JURONG JUNIOR COLLEGE
2013 JC2 Preliminary Examination

Name		Class	12S

PHYSICS **9646/3**
Higher 2

Structured Questions **16 Sep 2013**

2 hour

Candidates answer on the Question Paper.
No additional materials are required.

READ THESE INSTRUCTIONS FIRST

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

Write your **name** and **class** in the space provided at the top of this page.

Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use highlighters, glue or correction fluid.

Section A
Answer **every** question.

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 question paper consists of 22 printed pages)

Data

speed of light in free space,	c	$= 3.00 \times 10^{8}$ m s^{-1}
permeability of free space,	μ_o	$= 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	$= 8.85 \times 10^{-12}$ F m^{-1} = $(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	$= 1.60 \times 10^{-19}$ C
the Planck constant,	h	$= 6.63 \times 10^{-34}$ J s
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
molar gas constant,	R	$= 8.31$ J K^{-1} mol^{-1}
the Avogadro constant,	N_A	$= 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant,	k	$= 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant,	G	$= 6.67 \times 10^{-11}$ 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	$= v_o \cos \omega t$
	v	$= \pm\,\omega\sqrt{(x_o^2 - x^2)}$
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	$= \dfrac{Q}{4\pi\varepsilon_o r}$
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

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

1 **(a)** A stone is being thrown from the top of a cliff with a velocity of 20.0 m s^{-1} at an angle of 60° to the horizontal, as shown in Fig. 1.1.

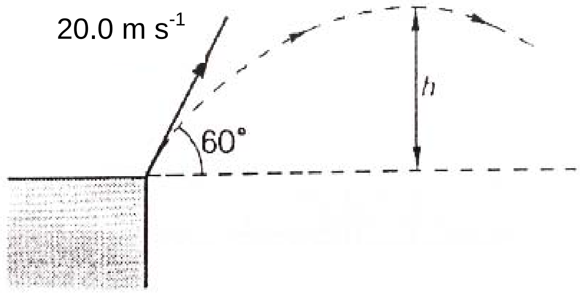

Fig. 1.1

On the axes of Fig. 1.2, draw graphs to represent the variation with time of

(i) V_H, the horizontal component of the velocity, [1]

(ii) V_V, the vertical component of the velocity of the stone. Identify your graphs. [3]

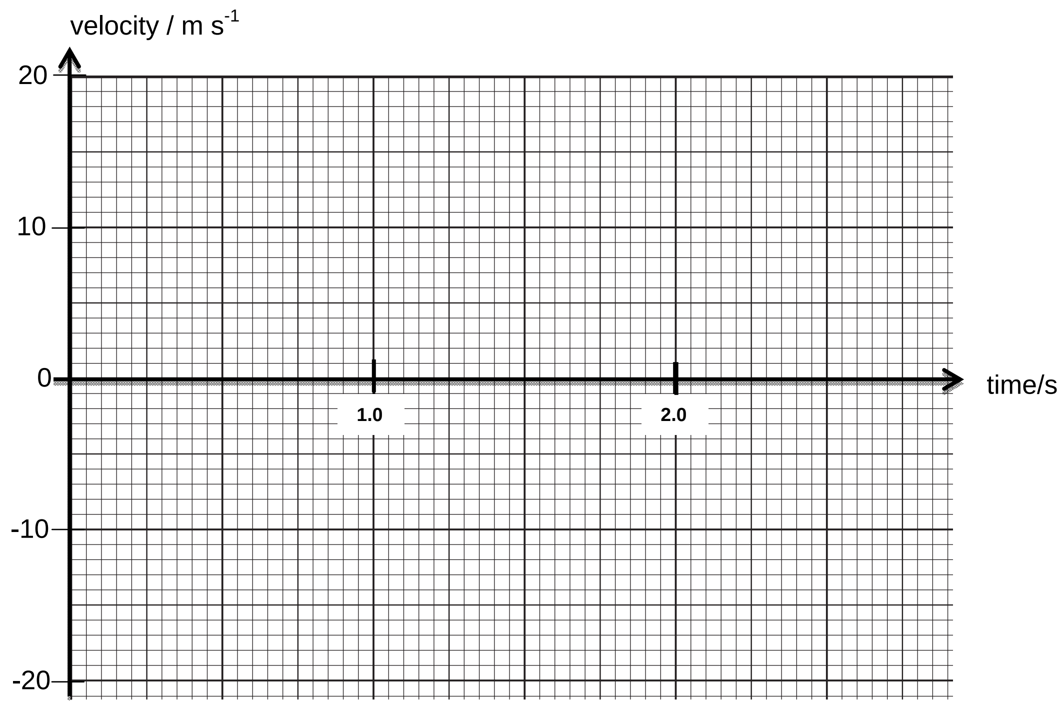

Fig. 1.2

(b) Use your answer in **(a)** to determine the maximum vertical height *h*.

maximum vertical height *h* = ... m [2]

2 **(a)** Distinguish between gravitational potential energy and electric potential energy.

....

....

....

.... [2]

(b) A hydroelectric power station has a power output of 2.0 MW when water of density 1000 kg m^{-3} passes through its turbines at a rate of 1.4 m^3 s^{-1}. The water is supplied from a reservoir which is 750 m above the power station turbines, as shown in Fig.2.

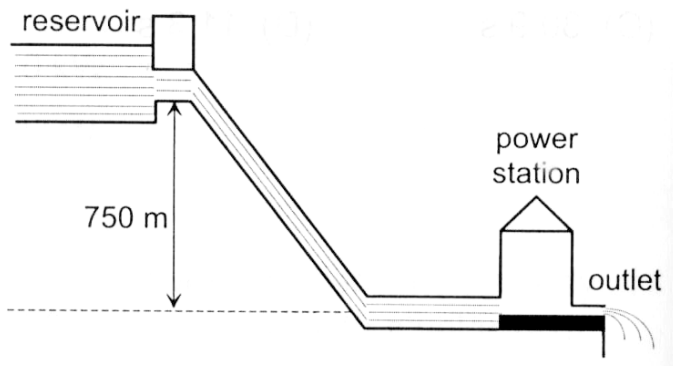

Fig. 2

(i) Show that the mass of the water passing through the turbines each second is 1400 kg s^{-1}. [1]

(ii) Calculate the rate of change in gravitational potential energy of the water flowing between the reservoir and the power station turbines.

rate of change in gravitational potential energy = ... $J\ s^{-1}$ [3]

3 **(a)** The first law of thermodynamics may be expressed in terms of the equation

$$\Delta U = q + w$$

(i) Identify each of the terms in this equation.

[1]

(ii) Some solids contract and some solids expand when they melt.

	Solid which *expands* on melting	Solid which *contracts* on melting
ΔU		
q		
w		

Fig. 3

Complete Fig. 3 with the symbols + or - to indicate the signs of the thermodynamic quantities for each of the two types of solid when the solids melt at constant pressure. [3]

(b) State qualitatively and *explain in molecular terms*, what happens to the internal energy of a fixed mass of an ideal gas when, separately,

(i) the volume is decreased at constant temperature,

[2]

(ii) the gas is compressed in a thermally-insulated container.

[2]

4. **(a)** State Newton's law of gravitation and hence show that the gravitational field strength *g* at a distance *R* from a point mass *M* is given by

$$g = \frac{GM}{R^2}$$

[3]

(b) A neutron star has mass 5.2×10^{30} kg and radius 1.7×10^{4} m.

(i) Calculate the gravitational field strength at the surface of the star.

field strength = ______________ $N\ kg^{-1}$ [2]

(ii) State the assumption made in your calculation in part (b)(i).

____

____ [1]

(iii) Determine the centripetal acceleration of a particle moving in a circular path of radius 1.7×10^{4} m and with a period of rotation of 0.21 s.

acceleration = ______________ $m\ s^{-2}$ [2]

(iv) The star rotates about its axis with a period of 0.21 s.

Use your answer to (i) and (iii) to suggest whether particles on the surface of the star leaves the surface owing to the high speed of rotation of the star.

____

____

____

____ [2]

5 **(a)** The resistivity of nichrome is $1.50 \times 10^{-6}\ \Omega$ m.

(i) Explain the term *resistivity*.

[2]

(ii) Determine the resistance of a nichrome wire of length 1.2 m and cross-sectional area 2.83×10^{-9} m^2.

resistance = ... Ω [1]

(b) The nichrome wire in **(a)** was then used as a potentiometer wire in the circuit shown in Fig. 5.1.

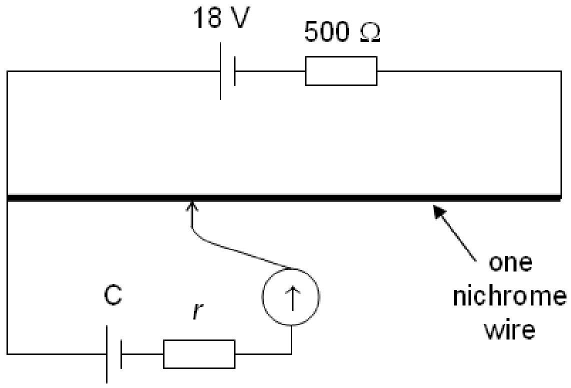

Fig. 5.1

The potentiometer circuit was then used to determine the unknown e.m.f. of cell C with internal resistance *r*. A balance length of 0.050 m was obtained.

(i) Determine the unknown e.m.f. of cell C.

unknown e.m.f. of cell C = ... V [2]

(ii) The internal resistance of the 18 V driver cell in the potentiometer circuit was assumed to be negligible. Explain why this assumption is valid.

....

....

.... [1]

(c) The experimenter was aware that the small balance length obtained in **(b)** introduced a large uncertainty in the experimental results. Instead of using a single nichrome wire, he decided to place five identical nichrome wires across the two junctions as shown in the circuit in Fig 5.2. A new balance length was obtained.

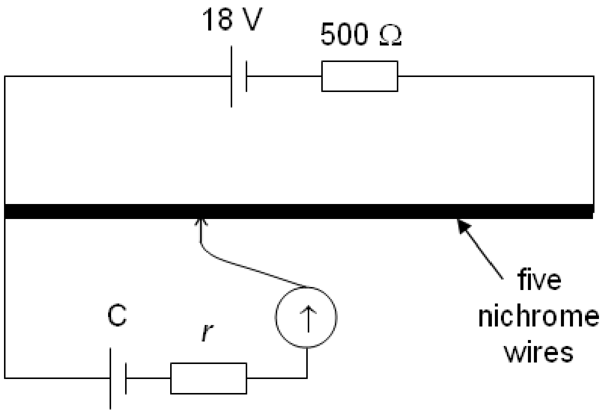

Fig. 5.2

(i) Show that the new resistance of the potentiometer wire is 130 Ω. [1]

(ii) Determine the new potential difference across the five nichrome wires.

new potential difference = ... V [1]

(iii) In order to determine the internal resistance *r* of cell C, another resistor of 6.0 Ω was connected across cell C as shown in the circuit in Fig 5.3.

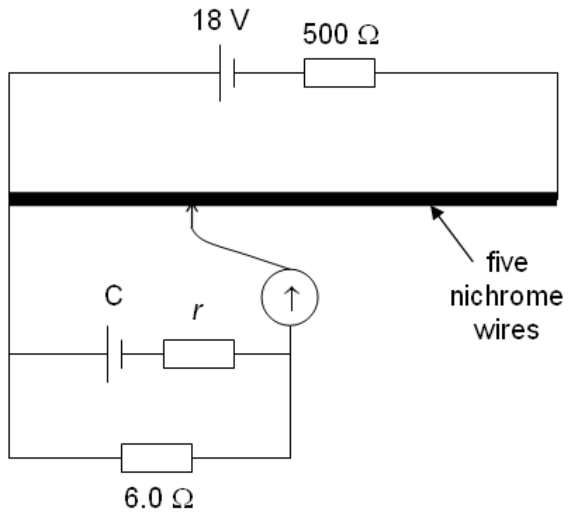

Fig. 5.3

The new balance length obtained after adding the 6.0 Ω resistor was 0.10 m. Determine the internal resistance *r* of cell C.

internal resistance *r* = ______________________ Ω [2]

Section B

Answer **two** questions from this section.

6 **(a)** Explain what is meant by

(i) a *progressive* wave,

[2]

(ii) the *diffraction* of a wave.

[2]

(b) Two microwave sources S_1 and S_2 are situated as shown in Fig. 6.1. The waves emitted by the two sources are in phase and are polarised in the same plane.

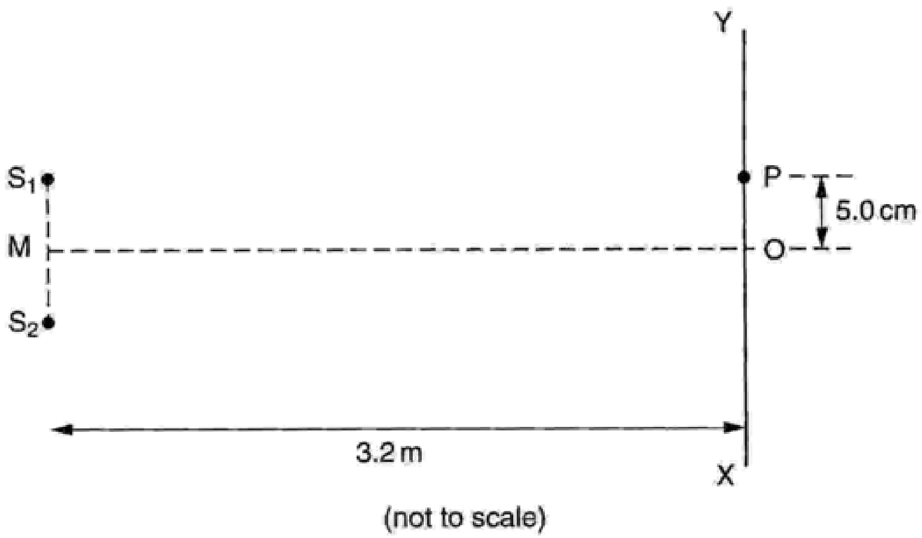

Fig. 6.1

A microwave detector is placed on a line XY which is parallel to, and 3.2 m from, the line joining S_1 and S_2. M is the midpoint of the line joining S_1 and S_2. The line from M perpendicular to the line S_1S_2 meets XY at O. The detector produces an output which is proportional to the displacement of the wave.

With only S_1 switched on, the change with time of the detector output measured at P, a distance of 5.0 cm from O, is as shown in Fig. 6.2.

The waveform detected at P for S_2 only is also shown on Fig. 6.2.

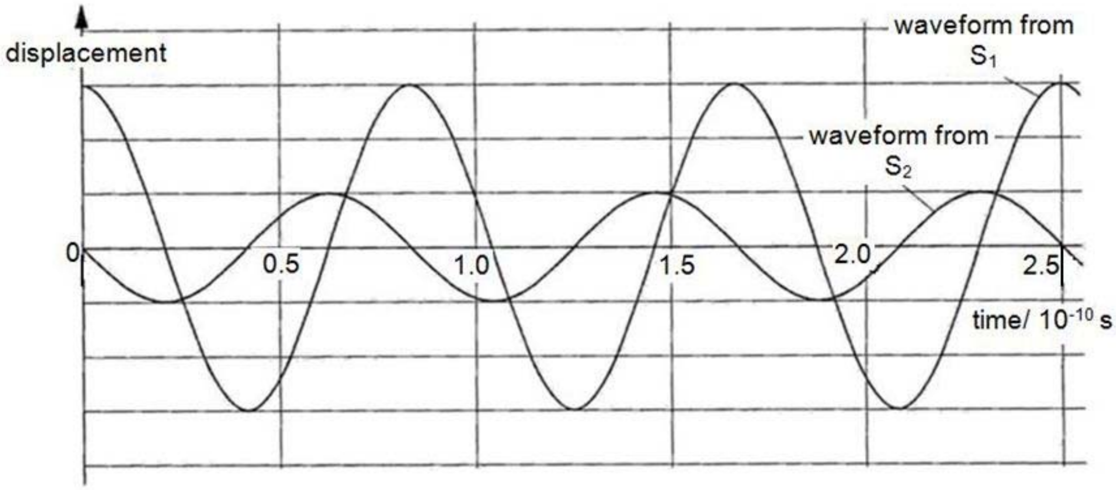

Fig. 6.2

(i) Use Fig. 6.2 to determine

1. the period of the waves,

period = ... s [1]

2. the phase difference between the waves at P,

phase difference = ... rad [1]

3. the ratio

$$\frac{\text{intensity at P of wave from } S_1}{\text{intensity at P of wave from } S_2}$$

ratio = ______________ [2]

(ii) Using your answer to (i)1., show that the wavelength of the microwaves from S_1 and S_2 is 2.5 cm. [2]

(iii) S_1 and S_2 are switched on together, with the emitted waves in phase. The detector is moved from P along the line OY, in the direction away from O. State and explain the approximate distance that the detector must be moved before the intensity is a maximum, given that there is no maximum between O and P.

____

____

____

____

____

____

____

[3]

____

(iv) Make an estimate of the separation of the sources S_1 and S_2.

separation = ... m [2]

(c) When a stretched string is plucked, a stationary wave is produced on the string.

The stationary wave has frequency f and wavelength λ.

(i) 1. State, in terms of λ, the minimum separation of two points that have zero amplitude of vibration.

minimum separation = ... [1]

2. State the phase angle between the vibrations of points on the string situated at adjacent antinodes.

phase angle = ... rad [1]

(ii) The speed v of a progressive wave is given by the expression $v = f\lambda$.

A stationary wave does not have a speed. By reference to the formation of a stationary wave, explain the significance of the product $f\lambda$ for a stationary wave.

....

....

....

....

....

....

.... [3]

7 **(a)** A long bar magnet hangs from one end of a spring. The magnet is displaced vertically downwards and then released. The subsequent vertical displacement *x* is found to vary with time *t* as shown in Fig. 7.1.

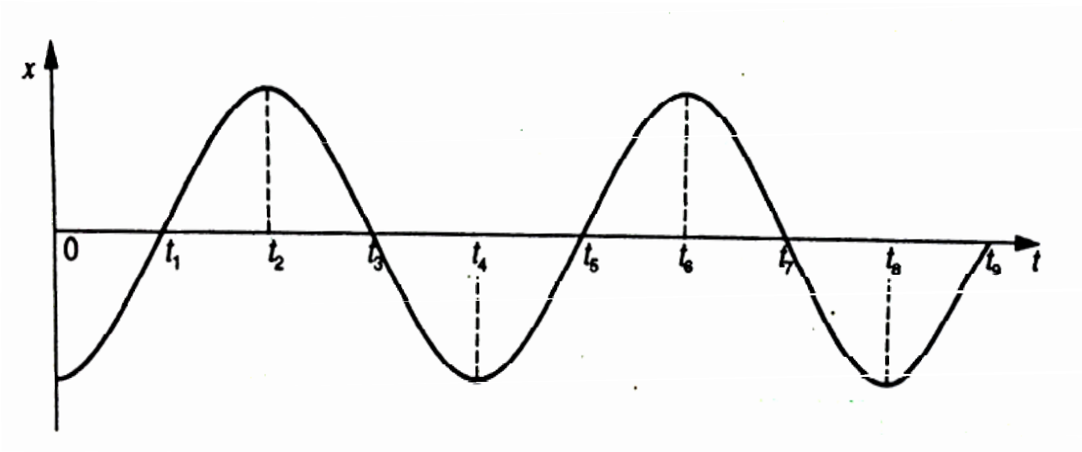

Fig. 7.1

(i) State two times, apart from *t* =0, at which the magnet is stationary.

t = ... [1]

(ii) State two times at which the magnet is moving vertically upwards with maximum speed.

t = ... [1]

(iii) State two times at which the magnet is moving vertically downwards with maximum speed.

t = ... [1]

(b) The north pole of the magnet is now placed Inside a coil of wire, as shown in Fig. 7.2.

The terminals of the coil are connected to the Y-plates of a cathode-ray oscilloscope (C.R.O) which may be assumed to have infinite input resistance.

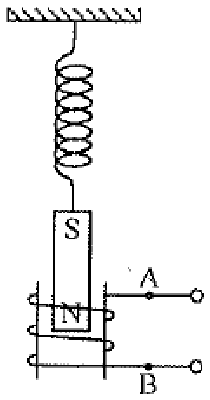

Fig. 7.2

(i) Sketch a graph in Fig. 7.3 to show how the induced e.m.f. in the coil will vary with time t when the magnet oscillates in the coil. [3]

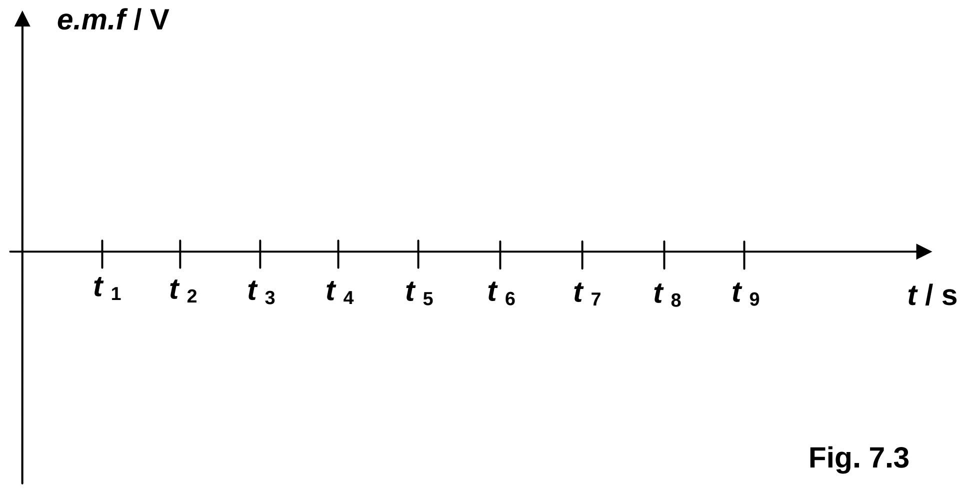

Fig. 7.3

(ii) Use the laws of electromagnetic induction to explain the shape of your graph.

[4]

(c) A high resistance resistor is now connected in parallel with the C.R.O. between the points A and B (see Fig. 7.2).

(i) On Fig. 7.3, draw a second graph to show how the e.m.f. will vary with time *t*. [2]

(ii) Explain, in terms of the *principle of conservation of energy*, why this graph is different from your first graph.

[3]

(d) Explain why it is necessary to use high voltages for the efficient transmission of electrical energy.

[3]

(e) Explain why it is advantageous to use alternating current when transmitting electrical energy.

[2]

8 **(a)** Some of the energy levels in atomic hydrogen are shown in Fig. 8.1.

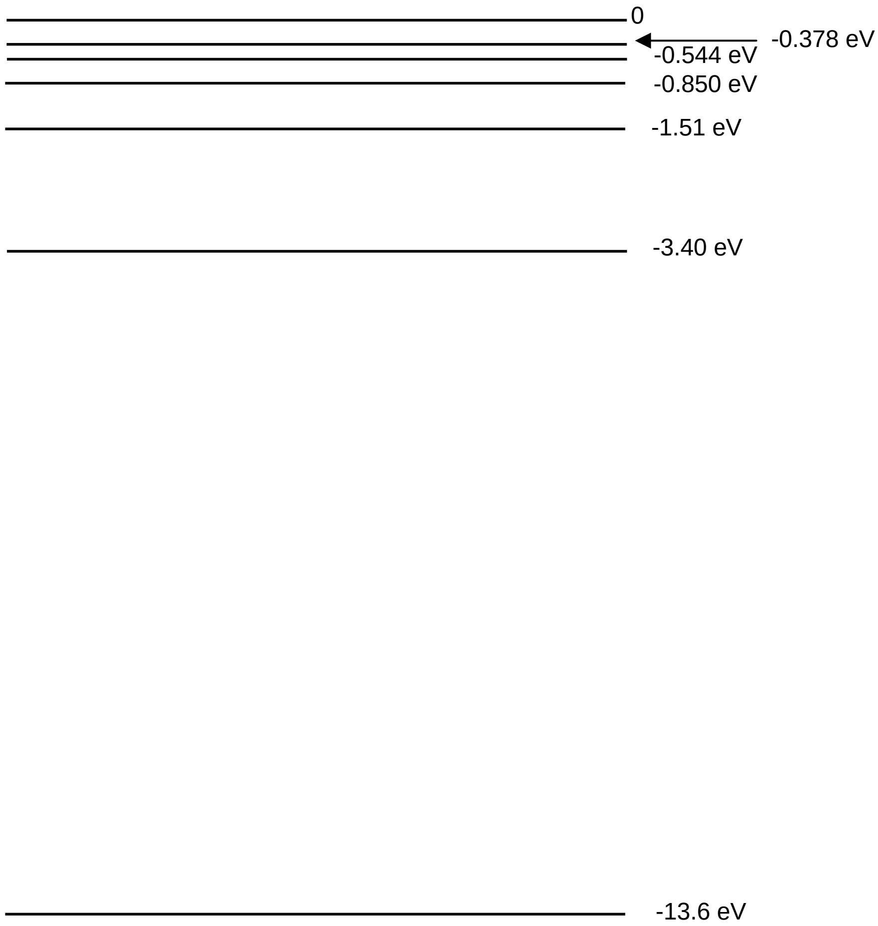

Fig. 8.1

`

(i) Calculate the minimum speed of an electron that could excite a hydrogen atom at ground state to an energy state of - 0.378 eV.

minimum speed = ... m s^{-1} [3]

(ii) A system of cold hydrogen gas is then excited to an energy state of - 0.378 eV by these electrons.

Sketch the pattern of visible line spectrum of hydrogen in Fig 6.2. This takes place when these excited atoms fall to the energy state of - 3.40 eV. Mark the red and violet ends of the spectrum.

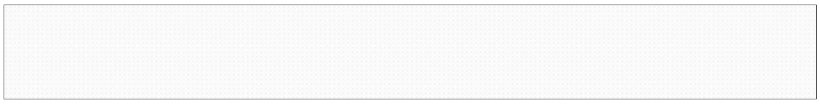

Fig. 8.2

[2]

(b) Fig. 8.3 is a graph showing the maximum kinetic energy E_k of electrons emitted from the sodium surface by light of different frequencies from a hydrogen light source.

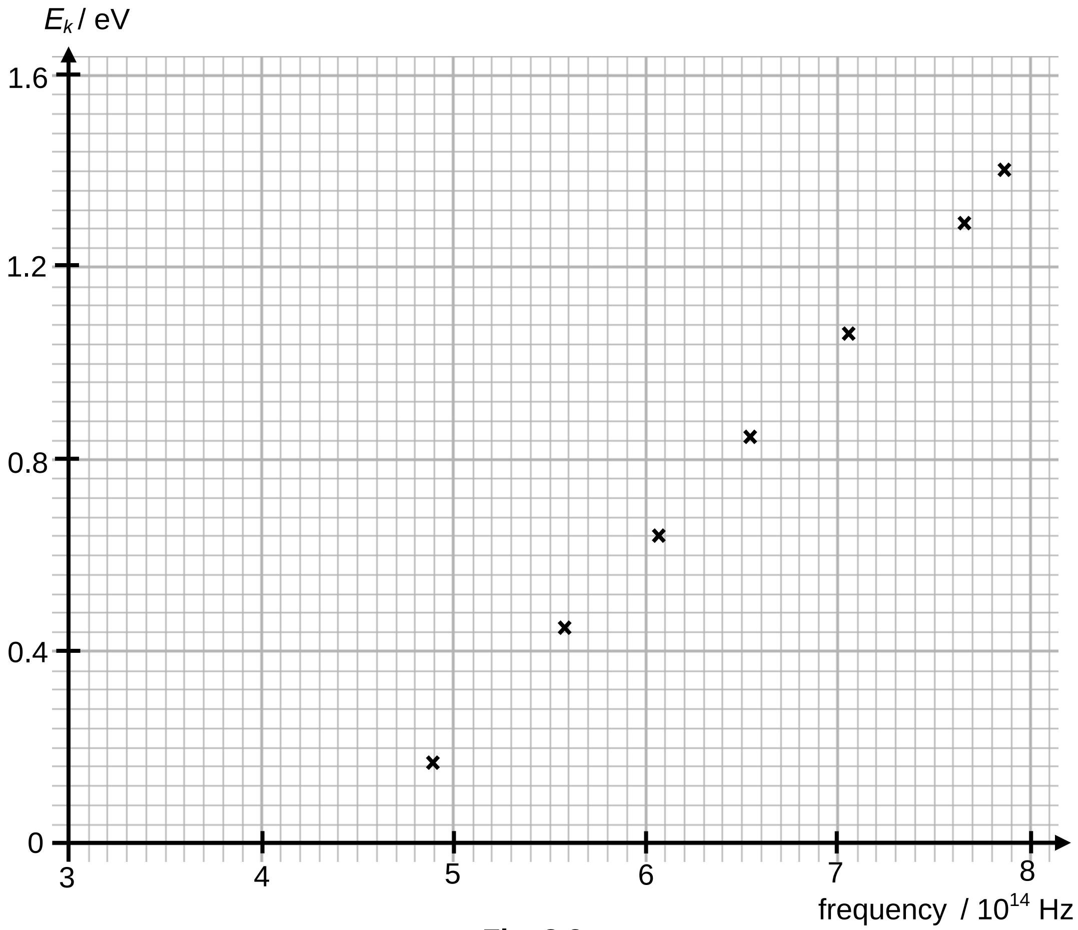

Fig. 8.3

Using Fig. 8.3,

(i) verify that the value of Planck constant is approximately 6.6 x 10^{-34} J s,

[2]

(ii) determine the work function of sodium,

work function = ... J [1]

(iii) state one feature of the graph that provides evidence for a particulate nature of electromagnetic radiation.

Explain how this evidence supports the particulate nature but contradicts the wave nature of electromagnetic radiation.

[3]

(c) A stationary nickel nucleus of mass 9.95×10^{-26} kg emits a photon of energy 1.20 MeV.

(i) Show that the wavelength of this photon is approximately 1.04×10^{-12} m. [1]

(ii) Calculate the momentum of this photon.

momentum = ………………… $kg\ m\ s^{-1}$ [1]

(iii) During this emission, explain using Newton's law(s) of motion why momentum is conserved.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

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

(iv) Calculate the speed of the nickel nucleus after the emission of the photon.

speed = ………………… $m\ s^{-1}$ [2]

(v) Suggest why these photons when incident on a metal surface can exert "radiation pressure".

[3]

End of paper