Anglo-Chinese Junior College

Physics Preliminary Examination
Higher 2

A Methodist Institution
(Founded 1886)

CANDIDATE NAME		CLASS	

CENTRE NUMBER	S	3	0	0	4	INDEX NUMBER					

PHYSICS **9646/03**

Paper 3 Longer Structured Questions

17 Sept 2014

2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your Name and Index number in the spaces on all the work you hand in.
Write in dark blue or black pen.
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.

You are advised to spend about one hour on each section

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 Examiners' use only	
Section A	
1	/ 7
2	/ 7
3	/ 7
4	/ 7
5	/ 7
6	/ 5
Section B	
7	/ 20
8	/ 20
9	/ 20
Total	/ 80

For Examiner's Use

DATA AND FORMULAE

Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	=	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	=	$\rho g h$
gravitational potential,	ϕ	=	$-\dfrac{Gm}{r}$
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	=	$\dfrac{3}{2}kT$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$\dfrac{Q}{4\pi\varepsilon_o r}$
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,	λ	=	$\dfrac{0.693}{t_{1/2}}$

Section A

For Examiner's Use

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

1 An electron having a horizontal velocity of 1.5×10^5 m s^{-1} enters a region of uniform electric field as shown in Fig. 1.1. The electric field $\vec{E}$ of magnitude 10 V m^{-1} is applied perpendicularly to the horizontal velocity. The electron travels a horizontal displacement of 5.0 cm before leaving the plate.

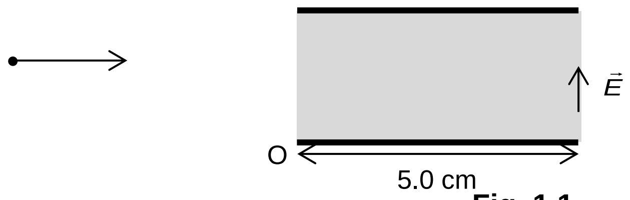

Fig. 1.1

(a) Show that the vertical velocity of the electrons as it exits the plates is 5.9×10^5 m s^{-1} .

[3]

(b) Determine the speed of the electron as it exits the parallel plate.

Speed of electron = ………………….. m s^{-1} [1]

(c) For motion within the plates, on Fig. 1.2, sketch the variation with horizontal displacement the

(i) kinetic energy , and the [2]

(ii) electric potential energy of the electron. [1]

Label the initial and final values of the energies.

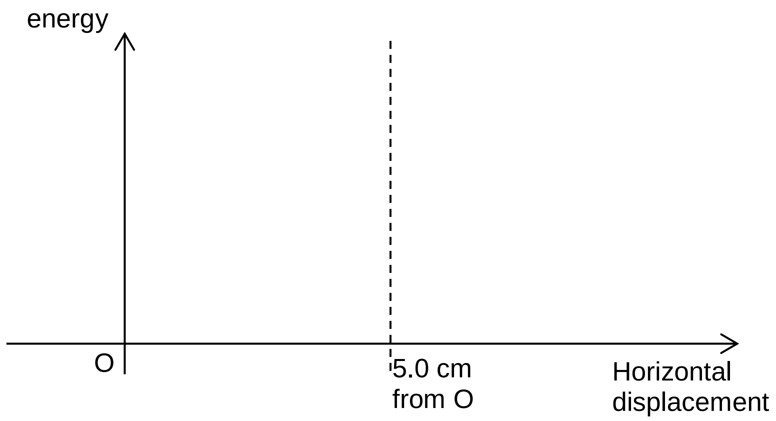

Fig. 1.2

For Examiner's Use

2 **(a)** Explain what is meant by the radian.

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....

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[1]

(b) Fig. 2.1 shows a stone of mass 150 g at point P which is at the top of a circular path. The stone is suspended on one end of a string. The radius of the circle is 70 cm and the speed of the stone at point P is 3.5 m s^{-1}.

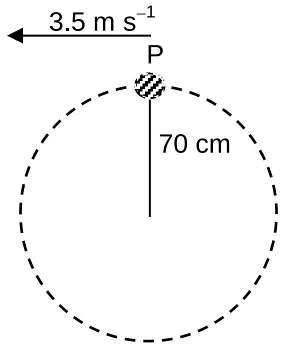

Fig. 2.1

When the stone is at point P,

(i) Calculate the resultant force acting on the stone,

resultant force = …………… N [2]

(ii) Hence determine the tension in the string.

tension = …………….. N [1]

(iii) Draw on Fig. 2.1 the forces acting on the stone. [1]

For Examiner's Use

(c) If the speed of the stone remains constant at 3.5 m s^{-1} during the circular motion, sketch on Fig. 2.2 a force-time graph showing the variation of tension in the string as the stone travels a complete circle.
[Take t = 0 s when stone is at point P]

Label **M** on your sketch the point of maximum tension in the string.

[2]

Fig. 2.2

For Examiner's Use

3 The circuit in Fig. 3.1 is use to detect changes in temperature. The variation of the resistance of the thermistor with temperature is shown in Fig. 3.2

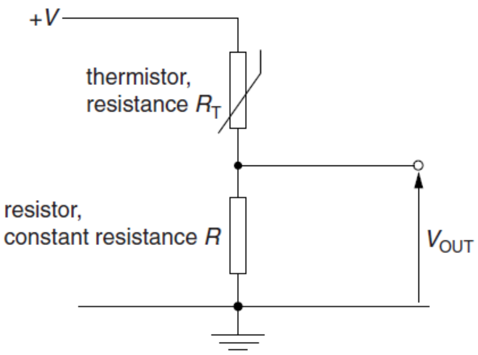

Fig 3.1

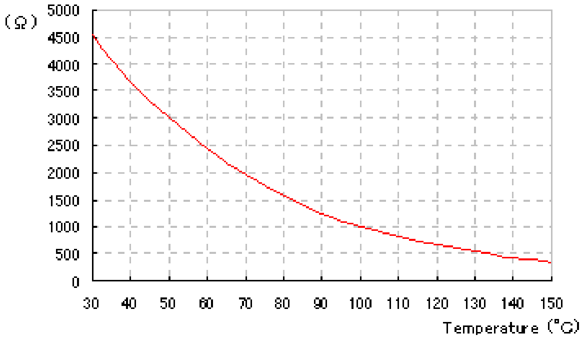

Fig 3.2

(a) **(i)** State the potential difference V_{out} across R in terms of R, R_T and V

V_{out} = …………. V [1]

(ii) The constant resistance R is 3.0 kΩ and the potential +V is +12 V. A fire alarm will be activated when the potential difference applied across it is 8.0 V.

Explain how the above circuit could be used to activate the fire alarm.

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.... [3]

(iii) Hence determine the temperature at which the fire alarm will be activated.

Temperature = …………….°C [2]

(b) State the purpose of the resistor of constant resistance in the circuit.

....

.... [1]

For Examiner's Use

4 Fig 4.1 shows the cross-section of two long straight wires X and Y perpendicular to the page. There is an electric current in both wires out of the page. The current in wire X is twice the current in wire Y.

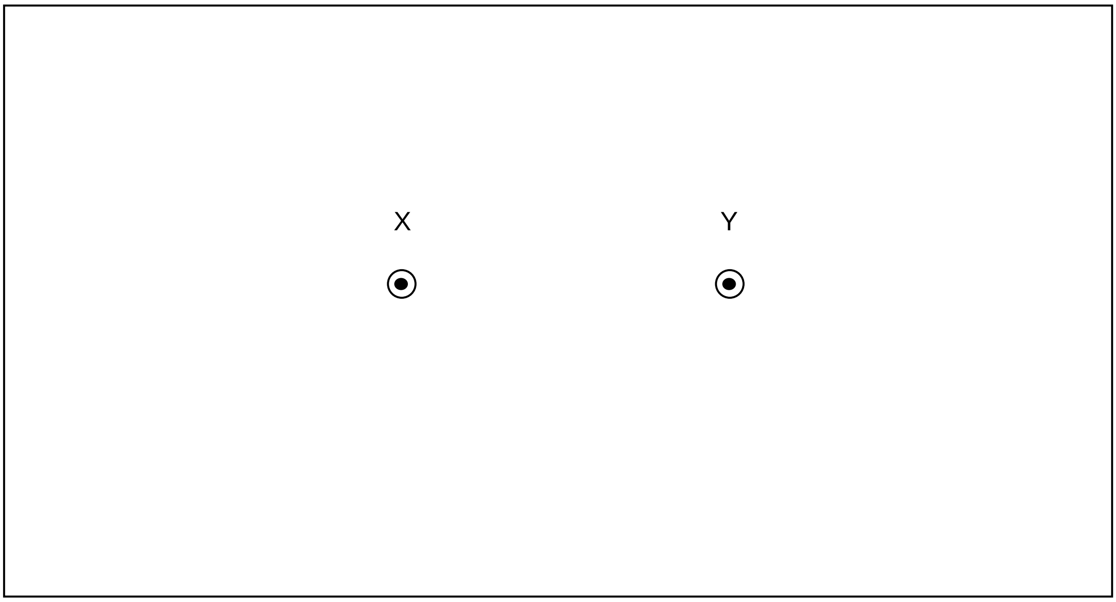

Fig 4.1

(a) Sketch the resultant magnetic field pattern around the wires within the box. Include direction arrows on the field lines. [3]

(b) Each wire exerts a force on the other wire. Draw arrows on the wires to show the direction of these forces. [1]

(c) Explain what Newton's third law implies about the magnitude of these forces.

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.... [1]

(d) Hence, deduce the expression for the force per unit length for each of these two forces, given that the wires X and Y are of infinite length, a distance d apart, and carrying current I in wire Y.

You are given that the magnetic flux density B at a perpendicular distance r from a long straight wire with current I is given by, $B = \frac{\mu_o I}{2\pi r}$

Force per unit length on wire X = ______________ Nm^{-1}

Force per unit length on wire Y = ______________ Nm^{-1} [2]

For Examiner's Use

5 A double slit with slit separation d = 0.400 mm is situated a distance 3.2 m from a detector moved vertically along XY as shown in Fig. 5.1. The double slit is illuminated with coherent light of wavelength λ .

(a)

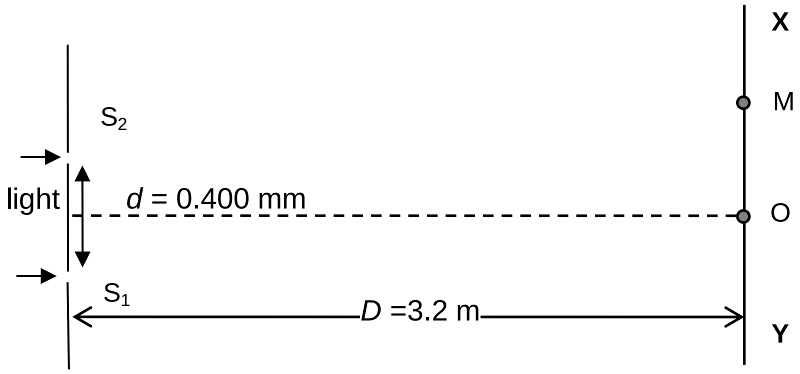

Fig . 5.1

A **detector** was moved along **XY** and the detected intensity is shown in Fig. 5.2. The relative positions of the peaks are with respect to O, the central maximum.

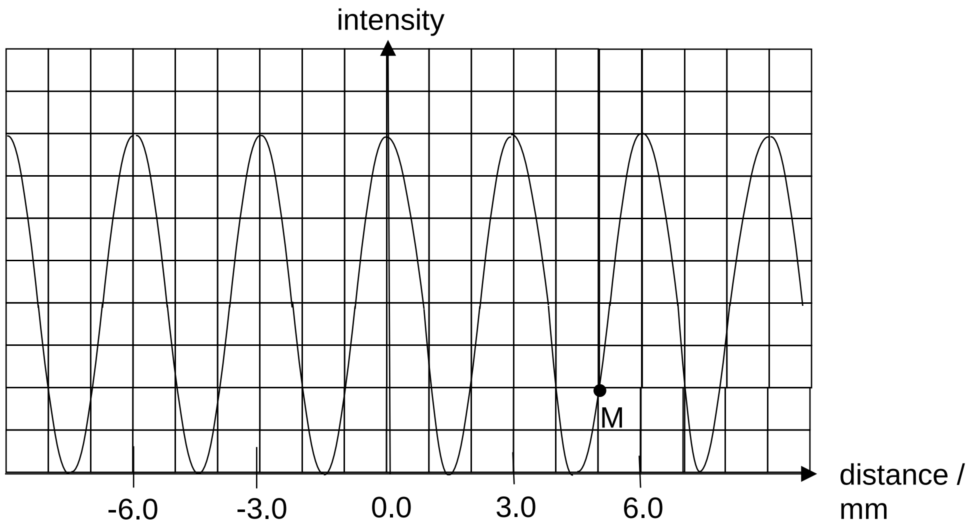

Fig . 5.2

(i) Deduce the wavelength λ of the light.

λ = ... m [2]

For Examiner's Use

(ii) With reference to Fig 5.1, calculate the phase difference between the two waves at point M.

Phase difference = ___________ π rad [2]

(b) Both the slits are covered with two identical thin transparent boxes. The one in front of S_2 is filled with vacuum whereas the one in front of S_1 is filled with gas of refractive index *n* as shown in Fig. 5.3.

It is considered that the actual path length in the gas to be the product of its refractive index and actual distance travelled, *d*.

The new light intensity pattern along **XY** is shown in Fig. 5.4.

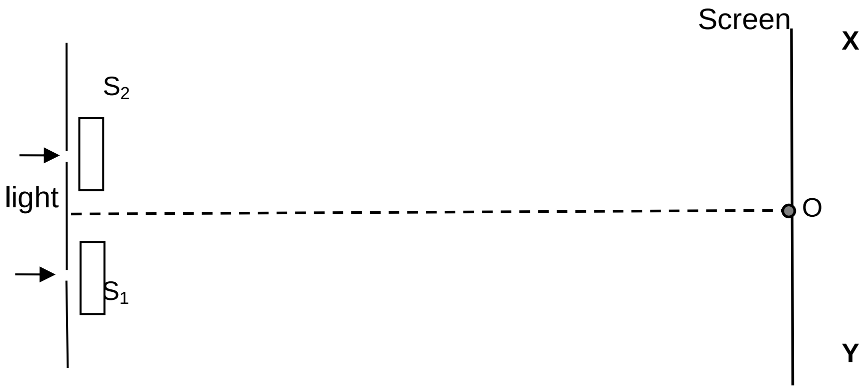

Fig 5.3

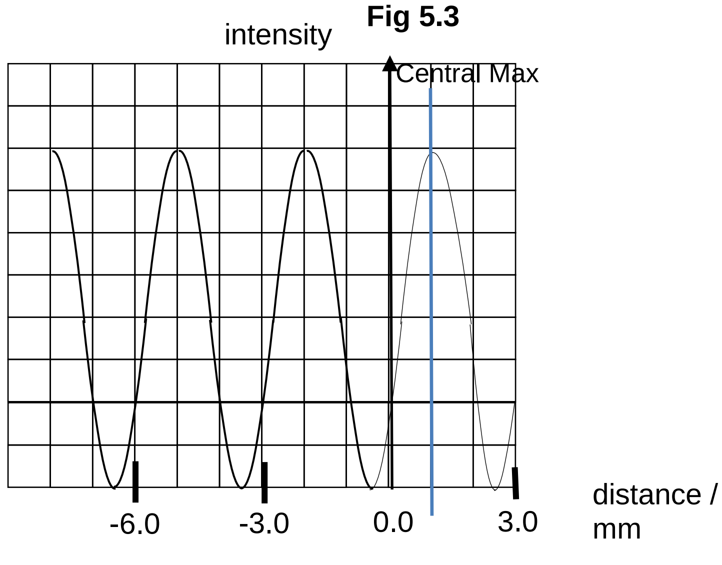

Fig 5.4

For Examiner's Use

With reference to Fig 5.2 and 5.4, the central peak has been shifted by 1.0 mm towards M.

By deducing the phase difference at the central position or otherwise, calculate the refractive index, *n* of the gas if the gas is 1.0×10^{-6} m thick.

Refractive index = ____________ [3]

For Examiner's Use

6 Fig.6 shows how emission and absorption spectra can be obtained.

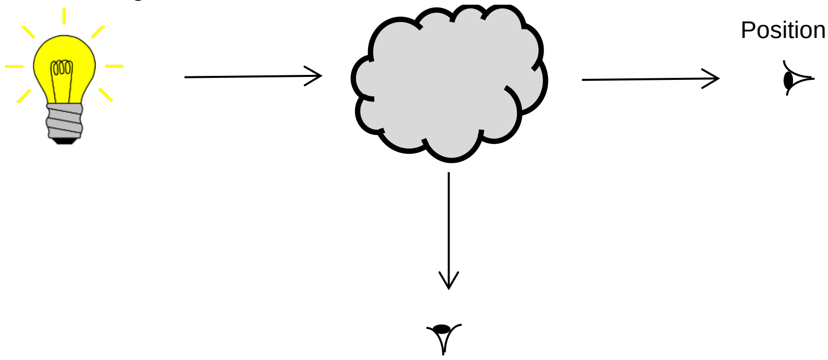

Fig 6

(a) State the type of spectrum the eyes at position A and B are expected to see:

Position A : _______________ spectrum

Position B : _______________ spectrum

[1]

(b) Explain how the emission spectrum is an evidence for discrete energy levels in an atom.

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[2]

(c) Suggest how absorption spectrum can be used to identify elements present in the sun.

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.... [2]

For Examiner's Use

Section B

Answer **two** questions for this section.

7 (a) Define *acceleration*

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.... [1]

(b) Fig 7.1 shows how the vertical component of the velocity of a parachutist changes with time during the first 20 s of his jump. To avoid air turbulence caused by the aircraft, he waits a short time after jumping before pulling the cord to release his parachute.

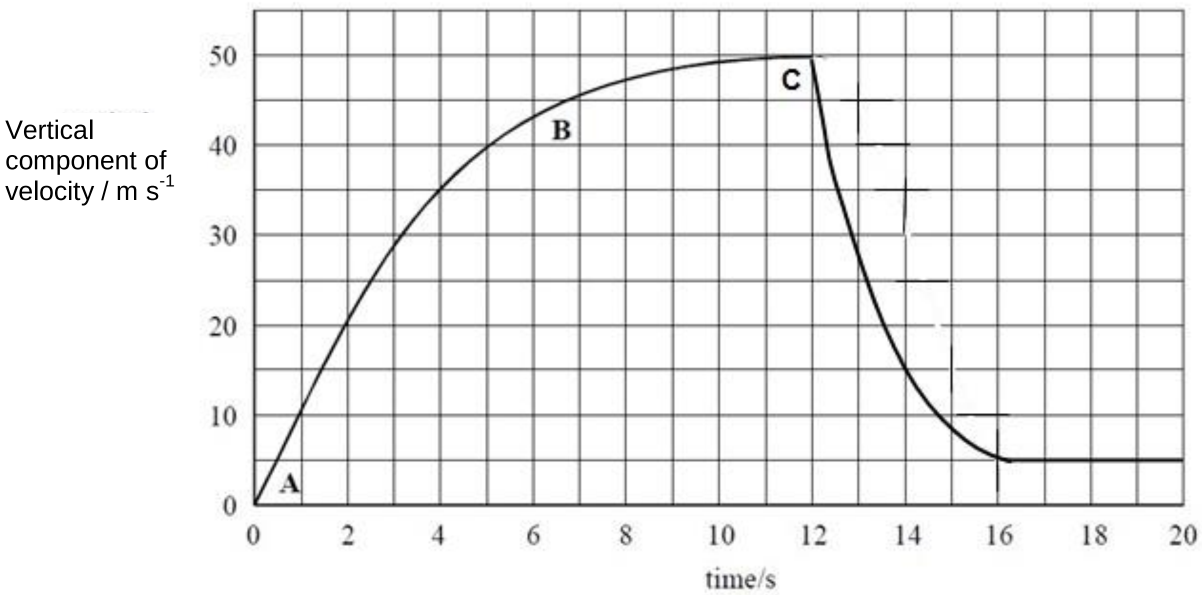

Fig 7.1

(i) Using Fig 7.1, determine the total vertical distance fallen by the parachutist in the first 11 s of the jump. Show your method clearly

Vertical distance fallen = ... m [3]

For Examiner's Use

(ii) **Regions A** (0 to 2 s), **B** (2 to 11 s) and **C** (11 to 12 s) of the graph show the speed before the parachute was opened. With reference to the forces acting on the parachutist, explain why the graph has this shape in the region marked,

1. A

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.... [2]

2. B

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....

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.... [2]

3. C

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.... [2]

(iii) Determine the acceleration of the parachutist at 6.0 s.

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

For Examiner's Use

(iv) Complete **Fig 7.2** (including the blank column with a suitable **ratio**) and hence deduce whether the air resistance experienced by the parachutist from 3.0 s to 9.0 s is directly proportional to the square of the velocity of the parachutist.

Take the acceleration of free-fall as 10.0 m s^{-2}.

***t*/s**	***v*/ m s^{-1}**	***a*/ m s^{-2}**	**(*g* – *a*) / m s^{-2}**	
3.0	28.5	6.90	3.10	
6.0	43.2			
9.0	48.0	1.20	8.80	

Fig 7.2

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.... [4]

(c) (i) Show that the maximum deceleration of the parachutist when the parachute opened at time 12 s is about 30 m s^{-2}.

[1]

(ii) Hence draw a graph on Fig 7.3 showing the variation with time of the acceleration of the parachutist during the first 18 s of the jump.
(No further calculations required.)

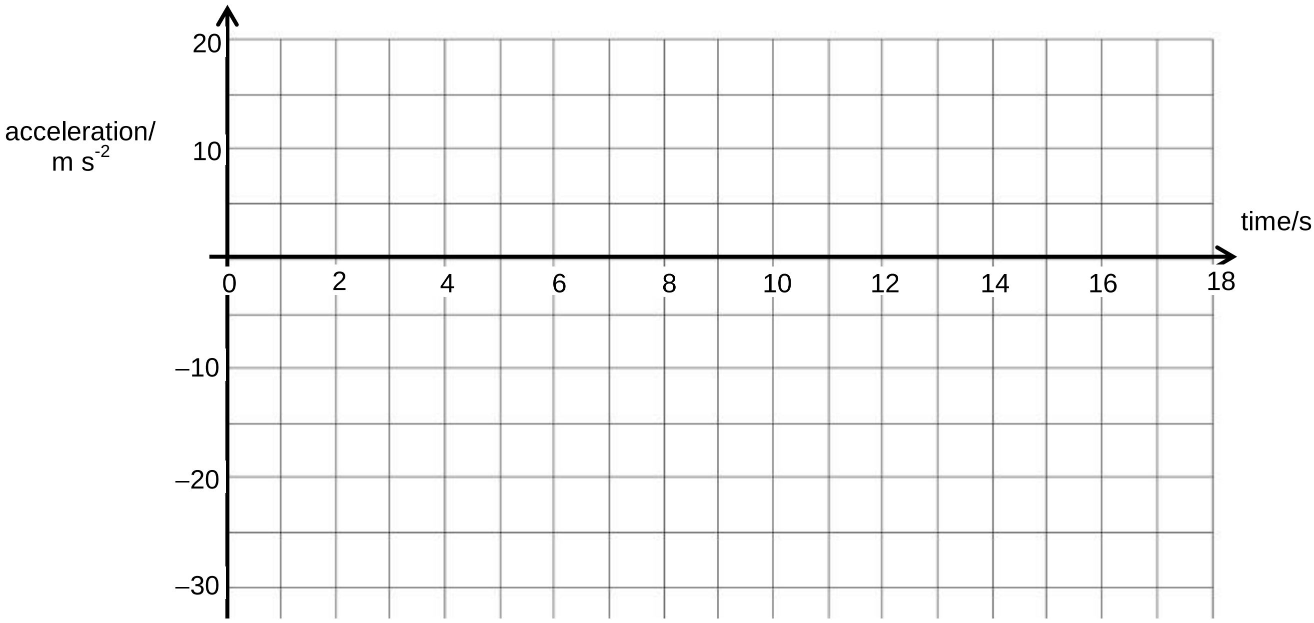

Fig 7.3

[3]

For Examiner's Use

8 A spring is attached to a sheet of aluminium and a mass, as illustrated in Fig. 8.1.

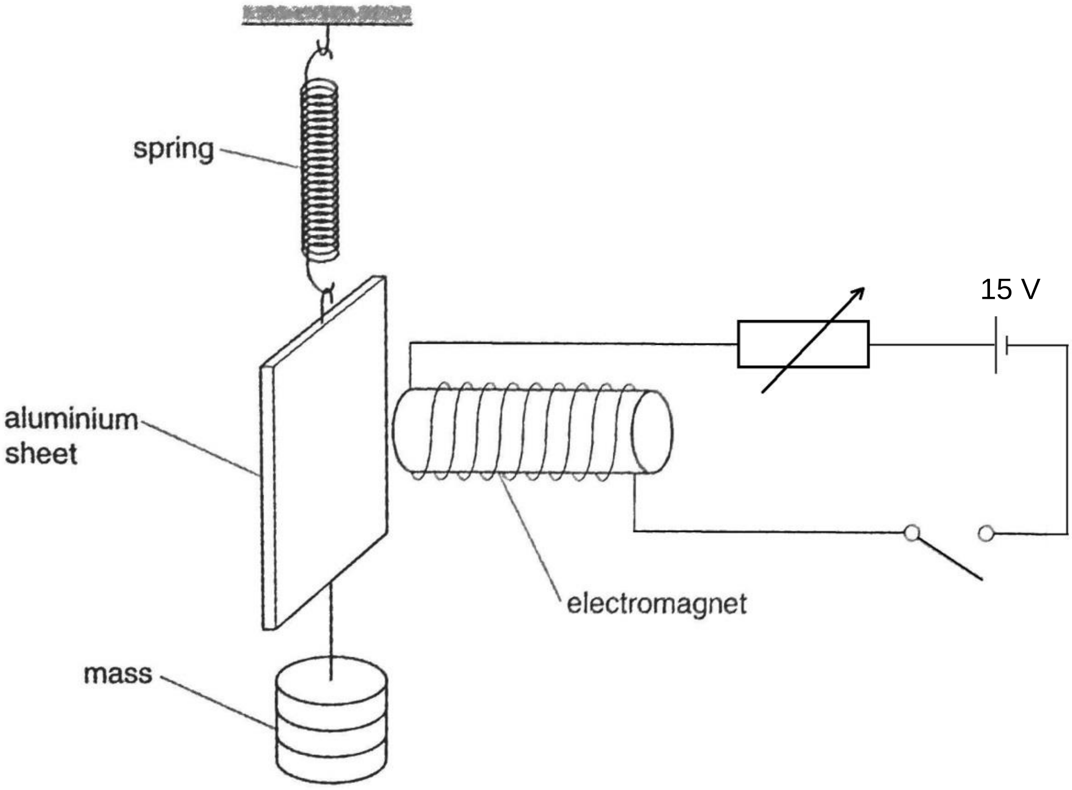

Fig 8.1

An electromagnet is placed near to the centre of the aluminium sheet. The mass is displaced vertically and, with the electromagnet **switched off**, the mass is released. The variation with time *t* of the displacement x of the mass is shown in **Fig. 8.2**.

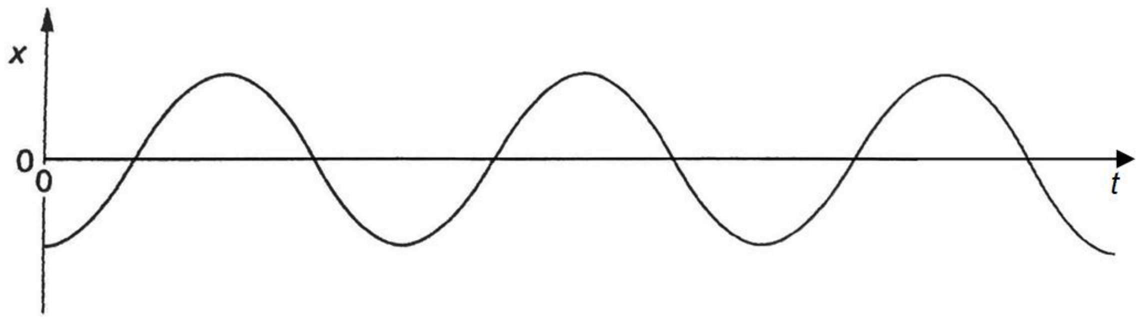

Fig 8.2

(a) The electromagnet is **switched on** and the experiment is repeated with the same initial displacement. Damped oscillations are observed.

(i) On **Fig 8.2**, sketch the new variation with time *t* of the displacement *x* of the mass. [2]

For Examiner's Use

8 (a) (ii) State Faraday's law of electromagnetic induction, and explain why the oscillations of the mass are damped, using principle of conservation of energy.

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.... [6]

(iii) Draw and label on **Fig 8.1** the followings, as the aluminium sheet **moves down** during the damped oscillation, the direction of

1. the current in the coils of the solenoid. [1]

2. the eddy currents in the aluminium sheet [1]

3. the direction of the induced magnetic field due to the eddy currents in the aluminium sheet. [1]

4. the resultant force on the aluminium sheet. [1]

For Examiner's Use

8 **(b)** Suggest how critical damping can be demonstrated using the apparatus of Fig 8.1.

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.... [4]

(c) The coil has a length 8.00 cm, radius of 1.00 cm, 50 turns and a resistance of 5.00 Ω. The variable resistor has a range of 0 – 20 Ω.

The magnetic flux density B at the centre of a solenoid is given by

$$B = \mu_o nI$$

where n is the number of turns per unit length.

Calculate the maximum magnetic flux density at one end of the solenoid.

Magnetic flux density = ______________ T [4]

For Examiner's Use

9 (a) Distinguish between a *nucleon*, a *nucleus* and a *nuclide*.

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.... [4]

(b) A nuclear power plant is capable of generating up to 4.7 gigawatts of power through neutron-induced fission of Uranium-235.

Fig 9.1 illustrates a typical nuclear fission reaction where a neutron is captured by a Uranium-235 nucleus.

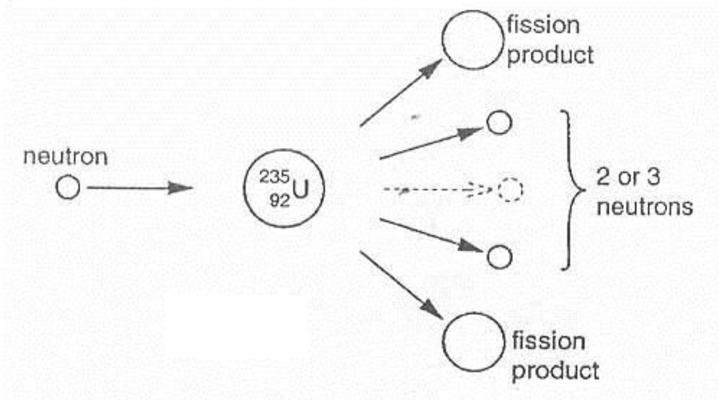

Fig. 9.1

On average, 2.5 neutrons are emitted in fission reactions and large amounts of energy are released. When conditions are suitable, a chain reaction can occur and if it is controlled, a source of continuous power may be created.

(i) Explain what is meant by *nuclear fission*.

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.... [2]

(ii) Two possible fission products that can be formed from the fission of Uranium--235 are Barium-141 ($^{141}_{56}Ba$) and Krypton-92 ($^{92}_{36}Kr$).

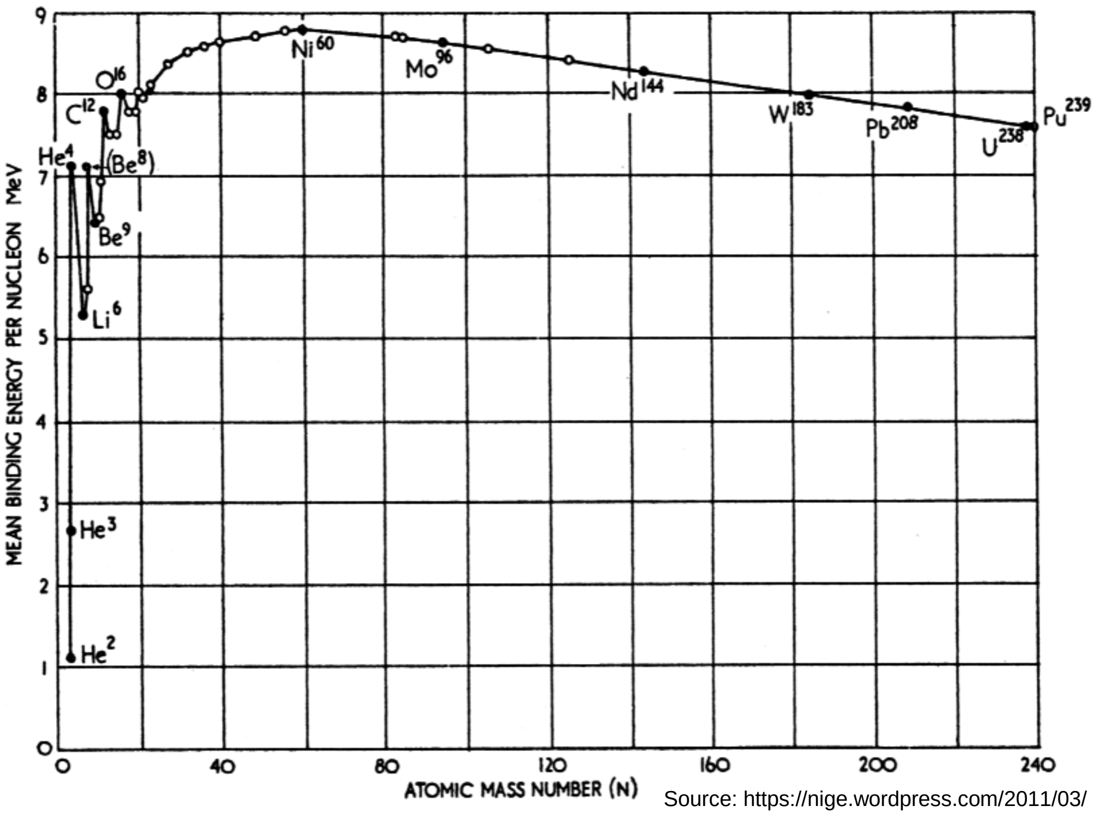
Write down the nuclear equation for this nuclear reaction.

....

.... [2]

For Examiner's Use

(c) Fig. 9.2 shows how the binding energy per nucleon of a nucleus varies with mass number.



Source: https://nige.wordpress.com/2011/03/

Fig. 9.2

(i) State what is meant by the *binding energy per nucleon* of a nucleus.

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.... [2]

(ii) Explain why fission of nuclei having low mass numbers (N < 60) is not associated with a release of energy.

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.... [2]

(iii) Using data from **Fig. 9.2** and **(b)(ii),** show that the energy released in one fission reaction is about 185 MeV.

[3]

For Examiner's Use

(iv) Suggest one form of energy in which the energy released in (c)(iii) is transformed to.

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.... [1]

(v) A typical nuclear reactor has about 100 tonnes (1 ton = 1000 kg) of Uranium spread throughout the fuel assemblies to act as fuel to generate electrical energy.

If a nuclear reactor is 30% efficient, estimate, in years, how long can a nuclear reactor supply electricity to the households in Singapore given that the total annual household electricity consumption is 6500 GWh.

……………….. years [4]