Name:		Centre/Index Number:		Class:	

DUNMAN HIGH SCHOOL
Preliminary Examination
Year 6

H2 PHYSICS 9749/03

Paper 3 Longer Structured Questions

18 September 2024

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	10
2	7
3	11
4	11
5	11
6	10
Section B	
7 / 8	20
Total	80

This document consists of **25** printed pages and **3** blank pages.

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)** State the two conditions necessary for the equilibrium of a body acted upon by a number of forces.

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

………

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

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

(b) A ***non-uniform*** beam of mass 20 kg and length 5.0 m is supported by a cable and hinged to the wall as shown in Fig. 1.1. The beam supports a mass of 5.0 kg at one end and is in equilibrium.

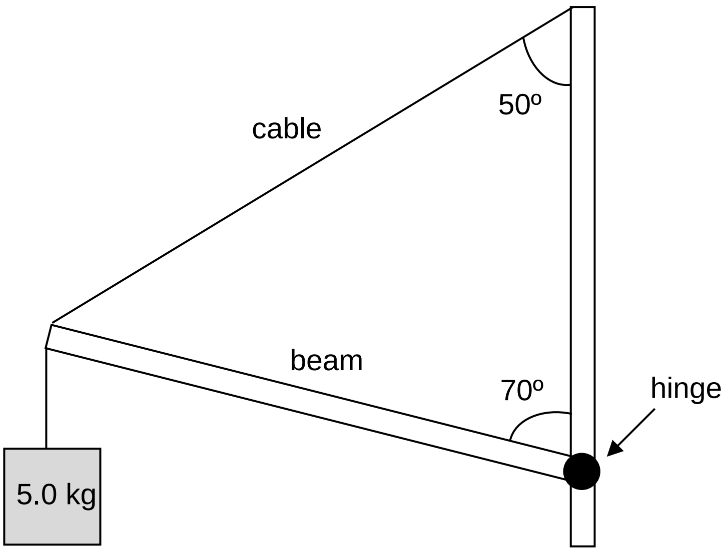

Fig. 1.1

(i) On Fig. 1.1, draw a free body diagram of the forces acting on the beam. [2]

(ii) If the tension in the cable is 120 N, calculate the position of the centre of gravity of the beam from the hinge.

centre of gravity = ……………………………… m [2]

(iii) Calculate the magnitude and direction of the force acting by the wall on the beam.

force = …………………………….. N

direction = ……………………………………with the beam [4]

[Total: 10]

2 A metal ball of mass 50 g travels in a horizontal circle of radius 10 cm around a smooth cone as shown by Fig 2.1. The metal ball makes 3.0 revolutions every second.

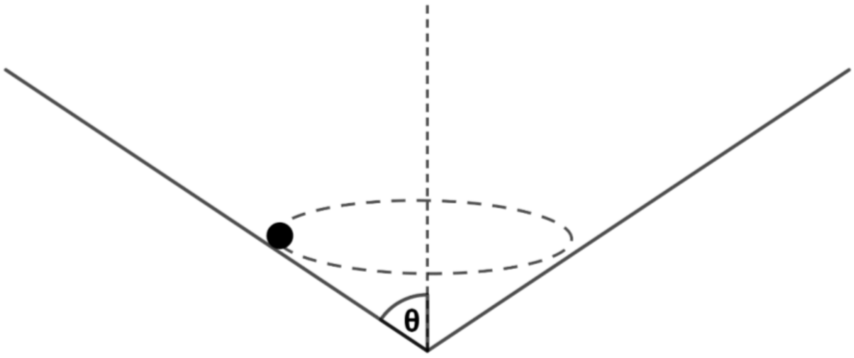

Fig. 2.1

(a) Explain why the metal ball in uniform circular motion is said to experience an acceleration.

....

....

....

.... [2]

(b) **(i)** Show that

$$\tan\theta = \frac{g}{r\omega^2}$$

where θ is shown in Fig. 2.1, r is the radius of the horizontal circle and ω is the angular velocity of the metal ball.

[2]

(ii) Hence determine θ.

θ = ………………………… ° [2]

(c) The angular velocity ω of the metal ball is now increased.

Sketch, on Fig. 2.2, a graph to show the variation with angular velocity ω, of the radius r of the horizontal circle of the metal ball around the cone.

Fig. 2.2

[1]

[Total: 7]

3 A scuba diver releases an air bubble, of diameter 3.0 cm from a depth of 14 m below the sea level. The air is assumed to behave like an ideal gas and the temperature of the water is constant at 25°C.

(a) (i) Explain how molecular movement of the gas molecules inside the air bubble causes pressure exerted by the gas.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

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

(ii) Given that the pressure at a depth of 14 m below the surface is 2.4×10^5 Pa, and the density of water is 1000 kg m^{-3}.

Calculate the volume of the air bubble when it reaches the surface of the water.

volume of air bubble = ………….………………… m^3 [2]

(b) **(i)** State the *First Law of Thermodynamics*.

……………………………………………………………………………….……………

……………………………………………………………………………….……………

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

(ii) State and explain whether heat is added or removed from the air bubble as the bubble rises.

……………………………………………………………………….……….…………

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

(c) State and explain how the pressure of the air bubble differs if the gas does not behave as an ideal gas.

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

……………………………………………………………………………………… [2]

[Total: 11]

4 Mr Tan is studying a water wave in which all the wavefronts are parallel to one another. The variation with time t of the displacement x of a particular particle in the wave is shown in Fig. 4.1.

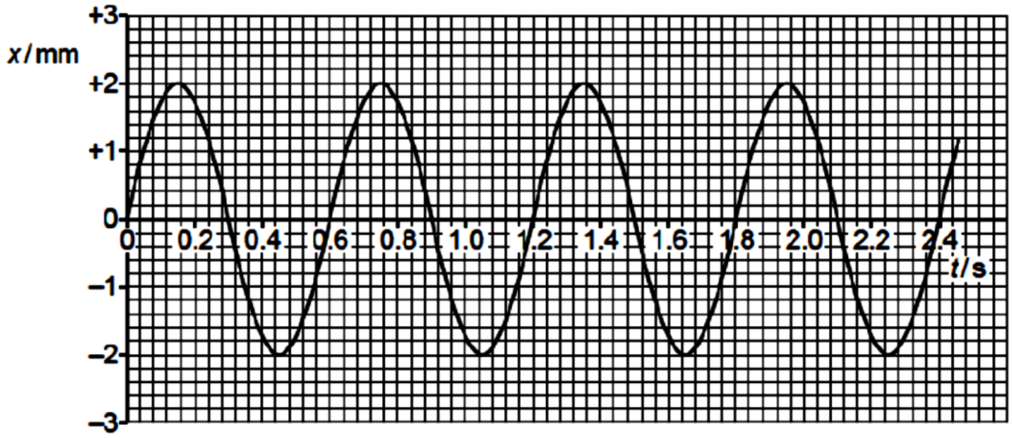

Fig. 4.1

The distance d of the oscillating particles from the source of the waves is measured.

At a particular time, the variation of the displacement x with this distance d is shown in Fig. 4.2.

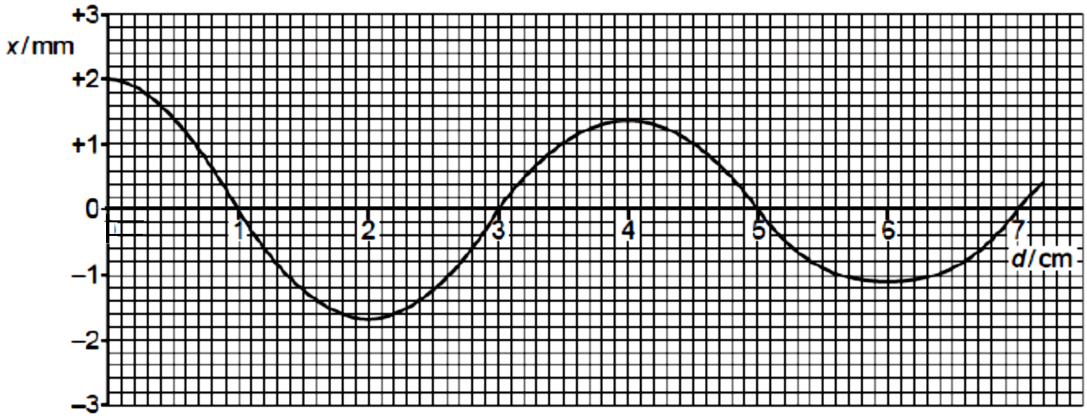

Fig. 4.2

(a) **(i)** Use Figs. 4.1 and 4.2 to state and explain whether the wave is losing power as it moves away from the source.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(ii) Determine the ratio $\frac{\text{intensity of the wave at source}}{\text{intensity of wave 6.0 cm from source}}$

ratio = ………………… [2]

(b) A beam of plane-polarised light of intensity I_o is incident on an ideal polariser. This polariser is rotated so that its polarising axis makes an angle θ with the plane of polarisation of the incident beam.

(i) State an expression for the intensity I of the light transmitted by the polariser.

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

(ii) On Fig. 4.3, sketch a labelled graph to show the variation with angle θ of the intensity I when the polariser is rotated through 360°.

Fig. 4.3

[2]

(iii) Fig. 4.4 shows two ideal polarisers A and B placed parallel to each other.

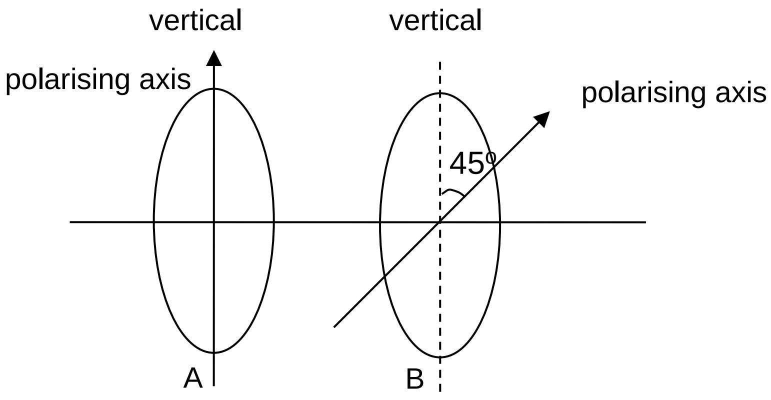

Fig. 4.4

1. Vertically polarised light of intensity I_o enters both polarisers, passing through in the direction from A to B. Determine the intensity I_{AB} of the light emerging from B.

I_{AB} = ………………… I_o [2]

2. The vertically polarised light of intensity I_o now enters both polarisers from the other side, passing through in the direction from B to A. Calculate the intensity I_{BA} of the light emerging from A.

I_{BA} = ………………… I_o [2]

[Total: 11]

5 An ideal transformer is shown in Fig. 5.1.

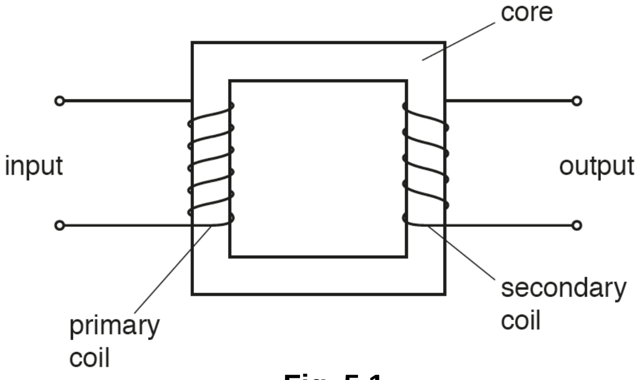

Fig. 5.1

(a) Explain why the core is

(i) made of soft iron,

………………………………………………………………………………………………

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

(ii) laminated.

………………………………………………………………………………………………

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

(b) Use Faraday's law to explain the operation of the transformer.

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

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

(c) A varying e.m.f. is connected to the input of the transformer and produces a current in the primary coil as shown in Fig 5.2.

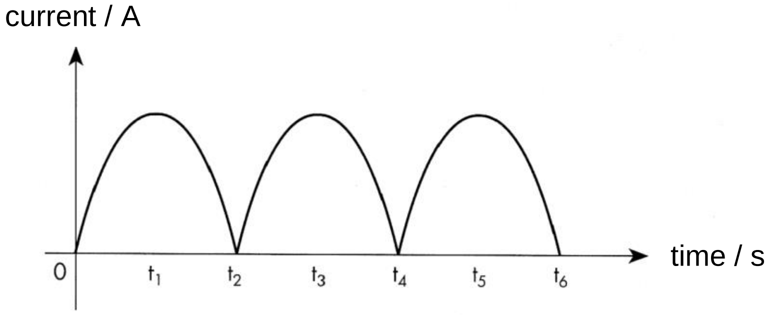

Fig. 5.2

(i) On Fig. 5.3, sketch a graph to show the variation with time of the magnetic flux produced by the current in the primary coil. The graph should extend from $t = 0$ to $t = t_6$.

Fig. 5.3 [1]

(ii) On Fig. 5.4, sketch a graph to show the variation with time of the e.m.f. induced across the secondary coil. The graph should extend from $t = 0$ to $t = t_6$.

Fig. 5.4 [1]

(iii) State and explain how the e.m.f. induced across the secondary coil is affected by

1. the number of turns in the primary coil,

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

2. the number of turns in the secondary coil.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

[Total: 11]

6 Radioactive decay is a *random* and *spontaneous* process.

(a) Explain what is meant by

(i) a random process,

……………………………………………………………………………………………

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

(ii) a spontaneous process.

……………………………………………………………………………………………

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

(b) Fig 6.1 illustrates the use of β-radiation to monitor the thickness of a sheet of aluminium foil. The output from the detector controls the separation of the rollers with the intention to maintain a constant foil thickness.

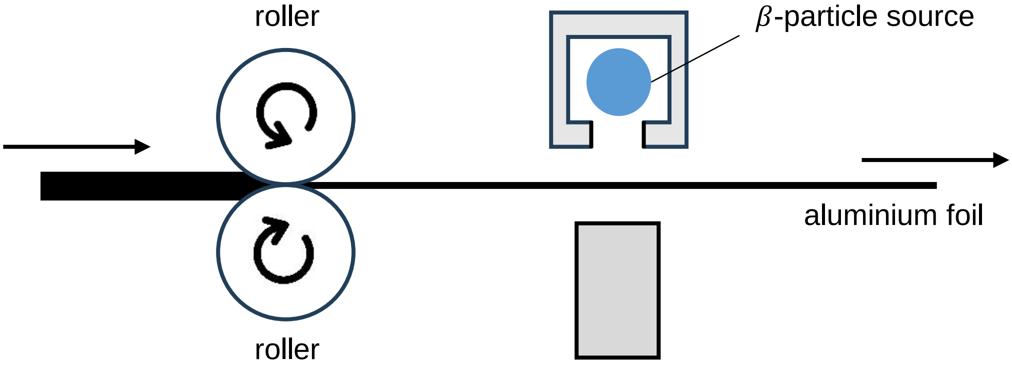

Fig. 6.1

The setup in Fig 6.1 is then installed with a β-radiation source of half-life 14 days and then used for a working day of 8.0 hours.

(i) Suggest and explain why a β-radiation source was used for monitoring changes instead of a γ-radiation source.

....

....

.... [2]

(ii) Determine the decay constant of the β-radiation source.

decay constant = ... s^{-1} [2]

(iii) Determine the ratio $\dfrac{\text{activity of source at end of working day}}{\text{activity of source at start of working day}}$

ratio = ... [2]

(iv) Due to an error, the set up was programmed to maintain a constant foil thickness based on the detector output at the start of the working day without making any allowance for radioactive decay.

With reference to your answer in **(b)(ii)**, state and explain the changes in foil thickness at the end of one working day.

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

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

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

[Total: 10]

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Section B

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

7 **(a)** Fig. 7.1 is a graph showing the variation with distance of the displacement of particles in a standing wave, at the instant when the displacement is a maximum.

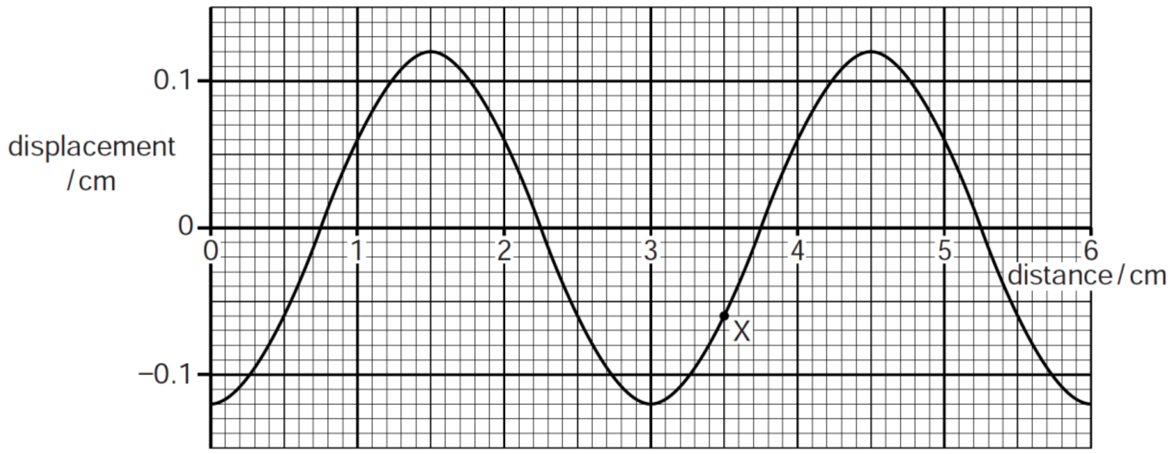

Fig. 7.1

The position of particle X is shown on the wave.

(i) On Fig. 7.1, mark the position of any particle which is π radians out of phase with particle X. Label it O. [1]

(ii) On Fig. 7.1, draw an arrow from particle X showing the direction of its instantaneous acceleration. [1]

(iii) Use the information in Fig. 7.1 to determine the distance moved by particle X during half a cycle.

distance = ……………………………… cm [1]

(b)

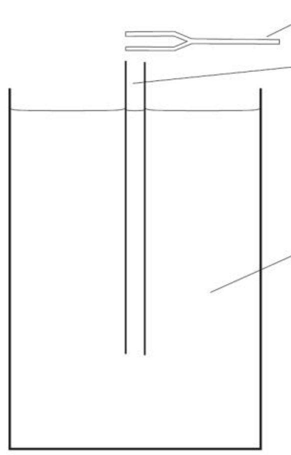

Fig. 7.2

A tube that is open at both ends is placed in a deep tank of water as shown in Fig. 7.2. A tuning fork of frequency 256 Hz is sounded continuously above the tube. The tube is slowly raised out of the water. At one position of the tube, a maximum loudness of sound is heard. The tube is gradually raised from a position of maximum loudness until the next position of maximum loudness is reached. The length of the tube above the water surface is increased by 65.0 cm.

Determine the speed of sound in air of the tube.

speed = ………………………………… m s^{-1} [2]

(c) A laser pointer is placed behind a glass microscope slide that has been painted black. A single vertical slit of width 0.0800 mm has been produced by scratching through the paint with a razor blade.

Light from the laser, of wavelength 633 nm, passes through the slit and hits a wall at 5.12 m from the slit. A light sensor connected to a data logger is moved across the wall and the variation with distance moved by the sensor of the intensity of light is shown in Fig. 7.3.

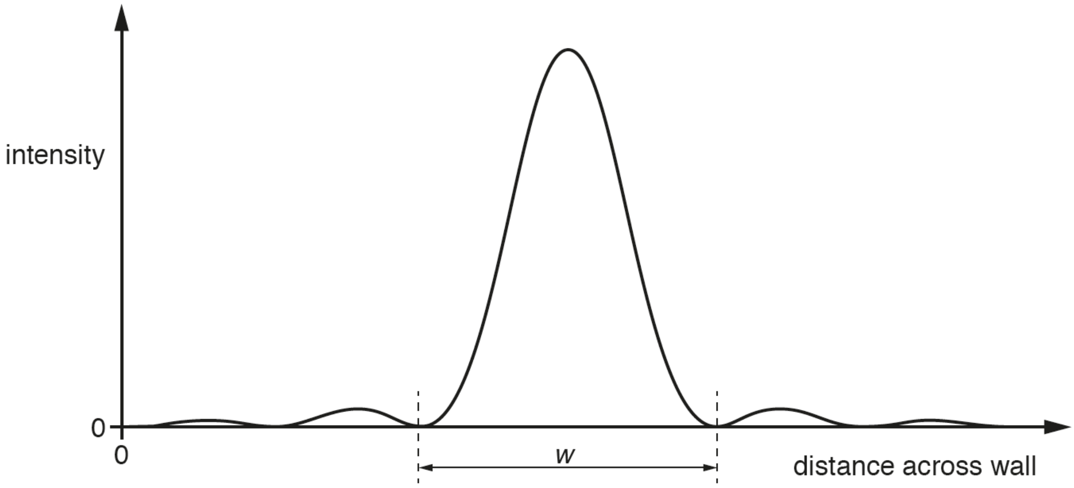

Fig. 7.3

The width *w* of the central patch is equal to the distance between the two minimum points on either side of the central patch where the intensity of the light is equal to zero.

(i) Determine *w*.

w = ………………………………… m [2]

(ii) A second vertical slit of width 0.0800 mm is scratched across the slide. The second slit is parallel to the first and its centre is a horizontal distance of 0.240 mm away from the centre of the first slit.

The slide now acts as a double slit. At the centre of the double-slit interference pattern on the wall, there are bright and dark fringes which are uniformly spaced.

1. Some parts of the screen that were brightly lit when only the first slit was present are now dark, even though the light is still passing through the first slit in the same way.

Explain what causes this to happen.

……………………………………………………………………………………………

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

2. Determine the separation *x* of the bright fringes.

x = ………………………………. m [2]

3. Most of the bright fringes are separated from adjacent bright fringes by a distance *x*. In a few places, away from the centre, however, there are separations of 2*x* and there is no light in the middle of the gap where a bright fringe might be expected.

Using the results from **(c)(i)** and **(c)(ii)2**, explain why there is no light at such places.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(d) The same laser pointer is now incident normally on a diffraction grating as shown in Fig. 7.4.

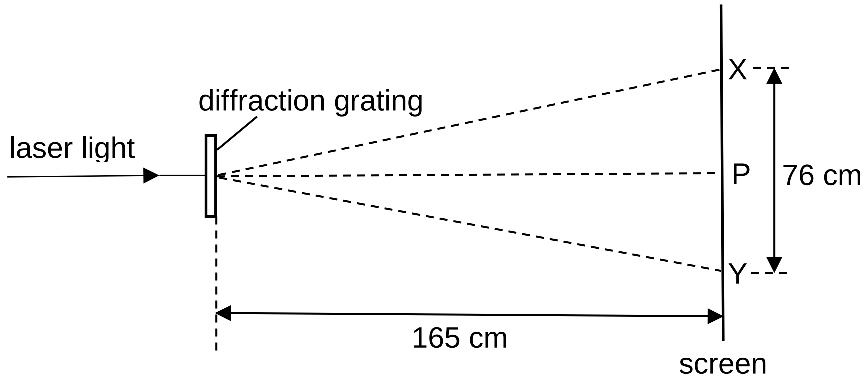

Fig. 7.4

Spots of light are observed on a screen placed parallel to the grating. The distance between the grating and the screen is 165 cm.

The brightest spot is P. The spots formed closest to P and on each side of P are X and Y. X and Y are separated by 76 cm.

(i) Calculate the number of lines per metre on the grating.

number per metre = …………………. [3]

(ii) Light of wavelengths 633 nm and 638 nm is now incident normally on the grating. Two lines are observed in the first order spectrum and two lines are observed in the second order spectrum, corresponding to the two wavelengths.

State two differences between the first order spectrum and the second order spectrum.

1 ……………………………………………………………………………………

……………………………………………………………………………………

2 ……………………………………………………………………………………

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

(e) The grating in **(d)** is now rotated about an axis parallel to the incident light, as shown in Fig. 7.5.

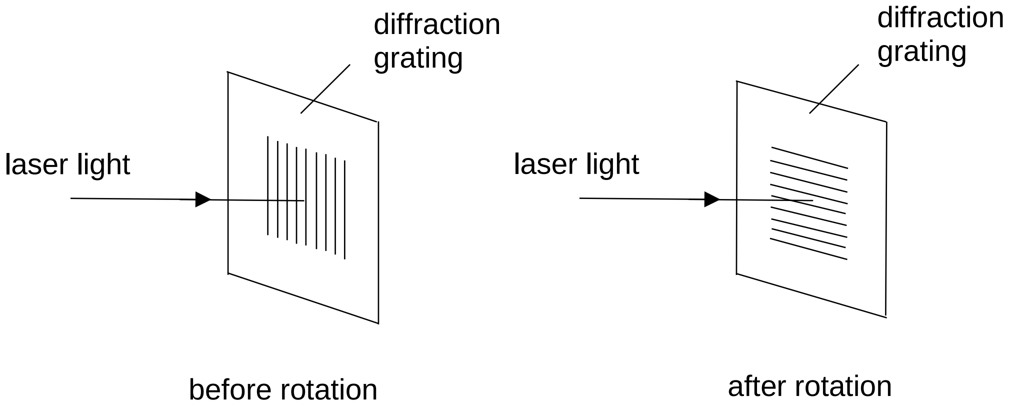

Fig. 7.5

(i) State what effect, if any, this rotation will have on the positions of the spots P, X and Y.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(ii) In another experiment using the apparatus in **(d)**, it was noticed that the distances XP and PY, as shown in Fig. 7.4, are not equal. Suggest a reason for this difference.

…………………………………………………………………………………………………

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

[Total: 20]

8 **(a)** State one similarity and one difference between a gravitational field and an electric field.

similarity: ……………………………………………………………………………………………

……………………………………………………………………………………………………

difference: ……………………………………………………………………………………………

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

(b) Three particles A, B and C are each placed in a different type of field. Complete Fig. 8.1 to identify the type of the field in which each particle is situated. [3]

particle	charge on particle	initial direction of motion of particle	direction of force on particle	type of field
A	neutral	stationary	in the direction of field	
B	negative	along direction of field	opposite to direction of field	
C	positive	normal to direction of field	normal to direction of field	

Fig. 8.1

(c) Fig. 8.2 shows some equipotential lines around Mars. The mass of Mars is 6.4×10^{23} kg and the radius of Mars is 3.4×10^{6} m.

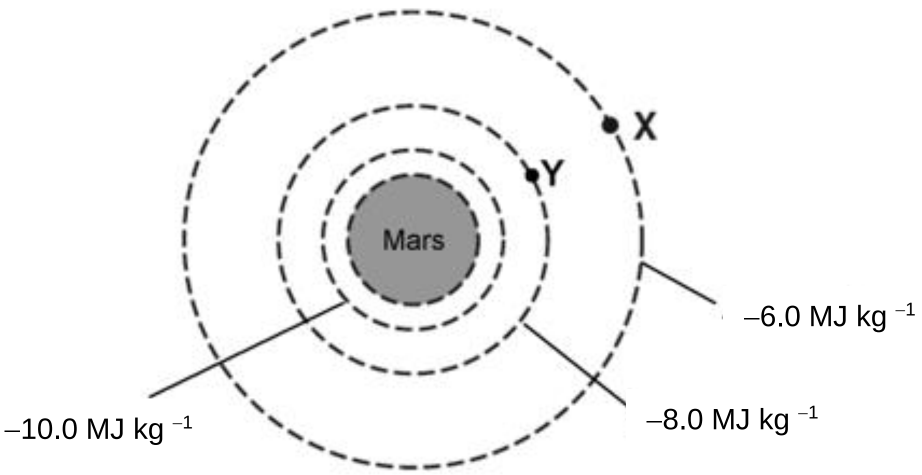

Fig. 8.2

(i) Define *gravitational potential* at a point.

……………………………………………………………………………………………………

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

(ii) Explain how Fig. 8.2 shows that the gravitational field strength decreases as the distance from the surface of the planet increases.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

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

(iii) A spacecraft at point X drops a satellite, of mass 90 kg, from rest onto the surface of the planet. Calculate the velocity of the satellite when it reaches point Y.

velocity = …………………………………. m s^{-1} [3]

(d) In Rutherford's α-particle scattering experiment, an α-particle approaches a stationary gold ($^{197}_{79}Au$) nucleus.

(i) Explain why gravitational potential has a negative value, whereas electric potential can be positive or negative.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

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

(ii) Without any calculations, suggest why in an α-particle scattering experiment gravitational effects are ignored.

…..……………………………………………………………………………………….

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

(iii) Calculate the electric potential due to the gold nucleus at a distance of 2.6×10^{-12} m from its centre. State any assumptions you make.

electric potential = ………………………………….. V

assumptions: ……………………………………………………………………….

……………………………………………………………………………….. [3]

(iv) For an α-particle approaching the stationary gold nucleus head-on, sketch the electric field lines between the α-particle and gold nucleus at the point of closest approach, in Fig. 8.3 below.

Fig. 8.3

[3]

[Total: 20]

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