NAME: ______________________________ **HT GROUP:** ____________

CATHOLIC JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATIONS, 2009

PHYSICS **8866 / 2**
Higher 1

80 marks

Monday
31 Aug 2009
2 hour

Instructions

Candidates will answer on the question paper for both Sections A and B.
Choose only 2 out of the 3 questions in Section B.

Data

Speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
Elementary charge	$e = 1.60 \times 10^{-19}$ C
The Planck constant	$h = 6.63 \times 10^{-34}$ Js
Unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
Rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
Rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
Acceleration of free fall	$g = 9.81$ m s^{-1}

Formula

Uniformly accelerated motion	$s = ut + ½ at^2$
	$v^2 = u^2 + 2as$
Work done on / by a gas	$W = p\Delta V$
Hydrostatic pressure	$P = \rho gh$
Resistors in series	$R = R_1 + R_2 + \ldots$
Resistors in parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$

Question	1	2	3	4	5	6 (Choose 2 out of 3)	7 (Choose 2 out of 3)	8 (Choose 2 out of 3)	Total	%
Marks										
Maximum	11	3	7	5	14	20	20	20	80	67

Section A

1. A car is stopped by varying the braking force. The braking force is increased to a maximum and then reduced, at the same rate, to zero just as stopping occurs. In this way a passenger in the car is subjected to the least possible jerk. The acceleration of the car, during the 10 s braking time, is shown in Fig. 1.1.

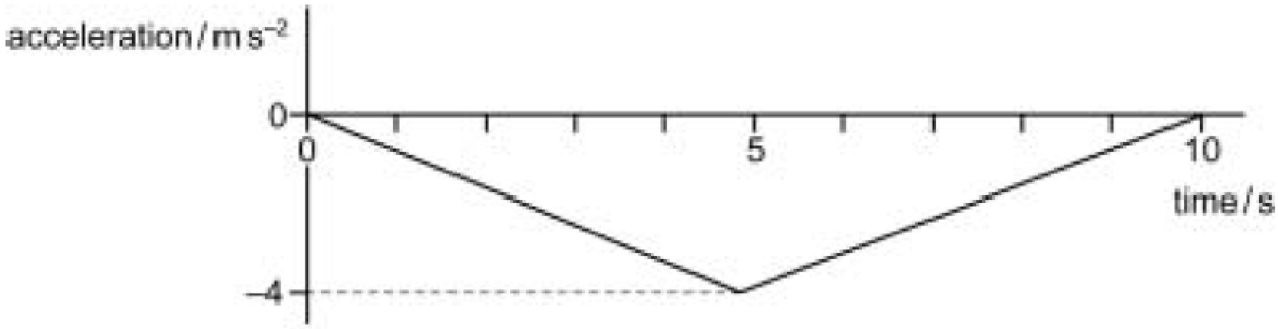

Fig. 1.1

(a) State what is meant by the term acceleration.

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....[1]

(b) On the axes of Fig. 1.2, sketch a graph to show how the velocity of the car will change during the 10 seconds braking time. The car starts with a velocity of 20 m s^{-1}.

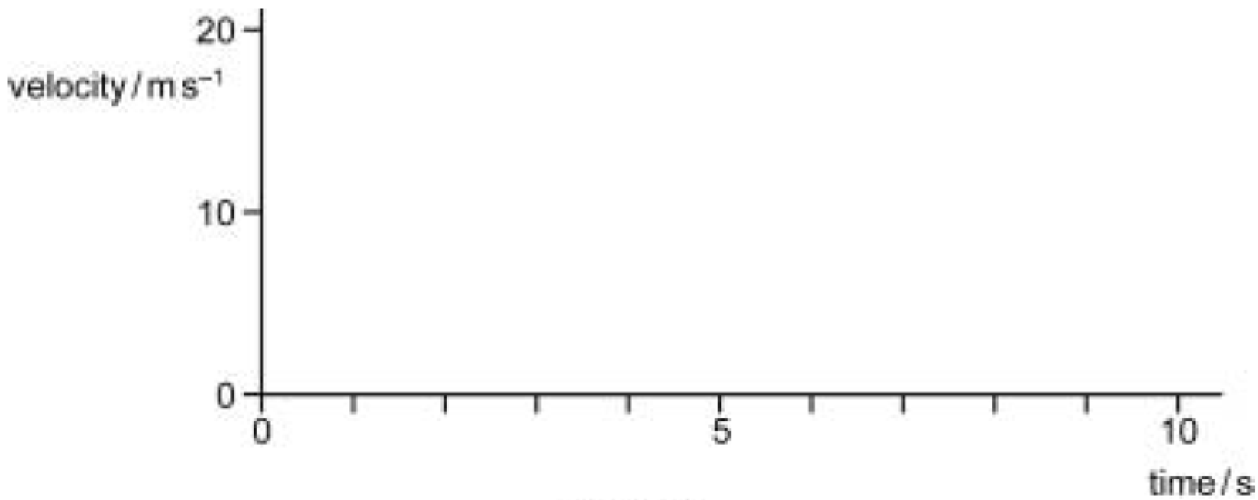

Fig. 1.2

[3]

(i) What feature of a velocity-time graph gives the displacement?

....

....[1]

(ii) Estimate the total distance travelled while braking. Show your reasoning.

Stopping distance = ... m [2]

(iii) On the axes of Fig. 1.3, sketch a displacement-time graph for the car for the 10 seconds braking time.

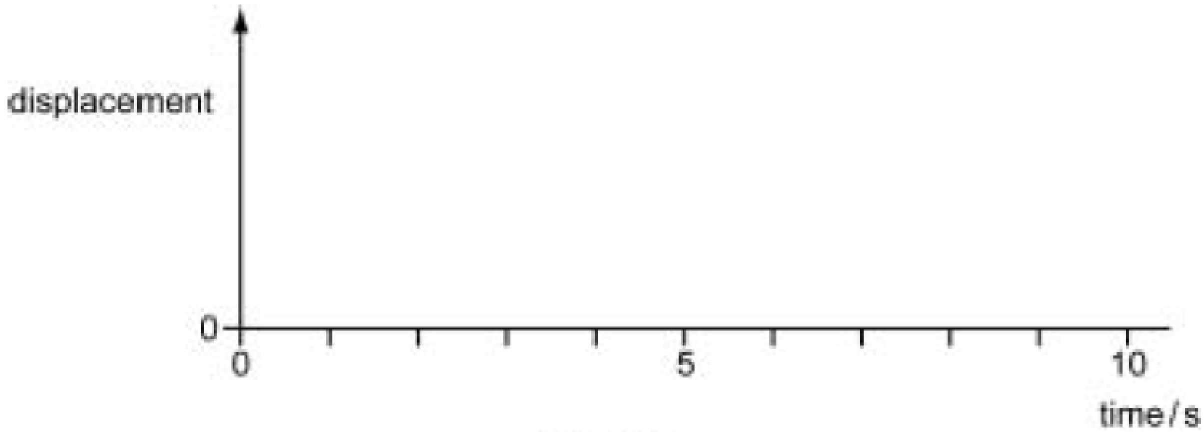

Fig. 1.3

[2]

(c) Suggest why this method of stopping is more comfortable for the passenger than a more usual method where the braking force is kept constant during deceleration.

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....[2]

2. A thin plastic bag is found to have a mass m when empty and pressed flat. When the bag is filled with air at atmospheric pressure and re-weighed, the mass is again found to be m. Explain why the two results are the same.

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....[3]

3. Explain the meaning of each of the following terms as applied to waves. You may include labelled diagrams if you wish.

(a) Stationary wave

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....[2]

(b) Diffraction

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....[2]

(c) Coherence

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....[2]

(d) Polarisation

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....[1]

4. (a) (i) A thin bar magnet is placed in a uniform magnetic field. Sketch how the bar magnet is aligned relative to the direction of the magnetic field in the figure 4.1.

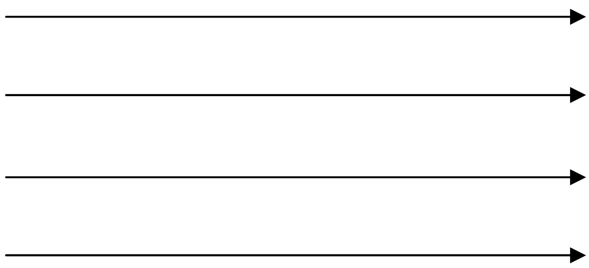

Figure 4.1

[1]

(ii) Define magnetic flux density or Magnetic field Strength.

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....[2]

(iii) Describe two differences between the force due to electric field and the force due to magnetic field on a charged particle.

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....[2]

5. LASER stands for Light Amplification by the Stimulated Emission of Radiation, which is slightly misleading since a laser is a light generator rather than an amplifier. An ordinary light bulb has a heated filament on which each atom gives out its own light, so the total beam of light is extremely chaotic, or incoherent. In a laser the atoms are given energy, raising electrons to a higher energy levels. Some of these levels are metastable, that is the electrons stay in their excited state for a short time. When one does drop back to its lowest level a photon is emitted. Spontaneously emitted photons are reflected along the laser material and back by mirrors at the ends, and these photons trigger, or stimulate, the drop in energy level of other electrons still in the metastable state. The beam now travelling along the axis of the laser has all the waves in step, i.e. it is coherent. These differences are illustrated in figures 5.1 and 5.2.

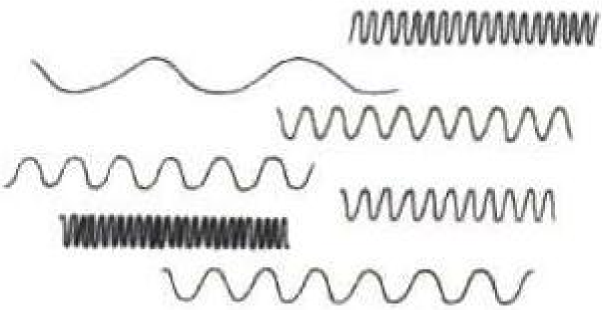

Figure 5.1 Incoherent light, spatially and in frequency, from filament

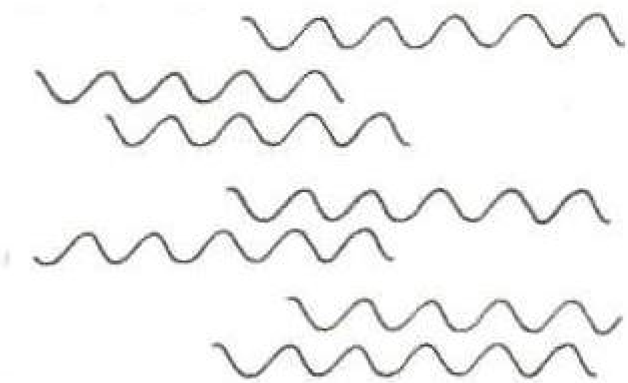

Figure 5.2 Coherent light, spatially and in frequency, from laser

The energy to raise the electrons to their metastable state energy levels can be provided in various ways. The simplest is in the laser diode, where a direct current through the diode provides the energy. A laser diode may be made of gallium arsenide doped with aluminium (AlGaAs) which gives light of 807 nm wavelength, but this light is not very bright or very coherent.

However the light can be used to transfer energy to, or ‘pump’, a laser made of a crystal of neodymium-doped yttrium aluminium garnet (Nd:YAG) a few millimetres long, which can emit light at wavelengths of 1320 nm, 1064 nm and 947 nm. (All wavelengths quoted are in air.) This produces much more coherence, to the extent that several lasers diodes, which are not coherent with each other, can pump the same Nd:YAG laser, so giving a much bigger power output. The principle is shown in figure 5.3.

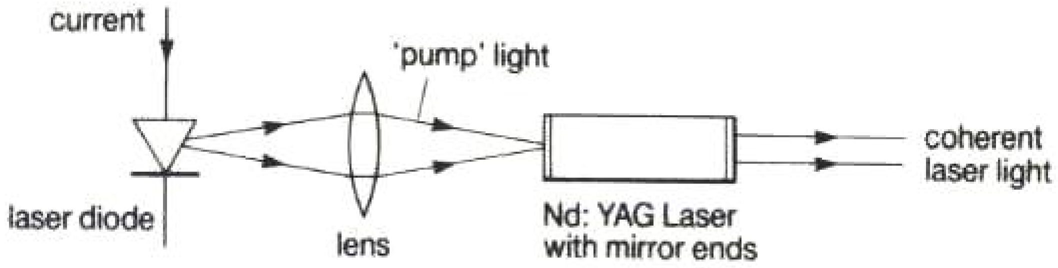

Figure 5.3

The system described above is quite efficient, the laser diode being about 25% efficient at transferring electrical energy to light, and the Nd:YAG laser transferring about 40% of this light into the more coherent output. It is very reliable because it is all solid-state and has no moving parts, and is quite compact. However, it cannot be miniaturised indefinitely, since the beam must be parallel inside the laser and a narrow beam spreads through diffraction. The drawback can be overcome by making the laser material into the core of an optical fibre, so that the beam is confined by total internal reflections in spite of the diffraction spreading.

(a) Why must the laser diode emit light of a shorter wavelength than any of the emissions from the Nd:YAG laser?

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....[2]

(b) Calculate the energy of a photon of light from the laser diode.

Energy: .... J [2]

(c) Calculate the frequencies of the three wavelengths emitted by the Nd:YAG laser.

Frequency 1 = ... Hz

Frequency 2 = ... Hz

Frequency 3 = ... Hz [3]

(d) What is the overall efficiency of the solid state laser system in transferring electrical energy to light?

Efficiency = ... % [1]

(e) The angle θ, from the straight through position, of the first minimum of the diffraction pattern caused by a circular aperture, diameter b, is given by $\sin \theta = 1.2\lambda/b$. If the laser has a diameter of 4×10^{-6} m, calculate this angle for the shortest wavelength from the Nd:YAG laser.

θ = ... ° [2]

(f) Calculate the 'spread' in a laser beam 3 mm long as shown in figure 5.4.

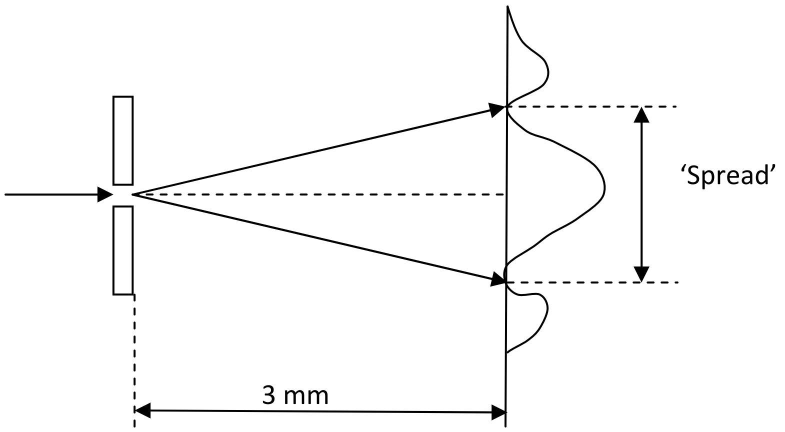

Figure 5.4

'Spread' = ... mm [2]

(g) Show on the figure 5.5, how total internal reflection keeps the beam within the laser material when it is connected to the core of the optical fibre.

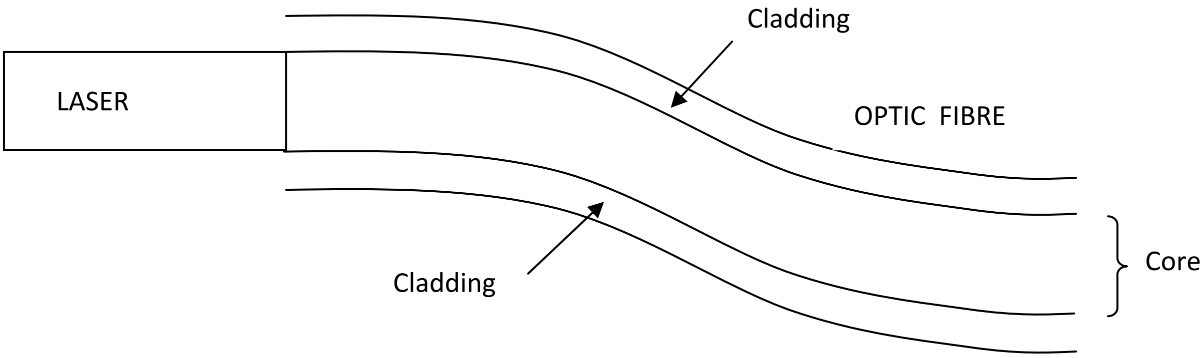

Figure 5.5 [2]

Section B (Choose 2 out of 3)

6. (a) (i) Define electric potential difference and state the SI unit in which it is measured.

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....[2]

(ii) Use your definition in (i) to show that P, the power dissipation in a resistor of resistance R is given by

$$P = \frac{V^2}{R}$$

where V is the potential difference across the resistor.

[3]

(b) A battery of e.m.f. E and internal resistance r is connected in series with a resistor of resistance R, as shown in Fig. 6.1.

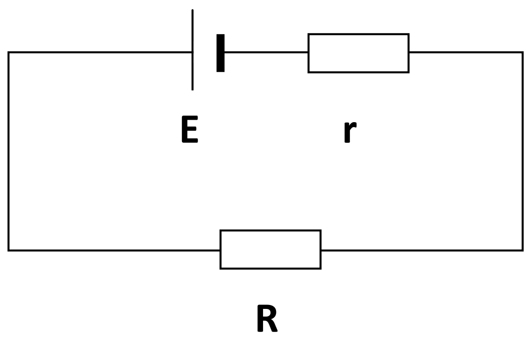

Figure 6.1

(i) Give expressions, in terms of E, r and R for

(1) The current I in the circuit,

[2]

(2) The power P_R dissipated in the external resistor.

[2]

(ii) The battery generates total power P_T.
Show that the fraction $\frac{P_R}{P_T}$ is given by

$$\frac{P_R}{P_T} = \frac{R}{R + r}$$

[2]

(c) A car battery of e.m.f. 12 V and internal resistance 0.014 Ω delivers a current of 110 A when first connected to the starter motor.

(i) Calculate

a. The resistance of the starter motor,

Resistance = ... Ω [2]

b. The fraction of the total power which is dissipated in the battery.

Fraction = ...[3]

(ii) After prolonged use, the internal resistance of the battery may increase. State and explain how the performance of the battery is affected by an increase in the internal resistance.

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....[4]

7. (a) (i) State the principle of conservation of linear momentum.

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....[1]

(ii) Explain what is meant by a perfectly elastic collision between two bodies.

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....[2]

(b) A sphere of mass m travelling in a straight line with speed u collides head-on with a stationary sphere, also of mass m. The collision is perfectly elastic. The final speeds are v_1 and v_2 respectively, as shown in the figure below.

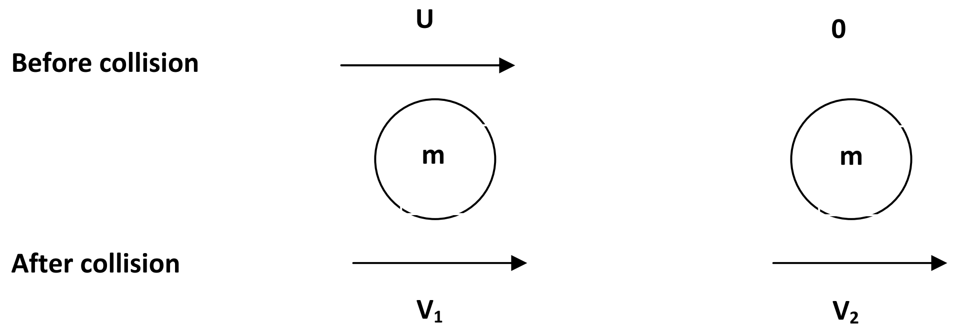

Figure 7.1

Write down expressions in terms of the quantities shown in the figure above to illustrate

(i) The principle of conservation of linear momentum,

[2]

(ii) The principle of conservation of kinetic energy.

[2]

Use these expressions to find v_2 in terms of u.

[2]

What happens after the collision to the incoming sphere?

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....[1]

(c) The collision experiment in (b) is repeated but this time the second sphere is not stationary but has speed u_2. The speed u of the incoming sphere is greater than u_2 as shown in the figure below.

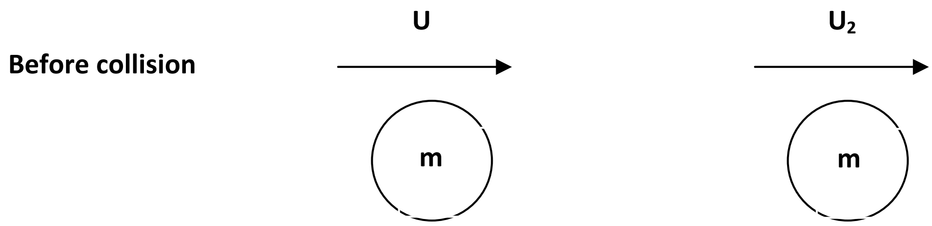

Figure 7.2

The incoming sphere of the kinetic energy E may lose an amount of kinetic energy W. The figure below shows how W/E, the fractional energy lost by the incoming sphere, depends on the ratio **U_2/U**.

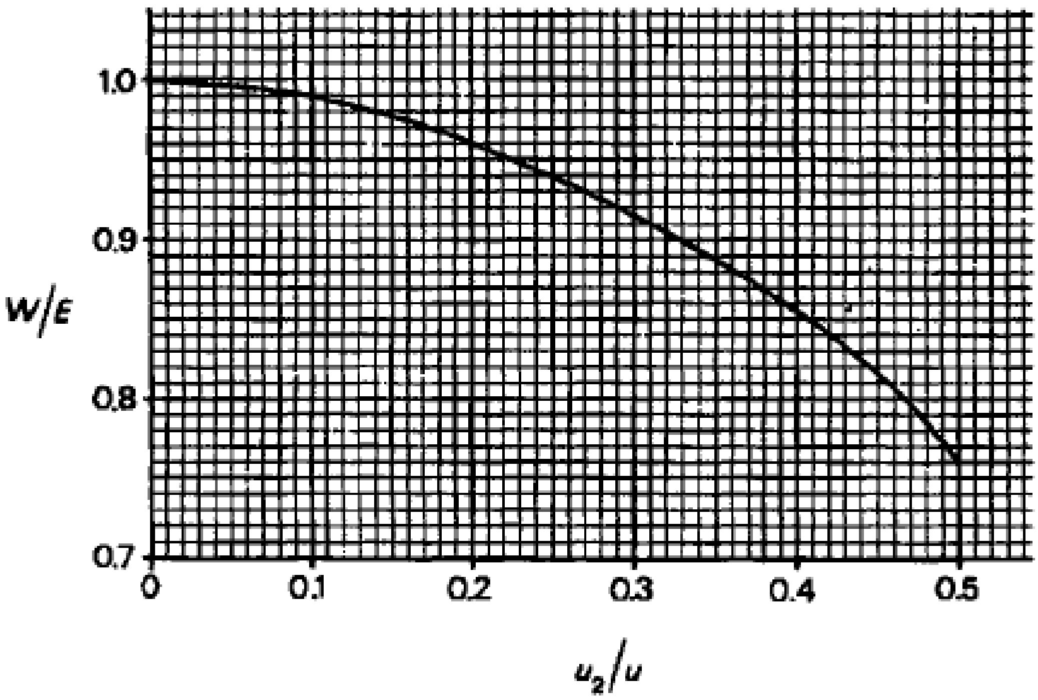

Figure 7.3

(i) What happens to the kinetic energy lost by the incoming sphere?

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....[2]

(ii) Given that the initial energy of the incoming sphere is 1.6×10^{-13} J, calculate the energy lost by this sphere in the perfectly elastic collision when $\mathbf{U_2/U}$ = 0.40.

Energy Lost: .... J. [4]

(iii) Use the graph of Fig. 7.3 to suggest why paraffin wax, which has a high number density of protons, is a good absorber of high speed neutrons.

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....[4]

8. (a) Give an expression for E, the energy of a photon, in terms of f, its frequency, and h, the Planck constant.

....[1]

(b) State a wavelength within the visible spectrum and, for that wavelength, calculate the energy of a photon.

Wavelength = ... nm

Energy of the Photon = ...J. [3]

(c) Wave theory predicts that, if electromagnetic radiation strikes a metal surface and ejects an electron, the kinetic energy of the electron should depend on the intensity of the wave. Observation shows that, in its interaction with matter to release an electron, it is the frequency of the electromagnetic wave, and not the intensity, which controls the maximum kinetic energy of the electron.

(i) What is the name given to the effect of using electromagnetic radiation to cause an electron to be emitted from a metal surface?

....[1]

(ii) Explain how this effect gave evidence for the particulate nature of electromagnetic radiation in its interaction with matter.

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....[3]

(iii) What is meant by, the term threshold frequency for the wave?

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....[2]

(c) Figure 8.1 is a graph showing the maximum kinetic energies, in electron volts, of electrons emitted from a sodium surface by light of different frequencies from a hydrogen light source.

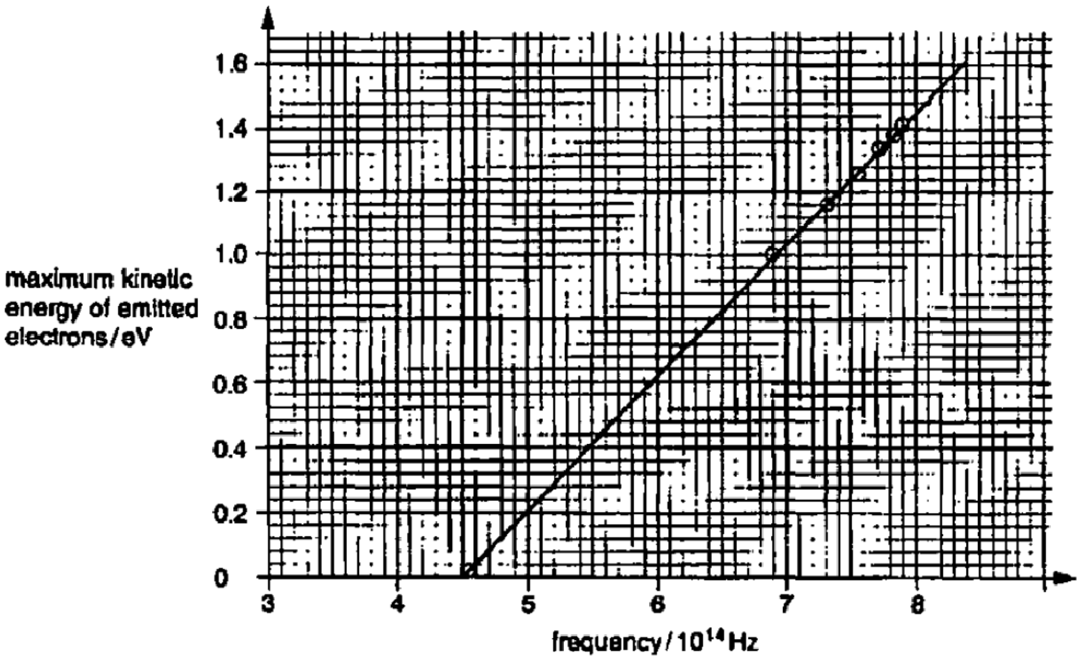

Figure 8.1

(i) What energy is 1 electron volt (1 eV) when expressed in joules?

1 eV = ... J. [1]

(ii) What is the threshold frequency for sodium?

f_o=..Hz. [1]

(iii) Calculate the work function energy, in joules, for sodium.

Work Function =... J. [2]

(iv) In calculations on electron emission, an equation which is often used is

$$photon\ energy = work\ function\ energy + maximum\ kinetic\ energy\ of\ the\ emitted\ electrons$$

With the help of the graph, state the numerical values for these three terms when the incident radiation from the hydrogen lamp has a frequency of 6.2 x 10^{14} Hz.

Photon Energy: .... J

Work Function Energy: .... J

Maximum Kinetic energy of the emitted electrons: ....J. [3]

(d) The frequencies of light from the lamp, shown by the small circles on the graph in Fig. 8.1, are the only frequencies obtained in this range. Explain how this shows the existence of discrete energy levels in hydrogen atoms. Without giving numerical values, sketch the pattern of these levels.

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....[3]

THE END