H

NANYANG JUNIOR COLLEGE
Science Department

JC 2 PRELIMINARY EXAMINATION

Higher 2

Candidate Name

Class

Tutor Name

PHYSICS 9646/03

Paper 3 Longer Structured Questions **18 September 2013**

2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class and tutor name on all the work you hand in.
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, paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer any **two** questions.

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.

For examiner's use	
Section A	
1	
2	
3	
4	
5	
Section B	
6	
7	
8	
Total	

This document consists of **26** printed pages

Nanyang Junior College

Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_0	=	8.85×10^{-12} Fm^{-1}
			$(1 / (36\pi)) \times 10^{-9}$ Fm^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-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	=	ρgh
gravitational potential,	ϕ	=	$-Gm / r$
displacement of particle in s.h.m.	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_0 \cos \omega t$
			$\pm\omega\sqrt{\left(x_o^{\,2} - x^2\right)}$
mean kinetic energy of a molecule of an ideal gas	E	=	$\frac{3}{2}kT$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$Q / 4\pi\varepsilon_0 r$
alternating current/voltage,	x	=	$x_0 \sin \omega t$
transmission coefficient,	T	$\propto$	$\exp(-2kd)$
	where k	=	$\frac{0.693}{t_{1/2}}\sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{0.693}{t_{1/2}}$

Section A

Answer **all** the questions in this section.

For Examiner's Use

1 Three similarly sized balls A, B, and C, of masses 0.40 kg, 0.20 kg, and 0.10 kg respectively, are connected by strings such that their centre-to-centre distances are as shown in Fig. 1.1 below. The setup is swung in a horizontal circle on a frictionless table about O. The balls and strings maintain a straight line, with the outermost ball having a speed of 6.0 m s^{-1}.

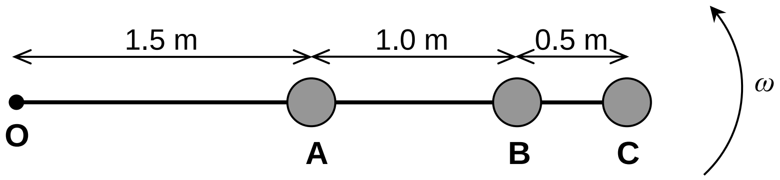


Fig. 1.1: Top View

Calculate

(a) the angular velocity ω of C.

$\omega = \frac{v}{r} = \frac{6.0}{1.5+1.0+0.5} = 2.0$ rad s^{-1} **[B1]**

ω = ... rad s^{-1} [1]

(b) the tangential speed of ball B.

Since the balls and strings maintain a straight line, the angular velocity of ball B must be the same as that of ball C. **[C1]**

$v = \omega r = 2.0(1.5 + 1.0) = 5.0$ m s^{-1} **[B1]**

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

(c) the tensions in

(i) string BC and

Considering the free body of ball C,
T_{BC} provides for the centripetal force for circular motion of C

$T_{BC} = m_c \omega^2 r_c$
$= (0.10)(2.0)^2(1.5 + 1.0 + 0.5)$ **[M1: correct substitution]**
$= 1.2$ N **[A1]**

<u>Examiner's Comments</u>

Common mistakes included the substitution of incorrect mass or radius of circular motion. Some candidates failed to interpret that the circular motion was on a horizontal table and hence the weight of the balls will not have any effect on the centripetal acceleration. Weaker candidates were not able to establish a correct relationship between the forces acting on C and the centripetal acceleration of C.

tension in BC = ... N [2]

For Examiner's Use

(ii) string AB.

Considering the free body of ball B,

T_{AB} - T_{BC} provides for the centripetal force for circular motion of B

$T_{AB} - T_{BC} = m_B\omega^2 r_B$ **[M1]**

$T_{AB} = (0.20)(2.0)^2(1.5 + 1.0) + 1.2$ **[M1: for correct substitution]**

$= 3.2$ N **[A1]**

Examiner's Comments

An appropriate free-body needs to be considered and the relationship between the forces and the centripetal acceleration needs to be clearly presented. In some scripts, the presentation of the answers seems to suggest that the candidates were adding/ subtracting 2 centripetal (resultant) forces instead.

tension in AB = ... N [3]

2 (a) State the First Law of Thermodynamics.

[The First Law of Thermodynamics states that] the **increase/change** in the internal energy of a system is the sum of the work done **on** the system and the heat supplied **to** the system.

Underlined concepts must be mentioned.

Bolded words should not be confused, e.g. "internal energy" vs "increase in internal energy", "work done on" vs "work done by", "heat supplied to" vs "heat supplied by".

.... [1]

(b) The variation with volume of pressure in the internal combustion engine of a car at maximum power output is shown in Fig. 2.1. The engine goes through 4 distinct stages A to D as shown.

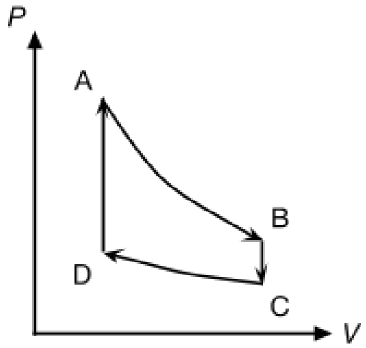


Fig. 2.1

Complete the rest of the table below to show how the First Law of Thermodynamics applies to the gas in the engine between each of the stages. [3]

Process	Δ*U* / J	*Q* / J	*W* / J
A→B	–1640	0	–1640
B→C	–720	–720	0
C→D	760	0	760
D→A	1600	1600	0

Students must demonstrate understanding of:

$\Delta U = Q + W$ [1]

$\Sigma \Delta U = 0$ [1]

$W_{B\rightarrow C}$, $W_{D\rightarrow A} = 0$ [1]

For Examiner's Use

(c) **(i)** Calculate the net work done by the gas per cycle when the engine goes through stages A to D.

Work done on gas = (–1640 + 760) J = –880 J
Work done by gas = 880 J
Must demonstrate understanding of difference between work done on gas and work done by gas, in their use of numbers or in written explanation.
Common misconceptions include taking absolute of W.D., or just removing the sign without explanation.

work done = ... J [1]

(ii) The car, travelling at a velocity of 30 m s^{-1} on a level road, experiences a total resistive force of 1.0 kN. The engine operates at a rate of 50 cycles per second.

1. Calculate the rate of net work done by the engine.

Work done by gas per second
= 880×50 = 44 kJ
Therefore rate of net work done = 44 kW = 4.4×10^4 W [1]

rate of work done = ... W [1]

2. Calculate the coefficient *P*, given by

$$P = \frac{\text{Useful power delivered to car}}{\text{Rate of net work done by engine}}$$

Engine power = 44 kW
at 30 m s^{-1}, useful power (to overcome friction) = Fv = 1000×30 = 30 kW [1]
P = 30/44 = 0.68 (accept 3 s.f.: 0.682) [1]
e.c.f. allowed if value of coefficient is reasonable, i.e. <=1 and positive.

coefficient *P* = ... [2]

3 **(a)** **(i)** Explain what is meant by a *longitudinal* wave.

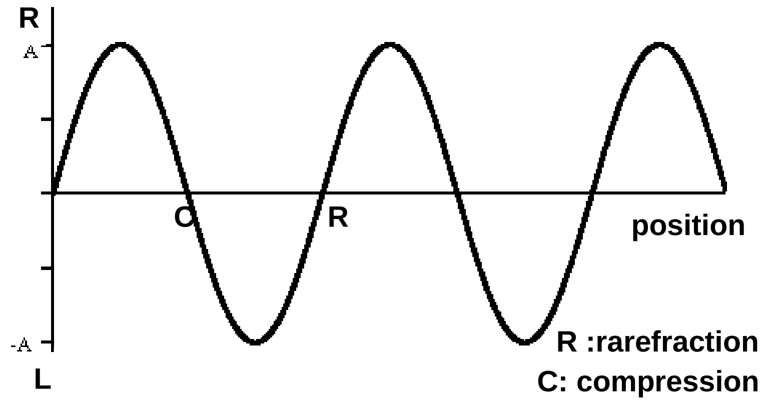
The direction of propagation of the wave is parallel to the direction of vibration of the particles. [1]

....

.... [1]

For Examiner's Use

(ii) With the aid of a diagram, explain the formation of compression and rarefraction points along a longitudinal wave.



Points of compression occur when the particles on both sides of a particle are displaced towards it.
Points of rarefraction occur when the particles on both sides of a particle are displaced away from it. [2]

(b) A constant-frequency siren vibrates with displacement y, where $y = A \sin 200\pi t$.

This sound causes vibrations of the diaphragm of an ear drum in an observer 500 m away. The speed of sound is 335 m s^{-1}.

(i) Calculate the frequency of the sound.

$\omega = 2\pi f = 200\pi$
f = 100 Hz [1]

f = ... Hz [1]

(ii) Show that the phase difference between the motion of the siren and the eardrum is $\pi/2$. [2]

$\lambda = v/f = 335/100 = 3.35$ m [1]
Hence, calculate the phase difference, $\phi = (x/\lambda)\, 2\pi = 149.25 \times 2\pi = 298.5\,\pi = \pi/2$ [1]

(c) **(i)** The siren can be considered as a point source. Fig. 3.1 shows the variation with time of displacement *y* of the siren.

Sketch a graph on Fig. 3.1 to illustrate the variation with time of displacement *y* of the eardrum at a distance of 500 m. [2]

Smaller amplitude, same period [1]
Negative cosine graph [1]

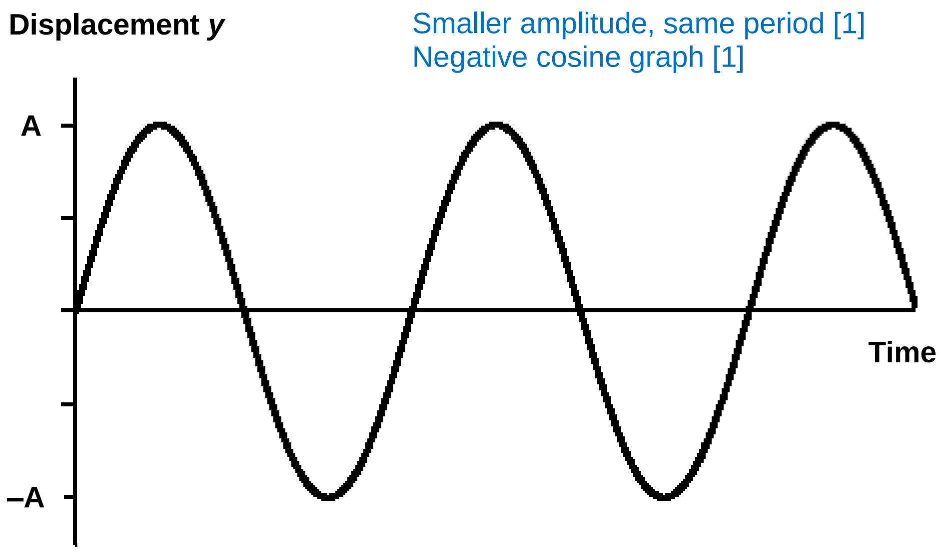
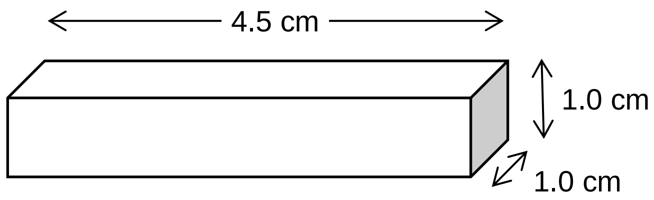


Fig. 3.1

4 A conducting block made of material X has dimensions 1.0 cm × 1.0 cm × 4.5 cm, as shown below.



When a potential difference of 9.0 V is applied across the square faces of the block, the *electrical resistance* of the block is 6.0 Ω.

(a) Define the term *electrical resistance* and the unit *Ω*.

Electrical resistance is the ratio of the potential difference across a conductor to the current in it.
1 Ω is the resistance of a conductor whose ratio of potential difference to current is 1 V to 1 A.

.... [2]

(b) Calculate the electrical resistivity of material X.

$\rho = R\,A / L = 6.0 \times 0.010^2 / 0.045$
$= 1.3\times10^{-2}\ \Omega\ m$

resistivity = ... Ω m [2]

For Examiner's Use

(c) Show that the strength of the electric field between the square faces of the block is 200 N C^{-1}, assuming that it is uniform. [1]

$E = \Delta V / d = 9.0 / 0.045$
$= 200 \text{ N C}^{-1}$

(d) Hence, or otherwise, calculate the work done by the electric field on an electron passing through the block. State clearly whether the work done is positive or negative.

$F = E q = 200 \times 1.6\times10^{-19} = 3.2\times10^{-17}$ N
$W = F s = 3.2\times10^{-17} \times 0.045 = + 1.44\times10^{-18}$ J
or
W = – change in electric PE
$= - q \Delta V = - (-1.6\times10^{-19} \times +9.0) = + 1.44\times10^{-18}$ J

work done = ... J [2]

(e) At steady state, the electrons move through the block with negligible change in their kinetic energies, despite the work done on them as calculated in **(d)**. Suggest why this is so.

The work done by the field was converted into internal energy of the conductor (heat) due to collisions with particles of the conductor.

.... [1]

5 Fig. 5.1 shows a beam of electrons, moving with speed 6.0×10^5 m s^{-1} in the x-direction, passing through a single slit of width 1 nm.

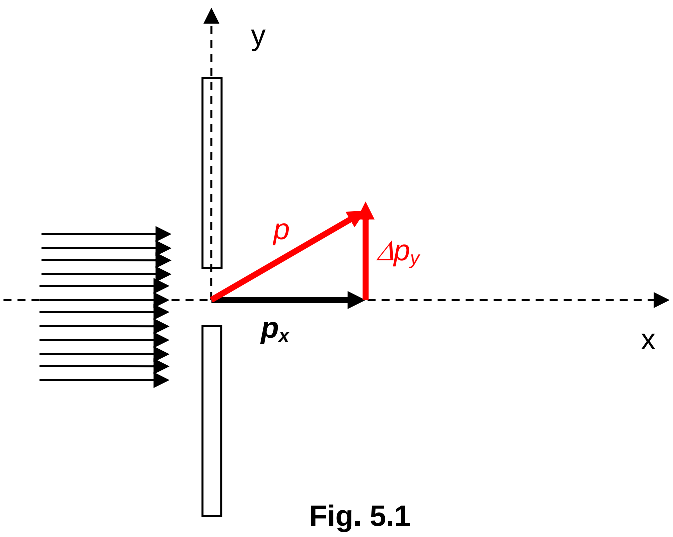


Fig. 5.1

For Examiner's Use

(a) Calculate the momentum of one of these electrons in the x-direction.

$p_x = mv = 9.11 \times 10^{-31} \times 6.0 \times 10^{5} = 5.5 \times 10^{-25}$ kg m s^{-1}

Comment: Very few made mistake in this part.

momentum = ... kg m s^{-1} [1]

(b) Determine the de Broglie wavelength of the electron.

$$\lambda = \frac{h}{p} = \frac{6.63x10^{-34}}{5.5 \text{ x } 10^{-25}} = 1.2x10^{-9} \text{ m}$$

Comment: Some students use tried to use v=fλ, and worst, a few substituted speed of sound into v.

wavelength = ... m [1]

(c) In terms of classical wave theory, explain why the electron diffraction will be prominent in this situation.

The slit width and the wavelength of the electron are in the order (10^{-9} m)

Comment: 1. Some students use 'slit separation' instead of 'slit width'. Separation is the distance between two slits! 2. Many students said from the calculation wavelength $\geq$slit width, therefore it is prominent. Worst, some said therefore diffraction 'will' occur. They thought there is a threshold condition, if the wavelength is smaller than the slit width, the phenomenon will not occur. Bear in mind that the degree of diffraction will just become more and more prominent when the slit is being narrowed down.

[1]

(d) In Fig. 5.1, an electron can go through anywhere within the slit, hence the uncertainty Δy of the y-position can be as big as the width of the slit,

Calculate the uncertainty of the momentum in the y-direction (Δp_y) of one electron that is passing through the slit.

$$\Delta p_y \Delta y \geq \frac{h}{4\pi}$$

$$\Delta p_y (1x10^{-9}) \geq \frac{h}{4\pi}$$

$$\Delta p_y \geq \frac{h}{4\pi(1x10^{-9})}$$

$$\Delta p_y \geq 5x10^{-26} \text{N s}$$

Comment: 1. Very few students forgot the equation.
2. Since it is an uncertainty, 1 sig fig will be sufficient.
3. Question already hinted the change is in the y-direction, still there were quite a few used Δx instead.

uncertainty = ... N s [2]

For Examiner's Use

(e) On Fig. 5.1, add in two more vectors to show the relation between p_x, Δp_y and the resultant momentum p of the electron. [1]

Comment: 1. Many restricted their Δp_y between the slit. Probably they were thinking about Δy. 2. The resultant p drawn mostly does not look like the diagonal of the rectangle formed by Δp_y and p_x.

(f) Fig. 5.2 shows the diffraction pattern on a screen formed by a beam of laser after passing through a small slit. The width of the centre maximum is found to be increasing when the slit width is being reduced. Such a phenomenon in light optics is called single slit diffraction.
Discuss the consistency between the electron diffraction and light diffraction from your

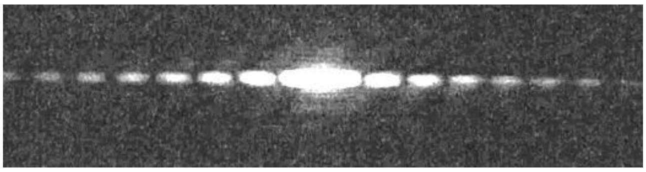


Fig. 5.2

working in **(d)**, **(e)**, and the description in **(f)**.

In (f), the narrower the slit, the greater the diffraction of light. In (d) and (e), the smaller the slit, the smaller is Δy, and by uncertainty principle, the larger is Δp_y. Hence the spread of the electrons will be larger.

Comments: (1) Many tried to explain why the brightness is highest at the center fringe. They said when Δx decreases, Δp_y decreases and more electrons arriving at the center. They obviously did not understand the hint given in the question. [2]

Section B

Answer **two** questions in this section.

For Examiner's Use

6 **(a)** A ball is held between two fixed points A and B by means of two stretched springs as shown in Fig. 6.1.

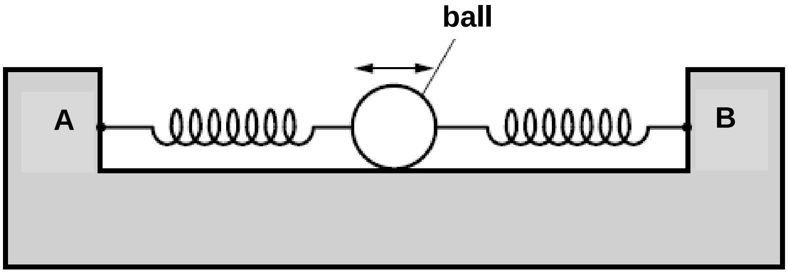


Fig. 6.1

The ball is free to oscillate horizontally along the line AB on the smooth plane.

The variation of the acceleration a of the ball with its displacement x from its equilibrium position is shown in Fig. 6.2.

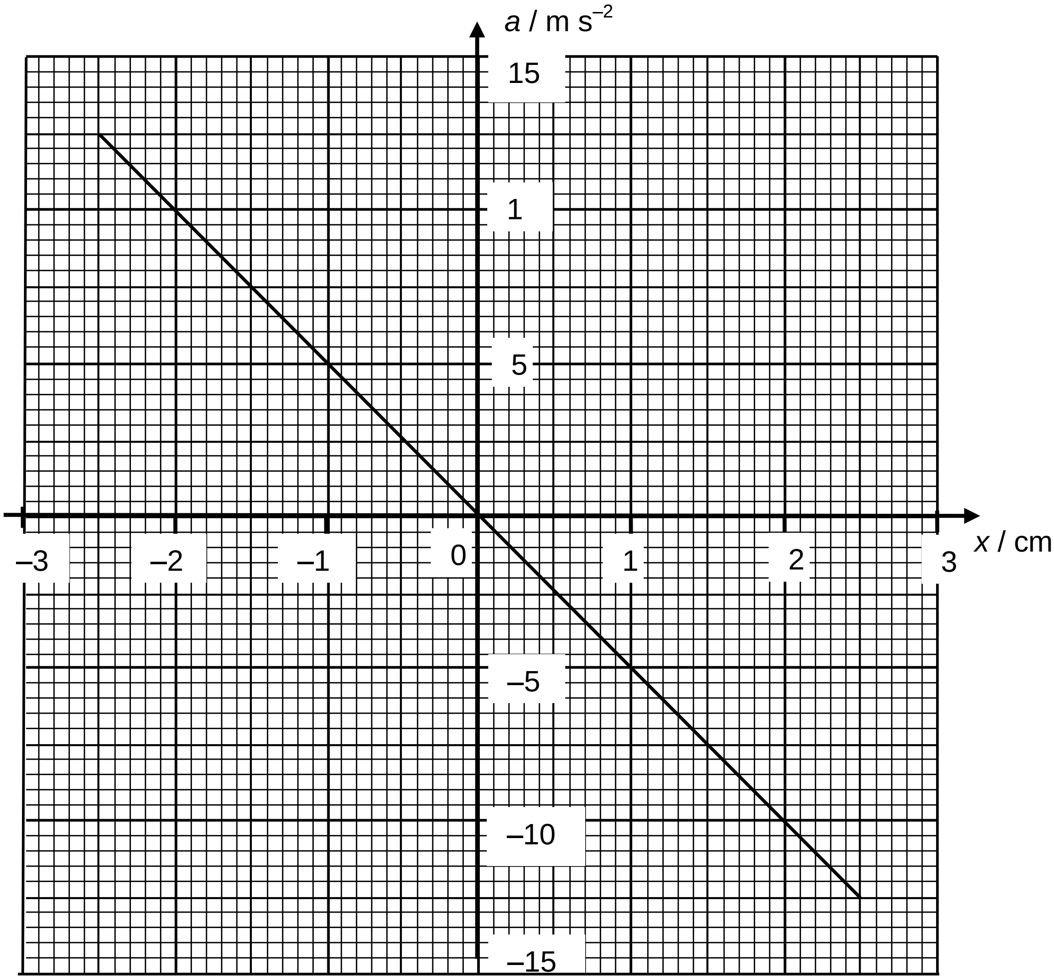


Fig. 6.2

For Examiner's Use

(i) State and explain the features of Fig. 6.2 which indicate that the motion of the ball is simple harmonic.

Feature of the graph are the shape, gradient and any x or y-intercept values.

The graph is a straight line that passes through the origin, this indicates that the acceleration is directly proportional to the displacement, which is a characteristic of simple harmonic motion.

The gradient of the graph is negative, which indicate that the direction of the acceleration and the displacement are in opposing direction or the acceleration is directed to a fixed equilibrium position. [3]

(ii) On Fig. 6.3, sketch the velocity-displacement graph of the simple harmonic motion which was illustrated in Fig. 6.2. [3]

From the graph, x_o = 2.5 cm = 0.025 m.

$a_o = 12.5\ ms^{-2}$, $a_o = w^2 x_o \rightarrow w^2 = 12.5 / 0.025 = 500\ s^{-2}$, $v_o = x_o w = 0.559\ ms^{-1}$

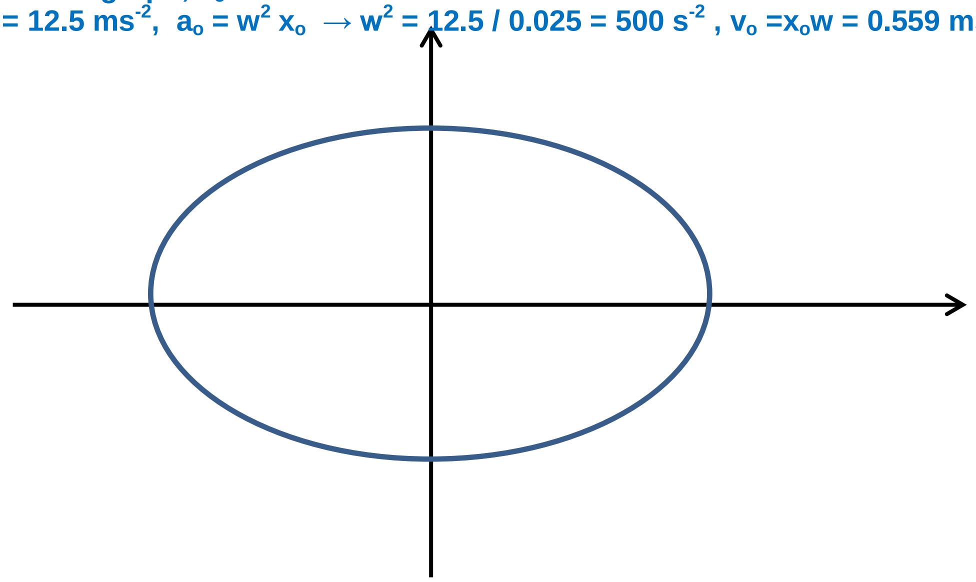


Fig. 6.3

(iii) State an assumption made about the spring for the motion of ball to be in simple harmonic motion, and explain your answer.

The 2 springs must obey Hookes' law and the elastic limit of the springs cannot be exceeded. [1]

Suppose the ball is displaced to the left, the spring at A will compress and exert a force on the ball and this force is proportional to the extension. Since the extension is proportional to the displacement of the ball, the force is therefore proportional to the displacement of the ball. [1]

The spring at B will be extended and exert a force proportional to the displacement of the ball. Since in the horizontal direction, there are only these 2 forces in the absence of friction, the net force acting on the ball is proportional to the displacement and acceleration will be proportional to the acceleration [1] and directed towards the same fixed point, which restore the ball to its equilibrium position. [3]

(b) A student removes the ball and attaches it to the apparatus illustrated in Fig. 6.4 in order to investigate the oscillation vertically.

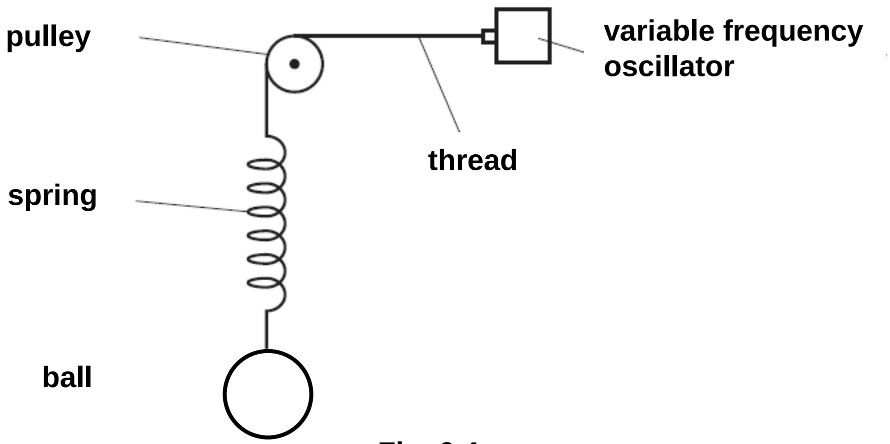


Fig. 6.4

The amplitude of the vibrations produced by the oscillator is constant. The variation with frequency of the amplitude of the oscillations of the ball is shown in Fig. 6.5. The mass of the ball is given to be 150 g, and its oscillations may be assumed to be simple harmonic.

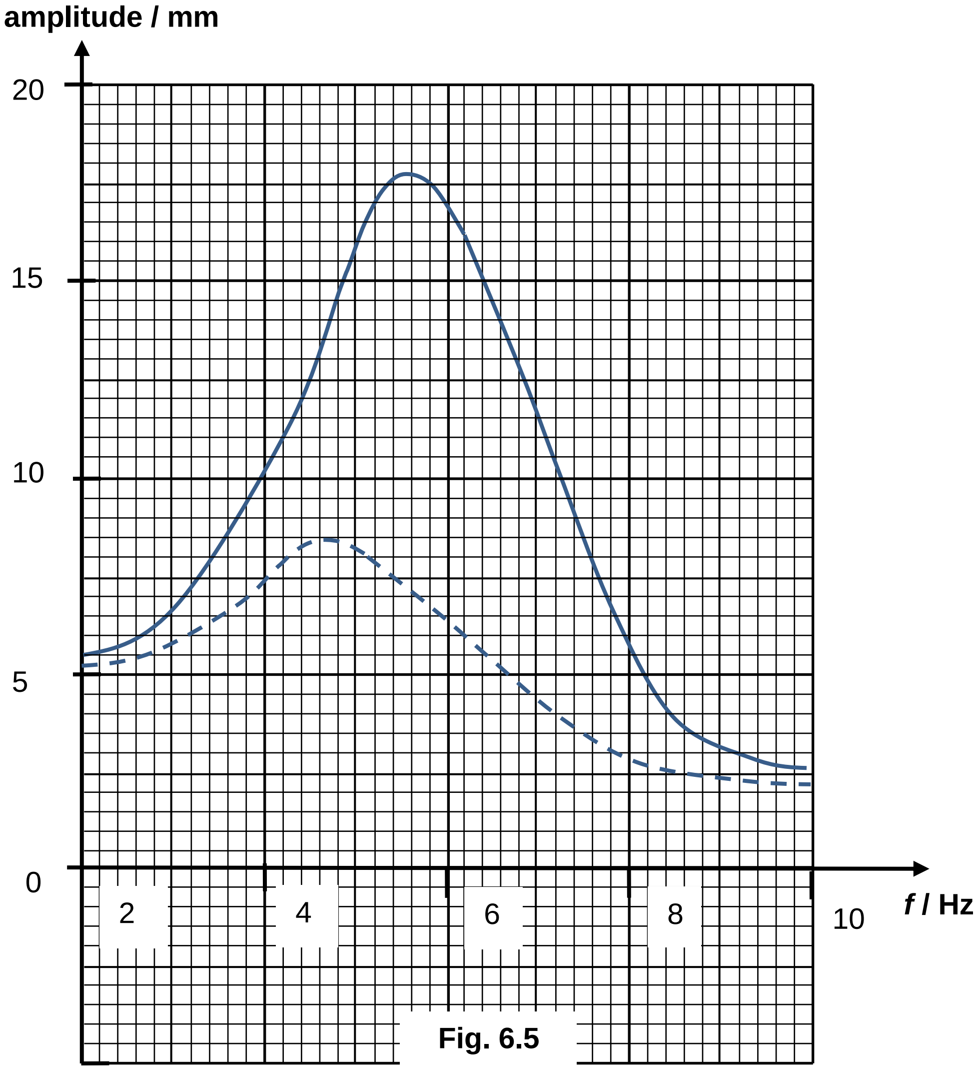


Fig. 6.5

For Examiner's Use

For Examiner's Use

(i) State the phenomenon illustrated in Fig. 6.5.

Resonance

....

.... [1]

(ii) For the maximum amplitude of vibration, state the magnitudes of the amplitude and the frequency.

amplitude = ...17.7.......... mm

frequency = ...5.6.......... Hz [2]

Determine

(iii) the maximum acceleration of the ball.

$$a_o = x_o w^2$$
$$= x_o (2\pi f)^2$$
$$= (0.0177)(4\pi^2)(5.6)^2$$
$$= 21.9 \text{ m s}^{-2}$$

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

(iv) the maximum tension in the spring.

At the maximum tension, the net force on the ball must be maximum.
By N2L, Fnet = mao
Fnet = Tmax -W
Tmax = Fnet + W
= mao + W
= (0.150)(21.9+9.81)
= 4.76 N

tension = ... N [3]

(v) the maximum kinetic energy of the ball.

$$KE = \frac{1}{2} m x_o^2 w^2$$
$$= \frac{1}{2}(0.150)(0.0177)^2(2\pi \text{ x } 5.6)^2$$
$$= 0.0291 \text{ J}$$

You cannot use conservation of energy as there are 2 pe, gpe and epe.

maximum kinetic energy = ... J [1]

Some very light feathers are attached to the surface of the ball so that the feathers extend outwards. The investigation is now repeated.

(vi) On Fig. 6.5, draw a line to show the new variation with frequency of the amplitude of variation for frequencies between 2 Hz and 10 Hz. [2]

7 **(a)** Mobile phones are required to be charged after they have been used for some time. Very often, this involves connecting the mobile phone to a charging device via a wire. This method is called "wired charging".

For Examiner's Use

Recently, a new way of charging called inductive charging (or "wireless charging") is being used. The mobile phone is placed on top of the charging device during charging. A simplified setup is shown in Fig. 7.1.

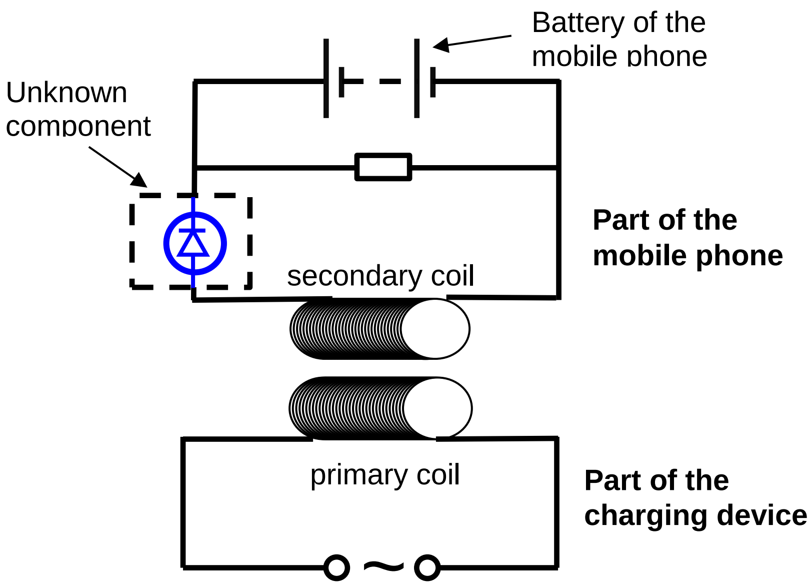


Fig. 7.1

(i) Explain how an e.m.f. can be induced in the secondary coil.

For Examiner's Use

The alternating current flowing in the primary coil produces a changing magnetic field. This changing magnetic field is linked to the secondary coil and there is a changing magnetic flux linkage in the secondary coil. By Faraday's Law, an e.m.f. is induced in the secondary coil.

Examiner's comments:

1. Students need to distinguish clearly the difference between magnetic flux, magnetic flux linkage and magnetic flux density. These terms have different meanings and cannot be used interchangeably.
   - Magnetic flux density is the same as magnetic field strength and is usually represented by the symbol *B*.
   - Magnetic flux is the product of the magnetic flux density normal to the surface $B_{\perp}$ and the area of the surface *A* and is usually represented by the symbol Φ.
   - Magnetic flux linkage is the total flux associated with many turns of wire.
2. Students need to study the question to see which phrase "cutting of magnetic flux" or "change in magnetic flux linkage" should be used. In this question, there is no motion of the secondary coil and so there is no cutting of the magnetic flux. Therefore, "change in magnetic flux linkage" should be used in this situation.
3. Students are reminded to state that the magnetic field produced by the primary coil is linked to the secondary coil. This will establish the fact that there is a magnetic flux linkage in the secondary coil.
4. It is incorrect to state "since there is a changing magnetic flux linkage in the primary coil, an e.m.f. will be induced in the secondary coil". The e.m.f. is induced in the secondary coil because there is a changing magnetic flux linkage in the secondary coil.

(ii) The charging device is connected to a 240 V power source. The number of turns in the primary coil is 100. If the number of turns in the secondary coil is 5, calculate the e.m.f. induced in the secondary coil.

Assume that the transformer is ideal.

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

$$V_s = \frac{5}{100} \times 240$$

$$= 12 \text{ V}$$

Examiner's comments:
Most students are able to do this part (except for a few due to careless mistake).

e.m.f. induced in secondary coil = **..............................** V [1]

(iii) In order to charge the mobile phone, several conditions need to be met. Some of the conditions are:

1. The e.m.f. induced in the secondary coil must be larger than 9 V.

2. Mobile phones can only be charged using direct current.

3. The current through the battery of the mobile phone must be in the direction shown in Fig. 7.2.

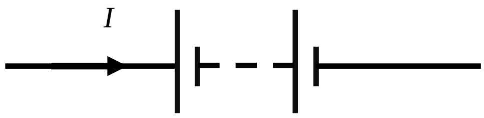


Fig. 7.2

Draw an appropriate component in the dotted box in Fig. 7.1 which satisfies the above conditions. [2]

Examiner's comments:
Students are reminded that they must know how to draw the circuit symbols that are shown in the last pages of the D.C. Circuit lecture notes. Many students drew the circuit symbol incorrectly.
Students are also reminded to follow the given instructions and not answer the question according to personal convenience.

(iv) Describe and explain one possible disadvantage of inductive charging over wired charging.

1. Lower efficiency for inductive charging due to flux in the primary coil not 100% linked to the secondary coil while there is no similar type of problem for wired charging.
2. The maximum distance the mobile phone can be placed away from the charging device for inductive charging is fixed and cannot be changed while the maximum distance for wired charging depends on the length of the cable which can be changed.
3. Any other reasonable answer.

Examiner's comments:
Students are reminded to know the material well before writing it down as an answer. Eddy currents and hysteresis loss are unacceptable since there is no soft iron core. Students stating about power loss must state clearly the origin of the power loss in order to get the marks as there is also power loss in wired charging.

(b) A bar magnet is removed from the centre of a coil in the direction shown in Fig. 7.3.

For Examiner's Use

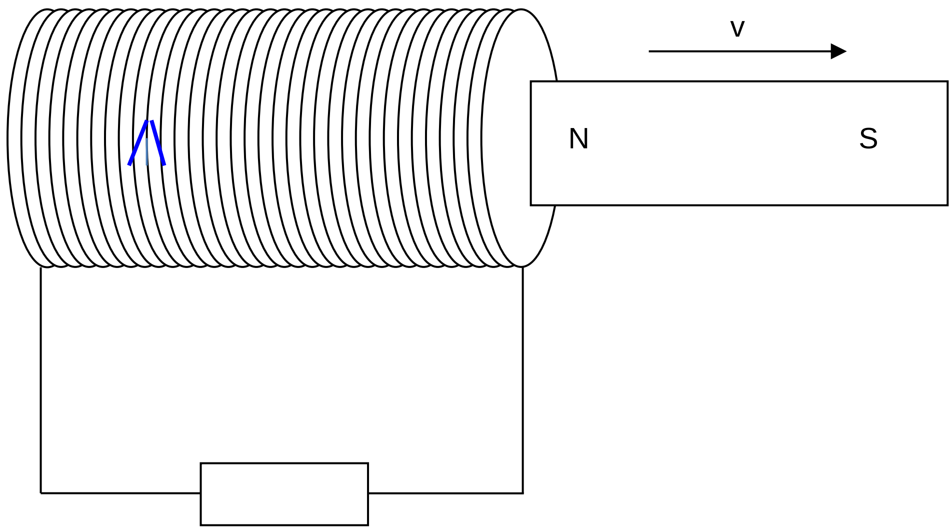


Fig. 7.3

Draw an arrow on the coil in Fig. 7.3 to show the direction of the current. [1]

Examiner's comments:
Students who do not score this mark are reminded that Lenz's Law opposes the **change** in magnetic flux linkage of the conductor. Determine whether the change is an increase or decrease as well as the direction of the change. Then apply Lenz's Law to determine the direction of the induced e.m.f.

(c) In Fig. 7.4, a circular loop of flexible wire is placed perpendicularly to a magnetic field between the poles of an electromagnet. A resistor is connected to the ends of the coil.

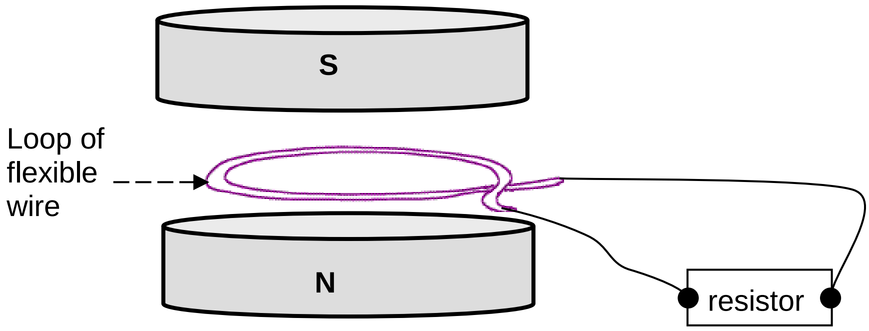


Fig. 7.4

Fig. 7.5 shows how the magnetic flux density *B* varies with time *t*.

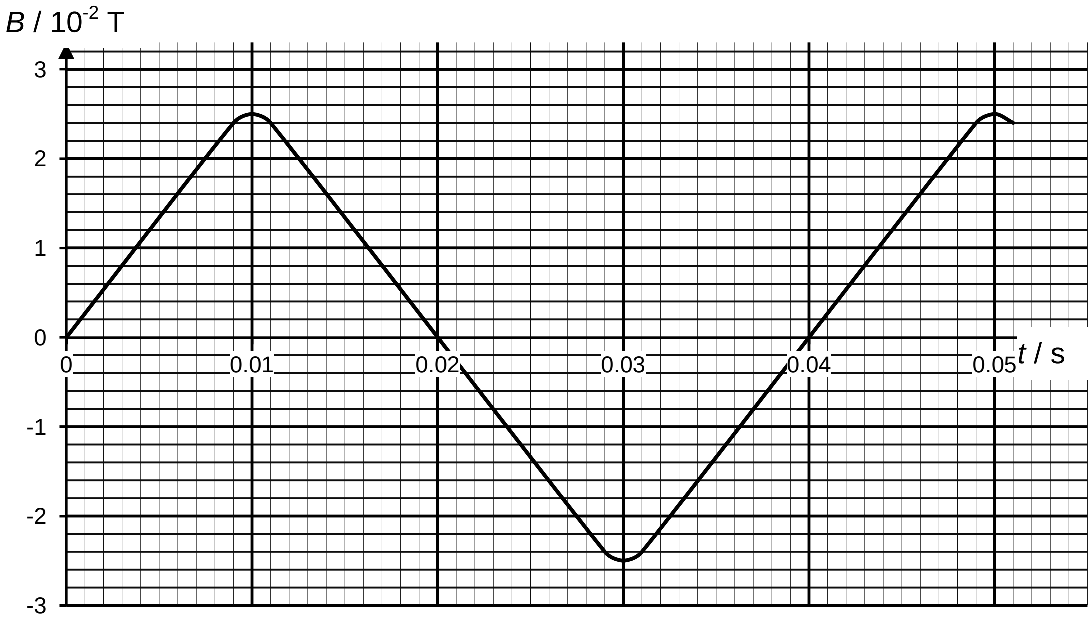


Fig. 7.5

(i) Using Fig. 7.5, calculate the maximum e.m.f. induced in the loop when its area is 120 cm^2.

Considering the magnitude of the induced e.m.f.,

$$\varepsilon = N\frac{d(BA)}{dt}$$

$$= NA\frac{dB}{dt}$$

From Fig. 7.4,

$$\frac{dB}{dt} = \frac{2.4-(-2.4)}{0.0490-0.0310}$$

$$\varepsilon = 1\times 120\times 10^{-4}\times \frac{2.4\times 10^{-2}-(-2.4\times 10^{-2})}{0.0490-0.0310}$$

$= 3.2\times 10^{-2}$ V   maximum e.m.f. induced = ... V [3]

–1 mark for not reading to ½ of the smallest division.

<u>Examiner's comments:</u>

1. Students are reminded to examine the graph carefully. You are to calculate the maximum e.m.f. which means that you should be looking for the maximum gradient. The maximum gradient occurs when the graph is a straight line so the maximum and minimum points of the graph should be avoided since the gradient at those points are less than the maximum gradient.
2. When obtaining values from graphs, you should always read to 0.5 of the smallest division. In this graph, y values should be given to 1 d.p while x values should be given to 4 d.p.

For Examiner's Use

(ii) The loop is observed to repeatedly expand and contract. Give an explanation of this phenomenon.

Since there is a closed circuit, a current flows through the loop. This will induce a magnetic force that acts along the radius of the loop since the loop is in a magnetic field. The induced e.m.f. in the loop will change direction due to the alternating nature of the magnetic field. This will cause the direction of the current to change, leading to a magnetic force which changes its radial direction. This causes the expansion and contraction of the loop.

OR

Lenz's Law states that the direction of the e.m.f. is such that it will oppose the change in magnetic flux linkage in the loop. When the magnetic flux density increases, the area of the loop will decrease such that there is no change in the magnetic flux linkage in the loop. When the magnetic flux density decreases, the area of the loop will increase to keep the magnetic flux linkage constant.

[4]

Examiner's comments:

1. Students are reminded to study the question carefully (both the words as well as the diagrams) and think about the things that have been taught. It can be seen from the given answers that many do not know what is going on and just depend on primary school knowledge (ex. the loop expands because of heat generated in the loop) for an easy way out.
2. Since this is a 4 mark question, details are expected from students but many gave very general answers. Students who gave general answers are advised to look for their tutors.

(iii) The total resistance of the circuit is 5.0 Ω. Calculate the maximum rate of flow of electrons in the coil.

$$I = \frac{\varepsilon}{R}$$

$$\frac{ne}{t} = \frac{\varepsilon}{R}$$

$$\frac{n}{t} = \frac{\varepsilon}{eR}$$

$$= \frac{3.2 \times 10^{-2}}{1.60 \times 10^{-19} \times 5.0}$$

$$= 4.0 \times 10^{16} \text{ s}^{-1}$$

Examiner's comments:
Most students are able to do this part.

maximum rate of flow of electrons = ... s^{-1} [3]

For Examiner's Use

8 **(a)** **(i)** Explain what is meant by the binding energy of a nucleus.

It is defined as the energy needed just to separate completely the individual nucleons in the nucleus.

.... [1]

The variation of the binding energy per nucleon with nucleon number of all the different nuclei is shown in Fig. 8.1.

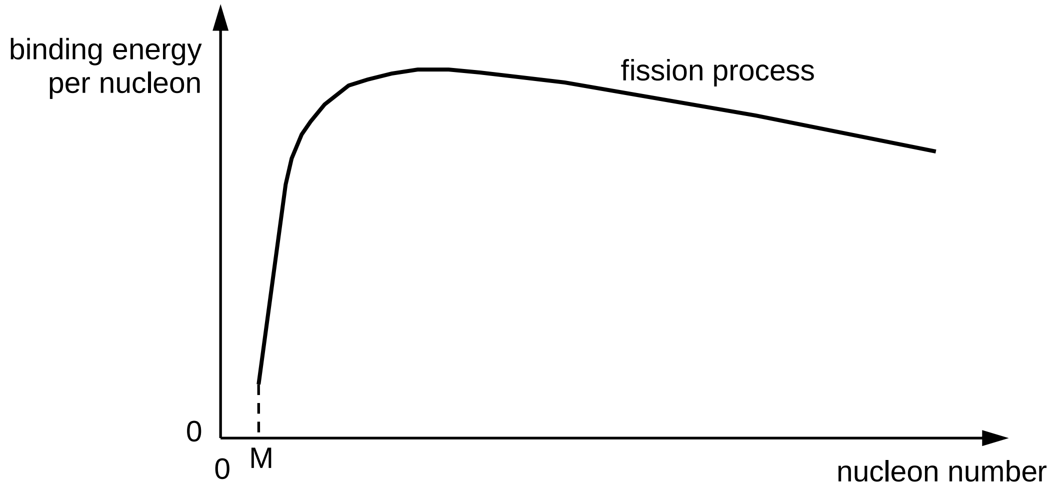


Fig. 8.1

(ii) State the value of M and explain your answer clearly.

value of M = ...**2**..........

Explanation: ....

If the nucleon number is only 1, it cannot be separated further. Hence the minimum number of nucleon needed to form a nucleus is 2.

.... [2]

Examiner's comments:
There is significant number of candidates who managed to correctly state the value of M and some good explanation given. But there are still a number of candidates who show a lack of understanding of binding energy despite able to answer (a)(I).

For Examiner's Use

(b) In a fission process, a neutron with speed of 2000 m s^{-1} collides with a Uranium-235 nucleus and causes a nuclear reaction summarised in the following equation.

$$^{1}_{0}\mathrm{n} + {}^{235}_{92}\mathrm{U} \rightarrow {}^{236}_{92}\mathrm{U} \rightarrow {}^{143}_{54}\mathrm{Xe} + {}^{90}_{38}\mathrm{Sr} + 3\,{}^{1}_{0}\mathrm{n} + \text{energy}$$

(i) Using the data from Table 8.2, show that the binding energy per nucleon for Strontium-90 is 8.73 MeV.

	Rest mass / u
Strontium, $^{90}_{38}\mathrm{Sr}$	89.9077 u
Proton, $^{1}_{1}\mathrm{p}$	1.0078 u
Neutron, $^{1}_{0}\mathrm{n}$	1.0087 u

Table 8.2

Mass defect = (_m_p + _m_n) – $m_{nucleus}$
= (38)(1.0078u) + (90-38)(1.0087u) – 89.9077 u = 0.8411 u.
BE = mass defect x c^2 = (0.8411 x 1.66 x10^{-27})(3.0 x 10^{8})^{2}(1/1.60 x 10^{-19}) eV
= 785 MeV
Hence BE per nucleon = BE/n = 8.73 MeV

[2]

Examiner's comments:
Candidates should note that they have to show detail explanation since the final value of binding energy per nucleon is already given. Any vague working will not be given full credit.

(ii) Hence calculate the total energy released during the nuclear fission reaction.

Data for binding energies per nucleon are shown in Table 8.3.

Isotope	*Binding energy per nucleon/MeV*
Uranium-235	7.59
Xenon-143	8.41

Table 8.3

Energy released = (total B.E.)$_{products}$ - (total B.E.)$_{reactants}$
= [(90)(8.73) +(143)(8.41) – (235)(7.59)] x 1.6 x 10^{-13} J
= 3.27 x 10^{-11} J

Examiner's comments:
Quite a number of candidates did not show sufficient working but overall most candidates are able to correctly calculate the energy released.

energy released = ... J [2]

Energy released = (total B.E.)$_{products}$ - (total B.E.)$_{reactants}$
= [(90)(8.73) +(143)(8.41) – (235)(7.59)] x 1.6 x 10^{-13} J
= 3.27 x 10^{-11} J

For Examiner's Use

(iii) Explain quantitatively why the kinetic energy of the neutron directed at U-235 is neglected.

KE of neutron = $(1/2mv^2) = (1/2)(1.67 \times 10^{-27})(2000)^2$
$= 3.3 \times 10^{-21}$ J

Since KE of neutron << energy released, it is neglected.

Examiner's comments:
This part was not well done by majority of candidates as they did not understand the concept of that small is relative and not absolute. Hence they need to make a comparison to justify the kinetic energy of neutron is small.

.... [1]

(iv) Give a reason why the total kinetic energy of the fission products and neutrons is less than the value calculated in **(b)(ii)**.

....

Part of the energy released can be as photon emitted due to gamma radiation.

Examiner's comments:
A significant number of candidates are able to correct explain this part but it is still disappointing as this section is covered in the tutorial and lecture a number of times. The students should realized that the tutorial is still the most important document for their learning.

For Examiner's Use

(c) Fig. 8.4 shows the possible directions of Sr-90, Xe-143, and neutrons when nuclear fission takes place. Assume that this is an isolated system.

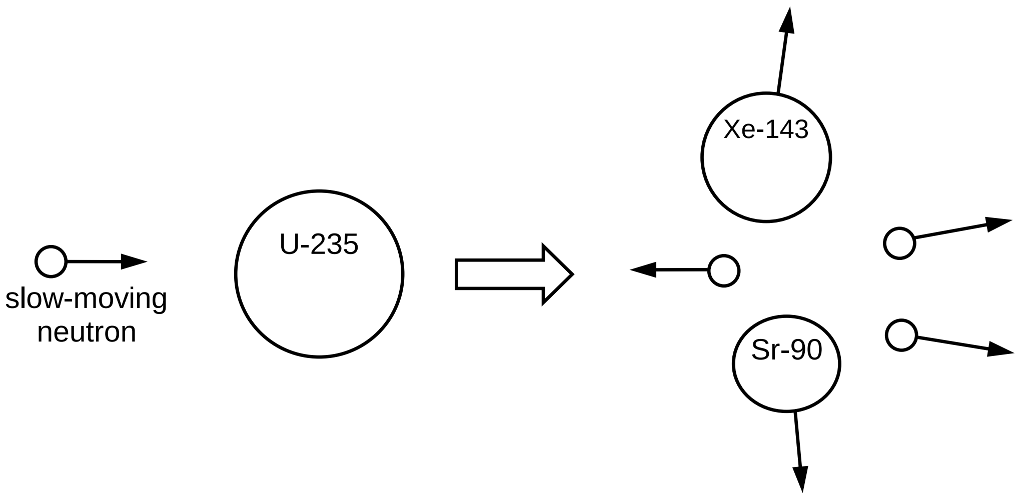


Fig. 8.4

(i) Explain why it is unlikely for the two fission products to move in the same direction after the fission process.

Assuming the initial momentum of the products to be zero, by conservation of momentum the total momentum of the products should be zero. Since the two fission products are relatively more massive than the neutrons, the final momentum will be more difficult to be zero if they move in the same direction.

Examiner's comments:
Overall very few candidates managed to give a good explanation. Quite a number feel that that the two fission products must move in opposite direction. This is incorrect as the neutrons have to be taken in consideration.

(ii) Explain why the total momentum of two fission products and neutrons after reaction is not zero even though the total momentum of U-235 and slow moving neutron may be taken to be zero.

momentum of photon may need to be taken into consideration since here is a emission of gamma photon. The photon will move off in a direction such that the vector sum of the total final momentum will be zero.

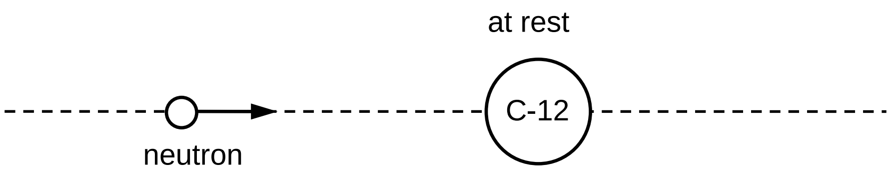
.... [2]

Examiner's comments:
The number of candidates who correctly answer this part is disappointing as this section is covered in the tutorial and lecture a number of times.

For Examiner's Use

(d) Neutrons emitted from a nuclear fission may hit another U-235 nucleus, causing a chain reaction.

(i) To control the reaction, neutrons emitted from a fission reaction may be slowed down by Carbon-12 nuclei, ${}^{12}_{6}C$. Show that when a neutron collides head-on with a Carbon-12 nucleus as shown, the speed is reduced by about 15%.



$\Sigma p_{inital} = \Sigma p_{final}$
$(m)(u) = m(v^1) + (12m)(v_2)$

apply relative speed equation
$v_2 - v_1 = u$

Solving
$v_1 = 0.85\ u$

[3]

(ii) On average, the neutron speed after each collision is 0.93 of its speed before the collision.

Suggest why this speed reduction is different from what is stated in **(ii)** for a nuclear reactor.

The collision is unlikely to be always a head on and hence the component of velocity along a particular direction will be reduced. Hence the speed reduction will be lesser.

.... [1]

Examiner's comments:
Only a few candidates are able to deduce that the reason for lesser speed reduction is most collision is unlikely to be head-on.

For Examiner's Use

(iii) Suggest why a slow neutron has a higher chance of being captured by U-235 to cause a fission reaction compared to a fast neutron.

Slow neutons can remains at a position relatively longer than a faster neutrons. Hence the chance of encountering a U-235 is much higher.

.... [1]

Examiner's comments:
Only a few candidates are able to correctly answer this part.

(e) The fission products are usually radioactive and give rise to a series of radioactive decay products. Each decay product has its own half life, but eventually a stable nuclide is reached.

One such fission product with its decay products and half life is shown below.

$$^{143}_{54}\text{Xe} \xrightarrow[0.511\text{ s}]{} {}^{143}_{55}\text{Cs} \xrightarrow[1.79\text{ s}]{} {}^{143}_{56}\text{Ba}$$

(i) Suggest how the number of Cs-143 nuclei inside the nuclear reactor may remain constant even when it decays to form Ba-143.

It may remains constant if the rate of decay of Xe can be equal to the rate of decay of Cs.

.... [1]

(ii) Explain why the Xenon-143 produced in the later part of the chain reaction may not necessarily decay at a later time than those produced in the earlier part of the chain reaction.

Due to the random nature of radioactivity decay, the time of decay of a nucleus cannot be predicted/fluctuate. Hence there is possibility that Xenon produced at a later time may decay

.... [2]

Examiner's comments:
A good number of candidates are able to give good explanation for this part.