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

This document consists of 25 printed pages.

Data

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

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

permittivity of free space, $\varepsilon_o = 8.85 \times 10^{-12}$ 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 $T/\text{K} = T/°\text{C} + 273.15$

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

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

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

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

electric current $I = Anvq$

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

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

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

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

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

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

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

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

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

Section A

Answer all 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.

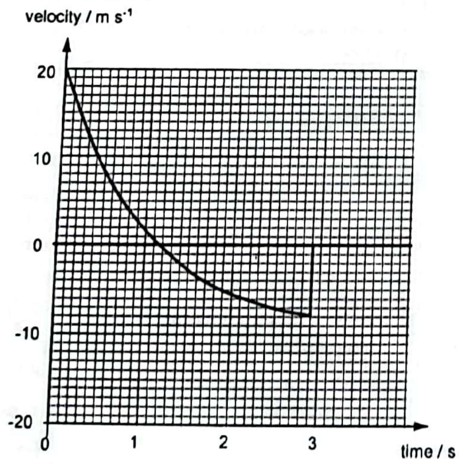

Fig. 1.1

(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.

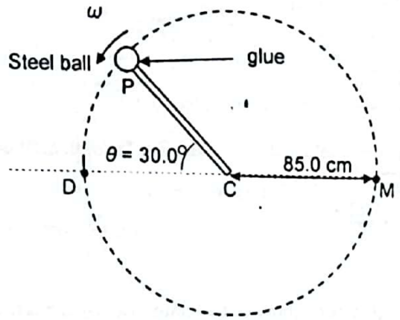

Fig. 2.1

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.

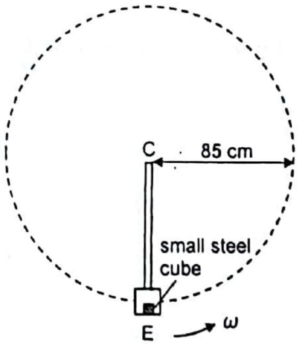

Fig 2.2

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.

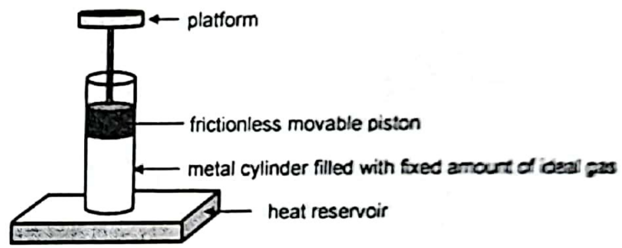

Fig. 3.1

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

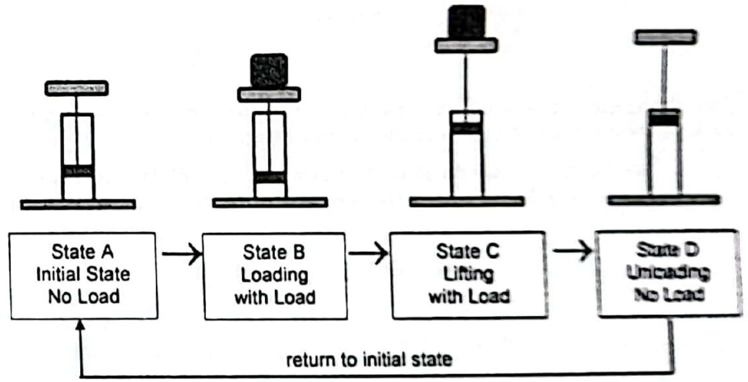

Fig. 3.2 one cycle of the heat engine

(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.

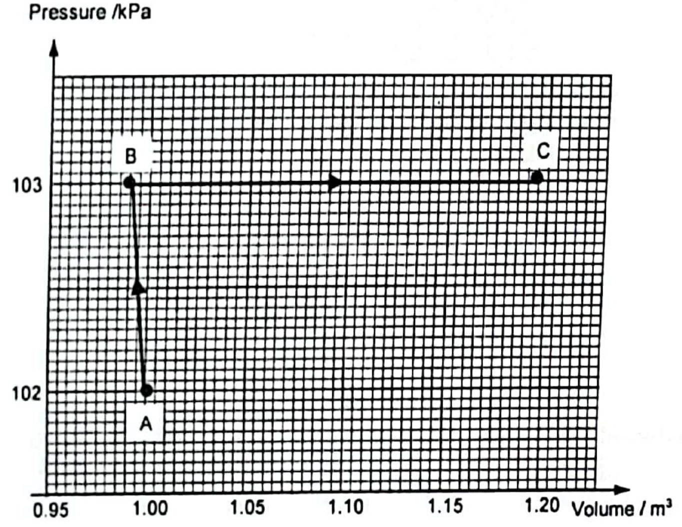

Fig. 3.3

(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.

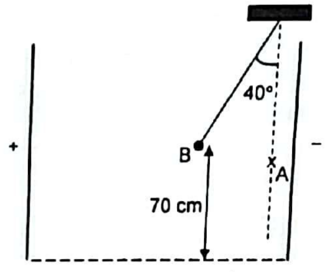

Fig. 4.1

(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.

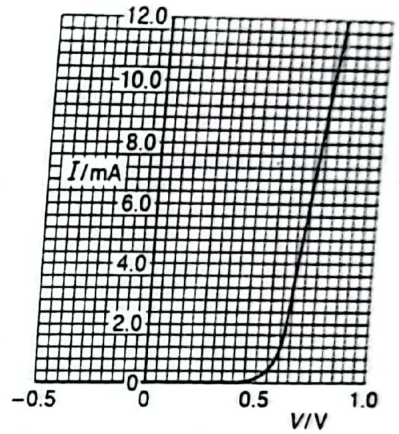

Fig. 5.1

(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.

....

....

....

.... [illegible]

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

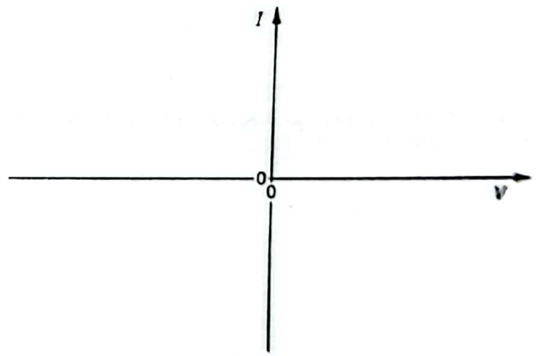

Fig 5.2

(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.

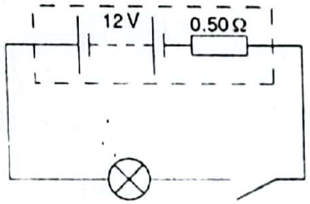

Fig. 5.3

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.

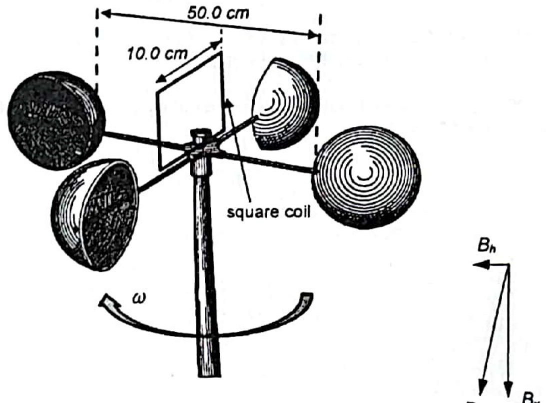

Fig. 6.1

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

....

....

....

.... [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.

....

....

....

.... [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.

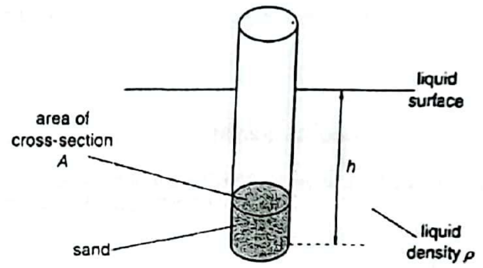

Fig. 7.1

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.

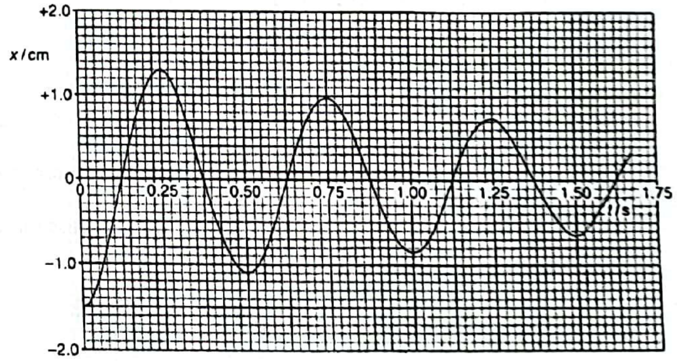

Fig. 7.2

(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.

....

....

....

....

.... [2]

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

....

....

....

.... [3]

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

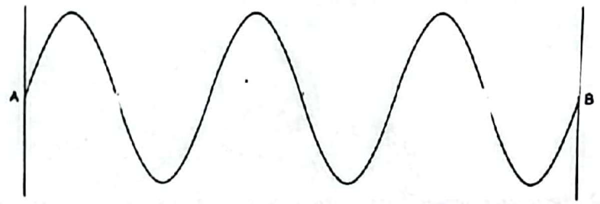

Fig. 7.3

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.

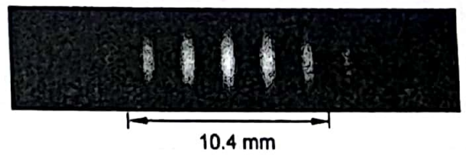

Fig. 7.4 (not to scale)

(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.

....

....

....

....

....

.... [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.

$$^{60}_{\dots}Co \rightarrow \;^{\dots}_{28}Ni + \;^{\dots}_{\dots}e + \gamma$$

[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.

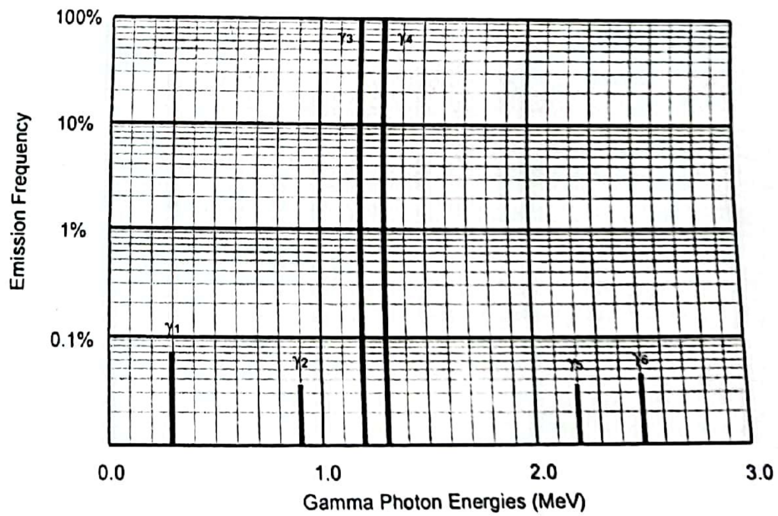

Fig. 8.1

(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.

....

....

....

.... [2]

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

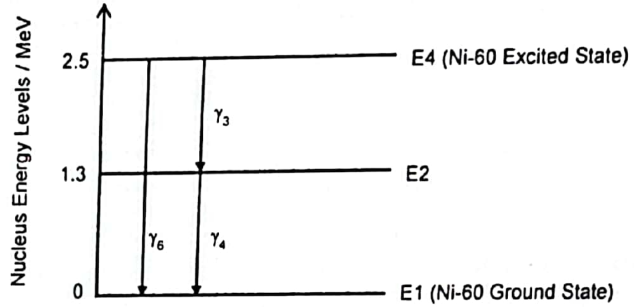

Fig. 8.2

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.

....

....

....

.... [2]

End of Paper