Name:		Centre/Index Number:		Class:	

DUNMAN HIGH SCHOOL
Preliminary Examination
Year 6

H2 PHYSICS — 9749/03

Paper 3 Longer Structured Questions

21 September 2023

2 hours

Candidates answer on the Question Paper

READ THESE INSTRUCTIONS FIRST

Write your centre number, index number, name and class at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer any **one** question.

The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	8
2	10
3	9
4	6
5	9
6	10
7	8
Section B	
8 / 9	20
Total	80

This document consists of **25** printed pages and **1** blank page.

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	=	ρgh
gravitational potential,	ϕ	=	$-Gm/r$
temperature,	T/K	=	T/°C + 273.15
pressure of an ideal gas,	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule,	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.,	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_0 \cos \omega t$
		=	$\pm\omega\sqrt{x_o^2 - x^2}$
electric current,	I	=	$Anvq$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current / voltage,	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire,	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil,	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid,	B	=	$\mu_0 nI$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1 A tritium nucleus moves towards a deuterium nucleus as illustrated in Fig. 1.1.

Fig. 1.1

The two nuclei initially have the same speed v and the interaction between the two nuclei is elastic. The tritium nucleus consists of two neutrons and a proton. The deuterium nucleus consists of a neutron and a proton. Assume that the proton and the neutron have the same mass m.

(a) State the *principle of conservation of momentum*.

....

....

....

.... [1]

(b) Explain why it is not possible for the nuclei to stop at the same instant.

....

....

....

....

.... [2]

(c) Determine the final velocities of each nucleus in terms of *v*.

final velocity of deuterium = ...

final velocity of tritium = ... [3]

(d) Given that the interaction between the two nuclei took a total time of *t* seconds, express the magnitude of the average force that the deuterium nucleus exerts on the tritium nucleus in terms of *m*, *v* and *t.*

magnitude of average force = ……................................ [2]

[Total: 8]

2 A 70.0 kg man standing on a platform makes a leap upwards with an initial speed of 2.00 m s^{-1} before falling towards a diving board that is located 1.50 m below the platform as shown in Fig. 2.1.

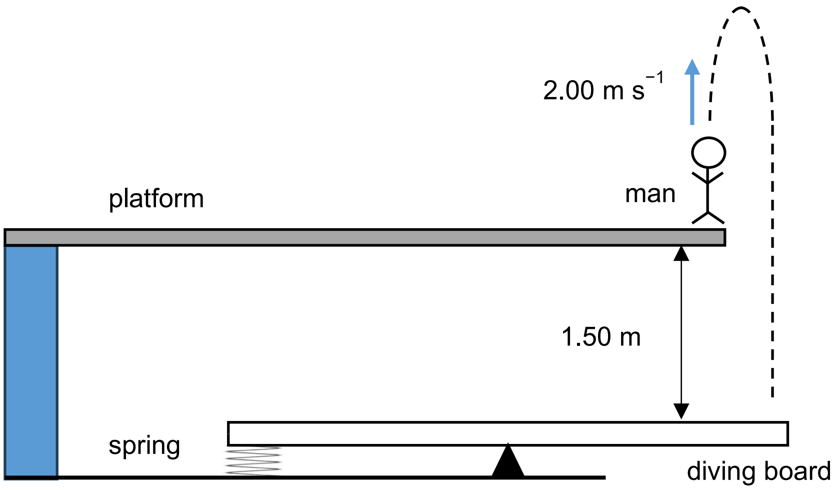

Fig. 2.1

(a) Calculate the loss in gravitational potential energy as the man falls from the platform to a point just before he hits the diving board.

loss in gravitational potential energy = ... J [1]

(b) Calculate the initial kinetic energy possessed by the man at the start of his jump.

initial kinetic energy = ... J [1]

(c) The uniform rigid diving board has a length 4.80 m and weight 300 N. It is pivoted at a point 2.40 m away from its left end and is attached to an unstretched spring with a force constant of 10.0 kN m^{-1} on one end.

When the man hits the diving board on the opposite end after jumping off the platform, the board rotates and causes the spring to stretch until the man comes to a momentary stop. At the instant that the man is momentarily at rest, the diving board makes an angle θ to the horizontal as shown in Fig. 2.2.

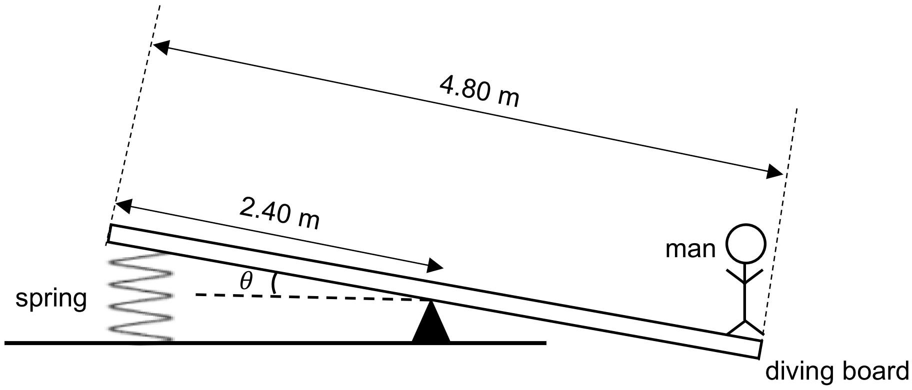

Fig. 2.2

(i) Explain why the weight of the diving board does not produce any moments at the pivot.

………………………………………………………………………………………………

………………………………………………………………………………………………

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

(ii) Show that the angle of tilt θ is 13.4°. Explain your workings and state any assumptions made.

[4]

(iii) Assuming that the spring only exerts a force vertically on the diving board, calculate the force exerted by the spring on the diving board.

force = ... N [1]

(iv) Calculate the magnitude of the normal contact force exerted by the pivot on the diving board.

magnitude of normal contact force = ... N [2]

[Total: 10]

3 The Earth may be assumed to be an isolated uniform sphere with its mass of 6.0×10^{24} kg concentrated at its centre.

A satellite of mass 1200 kg is in a circular orbit about the Earth in the Earth's gravitational field. The period of the orbit is 94 minutes.

(a) Define *gravitational field strength*.

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

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

(b) Calculate the radius of the orbit.

radius = ... m [3]

(c) Rockets on the satellite are fired so that the satellite enters a different circular orbit that has a period of 150 minutes.

(i) Show that the linear speed of the satellite in its new orbit is 6.6×10^3 m s^{-1}.

[3]

(ii) Determine the change in the potential energy of the satellite.

change in potential energy = ... J [2]

[Total: 9]

4 A cycle of changes in pressure, volume and temperature of gas inside the cylinder of a petrol engine is illustrated in Fig. 4.1. The gas is assumed to be ideal.

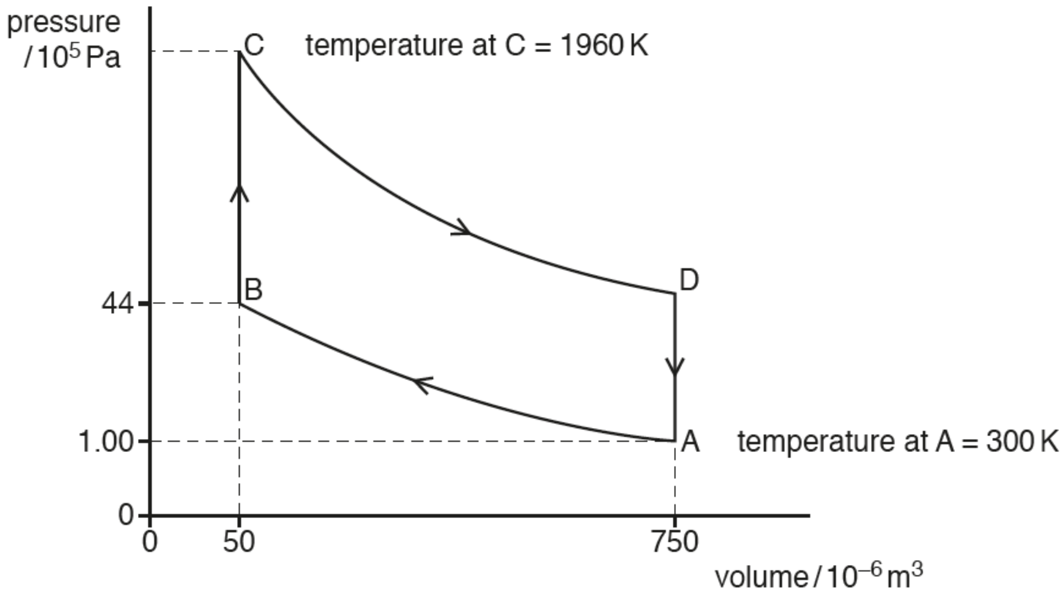

Fig. 4.1 (not to scale)

There are four stages in the cycle.

stage	description
A to B	Rapid compression of the gaseous petrol/air mixture with the temperature rising from 300 K at A and the pressure rising to 44×10^5 Pa at B.
B to C	The petrol/air mixture is exploded, resulting in an almost instant rise in pressure. At C the temperature has risen to 1960 K.
C to D	Rapid expansion and cooling of the hot gases.
D to A	Return to the starting point of the cycle.

(a) Explain what is meant by an *ideal gas.*

....

....

.... [1]

(b) Complete the table in Fig. 4.2 showing the work done on the gas, the heat supplied to the gas and the increase in the internal energy of the gas, during the four stages of one cycle.

stage	work done **on** gas /J	heat supplied **to** gas /J	**increase** in internal energy of gas / J
A to B	+ 360	0	
B to C	0	+ 670	
C to D		0	− 810
D to A			

Fig. 4.2 [3]

(c) Explain qualitatively how molecular movement causes the fall in temperature of the gas during the stage from C to D.

....

....

....

....

.... [2]

[Total: 6]

5 Fig. 5.1 shows the horizontal path of an electron travelling in a vacuum.

The electron leaves the electron gun with a constant speed v. The electron of mass m and charge e then enters a region of uniform magnetic field of flux density B.

The electron follows a circular path of radius r within the magnetic field.

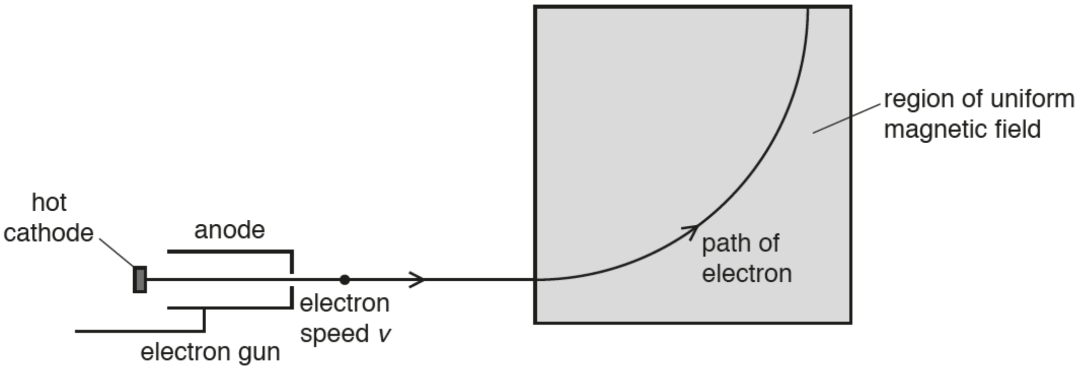

Fig. 5.1 (not to scale)

(a) **(i)** State the direction of the magnetic field.

.... [1]

(ii) Derive an expression for the speed of the electron in terms of B, e, r and m.

[2]

(b) The electron gun produces the electron by emission from the hot cathode. The electron is then accelerated from rest to speed v by the electric field between the anode and the cathode, where there is a potential difference of V.

(i) State the equation relating the gain in kinetic energy of the electron and the work done on it by the electric field.

[1]

(ii) The charge per unit mass of an electron e/m is called its specific charge. Its numerical value is 1.76×10^{11} C kg^{-1}.

Determine the radius of the circular path of an electron in Fig. 5.1 when the magnetic field has flux density 5.00 mT and the magnitude of the potential difference between the anode and the cathode is 576 V.

radius = ... m [3]

(c) Explain why the speed of the electron remains constant as it moves within the magnetic field.

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

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

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

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

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

[Total: 9]

6 **(a)** An alternating voltage of period 10 ms is being applied directly across a resistor of 5.0 Ω in a circuit. The variation with time t of voltage V is shown in Fig. 6.1.

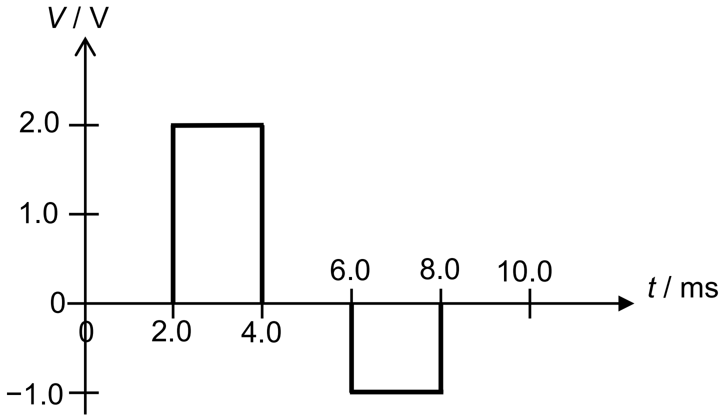

Fig. 6.1

Calculate the steady voltage that would produce an identical heating effect in the same resistor.

voltage = ... V [2]

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

....

....

....

....

.... [2]

(c) A sinusoidal voltage of 6.5 mV r.m.s. and 50 Hz is now connected to the primary coil of a transformer as shown in Fig. 6.2.

The transformer is assumed to be ideal and its turns ratio, $\frac{N_{\text{secondary}}}{N_{\text{primary}}}$ is 71.

The secondary coil is connected to a resistor *R*.

An average power of 0.040 W is produced in resistor *R*.

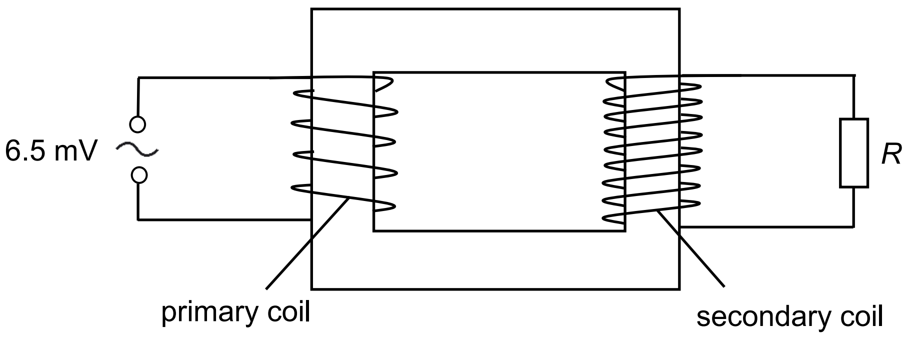

Fig. 6.2

(i) Calculate the r.m.s output voltage supplied to resistor *R*.

r.m.s. voltage = ... V [1]

(ii) In Fig. 6.3, sketch the variation with time *t* of the power *P* dissipated in the resistor *R.* Label all values on the axes.

Fig. 6.3

[2]

(iii) An ideal diode is now connected to the secondary coil with resistor *R* as shown in Fig. 6.4.

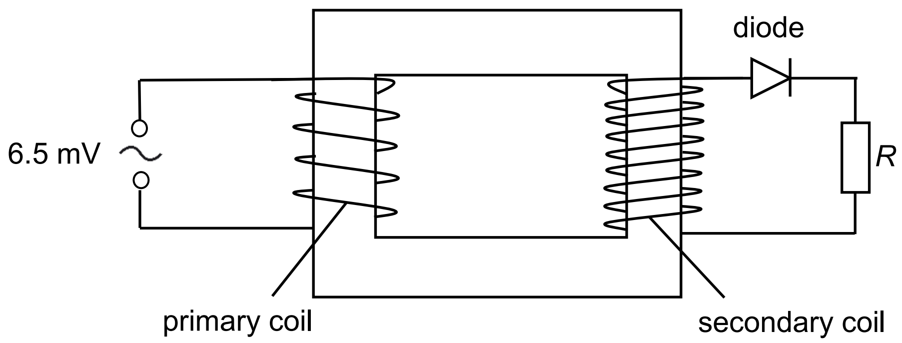

Fig. 6.4

Describe the variation with time of the

1. current flow through resistor *R*, and

....

....

....

.... [2]

2. voltage across resistor *R*.

....

....

.... [1]

[Total: 10]

7 **(a)** Describe the structure of an atom of ${}^{235}_{92}\text{U}$.

....

....

.... [2]

(b) The deflection of α-particles by a thin metal foil is investigated with the arrangement shown in Fig. 7.1. All the apparatus is enclosed in a vacuum.

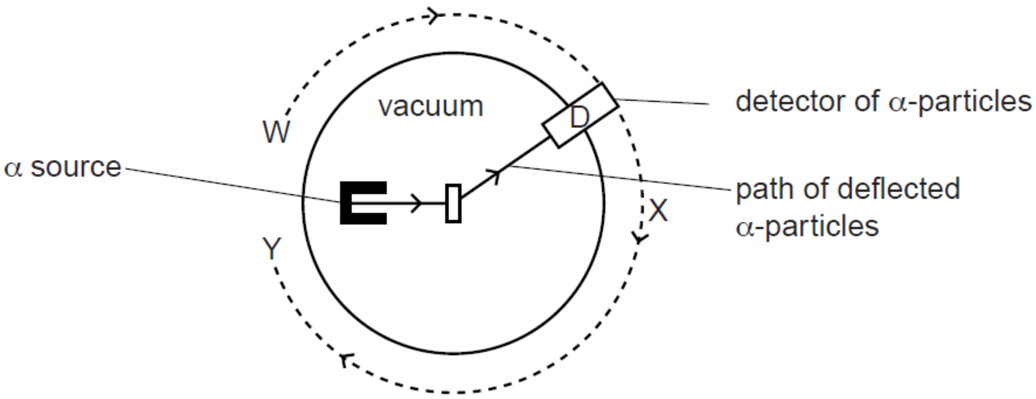

Fig. 7.1

The detector of α-particles, D, is moved around the path labelled WXY.

(i) Explain why the apparatus is enclosed in a vacuum.

....

.... [1]

(ii) State and explain the readings detected by D when it is moved along WXY.

....

....

....

....

....

.... [3]

(c) A beam of α-particles produces a current of 1.5 pA. Calculate the number of α-particles per second passing a point in the beam.

number = ... s^{-1} [2]

[Total: 8]

Section B

Answer **one** question from this section in the spaces provided.

8 **(a)** A source of sound has frequency *f*. Sound of wavelength λ is produced by the source.

(i) State

1. what is meant by the *frequency* of the source,

....

.... [1]

2. the distance moved, in terms of λ, by a wavefront during *n* oscillations of the source.

distance = ... [1]

(ii) Hence derive an expression for the speed *v* of the wave in terms of *f* and λ.

[2]

(b) The waveform of a sound wave produced on the screen of a cathode ray oscilloscope (c.r.o.) is shown in Fig. 8.1.

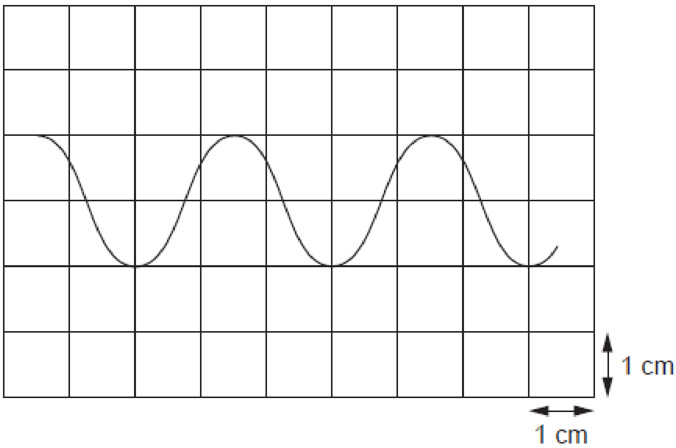

Fig. 8.1

The time base setting of the c.r.o is 2.0 ms cm^{-1}.

Determine the frequency of the sound wave.

frequency = ... Hz [2]

(c) Microwaves of the same amplitude and wavelength are emitted in phase from two coherent sources P and Q. The sources are arranged as shown in Fig. 8.2.

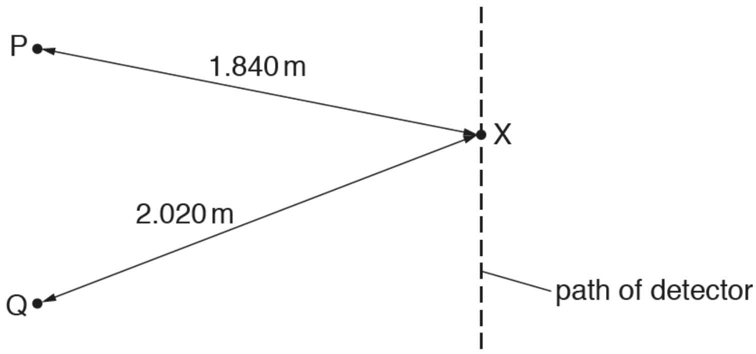

Fig. 8.2

A microwave detector is moved along a path that is parallel to the line joining P and Q. A series of intensity maxima and minima are detected.

When the detector is at point X, the distance PX is 1.840 m and the distance QX is 2.020 m. The microwaves have a wavelength of 6.0 cm.

(i) State what is meant by *coherent sources.*

....

.... [1]

(ii) Calculate the frequency of the microwave.

frequency = ... Hz [2]

(iii) Describe and explain the intensity of the microwaves detected at X.

....

....

....

....

....

.... [3]

(iv) The wavelength of the microwaves is then decreased.

Describe the effect on the interference pattern along the path of the detector.

....

....

.... [1]

(d) Red and green light of wavelengths 640 nm and 520 nm respectively are simultaneously directed through a narrow slit on to a diffraction grating. The grating is perpendicular to the light and has a line spacing of 1.60 μm.

(i) Complete Fig.8.3 by calculating the values of all the angles of maxima for both colours. Indicate **nil** if there are no maxima detected.

order, *n*	**angle for red maximum / °**	**angle for green maximum / °**
0	0	0
1		
2		
3		
4		

[4]

Fig. 8.3

(ii) The grating is replaced with a double slit of the same spacing. Describe and explain how the new pattern produced differs from the one for the diffraction grating.

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

[Total: 20]

9 **(a)** State what is meant by a *photon*.

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

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

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

(b) It has been observed that, where photoelectric emission of electrons takes place, there is negligible time delay between illumination of the surface and emission of an electron.

State three other pieces of evidence provided by the photoelectric effect for the particulate nature of electromagnetic radiation.

1. ………………………………………………………………………………………………...

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

2. ………………………………………………………………………………………….........

………………………………………………………………………………………………

3. ………………………………………………………………………………………………

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

(c) The work function energy of a metal surface is 3.5 eV. Light of wavelength 450 nm is incident on the surface.

Determine whether electrons will be emitted, by the photoelectric effect, from the surface.

[3]

(d) When free electrons collide with atoms in their ground state, the atoms can be excited or ionised.

(i) State what is meant by *ground state*.

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

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

(ii) Explain the difference between *excitation* and *ionisation*.

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

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

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

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

(e) An atom can also become excited by the absorption of photons. Explain why only photons of certain frequencies can cause excitation in a particular atom.

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

(f) Fig. 9.1 shows five electron energy levels in an atom and some transitions between them.

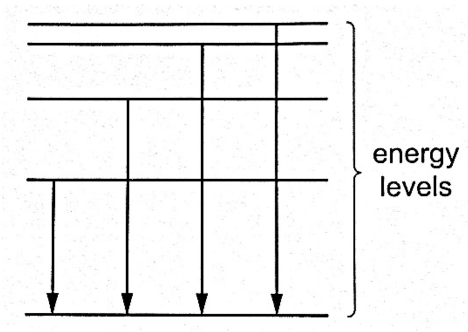

Fig. 9.1

The line spectrum produced is in the visible region of the electromagnetic spectrum.

Sketch, on Fig. 9.2, the line emission spectrum that corresponds to the four energy level changes, assuming that the energy levels are drawn roughly to scale.

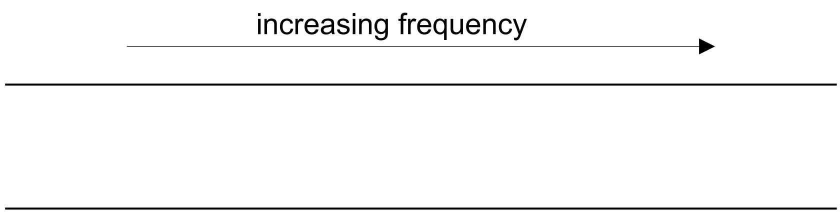

Fig. 9.2

[2]

(g) Ernest Rutherford proposed a planetary model for the hydrogen atom. In the model, a single electron is treated as a point-like charged particle, moving in a circular orbit around a stationary proton (the nucleus) as shown in Fig. 9.3.

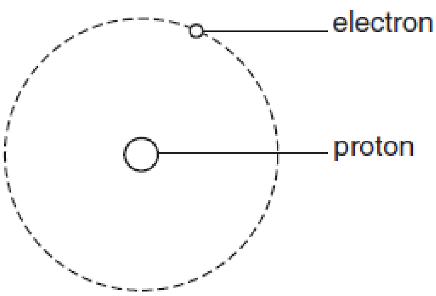

Fig. 9.3

Rutherford's planetary model allows any size for the electron orbits, but quantum theory puts a lower limit on the size of the hydrogen atom. To understand why this is the case, we can use the Heisenberg uncertainty principle for position and momentum.

$$\Delta p \Delta x \geq h$$

Δp is the uncertainty in the (x-component) of momentum of the electron, and Δx is the uncertainty in the (x-component) of the position of the electron.

(i) State the changes in Δp and Δx when the atom is made smaller by reducing the radius of the electron orbit.

....

.... [1]

(ii) Explain how the change in Δp affects the kinetic energy of the orbiting electron.

....

....

....

.... [2]

(iii) By considering your answers to **(g) (ii)**, explain why there is a minimum radius for an electron orbit in the hydrogen atom.

....

....

.... [1]

[Total: 20]

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