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 **29** 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} F m^{-1}
			$(1/(36\pi)) \times 10^{-9}$ F m^{-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	=	$v_0 \cos \omega t$
		=	$\pm\omega\sqrt{(x_o^2 - x^2)}$
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, $x = x_0$ xo exp (−(−λt))

decay constant $\lambda = \dfrac{0.693}{t_{\frac{1}{2}}}$

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~~$v^2 = u^2 + 2as$~~

~~work done on/by a gas,~~ ~~$W = p\Delta V$~~

~~hydrostatic pressure,~~ ~~$p = \rho gh$~~

~~gravitational potential,~~ ~~$\phi = -Gm/r$~~

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

~~velocity of particle in s.h.m.~~ ~~$v = v_o \cos \omega t$~~

~~$= \pm\omega\sqrt{(x_o^2 - x^2)}$~~

~~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,~~ ~~$V = Q / 4\pi\varepsilon_o r$~~

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

~~transmission coefficient,~~ ~~$T \propto \exp(-2kd)$~~

~~where $k = \sqrt{\dfrac{8\pi^2 m(U-E)}{h^2}}$~~

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

~~decay constant~~ ~~$\lambda = \dfrac{0.693}{t_{\frac{1}{2}}}$~~

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}.

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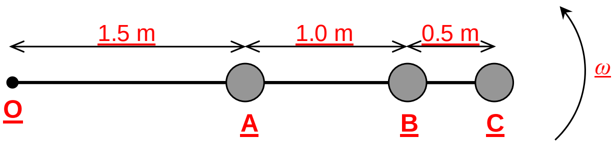

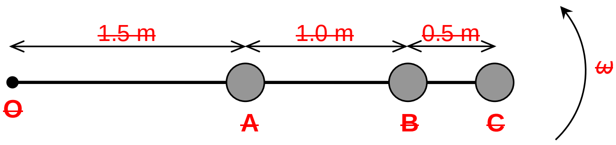

Fig. 1.1: Top View

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Calculate

(a) the angular velocity ω of C.

ω = ... rad s^{-1} [1]

(b) the tangential speed of ball B.

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

(c) the tensions in

(i) string BC and

tension in BC = ... N [2]

(ii) string AB.

For Examiner's Use

tension in AB = ... N [3]

2 (a) State the First Law of Thermodynamics.

[The First Law of Thermodynamics states that] the **increase** 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.

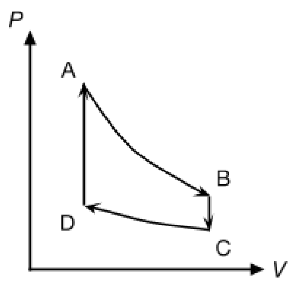

Fig. 2.1 *2.1* Changes of state in an internal combustion engine

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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		0	
B→C	–720		
C→D	760	0	
D→A	1600	1600	

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 = ... 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.

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

2. Calculate the coefficient *P*, given by

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

coefficient *P* = ... [2]

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

....

....

.... [1]

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

For Examiner's Use

....

....

.... [2]

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

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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.

f = ... Hz [1]

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

For Examiner's Use

(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]

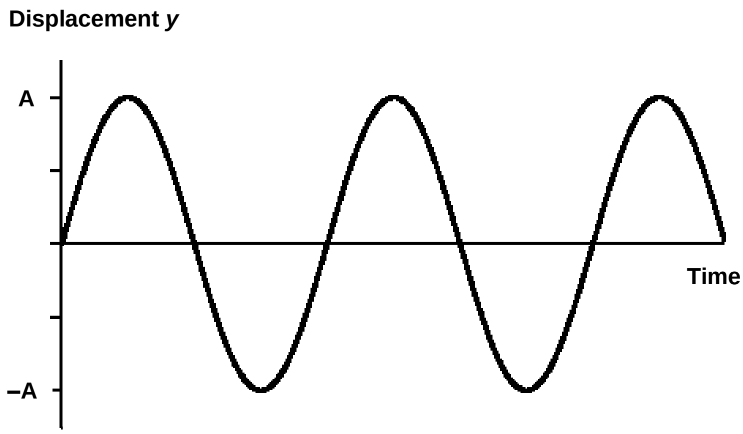
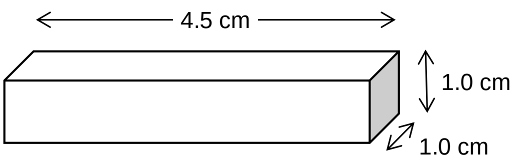


Fig.~~Figure~~ **3.1**

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*.

....

....

.... [2]

(b) Calculate the electrical resistivity of material X.

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]

(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.

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.

....

.... [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.

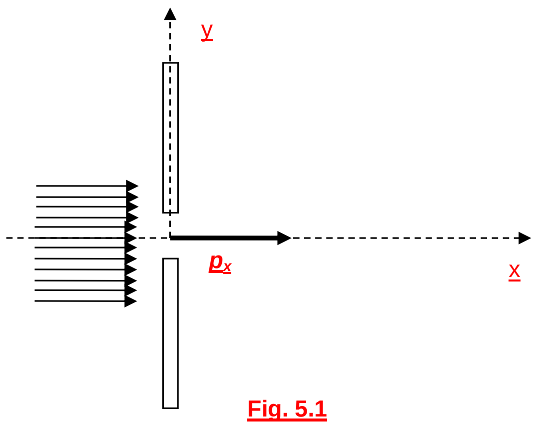


Fig. 5.1

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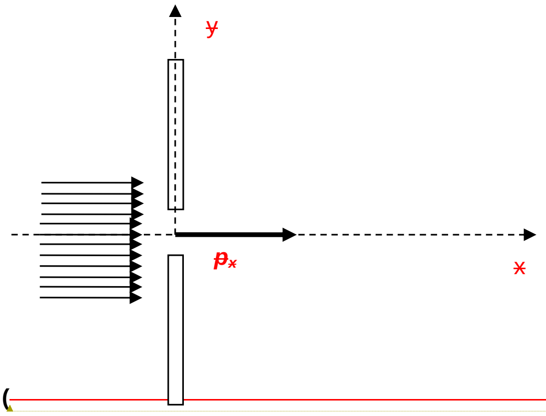

~~Fig. 5.1~~

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For Examiner's Use

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

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

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

wavelength = ... m [1]

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

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…………………………………………………………………………………………… [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.

For Examiner's Use

uncertainty = ... N s [2]

(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]

For Examiner's Use

(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.

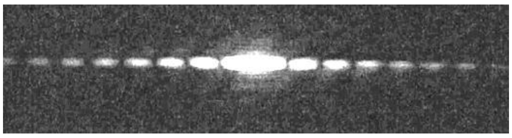

Fig. 5.2

Discuss the consistency between the electron diffraction and light diffraction from your working in **(d)**, **(e)**, and the description in **(f)**.

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…………………………………………………………………………………………………… [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.

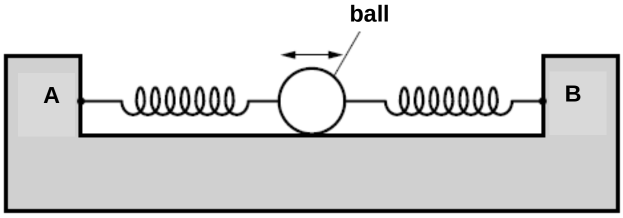

Fig. 6.1

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.

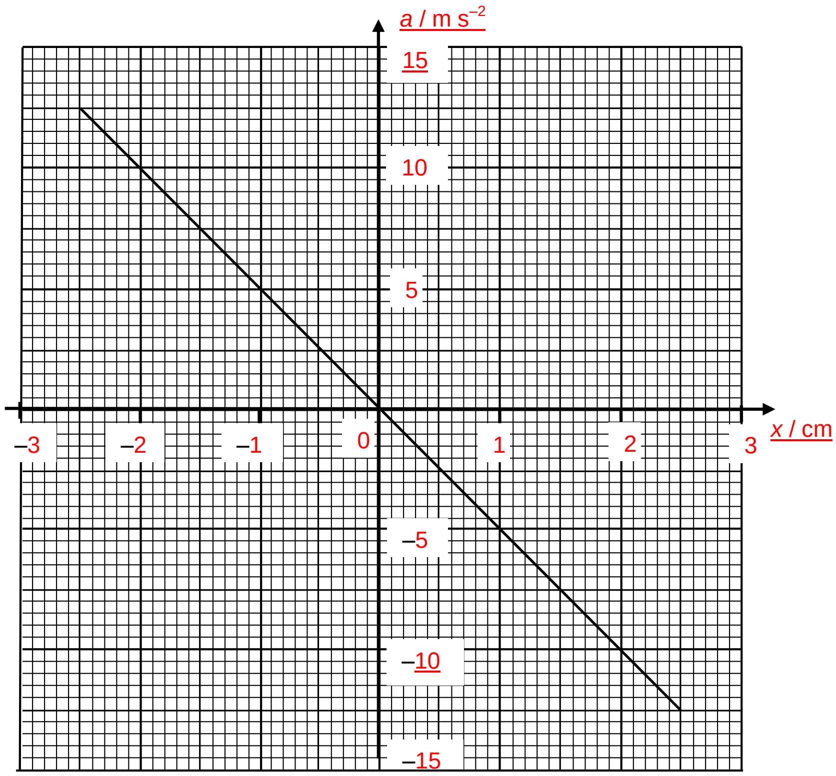

Fig. 6.2

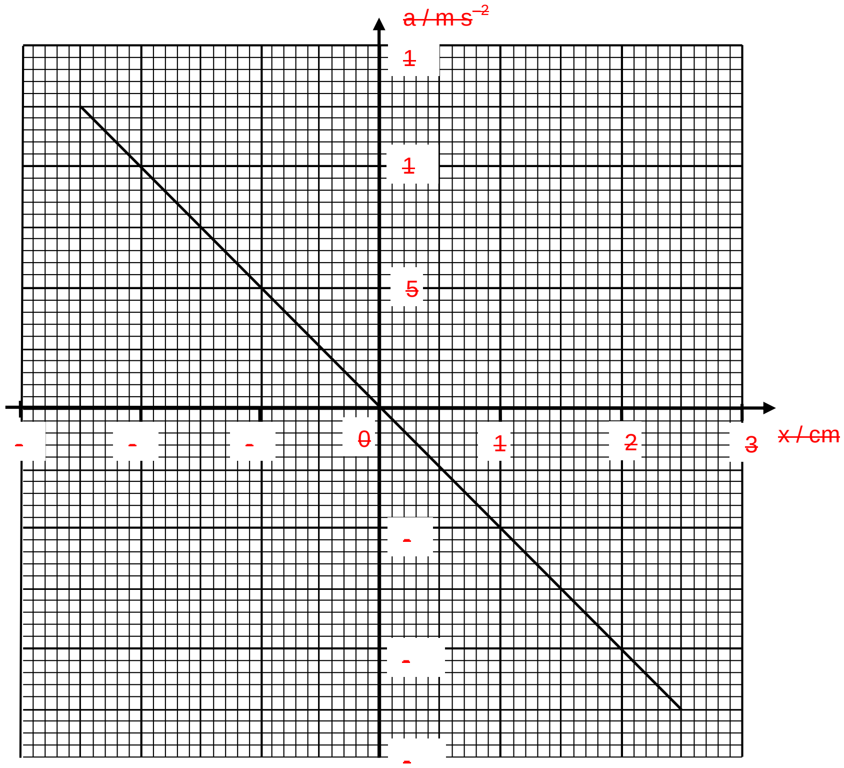

Fig. 6.2

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.

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

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

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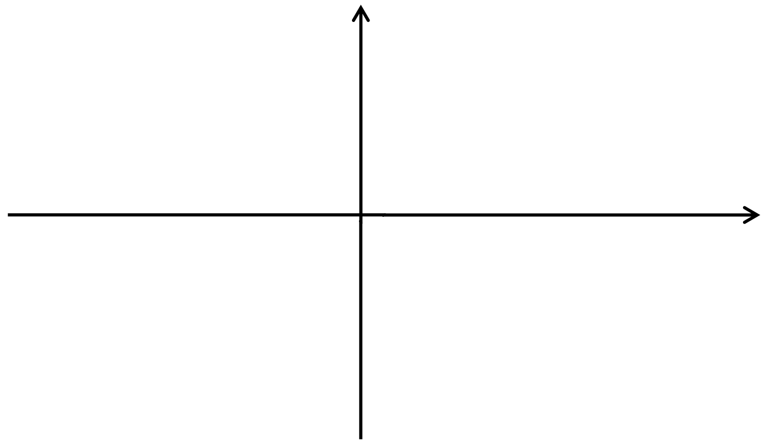

Fig. 6.3

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

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

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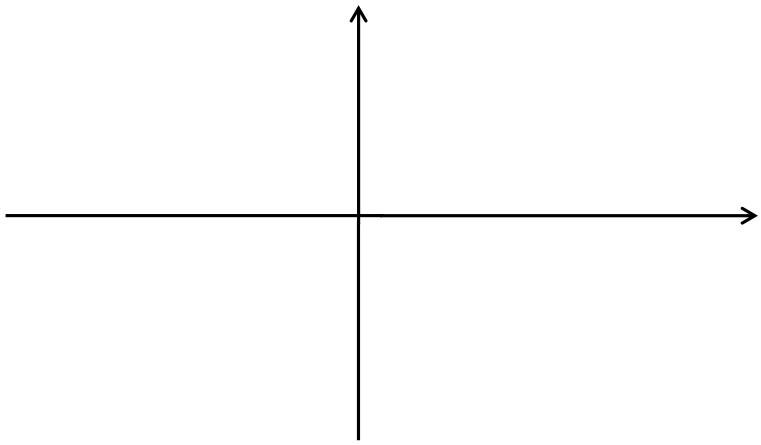


Fig. 6.3

(

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

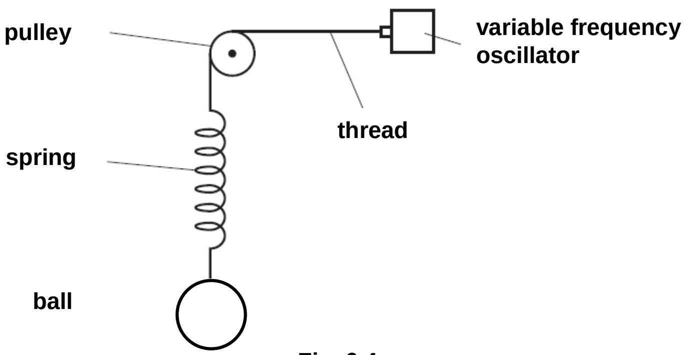


Fig. 6.4

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.

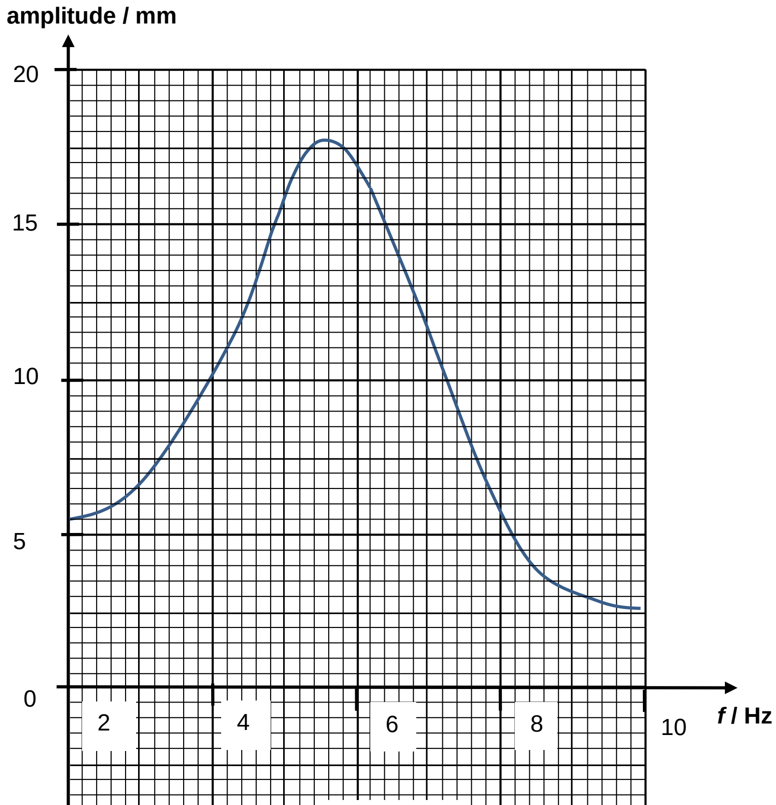


Fig. 6.5

For Examiner's Use

For Examiner's Use

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

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

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

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

amplitude = ... mm

frequency = ... Hz [2]

Determine

(iii) the maximum acceleration of the ball.

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

(iv) the maximum tension in the spring.

tension = ... N [3]

(v) the maximum kinetic energy of the ball.

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]

For Examiner's Use

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".

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.

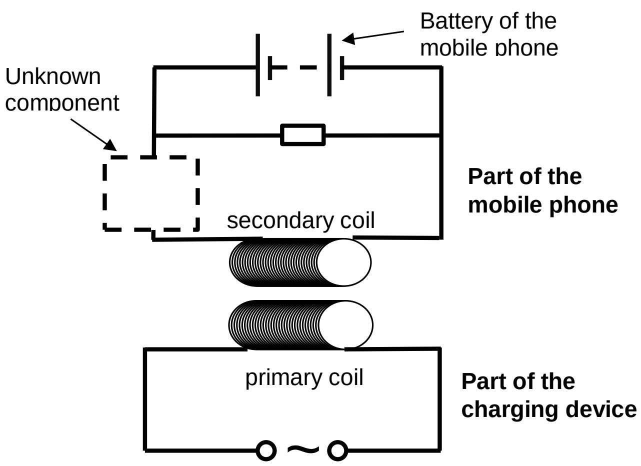
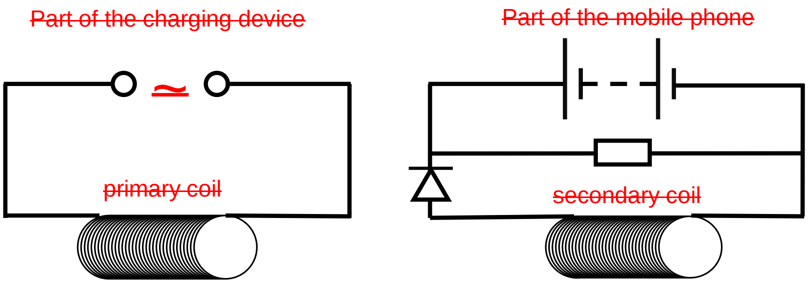


Fig. 7.1



~~Fig. 7.1~~

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

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…………………………………………………………………………………………… [4]

For Examiner's Use

(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.

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.

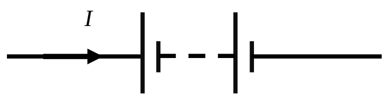

Fig. 7.2

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

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

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

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

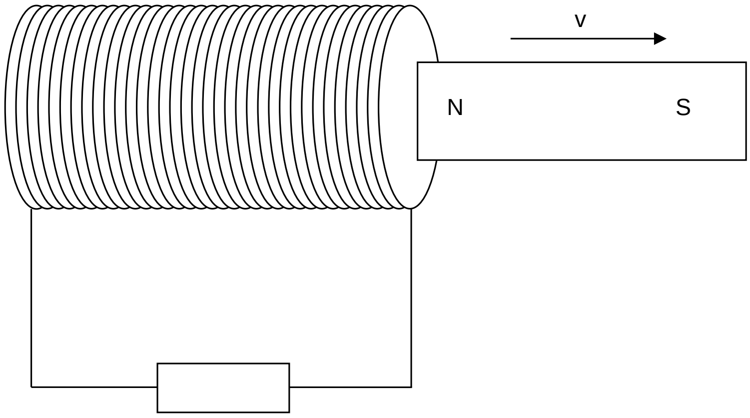

Fig. 7.3

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

(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.

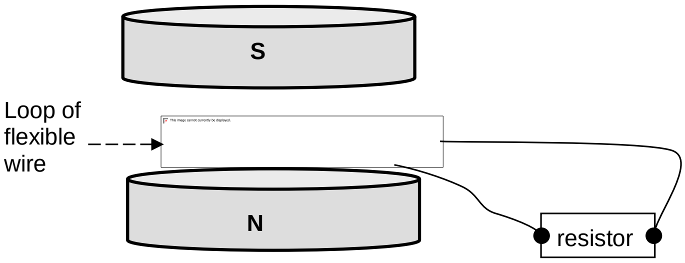

Fig. 7.4

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

For Examiner's Use

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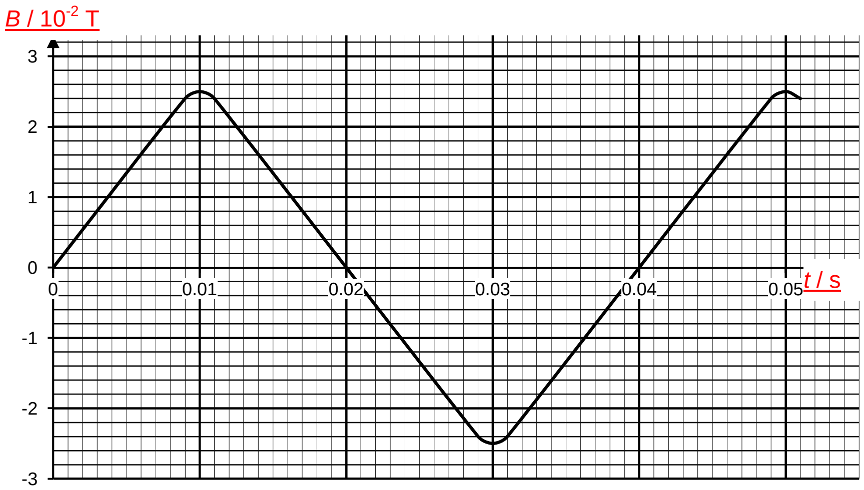

Fig. 7.5

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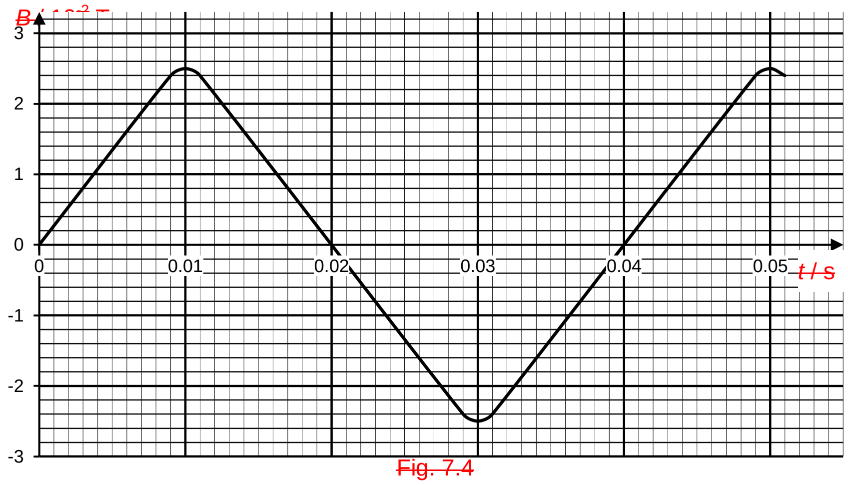

~~Fig. 7.4~~

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

maximum e.m.f. induced = ... V [3]

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For Examiner's Use

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

....

....

....

....

....

.... [4]

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

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

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

....

.... [1]

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

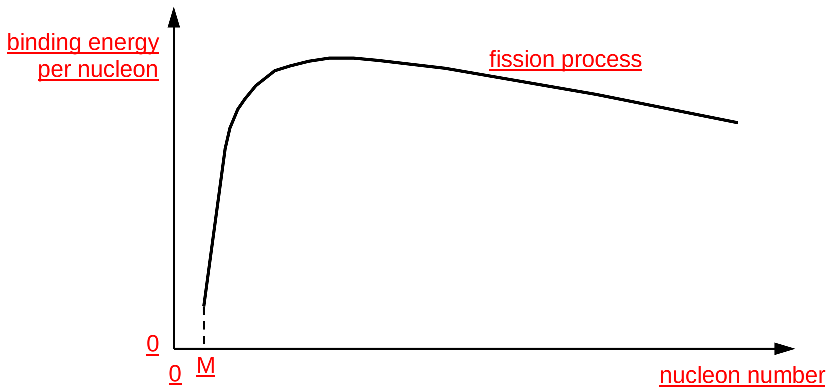

Fig. 8.1

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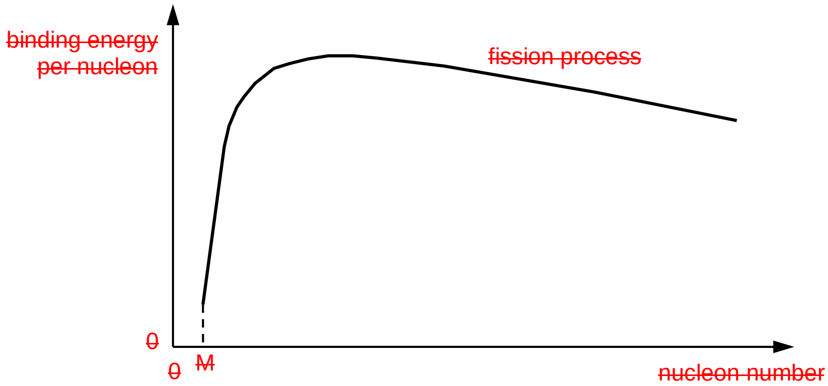

Fig. 8.1

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

value of M = ...

Explanation: ....

....

.... [2]

(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.

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

(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, ${}^{90}_{38}Sr$	89.9077 u
Proton, ${}^{1}_{1}p$	1.0078 u
Neutron, ${}^{1}_{0}n$	1.0087 u

Table 8.2

[2]

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

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

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

Table 8.3

energy released = ... J [2]

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

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

……………………………………………………………………………………………... [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)**.

…………………………………………………………………………………………….

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

(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.

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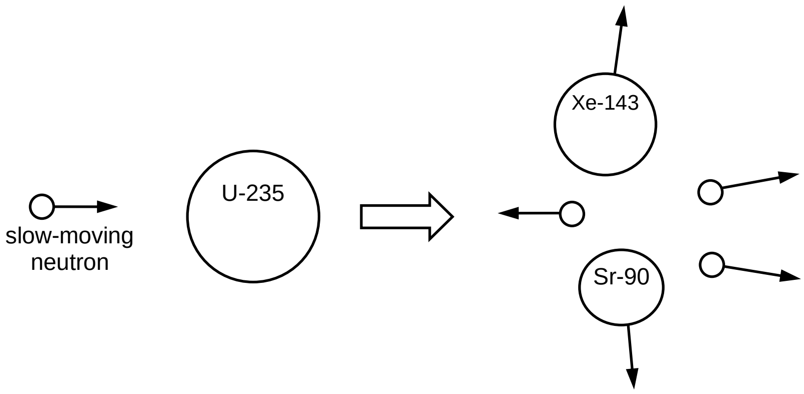

Fig. 8.4

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

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(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.

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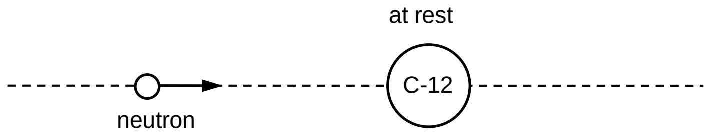
(d) Neutrons emitted from a nuclear fission may hit another U-235 nucleus, causing a chain reaction.

(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%.



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[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.

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(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.

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(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.

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(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.

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