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_0 =	$4\pi \times 10^{-7}$ 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	=	$-Gm/r$
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.

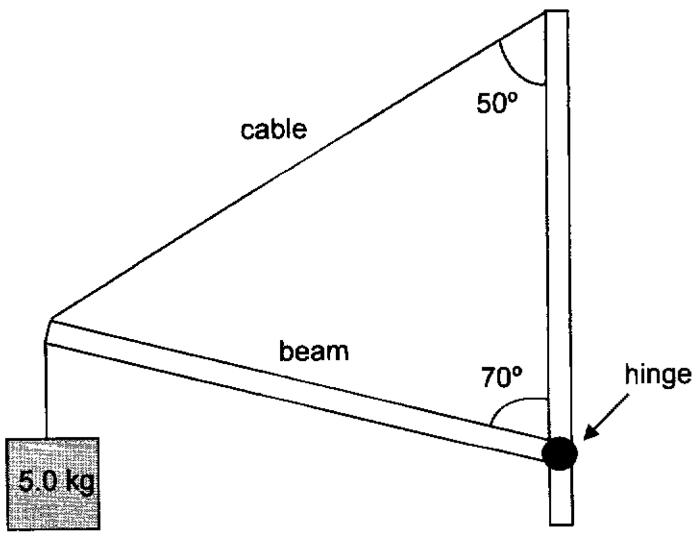

Fig. 1.1

(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.

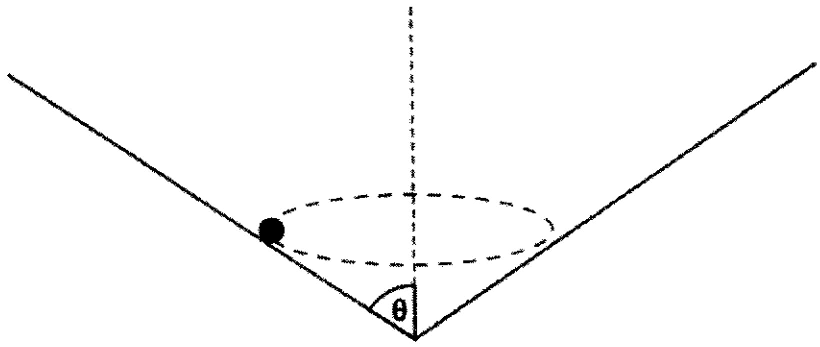

Fig. 2.1

(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.

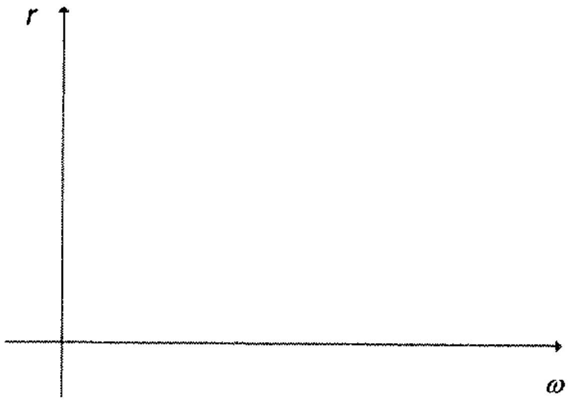

Fig. 2.2

[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.

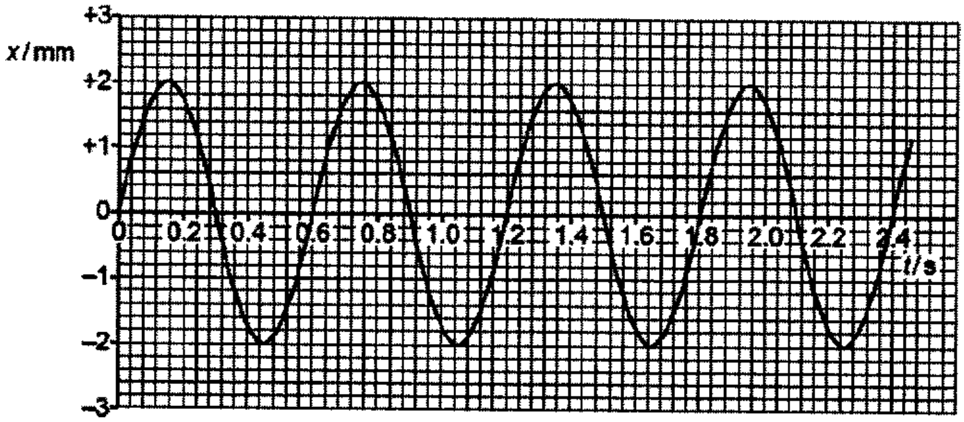

Fig. 4.1

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.

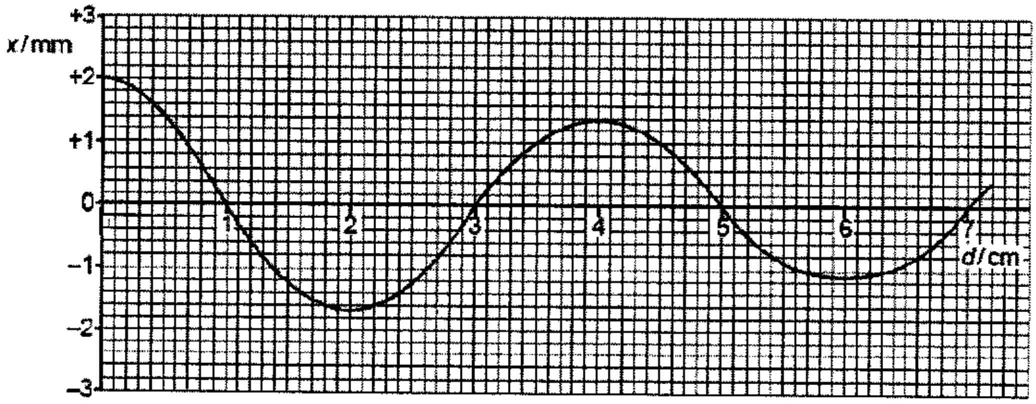

Fig. 4.2

(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 $\dfrac{\text{intensity of the wave at source}}{\text{intensity of wave 6.0 cm from source}}$

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°.

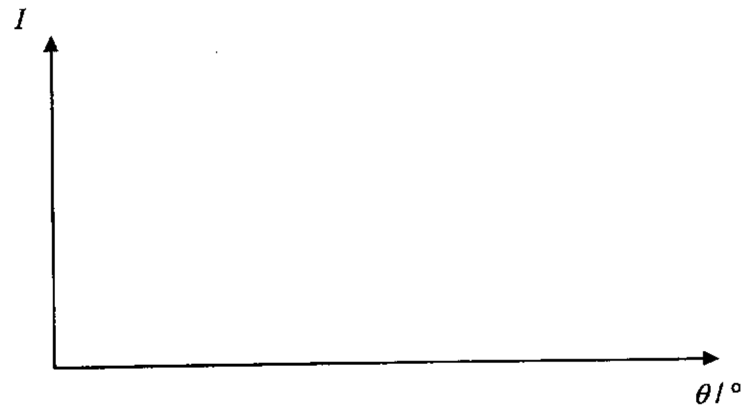

Fig. 4.3

[2]

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

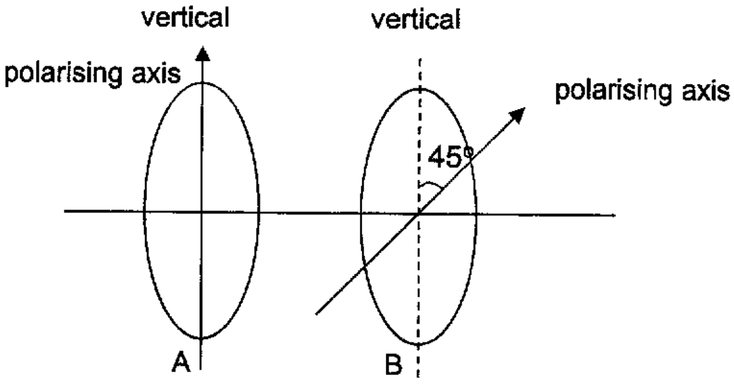

Fig. 4.4

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.

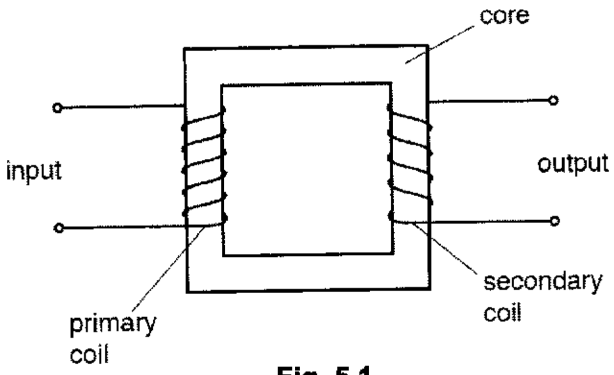

Fig. 5.1

(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.

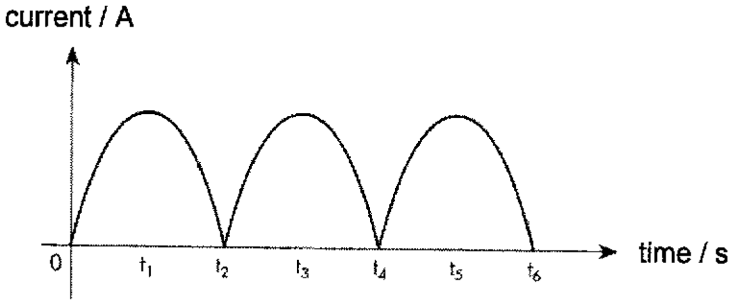

Fig. 5.2

(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 $t = t_6$.

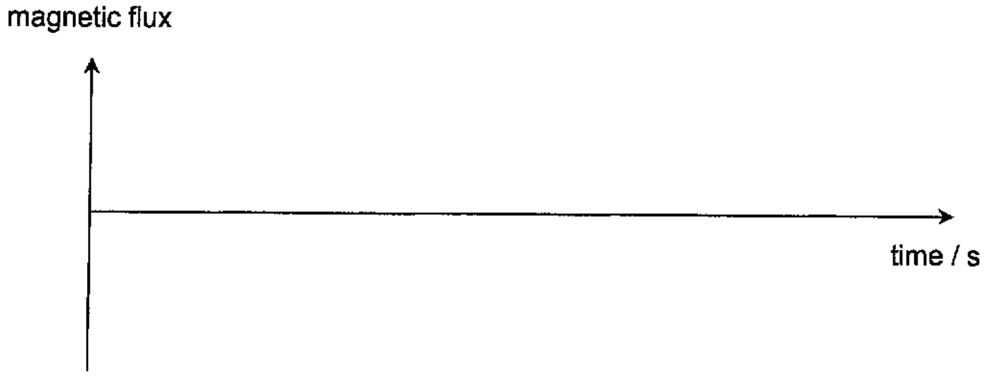

Fig. 5.3 [1]

(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 $t = t_6$.

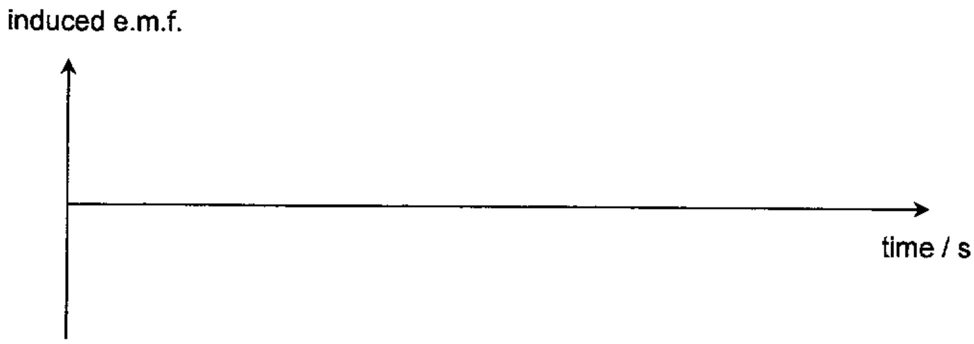

Fig. 5.4 [1]

(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.

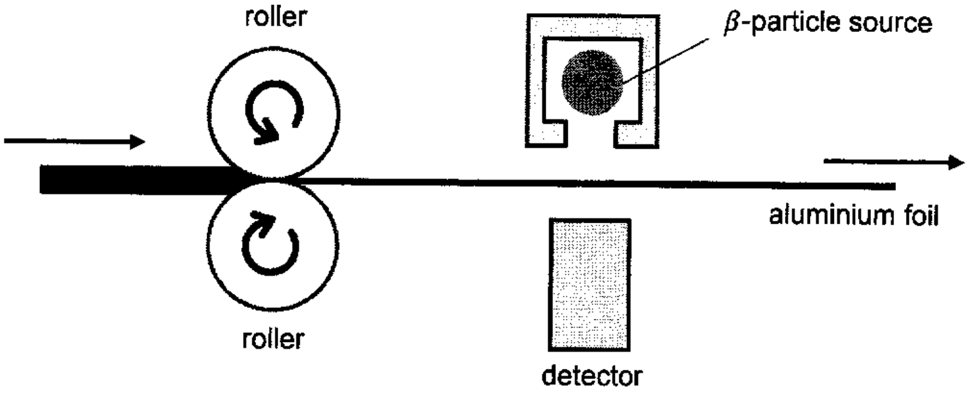

Fig. 6.1

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.

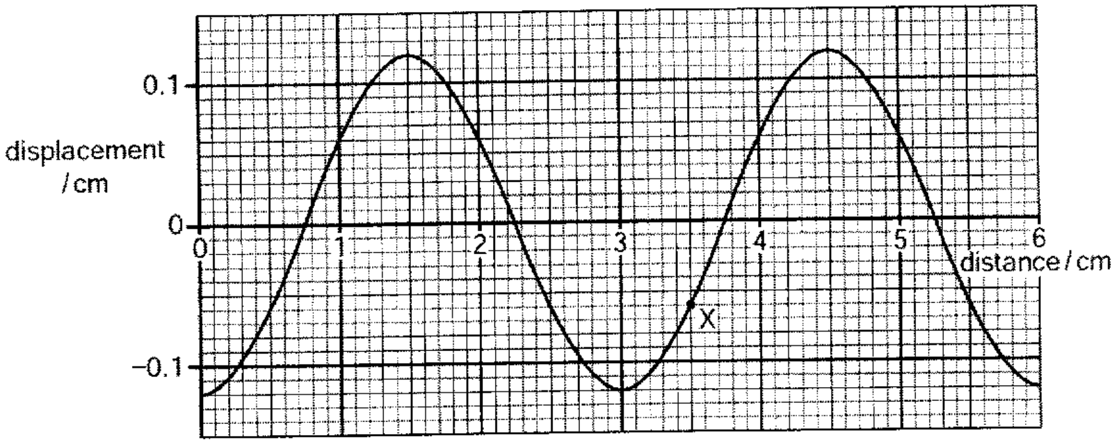

Fig. 7.1

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)

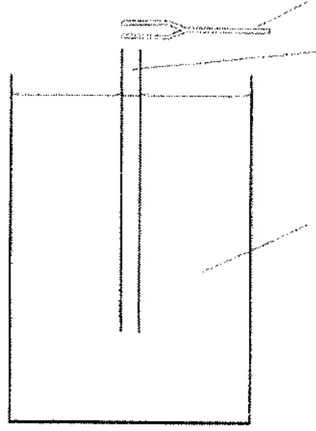

Fig. 7.2

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.

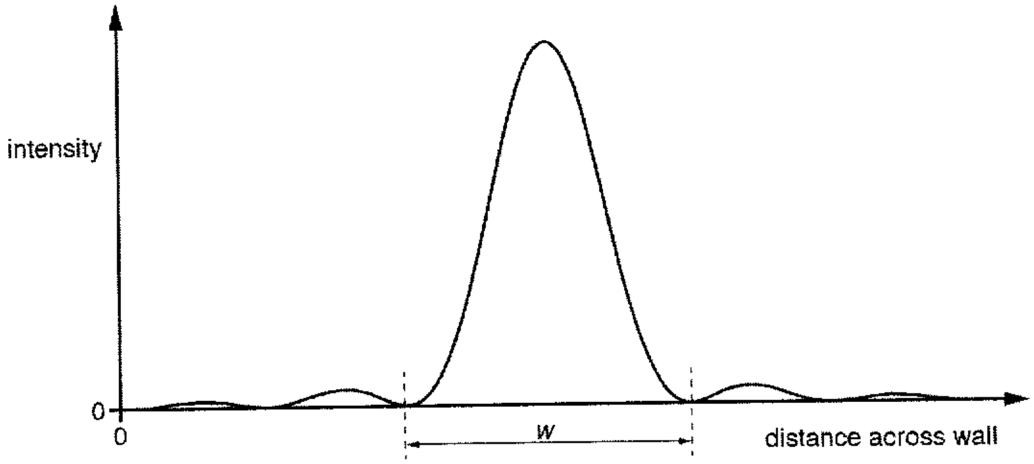

Fig. 7.3

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.

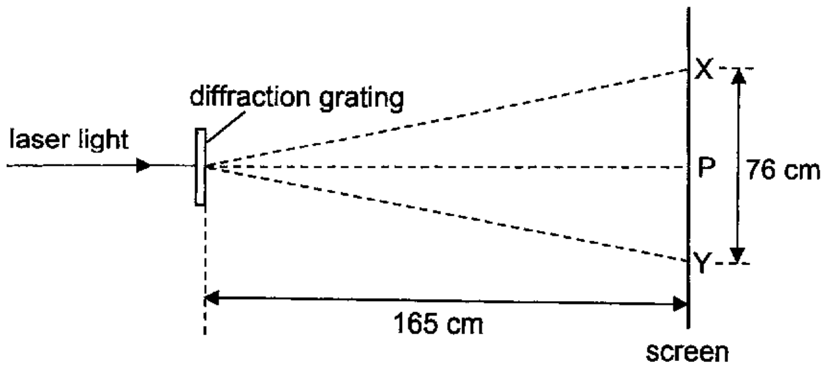

Fig. 7.4

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.

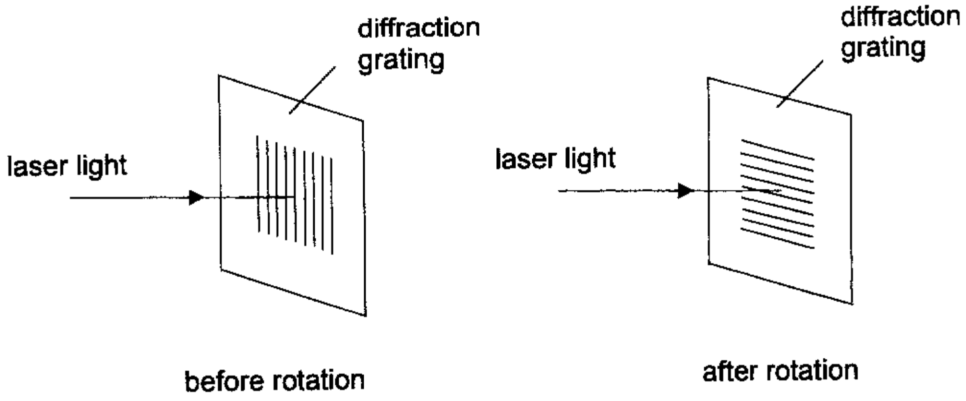

Fig. 7.5

(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.

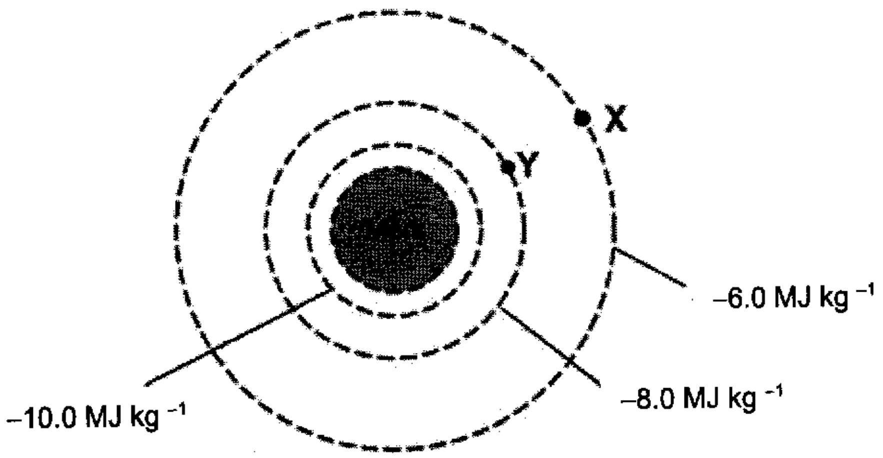

Fig. 8.2

(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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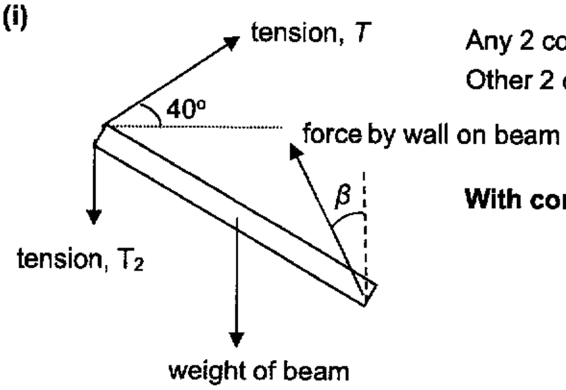
2024 DHS H2 Physics Prelim Paper 3 Suggested Solutions

Section A

1 **(a)** Resultant force on it must be zero in any direction. **B1**
Resultant torque on it must be zero about any axis (of rotation). **B1**

MC:	Quite badly done. Missing key words in conditions stated. Marks penalized if there is no mention of about any axis (for torque) or in any direction (for force) in answers.

(b) **(i)**



Any 2 correct pairs of forces **B1**
Other 2 correct pairs of forces **B1**

With correct direction and label

MC:	The question specifically mention to draw in Fig 1.1, but some drew a separate diagram instead. BOD awarded if T_2 is replaced by weight of the 5.0 kg, Force by wall is not a normal force since it is not 90°. Many students drew the force by the wall wrongly, they either assumed its horizontal, or along the beam.

(ii) Let x be the distance of c.g of beam from the hinge.

Taking moments about hinge,

sum of clockwise moments = sum of anticlockwise moments

$120\,(5 \sin 60^\circ) = 5g\,(5 \sin 70^\circ) + 20g\,(x \sin 70^\circ)$ **C1**

$x = 1.57 = 1.6$ m **A1**

MC:	Poorly done, because many could not obtain the correct clockwise or anticlockwise moment about the hinge. Some made mistakes when determining the necessary angle needed for calculations.

(iii) Vertical summation of forces:

$F_Y + 120\,(\sin 40^\circ) = 5g + 20g$

$F_Y = 168.1$ N

Horizontal summation of forces: **C1**

$F_X = 120\ (\cos 40^o)$
$= 91.93\ N$

$F = \sqrt{F_X^2 + F_Y^2} = \sqrt{91.93^2 + 168.1^2} = 192\ N$ **A1**

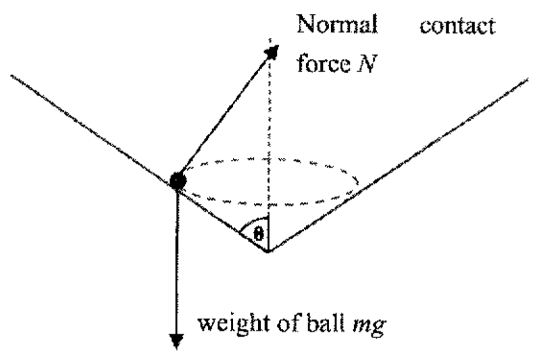
$\tan \beta = \frac{91.93}{168.1}$

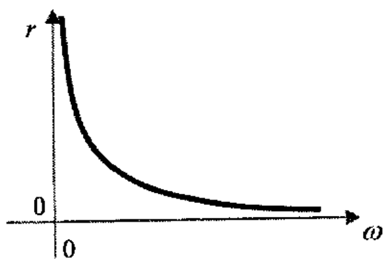
$\beta = 29^o$ **A1**

Force is at an angle of 41° with the beam **A1**

MC:	Many failed to resolve horizontally and vertically. A few did not calculate the numerical angle of the force by wall, while many did not express the angle correctly with the beam.

2(a)	In uniform circular motion, the **speed of the metal ball is constant**, but its **velocity** is **constantly changing direction**. Since **acceleration is the rate of change of velocity**, the metal ball experiences an acceleration.	**B1** **B1**
	OR In uniform circular motion, the **speed of the metal ball is constant**, but there is a **net non-zero force acting on the metal ball according to Newton's 1st law** because **it is moving in a circular path**. From **Newton's 2nd law for constant mass**, there must be an **acceleration in the same direction as the net force**.	**B1** **B1**

CKW MC	• Most candidates demonstrated a lack of understanding regarding the significance of *uniform circular motion*. Paraphrasing the question, candidates should explain why a metal ball moving at a constant speed in circular motion is still considered to be accelerating. • Some candidates mentioned the presence of a centripetal force without explaining why the centripetal force exists • Some candidates explained why the metal ball experiences a centripetal acceleration and not an acceleration. • Some candidates quoted Newton's 2nd law in general or in mathematical form, without explaining why acceleration cannot be zero. • For the A-level syllabus, because of the general case of variable mass systems, a force can be defined as the rate of change in momentum, and it is the change in momentum that leads to the emergence of a force.	
2(b)(i)	 **Horizontal component of normal contact force** provides the **centripetal force**: $N\cos\theta = mr\omega^2$ --- (1) The **weight is balanced** by the **vertical component of the normal contact force**: $N\sin\theta = mg$ --- (2) (2) / (1) : $\tan\theta = \frac{g}{r\omega^2}$	**B1** **C1** **A0**

CKW MC	• Many candidates did not provide proper statements for the "show" question. • Quite a number of candidates recognized that tan θ is a ratio of mg and $mr\omega^2$ mathematically. However, they do not go on to explain how tan θ comes about from Newton's 2nd law, in the horizontal direction, and Newton's 1st law, in the vertical direction.	
2(b)(ii)	$\omega = 2\pi f = 2\pi(3) = 6\pi$ rad s^{-1} Since $v = r\omega$, $\tan\theta = \frac{g}{r\omega^2} = \frac{9.81}{0.10(6\pi)^2}$ $\theta = 15°$	**C1** **A1**
CKW MC	This part was generally well done, except for careless mistakes in calculations, e.g. forgetting to square, or conversion of units.	
2(c)		**A1**
CKW MC	• $\tan\theta = \frac{g}{r\omega^2}$ → For same θ and g, $r \propto \frac{1}{\omega^2}$. The graphs shows that as ω increases r decreases. • Some candidates did not realise there were 2 asymptotes. • Many candidates did not label the origin.	

3 (a) (i) When the gas molecules that are in continuous random motion collides with the inner wall of the bubble and rebounds, there is a change in velocity and hence a change in momentum. **B1**

By Newton's Second Law, the bubble walls will exert a force on the gas molecules. By Newton's Third Law, the gas molecules will exert an equal an opposite force on the inner walls of the bubble. **B1**

The force per unit area exerted by the gas molecules on the inner walls of the bubble gives rise to the pressure of the bubble. **B1**

MC:	Generally, the question was not very well done despite being rather lenient in the marking. Many responses were essentially a regurgitation of the answers that was used in Junior High/O-level without bringing in concepts learnt at the A-levels. Students need to be aware that the level and depth of their response must evolve in proportion to the level of the exam that they are sitting for. **<u>Some common misconceptions/issues include:</u>** • Gas molecules moving around and colliding **<u>with each other</u>** which causes a change in momentum (this is a violation of ideal gas assumption and also the wrong reason for the change in momentum of gas particles resulting in pressure) • Pressure was due to the collision of the gas molecules **<u>with water molecules</u>** (Pressure of gas is due to collisions of gas molecules with the inner walls of its container – appropriate terminologies should be used in explanations) • **<u>No explicit links made to Newton's 3rd law</u>** in their explanations. Many jumped straight to stating that since the gas molecules experienced a change in momentum, the gas molecules exert a force on the inner walls of the bubble. • There is a change in momentum of the inner walls of the bubble when the gas molecules collide (Note that while this is technically not a misconception, since $m_{wall} >> m_{particle}$, by using conservation of momentum, $v_{wall} \approx 0$ both before and after collision. - Therefore, it is more meaningful to centre the discussion based on the gas molecules.)

(ii) Since temperature constant:

$$p_1V_1 = p_2V_2$$

$$p_1\left(\frac{4}{3}\pi r^3\right) = (p_1 - h\rho g)(V_2)$$

$$(2.4\times10^5)\left[\frac{4}{3}\pi(0.015)^3\right] = \left[2.4\times10^5 - 14(1000)(9.81)\right]V_2$$ **C1**

$$V_2 = 3.3050\times10^{-5}\ \text{m}^3$$

$$= 3.3\times10^{-5}\ \text{m}^3$$ **A1**

MC:	Poorly done. Common (more eye-catching) issues include: • Erroneously assuming P_{atm} = 101325 Pa or 1.01×10^5 Pa. Values were given in the question to calculate the pressure of the atmosphere in this context. (Very common mistake) • Wrong formula used for the volume of sphere. A number of candidates used πr^2 instead. • Using diameter instead of radius to compute initial volume.

(b) (i) The First Law of Thermodynamics states that the increase in internal energy of a system **B1**
is the sum of the heat supplied to the system and the work done on the system. **B1**

MC:	Very commonly tested definition, which has **very specific keywords** that have been clearly outlined by the syllabus outcomes. Hence close to zero variance in answers will be accepted. (except minor things like swapping the order of Q and W in the definition) **Common mistakes:** • **Change or total** in internal energy • Heat supplied to **the gas** / work done on **the gas** (First law of thermodynamics applies to systems that are non-gaseous as well, for eg. Electrical circuits)

(ii) Since the bubble has expanded at a constant temperature, the work done on the gas is negative and the increase in internal energy of the gas is zero. **B1**
Hence, by the First Law of Thermodynamics, heat is added into the system. **B1**

MC:	Was decently done. Most students who applied the first law of thermodynamics were able to arrive at the correct conclusion. Those who tried using PV = nRT to were generally not successful in gaining credit.

(iii) The pressure of the bubble decreases. **A1**
A non-ideal gas has non-negligible intermolecular forces of attraction which reduces the average force exerted by the gas molecules on the walls of the container. **B1**

Do not Accept: Non-ideal gas will collide inelastically with the walls of the container and hence average force exerted by gas molecules to decrease.

MC:	Was decently done. Most students were able to state that the intermolecular forces of attraction would cause the pressure to decrease. Those who attained partial credit generally did not make the link between how intermolecular forces of attraction will cause pressure to decrease.

4 (a) (i) From Fig. 4.2, amplitude decreases with distance from the source. **B1**
Since intensity (or power) is proportional to (amplitude)^2, **B1**
wave is losing power as it moves away from the source.

MC:	When symbols were used in the explanation, there is a need to define the meaning of the symbols e.g. $I \alpha A^2$ will not be accepted unless the meaning of I and A is explained.

(ii) intensity α (amplitude)^2

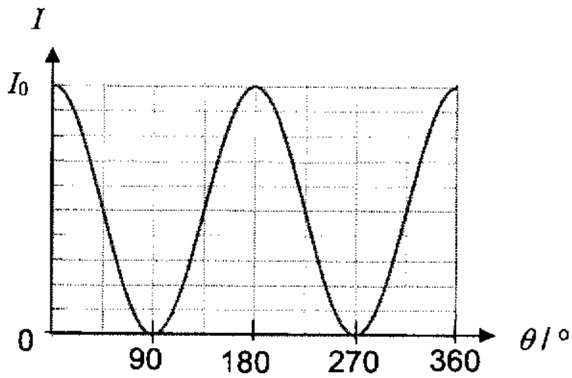
ratio = $\dfrac{(2.0)^2}{(1.1)^2}$ **M1**

= 3.3 **A1**

MC:	Students need to evaluate the ratio and not leave in fraction or ratio form.

(b) (i) $I = I_0 \cos^2\theta$ **A1**

(ii)



shape **A1**
correct values **A1**

MC:	While it is a sketch, students should also pay attention to the correct shape of the $\cos^2\theta$ graph, especially its turning points.

(iii) 1 After passing through A, intensity is still I_o, and after passing B,

$I_{AB} = I_o\cos^2 45°$ **A1**
$= 0.5I_o$ **A1**

2 After passing through B, intensity becomes $0.5I_o$, and after passing through A, intensity $I_{BA} = 0.5I_o\cos^2 45°$ **C1**
$= 0.25\, I_o$ **A1**

MC:	Never leave the final answer in fraction form.

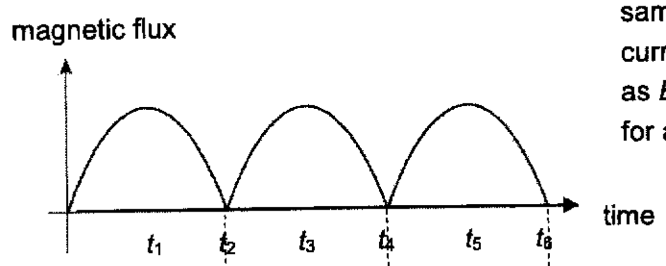
5 (a) (i) This increases the magnetic flux linkage with secondary coil **B1**

(ii) This reduces heat/energy losses caused by eddy currents in the core **B1**

(b) The changing current in the primary coil gives rise to changing magnetic field and hence changing magnetic flux in the iron core. **B1**
The iron core links the magnetic flux in the primary to the secondary coil. **B1**
From Faraday's law, the changing flux in the secondary coil induces e.m.f. in secondary coil. **B1**

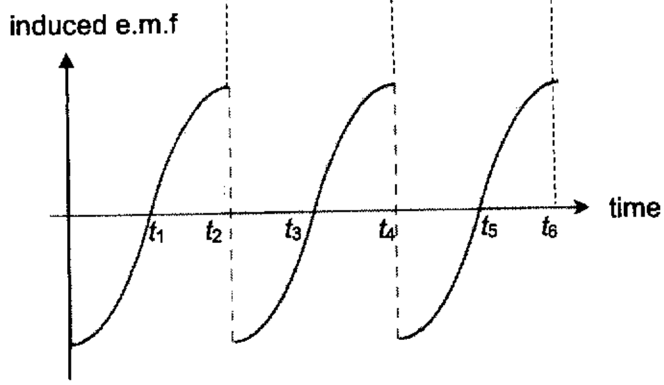
MC:	Generally poorly attempted. Some poor answers include: changing current causes changing magnetic flux and general statement of Faraday's law without applying it in context to the question does not gain credit.

(c) (i)



same change as current-time graph as B proportional to I for a solenoid.

(ii)



MC:	According to Faraday's law, e.m.f. induced in secondary coil = rate of change of magnetic flux linkage in secondary coil or $\varepsilon \propto \frac{d\Phi}{dt}$ Assuming number of turns is same for both primary and secondary coil, then flux linkage is the same in both coils. Graph of e.m.f. is the negative gradient of the magnetic flux-time graph.

(iii) 1 If the number of turns in the primary coil increases, the e.m.f. induced in the secondary coil decreases, assuming the number of turns in the secondary coil remains the same. **B1**
This is because the e.m.f. induced in the secondary coil is inversely proportional to the number of turns in the primary coil when the input p.d. also remains constant. **B1**

2 If the number of turns in the secondary coil increases, the e.m.f. induced across the secondary coil increases, assuming the number of turns in the primary coil remains constant. **B1**
This is because the e.m.f. induced in the secondary coil is directly proportional to the number of turns in the secondary coil when the input p.d. also remains constant. **B1**

MC:	Generally poorly done. Answers to (c)(iii) can easily be understood from the ideal transformer equation

6 (a) (i) Random means cannot predict when the decay will occur, or which nuclide will decay. **B1**
OR
Constant probability of decay per unit time **B1**

(ii) Spontaneous means occurs without any external stimuli such as changes in temperature or pressure. **B1**

MC:	For (a)(i) and (a)(ii), these are very commonly tested definitions, Hence, little variance in answers was accepted. Students are advised to be familiar with these definitions by hard. Generally not very well done. Most students had an idea of what the random and spontaneous mean, but many responses tended to have missing parts/keywords or students attempted to phrase it in their own way.

(b) (i) Gamma radiation has a greater penetrating power and will penetrate through a thin sheet of aluminium foil with little loss in intensity. **B1**

Any differences in the intensity of gamma radiation detected by the detector due to variations in the foil thickness would be too small to detect easily. **B1**

MC:	Many candidates were at least able to hint at the penetrating power being greater for gamma radiation. However, usage of keywords such as "penetrating power" was generally very poorly utilized. Most candidates ended up listing examples to illustrate this point. Most students also fell short in re-contextualisation of their answers to answer the question. Most just stated that the penetrating power is greater without making the link or explaining how it would affect the operation of the setup in the question. Hence, most candidates could only score partial credit at best. **<u>Common misconceptions:</u>** • **<u>All</u>** gamma radiation will pass through the foil regardless of thickness (false – there is attenuation albeit a very small/negligible amount, which does alter the count rate received by the detector) • The machine will recognize an increase in thickness if the count rate of beta particles is zero. (not necessarily true as the machine can operate by ensuring a fixed count rate, thickening of the foil can cause the count rate to decrease but not necessarily reach zero)

(ii)

$$\lambda = \frac{\ln 2}{t_{1/2}}$$

$$= \frac{\ln 2}{14 \times 24 \times 60 \times 60}$$ **C1**

$$= 5.7303 \times 10^{-7}$$

$$= 5.7 \times 10^{-7} \text{ Bq}$$ **A1**

(iii)

$$A = A_0 e^{-\lambda t}$$

$$\frac{A}{A_0} = e^{-\lambda t}$$

$$= e^{-\left(\frac{\ln 2}{14 \times 24}\right)8}$$ **C1**

$$= \left(\frac{1}{2}\right)^{\frac{8}{14 \times 24}}$$

$$= 0.98363$$

$$= 0.98 \text{ (to 2sf)}$$ **A1**

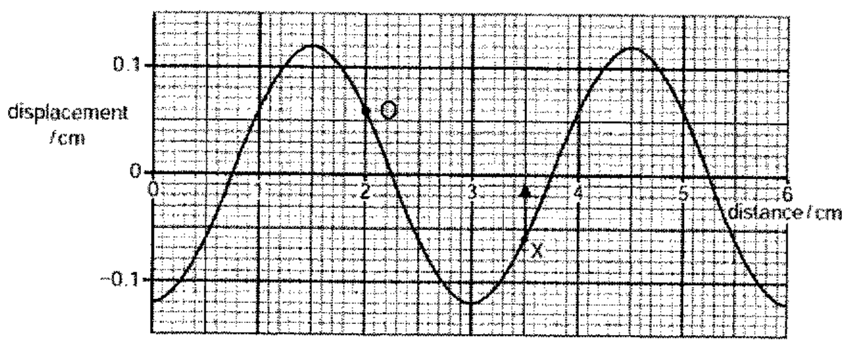
MC:	(ii) and (iii) were generally well answered. A vast majority who attempted were able to score full credit for these two parts.

(iv) When the detector detects a lower count rate, the set up interprets the decrease in count rate as a thickening of the foil. <u>To maintain a constant foil thickness at the original calibrated value</u>, the separation of the rollers decreases. **B1**

Hence, the foil thickness <u>decreases</u>. **B1**

MC:	Most candidates were able to identify that the foil thickness will decrease. However similar to (b)(i), many were not able to link their answers to the context of the question. Majority was also showed **very poor command and usage of key terms** (eg. Activity, count rate). Most did not showcase a good understanding of how the set up works but only seemed to have a vague idea of what the machine does. Incomplete answers included: • When the activity of the source decreases, the machine will thin the foil to increase the count rate. (missing: to ensure that the count rate detected by the detector remains the same at the calibrated value)

Section B

7(a)(i)	O is on the line in an adjacent segment of X, that is not a node.	**A1**
CKW MC	This part was well done	
7(a)(ii)	arrow drawn at X pointing vertically upwards 	**A1**
CKW MC	This part was generally well done, although there were answers in other directions.	
7(a)(iii)	distance = 2 x 0.06 cm = 0.120 cm	**A1**
CKW MC	This part was well done, though some candidates did not realise the distance travelled was for half a period.	

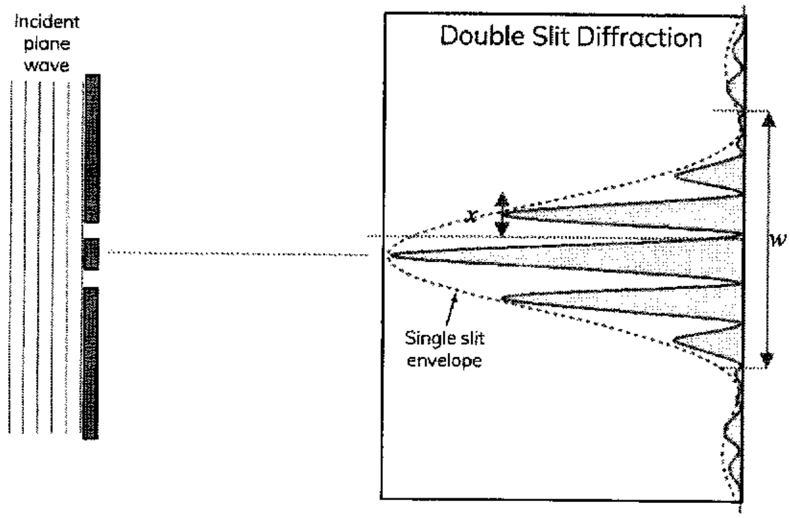
7(b)	$\frac{1}{2}\lambda = 65.0$ cm speed = 0.650 x 2 x 256 = 333 m s^{-1}	M1 A1
CKW MC	Some candidates did not deduce the correct wavelength.	
7(c)(i)	$b \sin \theta = \lambda$ $\sin \theta = \frac{633 \times 10^{-9}}{0.0800 \times 10^{-3}}$ $\theta = 0.453°$ $w = 2 \times 5.12 \times \tan \theta = 2 \times 5.12 \times \tan (0.453°)$ = 0.0810 m	C1 A1
CKW MC	This part was generally well done. Usually, the wrong answer was off by a factor of 2.	
7(c)(ii)1.	**Destructive interference** occurs when light from second slit meets **anti-phase** with light from first slit.	B1
CKW MC	This part was well done	
7(c)(ii)2.	$x = \frac{\lambda D}{a} = \frac{(633 \times 10^{-9})(5.12)}{0.240 \times 10^{-3}}$ = 0.0135 m	C1 A1
CKW MC	This part was well done	
7(c)(ii)3	$w = 6x \approx 0.0810$ m (The 3rd maxima from the central maxima of the double-slit interference pattern coincides with the 1st order minima of the single slit spectrum due to the width of the slit.) These places are **minima of the single slit** envelope.	B1 B1

CKW
MC

Realistic Double Slits

In real life, the double slits are never infinitely thin (they are not really point sources), they actually have a width.

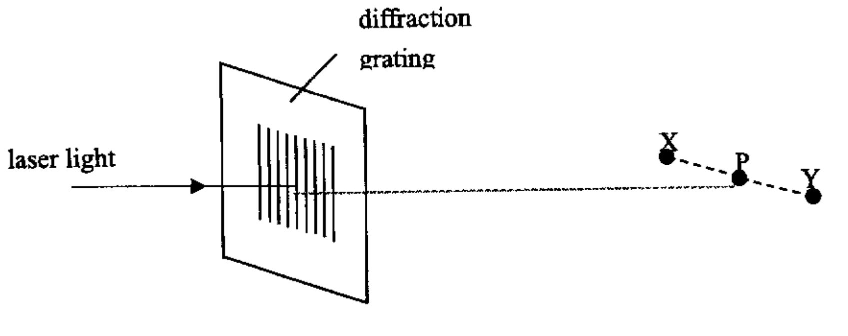
- This means that each of the two slits will generate a single-slit diffraction pattern.
- The result is that we have a **single-slit envelope** with the pattern of dark and bright fringes from the actual double slit interference.



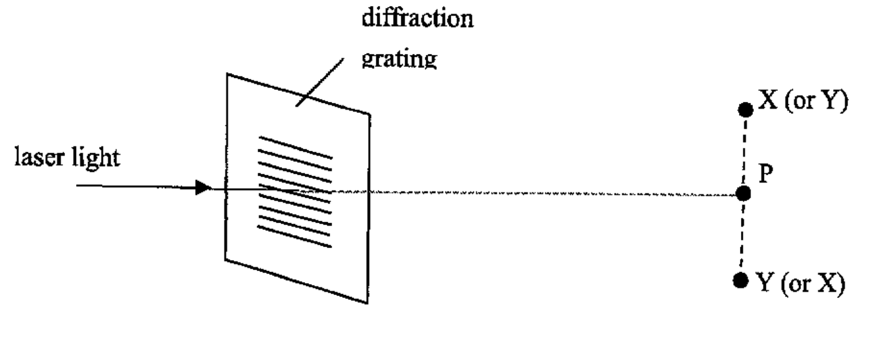
- To get information about the **distance** between the two slits, you have to look at maxima generated by the **double slit pattern**.

- To get information about the **width** of each slit, you have to look at the **position of the 1st order minima** of the single slit envelope.

7(d)(i)	$\tan\theta = \frac{38}{165} = 0.230$ or $\sin\theta = \frac{38}{\sqrt{38^2 + 165^2}} = 0.224$ or $\theta = 12.97^\circ$ $d\sin\theta = \lambda$ $d\sin 13^\circ = 6.33 \times 10^{-7}$ $d = 2.82 \times 10^{-6}$ m number per metre = $\frac{1}{d}$ **= 3.5 × 10⁵ m⁻¹**	**C1** **C1** **A1**
CKW **MC**	• Most candidates omitted the unit. • Small angle approximation is not needed. $\theta = \frac{s}{r} = \frac{38}{165} = 0.230 = \tan\theta \neq \sin\theta$	
7(d)(ii)	**1** Lines are further apart in second order, than in first order. **2** Lines are brighter **and** sharper in first order, than in second order.	**B1** **B1**
CKW **MC**	• Most candidates did not provide a complete comparison of the shape of the maxima i.e. both the intensity and width. • The wavelengths of 633 nm and 638 nm are too close for the colours to be different.	
7(e)(i)	P remains in the same position. X and Y rotate through 90°.	**B1** **B1**



before rotation



after rotation

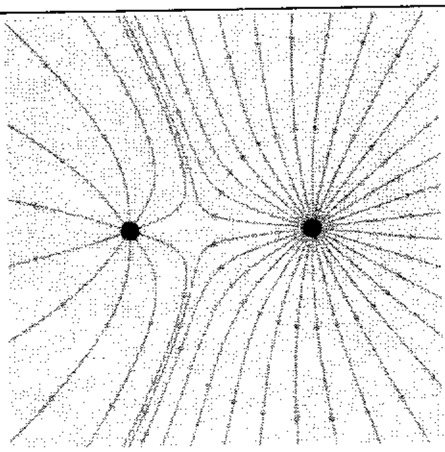
CKW MC	• It is not possible to deduce if the rotation is clockwise or anticlockwise. • It is important to identify that the position of P is not affected, as it is possible that there is a translation in the diffraction pattern.	
7(e)(ii)	screen is not parallel to grating **OR** grating is not normal to incident light	**B1**
CKW MC	Many candidates did not realise the same grating was used, so the adjacent slit centre-to-centre separation remains unchanged.	

8(a)	Any one **[significant]** similarity and difference each: [Not just isolated point mass or isolated point charges!] [Not just small test mass or small test charge!] Similarity: • They are both regions of space in which an object can experience a non-contact force. • They are conservative. [Not in H2 syllabus; note magnetic fields are not conservative.] Difference: • Gravitational fields are created by mass while electric fields are created by charge. • Gravitational fields cause a mass placed in them to experience a force while electric fields cause a charge placed in them to experience a force. **[Learning Outcomes (a)** of the topics of "gravitational fields", "electric fields" and "electromagnetism" require candidates to identify a gravitational field, an electric field and a magnetic field as *examples of a field of force*. For a magnetic field, it must be *produced by either by current-carrying conductors or by permanent magnets*.] • Electric fields can be shielded but gravitational fields cannot be shielded.	**B1** **B1**
CKW MC	• Some students confused *field* with *field strength*, *force* or the physical quantity that create it i.e. mass or charge. • Trivial similarity or difference without explaining the significance of the root words of *gravitational*, *electric* & *fields*, e.g. both are fields, or both can be represented by field lines, are not accepted.	
8(b)	Particle A: **Gravitational** field Particle B: **Electric** field Particle C: **Magnetic** field	**A1** **A1** **A1**
CKW MC	This part was well done though some candidates associate particle C with the presence of an electric field!	
8(c)(i)	The gravitational potential at a point is the **work done per unit mass** in bringing a **small test mass** from **infinity to that point.**	**B1**

CKW MC	Many candidates defined *gravitational potential energy* instead.	
8(c)(ii)	The magnitude of the **gravitational field strength** g **is numerically equal to the potential gradient** $\frac{dV}{dr}$. i.e. $\lvert g \rvert = \frac{dV}{dr}$ For the **same change in gravitational potential between adjacent equipotential lines** $(\Delta V = 2.0 \text{ MJ kg}^{-1})$, the **separation between <u>adjacent</u> equipotential lines** (Δr) **increases** as the distance from the surface (or centre) of the Mars increases.	**B1** **B1**
CKW MC	• Some candidates used mathematical expressions without defining them in their explanations. • Many candidates did not show an understanding of the difference between *change in gravitational potential* ΔV and *gravitational potential* V or distance from centre of Mars r and separation between the (adjacent) equipotential lines Δr. • The definition of gravitational field strength is *not* the rate of change of gravitational potential or $\frac{dV}{dt}$. As per **Learning Outcomes (c) and (j)** of the topic of "electric fields", candidates need to relate field strength to the concept of potential gradient.	
8(c)(iii)	$\lvert \Delta U_G \rvert = \frac{1}{2} m v^2$ $m(\phi_x - \phi_y) = \frac{1}{2} m v^2$ $v = \sqrt{2(\phi_x - \phi_y)}$ $= \sqrt{2(-6.0 + 8.0) \times 10^6}$ $= 2000 \text{ m s}^{-1}$	**M1** **C1** **A1**
CKW MC	This part was generally well done	

8(d)(i)	For gravitational potential at a point, the **displacement of a small test mass from infinity to that point** is always in the **opposite direction to the external force** acting on the small test mass because gravitational forces between two masses are always attractive. For electric potential at a point, the **displacement of the small test charge from infinity to that point** can be in the **opposite or same direction to the external force** acting on the small positive test charge because electric forces between two charges can be attractive or repulsive.	B1 B1
	OR [w.r.t. to DHS G.Field Tut] Due to the **attractive** nature of the gravitational force, **work done by an external force** to bring any mass **from infinity to that point** is always negative. However, **electric** force can be **attractive or repulsive**, thus **work done by an external force** to bring any charge **from infinity to that point can be positive or negative.**	B1 B1
CKW MC	Some candidates referenced the formulae for gravitational and electric potential in their discussions but failed to address the **key** conceptual difference between the two types of potentials, despite their similar definitions i.e. in terms of work done by an external force.	
8(d)(ii)	The **electric force** between an alpha particle and a gold nucleus is many orders of magnitude **larger than the gravitational force** between the alpha particle and gold nucleus.	B1

CKW MC	• A correct identification of the forces involved, and their comparison is needed to successfully answer this part. • No matter how small the gravitational force between an alpha particle and a gold nucleus is, if it is the only force present, then it cannot be neglected. • The order of magnitude of a gravitational force between two point masses is not only dependent on the product of the masses but also on the gravitational constant and the separation of the masses. • At the same separation r, the electric force is given by $F_e = \frac{(79e)(2e)}{4\pi\varepsilon_0 r^2}$ while the gravitational force is given by $F_g = G\frac{(197u)(4u)}{r^2}$. Thus, $\frac{F_e}{F_g} = \frac{(79e)(2e)}{4\pi\varepsilon_0 G(197u)(4u)}$ $= \frac{(79)(2)(1.6 \times 10^{-19})^2}{4\pi(8.85 \times 10^{-12})(6.67 \times 10^{-11})(197)(4)(1.66 \times 10^{-27})^2}$ $\approx 3 \times 10^{35}$	
8(d)(iii)	Assumption: The gold nucleus acts as a **point** positive **charge**. $V = \frac{Q}{4\pi\varepsilon_0 r}$ $= \frac{79(1.6 \times 10^{-19})}{4\pi(8.85 \times 10^{-12})(2.6 \times 10^{-12})}$ $= 43714$ $= 44000$ V	**B1** **C1** **A1**
CKW MC	• The assumption that "the gold nucleus is isolated" is not valid since the electric potential required is specified to be due to the gold nucleus in the question. • The formula used is only applicable for a point charge, which the gold nucleus is not physically in reality. • Some students thought the charge of a proton is 1 C.	

8(d)(iv)		**B1:** Direction of arrows **B1:** Position of neutral point (closer to alpha particle) **B1:** Field line pattern: • Field lines do not intersect. • Density of field lines around alpha particle is less than gold nucleus. • Symmetrical about the horizontal, asymmetrical about the vertical. • The circle represents an equipotential volume. The field lines are normal to the surface. [The suggested answer shows the simulated field lines between a charge of +1 C and +5 C. The actual field lines between a charge of +2e & +79e is more asymmetric.]

CKW MC	• Some candidates sketched
	    o equipotential lines, or
	    o magnetic field lines
	• instead of electric field lines.
	
	• The imaginary line joining the points of zero resultant electric field strength were observed to vertically straight in many cases; this is only possible if the charges have the same magnitude and same sign.
	
	Some sites to simulate electric field lines between two point charges:
	    o <u>E-Field Simulation - Ithaca College PER</u>
	    o <u>Electric field line simulator</u>	