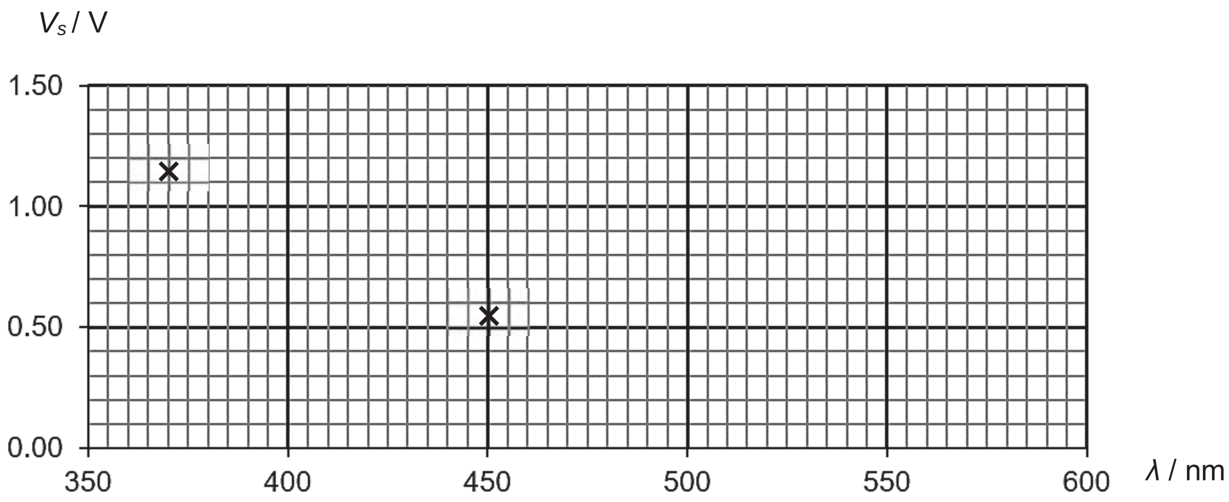

Fig. 5.1

(a) What is the maximum kinetic energy of a photoelectron emitted from the metal surface by radiation of wavelength 370 nm?

maximum kinetic energy = ………….……….…….. J [2]

(b) Calculate the energy of a photon of wavelength 370 nm.

energy of photon = ………….……….…….. J [2]

(c) Using your answers to **(a)** and **(b)**, show that the threshold wavelength is 560 nm.

[2]

(d) Without further calculations, sketch in Fig. 5.1 the graph that the student should obtain at the end of the experiment.

[2]

(e) The student decided to repeat the experiment by doubling the intensity of the radiation incident on the metal surface. State and explain whether this change would affect the results obtained in Fig. 5.1.

………

………

………

………[2]

6 **(a)** Isotope X undergoes radioactive decay to form isotope Y. The half-life of isotope X is 2.0×10^5 years. The activity of a pure sample of isotope X extracted from an ore is measured to be 1.1×10^7 Bq.

(i) State what is meant by isotopes.

……………………………………………………………………………………………………

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

(ii) Explain why the measured activity of the sample X is relatively constant.

……………………………………………………………………………………………………

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

(iii) It is discovered that isotope Y undergoes radioactive decay to form isotope Z. The half-life of isotope Y is 1.5 hours.

1. Calculate the decay constant of Y.

decay constant of Y = ………………………………… s^{-1} [1]

2. The number of isotope Y in the sample is found to be constant. Explain how this is possible.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

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

3. Hence, determine this amount of Y.

amount of Y = ………………………………… atoms [2]

(b) Th-232 decays by alpha-emission with a decay constant of 1.57×10^{-18} s^{-1}. This is the beginning of a decay chain which eventually ends in Pb-208. A sample of rock is found to contain both Th-232 and Pb-208 in the ratio of 5:1.

(i) When the rock was formed, there was no Pb-208 present in the sample. Estimate the age of the rock.

age of rock = ……………………………… years [2]

(ii) State the assumption made in **(b)(i)** regarding the intermediate product nuclei.

……

……

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

(iii) State with a reason, whether your answer in **(b)(i)** is an overestimate or an underestimate of the age of the rock if the assumption in **(b)(ii)** is not valid.

……

……

……

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

7 The article below is freely adapted from "What if I Double It?" by Thomas Humphrey.

Read the article and then answer the questions that follow.

What if I Double It?

Suppose you are responsible for cooking a turkey and have access to a large range of cookbooks. You have a 9.0 kg turkey but the first cookbook you consult only tells you how long it takes to cook a 4.5 kg turkey. Since the 9.0 kg turkey is twice the size of a 4.5 kg bird, at first the answer might seem obvious. Simply double the cooking time suggested for a 4.5 kg turkey. But is this really the right thing to do?

A second cookbook suggests that when you double the weight of a turkey, you don't have to double the cooking time. It indicates a cooking time of 4.0 hours for the small bird and 6.5 hours for the larger bird. So even though the 9.0 kg turkey is twice the weight of the 4.5 kg turkey, you only have to cook it about 1.6 times as long. Why would that be?

A more detailed analysis reveals that a turkey has more features than just its mass. When the mass is doubled other features such as width, surface area and volume are also scaled up. The turkey also has a density, a thermal conductivity (how well it transfers the oven's heat to its interior), and a specific heat capacity (how much heat it needs to climb one degree Celsius in temperature). How do some or all of these factors change in going from a 4.5 kg to a 9.0 kg turkey?

Let's imagine that our turkey is shaped like a cube. This will make it easier to see how the various factors change. Take a look at the cubical turkeys in Fig. 7.1.

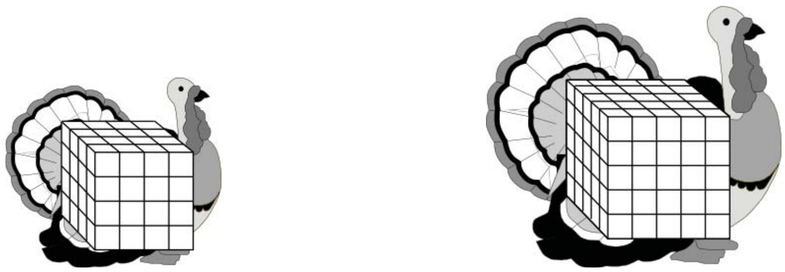

Fig.7.1

If you count the number of small cubes in the 4.5 kg turkey, you will find that there are 4 × 4 × 4,
or 64 cubes. The number of cubes in the 9.0 kg turkey is 5 × 5 × 5, or 125 cubes. That's not exactly double, but it's pretty close. So now we know that the 9.0 kg turkey is about twice the volume of the 4.5 kg turkey (that is, it contains twice as many little cubes), and therefore it weighs about twice as much.

So when you double the size of the turkey, what happens to its width and surface area? Do they double too? If you look at the cubical turkeys above, you can see that the widths of the two turkeys are 4 and 5 blocks respectively. So the bigger turkey is about 25% wider than the smaller one. The width did not double.

If we look at surface area, the smaller turkey has 6 sides × 16 blocks per side, or 96 blocks. The surface area of the big turkey has 6 sides × 25 blocks per side, or 150 blocks. That means that the big turkey has about 50 percent more blocks on its surface than the small turkey. The surface area did not double either.

More precisely, on a real turkey, the width and all other linear dimensions increase by a factor of 1.26 and the surface area by a factor 1.59. Now let's analyse how this information allows us to make predictions as to a turkey's cooking times.

The 9.0 kg turkey, because it has doubled in volume, has twice as much stuff in it to be heated up, so we need to put in twice as much heat. How does this heat get into it? It is transferred across the surface of the turkey, traveling from the surface to the core of the bird. The bigger turkey has more surface area. That should speed up the transfer of heat, but the heat has to travel a longer way to the centre. That will slow things down. The net result is that it doesn't take twice as long to cook a twice-as heavy turkey. The physics fits with the information in the cookbook!

If we put the three factors together, the cooking time increases by a factor of 1.59 to 6.4 hours. Our cook book says to increase the time to 6.5 hours, or by a factor of 1.62. (6.5 hrs ÷ 4 hrs = 1.62). That's pretty close!

So now we know how to cook a turkey. We have discovered that the seemingly innocuous question, " What happens if you double it?" has turned out to be rather more complex than we had initially thought. We must be very specific about which feature of the turkey we are doubling because we don't seem to be able to double everything at once!

(a) An important factor is missing from the explanation of specific heat capacity. Modify the statement to make it more accurate (lines 13-14)

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

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

(b) **(i)** Show how the factors 1.26 and 1.59 mentioned in line 32 can be proven mathematically.

[2]

(ii) The smaller (4.5 kg) turkey has a width of 22 cm. Calculate the width of the larger (9.0 kg) turkey (lines 31-33)

width = ……………..………..…….. cm [1]

(iii) The larger turkey (9.0 kg) has a surface area of 0.46 m^2. Calculate the surface area of the smaller (4.5 kg) turkey (lines 31-33)

surface area = ……………..………..…….. m^2 [1]

(c) The turkeys are considered to be cooked when their average temperature has risen 90 ^oC.

(i) How much thermal energy does this require for the 9.0 kg turkey? (Specific heat capacity of turkey = 3200 J $kg^{-1}\,^oC^{-1}$).

energy = ……………………………….. J [2]

(ii) The electrical power supplied to the cooking oven was 2200 W. If all this energy was transferred as thermal energy to the turkey, how long should the 9.0 kg turkey have taken to cook?

time = ……………………………….. s [1]

(iii) Suggest two reasons why there is such a large difference between the answer to **(c)(ii)** and the time given in the passage?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

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

(d) Show mathematically how the three factors discussed in lines 34-40 when combined, lead to the conclusion that the 9.0 kg turkey requires a cooking time 1.59 times longer than for a 4.5 kg turkey.

[2]

(e) The rate of heat transfer through a cylindrical object is given by the equation

$$\frac{\Delta Q}{\Delta t} = kA\frac{\Delta \theta}{\Delta x}$$

where
k is a constant which is the thermal conductivity of the object,
A is the cross-sectional area of the cylinder,
Δx is the length of the cylinder, and
$\Delta \theta$ is the temperature difference across the length of the cylinder.

This equation can be used to provide a crude estimate of the rate of heat conduction from the surface to the core of the turkey.

(i) You may assume that during the cooking of the turkey, the temperature difference ($\Delta \theta$) remains at a constant 140 ^{o}C and that this temperature gradient occurs over **half the width of the turkey.** Estimate the rate of heat transfer for the 9.0 kg turkey (with the help of data from **(b)(ii)** and **(b)(iii)**).
(Thermal conductivity, k for the turkey = 0.60 in S.I. units)

rate of heat transfer = ………….……….…….. W [3]

(ii) Assuming that this rate of heat transfer to the turkey remains constant over the cooking time and using your result of **(c)(i)**, calculate the cooking time for the 9.0 kg turkey in hours.

time = …………..………..…….. hr [1]

(iii) Use the answer to **(e)(ii)** to calculate the cooking time for an 18.0 kg turkey.

time = …………..………..…….. hr [1]

(iv) What are the S.I. base units for the constant *k*?

S.I. base units = …………..………..…….. [2]

End of Paper

HWA CHONG INSTITUTION
JC2 Preliminary Exam
Higher 2

CANDIDATE NAME		**CT GROUP**	16S
TUTOR NAME			

PHYSICS

9749/03

Paper 3 Longer Structured Questions

15 Sep 2017

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

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

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

Section A
Answer **all** questions.

Section B
Answer **one** question only.

You are advised to spend one and half hours on Section A and half an hour on Section B.

At the end of the examination, fasten all your work securely together.
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		**10**
2		**10**
3		**10**
4		**10**
5		**9**
6		**11**
Section B (Answer **ONE** question only and circle below the question answered)		
7		**20**
8		**20**
Deductions		
Total		**80**

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,
$\varepsilon_o = 8.85 \times 10^{-12}$ 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 $p = \rho g h$

gravitational potential, $\phi = -\frac{Gm}{r}$

temperature T/K = T/ °C + 273.15

pressure of an ideal gas $P = \frac{1}{3}\frac{Nm}{V} < c^2 >$

mean kinetic energy of a molecule of an ideal gas
$E = \frac{3}{2}kT$

displacement of particle in s.h.m., $x = x_o \sin \omega t$

velocity of particle in s.h.m., $v = v_o \cos \omega t$
$= \pm \omega \sqrt{(x_o^2 - x^2)}$

electric current $I = Anvq$

resistors in series, $R = R_1 + R_2 + \ldots$

resistors in parallel, $1/R = 1/R_1 + 1/R_2 + \ldots$

electric potential, $V = \frac{Q}{4\pi\varepsilon_o r}$

alternating current / voltage, $x = x_o \sin \omega t$

magnetic flux density due to a long straight wire
$B = \frac{\mu_o I}{2\pi d}$

magnetic flux density due to a flat circular coil
$B = \frac{\mu_o N I}{2r}$

magnetic flux density due to a long solenoid
$B = \mu_o n I$

radioactive decay, $x = x_o \exp(-\lambda t)$

decay constant, $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1 **(a)** **(i)** Define *acceleration*.

....

.... [1]

(ii) Use your definition in (a)(i) and the definition of average velocity to derive an expression for *v* in terms of *u*, *a* and *s* where *v* is the final velocity, *u* is the initial velocity, *a* the uniform acceleration, *t* the time interval and *s* the distance travelled.

[2]

(b) The graph of Fig 1.1 shows the variation with time of the velocity *v* of a ball of mass 320 g from the moment it is thrown with a velocity of 20 m s^{-1} vertically upwards to the moment it returns to the thrower's hand.

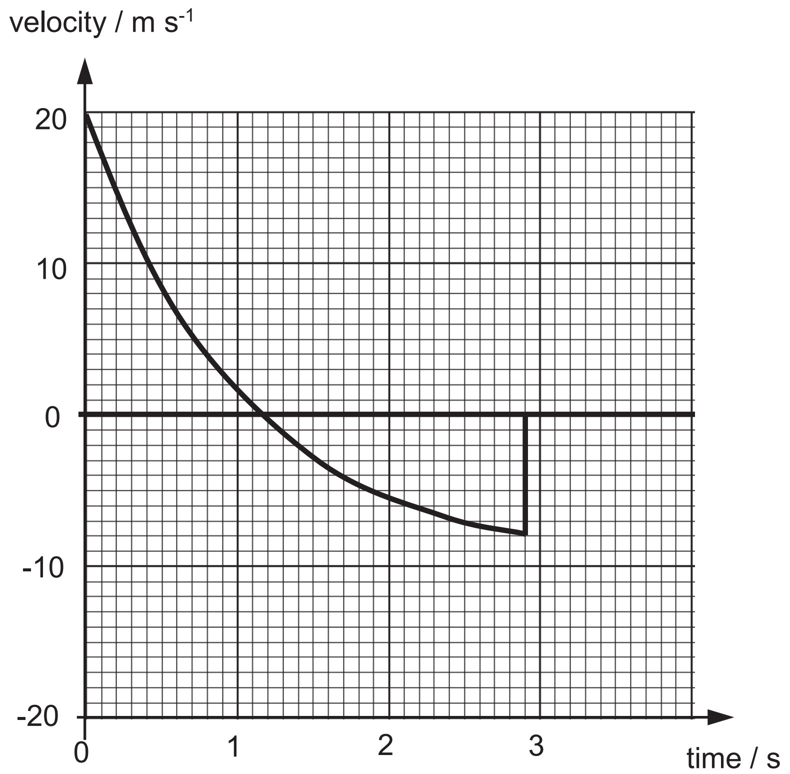

Fig. 1.1

(b) **(i)** State the time at which the ball reaches its maximum height.

time = ……………………… s [1]

(ii) Determine the acceleration of the ball 0.5 s after leaving the thrower's hand.

acceleration = ………………… m s^{-2} [2]

(iii) Based on your answer in (b)(ii), determine the magnitude of the drag force on the ball 0.5 s after leaving the thrower's hand.

drag force = ………………………… N [2]

(iv) Explain why the time taken on the way up to maximum height is less than the time taken on the way down to the thrower's hand.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

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

2 A steel ball of mass m = 200 g is fixed, using glue, to one end P of a light rigid rod CP of negligible mass as shown in Fig. 2.1.

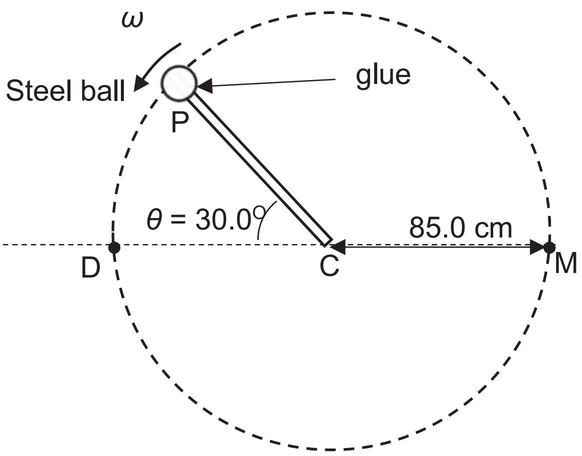

Fig. 2.1

The rod is rotated by an electric motor in a vertical plane about end C so that the ball moves in a vertical circle of radius 85.0 cm with constant angular velocity ω.

(a) **(i)** Determine the loss in the gravitational potential energy of the steel ball when it is being rotated from the position 30° above horizontal, P, to the horizontal position D.

loss in gravitational potential energy = ……………….. J [2]

(ii) Hence, explain whether the work done by the electric motor on the rod and the ball is positive or negative when the ball is moved from P to D.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(iii) State the work done by the electric motor on the rod and the ball when the steel ball is being rotated from P to D.

work done by electric motor = ……………….. J [1]

(b) The angular speed of the rod and ball is gradually increased until the glue fixing the ball snaps. The glue snaps when the tension in it is 8.50 N.

(i) Mark with the letter S on the dotted circle in Fig. 2.1 the position of the ball where the glue is likely to snap. Sketch on Fig. 2.1 the subsequent path taken by the ball after the glue snaps. [2]

(ii) Calculate the angular speed of the ball when the glue holding the steel ball to the rod snaps.

angular speed of the ball = …………………… rad s^{-1} [2]

(c) The steel ball is replaced with a hollow box containing a small steel cube. The hollow box is **permanently fixed** to the rigid rod. The small steel cube is free to move inside the box as shown in Fig 2.2. The mass of the small steel cube is 50 g.

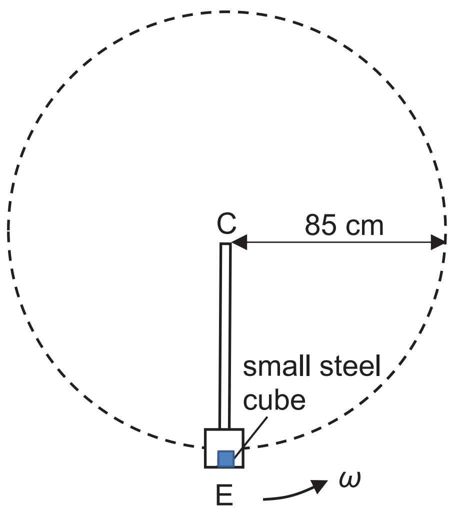

Fig 2.2

Determine the minimum angular speed, ω_0, at which the steel cube remains in contact with the edge E of the box all the time.

ω_0 = …………………… rad s^{-1} [2]

3 Fig. 3.1 shows a simple heat engine. A load on the platform is raised and thereby gained gravitational potential energy when gas inside the metal cylinder is heated by the heat reservoir. In this way, thermal energy is converted into mechanical energy.

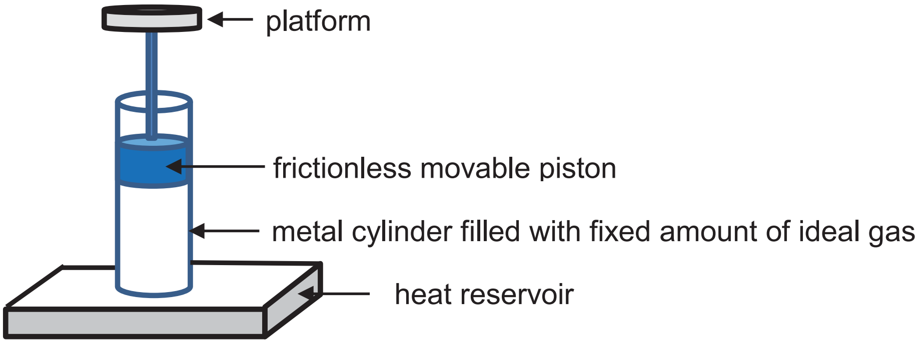

Fig. 3.1

In one cycle, the heat engine goes through the states $(A \rightarrow B \rightarrow C \rightarrow D \rightarrow A)$ as shown in Fig. 3.2.

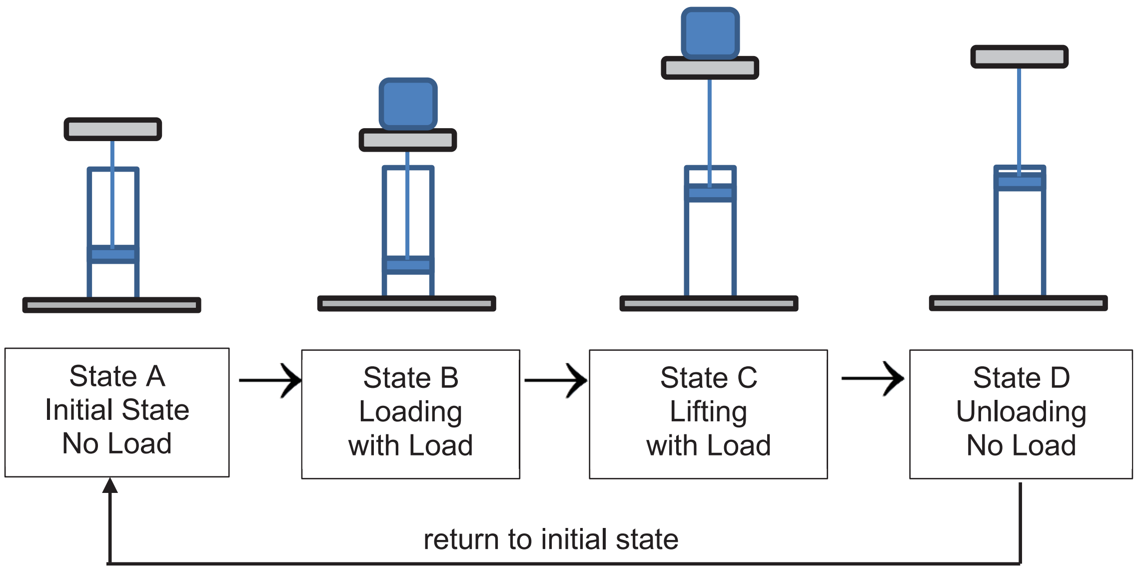

Fig. 3.2 one cycle of the heat engine

(a) Table 3.1 shows the pressure, volume and temperature of the ideal gas inside the metal cylinder for states A, B, C and D.

	Ideal Gas		
State	Pressure (kPa)	Volume (m^3)	Temperature (K)
A	102	1.000	292
B	103	0.990	292
C	103	1.197	353
D	102		353

Table 3.1

(i) Explain why the pressure for states A and D are the same.

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

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

(ii) Complete Table 3.1 by filling in the volume for state D.

[2]

(b) The *P-V* graph (Fig. 3.3) below illustrates the cycle of changes of pressure, volume and temperature undergone by the fixed mass of ideal gas inside the metal cylinder from state A to state B to state C.

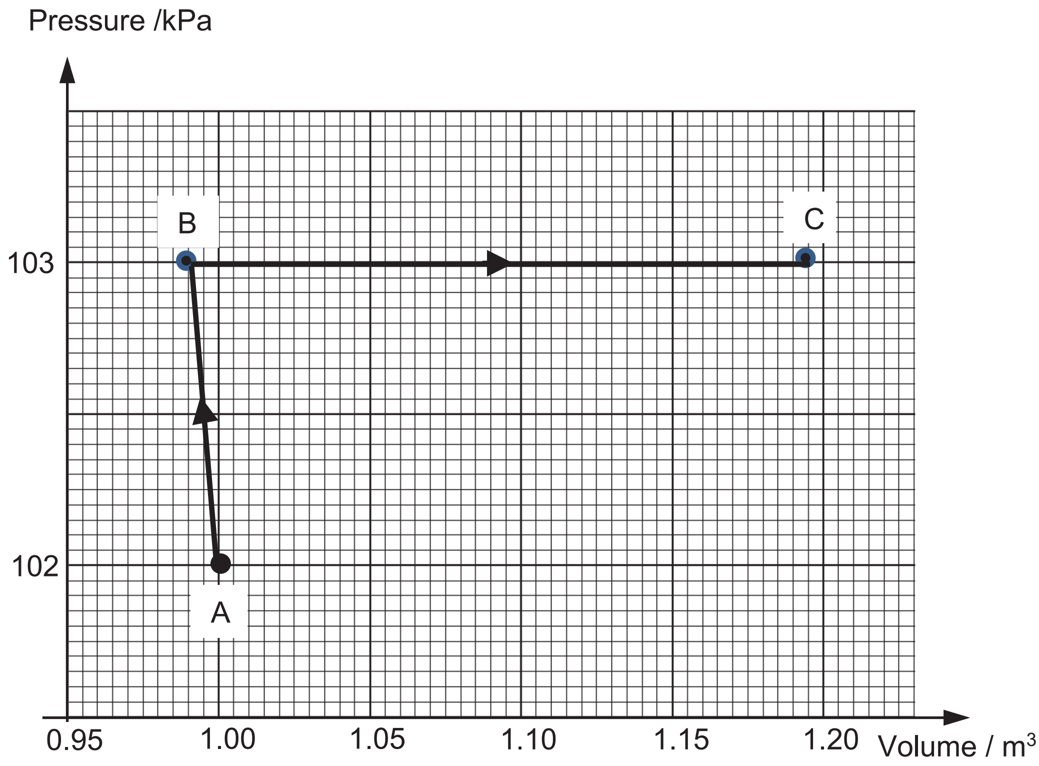

Fig. 3.3

(i) Mark and label state D on Fig. 3.3 and draw the process lines joining state C to state D to state A. [1]

(ii) Hence, using Fig. 3.3, estimate the work done by the ideal gas in one cycle.

work done = ……………………….. J [2]

(c) By considering the kinetic energy of the ideal gas in the metal cylinder, determine the amount of thermal energy, Q absorbed by the gas from the heat reservoir as it goes from state B to C.

Q = …………………….. J [4]

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

………………………………………………………………………………………………………

…… [1]

(b) A small charged sphere of mass 250 g and charge –12 mC is suspended between two parallel plates with a potential difference set up between them. The angle of inclination to the vertical is 40°, as shown in Fig. 4.1.

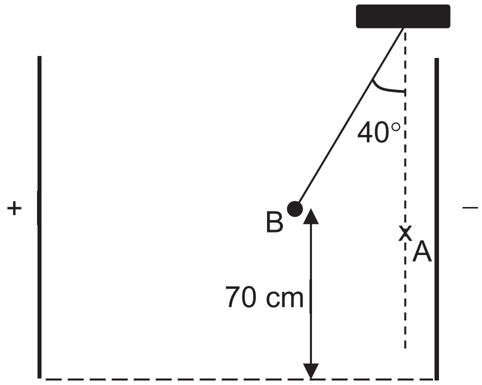

Fig. 4.1

(i) Show that the tension in the string is 3.2 N.

[1]

(ii) 1. Calculate the electric field strength between the plates.

electric field strength = …………………… V m^{-1} [2]

2. Given further that the length of the string is 0.70 m, calculate the electric potential difference the sphere moves through between positions A and B.

potential difference = ………………… V [2]

(iii) The string is cut at the position shown on Fig. 4.1. Draw on Fig. 4.1 the path the sphere takes until the point it exits the plates. [1]

(iv) Use energy considerations to calculate the gain in kinetic energy of the sphere when it exits the electric field.

gain in kinetic energy = ………………………….. J [3]

5 The variation with potential difference (p.d.) V of current I for a semiconductor diode is shown in Fig. 5.1.

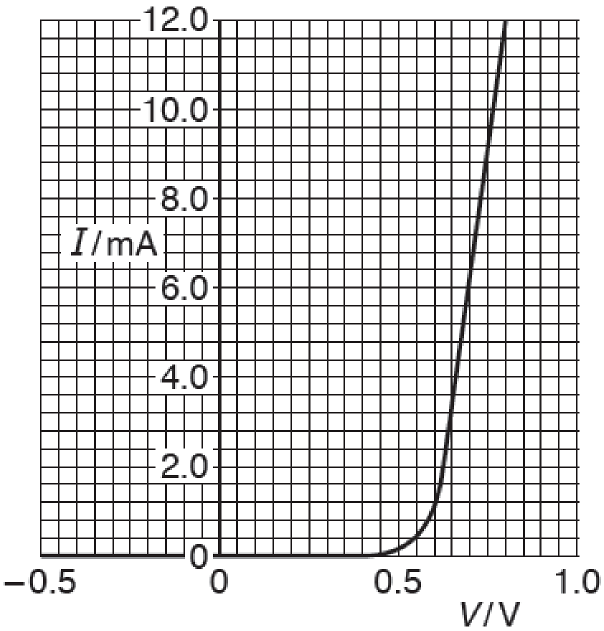

Fig. 5.1

(a) With reference to Fig. 5.1, describe the variation of the resistance of the diode between $V = -0.5$ V and $V = 0.8$ V.

....

....

....

.... [2]

(b) On Fig. 5.2, sketch the variation with p.d. V of current I for a filament lamp. Numerical values are not required. [2]

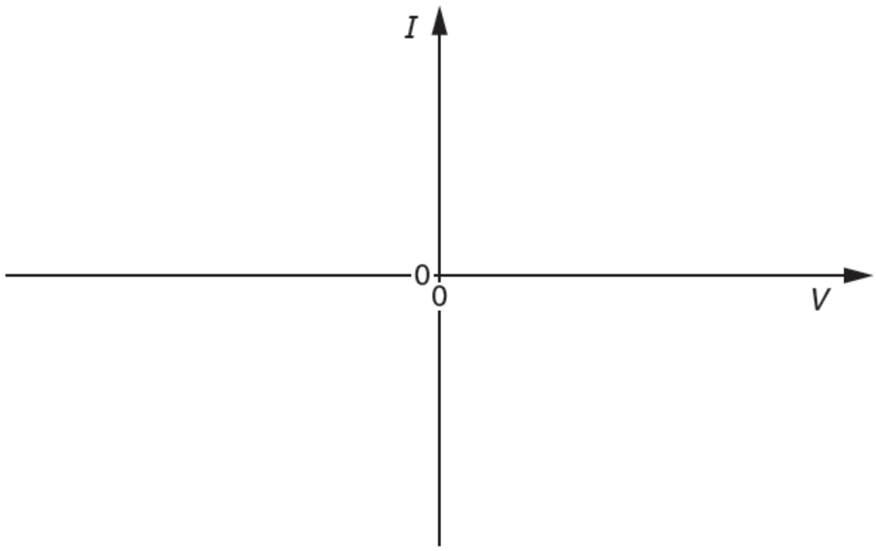

Fig 5.2

(c) **(i)** A filament lamp has a power rating of 36 W when the p.d. across it is 12 V. Calculate the resistance of the lamp when the p.d. across it is 12 V.

resistance = ……………………….Ω [1]

(ii) The filament lamp in (c)(i) is connected in series to a switch and a power supply of electromotive force (e.m.f.) 12 V and internal resistance 0.50 Ω as shown in Fig. 5.3.

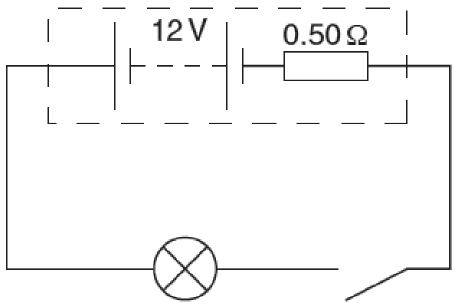

Fig. 5.3

The switch is closed and the current in the lamp is 2.8 A. Calculate the resistance of the lamp.

resistance = ……………………….Ω [2]

(iii) Hence, determine the percentage of the power supplied by the cell dissipated across the filament lamp in the circuit in Fig. 5.3.

percentage of power supplied = ………………………. [2]

6 (a) State *Faraday's Law of Electromagnetic Induction*.

....

....

....

.... [2]

(b) An anemometer is a gauge for measuring the velocity of the wind. It is made by attaching cups to each end of a metal rod 50.0 cm long fixed rigidly to a central vertical column which can rotate freely. A square vertical coil of side 10.0 cm is attached to the column, as shown in Fig. 6.1, and the wind speed is measured by finding the e.m.f. induced in the coil.

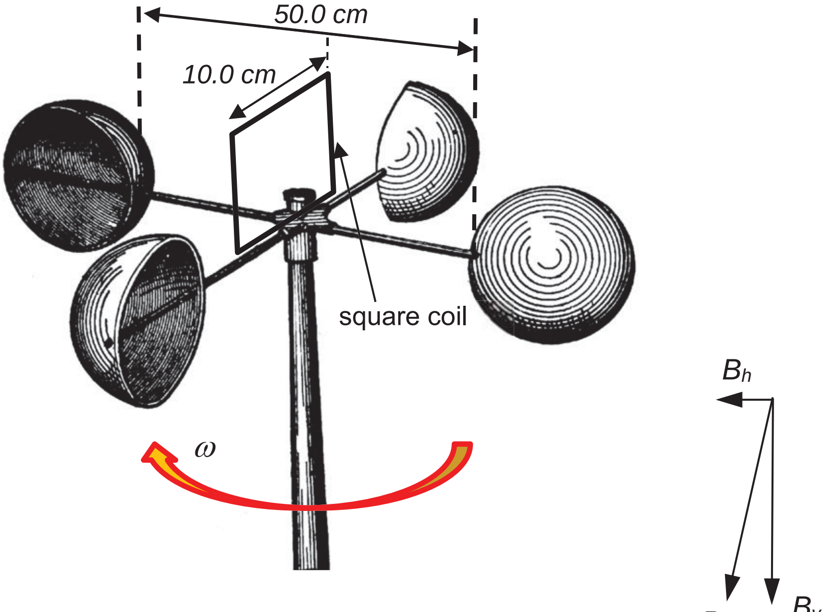

Fig. 6.1

Assume that the horizontal B_h and vertical B_v components of the earth's magnetic field B are 1.5 x 10^{-5} Wb m^{-2} and 5.5 x 10^{-5} Wb m^{-2} respectively.

(i) Explain why an e.m.f. is generated when the coil rotates in the earth's magnetic field.

....

....

....

.... [2]

(ii) Explain briefly why the e.m.f. is sinusoidal when the anemometer rotates with constant angular velocity ω.

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……………………………………………………………………………………………………

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

(iii) If the maximum wind velocity to be measured is 200 km h^{-1}, find the angular velocity of the rotation of the cups, ω.

ω = ……………………… rad s^{-1} [1]

(iv) State an expression for the maximum e.m.f. induced, ε_{max} during rotation of the coil in terms of ω, B_h, n and A where n is number of turns of the coil and A is area of the square coil.

ε_{max} = ………………………………… [1]

(v) Hence calculate the number of turns of the coil, n, if the maximum induced e.m.f. is 15 mV.

n = …………………………… [1]

(vi) Briefly state and explain if there will be any potential difference across the two ends of each 50.0 cm metal rod during rotation at maximum speed.

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

Section B

Answer **ONE of** the two questions in this section in the spaces provided.

7 (a) A tube, sealed at one end, has a uniform area of cross-section A. Some sand is placed in the tube so that it floats upright in a liquid of density ρ, as shown in Fig. 7.1. The tube has total mass m of 32 g and the area A of its cross-section is 4.2 cm^2.

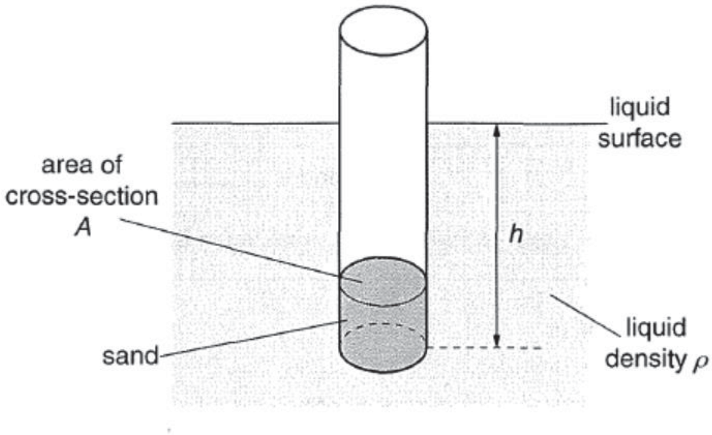

Fig. 7.1

The tube is displaced vertically and then released. For a displacement x, the acceleration a of the tube is given by the expression

$$a = -\left(\frac{\rho A g}{m}\right)x$$

where g is the acceleration of free fall.

The tube experiences damped oscillations in the liquid as shown in Fig. 7.2.

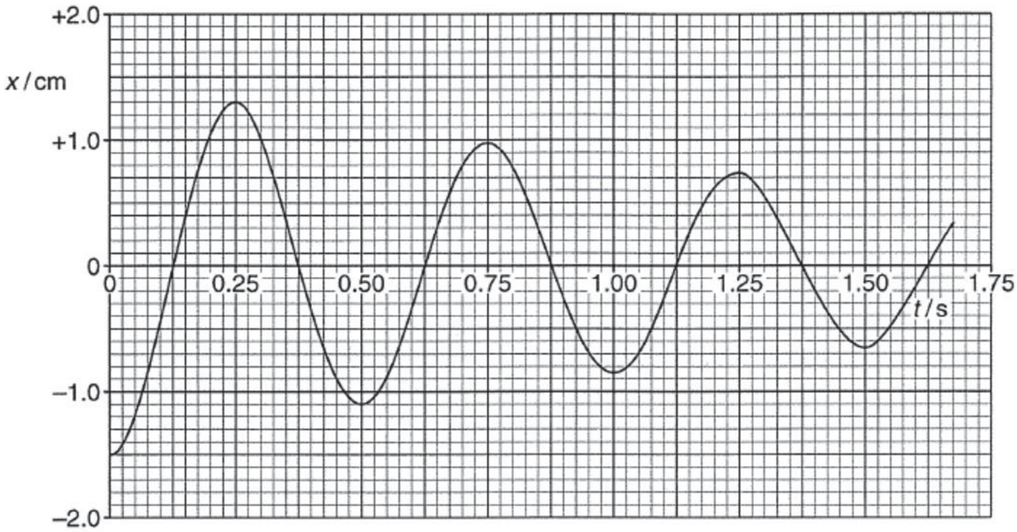

Fig. 7.2

(i) Determine the frequency of the oscillation.

frequency = …………………. Hz [1]

(ii) Calculate the density of the liquid.

density = …………………… kg m^{-3} [3]

(iii) Calculate the percentage loss of the energy of the oscillation during the first 1.50 seconds.

energy loss = __________ % [3]

(iv) The tube is now placed in a liquid which is more viscous. It starts to oscillate from the same displacement at t = 0.00 s.
Explain in terms of energy changes why the amplitude of oscillation in this liquid decreases more over the same period.

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

(b) **(i)** Describe the difference between a travelling wave and a stationary wave in terms of their amplitudes of vibration and energies.

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……………………………………………………………………………………………………

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

(ii) A stationary microwave is formed between a microwave source at A and a reflector at B, as illustrated in Fig. 7.3.

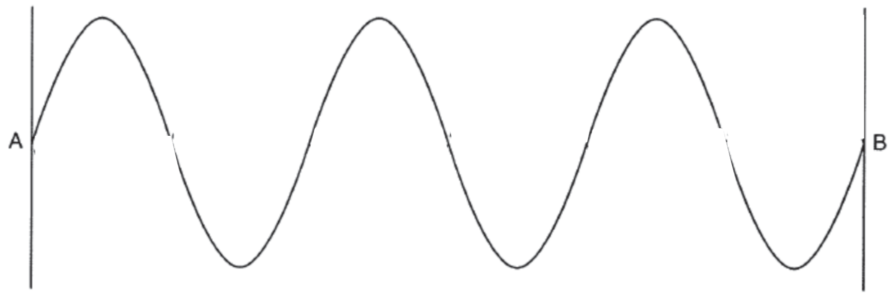

Fig. 7.3

At time t = 0, the standing wave is at its amplitude position as shown by the solid line in Fig. 7.3.

Sketch on Fig.7.3 the shape of the wave

1. when $t = T/8$. Label this wave as shape X.

2. when $t = 3T/4$. Label this wave as shape Y.

3. when $t = 5T/8$. Label this wave as shape Z.

[3]

(c) A student wishes to measure the separation of two narrow parallel slits.
A beam of laser light of wavelength 633 nm is directed normally at the plane of the slits. The light emerging from the slits is viewed on a screen placed 2.95 m away from the slits.
Part of the fringe pattern observed on the screen, together with a measurement for the width of some fringes, is shown in Fig. 7.4.

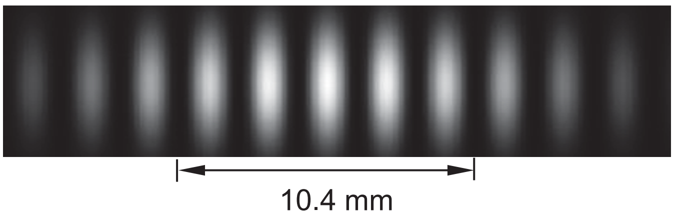

Fig. 7.4 (not to scale)

(i) Determine the separation, in mm, of the slits.

slit separation = ………………………. mm [2]

(ii) The student wishes to compare the fringe pattern with when an identical beam of light passes through a diffraction grating of 100 lines / mm under the same conditions.

State three changes the student will observe.

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

8 Cobalt-60, an isotope widely used in medicine, decays by emitting an electron (β^- decay) with a half-life of 5.272 years into an excited state of nickel-60, which then de-excites very quickly to the ground state of nickel-60 by emitting a number of gamma photons.

(a) (i) Complete the nuclear equation for the Co-60 decay below.

$$^{60}_{.....}\text{Co} \rightarrow \, ^{.....}_{28}\text{Ni} + \, ^{.....}_{.....}\text{e} + \gamma$$

[2]

(ii) Determine the number of nuclei in 1.00 g of Cobalt-60.

Number of nuclei = ……………………………… [1]

(iii) The total energy released in each Co-60 decay is 2.8 MeV. Hence, show that the initial radiation power for Co-60 is 19 W g^{-1}.

[2]

(b) The emission spectrum of the gamma photons emitted due to the de-excitation of nickel-60 are shown in Fig. 8.1.

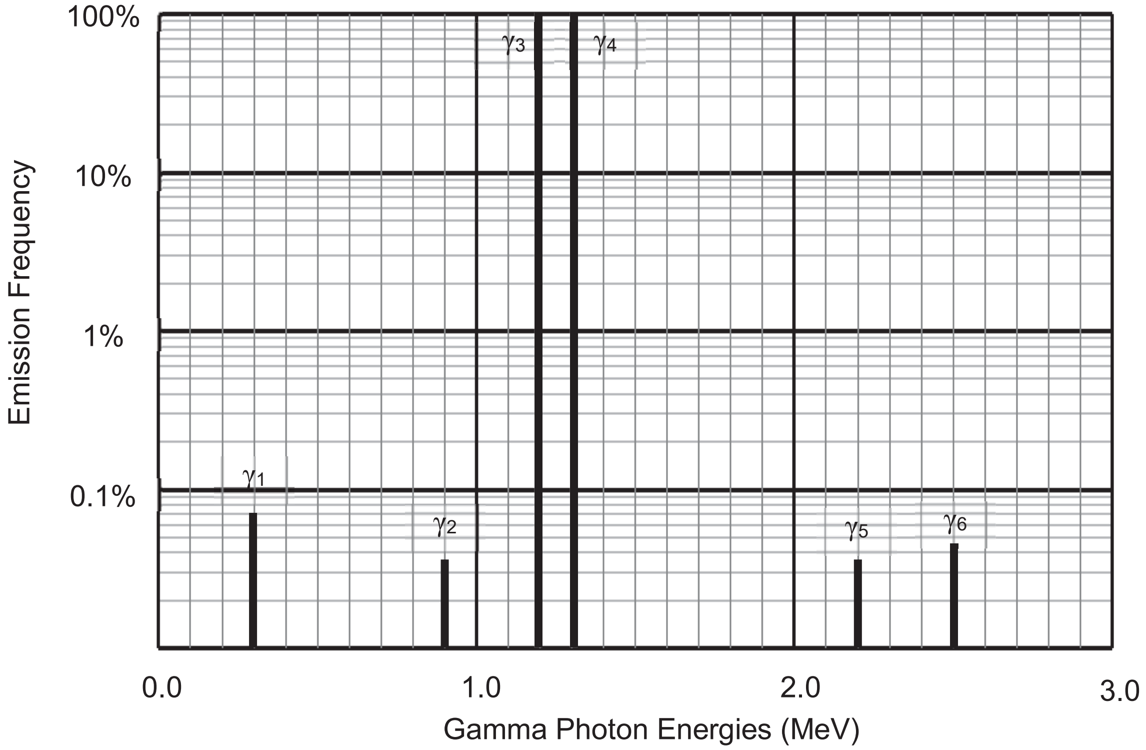

Fig. 8.1

(b) **(i)** Explain what is meant by a *gamma photon*.

…………………………………………………………………………………………………

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

(ii) Calculate the momentum of gamma photon associated with spectral line γ_4.

momentum = ……..……………N s [2]

(iii) Explain why Fig. 8.1 provides evidence that the nucleus has discrete energy levels.

…………………………………………………………………………………………………

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

(iv) The energy levels of the nucleus of nickel-60 are shown in Fig. 8.2.

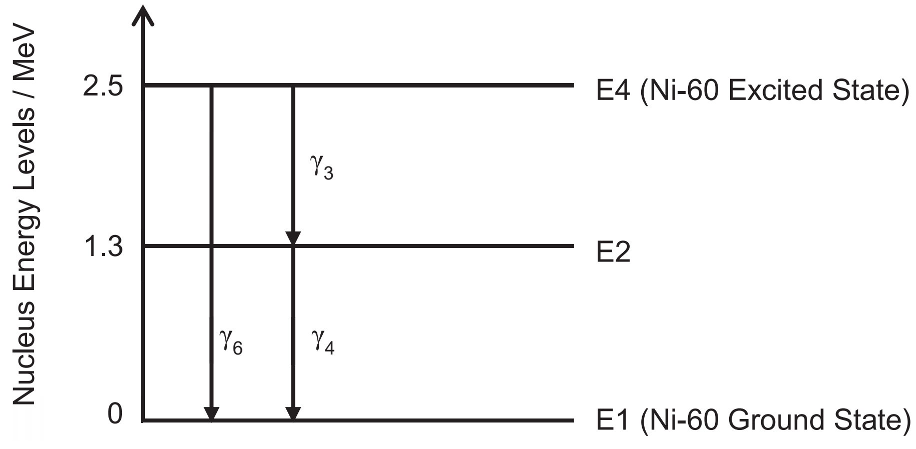

Fig. 8.2

1. There is a missing energy level in Fig. 8.2. With reference to Fig. 8.1, draw and label the missing energy level, and fill in the transitions corresponding to γ_1, γ_2, and γ_5.

[2]

2. The rest-mass of the Ni-60 nucleus at the ground state E1 is 59.93079*u*. Calculate the mass of the Ni-60 nucleus at its excited state E4. Explain the principle behind your calculation.

mass = ……..……………*u*

……………………………………………………………………………………………

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

(c) Co-60 sources are often kept in lead containers. The interaction between the β^- particles and the lead atoms give rise to Bremsstrahlung and characteristic X-ray radiation.

(i) By considering the energy of the β^- particles and an excited nickel-60 nucleus, calculate the cut-off wavelength of the Bremsstrahlung radiation.

wavelength = ……..……………m [2]

(ii) Explain the origin of the **characteristic** X-ray.

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

End of Paper

HWA CHONG INSTITUTION
JC2 Preliminary Examination
Higher 2

CANDIDATE NAME		**CT GROUP**	16S
TUTOR NAME			

PHYSICS — 9749/04

Paper 4 Practical

23 August 2017

2 hours 30 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your **name, CT class** and **subject tutor's name** in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paperclips, highlighters, glue or correction fluid.

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

Answer **all** questions.

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, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

Shift
Laboratory

For Examiner's Use	
1	/ 15
2	/ 8
3	/ 20
4	/ 12
Total	/ 55

1 This investigation considers the size of the hole needed in a salt shaker for the salt to flow at a suitable rate.

(a) You have been provided with a beaker labelled **P** containing 100g of salt as shown in Fig. 1.1.

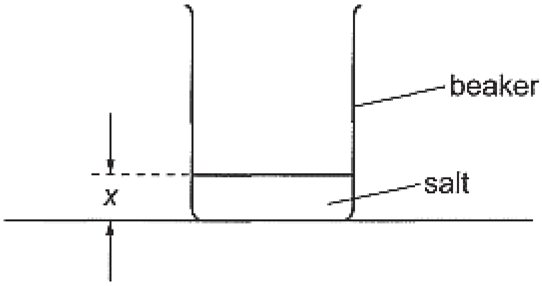

Fig 1.1

(i) Measure and record the depth *x* of salt in beaker **P** using the vernier caliper.

x = ... [2]

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

percentage uncertainty = ... [1]

(b) You have been provided with two cards. Each card has a hole of different size.

(i) Measure and record the diameter *d* of the **smaller** hole.

d = ... [1]

(ii) Determine the area *A* of the **smaller** hole.

A = ... [1]

(c) **(i)** Fill the boiling-tube, as shown in Fig. 1.2, with salt from beaker **P**.

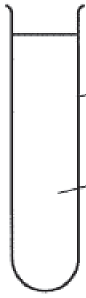

Fig. 1.2

(ii) Cover the open end of the boiling-tube with the card that has the **smaller** hole.

Use tape to attach the card to the boiling-tube.

The hole should not be covered by tape. When the boiling-tube is inverted it should not be possible for salt to leave the boiling-tube other than through the hole.

(iii) Invert the boiling-tube over the empty beaker **Q**. Measure the time taken for ALL the salt to flow through the hole into beaker **Q**.

It may be necessary to shake the boiling-tube gently from time to time to achieve constant flow.

Time taken = ...

(iv) Tap beaker **Q** gently on the bench to ensure that the surface of the salt is level.

Measure and record the depth *x* of salt in beaker **Q**.

x = ...

(v) Estimate the mass *m* of salt in beaker **Q**.

m = ... [1]

(d) The recommended daily intake of salt for an adult is 5 g.

Use your data to calculate the time that a shaker with a hole the same size as that in **(c)(ii)** should be inverted to apply 5 g of salt to food.

time taken = ... [1]

(e) It is suggested that the rate of flow of salt R is proportional to the area A of the hole.

Use the card with the larger hole to take further measurements to investigate this suggestion. State and explain whether or not you agree with this suggestion.

Present your measurements and calculated results clearly.

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……………………………………………………………………………………………... [6]

(f) A statement found on the internet says that:

"*The salt shaker may be distinguished primarily by the size of the holes, and then by the number of holes. Salt is coarser than pepper, and needs the larger hole. It is also heavier and flows much more freely than pepper, accordingly there are often fewer holes on the salt shaker to help control the flow. However, there is no manufacturing standard.*"

Suggest changes that could be made to the salt investigation to study the flow of pepper from a shaker.

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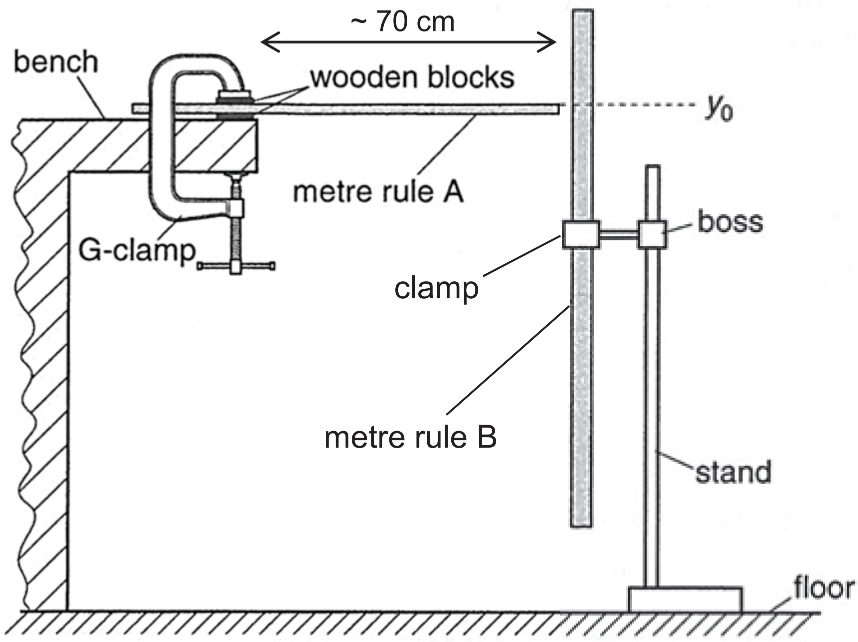
…………………………………………………………………………………………………….... [2]

[Total: 15 marks]

2 In this experiment you will investigate the deflection of a loaded metre rule.

(a) **(i)** Set up the apparatus as shown in Fig. 2.1.



y_0 is the point on rule B level with the top of rule A.

Fig. 2.1

(ii) Record the reading y_0.

y_0 = ... [1]

(iii) Place a 200 g mass on the end of rule A as shown in Fig. 2.2.

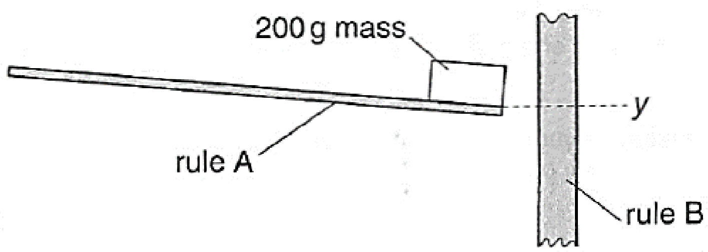


Fig. 2.2

y is the point on rule B level with the top of rule A.

(iv) Record the reading y.

y = ...

(v) Remove the 200 g mass from rule A.

(vi) Calculate the deflection ($y - y_0$).

($y - y_0$) = ... [1]

(vii) Determine the percentage uncertainty in ($y - y_0$)

percentage uncertainty in ($y - y_0$) = ... [1]

(b) **(i)** Repeat **(a)(ii)**.

y_0 = ...

(ii) Place the 200 g mass at a position approximately halfway along rule A.

(iii) Repeat **(a)(iv)**, **(a)(v)** and **(a)(vi)** with the 200 g mass placed at a position approximately half way along rule A.

y = ...

($y - y_0$) = ...

(c) **(i)** it is suggested that:

"if both masses are placed on rule A in different positions at the same time, the deflection will equal the sum of the deflections for each mass on its own."

Take more readings to investigate this suggestion. Present your results in a table. [2]

(ii) State whether or not the results of your experiment support the suggestion.

Justify your answer by referring to your calculated percentage uncertainty in **(a)(vii)**.

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

(d) **(i)** State a significant source of error in this experiment.

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

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

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

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

……………………………………………………………………………………………………

……………………………………………………………………………………………………

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

[Total: 8 marks]

CANDIDATE NAME		CT GROUP	16S

You may not need to use all of the materials provided.

3 In this experiment, you will determine the resistivity of a metal in the form of a wire.

(a) **(i)** Measure and record the diameter *d* of the short sample of wire that is attached to the card. You may remove the wire from the card.

d = ... [1]

(ii) Calculate the cross-sectional area *A* of the wire, in m^2, using the formula

$$A = \frac{\pi d^2}{4}$$

A = ... m^2

(b) **(i)** Use the wire attached to the metre rule, one of the voltmeters and one of the resistors to set up the partial circuit shown in Fig. 3.1.

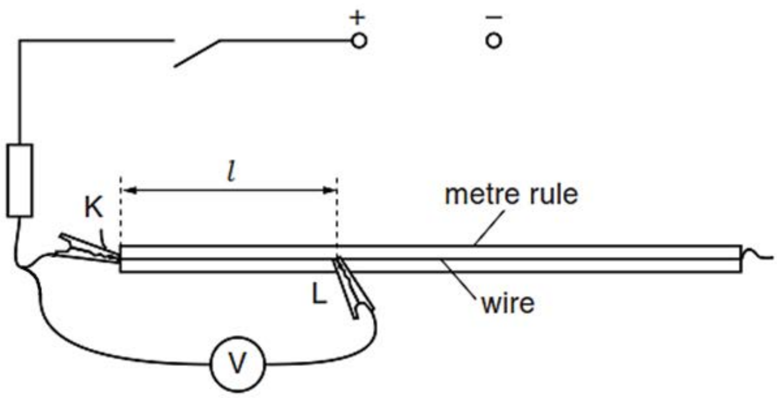

Fig. 3.1

There are two crocodile clips, one labelled K and the other labelled L.
Place K and L so that the distance l between them is approximately 30 cm.

(ii) Measure and record the distance l between K and L.

l = ...m

(iii) Use the other resistor and the other voltmeter to complete the circuit shown in Fig. 3.2.

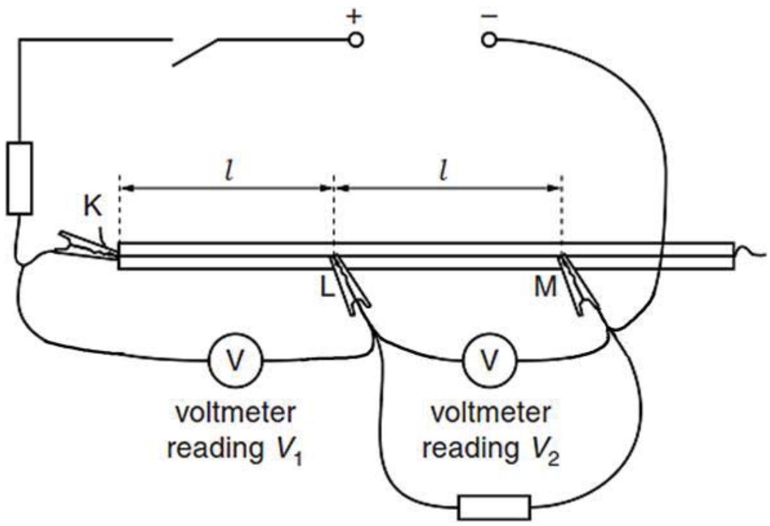

Fig. 3.2

(iv) Place the crocodile clip M at a distance l from L. The value of l should be the same as in **(b)(ii)**.

(c) **(i)** Switch on the power supply.

(ii) Record the voltmeter readings V_1 and V_2 as shown in Fig. 3.2.

V_1 = ...V

V_2 = ...V
[1]

(iii) Switch off the power supply.

(d) Repeat steps **(b)(ii)**, **(b)(iv)** and **(c)** to obtain further sets of readings for l, V_1 and V_2. For each set of readings, l should be greater than 20 cm, while distances KL and LM should both be l.

[7]

(e) Theory suggests that l, V_1 and V_2 are related by the equation

$$\frac{V_1}{V_2} = Pl + Q$$

where P and Q are constants.

Plot a suitable graph to determine P and Q.

P = ...

Q = ...[4]

[3]

[Turn over

(f) Comment on any anomalous data or results that you may have obtained. Explain your answer.

………

………

………[1]

(g) The resistivity ρ of the material of the wire, in Ω m, can be found using the relationship

$$\rho = PAR$$

where R = 10 Ω

Use your answers in **(a)(ii)** and **(e)** to calculate a value for ρ.

ρ = ... Ω m [1]

(h) **(i)** State one significant source of error in this experiment.

……………………………………………………………………………………………………

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

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

……………………………………………………………………………………………………

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

[Total: 20 marks]

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CANDIDATE NAME		**CT GROUP**	**16S**

4 Concrete is widely used for construction and its manufacture contributes 5% to the world's carbon dioxide (CO_2) production. One way of reducing the amount of CO_2 produced could be to use less cement in the production of concrete.

A company is producing concrete with low cement content and wishes to see how the material behaves under a compressive force. A compressive force applied to a concrete object will reduce the length of the object in the direction of the force very slightly.

The reduction in length of the object is to be measured using a strain gauge.

When a wire has its length changed, its resistance changes. A strain gauge consists of a length of thin wire as shown in Fig. 4.1.

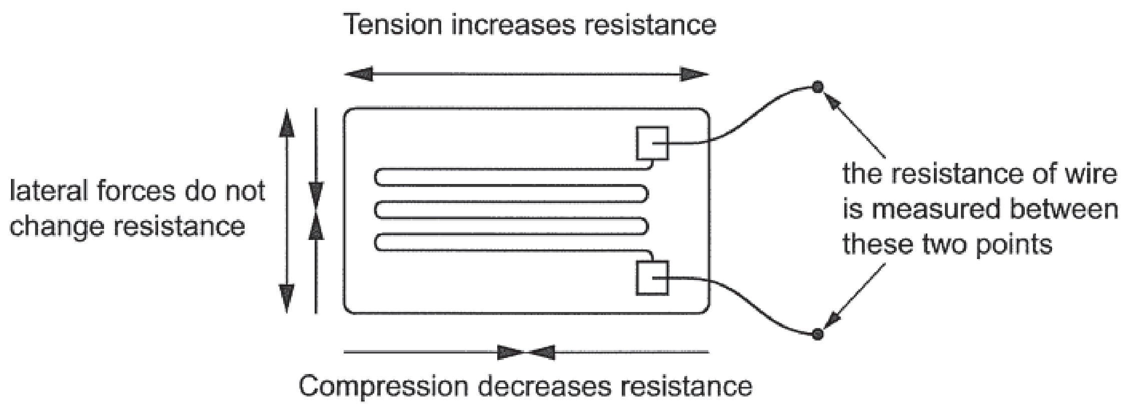

Fig. 4.1

The gauge consists of a wire wound backwards and forwards and embedded in thin plastic. The plastic is then bonded firmly to the specimen being investigated.

The relation between change in resistance ΔR and change in force ΔF is

$$\Delta R = k\,(\Delta F)^n$$

where k and n are constants.

You are provided with some heavy masses, a low voltage power supply and other equipment usually found in a Physics laboratory.

Design an experiment to determine the value of n for compressive forces applied to a small concrete cylinder along its axis.

You should draw a labelled diagram to show the arrangement of your apparatus and you should pay particular attention to

(a) the equipment you would use,
(b) the procedure to be followed,
(c) how the compressive force and change in resistance are measured,
(d) the control of variables,
(e) any precautions that would be taken to improve the accuracy and safety of the experiment.

Diagram

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[Turn over

………[12]

2017 HCI Prelim Exam H2 Physics 9749 P4 (Practical) Preparation List

Question 1

Apparatus List:

1	Two identical 250 ml beakers. One of the beakers should contain 100 g of fine salt and be labelled P. The other should be labelled Q. See **Note 1**.
2	Boiling-tube of approximate length 15cm and approximate diameter 2.5cm.
3	Stopwatch reading to 0.1 s or better.
4	Manual vernier caliper reading to 0.1 mm with a depth probe.
5	Two circular pieces of thin card. See **Note 2.**
6	Small roll of adhesive tape.
7	Scissors.
8	One filter funnel
9	Tray with approximate dimensions 30cm x 40cm x 5cm.

Notes

1 The salt must be in loose grains and should be prepared only on the day of assessment.

2 The card should be of approximate thickness 0.2 mm. 140 gsm paper is suitable. The pieces of card should be of the same size as the open end of the test tube (including the 'lip'). Each card should have a central circular hole as shown in Fig. 1.

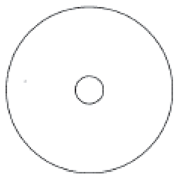


Fig. 1

One hole should be of approximate diameter 3 mm. This could be made with a nail of approximate diameter 6 mm. The other hole should be made with a hole-punch to yield a hole of approximate diameter 8 mm.
Candidates are entitled to ask for replacement cards during the test.
If the apparatus is to be used by a second candidate, it should be restored to its original state with new cards supplied.

Question 2

Apparatus List:

1	One large G-clamp
2	Two metre rules each with the smallest division of 1 mm (See Note(i))
3	Two small wooden blocks. (See Note (ii))
4	Two 200 g masses. See Note (iii)
5	One stand, one boss and one clamp.

Notes

(i) One of the metre rules should be clearly labelled ‘A’. The other metre rule should be clearly labelled ‘B’.

(ii) The wooden blocks should enable a metre rule to be held firmly to the bench or table top using the G-clamp as shown in Fig. 1.1.

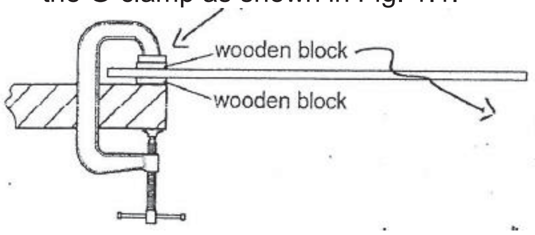


Fig. 1.1

(iii) Each 200 g mass should consist of two 100 g slotted masses taped together. Each 200 g mass should be labelled ‘200 g’.

(iv) The apparatus should be laid out on the bench unassembled. The Supervisor should ensure that each candidate has sufficient space to perform the experiment. A distance of at least 1.2 m beyond the edge of the bench is required.

Question 3

Apparatus List:

1	Low voltage power supply fixed at 1.5 V d.c.
2	Two digital voltmeters set to the range 0 – 2 V reading to the nearest 0.001 V. If digital multimeters are used, the range should be fixed and any unused terminals should be covered.
3	30 cm ruler with a millimetre scale.
4	Metre rule with a millimetre scale. See Note 1.
5	110 cm length of 36 swg constantan wire. See Notes 1 and 2.
6	20 cm length of 36 swg constantan wire taped to a card and labelled 'sample of wire'. See Note 2.
7	Two 10 Ω resistors each in a component holder with terminals.
8	Eleven connecting leads. See Note 3.
9	Switch.
10	Access to a micrometer screw gauge.

Notes

1 The 110 cm length of wire should be attached to the metre rule with 5 cm protruding at each end. It should be possible to attach a crocodile clip to each end of the wire. The wire should be attached to the rule firmly enough (e.g. using adhesive tape at the ends of the rule) to minimise any looseness or kinks.

2 If 36 swg constantan wire is unavailable then 32 swg nichrome wire may be used.

3 Three of the leads should have a length of at least 0.5 m and should each have a crocodile clip attached to one end.

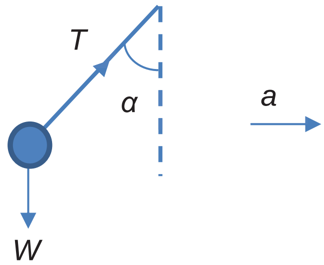
The crocodile clips should be labelled K, L and M. It should be possible to connect several leads together, for example with stackable plugs.

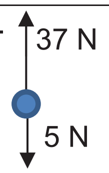
4 The apparatus should be laid out on the bench. If the apparatus is to be used by another candidate, then it should be restored to its original state.

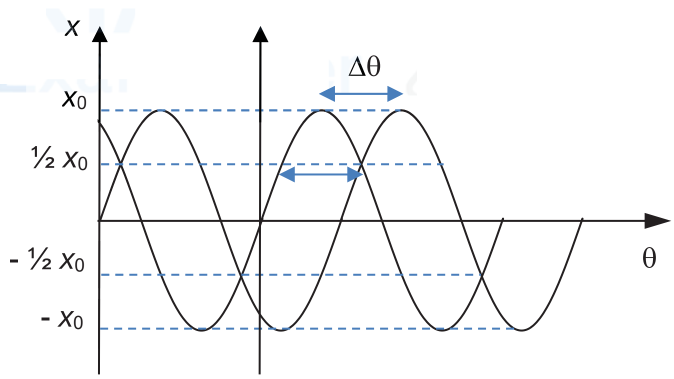
If the sample of wire has been removed from the card, it should be re-attached.

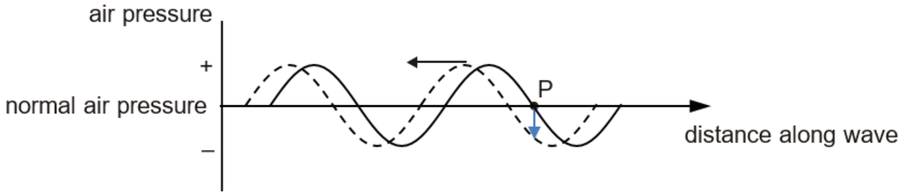
2017 HCI Prelim H2 Physics Paper 1 Answers and Solutions

1	**D**	6	**C**	11	**C**	16	**B**	21	**D**	26	**C**
2	**C**	7	**B**	12	**B**	17	**A**	22	**C**	27	**D**
3	**C**	8	**B**	13	**A**	18	**C**	23	**A**	28	**A**
4	**C**	9	**B**	14	**A**	19	**B**	24	**C**	29	**C**
5	**B**	10	**C**	15	**B**	20	**D**	25	**A**	30	**A**

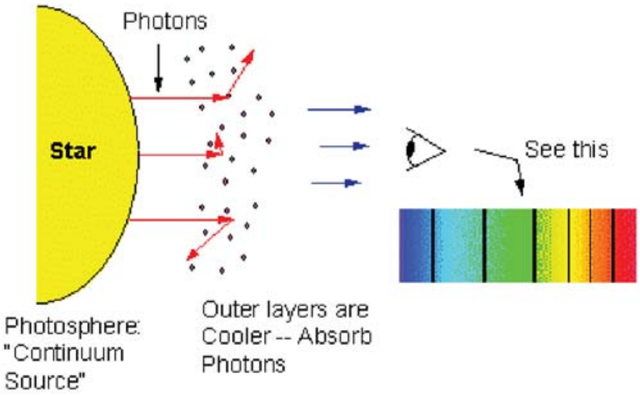
1	**D**	37.86×10^{-4} MJ cm^{-4} = $37.86\times10^{-4}\ 10^{6}$J $(10^{-2}$ m$)^{-4}$ = $37.86\times10^{-4}\times10^{8}\times10^{6}$ J m^{-4} = 3.786×10^{11} m^{-4}J = 378.6×10^{9} J m^{-4} = 378.6 GJ m^{-4}
2	**C**	Estimate the population as 6 million people and the land as 700 km^2. $\dfrac{6\times10^{6}}{7\times10^{2}\ \text{km}^2}\approx10^{4}\ \text{km}^{-2}$
3	**C**	The distance travelled by each vehicle is given by the area under their respective graphs. For both car and lorry, the distance travelled between 0 and 40 seconds is the same at 400 m. This means the separation distance is zero at 40 s, which is also the least distance.
4	**C**	Option A: True. At the uniform speed the rope does not experience any horizontal acceleration. Hence, the angle is zero. Option B: True.  T sin α = ma T cos α = W = mg tan α = a / g Option C: False. Tension is W / sin α when it is accelerates. Tension is equal to W when it moves with a uniform speed. W / sin α > W Option D: True. When the car decelerates, the net horizontal force is leftwards which swings the rope to the right.
5	**B**	Since the railway platform is in contact with the Earth, the Earth absorbs the vertical momentum, vertical component of the recoil is negligible. Thus, considering the horizontal (x) components, by PCOLM, P_{1x} = - P_{2x} 1: bullet 2: gun M_1v_1cos45° = - m_2v_{2x} v_{2x} = - (500)(200)cos 45° / 70000 = - 1.01 ms^{-1}

6	C	Raw Power input = Rate of GPE converted to Electrical Energy $= \dfrac{mgh}{t}$ $= \dfrac{\rho Vgh}{t}$ $= \dfrac{1000(6.0)(9.81)(80)}{1\text{ sec}}$ = 4.7088 MW Since Efficiency $= \dfrac{P_{out}}{P_{in}} = 0.60$ Then P_{out} = 0.60 x 4.7088 = 2.8 MW
7	B	The driving force by the propeller equals the drag force on the boat when the boat is at constant speed. $P_{engine} = F_{engine}v = F_{drag}v$ $30000 = F_{drag}(15.0)$ $F_{drag} = 2000$ N Since $F_{drag} = kv^2$ $2000 = k\,(15.0)^2$ So drag constant k = 8.889 When v = 5.0 m s^{-1}, $F_{drag} = kv^2 = 8.889 \times 5.0^2 = 222$ N When the boat is being towed at constant speed at 5.0 m s^{-1}, the drag force equals the towline tension.
8	B	Maximum tension and speed occurs at the bottom of the vertical circular path. (resultant) Centripetal force is upwards. $F_{net} = ma_c = mr\omega^2$ $37 - 5 = 0.5\,(4.00)\,\omega^2$ $\omega = 4.0$ rad s^{-1} 
9	B	For a mass, m, projected from a planet of mass M and radius r with escape velocity, v_{esc} : $\frac{1}{2} m v_{esc}^2 - GMm / r = 0$ $v_{esc} = \sqrt{\dfrac{2GM}{r}}$ $(v_{esc})_{Earth} / (v_{esc})_{Mars} = \sqrt{\dfrac{M_{Earth}}{R_{Earth}}} / \sqrt{\dfrac{M_{Mars}}{R_{Mars}}} = \sqrt{\dfrac{M_{Earth}}{R_{Earth}} \dfrac{R_{Mars}}{M_{Mars}}}$
10	C	Acceleration due to gravity at the surface of a planet of mass M and radius R, $g = \dfrac{GM}{R^2} = \dfrac{G(\rho \frac{4}{3}\pi R^3)}{R^2} = G\rho\dfrac{4}{3}\pi R$ $\dfrac{g_X}{g_Y} = \dfrac{\rho_X R_X}{\rho_Y R_Y} = \dfrac{2R_Y}{R_Y} = 2$

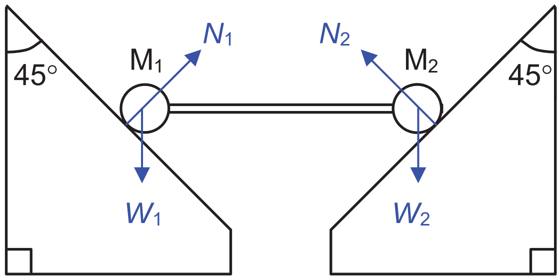
11	C	Heat lost by water = Heat gained by ice to just melt, $M_{water}c_{water}(T - 0) = M_{ice}c_{ice}\Delta T + m_{ice}L_f$ $T = \dfrac{2.0(2100)(20) + 2(3.35 \times 10^5)}{4.0(4200)} = 45°C$
12	B	From the formula list: $P = \frac{1}{3}\rho v_{rms}{}^2$ Therefore, 100 000 = 0.178 v_{rms}^2 / 3 v_{rms} = 1298 m s^{-1} = 1300 m s^{-1}
13	A	For an ideal gas, PV = Nrt Hence, $\dfrac{V_2}{V_1} = \dfrac{T_2}{T_1}$ $\dfrac{100 \times 10^{-3}}{25 \times 10^{-3}} = \dfrac{T_2}{200}$ T_2 = 800 K. Since $U = \frac{3}{2}nRT$ $\Delta U = \frac{3}{2}nR\Delta T = \frac{3}{2}(1)(8.31)(800 - 200)$ = 7479 J Other possible distractors: 5000 J (use PΔV with P = nRT/V = 66480 Pa)
14	A	Δ*U* is negative. At freezing point, temperature is constant, thus microscopic KE remains unchanged, but molecules are held more strongly together by intermolecular forces of attraction, the microscopic PE decreases. *q* is negative as heat flows out of the system. *w* is positive as the substance contracts, volume decreases thus $p\Delta V < 0$.
15	B	Since we are determining phase difference, it is easier to work directly in x- θ equation instead of x-t equation. Determine the phase angle such at x = x_0/2: $x_0/2 = x_0 \sin\theta \Rightarrow \theta = \sin^{-1}(½)$ = 30°, 150°  Δθ = 150° - 30° = 120°

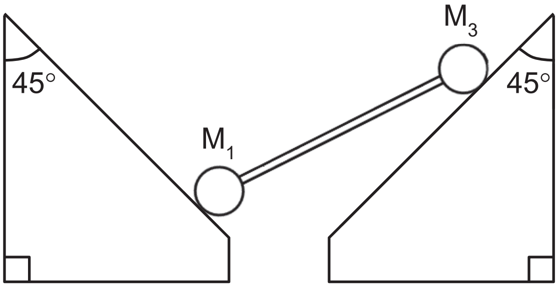
16	**B**	The pressure variation "moves" along with the energy, compression and rarefaction will move to the left. 
17	**A**	Beyond A, the light intensity is always I . B lets all of the light from A go through, implies that the axes of polarization of A and B are parallel. With C between A and B: angle between the axis of A and the axis of C = angle between the axis of C and the axis of B = θ Beyond C, applying Malus' Law: $$I_C = I\cos^2\theta$$ Beyond B, applying Malus' Law: $$I_B = I_C\cos^2\theta$$ $$\frac{2I}{3} = \left(I\cos^2\theta\right)\cos^2\theta = I\cos^4\theta$$ $$\cos^4\theta = \frac{2}{3}$$ $$\theta = \cos^{-1}\left(\frac{2}{3}\right)^{\frac{1}{4}} = 25.4°$$
18	**C**	The longitudinal stationary wave will form a displacement node at the closed (water) end and a displacement antinode at the open end (loudspeaker, with vibrating diaphragm)
19	**B**	$V_1 = V_2$ $$\frac{kq_1}{r_1} = \frac{kq_2}{r_2}$$ $$\frac{q_1}{q_2} = \frac{r_1}{r_2}$$ $$\frac{E_1}{E_2} = \frac{kq_1/r_1^2}{kq_2/r_2^2} = \frac{q_1}{q_2}\times\frac{r_2^2}{r_1^2} = \frac{r_2}{r_1}$$

20	**D**	For the same p.d. V, resistance of wire decreases when its diameter decreases, since $R=\frac{\rho l}{A}$, and current increases as I is proportional to A as $I=\frac{V}{R}=\frac{AV}{\rho l}$. Comparing with current $I = nv_dqA$ $\Rightarrow I$ is proportional to A or d^2, v_d remains the same as it is independent of d.
21	**D**	Compute the effective resistance for each case. D having the smallest resistance draw the largest current.
22	**C**	By potential divider principle, increasing resistance of *R* will decrease the p.d. across the potentiometer wire, and resulting in smaller p.d. per unit length. Thus balance point will be nearer to *M*.
23	**A**	The point charge's velocity is parallel to resultant magnetic flux density at the centre of the two wires. Thus magnetic force is zero.
24	**C**	To find maximum instantaneous speed: $mg\Delta h=\frac{1}{2}mv^2 \rightarrow v=\sqrt{2gh}=\sqrt{2(9.81)(0.274)}=2.32 \text{ m s}^{-1}$ maximum average speed = $\left(\frac{v}{2}\right)=1.16 \text{ m s}^{-1}$ maximum induced e.m.f. = $Bl\left(\frac{v}{2}\right)=1.5(0.800)(1.16)=1.4 \text{ V}$
25	**A**	Since inner loop experiences decreasing flux linkage, current in the inner wire will flow in the same direction as that in the outer wire to oppose this deceasing flux linkage (Lenz's law). Since the rate of decrease of current with time is constant, the rate of decrease of B and hence flux linkage is constant, hence e.m.f. induced in inner loop is constant and the current in the inner loop is constant.
26	**C**	For sinusoidal a.c. $V_{rms}(a) = V_{peak} / \sqrt{2}$ For the case of full square wave ac, <P> = V^2_{peak} /R Half-wave rectified square wave ac, <P'>= V^2_{peak} /2R V^2_{rms} /R = V^2_{peak} /2R $V_{rms}(b) = V_{peak} / \sqrt{2}$ Thus the ratio is 1.

27	**D**	In the solar absorption line spectra, the dark lines are caused by photons being absorbed by elements in the cooler photosphere, to excite to higher energy states. 
28	**A**	By conservation of energy, KE gained by electron = ePE lost by electron $$\frac{p^2}{2m} = eV \Rightarrow \frac{\left(\frac{h}{\lambda}\right)^2}{2m} = eV$$ $$\lambda = \frac{h}{\sqrt{2meV}}$$ when V is doubled, $$\lambda' = \frac{h}{\sqrt{2me2V}} = \frac{h}{\sqrt{2}\sqrt{2meV}}$$ $$\frac{\lambda' - \lambda}{\lambda} = \frac{\frac{h}{\sqrt{2}\sqrt{2meV}} - \frac{h}{\sqrt{2meV}}}{\frac{h}{\sqrt{2meV}}} = \frac{\frac{1}{\sqrt{2}} - 1}{1} = -0.29 = -29\%$$
29	**C**	Energy is released in nuclear fusion (not fission) reactions from nuclei in region P.
30	**A**	$^{8}_{3}\text{Li} \rightarrow {}^{8}_{4}\text{X} + {}^{0}_{-1}\text{e}$ $^{8}_{4}\text{X}$ has 4 protons and 4 neutrons, corresponding to A.

JC2 HCI H2 Physics Prelim Paper 2 Suggested Solutions

1	a)	Net force acting on the body is zero Net torque /moment acting on the body about any point is zero		B1 B1
	b)	Two smooth spheres M_1 and M_2, both of mass 2.0 kg, are connected by an inextensible bar of negligible mass to form a rigid body. The spheres rest on smooth 45° inclines as shown in Fig. 1.1.		
		(i)	 **Fig. 1.1**	
			correct identification of forces correct orientation of forces (marker please decide)	B1 B1
		(ii)	$N\cos 45° = 2(9.81)$ $N = 27.7$ N	M1 A1
	(c)	(i)	Yes. The horizontal components of N1 and N2 must be equal in magnitude (so that horizontal net force is zero).	B0 B1
		(ii)	Consider moments about the intersection of N_1 and N_3. The clockwise moment produced by 4g is larger than the anti-clockwise moment produced by 2g. OR Consider the lines of action of N_1, N_3 and 6g. Since the C.G. lies closer to M_3 than M_1, the lines of action will not intersect at one point.	B1 B1

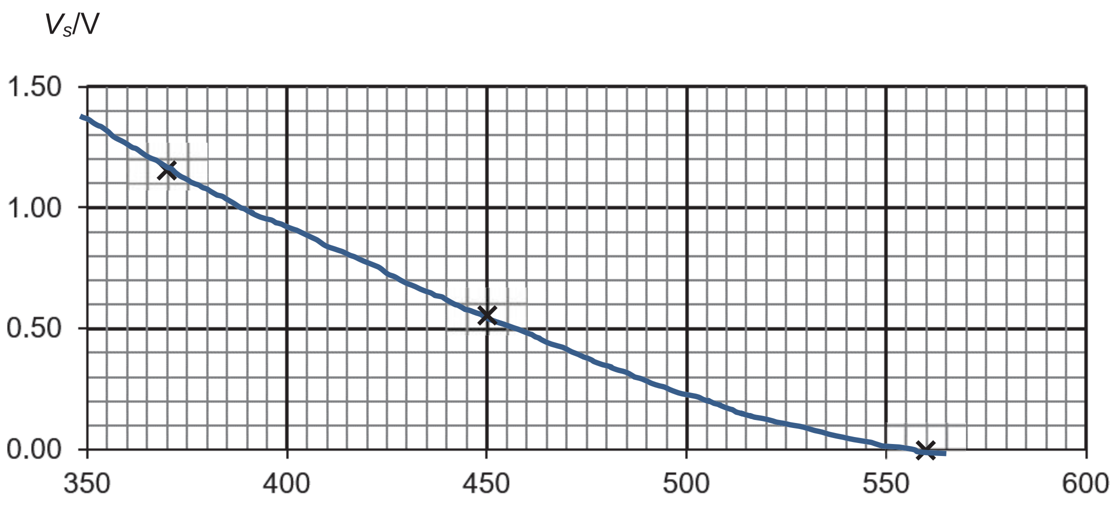
		(iii)	 **Fig. 1.2**	[1]

2(a)		The **gravitational field strength *g*** at a point is the *gravitational force per unit mass* acting on a small mass placed at the point.	[1]
(b)	**(i)**	Acceleration of the satellite = g at that point = $\frac{GM_E}{r^2}$	[1]
	(ii)	The gravitational force on satellite by Earth provides for the required centripetal force to keep the satellite in circular orbit. $\frac{GM_E m}{r^2} = mr\omega^2$ ω – angular velocity Since $T = \frac{2\pi}{\omega}$, $\frac{GM_E m}{r^2} = mr(\frac{2\pi}{T})^2$ $T^2 = \frac{4\pi^2 r^3}{GM_E}$ $T^2 \propto r^3$ (Shown) and constant of proportionality is $\frac{4\pi^2}{GM_E}$	[1] [1] [1]
	(iii)	Period for geostationary satellite, T = 24 h = 24 x 60 x 60 s = 86400 s	[1]

		Angular velocity, $\omega = \dfrac{2\pi}{T}$ = 7.3 x 10^{-5} rad s^{-1}	
	(iv)	$r^3 = \dfrac{GM_E}{\omega^2} = \dfrac{(6.67\times10^{-11})(6.0\times10^{24})}{(7.3\times10^{-5})^2}$	[1]
		$r = (7.51\times10^{22})^{1/3}$ = 4.22 x 10^7 m	[1]
		Thus, altitude = r - R_E = 3.6 x 10^7 m	[1]
	(v)	One possible use is for communication purpose to a particular region on Earth where there is a line of sight to the satellite. The geostationary satellite is always at a fixed position above the Earth and this ensure an uninterrupted communication channel with the satellite. Or For monitoring / spying a particular region on Earth below the satellite as the geostationary satellite is always at a fixed position above the Earth.	[2]

3	**(a)**	At the equilibrium point, $F_{res} = 0 \rightarrow kx - mg = 0$ $kx = mg \rightarrow k = \frac{mg}{x}$, where x is the extension of spring. Any of these points or other correct points from the graph; When a mass of 150 g is hung, the extension on the spring is 10.0 cm. When a mass of 300 g is hung, the extension is 20.0 cm. When a mass of 450 g is hung, the extension is 30.0 cm $k = \frac{0.150g}{0.100} = 14.7\ \text{N m}^{-1}$.		M1 M1 A0
	(b)	**(i)**	$\omega = 2\pi f \rightarrow f = \frac{1}{2\pi}\sqrt{\frac{14.715}{0.450}} = 0.91\ \text{Hz}$	M1 A1
		(ii)	$\Delta GPE = Mg(extension) = 0.450 \times 9.81 \times 0.300 = 1.32435\ \text{J}$ $\Delta EPE = \frac{1}{2}k(e_2^{\,2} - e_1^{\,2}) = \frac{1}{2}(14.715)(0.400^2 - 0.100^2) = 1.103625\ \text{J}$ $\Delta KE = 1.32435 - 1.103625 = 0.220725\ \text{J}$ $0.220725 = \frac{1}{2}mv^2 \rightarrow v = 0.990\ \text{m s}^{-1}$ OR Note that question is asking for v for an oscillation with amplitude 20.0 cm at displacement of 10.0 cm. $v = \omega\sqrt{x_0^{\,2} - x^2} = 2\pi(0.91)\sqrt{0.200^2 - 0.100^2}$	M1 M1 M1 A1
	(c)		The effective mass of the spring-mass system increases. The resonant frequency of heavier masses is at lower values of frequencies (or at greater periods). Hence, the frequency of the oscillation would be reduced. OR use $\omega = 2\pi f \rightarrow f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$, deduce that f is inversely proportional to $\sqrt{m}$. When m increases, f is reduced.	M1 A1

4	(a)	Diffraction is the spreading of waves (into their “geometrical shadows”), after passing through small apertures or round obstacles.		B1
		Destructive interference is when two waves superpose/meet/overlap completely out of phase, resulting in a wave of zero (or reduced) amplitude.		B1 B1 [3]
	(b)	(i)	$d\sin 90° \geq n\lambda$ $n \leq \frac{d}{\lambda} = \left(\frac{10^{-2}}{1000}\right)\left(\frac{f}{c}\right) = \left(\frac{10^{-2}}{3000}\right)\left(\frac{4.69\times10^{14}}{3.00\times10^{8}}\right) = 5.2$ $n = 5$ (correct d - 1, correct λ - 1)	[2]
			The possible number of maxima = 5 + 5 + 1 = 11	[1]
		(ii)	$\sin\theta = \frac{n\lambda}{d} = n\left(\frac{3000}{10^{-2}}\right)\left(\frac{c}{f}\right) = 5\left(\frac{3000}{10^{-2}}\right)\left(\frac{3.00\times10^{8}}{4.69\times10^{14}}\right)$ $\theta = 73.6°$	[1]
			$\tan 73.6° = \frac{x}{2.30}$ $x = 2.30\tan 73.6° = 7.83$ m	[1]
	(c)	$\sin\theta = \frac{n\lambda}{d}$ As green light has shorter wavelength, λ is decreased then sin θ also decreases. This means the separation between maxima will be closer.		[1]
	(d)	The diffraction grating causes sharper, brighter maxima, which spread out a lot more than a double slit. The bigger angle and better visibility give more accurate data to calculate the wavelength.		[1]

5a) $KE_{max} = eV_s$ $= (1.60 \times 10^{-19})(1.15)$ $= 1.84 \times 10^{-19}$ J	
b) $\dfrac{hc}{\lambda} = \dfrac{(6.63 \times 10^{-34})(3.00 \times 10^{8})}{370 \times 10^{-9}}$ $= 5.38 \times 10^{-19}$ J	
c) $KE_{max} = \dfrac{hc}{\lambda} - \Phi$ $1.84 \times 10^{-19} = 5.38 \times 10^{-19} - \Phi$ $\Phi = 3.54 \times 10^{-19}$ J	
$\dfrac{hc}{\lambda_0} = \Phi$ $\dfrac{(6.63 \times 10^{-34})(3.00 \times 10^{8})}{\lambda_0} = 3.54 \times 10^{-19}$ $\lambda_0 = 562$ nm	
d)	
	
B1 for (560, 0.00)	
B1 for $\dfrac{1}{x}$ curve	
e) There is no effect.	
Doubling the intensity will double the rate of arrival of photons on the metal surface,	
but the energy of individual photon remains unchanged.	

6	**(a)**	**(i)**	Isotopes are atoms that have the same number of protons but different number of neutrons.	[1]
		(ii)	As the half-life of X (in years) is very long, the measured activity of sample X is thus relatively constant.	[1]
		(iii) 1	Decay constant of Y, $\lambda_Y = \dfrac{\ln 2}{t_{1/2}} = \dfrac{0.693}{1.5\times 60\times 60}$ = 1.283 x 10^{-4} s^{-1}	[1]
		2	Equilibrium is reached when the rate of production of Y (from the decay of X) is equal to its rate of decay. Hence, the number of isotope Y in the sample will stabilise at a constant value.	[1]
		3	Thus, the activity of Y is about 1.1 x 10^7 Bq. Amount of Y, $N_Y = \dfrac{A_Y}{\lambda_Y} = \dfrac{1.1\times 10^7}{1.283\times 10^{-4}}$ = 8.6 x 10^{10} atoms	[1] [1]
	(c)	**(i)**	By $N = N_o e^{-\lambda t}$: $5N = 6Ne^{-\lambda t}$ Take ln on both sides, $\ln 5 = \ln 6 - \lambda t$ $t = \dfrac{\ln 6 - \ln 5}{1.570\times 10^{-18}} = 1.161\times 10^{17}$ s = 3.682 x 10^9 years = 3.7 x 10^9 years	[1] [1]
		(ii)	Decay of Th-232 will give rise to a radioactive series where there will be a number of radioactive daughter products before ending up as the stable Pb-208. It is assume that these intermediate radioactive daughter products have very short half-life (much shorter than that of Th-232) so the number of intermediate daughter products are insignificant compared to Th-232 and Pb-208.	[1]
		(iii)	If the assumption is not valid, the current amount of decay products will be more than 1N. The fraction of undecayed Th-232 is actually less than $\dfrac{5}{6}$, thus answer for **(b)(i)** will be an under-estimate.	[1]

7 (a)	"per unit mass' is missing	[1]
(bi)	A turkey of twice the mass will have twice the volume. Since $V \alpha L^3$, $L \alpha \sqrt[3]{V}$ and so if volume is doubled L will increase by a factor of $\sqrt[3]{2} = 1.2599$ Since $A \alpha L^2$, A will increase by a factor of $\left(\sqrt[3]{2}\right)^2 = 1.5873$	[2]
(bii)	22 × 1.26 = 27.7 cm	[1]
(biii)	0.46/1.59 = 0.29 m^2	[1]
(ci)	$E = mc\Delta t = 9 \times 3200 \times 90 = 2.59MJ$	[2]
(cii)	$P = \frac{E}{t} = \frac{2590000}{2200} = 1200s$	[1]
(ciii)	Vast majority of heat is lost. Heat is lost to surroundings/ endothermic chemical reactions/change of state of water.	[2]

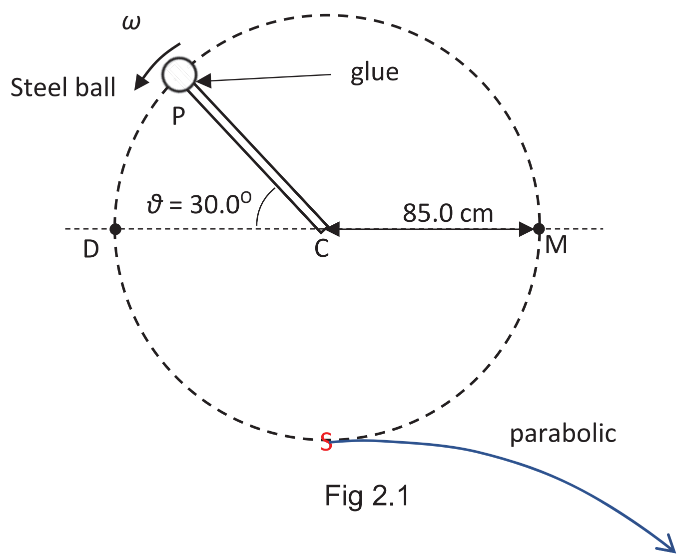
(d)		Mass ×2 Surface area ×1/1.5873 Width ×1.2599 Scale factor is therefore given by 2× 1/1.5873 × 1.2599 = 1.59	[2]
(e)	(i)	Half width of 9 Kg turkey = 0.277/2 = 0.1385 m Area of 9 kg turkey = 0.46÷2=0.23 m^2 $\frac{\Delta Q}{\Delta t} = 0.6 \times 0.23 \times \frac{140}{0.1385} = 139W$	[3]
	(ii)	$t = \frac{E}{P} = \frac{2590000}{139} = 18633s = 5.18 hours$	[1]
	(iii)	Since 18.0 kg turkey is double the mass of the 9.0 kg turkey the cooking time will increase by the same factor as before i.e. 1.59. Hence cooking time = 5.18×1.59 = 8.24 hours.	[1]
	(iv)	S. I units are W m^{-1} $^{o}C^{-1}$ Base units are kg m s^{-3} $^{o}C^{-1}$	[2]

2017 HCI Prelim 9749 P3 Suggested Solution

Section A

1	**(a)**	**(i)**	Define *acceleration*. Acceleration is the rate of change of velocity with respect to time.	[1]
		(ii)	Use your definition in (a)(i) and the definition of average velocity, to show that for constant acceleration $v^2 = u^2 + 2as$ where v is the final velocity, u is the initial velocity, a the acceleration and t the time interval. For constant acceleration $a = \frac{v-u}{t}$ The displacement is given by $s = \left(\frac{v+u}{2}\right)t$ (average velocity x time) Rewriting, we get $\frac{1}{t} = \left(\frac{v+u}{2}\right)\left(\frac{1}{s}\right)$ and $a = (v-u)\left(\frac{v+u}{2}\right)\left(\frac{1}{s}\right)$ $2as = (v-u)(v+u)$ Hence $v^2 = u^2 + 2as$	[2]
	(b)	**(i)**	State the time at which the ball reaches its maximum height. Time = 1.15 s	[1]
	(b)	**(ii)**	Determine the acceleration of the ball 0.5 s after leaving the thrower's hand. Determine the gradient of graph at t = 0.5 s Acceleration = -17 m s^{-2} m s^{-2}	[2]

	(b)	**(iii)**	Based on your answer in (b), determine the drag force on the ball 0.5 s after leaving the thrower's hand. Net force $F = W + F_{Drag} = ma$ $F_{Drag} = ma - mg = (0.320)(17.0) - (0.320)(9.81)$ [1] (Working) $= 2.30\ N$ [1] (Correct answer) Drag force = ____________________ N	[2]
	(b)	**(iv)**	Explain why the time taken to reach maximum height is less than the time taken on the way down to the thrower's hand. Without drag force, the speed of the ball on returning to the thrower's hand is the same as the initial speed when the ball is thrown upwards. With drag force, energy is loss to the environment. Hence the speed on return is less than the speed of throw. Therefore the average speed on the way up is larger than the average speed on the way down. [1] The distance travelled on the way up and down is the same. For the same distance travelled, the time taken is inversely proportional to the average speed. Therefore the time taken on the way up must be smaller because its average speed is larger. [1]	[2]

2	a)	(i)	loss in GPE = m g h = m g r sin θ = 0.200 (9.81) 0.850 sin 30.0° [1] = 0.834 J [1]	[2]
		(ii)	As the ball falls, it loses gravitational potential energy. To maintain constant angular velocity and to prevent the kinetic energy from increasing, the work done by the electric motor must be negative [1] to remove the energy from the system.	[1]
		(iii)	Work done = - loss in GPE= - 0.834 J [1]	[1]
	b)	(i)	mark with the letter S on the dotted circle in Fig 2.1 the position of the ball. Sketch the subsequent path taken by the ball after the glue snaps.	
	 Fig 2.1			[2]
			[1] S at the bottom [1] path is tangent to the circle at the start, and curves parabolically downwards.	
		(ii)	By Newton's 2nd law, F_{net} on the ball = max glue tension - weight = ma_c $8.50-0.200(9.81)=0.200(0.850)\omega^2$ [1] ω = 6.20 rad s^{-1} [1]	[2]

	c)	The minimum angular speed is determined by the condition that the ball stays in contact with E at the top, where the net force is the minimum and is only provided by the weight of the ball. $mg = mr\ \omega^2$ $9.81 = 0.85\ \omega^2$ [1] ω = 3.40 rad s-1. [1]	[2]

3 **(a)** The table below shows the pressure, volume and temperature of the ideal gas inside the metal cylinder for states A, B and C.

(i) Explain why the pressure for states A and D are the same. [1]

The pressure in the gas is given by the sum of the atmospheric pressure and the pressure due to the combined weight of the piston, connecting rod and platform. Since these components are the same for both states A and D, the pressure for State D is therefore the same as that for State A.

(ii) Complete the table by filling in the volume for state D. [2]

	Ideal Gas		
State	Pressure (kPa)	Volume (m^3)	Temperature (K)
A	102	1.000	292
B	103	0.990	292
C	103	1.197	353
D	102	**1.209**	353

Table 3.1

(b)

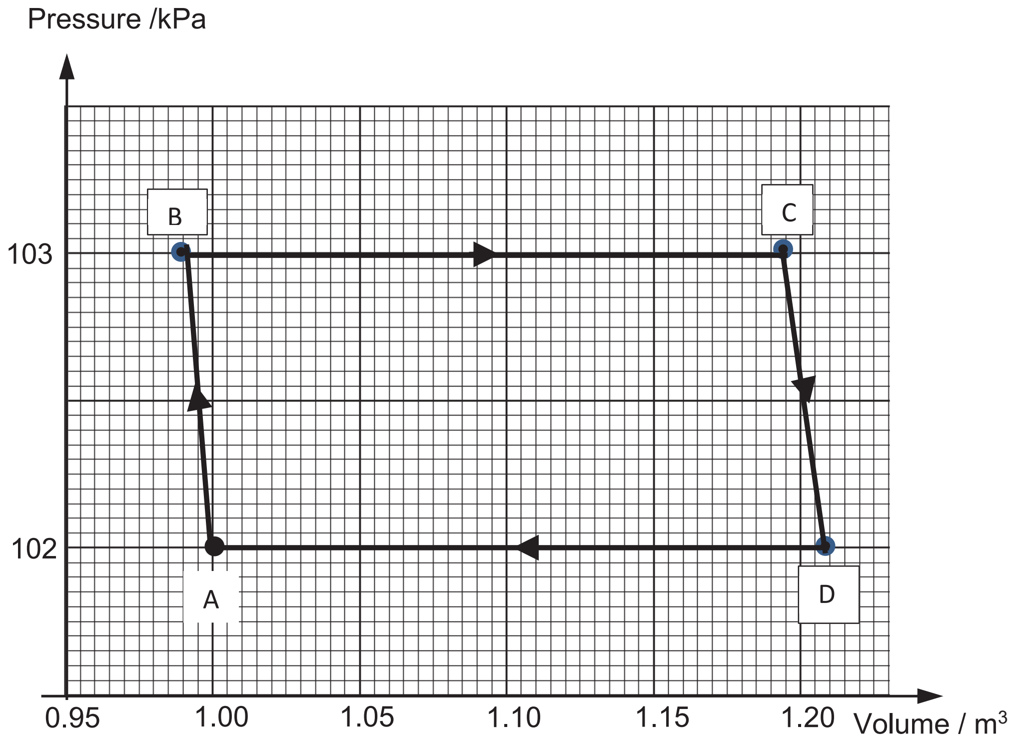
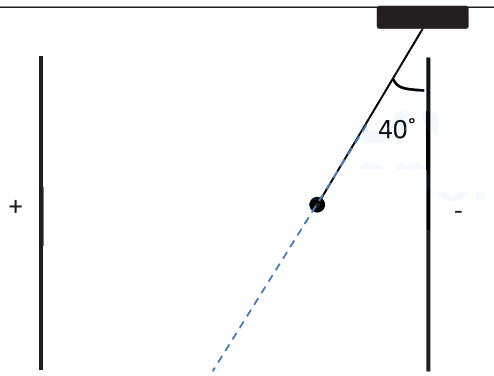


Fig. 3.3

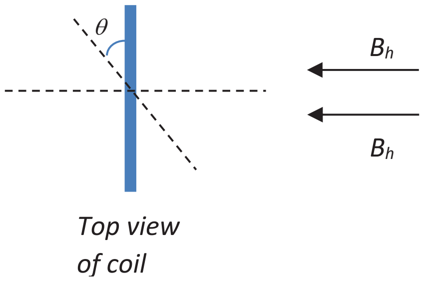
	(i)	Mark and label state D on Fig. 3.3 and draw the process lines joining state C to state D to state A. State D plotted correctly to accuracy of half the smallest square.	[1]
	(ii)	Hence, using Fig. 3.3, estimate the work done by the ideal gas in one cycle. Workdone is area enclosed by the graph $W = (103000 - 102000)(1.209 - 1.000)$ [1] (Working) $= 209\ J$ [1] (Correct answer) Recognise that the enclosed area is approximately a parallelogram. Alternatively, area can also be obtained by counting of squares. Work Done = <u>209 J</u>	[2]
	(c)	By considering the kinetic energy of the ideal gas in the metal cylinder, determine the amount of thermal energy, *Q* absorbed by the gas from the heat reservoir as it goes from state B to C. For ideal gas, the internal energy equals its kinetic energy. Internal energy at B, Since $PV = nRT$, the internal energy is $U = \frac{3}{2}nRT = \frac{3}{2}PV$ [1] The change in internal energy from B to C, $\Delta U = \frac{3}{2}\left[\left(103\times10^{3}\right)(1.197) - \left(103\times10^{3}\right)(0.990)\right] = 31982\ J$ [1] (find change in U) Based on the First Law of Thermodynamics $Q = \Delta U - W = 31982 - \left[-\left(103\times10^{3}\right)(1.197 - 0.990)\right]$ [1] (1st Law of Thermodynamics) $= 53303\ J$ [1] (correct answer)	[4]
	(f)	Determine the efficiency of the heat engine. Efficiency $= \frac{\text{Output energy}}{\text{Input energy}} \times 100\%$	[1]

		$=\frac{209}{32190}\times 100\%=0.65\%$	

4	(a)	Electric field strength at a point is the electric **force per unit positive charge** on a small test charge placed at that point.		[1]
	(b)	(i)	Net force in the vertical direction = 0 T cos40° = mg $T = \frac{(0.250)(9.81)}{\cos 40°}$ T = 3.2 N	[1]
		(ii)	1. Net force in the horizontal direction = 0 T sin40° = qE $E = \frac{(3.2)\sin 40°}{12 \times 10^{-3}}$ E = 170 V m^{-1}	[1] [1]
			2. E = ΔV/Δx ΔV = EΔx = 171 × 0.70 sin40° = 77 V	[1] [1]
		(iii)		[1]

		(iv)	Gain in kinetic energy = loss in gravitational PE + loss in electric PE = $mg\Delta h + qE\Delta x$ = $(0.250)(9.81)(0.70) + (0.012)(171)(0.70 \tan 40^\circ)$ = 2.9 J	[1] [1] [1]

5	**(a)**		very high/infinite resistance for negative voltages up to about 0.4 V resistance decreases from 0.4 V	B1 B1
	(b)		initial straight line from (0,0) into curve with decreasing gradient but not to horizontal repeated in negative quadrant	M1 A1
	(c)	**(i)**	R = 122 / 36 = 4.0 Ω or I = P / V = 36 / 12 = 3.0 A and R = 12 / 3.0 = 4.0 Ω	A1
		(ii)	R = V / I = (12 – 0.5 × 2.8) / 2.8 or E = 12 = 2.8 × (R + r) = 3.8 (3.79) Ω or R = 3.8 Ω	C1 A1
		(iii)	Power dissipated across filament lamp = $(2.8)^2$ (3.79) = 29.7 W Power supplied by cell = (2.8)(12) = 33.6 W Percentage of power supplied by cell dissipated across the filament lamp = (29.7 / 33.6) x 100% [1] = 88.4 % [1]	[2]

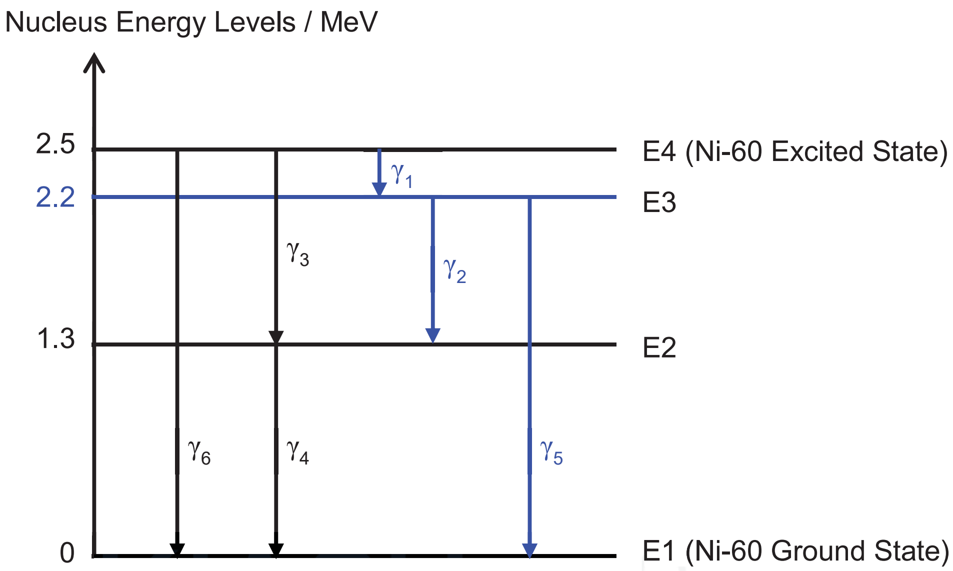
6	a)	Faraday's Law of Electromagnetic Induction states that the magnitude of the induced e.m.f. is directly proportional to the rate of change of magnetic flux linkage or the rate of cutting of magnetic flux B2	
	b)	(i)	When the coil rotates, the area of the coil that is perpendicular to the horizontal component of the earth's magnetic field (B_h) changes. Thus there is a changing magnetic flux linkage in the coil. B1 By Faraday's law of EMI, an e.m.f. of magnitude directly proportional to the rate of change of magnetic flux linkage will be induced in the coil. B1 OR As the coil rotates at a constant speed, it cuts the magnetic flux due to the earth's magnetic field. B1 By Faraday's law of EMI, an e.m.f. of magnitude directly proportional to the rate of change of magnetic flux will be induced in the coil. B1
		(ii)	 Magnitude of e.m.f. $\varepsilon = d\Phi/dt = d(nB_hA\sin\theta)/dt = d(nB_hA\sin\omega t)/dt = \omega nB_hA\cos\omega t$ Since Φ is sinusoidal, ε is also sinusoidal M1 A1
		(iii)	$\omega = v/r = 200 \times 10^3/(3600)(0.250) = 222.2$ rad s^{-1} A1
		(iv)	$\varepsilon_{max} = n\omega AB_h$ B1
		(v)	$n = \varepsilon_{max}/\omega AB_h = 15 \times 10^{-3}/222.2 \times 10^{-2} \times 1.5 \times 10^{-5} = 450$ turns A1
		(vi)	The rod which holds the cups is rotating at right angles to the vertical component of the Earth's magnetic field, and therefore is acting as a crude form of spinning Faraday's disk. The e.m.f. is established between the centre and either ends of the rod, hence there will be no potential difference across the two ends of each metal rod during rotation at maximum speed.

Section B

7	(a)	(i)	$f = 1/T = 1/0.50 = 2.0$ Hz	A1
		(ii)	$a = -\omega^2 x \rightarrow \omega^2 = \left(\dfrac{\rho A g}{m}\right)$	M1
			$\rightarrow 4\pi^2 f^2 = \left(\dfrac{\rho A g}{m}\right) \rightarrow \rho = \dfrac{4\pi^2 f^2 m}{Ag}$	M1
			$\rho = \dfrac{4\pi^2 (2.0)^2 0.032}{4.2\times10^{-4}(9.81)} = 1226 \text{ kg m}^{-3}$	A1
		(iii)	The energy of the oscillations is given by $\dfrac{1}{2}m\omega^2 x^2$, where x is the displacement from the equilibrium point.	M1
			$E_{t=0} = \dfrac{1}{2}m\omega^2 x_0^2 = \dfrac{1}{2}0.032(4\pi^2 2.0^2)(-1.5)^2 = 5.68\times10^{-4}$ J $E_{t=1.50\text{ s}} = \dfrac{1}{2}m\omega^2 x_{1.50}^2 = \dfrac{1}{2}0.032(4\pi^2 2.0^2)(-0.65)^2 = 1.07\times10^{-4}$ J	M1
			% loss = $\dfrac{5.68\times10^{-4}\text{ J} - 1.07\times10^{-4}\text{ J}}{5.68\times10^{-4}\text{ J}} = 81\%$ loss	A1
		(iv)	As the liquid is more viscous, greater damping forces will act on the tube. More negative work done by the tube against these forces per oscillation. Hence, the tube oscillates with much less energy in this liquid. Energy is directly proportional to the square of the amplitude. Therefore, the tube oscillates at smaller amplitudes.	M1 M1 A0
	(b)	(i)	The amplitude of vibration is **the same at all points in a travelling** (progressive) wave but it **varies with position in a stationary wave**, from **zero at nodes to maximum at antinodes**. The energy is **being transmitted in a travelling wave** however it is stored/**not transmitted in a stationary wave**.	M1 M1 M1
		(ii)	Shape X: Sine wave with less amplitude Shape Y: Horizontal line Shape Z: Negative sine wave with less amplitude	M1 M1 M1
	(c)	(i)	5 fringe separations = 10.4 mm $\Delta y = \dfrac{\lambda L}{d}$	M1

			$\frac{10.4 \times 10^{-3}}{5} = \frac{633 \times 10^{-9}(2.95)}{d}$ $d = 8.98 \times 10^{-4}$ m = 0.898 mm	M1
		(ii)	Any of 3 below: • Greater angle for bright spots (principal maxima) • Less number of bright spots • Greater intensity at bright spots • Greater distance between subsequent bright spots	M1 M1 M1

8	**(a)**	**(i)**	${}^{60}_{27}\text{Co} \rightarrow {}^{60}_{28}\text{Ni} + {}^{0}_{-1}\text{e} + \gamma$ [B1] for e. [B1] for the other 2.	[2]
		(ii)	Number of nuclei in 1 g of C0-60 $= \frac{1}{60} \times 6.02 \times 10^{23}$ [M1] $= 1.003 \times 10^{22}$	[1]
		(iii)	$A = \lambda N$ $= \frac{\ln 2}{5.272 \times 265 \times 24 \times 60 \times 60} 1.003 \times 10^{22}$ [M1] $= 4.182 \times 10^{13}$ Bq radiation power $= (4.182 \times 10^{13}) \times 2.8$ $= 1.171 \times 10^{20}$ eV $= 18.7$ W [A1]	[2]
	(b)	**(i)**	A packet of electromagnetic radiation energy of [1] energy > 100 keV OR wavelength < 10 pm. [1]	[2]
		(ii)	Method 1 $E = \frac{hc}{\lambda}$ $(1.3 \times 10^{6})(1.60 \times 10^{-19}) = \frac{(6.63 \times 10^{-34})(3.0 \times 10^{8})}{\lambda}$ [M1] $\lambda = 9.5625 \times 10^{-13}$ m	[2]

			$p=\dfrac{h}{\lambda}=\dfrac{(6.63\times10^{-34})}{9.5625\times10^{-13}}=6.93\times10^{-22}\ \text{kg m s}^{-1}$ [A1] <u>Method 2</u> From $\lambda=\dfrac{h}{p}$ and $E=\dfrac{hc}{\lambda}$, we obtain $E=pc$ $p=\dfrac{E}{c}=\dfrac{(1.3\times10^{6})(1.60\times10^{-19})}{3.00\times10^{8}}$ $=6.93\times10^{-22}\ \text{kg m s}^{-1}$	
		(iii)	When the nucleus de-excites from a higher to lower energy level, a gamma photon of energy equal to the energy transition is emitted. [B1] Since the energy levels of the nucleus is discrete, the emission spectrum is a **line spectrum** [B1]	[2]
		(iv)	**1.** 	[2]
			2. $\Delta E=\Delta m.c^2$ $(2.5\times10^{-6})(1.60\times10^{-19})=\Delta m.(3.00\times10^{8})^2$ [M1] $\Delta m=4.444\times10^{-30}\ \text{kg}$ $=0.0002677\ \text{u}$ At excited state $m=59.93079+0.0002677=59.93347u$ [A1]	

			By the mass-energy equivalence principle, the mass of the excited nucleus has more energy and therefore larger mass than the nucleus in its ground state. [B1]	[3]
	(c)	(i)	Energy of beta-particle $= 2.8 - 2.5 = 0.3$ MeV [M1] $\frac{hc}{\lambda_{min}} = E_{\beta}$ $\frac{(6.63 \times 10^{-34})(3.00 \times 10^{8})}{\lambda_{min}} = (0.3 \times 10^{-6})(1.6 \times 10^{-19})$ $\lambda_{min} = 4.14 \times 10^{-12}$ m [A1]	[2]
		(ii)	Beta-particles knock the innermost shell electrons out of the lead atoms, creating vacancies in the innermost shell. [B1] When electrons from higher shells cascade down to fill the vacancy, X-ray photons with energy corresponding to the energy transitions are emitted. [B1]	[2]

HWA CHONG INSTITUTION

H2 Physics 9749
2017 C2 Prelim Exam
Paper 4 (Practical)
Suggested Mark Schemes

These mark schemes are published to serve as a guideline to teachers and students, to indicate the requirements of the test. They show the basis on which the marks are awarded, however it is expected that alternative correct answers and unexpected approaches will sometimes be encountered. **Due credit will be given at the discretion of the teachers** provided the students have shown understanding of the concepts tested. In the same vein, **students who arrived at the correct answer or provided a correct statement but otherwise in their working contradicted themselves or showed that they did not really understand the concept will/may not be credited**.

Mark schemes must be read in conjunction with the question. HCI will not enter into discussions or correspondence in connection with these mark schemes.

About H2 Physics 9749 Paper 4 (SEAB Assessment Syllabus Document)

Paper 4 is designed to assess a candidate's competence in those practical skills which can realistically be assessed within the context of a formal practical assessment.

Candidates will be assessed in the following skill areas:

(a) **Planning (P)**

Candidates should be able to:

- define a question/problem using appropriate knowledge and understanding
- give a clear logical account of the experimental procedure to be followed
- describe how the data should be used in order to reach a conclusion
- assess the risks of the experiment and describe precautions that should be taken to keep risks to a minimum.

(b) **Manipulation, measurement and observation (MMO)**

Candidates should be able to:

- demonstrate a high level of manipulative skills in all aspects of practical activity
- make and record accurate observations with good details and measurements to an appropriate degree of precision
- make appropriate decisions about measurements or observations
- recognise anomalous observations and / or measurements (where appropriate) with reasons indicated.

(c) **Presentation of data and observations (PDO)**

Candidates should be able to:

- present all information in an appropriate form
- manipulate measurements effectively in order to identify trends / patterns
- present all quantitative data to an appropriate number of decimal places / significant figures.

(d) **Analysis, conclusions and evaluation (ACE)**

Candidates should be able to:

- analyse and interpret data or observations appropriately in relation to the task
- draw conclusion(s) from the interpretation of experimental data or observations and underlying principles
- make predictions based on their data and conclusions
- identify significant sources of errors, limitations of measurements and / or experimental procedures used, explaining how they affect the final result(s)
- state and explain how significant errors / limitations may be overcome or reduced, as appropriate, including how experimental procedures may be improved.

The assessment of skill area P will be set in the context of the content syllabus, requiring candidates to apply and integrate knowledge and understanding from different sections of the syllabus. It may also require treatment of given experimental data to draw a relevant conclusion and in the analysis of a proposed plan.
The assessment of skill areas MMO, PDO and ACE will be set in the context of the syllabus. The assessment of PDO and ACE may also include questions on data analysis which do not require practical equipment and apparatus.
Candidates are not allowed to refer to notebooks, textbooks or any other information in the Practical examination.

Suggested Mark Schemes and Markers' Comments

Qn 1 Mark Scheme and Markers' Comments

Question	Answer	Marks
1(a)(i)	**PDO** Repeat measurements of x and find average. **MMO** Value of x to the appropriate precision (i.e. 2 d.p. in cm) with unit.	**1** **1**
1(a)(ii)	**ACE** Percentage uncertainty in x calculated correctly using sensible value of Δx (absolute uncertainty of x) (accepted range of Δx is 0.5 mm to 2.0 mm) to indicate unevenness of surface rather than precision of vernier caliper.	**1**
1(b)(i)	**MMO** Value of d to the nearest 0.1 mm with unit. (accepted range of small hole is between 0.50 cm and 0.80 cm)	**1**
1(b)(ii)	**ACE** Calculation of A in suitable units with same or one more significant figure than d.	**1**
1(c)(v)	**ACE** Estimation of m using ratio of x values and 100 g with unit.	**1**
1(d)	**ACE** Correct calculation of time taken for 5 g with unit.	**1**
1(e)	**MMO** Measurement of d for big hole. (accepted range of big hole is between 0.70 cm and 1.00 cm) **ACE** Calculation of A. **PDO** Values of d to appropriate precision and A to appropriate number of significant figures with units. **PDO** Flow rate R with appropriate units, e.g. g s^{-1}. **ACE** Determination of constant of proportionality. (i.e $k = R / A$) **ACE** Draw conclusion based on stated criterion e.g. not obeyed because more than 20% difference in values of k.	**6**

1(f)	**ACE** Investigate flow of pepper with hole size. Use smaller holes. Investigate flow of pepper with number of holes. Use more than one hole of this size.	**2**
	Total	**15**

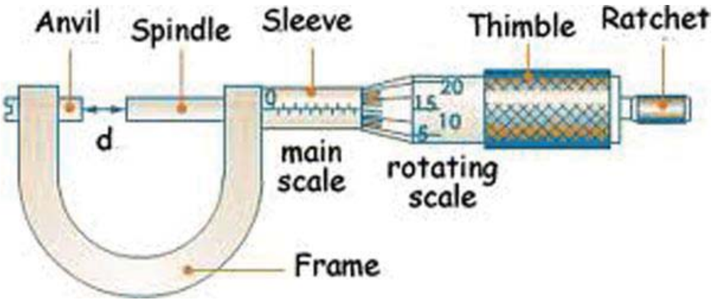
Qn 2 Mark Scheme and Markers' Comments

Question	Answer	Marks
2(a)(ii)	**MMO** Value of y_0 to the appropriate precision with unit.	**1**
2(a)(vi)	**ACE** Calculation of $(y - y_0)$ in suitable units to an appropriate decimal place (maintain same d.p. as y_0 and y).	**1**
2(a)(vii)	**ACE** Percentage uncertainty in $(y - y_0)$ calculated correctly using sensible value of $\Delta(y - y_0)$ (absolute uncertainty of $y - y_0$). (accepted range of $\Delta(y - y_0)$ is 2 mm to 6 mm)	**1**
2(c)(i)	**MMO** y_0 and y for both masses on Ruler A **ACE** Calculation of $(y - y_0)$ and percentage change of $(y\text{-}y_0)$. **PDO** Values of y_0 to appropriate precision and $(y - y_0)$ to appropriate number of decimal places with units.	**2**
2(c)(ii)	**ACE** Draw conclusion based on comparison of the percentage change and percentage uncertainty.	**1**
2d(i)	**ACE** Relevant points (with appropriate elaboration) might include: • difficulty in judging whether metre rule B, that is clamped, is vertical • uncertainty in reading y and y_0 due to the thickness of rule or parallax error as rule B is a small distance from rule A.	**1**
2d(ii)	**ACE** Relevant points (with appropriate elaboration) might include: • use spirit level to check that metre rule B is vertical. • attach needle as a pointer at the end of rule A.	**1**
	Total	**8**

Qn 3 Mark Scheme and Markers' Comments

The beginning parts

3ai
Value for d in the range 0.17 mm ≤ d ≤ 0.21 mm, with **unit**.
Accept: 0.00019 m, 0.019 cm
Reject: 0.190 mm



3cii
Value for V_1 range 0.300 V ≤ V_1 ≤ 0.600 V
Value for V_2 range 0.200 V ≤ V_2 ≤ 0.400 V
V_1 larger than V_2 by 0.1 V

Tabulation

3d

Data (2 marks)
Deduct 1 mark if only 5 sets **tabulated**.
Deduct 2 mark if 4 or less sets tabulated.
Deduct 1 mark per column of nonsensical data collected.
Deduct 1 marks if minor assistance rendered.
Deduct 2 marks if major assistance rendered.

Heading (1 mark)
Units must be presented.
Penalise broken table

Range of IV (1 mark)
$\Delta\, l \geq 25$ cm.

Decimal Place (1 mark)
l to nearest 1 mm
V_1 and V_2 to the nearest 0.001 V.

Significant Figure (1 mark)
V_1/V_2, the number of s.f. should be correct.

Calculation (1 mark)
All V_1/V_2 calculated correctly.
Penalise rounding off error.

Graph
3e

Scale
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 units if any).

Plots
All observations must be plotted to an accuracy of half a small square or less.
Penalise student who used x to mark a grad point.

BFL
There must be a fair scatter of points either side of the line.
Penalise student who identified anomalous point(s) wrongly.
Student must have at least 5 non-anomalous data points to be awarded the BFL mark.
The data points show no trend at all, the BFL mark is forfeited.

Linearising equation.
Gradient
Gradient – the hypotenuse must be greater than half the length of the drawn line. Read-offs must be accurate to within half a small square.

y-intercept
y-intercept is calculated from $y = mx + c$ **using a point on the line**.
Or
y-intercept must be read off to the nearest half small square **accuracy**

P and Q
Values of P and Q calculated correctly with **units**.

The ending parts

3f
There is no anomalous data as no data point deviates substantially from the linear trend set by the other data points. All data points are closely and evenly scattered **about** the best fit line.
Or
(X,Y) is a anomalous point because it deviates significantly from the linear trend set by the other data points.

3g
Working (substitution) must be presented.
ρ in range 3×10^{-7} to $7\times10^{-7}\,\Omega$ m. (4.9×10^{-7} is the theoretical answer)

3hi
Sources of errors:
1. Uncertainty in determining the position of L and M | Uncertainty in measurement of l because of considerable **thickness** of crocodile clips.

3hii
Improvements
1. replace the crocodile clips with jockeys

Qn 4 Mark Scheme and Markers' Comments

Suggested Mark Scheme for Q4 Planning Question:

	Marks	Marking Points
Diagram	3	• Strain gauge stuck in correct orientation to cylinder (can be credited in procedure) • Cylinder with mass on top and resting on platform/table-top and not floating. • Electrical circuit correctly drawn.
Variables	4	**V1.** How to vary compression 10 times (load different masses) **V2.** How to measure the mass and calculate force ($\Delta F = mg$) (or use force meter) **V3.** How to measure resistance **V4.** How to measure ΔR (before and after loading)
Analysis	1	**A1.** What graph to plot and how to obtain n
Reliability	3	Any good further design details, some of these might be: **R1, R2 and R3** • **Control!** Keep temperature constant, monitor with a thermometer • **Preliminary experiments** to determine suitable range of masses to obtain observable/meaningful results • Way to apply compressive force uniformly over the cross-section of cylinder • Repeat measurement of mass/ resistance and take average to reduce random error. • After each unloading, check that the resistance value returns to the original value, otherwise some permanent deformation might have taken place and the load might have been excessive for the experiment
Safety	1	Any relevant safety precaution **S1** e.g.: • Wear goggles in case concrete cracks • Reasonable measure to prevent cylinder/ heavy masses from toppling • Wear gloves to prevent getting burnt by hot wires (for those using power source)
Total	12	

Analysing the Question

Back ground info

4 Concrete is widely used for construction and its manufacture contributes 5% to the world's carbon dioxide (CO_2) production. One way of reducing the amount of CO_2 produced could be to use less cement in the production of concrete.

A company is producing concrete with low cement content and wishes to see how the material behaves under a compressive force. A compressive force applied to a concrete object will reduce the length of the object in the direction of the force very slightly.

The reduction in length of the object is to be measured using a strain gauge.

When a wire has its length changed, its resistance changes. A strain gauge consists of a length of thin wire as shown in Fig. 4.1.

Intro to new instrument. Read carefully!

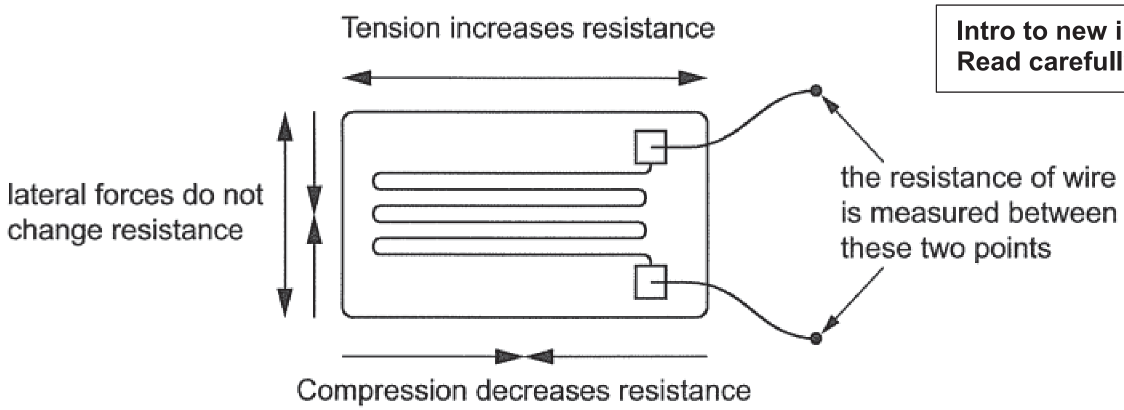


Fig. 4.1

The gauge consists of a wire wound backwards and forwards and embedded in thin plastic. The plastic is then bonded firmly to the specimen being investigated.

The relation between change in resistance ΔR and change in force ΔF is

Need to define ΔR and ΔF

$$\Delta R = k\,(\Delta F)^n$$

Relation given, no need to hypothesize

where k and n are constants.

You are provided with some heavy masses, a low voltage power supply and other equipment usually found in a Physics laboratory.

Can't assume normal slotted mass! **Safe, won't get electrocuted!**

Design an experiment to determine the value of n for compressive forces applied to a small concrete cylinder along its axis.

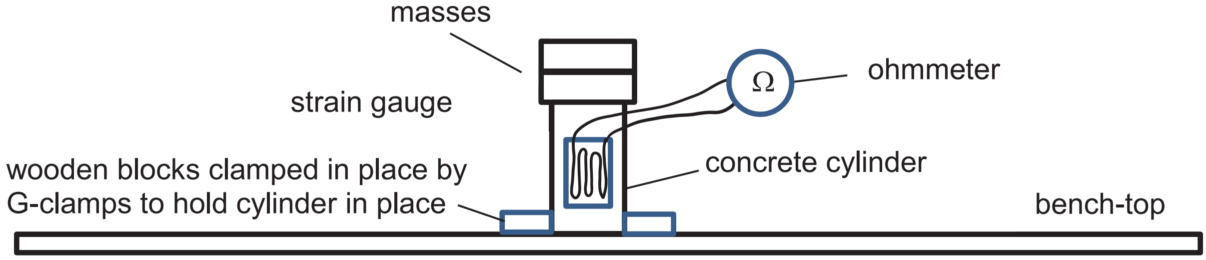
TASK OBJECTIVE!!

You should draw a labelled diagram to show the arrangement of your apparatus and you should pay particular attention to

(a) the equipment you would use,
(b) the procedure to be followed,
(c) how the compressive force and change in resistance are measured,
(d) the control of variables,
(e) any precautions that would be taken to improve the accuracy and safety of the experiment.

Important hints!

Diagram



1. Set up the apparatus as shown. Adhere the strain gauge to the cylinder using in the orientation shown.
2. Conduct the experiment in a temperature controlled room. Monitor temperature with a thermometer.
3. Before loading the cylinder, measure the resistance R_1 using an ohmmeter.
4. Load the cylinder evenly across its cross section by placing the mass centrally on the cylinder.
5. Calculate the compressive force using $\Delta F = mg$, where m is measured with an electronic mass balance.
6. Measure the new resistance R_2, and calculate $\Delta R = R_2 - R_1$
7. **Repeat steps 3 to 6** until a total of **10 sets of data** have been collected.
8. $\Delta R = k\,(\Delta F)^n$
   $\lg \Delta R = \lg k + n \lg (\Delta F)$

   Plot lg ΔF against lg ΔR to obtain a straight line and determine the gradient of the line which is the numerical value for n.

<u>Additional details</u>
1. Conduct preliminary experiments to determine suitable range of masses to obtain observable differences.
2. After each unloading, check that the resistance returns to its original value. Otherwise the load might have been too much, and has caused permanent deformation.
3. Repeat for each load, average the readings to check for reproducibility/reduce random error.

<u>Safety</u>
1. Wear safety goggles to protect eyes in case concrete cracks and fragments flies off as projectiles.
2. Wedge the cylinder lightly on opposite sides using G-clamps to secure it and prevent possible toppling.

Alternative setup
*Find resistance using $R = V/I$