MERIDIAN JUNIOR COLLEGE
Preliminary Examination
Higher 2

H2 Physics 9646/3

Paper 3

24 September 2013

2 hours

Class Reg Number

Candidate Name ______________________________

READ THESE INSTRUCTIONS FIRST

This booklet contains Sections A and B of the Preliminary Examination Paper 3.

Do not open this booklet until you are told to do so.

<u>Section A</u>
Answer **all** questions.

<u>Section B</u>
Answer any **two** questions.

You are advised to spend about one hour on each section. Write your answers on this question booklet in the blanks provided.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets [ ] at the end of each question or part question. Marks will be deducted if units are not stated where necessary or if answers are not quoted to the appropriate number of significant figures.

All working for numerical answers must be shown. You are reminded of the need for good English and clear presentation of your answers.

Examiner's Use	
Section A	
Q1	**/10**
Q2	**/10**
Q3	**/12**
Q4	**/8**
Section B	
Circle the questions you have attempted	
Q5	**/20**
Q6	**/20**
Q7	**/20**
Deductions	
Total	**/80**

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_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	=	$-\frac{Gm}{r}$
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	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	x	=	$x_o \sin \omega t$
transmission coefficient	T	$\propto$	$exp(-2kd)$
	where k	=	$\sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay	x	=	$x_o\, exp(-\lambda t)$
decay constant	λ	=	$\frac{0.693}{t_{\frac{1}{2}}}$

Section A

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

1 **(a)** An object is thrown vertically upwards with initial velocity v near the surface of Earth. Air resistance can be neglected.

Sketch labelled graphs on the axes below to show how **(i)** the velocity, and **(ii)** the acceleration of the object, varies with time.

Mark on the graphs the time, t_1, at which the object reaches maximum height and the time, t_2, at which it returns to its original position. [3]

(i) velocity / m s^{-1}

(ii) acceleration / m s^{-2}

(b) When air resistance is not negligible, the object will experience drag force in motion. Sketch on the velocity – time graph in **(a)(i)** above, how the velocity of the object varies with time when air resistance is present. Label this sketch **B**. [2]

(c) A water fountain shoots a jet of water at 5.0 m s^{-1} towards a target a distance away as shown in **Fig 1.1**.

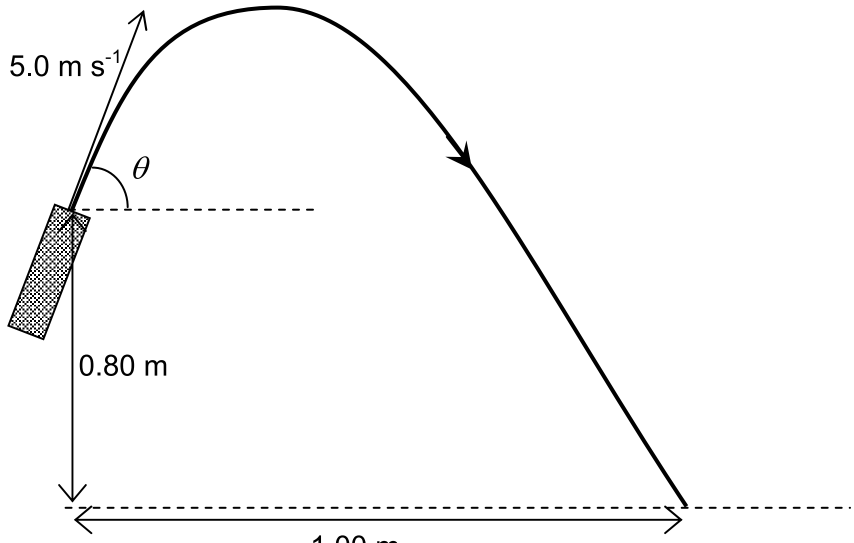


Fig 1.1

(i) State the relationship of vertical displacement, s_y, and horizontal displacement, s_x, in terms of t and θ. [2]

(ii) Hence, determine the required projection angle θ of the jet of water for it to hit the target.

You may wish to use the following relationship: $\dfrac{1}{\cos^2\theta} = 1 + \tan^2\theta$

θ = …………………… ° [3]

2 Two rubber balls are moving toward each other in an elastic head-on collision as shown in **Fig 2.1**. The mass of ball **A** and **B** are 1.7 kg and 1.6 kg respectively.

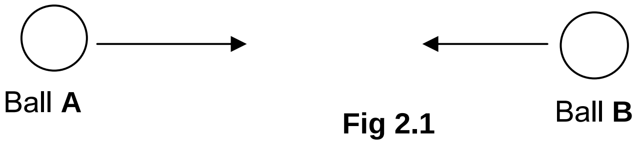


Fig 2.1

(a) Given that the initial speed of ball **A** and ball **B** are 10.0 m s^{-1} and 3.0 m s^{-1} respectively before collision, determine the final speed and direction of the balls after collision.

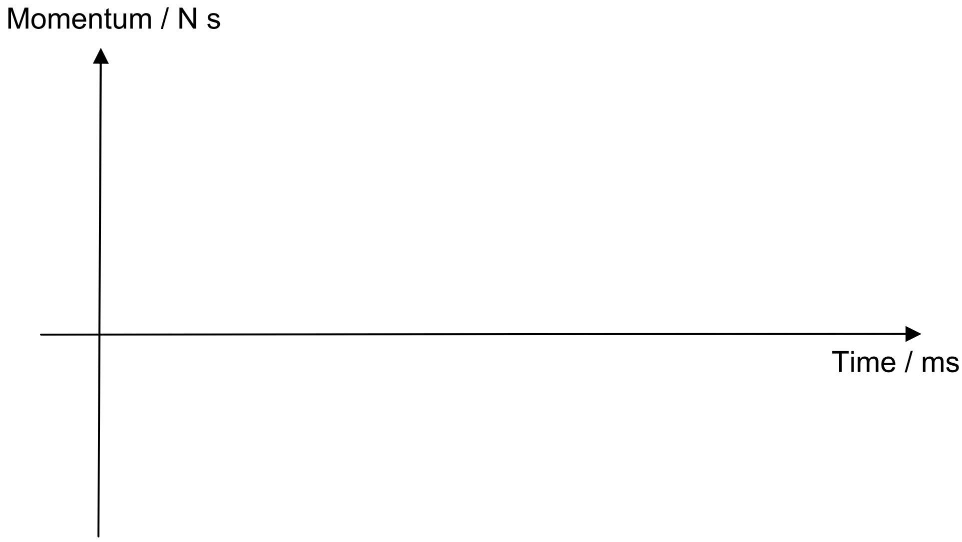
Final speed of ball **A** = ……………………… m s^{-1}

Direction of travel of ball **A** = ……………………………

Final speed of ball **B** = ……………………… m s^{-1}

Direction of travel of ball **B** = …………………………… [3]

(b) **(i)** Given that the two balls are in contact for 10.0 ms during collision, draw on the same axes below, the momentum-time graph for ball **A** and ball **B**, before, during and after the collision. [2]



(ii) Sketch on **b(i)** to show how the total momentum varies with time. [1]

(iii) State and explain whether the total kinetic energy remains constant throughout the entire duration of impact.

....

....

.... [2]

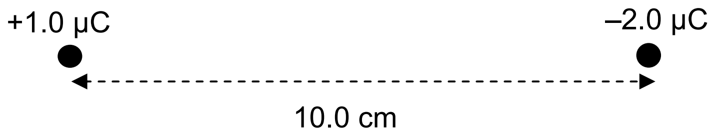
(iv) If the collision is an inelastic one, state and explain how the speeds of the balls after the collision will differ from your answers in **(a)**.

....

....

.... [2]

3 **(a)** Two point charges +1.0 μC and –2.0 μC of the same mass are placed 10.0 cm apart.



(i) Draw the electric field lines for the two charges in the space provided below, clearly labelling the two charges. [2]

(ii) A third charge is placed such that there is no net electrostatic force acting on it. Determine its position *x* with respect to the positive charge.

x = ………………………........................... [2]

(b) The two charges in **(a)** are now placed in a region of uniform magnetic field.

(i) The two charges are projected with a speed *v* perpendicular to the magnetic field. Compare the paths taken by the two charges.

....

....

....

....

.... [3]

(ii) The two charges are now projected with the same speed *v* at an angle to the magnetic field. Explain if there are any differences in the path, as compared to that in **(b)(i)**.

....

....

.... [2]

(c) Explain how electric and magnetic fields can be used in velocity selection for charged particles. Include any relevant equation, if necessary, to aid in your explanation.

....

....

....

....

....

....

....

.... [3]

4 **(a)** The energy of the sun is produced by the thermonuclear fusion reaction represented by

$$4\,{}^{1}_{1}H \rightarrow {}^{4}_{2}He + 2\,{}^{0}_{+1}e$$

You may use the following masses in answering this question:

Mass of ${}^{1}_{1}H$ = 1.007825 u

Mass of ${}^{4}_{2}He$ = 4.002603 u

Mass of ${}^{0}_{+1}e$ = 0.000549 u

(i) Determine the energy released per nuclear reaction.

Energy released per reaction = ……………………. MeV [2]

(ii) Given the Earth is at a distance 1.5 x 10^{11} m away from the Sun, and 1.35 kW m^{-2} of the Sun's energy is incident on Earth per second per unit area, determine the rate at which hydrogen nuclei are reacting in the Sun.

Rate = …………………. s^{-1} [3]

(b) **Fig. 4.1** shows the variation with nucleon number *A* of the binding energy per nucleon *E* of nuclei.

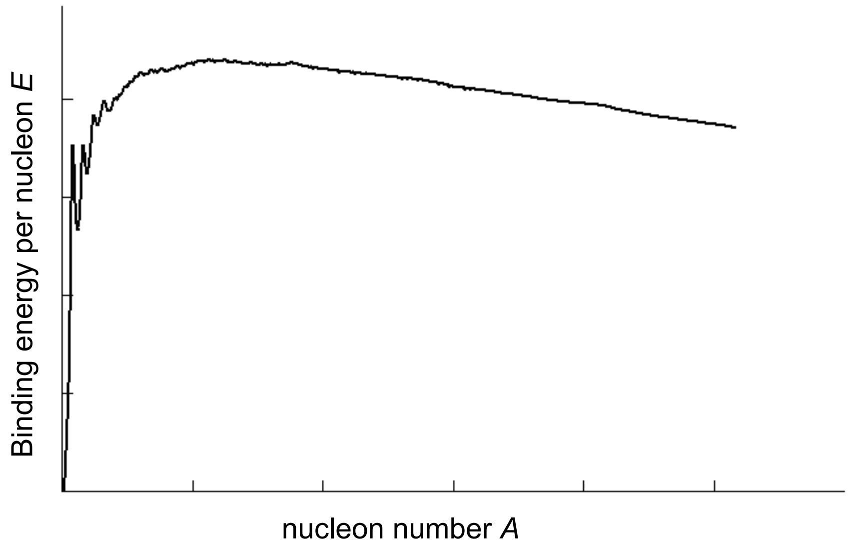


Fig. 4.1

(i) With the aid of **Fig. 4.1**, explain why more energy per nucleon is released in fusion than in fission.

……

……

……

…… [2]

(ii) Even though fusion generates more energy per nucleon than a fission reaction, suggest why it is not viable to build a fusion reactor to simulate the fusion reactions happening in the sun.

……

……

…… [1]

Section B

Answer **two** questions in this section.

5 (a) An electron gun produces an electron beam of a well-defined energy. The electrons are first released from the metal cathode surface by electrical heating. The design of a simple tungsten cathode is shown in **Fig. 5.1 (a)** below. The tungsten cathode sits in an insulated casing such that only a square face **A** is exposed (**Fig. 5.1 (b)**).

The dimensions of the tungsten block are 5.0 mm x 5.0 mm x 1.0 mm.

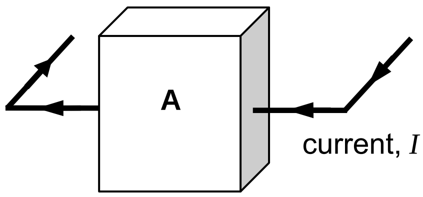


Fig. 5.1(a)

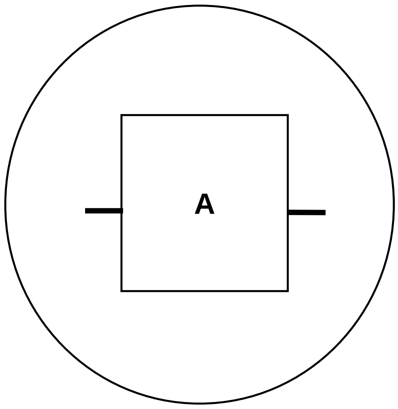


Fig. 5.1 (b)

(i) Given that the resistivity of tungsten is $5.60 \times 10^{-8}\ \Omega$ m, determine the resistance of the cathode.

resistance = ... Ω [2]

(ii) The cathode is connected to a 6.3 V DC power supply in series with a 10 Ω resistor. Explain the need for the resistor.

....

....

....

.... [2]

(b) The rate of electron emission from the cathode depends on the surface area and temperature of the cathode material. The variation of the current density, *J*, with temperature *T* for tungsten is shown in **Fig. 5.2**.

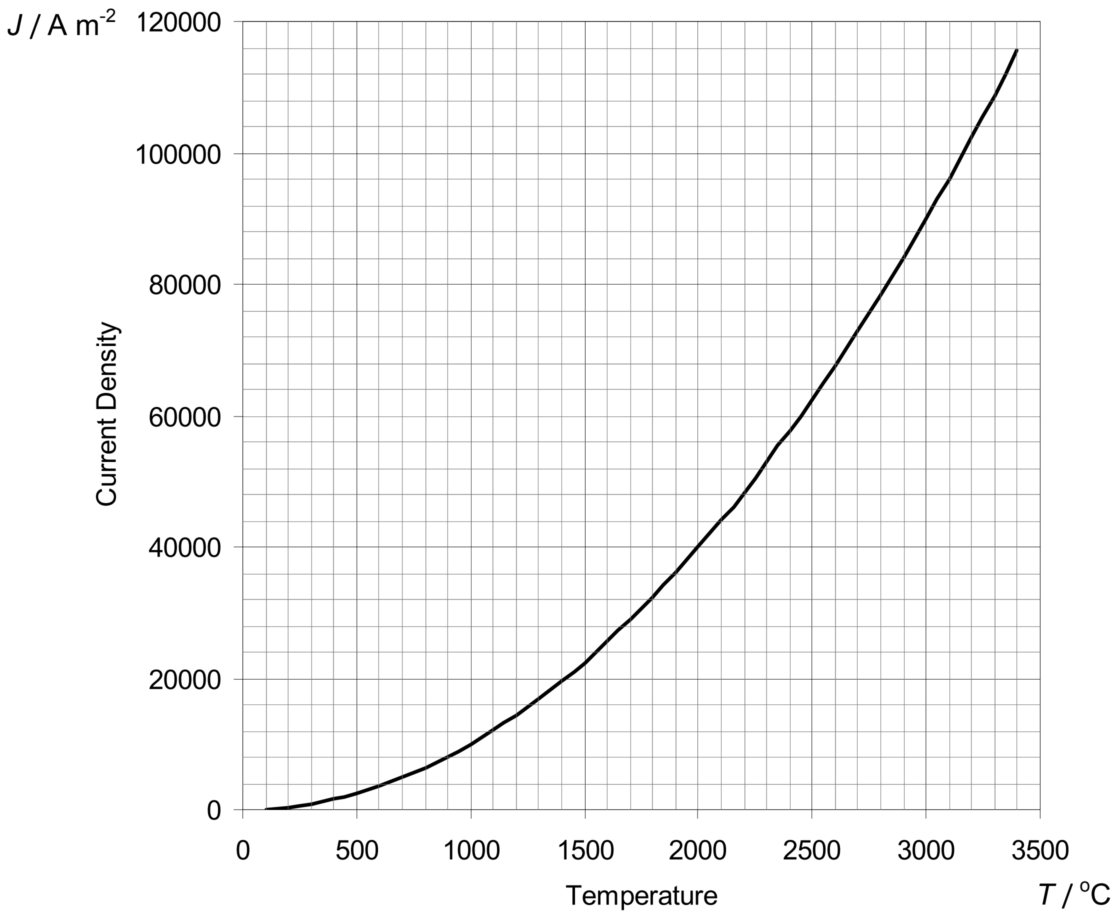


Fig. 5.2

(i) Determine the electron current that can be extracted when the cathode in **(a)** is heated to a temperature of 2000 °C.

electron current = ... A [2]

(ii) Determine the number of electrons released from the cathode when it is held at a temperature of 2000 °C for 1 minute.

number of electrons = ... [2]

(iii) State a physical property of tungsten that will limit the electron current that can be extracted from the cathode.

.... [1]

(c) A high power electron gun delivers 10.0 A of electron current at an accelerating potential of 100 kV. The electron beam is "pulsed" as shown in **Fig. 5.3** and it is directed onto a thick metal target.

Fig. 5.3

Determine the power delivered to the target. Show all your steps clearly.

You can assume that the electrons are released from the cathode with negligible kinetic energy.

power = ... W [3]

(d) A resistor "ladder" with 2 stages of resistors with values of *R* and 2*R* are connected to an ideal cell of emf *E* as shown in **Fig. 5.4**.

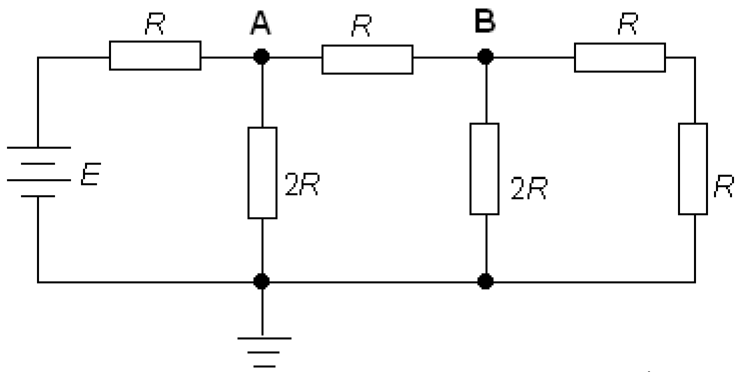


Fig. 5.4

(i) Determine the effective resistance of the circuit in terms of *R*.

effective resistance = ... [2]

(ii) Show that the potential at point **A**, $V_A = E/2$. [2]

(iii) Using **d(ii)** or otherwise, determine the potential at point **B**, V_B.

V_B = ... [2]

(iv) Four additional R-$2R$ stages, **C**, **D**, **E** and **F**, are added to the resistor "ladder" as shown in **Fig. 5.5**.

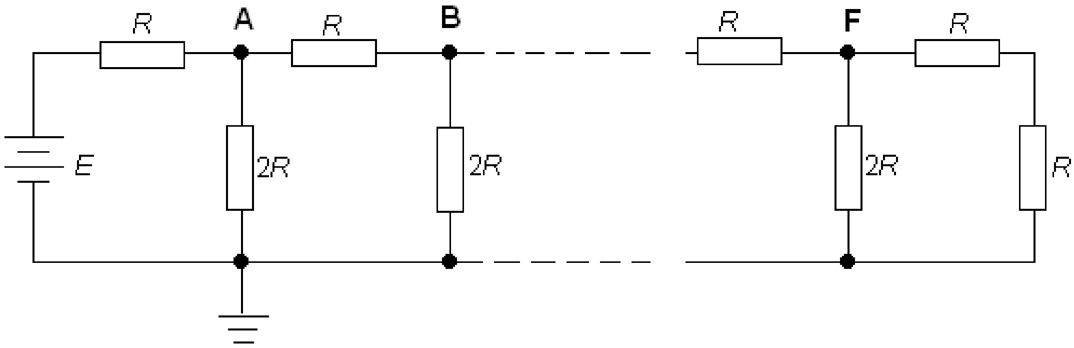


Fig. 5.5

Using your answers from **d(ii)** and **d(iii)**, deduce the potential at point **F**, V_F in **Fig. 5.5**.

V_F =................... [2]

6 **(a)** A car with a damaged suspension is driven at a steady speed over a bumpy road on which the surface height varies sinusoidally (as illustrated in **Fig. 6.1** below). At a certain speed, the amplitude of the vertical oscillation becomes very large.

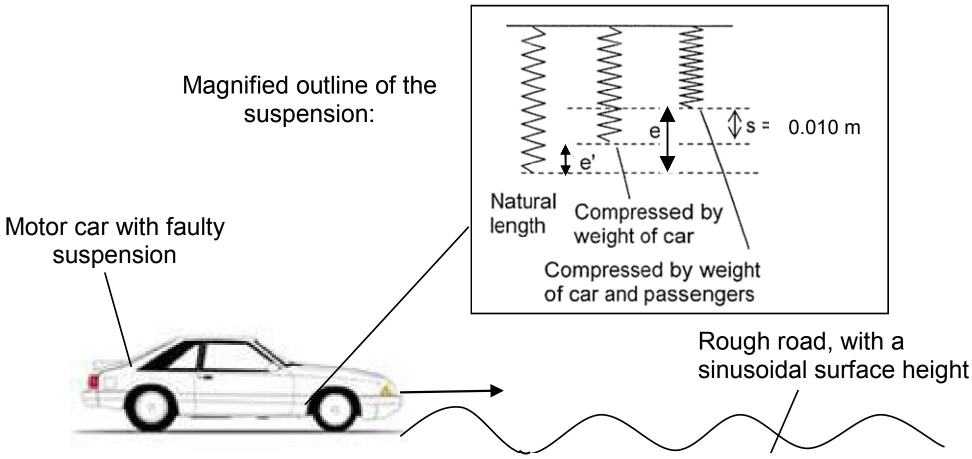


Fig. 6.1

Use the information below to answer the following questions:

Total mass of the empty car = 1500 kg

Vertical rise of the car when passengers get out = 0.010 m

Mass of the passengers = 300 kg

Separation of two adjacent humps along the road surface = 18 m

Vertical height from lowest point to the highest point along the road surface = 10 cm

(i) Given that the natural frequency f_0 of the car is similar to that of the spring, $f_0 = \dfrac{1}{2\pi}\sqrt{\dfrac{k}{m}}$ where k is the force required to produce unit extension of the spring and m is the mass on the spring, calculate the natural frequency of a fully loaded car.

f_0 = ………………….. Hz [3]

(ii) Large vertical oscillations are observed when the car travels over the series of bumps at a certain speed *v*.

State and explain this observation.

....

....

....

.... [2]

(iii) Determine the linear speed *v* of a fully loaded car when the amplitude of the vertical oscillation is at maximum.

v = ………………… m s^{-1} [2]

(iv) The variation of the amplitude of the oscillation of the car with the frequency of the car passing humps is shown in **Fig 6.2** below.

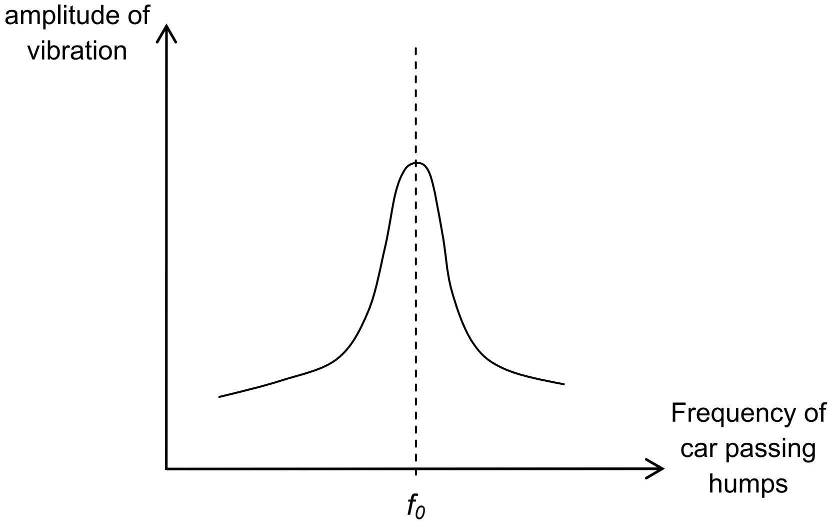


Fig. 6.2

Explain how the variation of the amplitude of the car with the frequency of the car passing humps will change if one passenger is removed from the car.

....

....

.... [1]

(v) State and explain the type of damping that is most suitable for the suspension system of a motor car loaded with passengers, making reference to the oscillation of the car and the passengers.

....

....

....

.... [2]

(b) A horizontal steel wire is fixed at one end and is kept under tension by the means of weights suspended over a pulley, as shown in **Fig. 6.3**.

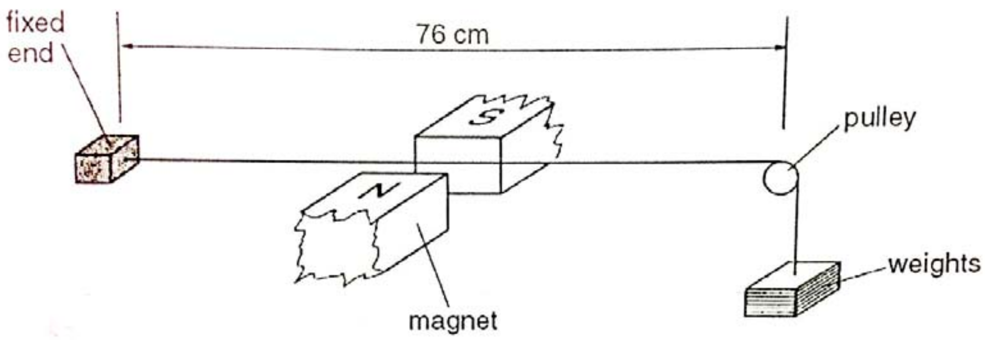


Fig. 6.3

A low voltage alternating supply of frequency 50 Hz is connected to the wire between the fixed end and the pulley. Magnets are placed near the centre of the horizontal section of the wire in order to produce magnetic field at right angles to the wire.

The tension in the wire is gradually increased from a small value by the addition of weights. It is observed that the amplitude of vibration increases to the maximum and then decreases again.

(i) Explain why the wire vibrates.

....

....

....

.... [2]

(ii) **1.** A weight of 6.00 N is hung from the wire as shown in **Fig 6.3**. A stationary wave with 3 antinodes can be seen on the wire.

Draw a labelled sketch showing all the positions of the displacement nodes and antinodes for the resonant frequency of 50 Hz. Indicate clearly the wavelength of the wave on your diagram. [2]

2. The speed v of waves on a string is given by the expression $v = \sqrt{\dfrac{T}{m}}$ where T is the tension in the string and m is its mass per unit length. Determine the mass per unit length of the string.

Mass per unit length = ………………… kg m^{-1} [2]

(c) **Fig. 6.4** shows an experimental set-up for the Young's double slit experiment in which the source is a laser of wavelength λ.

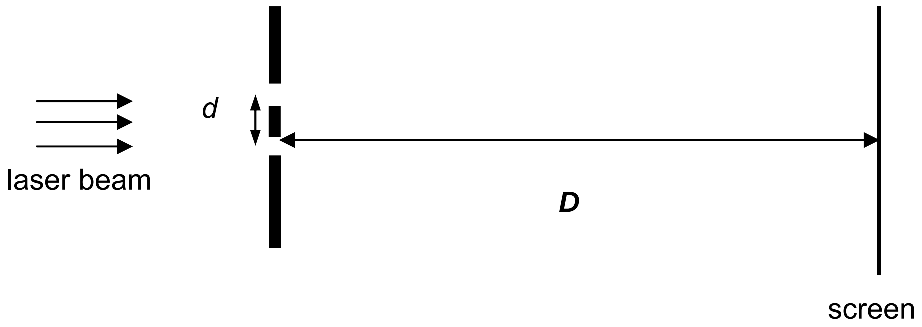


Fig. 6.4

The following measurements were obtained from the experiment:

slit separation, d = (0.50 ± 0.01) mm

distance between bright fringes/fringe separation, x = (2.03 ± 0.01) mm

distance between slits and screen, D = (1.50 ± 0.01) m

Determine the wavelength λ and express it with its associated uncertainty.

λ = ... m [4]

7 **(a)** Einsten's interpretation of the photoelectric effect on a metal surface led him to the formulation of the photoelectric equation given by $hf = \Phi + E_k$

(i) State what the following terms represent.

hf **:** ....

Φ **:** ....

E_k **:** .... [2]

(ii) State the principle that the photoelectric equation follows.

.... [1]

(iii) In a photoelectric experiment, a metal surface is illuminated with a beam of monochromatic radiation, of wavelength 300 nm and intensity 0.500 W m^{-2}, over an area of 4.50 x 10^{-5} m^2. The Φ of the metal surface is 2.03 eV.

1. Calculate the stopping potential.

stopping potential = ………………..… V [2]

2. By assuming 50% efficiency, determine the maximum photoelectric current.

maximum photoelectric current = ………………..… A [3]

(b) An electron beam, capable of firing individual electrons, is directed at a wall made of a gold-coated silicon membrane. The wall had two 62 nm wide slits in it with a centre-to-centre separation of 272 nm.

The electrons were created at a tungsten filament and accelerated across 600 V. After passing through the double slit, they were detected using a suitable screen placed 240 mm behind. A resulting pattern formed after several hours is shown in **Fig. 7.1**. *d* is the separation between the centres of adjacent bright spots.

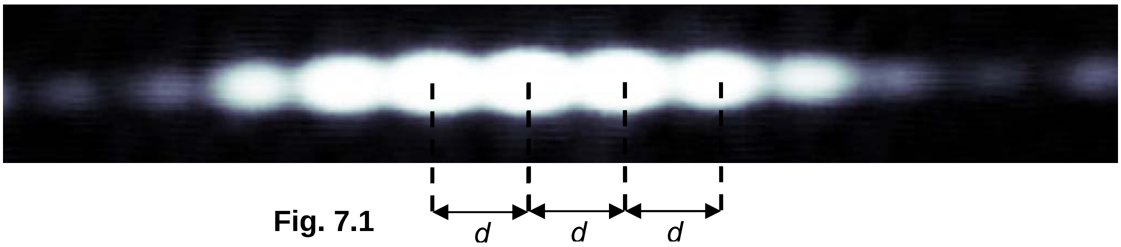


Fig. 7.1

(i) Suggest the significance of this experiment.

....

.... [1]

(ii) Show that the momentum of the electron when it is at the double slit wall is 1.32×10^{-23} N s. [2]

(iii) Hence determine the separation *d*.

d = ………………… m [3]

(c) **Fig. 7.2** below shows some of the energy levels (in electron-volts) of an atom X.

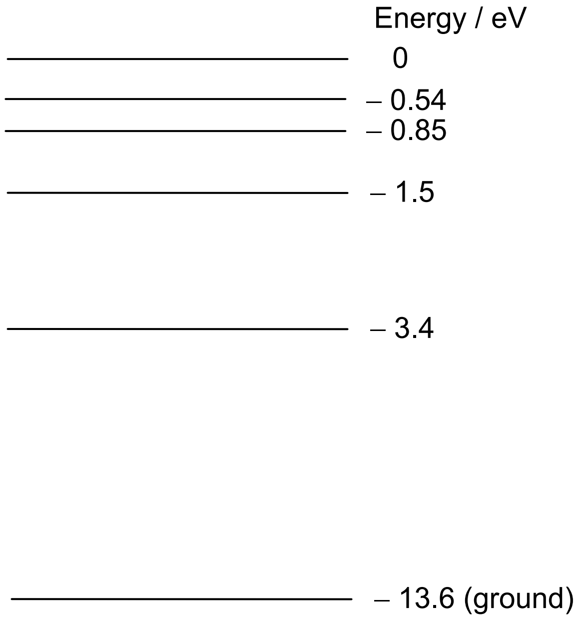


Fig. 7.2

Cool vapour of X at low pressure is bombarded with electrons that are accelerated from rest through an accelerating potential of 12.8 V.

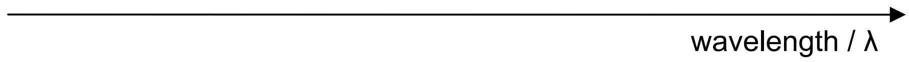
(i) State the ionisation energy of X.

ionisation energy = …………………. eV [1]

(ii) Determine the number of different wavelengths of radiation that will be emitted.

number of wavelengths = …………………. [2]

(iii) Draw the spectral lines in the axis given below. Label the line corresponding to the highest energy radiation. [2]



(iv) Determine the wavelength of the highest energy radiation.

wavelength = ………………..… [1]

End of Paper