H2 Physics 9646 – 2015 A Level Exam

Paper 1

1	Keywords: • Base quantity • SI units Answer: A
2	Keywords: • Average speed Essential Questions: • How do you determine the average speed of the vehicle? • How do you determine the total distance travelled from a speed-time graph? Answer: D
3	Keywords: • Thrown Horizontally • Air resistance is negligible Essential Questions: • What are the forces acted on the stone after it leaves the cliff? • Which component of the velocity is affected? Use kinematics equations to determine the x and y components of the final velocity just before it hits the surface of the water. Answer: C
4	Keywords: • Propelling force is constant • Water runs out of the tanker Essential Questions: • What happens to the mass of the water tanker? • What are the changes in the variation of the resistive forces and ultimately, the net force? Answer: A
5	*Q: What physics relationships hold for a **head-on elastic collision**?* ➔ **(1): Total momentum is conserved throughout the motion AND** ➔ **(2): Total KE before the collision equals to total KE after the collision.** ➔ **(3): A consequence of solving (1) and (2) simultaneously is that the Relative velocity of approach between the two bodies before the collision equals to their Relative velocity of separation after their collision..** **Take direction to the right as positive.** **Applying (1), we get: $mu_1 + m(-u_2) = mv_1 + mv_2$** ➔ **$u_1 - u_2 = v_1 + v_2$** ➔ **Tallies with option B** **Applying (2), we get: $\frac{1}{2} m u_1^2 + \frac{1}{2} m u_2^2 = \frac{1}{2} m v_1^2 + \frac{1}{2} m v_2^2$** ➔ **$u_1^2 + u_2^2 = v_1^2 + v_2^2$** ➔ **Tallies with option C** **Applying (3), we get: $u_1 - (-u_2) = v_2 - v_1$** ➔ **$u_1 + u_2 = v_1 - v_2$**

	➔ **No such option.** Answers: B and C *Note: the proposed answer by Cambridge was C, but later found to be an error as both B and C are valid.*
6	Keywords: • Diagram showing a section of canal • Extra weight Essential • What is the meaning of extra weight ? • If there is extra weight, where does it comes from? • Before the barge cross the bridge, how much weight does the bridge supports? • When the barge is at the bridge, what are the forces acting on the barge? Proposed Solution: When the barge moves onto the bridge (aqueduct), it is displaces an amount of water and the weight of the displaced water is equal to the weight of the barge. The displaced water moves off the aqueduct as the boat moves onto it. Thus there is no extra weight supported by the bridge. Answer: A
7	Keywords: • Held below the surface of water • Released and floats to the surface • Fully submerged • Floating Essential questions 1. How forces are balanced when the ice is floating? 2. How can weight be expressed in terms of density and volume? 3. What expressions can be written when fully submerged and floating? Proposed Solution: Let the volume of ice be V_{ice} = A(Surface area) x H (thickness) , ρ_{ice} = density of ice, ρ_w = density of water, d = height of ice submerged in water, V_f = volume of water displaced when ice floats and W_{ice} = weight of ice Ice held below surface of water ➔ Fully submerged, Upthrust $U_H = \rho_w V_{ice}\, g = \rho_w (AH)\, g$ ----- (1) Ice floats ➔ Upthrust $U_d = \rho_w V_f\, g = \rho_w (Ad)\, g$ ----- (2) ➔ Upthrust = Weight of ice → $\rho_w (Ad)\, g = W_{ice}$ $\rho_w (Ad)\, g = \rho_{ice} (AH)\, g$ $\Rightarrow \frac{H}{d} = \frac{\rho_w}{\rho_{ice}}$ Therefore from (1) and (2) ,

	$$\frac{(1)}{(2)} \quad \Rightarrow \quad \frac{U_H}{U_d} = \frac{H}{d} = \frac{\rho_w}{\rho_{ice}} = \frac{1.0}{0.9} = 1.1$$ Answer: D
8	Keywords: • Constant speed • Total Frictional proportional to the square of speed Essential Questions: • What is the net force at force speed? • What is the engine force at constant speed? • How is power related to speed at constant speed? Answer: C
9	Key info: - Gas - Pressure and volume graph (Note the units) - NET work done BY gas in ONE CYCLE Essential questions: 1) How to determine 'work done' from a p-V graph? • In general, where p is not necessarily constant, W = ∫ p dV • Thus work done W is determined from the area under p-V graph 2) How to find NET work done? • Sum up the work done at every stage of the cycle. Following the sign convention for W, include '+' sign for work done ON gas and '-' sign for work done BY gas. • For a cycle, net work done = area enclosed within the 'loop' 3) When is there work done BY gas, and, when is there work done ON gas? In this scenario, is there NET work done BY gas or ON gas? • There is positive work done BY gas when the gas is expanding (increasing in volume); there is positive work done ON gas when the gas is being compressed (decreasing in volume). • In this thermodynamic cycle, the area under the graph during the expansion stage is greater than that during the compression stage, hence there is positive net work done BY gas…anyway, all the options given are positive. Answer: A
10	Key info: - horizontal circle - forces on the **string** (Always take note of whose free-body diagram the question is asking for) Essential questions: 1) How do forces arise? • Forces arise due to interaction between 2 bodies; can be contact or non-contact force 2) What other body/bodies are interacting with the string? • The vertical pole that the upper end of the string is tied to, and, the ball on the lower end of the string. String is massless, so no gravitational force acts on it. • But all four options A to D gives two forces…what is the difference between the options? → the directions of the forces! → A string can only experience tensile forces, and tensile forces act long its length! Answer: C

11	Key info: - Minute hand → 1 revolution in 60 minutes (this is the period) - 3.00 m long → radius of circular motion - **Magnitude** of **angular velocity** Essential questions: 1) How is ω related to the information given (i.e. period T and radius r)? • $\omega = 2\pi/T$, where T = 60 mins • r is not needed Answer: B
12	Key info: - meteorite…**initially zero** velocity **relative to** planet - ….**falls** from a **large distance** to the planet… -→ assume meteorite is initially at infinity - no atmosphere → no air resistance - gravitational potential - r **from centre** of planet - Which expression…maximum kinetic energy…as it hits the surface Essential questions: 1) How to link KE to potential? • Both are related to energy. Apply conservation of energy. • Loss in GPE = Gain in KE • $GPE_i - GPE_f = KE_f - KE_i$ • Based on key info in the question, assume $GPE_i = 0$ and $KE_i = 0$ • Thus, 0 – m multiplied by potential at surface = max KE – 0 Answer: A
13	Essential Questions: 1. What does it mean by "which force = mass x acceleration equation"? F = ma, it is the simplified version of Newton's second law. F in this equation refers to the resultant force on the satellite according to the context of the question. 2. What is the resultant force on the satellite? The centripetal force (as according to the question, the satellite rotates in a circle, i.e. circular motion) 3. Where is centripetal force pointing at? (Why is this important? Because then you will be able to know which force should be larger). It is pointing towards the Sun as the satellite rotates around the Sun. Hence the resultant force on satellite = Centripetal force = $m(R\omega^2)$ = Gravitational force by Sun on Satellite – Gravitational force by Earth on Satellite Answer: D
14	Essential Question: 1. What feature do we see on the graph? A straight line with negative gradient passing through the origin. This graph represents the defining equation for Simple Harmonic Motion: $a = -\omega^2 x$, where ω is a constant. Hence the graph is a against x. Answer: A
15	Essential Questions: 1. What does the change of GPE and EPE compares with the value at the centre mean? It means that we take the centre point as reference point for both its GPE and EPE, i.e. set them as zero. 2. How do these energies relate to one another? Total energy = KE + EPE + GPE = constant.

	At the centre (equilibrium point), KE is maximum while EPE and GPE = 0. Hence TE = KE_{max} = ½ mv^2 = 1.8 J Only option A satisfies this condition. Answer: A
16	By definition. Answer: A
17	Keywords: • Relate p to v • Before and after tap is opened and temperature = T Essential Questions • What law do you apply to the gas? • How to apply the law, to X or Y or to both? • From the ideal gas equations for gas in X and Y, before and after how to relate p & V to p_x, p_y, V_x and V_Y? • What remains constant before and after the process? Answer: C
18	Keywords: • Time t = 0 • Time t = 1.5 s to 2.0 s Essential Questions: • How does the displacement change with time as a wave passes by? • How long does it take for the complete wave to move across in the time of 0.5 s? • How far do the waves move in one period? Answer: C
19	Keywords: • 2.5 J of energy every second • Small source Essential Questions: • How to find the intensity at 1.0 m from the loudspeaker • What is the relation between amplitude and intensity? Answer: C
20	Keywords: • Whole number of wavelengths • RS perpendicular to PQ and halfway PQ Essential Questions • What is a stationary wave? • How are stationary waves formed? Answer: B
21	Keywords: • Concept words: node (at one end), antinode (at the other end), sounds of different frequencies, varying number of nodes • Contextualization words: series Essential Question: • How are the resonance frequencies of a stationary wave related to a tube that is open at one end and close at the other? The general equation to describe the resonance frequencies and the length of an open-close

	tube is, $f = \frac{(2n-1)v}{L}$ where v is the velocity of the progressive waves that make up the stationary wave, L is the fixed length of the tube and n is the number of resonance frequency, n = 1, 2, 3, … Therefore, if we are to take 50 Hz as the fundamental frequency, only option C shows odd integer multiple of the frequency. Even though option D are also odd integer multiple of the fundamental frequency, it skips n = 3, 7, 11. Hence, not in the sequential requirement of the keyword, "series". Answer: C
22	Keywords: • diffraction grating, second-order diffracted beams, angle, spacing of lines Essential Question: • How is the angle stated in the question different or the same as the angle θ defined in the usual $d \sin \theta = n\lambda$ defined? The angle given in the question is 2 times the usual θ that is used in the equation. The spacing of lines is represented in d. By the dimensional analysis, d has the same unit as λ which may cause students to question their method as the unit for the wavelength given is in nm while the answers are all in μm. Answer: D
23	Keywords: • electric potential, electric field strength, point charge Essential Question • How is the electric field strength and electric potential at a point from a point charge related? A possible misconception that student might have from this question is to generalize the relationship between them as obtaining electric field strength by dividing the separation distance r from the electric potential V. It just so happens that it is only the case for a point charge context when the general relationship, $\lvert E\rvert = \left\lvert \frac{dV}{dr} \right\rvert$ yields the specific solution, $\lvert E\rvert = \left\lvert \frac{V}{r} \right\rvert$. Answer: B
24	Keywords: • charged particle, constant speed, straight line vacuum, charged plates, deflected, electric field, parabolic, circular arc This question tests students on their possible confusion between charged particles moving in a magnetic field and in an electric field. Path in an electric field is either straight line or parabolic (this case). Speed increases as the magnitude of the vertical component of the velocity increases while the horizontal component of the velocity stays the same. Answer: B
25	Key Points: Remember that resistance of a conductor is the ratio of the potential difference across the conductor to the current flowing through it. NOT the gradient. Also the graph clearly shows there is current when a reverse potential is applied across the conductor. So the resistance is not infinite in the negative potential region. A: As the increase in current is larger than the increase in potential difference (p.d) when the

	p.d across the semiconductor diode is larger than 0.6 V, the resistance of the semiconductor reduces at p.d above 0.6 V. B: Take note of the detail in this questions which shows clearly there is current in the negative potential difference values. C: At a potential difference of 1.2 V the current flowing through the semiconductor diode is approximately 1.5 mA. This results in a resistance of approximately 800 Ω. D: Between 0 and 0.6 V, the resistance is infinite. That is why no current is able to pass through the diode. Answer A
26	Key Points: Be aware of the positions of the voltmeter and the ammeter placed in the circuit so as to understand accurately what these meters are measuring. Potential difference across the 4 Ω and 13 Ω resistors = 1.3 x 4 = 5.20 V Current flowing through 13 Ω resistor = $\frac{5.20}{13}$ = 0.400 A Total current flowing in circuit = 0.400 + 1.3 = 1.70 A Internal resistance value = $\frac{1.70}{(1.623)^2}$ = 0.645 Ω E.m.f of cell = 1.623 x (0.645) + 5.20 +2.0 = 8.2 V Answer B
27	Key Points: Be aware of the lengths used in the calculation for the resistance. Resistance of wire = $\frac{\rho L}{A} = \frac{(1.3\text{x}10^{-8})\left(30 \text{ x } 2\pi\left(\frac{1.50\text{x}10^{-2}}{2}\right)\right)}{\pi\left(\frac{0.50\text{x}10^{-3}}{2}\right)^2}$ = 0.094 Ω Answer B
28	Key Points: Don't mistake the position of the ammeter to measure the current passing through the entire circuit. Rather it is only through one of the 6.0 Ω resistor. Effective resistance = $\frac{6.0}{2}$ +3.0 = 6.0 Ω Total Current flowing = $\frac{6.0}{6.0}$ = 1.0 A Answer B
29	Key Words: • Connected in series • Connected in parallel • Same cell • Negligible internal resistance

	Essential Questions: • What info can I determine from the I-V graph? (Read off values of V across R and X for a current of 0.3 A. Read off values of I for a voltage of 1 + 1.5 = 2.5 V) • How is p.d. shared by cells in series and cells in parallel arrangement? Answer: D
30	Key Words: • Magnetic fields • Reinforce • ALL the coils Essential Questions: • How do I determine the direction of the field due to each current at the different regions? (use right hand grip rule) Answer: B
31	Key Words: • Velocity selector • Electrons • Direction of electric field is vertically downwards • Leave …unaffected (this implies resultant force on electron is 0) Essential Questions: • What direction is the electric force on the electron? (vertically upwards. This means that magnetic force on electron must act vertically downwards) • How do I determine the magnetic field direction when I know the electron velocity direction as well as magnetic force direction (downwards)? Answer: B
32	Key Words: • Induced e.m.f. • Short duration Essential Questions: • Will the direction of e.m.f. change? • How will the magnetic flux linkage change as magnet approaches and leaves coil? • How will the magnitude of e.m.f. change for a short duration? Answer: D
33	Key words: - peak alternating voltage, doubled, rms current and mean power Essential questions: 1) How does peak AC voltage related to the rms voltage across resistor? 2) How does rms voltage relate to mean power? Note: The question here doesn't state explicitly if it is a sinusoidal or non-sinusoidal a.c. By right, we should only use the general equations that apply to all a.c.. However since we are given V_o and not V_{rms}, to proceed with this problem solving, we have no choice but to assume it is a sinusoidal a.c. However, remember that as a general rule of thumb, if question doesn't make it explicit if it is sinusoidal or not in text/graph/equation/pictorial representation, you should only use the general equations for a.c. Mostly, Cambridge question does make it clear. Solution: Across a fixed resistor: $V_{rms} = \frac{V_0}{\sqrt{2}}$ Assume it is a sinusoidal a.c.

	$\langle P \rangle = \frac{V_{rms}^2}{R}$ As V_0 doubles, V_{rms} will also double, but $\langle P \rangle$ will be quadrupled (4 times the initial). Answer: B
34	Key words: - Alternating current across 10Ω resistor, mean power Essential questions: 1) How does mean power relate to rms current across resistor? Across a fixed resistor: $$I_{rms} = \frac{I_0}{\sqrt{2}}$$ $$\langle P \rangle = I_{rms}^2 R = \left(\frac{I_0}{\sqrt{2}}\right)^2 R = \frac{1}{2} I_0^2 R = \frac{1}{2}(5)^2(10) = 125\,W$$ As V_0 doubles, V_{rms} will also double, but $\langle P \rangle$ will be quadrupled (4 times the initial). Answer: C
35	Key words: - White light, passed through sodium vapour, diffraction grating Essential questions: 1) Which frequencies are present in the photons from the white light? 2) What will happen to the photons when they are passed through the sodium vapour? 3) Is the sodium vapour heated up? As the sodium vapour is not heated up, photons that are passed through the vapour will be absorbed by the vapour if the energy of the photons are matched with the energy difference between the energy levels in the sodium gas atom (photons of these frequencies will subsequently be reradiated, directed in random directions, not contributing to the line spectrum). The rest of the photons will pass through the gas without being absorbed. Therefore, dark lines (signifying the photons that were absorbed by the vapour) will be seen on a coloured spectrum. Answer: C
36	Key words: - Heisenberg uncertainty, electrons Essential questions: 1) Which direction of the momentum is considered in this equation? 2) Which part of the experiment is the uncertainty principle utilized – at the slit or screen? What is the Heisenberg Uncertainty Principle about? The Heisenberg Uncertainty Principle is applied to a **particle** in describing it as having a **wave nature**. In the setup, the **electrons** passing through the slit will exhibit **wave nature** at the beginning of the setup (i.e. the slit). Thus, the **uncertainties will apply to the position at the slit**. *[Because it is at the slit where the position of the electron is being confined, which by Heisenberg Uncertainty Principle means that momentum of the electron will be less well defined.]* It is the **p and x which are along the <u>same</u> direction** that are paired in Heisenberg Uncertainty

	Principle. Answer: A *Examiner's Report:* *The initial uncertainties were required for this question.*
37	Keywords: • Conduction and Valence Bands Essential Questions: • According to Band Theory, how do the bands form? What must be done to get the atomic energy levels to form bands? The energy level bands are formed when the atoms in solids are placed close together, such that degenerate (same) energy levels split due to the Pauli Exclusion Principle. The x-axis is thus the separation of adjacent atoms. The y-axis, then, represent the energy values, since as an axis of graph, it must represent a physical quantity (energy) and not a phenomenon (energy bands). Answer: C
38	Keywords: • Laser levels • Metastable, unstable and stable Essential Questions: • How does the metastable energy level help in the setting up population inversion required for the production of a consistent laser beam? For the production of a consistent beam, there must be a ready supply of atoms in an excited state that will undergo stimulated emission. This is set up by means of a population inversion. However, for the population inversion to be maintained, it is expected that the upper level of the lasing transition is a metastable one. In addition, since atoms need to be excited via optical pumping to a higher energy level for there to be a population inversion, there is also a steady supply of incoming photons required. However, if the metastable state is also the level that the atoms are pumped, the photons that are used for stimulated emission or optical pumping will also cause stimulated emission. Therefore, the solution would be to pump the atoms up to the next highest unstable level above the metastable state and spontaneously de-excite into the metastable state. Answer: A
39	Keywords: • Nuclear reactions • Number of neutrons (and relatedly, proton number and nucleon number) Essential Questions: • What numbers must be balanced on both sides of a nuclear reaction? • What is the nucleon and proton number of a neutron? • How is the number of neutrons calculated from the nucleon and proton number? Balancing the proton number: $92 + 0 = 56 + Z_Z + 0$ $Z_Z = 36$ Balancing the nucleon number: $235 + 1 = 144 + A_Z + 2$

	$A_Z = 90$ Computing the number of neutrons of Z: number of neutrons = nucleon number – proton number = 90 – 36 = 54 Answer: D
40	Keywords: • Half-life and count-rate • Background radiation Essential Questions: • How is half-life of a radioactive substance determined from the changes of its cout-rate over time? • How is background radiation accounted for in experiments? To account for the background radiation, we need to subtract the background count-rate from the original count-rate. Initial count-rate: 77.3 – 8.3 = 69.0 counts per second Final count rate: 61.6 – 8.3 = 53.3 counts per second $C = C_0 e^{-\lambda t}$ $53.3 = 69.0 e^{-280\lambda}$ $\lambda = 9.22 \times 10^{-4}$ s^{-1} $t_{1/2} = \frac{\ln 2}{\lambda} = 752$ s Answer: B

Paper 2

				Marks
1	**(a)**		*Watch out for the axes in this question.* *The horizontal-axis represents total length l, and not the extension of the spring x.* *The vertical-axis represents mass M, and not the force of the weight W = Mg.* Energy stored in the spring = Work done by the load on the spring, $\int (Mg)\ dx$ = (Area bounded by the graph and *l*-axis).(acceleration due to gravity, g) = ½ (0.700 – 0.400) (0.450).(9.81) ****Beware units conversion for both l- and M- axes!!*** = 0.662 J **Examiner's Report** *A large number of candidates attempted to calculate the energy stored in the spring by assuming a constant force for the extension of the spring. A significant number of candidates did not read the question carefully and did not appreciate that the quantities plotted on the graph were not force and extension.*	 **C1** **A1**
	(b)	**(i)**	Key Points: Don't confuse natural length and equilibrium position. The elastic potential energy is store only when the spring stretches beyond the natural length.	

			- There is an increase in kinetic energy (KE) and elastic potential energy (EPE) while the mass-spring system experiences a loss in gravitational potential energy (GPE) as it is released from rest at its natural length. - The KE reaches a maximum value at the equilibrium point. - As the mass passes the equilibrium point, the mass-spring system loses KE and continues to lose GPE, while the EPE continues to increase. - At the lowest point the GPE of the mass-spring system is at a minimum while the KE is zero and the EPE is a maximum. **Examiner's Report:** *There seemed to be **confusion between zero and minimum gravitational potential energy at the lowest position**.*	**B1** **B1**
		(ii)	Key Points: Be careful of the energy conversions in the motion of the mass while oscillating. By the law of conservation of energy, Loss in GPE = Gain in KE + Gain in EPE $mgh = \frac{1}{2}mv^2 + 0.662$ $(0.300)(9.81)(0.300) = \frac{1}{2}(0.300)v^2 + 0.662$ $v = 1.21 \text{ m s}^{-1}$ **Examiner's Report:** *The majority of candidates were generally unable to produce a correct link between the terms representing the changes in energy as the spring extended. The common error was to link the gain in elastic potential energy with the gain kinetic energy. The loss in gravitational potential energy was ignored. There were a significant number of candidates who obtained an incorrect answer for part (a) and this resulted in a negative value for the kinetic energy.*	**C1** **C1** **M1** **A1**
		(iii)	Key Points: The lowest position of the spring mass system will have zero KE and maximum EPE. By the law of conservation of energy, Loss in GPE = Gain in EPE $mgh = \frac{1}{2}kx^2$ $(0.300)(9.81)(x) = \frac{1}{2}\left(\frac{0.450 \text{ x } 9.81}{0.300}\right)x^2$ $x = \left(\frac{2(0.300)^2}{0.450}\right)$ $x = 0.400 \text{ m}$ **Examiner's Report:**	**C1** **M1**

<table>
<tr><td></td><td></td><td></td><td>A small minority of candidates were able to link the loss in gravitational potential energy with the gain in elastic potential energy. A large number of candidates attempted to use equations for constant acceleration. Correct solutions were only produced by better performing candidates.</td><td>A1</td></tr>
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<tr><td>2</td><td>(a)</td><td></td><td>Key words:
- Use Fig. 2.1, proportional

Essential questions:
1) What does it mean when a quantity is proportional to another?

For a quantity A to be proportional to another B, it must follow the condition $A \propto B$, and thus
$$\frac{A}{B} = constant$$
Therefore, we need to take various values of I and V and compare if they have the same relationship. To do so, consider the following points on the graph and their respective ratios.

Solution:

<table><tr><td>V</td><td>6.0</td><td>7.2</td><td>8.4</td><td>9.6</td><td>10.8</td><td>12.0</td></tr><tr><td>I</td><td>1.25</td><td>1.50</td><td>1.75</td><td>2.00</td><td>2.25</td><td>2.50</td></tr><tr><td>V/I</td><td>4.8</td><td>4.8</td><td>4.8</td><td>4.8</td><td>4.8</td><td>4.8</td></tr></table>(minimum 3 points will do)

Since the ratio of V/I is a constant for the various values in the graph for this range, it is therefore conclusive that V = 4.8I and therefore $V \propto I$.

Examiner's Report:
Most candidates were able to explain and show the condition for proportionality. A minority of candidates thought that the gradient being positive and constant was the condition for V and I to be proportional.</td><td>M1

M1
A0</td></tr>
<tr><td></td><td>(b)</td><td>(i)</td><td>Key words:
- Resistance of X

Essential questions:
1) What is the definition of resistance?

The resistance of resistance X
= ratio of V:I
= 4.8 Ω (as calculated in part a)

Examiner's Report:
Most candidates obtained the correct answer.</td><td>B1</td></tr>
<tr><td></td><td></td><td>(ii) 1.</td><td>Key words:
- Wire AB

Essential questions:
1) How does current in wire AB link to the emf and the 5.0 Ω resistor?

Using</td><td></td></tr>
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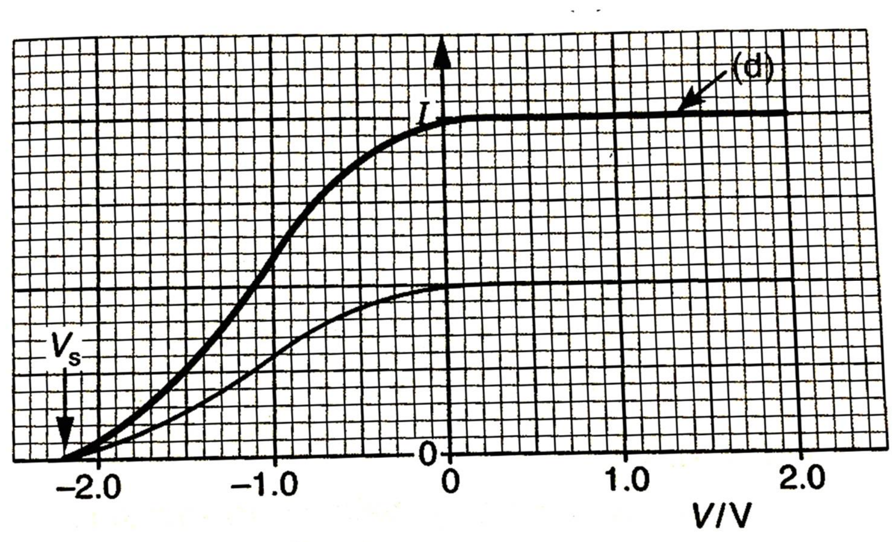
			$$V = IR$$ $$I = \frac{V}{R}$$ $$= \frac{12}{4.0 + 5.0}$$ $$= 1.3\ A$$ *Examiner's Report:* *Most candidates obtained the correct answer.*	**B1**
		(ii) 2.	Key words: - Resistor X Essential questions: *1)* How does current in resistor X link to the emf and the 2.7 Ω resistor? Using $$V = IR$$ $$I = \frac{V}{R}$$ $$= \frac{12}{4.8 + 2.7}$$ $$= 1.6\ A$$ *Examiner's Report:* *Most candidates obtained the correct answer.*	**B1**
		(iii)	Key words: - Potential difference between C and D Essential questions: 1) What is the potential at A? *2)* What is the potential difference between A and C? *3) What is the potential at C?* *4) What is the potential difference between A and D?* *5) What is the potential at D?* Potential difference between A and C $=\frac{l_{AC}}{l_{AB}}V_{AB}$ $=\frac{l_{AC}}{l_{AB}}IR_{AB}$ $=\frac{0.75}{1}(1.3)(4.0)$ =3.9 V Therefore, V_C = 12- 3.9 = 8.1 V Potential between A and D = 7.7 V (as read off from the graph) Therefore potential at D = 12 – 7.7 = 4.3 V Therefore V_{CD} = V_C - V_D = 8.1 – 4.3 3.8 V *Examiner's Report:* *Many candidates completed this question correctly. There was some*	**B1** **M1** **A1**

			confusion between the potential at a point and the potential difference across a resistor.	

				Marks
3	(a)		Key words: - Energy changes, required condition, electrons to be emitted from the surface Essential questions: *1)* How is an electron able to be liberated from the metal surface? / How does photoelectric effect occur? *2)* What are the energy conversions happening in photoelectric effect? To eject **one** electron from the metal surface, it must **<u>absorb</u> one photon.** The **photon energy must be <u>at least</u> equal to** the **work function energy <u>of the metal</u>.** Any **excess of photon energy** after overcoming the work function energy will be **<u>converted to</u> kinetic energy of the <u>ejected electron</u>**. *Note:* • *<u>Quantised nature</u> of EM radiation (photon energy) must be expressed; hence the first point.* • *Including all 3 points above would be a fuller answer – depending on number of marks awarded.* Recap: Work function energy is equivalent to the minimum energy that the *delocalised* electrons of the metal must gain to be liberated from the metal surface. → But no need to explain what work function energy for this question. *Examiner's Report:* *Many of the answers were in general terms rather than in terms of energy changes. Some answers referred only to electromagnetic radiation and threshold frequency.*	**B1** **B1**
	(b)	(i)	Key words: - Energy changes Essential questions: *1)* What is the energy possessed by the photoelectrons upon liberation? *2)* How does the stopping potential affect the movement of the electron and its energy changes? **Electrons of a <u>range</u> of kinetic energy (KE) are emitted from M**. **When V is negative, these electrons will experience a retarding force (electric force), causing them to lose KE and gain electrical potential energy as they move towards C**. As V is increasingly negative, fewer and fewer electrons have sufficient KE to reach C. **V_s is the minimum potential difference that will cause the <u>maximum</u> KE electrons to lose <u>all</u> its KE <u>just</u> before reaching C**, thus reducing the current detected in the circuit to zero. *Examiner's Report* *The majority of answers did not answer the question and simply explained the meaning of the stopping potential. Some candidates discussed the*	**B1**

			energy of the electron with the maximum kinetic energy transferring to electrical potential energy.	
		(ii)	Key words: - Current not continuing to increase Essential questions: *1)* What causes current to flow? *2)* What determines the value of the maximum current? Each ejection of electron from M is due to the absorption of a photon of high enough energy. The **current measured is proportional to the rate of electron reaching C. The rate of electron ejection from M arriving at C is fixed because it is proportional to the rate of photon incidence which is fixed when electromagnetic radiation is at a fixed intensity and fixed frequency.** For positive values of V, the photoelectrons experience an accelerating force towards C, so **all** the photoelectrons released will be collected at C. Therefore, the current will also be fixed at a maximum value. *Examiner's Report* *The majority of answers stated that the potential had no effect on the current if the intensity of the radiation was constant. The question was not answered in terms of the why there is a constant current when the potential difference becomes positive.*	**B1**
	(c)		Key words: - Use Fig. 3.2, calculate frequency of radiation Essential questions: *1)* How does the work function relate with the frequency of radiation? Using Einstein's Equation: $hf = \emptyset + KE_{max}$ $hf = \emptyset + eV_s$ $f = \frac{\emptyset}{h} + \frac{eV_s}{h}$ $f = \frac{1.8 \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34}} + \frac{1.6 \times 10^{-19} \times 2.2}{6.63 \times 10^{-34}} = 9.7 \times 10^{14} Hz$ *Examiner's Report:* *The majority of candidates were able to calculate the correct frequency for the electromagnetic radiation. There were a significant number of candidates who either misread the graph or ignored the stopping potential and used*	**M1** **A1**

			only the work function energy to determine a frequency.	
	(d)		Essential questions: *1)* What are the significant features of this graph? → max current & stopping potential *2)* How would the max current be affected? (What factors determine the max current?) *3)* How would the stopping potential be affected? (What factors determine the stopping potential?)  The **stopping potential remains the same**, while the **max current will double**. 1 mark: shape of graph 1 mark: same stopping potential *Examiner's Report:* *The vast majority of candidates drew a graph that started from the same stopping potential and reached a current value of twice the original current at V = 0.*	

				Marks
4	**(a)**		Key Words: • Orbit Jupiter • Radius of orbit Essential Questions: • How is centripetal acc linked to period and orbital radius? Solution: Centripetal acc, $a = r\omega^2 = r\left(\frac{2\pi}{T}\right)^2$	**M1**
			$= 4.22 \times 10^5 \times 10^3 \times \left(\frac{2\pi}{1.53\text{x}10^5}\right)^2$ $= 0.712 \text{ m s}^{-2}$ ER: A small minority of candidates made a power of ten error for the radius	**A1**
	(b)	**(i)**	Key Words:	

			• Same magnitude & direction Essential Questions: • How is g related to a_c? Solution: As the gravitational force, (F_g = mass of moon x gravitational field strength) provides the centripetal force (F_c = mass of moon x centripetal acceleration) for the moon to orbit Jupiter, gravitational field strength g is of the same magnitude as the centripetal acceleration a_c. As gravitational field strength points towards the centre of Jupiter, centripetal acceleration also points towards the centre of Jupiter.	**B1** **B1**
		(ii)	Essential Question: • How is radius related to centripetal acceleration? • Why did (i) ask us to consider gravitational field strength? Solution: Using $g = \frac{GM}{r^2}$ $\frac{\text{orbital radius of } I_o}{\text{orbital radius of Amalthea}} = \sqrt{\frac{\text{g of Amalthea}}{\text{g of } I_o}} = \sqrt{\frac{\text{centripetal acc of Amalthea}_o}{\text{centripetal acc of } I_o}}$ $= \sqrt{\frac{3.87}{0.712}} = 2.33$ ER: Many candidates used a = ω^2R and assumed that ω was constant.	**M1** **A1**

				Marks
5	**(a)**	**(i)**	Key Words: • Uniform electric field • Due to electric field Solution: F = qE = 2 x 1.60 x 10^{-19} x (1.5x10^5) = 4.8 x 10^{-14} N	**A1**
		(ii)	Essential Question: • What is the equation for force between point charges? Solution: Electrostatic force $= \frac{q_1 q_2}{4\pi\varepsilon_o r^2}$ $= \frac{(2\text{x}1.6\text{x}10^{-19})^2}{4\pi\varepsilon_o(4\text{x}10^{-12})^2}$ = 5.8 x 10^{-5} N	**M1** **M1** **A1**
	(b)		Key Words: • Molecule AB • Resultant force is zero Solution:	

			Due to the external electric field A and B are in, they will experience an **electric force** of 4.8 x 10^{-14} N of **same magnitude** as they are of the **same magnitude of charge.** The **forces** on A and B are of **opposite direction to each other** as their **charge is of different sign** (A is positively charged whereas B is negatively charge). Therefore, the resultant force on the molecule will be zero. As we are looking at the molecule as a whole, the electrostatic forces that each exert on each other are considered as internal forces.	**B1** **B1**
	(c)		Key Words: • Molecule AB Essential Question: • What forces do we consider and how are these forces related to one another? Solution: The forces due to the external uniform electric field on charge A and B will contribute to a couple on the 2 charges. The perpendicular distance between the line of action of those 2 forces is (4 x 10-12) sin 60 = 3.46 x 10-12 m Torque = F x d = 4.8 x 10-14 x 3.46 x 10-12 = 1.66 x 10-25 Nm. Examiner's Report: The majority of candidates gave answers that described the effect of only one of the types of force that had been calculated in (a)(i) and (ii). There were references to forces cancelling out or where the nature of the force was not identified.	**M1** **A1**

				Marks
6	**(a)**		Since a β particle is emitted, i.e. ${}^{0}_{-1}\beta$, to conserve the nucleon number and proton number the notation for nuclide D is $${}^{128}_{54}D$$ **<u>Examiner's Report:</u>** *Most candidates answered correctly. Some candidates did not identify the atomic and mass numbers for a β-particle, or used those for an α-particle.*	**A1**

	(b)		Key Points: The radioactive decay law is applicable at any instant of the decay process. So the timings can be offset to make 2000s as the initial decay timing. At t = 2000 s, C = 175 s^{-1} At t = 6000 s, C = 28 s^{-1} Assuming C_0 = 175 s^{-1} @ t = 2000 s, Using $C = C_0 e^{-\lambda t}$ Then $28 = 175\, e^{-\lambda(4000)}$ $-4000\,\lambda = \ln\frac{28}{175}$ $-4000\,\frac{\ln 2}{t_{\frac{1}{2}}} = \ln\frac{28}{175}$ $t_{\frac{1}{2}} = \frac{-4000 \cdot \ln 2}{\ln\left(\frac{28}{175}\right)}$ $t_{\frac{1}{2}}$ = 1510 s (3 s.f.) **<u>Examiner's Report:</u>** *The majority of candidates determined the correct answer.*	**C1** **M1** **A1**

				Marks
7	**(a)**	**(i)**	*Note that y_1 and y_2 are NOT average values of y but two different set of readings y with respect to different thickness.* *Keywords:* *Show that data supports the suggestion that s is -3* *Essential questions:* 1. *What exactly is the suggestion?* 2. *How to link the suggestion to the theory and then link to the equation?* 3. *What will be the equation like when s = -3?* 4. *Why were two values of d (beam thickness) given? How can I use these two values?* 5. *What trends of the data or feature of the equation must be shown to support the suggestion?* Solution: Given s = -3, rewrite 2 equations based on y_1 and y_2 with its respective thickness: $y_1 = kMgl^r(5.00 \times 10^{-3})^{-3}b^{-1}$ ––––(1) $y_2 = kMgl^r(6.00 \times 10^{-3})^{-3}b^{-1}$ ––––(2)	

$$\frac{(1)}{(2)} \Rightarrow \frac{y_1}{y_2} = \left(\frac{5}{6}\right)^{-3} = 1.728$$

M1

y_1	y_2	$\frac{y_1}{y_2}$	Ave value of $\frac{y_1}{y_2}$
0.257	0.148	1.736	1.7395
0.178	0.103	1.728	
0.118	0.068	1.735	
0.073	0.042	1.738	
0.042	0.024	1.750	
0.021	0.012	1.750	

Since the ratio of y_1 and y_2 differs from the true value of 1.728, by 0.0115 or 0.7%, we conclude that the data supports the suggestion. **A1**

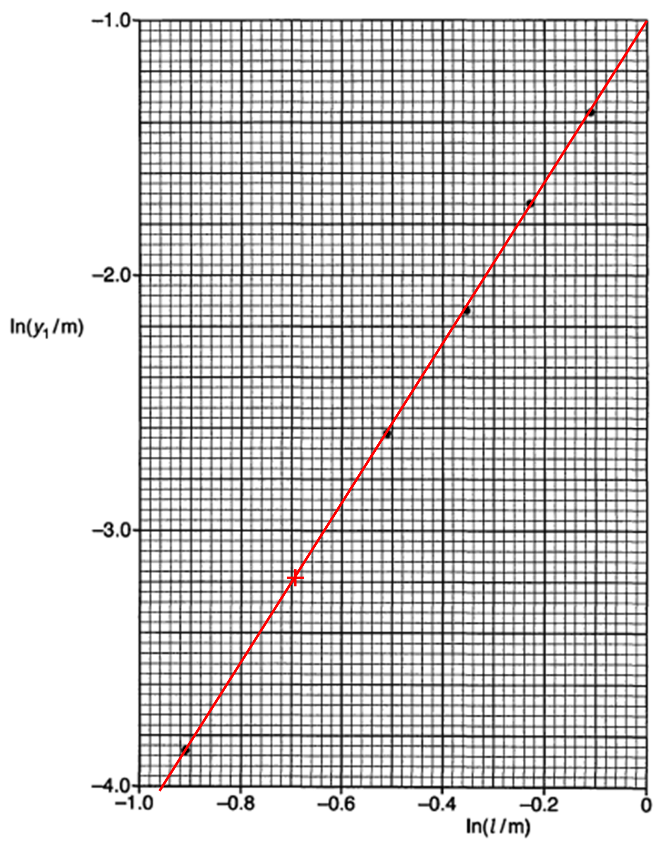
Examiner's Report:
A minority of candidates completed this 'show that' question. Many answers suggested two ratios of different numbers were equal without completing the calculation of each ratio. Some candidates simply restated the number given in the question stem without showing a calculation to the correct number of significant figures.

(a) (ii) Solution:

For l = 0.500 m,

ln(0.042) = -3.170
ln(0.500) = -0.693 **A1**

(a) (iii) 1.
2.



B1 – accurate plot
B1 – line of best fit

	(a)	**(iv)**	Solution: $$Gradient = \frac{-1-(-4.0)}{0-(-0.96)}$$ $$= 3.125 = 3.13\ (3\ s.f.)$$	**M1** **A1**
	(a)	**(v)**	*Essential questions:* 1. *What is the equation of a straight line graph?* 2. *How do you express the given equation into Y = mX + c?* 3. *Must you breakdown the expressions Mgd^sb^{-1} into individual ln function?* Solution: By taking the natural log on both sides of the equation, $$y = kMgl^r d^s b^{-1}$$ $$\ln y = r\ln l + \ln(kMgd^s b^{-1})$$ By plotting $\ln y$ vs $\ln l$, it is expected to obtain a straight line graph of gradient r and a y-intercept of $\ln(kMgd^sb^{-1})$ which is supported by the graph of Fig. 7.3. ***Examiner's Report:*** *Many candidates did not answer the question, providing answers that described what would be expected if logs were taken of the given expression but there was no comparison with the graph that had been drawn. Some candidates described the graph as showing the quantities plotted on the graph were proportional as a straight line was obtained despite the fact that the line clearly had a y-intercept.*	**M1** **A1**
	(a)	**(vi)**	Solution: Since gradient = 3.13, r is the gradient and r is an integer, Therefore, r = 3. ***Examiner's Report:*** *Many candidates misunderstood what was meant by integer.*	**A1**
	(b)		*Essential questions:* 1. *Do you calculate y-intercept or can you read off y-intercept from the graph?* 2. *How do you read off the y-intercept from the graph?* 3. *Does the y-axis cut the x-axis where x = 0?* Solution: From the graph, y-intercept = -1.0 $$\ln(kMgd^sb^{-1}) = -1.0$$ $$k = \frac{e^{-1.0}}{Mgd^sb^{-1}}$$	**M1**

			$$k = \frac{e^{-1.0}}{0.5 \times 9.81 \times (5 \times 10^{-3})^{-3} \times (3 \times 10^{-2})^{-1}}$$ $$k = 2.81 \times 10^{-10} \approx 3 \times 10^{-10} \quad (Shown)$$	**M1** **A0**
	(c)	**(i)**	Solution: Since $\frac{b}{kMgd^s l^r}$ is a constant, the beam acceleration a is directly proportional to its displacement x from its equilibrium position and the negative sign indicates that its acceleration is opposite in direction to its displacement, which supports the definition of a simple harmonic motion.	**A1**
	(c)	**(ii)**	Solution: Comparing to the equation of S.H.M, $$a = -\omega^2 x$$ $$\omega^2 = \frac{b}{kMd^s l^r}$$ $$\omega^2 = \frac{3 \times 10^{-2}}{(3 \times 10^{-10}) \times 0.5 \times (5 \times 10^{-3})^{-3} \times (0.6)^3}$$ $$\omega^2 = 115.7$$ $$\omega = 10.76 \quad \Rightarrow \quad \frac{2\pi}{T} = 10.76$$ $$T = \frac{2\pi}{10.76} = 0.584\ s$$ ***Examiner's Report:*** *A significant number of candidates compared the given expression with that used for s.h.m., obtaining a value for ω and hence the time period. Most candidates were not able to start the calculation or made errors in the substitution or calculation. A common error was to use the constant given in the equation for the acceleration as ω instead of ω^2*	**M1** **A1**

8			**Planning Question**	
			Solution: Procedure: 1. Set up the apparatus as shown	

2. Connect the circuit as shown

3. Measure the mass m of the water in the beaker using a balance
4. Measure the initial temperature θi of the water using a thermometer.
5. Turn on the switch and start the stop watch. The water must be stirred to ensure that the temperature of the water is uniform.
6. Record I, the ammeter reading and V, the voltmeter reading.
7. Record the final temperature θf after a duration of time t. The duration of time should long enough to allow the temperature to rise by a few degrees.
8. Calculate the electrical energy input (which is the energy dissipated from the lamp) using Ei = IVt.
9. Calculate the thermal energy (which is the energy absorbed by the water) using Eo = mc $\Delta\theta$ = mc (θf - θi) where c is the specific heat capacity of the water. The value of the c can be obtained from data book.
10. Hence the efficiency can be calculate from η = 1 – Eo/Ei.
11. Repeat the experiment for at least 6 readings and with a good range of values of V, the p.d. across the lamp by adjusting the rheostat.
12. Tabulate the values of V, θI, θf, t , Ei, Eo and η log V and log η
13. Let $\eta = aV^b$, log η = log a + b log V
14. Plot a graph of log η against log V where y intercept = log a and gradient = b
15. The values of a and b can be determined from a = $10^{\text{y-intercept}}$ & b = gradient of graph
16. *Hence the relation between* η and V *established*

Additional points

1. The beaker of water must be well lagged by placing it in a styroform container to reduce the heat loss to the surroundings.

2. The beaker should have a low value of heat capacity. Otherwise the heat absorbed by the beaker should be considered. The thermal output of the lamp should be the heat absorbed by the water + heat absorbed by the beaker. The heat absorbed by the beaker = C ($\Delta\theta f$ - θi) where C is the heat capacity of the beaker which is found in a separately experiment.

3. The whole lamp should be completely submersed in the water to reduce heat loss through radiation to the surroundings.

4. The p.d. V may vary during the experiment due to changing in the battery e.m.f. or the resistance of the lamp. The p.d. can be maintained by adjusting the rheostat.

5. For accurate result, the temperature change should be larger enough (at least 5 degree to allow an uncertainty of 10 %).

Precautions:

1. The d.c. supply used must not be more than the normal operating voltage of the lamp
2. The glass bulb and the beaker with hot water should be handled with gloves or tongs.
3. Do not immerse the lamp into the water or remove it from the water when it is still not to reduce breakage due to sudden change in temperature of the glass.
4. The lamp should be clamped onto a retort stand to prevent it from dropping into the beaker.
5. The thermometer should be clamped onto a retort stand to prevent it hitting the beaker.

Key words

Determine the relationship between n and V

A beaker of water….

Essential questions

What is the purpose of the water provided in the weaker?

How to find the thermal energy output from the lamp?

What measurements to be taken and what formulae can be used to determined the thermal energy output? What is the dependent variable?

How to find the electrical energy input to the lamp?

What is the circuit to be set up to provide the power?

What measurements to be taken and what formulae can be used to determined the electrical energy input? What is the independent variable?

How to change the independent variable?

Given $n = aV^b$, what quantities to be measure in order to determine the relationship between n and V?

What graph to be plotted to determine the relationship between n and V?

How to find a and b from the graph?

Suggested Mark Scheme

	Code	Mark
Labelled diagram of a workable procedure	A1	1
Labelled diagram of a workable circuit	A2	1
Define & Method in measuring the DV	DV	1
Define & Method in measuring the IV	IV1	1
Method in changing the IV	IV2	1
Analysis of results Method to find efficiency Method to establish relationship	 AN1 AN2	 2 1
Control variables (state + explain how)	C	1
Details to ensure reliability and accuracy	D	2
Safety precautions	SP	1
Total		Max 12

			Examiner's report:	
			Question 8 **Diagram** The circuit diagram was often poorly drawn, with an ammeter or voltmeter missing. The filament lamp was often included in the circuit but the lamp was positioned at a fixed distance from a beaker of water, rather than in the water. Labelling was often insufficient. The independent and dependent variables were identified by a significant number of candidates. Candidates often gave a long list of variables to be controlled and therefore kept constant with only one or two items on the list being relevant. **Procedure** Most answers correctly described the measurement of the potential difference across the lamp and the current. Candidates who performed less well did not mention a measurement of the mass of the water or assumed that a volume measure was sufficient. Candidates usually stated the time for the lamp to be on, but often did not include time when determining the energy supplied, using VI rather than VIt. Some candidates suggested leaving the lamp on until the temperature stabilised. Most candidates suggested repeating the experiment for at least five values of the potential difference. **Safety and Analysis** The main safety feature mentioned was the use of gloves or tongs when adjusting the lamp or moving the hot beaker. A few candidates suggested that the circuit could cause electrocution when cells of batteries up to 12 V were being used. Most candidates suggested a workable form of analysis. Some candidates did not provide sufficient detail, such as the quantities to plot on each of the axes or how the unknowns in the given expression are to be determined from the graph. **Details** A minority of candidates suggested covering the beaker; even fewer mentioned clamping the thermometer or the lamp or that the water should be stirred. Many candidates did not give sufficient detail.	

Paper 3

				Marks
1	**(a)**		*Essential questions:* *System* *Conditions* Solutions The resultant force of all the forces acting on the system is zero The resultant moment of all the forces acting on the system about any point is zero.	**B1** **B1**
1	**(b)**	**(i)**	*Essential questions:* 1. *Can a moving body be in equilibrium or only static body can be in equilibrium?* 2. *Under what condition, does a moving body in equilibrium?* Solution: Yes. A ball falling at constant speed in air has no acceleration. According to Newton's 2nd law of motion, there is no resultant force. ***Examiner's Report:*** *Reference to constant speed in the question meant that the majority of answers were based, correctly, on there being no acceleration and hence no resultant force.*	**B1** **B1**

1	**(b)**	**(ii)**	*Key Words:* • *Equilibrium* • *Circular earth orbit* Solution: A satellite in orbit is accelerating continuously since its direction of velocity changes continuously. By Newton's 2nd law of motion, the satellite must experience a net force to be able to accelerate. Therefore it is not in equilibrium. The gravitational force exerted by the Earth on the satellite provides this net force / centripetal force. *Examiner's Report:* *The fact that either there is a resultant gravitational force acting on the satellite or that the satellite is accelerating continuously provided the starting point for the explanation. In a significant number of scripts, this was not seen.*	 **B1** **B1** **B1**

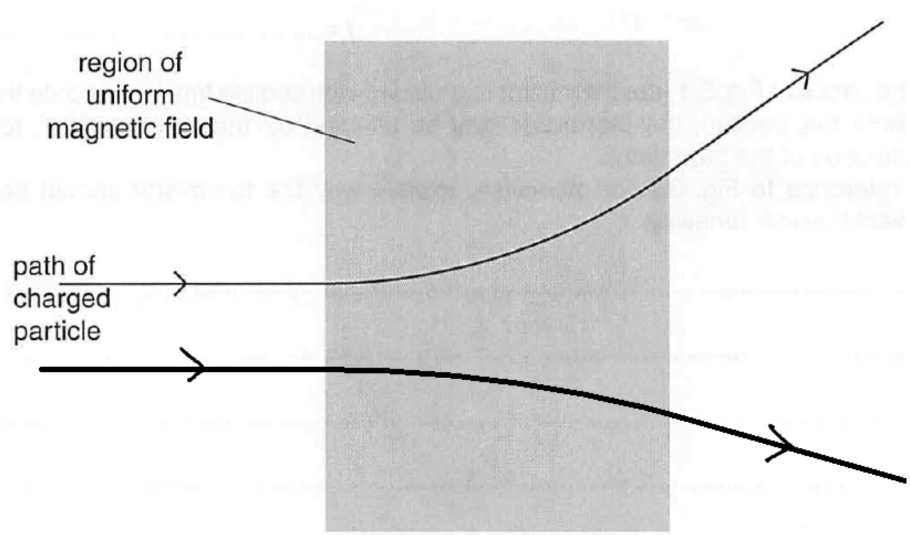
				Marks
2	**(a)**		Key words: - Screen placed parallel to the plane of the slits Essential questions: *1)* What quantities determine the value of the wavelength of the laser light? *2)* Is there a formula that can be used straight away? $x = \frac{\lambda D}{a}$ $\lambda = \frac{xa}{D}$ $= \frac{1.4 \times 10^{-3} \times 0.95 \times 10^{-3}}{2.1} = 6.3 \times 10^{-7} m$ *Examiner's Report* *There were very few instances where the correct answer was not obtained, with adequate explanation.*	 **M1** **A1**

	(b)		Key Points: Note the effects of the size of the slits on the amount of light that passes through it. Large slit more light hence larger amplitude of the wave. - The fringe separation/distance between successive bright/dark fringes remains unchanged. - The intensity of the maximas/bright fringes reduces since the amplitudes of the laser light from the two slits arriving at the screen are no longer equal. - At the dark fringes the intensity is no longer zero as the amplitudes of the laser light from the two slits no longer cancel each other out completely. Instead there will be a finite intensity of light obtained at these locations. - Hence the contrast between the dark and bright fringes reduces. **Examiner's Report:** *Most answers dealt with the change in the brightness of the light and of the dark fringes.*	 **B1** **B1** **B1**
	(c)		Essential questions: • What effect does widening the slit have on the waves that are passing through the slit? • What are the conditions required for waves from two slits to interfere and form fringes? • How does widening the slits (which causes the waves to spread less) lead to the waves from the two slits not forming fringes on the screen? Solution: When the two slits are widened, the **light waves passing through each slit will diffract less.** A smaller degree of diffraction causes the region in which the two waves overlap and interfere to become smaller. **If the widths of the slits are too wide, the two waves do not overlap at all and hence no interference occurs**. Hence, the fringes are no longer observed. *Note: As a **laser** beam is used, widening the slits do **not** cause the waves to be incoherent! Citing incoherence as the reason is wrong!* Examiners' Report: Most candidates attributed the effect to reduced diffraction at the double slit. The failure to observe fringes was frequently said to be due to either 'less interference' or 'less overlapping' or 'no coherence'. ER Interpretation: The description of the cause needs to be more precise than the terms mentioned in the report. It needs to be emphasized that students need to elaborate on what "less overlapping" means if they use the term (e.g. a smaller region where the two waves overlap due to the lesser extent of diffraction).	 **B1** **B1**

				Marks
3	**(a)**		Essential questions: • What is the relationship shown in Fig. 3.2? • Given that the question wants to find the temperature for a particular	

			current, what information does the graph provide? • How can we link the resistance at a given temperature to the current? When the current is 1.60 mA, the resistance in thermistor, R is given by the ratio of the potential difference across the thermistor, V_T and the current through it, I To find V_T, the sum of the potential difference of the two resistors must be the e.m.f. $E = I(R + 1500)$ $(R + 1500) = \frac{E}{I} = \frac{6}{1.6 \times 10^{-3}} = 3750$ $R = 2250\Omega = 2.25\text{k}\Omega$ From Fig 3.2, When R = 2.25 kΩ, θ = 14.0 °C ***Examiner's report:*** There was a variety of ways in which the calculation could be approached. With few exceptions, the correct answer was obtained. ***Extension questions:*** What other way could the calculation be approached? Can the potential divider method be used? How would this be done?	 **M1** **M1** **M1** **A1**
	(b)		Essential Questions: • What do you understand by the term "thermal runaway"? How would such an effect destroy the thermistor? Why would be mitigated by using cooling fins? • Why does the thermistor need to be kept cool? What happens when the thermistor gets warm? • A "runaway" implies a feedback loop of cause and effect that goes on to infinity. How could possibly occur? What information does the graph Fig 3.2 provide with respect to the thermistor warming up? • How does the decreased resistance cause the thermistor to continue to warm up? And what effect that does the increase temperature have on the thermistor? **As current flows through the thermistor,** the thermistor will dissipate energy in the form of thermal energy that will **heat up the thermistor even further**. As shown in Fig. 3.2, as the **temperature increases, the resistance in the thermistor will decrease, increasing the current in the circuit**. **This will increase the power dissipated in the resistor, further heating the thermistor and lead to overheating**. Therefore, to prevent this from happening, the **thermistor has to be kept at a constant temperature** by means of the cooling fins. ***Examiners' Report*** Most answers involved a statement that the resistance of the thermistor would decrease as the temperature rose. Some candidates thought that the resistance would decrease to zero. A number of candidates did not link the increase in current to a heating effect in the thermistor.	 **B1** **B1**

				Marks
4	(a)		The tesla is the SI unit for magnetic flux density. If a **straight conductor** carrying a **current of one ampere** **is placed at right angles to a uniform magnetic field** of flux density one tesla, then the **force per unit length** on the straight conductor is **one newton per metre**. ***Examiners' Report***: This was not well answered.	**B1** **B1** **B1**
	(b)	(i)	Essential Questions: • What are the conditions for motion in a circle? • How does the force acting on a moving charge in a uniform magnetic field fulfil these conditions? **The magnetic force exerted by the magnetic field on the *moving* charged particle is <u>always</u> normal to the direction of the particle's <u>velocity</u> and directed towards a fixed point. This force thus continuously changes the direction of the linear velocity but not the magnitude of the linear velocity**. **The constant speed in turn keeps the magnitude of the magnetic force constant, and hence the particle moves in a circular path <u>of constant radius</u>.** ***Examiners' Report***: Most candidates stated that the magnetic force on the particle is normal to the direction of motion of the particle.	**B1** **B1**

		(ii)	Essential questions: • What provides for the centripetal force in the circular motion? • What are the equations for the magnetic force and the centripetal force? The magnetic force acting on the charge provides the centripetal force: $F_B = F_C$ $Bqv = \frac{mv^2}{R}$ $p = mv = BqR$ $p = (0.24)(1.6\times10^{-19})(0.062) = 2.38\times10^{-21}\ \text{kgms}^{-1}$ ***Examiners' Report***: Most candidates equated magnetic force to centripetal force and the correct answer was obtained.	M1 M1 A1
	(c)		Essential Questions: • How does momentum affect that the path of the particle? What about the sign of the charge? Explain your reasoning using the equation obtained in (b)(ii) • What is the path of the particle within the field? What about the path of the particle outside the field? Since the momentum of the particle is $p = BqR$, using a particle with a higher momentum, but moving in the same field and having the same magnitude of charge, means that only the radius of curvature will increase. By Fleming's Left Hand Rule, since a particle of opposite charge represents a current moving in the opposite direction, the direction of force must be reverse, and so the direction of the arc is also reversed. Outside the field, the particle experiences no force, so By Newton's First Law, the particle's path is a straight line.  1 Mark: Shape: correct direction of circular curvature within field, straight line after exiting field	B1 B1

			1 Mark: Smaller radius of curvature within field compared to the given path ***Examiners' Report*** Many diagrams were drawn carelessly. Most candidates drew the path curving in the correct direction but drew the path as straight until the particle was well within the field, or the radius of curvature changed significantly partway along the curved path.	

				Marks
5	**(a)**		By definition, a photon is a quantum of electromagnetic radiation energy. ER: It was common to find that there was no reference either to energy or to electromagnetic radiation.	**B1**
	(b)	**(i)**	Keywords: • Change in energy • Photon Essential Question: • How is change in wavelength related to changes in energy? Change in energy $= E_{incidence} - E_{deflected}$ $= \frac{hc}{\lambda_i} - \frac{hc}{\lambda_d}$ $= (6.63 \times 10^{-34})(3 \times 10^8)(\frac{1}{965\times10^{-12}} - \frac{1}{966.8\times10^{-12}})$ $= 3.84 \times 10^{-19}$ J ER: In most scripts, the relevant formula was quoted and the correct answer was given to an appropriate number of significant figures.	 **M1** **A1**
		(ii)	Keywords: • Conservation of energy • Momentum of deflected electron • Show Essential questions: • What energy conversions take place? • How is energy related to momentum? By conservation of energy, Total energy of incidence photon = total energy of deflected photon and deflected electron. Hence the energy of deflected electron = the change in energy of photon $= 3.8374 \times 10^{-19}$ J Since momentum, p = mv $\frac{p^2}{2m} = \frac{1}{2}mv^2$ = Energy of deflected electron $p = \sqrt{2mE}$ $p = \sqrt{2(9.11 \times 10^{-31})(3.8374 \times 10^{-19})}$ $= 8.36 \times 10^{-25}$ Ns ER: This is a "show that" question and the answer was given to candidates. Some candidates made a clear statement involving energy change (not just symbols) and showed the full substitution into the relevant formula.	 **M1** **M1** **A0**
	(c)		Keywords: • Components of momentum at right-angles to direction of incident photon	

			• Angle of deflection of the electron • Stationary electron By conservation of linear momentum, Total initial momentum = total final momentum Hence the total momentum of the deflected photon and deflected electron must be the same as the initial momentum of the incidence photon, in both its magnitude and direction. i.e. the total final momentum is along the same direction as the momentum of the incidence photon. Therefore the resultant momentum at the right angles to the direction of the incident photon must be zero. $p_1 \sin 75° = p_2 \sin \alpha$ $\frac{h}{\lambda} \sin 75° = 8.3617 \times 10^{-25} \sin \alpha$ $\frac{6.63 \times 10^{-34}}{966.8 \times 10^{-12}} \sin 75° = 8.3617 \times 10^{-25} \sin \alpha$ $\alpha = 52.4°$ ER: There were some very clear concise answers, stating the conservation of momentum at right angles to the incident photon. Some candidates confused momentum components in the two directions.	**B1** **B1** **B1** **M1** **A1**

				Marks
6	**(a)**	**(i)**	Acceleration is the rate of change of velocity with respect to time. ER: This was generally answered satisfactorily.	**A1**
		(ii)	Keywords: • Near earth's surface • constant The acceleration of a free falling body in a gravitational field is equivalent to the acceleration produced by the body's weight and hence a, the acceleration of free fall equals to g, gravitational field strength. Consider a point that is height h above the Earth's surface, $g = GM/(R+h)^2$, where M is the mass of Earth, R is the radius of Earth. If h is very much smaller than R, g will be approximately equals to GM/R^2 which is a constant as we assume that mass of Earth and radius of Earth is approximately the same everywhere on Earth. Therefore the acceleration of free fall near the Earth's surface is constant. ER: Most candidates quoted the expression $g = GM/R^2$, although they often failed to explain the symbols.	**B1** **B1** **B1**
	(b)	**(i)**	Essential Questions: • What factors affect the effect of drag force due to air resistance? Steel ball has a high density, hence high mass, and the steel ball used has a small surface area (diameter 1.2 cm). Therefore, the effect of air resistance is not observable in this case.	**B1**

			Examiner's Report: Most suggestions centred around a small surface area giving rise to low air resistance.	
		(ii) 1.	$s = ut + \frac{1}{2}at^2$ $44.1 \times 10^{-2} = 0 + \frac{1}{2}at^2$ $t = \sqrt{\frac{2(44.1 \times 10^{-2})}{9.81}}$ $t = 0.300$ s (to 3 s.f. as requested by the question) Examiner's Report: With very few exceptions, this calculation was completed successfully.	**M1** **A1**
		(ii) 2.	Essential Questions: • When looking at the diagram, how is the position of the ball affect your determination of the vertical distance travelled? • Which point of the steel ball is taken to be the reference to take for its position? Calculating the time taken to reach 56.6 cm from 0.0 cm AND accounting for the 1.2 cm diameter of the steel ball (there is a difference when analyzing the dotted ball and the solid ball in Fig. 6.1), $s = ut + \frac{1}{2}at^2$ $(56.6 - 1.2) \times 10^{-2} = 0 + \frac{1}{2}at^2$ $t = \sqrt{\frac{2(55.4 \times 10^{-2})}{9.81}}$ $t = 0.33607$ s Therefore, $T = 0.33607 - 0.300$ $T = 0.036$ s	**M1** **M1** **A1**
	(c)		Percentage Uncertainty, $\% = \frac{\text{Actual T} - \text{Stated T}}{\text{Stated T}} \times 100\%$ $\% = \frac{0.036 - 0.033}{0.033} \times 100\%$ $\% = 9.1\%$ (to 2 s.f.)	**M1** **A1**
			Examiner's Report: A significant number of candidates used their answer to (b)(ii)2 as the denominator of the expression for the uncertainty.	
	(d)	**(i)**	Key Strategy: • How do we translate the text description to a pictorial diagram which will aid us in solving this problem? The time taken will be shorter than the time determined in (b)(ii)1. When the scale is knocked sideway with the same initial position as the origin, the 44.1 cm mark is shifted upwards, hence the true vertical distance travelled is shorter, making the time travel to be smaller.	**B1** **B1**

			Examiner's Report: With few exceptions, the explanation was satisfactory.	
		(ii)	Key Questions: • What does the phrase "does not fall freely" suggests about the force(s) acting on the steel ball for that short distance? • What is the origin force? What is its possible magnitude and direction? • What happen to the acceleration of the steel ball after that "short distance"? The actual time for the ball to fall to 44.1 cm mark is longer as compared to the time determined in (b)(ii)1. Initially when the steel ball is just released, if the ball retains some magnetic effect, it will attract to the electromagnet even though there is no current flowing through the electromagnet. This would cause the initial downward resultant force to be lower and hence a lower initial acceleration. Therefore, the ball will have an overall lower average velocity which results in a lower time of travel of the same vertical distance of 44.1 cm.	 **B1** **B1** **B1**
			Examiner's Report: Some candidates misread the question and attempted to give an explanation as to why the ball would not have an initial acceleration of g. The majority of candidates did not make it clear that only the initial acceleration would be less than g.	
	(e)		Key Questions: • What does the question want when the word "acceleration" is italicised? ➢ Key focus is on explaining what happens to ball's ACCELERATION but analysing the Forces acting & hence the Net force acting. Characteristics of air resistance (R): Magnitude of R increases with speed, and, direction of R is opposite direction of velocity. Since ball was released from rest, R increased from zero. Whereas ball's weight (W) remains constant, and direction of W is in the same direction as velocity in this case. Hence the Net downward force (F) on the ball decreases as it moves. Eventually, when the ball has fallen through a long distance, R increases to a magnitude equals to W, causing F to reduce to zero. By Newton's 2nd law of motion (F = ma), since ball's mass (m) is constant, ball's acceleration (a) is proportional to F. Thus acceleration decreases from a value equal to the acceleration due to gravity (g) to zero eventually.	 **B1** **B1** **B1**
			Examiner's Report: This was generally answered well. Some candidates referred to acceleration without first describing the effect of increase of air resistance on the acceleration.	

				Marks
7	**(a)**	**(i) 1.**	For a sinusoidal potential function, $V_{rms} = \frac{V_0}{\sqrt{2}}$	

			$V_0 = \sqrt{2}V_{rms}$ $V_0 = \sqrt{2}(17)$ $V_0 = 24.0\,\text{V}$	**M1** **A1**
			Examiner's Report: With very few exceptions, both parts were answered correctly.	
		(i) 2.	Essential questions: 1) How is f related to the given information? 2) What other variable(s) is f related to in a.c.? Solution: Compare the given equation with the general form: $V = V_o \sin(\omega t)$ where $\omega = 2\pi f$ Thus, $f = \omega / 2\pi = (380\text{ rad s}^{-1}) / 2\pi$ $= 60.479 = 60.5$ Hz (3 s.f.)	 **M1** **A1**
		(ii)	Keywords: Heating effect Essential questions: What is the heating effect dependent on? If we use the average value of the AC current, then the average power dissipated (heating effect) in the heating coil would be zero. A better representative quantity would be the root-mean-square current. It is the value of the steady direct current that dissipates energy at the same rate as the alternating current in a given resistance. ***Examiner's report:*** *A significant number of candidates discussed the meaning of r.m.s values. Some linked the heating effect to current.*	 **B1** **B1**
	(b)	**(i)**	Definition question. The specific heat capacity of a substance is defined as the amount of thermal energy needed to raise the temperature of unit mass of the substance by 1 kelvin. ***Examiner's report:*** *Most candidates clearly understood the basis of the definition but then included both quantities and units in their statements.*	 **A2**
		(ii)	Key words: Intercept on power axis Essential Questions: Would there be 100% transfer of energy from the heating coil to the water? $Pt = m_w c_w \Delta\theta + P_{loss} t$ $m_w c_w \Delta\theta = Pt - P_{loss} t$ $\frac{m_w c_w \Delta\theta}{t} = P - P_{loss}$ $\frac{m_w}{t} = \frac{1}{c_w \Delta\theta}(P - P_{loss})$	

			When $\frac{m_w}{t}$ is zero, the intercept on the power axis is simply the power loss from the apparatus. ***Examiner's report:*** *Many thought that the intercept represented the initial heating of the apparatus or the losses for zero flow of water.*	**A1**
		(iii)	From, $$\frac{m_w}{t} = \frac{1}{c_w \Delta\theta}(P - P_{loss})$$ The gradient of the graph will give us the value for $\frac{1}{c_w \Delta\theta}$. Determine the value of heat capacity of water from there. Gradient = $\frac{3.8-2.3}{75-51}$ = 0.0625 $gs^{-1}W^{-1}$ $$\frac{1}{c_w \Delta\theta} = 0.0625$$ $$c_w = \frac{1}{(38.8 - 35.0)0.0000625}$$ $$c_w = 4210\, Jkg^{-1}K^{-1}$$ ***Examiner's report:*** *The majority of candidates completed this calculation successfully.*	 **M1** **M1** **M1** **A1**
	(c)		Keywords: Repeated with water Essential Questions: What changes are there to the gradient and intercepts? The temperature difference is still the same and so is the specific heat capacity of water. Therefore the gradient remains the same. With an increase in the temperature of the water, the power loss is higher as well; therefore the P-intercept is larger. ***A1 - Same gradient*** ***A1 - The P-intercept is larger*** ***Examiner's report:*** *Most candidates did draw an appropriate successfully.*	
	(d)	**(i)**	It states that the ***increase*** **in internal energy ΔU** of a **<u>closed</u> system** is the **sum of the heat *<u>supplied to</u>* the system Q and the work done *<u>on</u>* the system W.** ***Examiner's report:*** *The law was well known by many candidates. A small number of candidates either did not make it clear that the heat supplied and the work done have to be summed or did not reference energy, rather than work done.*	**A2**
		(ii)	Keywords: Constant volume and pressure Different	

			Essential Questions: Which quantity does specific heat capacity relate to in the First Law? (What is the definition of specific heat capacity?) ➔ Relates to Q needed to raise temperature the temperature of per unit mass of a substance by 1 kelvin. At the same time, because of the relationship to temperature change, it has an implication on ΔU as well since $\Delta U \propto \Delta T$ for an ideal gas. Which quantity in the First Law differs between a constant volume and constant pressure process? ➔ W = 0 for constant volume; W is negative when temperature increases by 1 kelvin (work is done by gas as the gas expands). $\Delta U = Q + W$ $Q = \Delta U - W$ Solution: At constant volume, the gas does not do any work and all of the thermal energy **required** to **raise** the temperature of per unit mass of the gas **by 1 kelvin** is only equal to the **increase in** internal energy. However, at constant pressure, the thermal energy **required** to **raise** the temperature of per unit mass of the gas **by 1 kelvin** is the **sum of** the **increase in** internal energy and work done **by** the gas going through **expansion**. Hence, the specific heat capacity of the ideal gas measured at constant volume is **smaller** than the specific heat capacity measured at constant pressure. ***Examiner's report:*** *Most were able to state the effect of constant pressure on work done but there was confusion as to whether the work would be done on the gas or by the gas.*	 **B1** **B1** **B1**

				Marks
8	**(a)**	**(i)**	Definition Question Simple Harmonic Motion is an oscillatory motion in which the body's acceleration is directly proportional to its displacement from its fixed equilibrium position and is always in opposite direction to this displacement. ***Examiner's report:*** *Most candidates gave a correct definition.*	
8	(a)	(ii) 1.	Key words: - state and explain - how it can be deduced → must **make reference to the relevant feature(s) of the graph** that support(s) your statement and explanation Essential questions: 1) What causes motion? And under what condition will a body oscillate? • A net force causes changes in state of motion of a body • A body that is oscillating moves to and fro about a fixed point. This can only happen if it experiences a restoring force (which is a net force) directed towards its equilibrium position (the fixed point). 2) Making deductions from the graph….What feature of the graph	

			shows that the ball experiences a restoring force directed towards its equilibrium position? • How is 'net force' related to 'acceleration'? → By Newton's 2nd law of motion, F_{net} is directly proportional to a. → F-x graph would be of the same shape as the a-x graph • How should F be related to x if F is a restoring force? → F must always be oppositely directed to x whenever x is non-zero → Does the graph show this? → Yes! Because the graph has a negative gradient! Solution: **a and x are always opposite in sign** (except at the origin), showing that the acceleration of the mass is always oppositely directed to its displacement from the equilibrium position. This implies that whenever the mass is away from the equilibrium position, it experiences an acceleration towards the equilibrium position, causing it to move to and fro the equilibrium position, hence it is oscillating. ***Examiner's report:*** *In most answers, it was recognised that the acceleration is opposite in direction to the displacement.*	**B1** **B1**
		(ii) **2.**	The **a-x graph is not always linear**, showing that acceleration is not always proportional to the displacement, hence not simple harmonic motion. ER: Most candidates realized that the line is not straight.	**B1** **B1**
	(b)	**(i)**	1. It is a wave in which the oscillations in the wave are parallel to the direction of transfer of energy of the wave. 2. It is the distance travelled by a wave profile per unit time. Examiner's report: Candidates found this question particularly challenging. Many defined speed as the product of frequency and wavelength which is not acceptable as a definition	**B1** **B1** **B1**
		(ii) **1.**	Essential questions: 1) How to determine period from the graph? How does KE of a simple harmonic oscillator vary with time? • EK-t graph is a sine-squared graph, so EK repeats its pattern every half-period • Or from observation of a SHM, EK reaches maximum value twice per oscillation • Hence period T is equal to t2. 2) But we don't know the value of t2. Question expects a numerical answer. So how? → What other information in the question is T related to? • Frequency! Solution: T = 1/f = 1/835 = 1.1976×10^{-3} = 1.20×10^{-3} s (3 s.f.)	**M1** **A1**

		2.	Essential questions: 1) See part 1. Solution: (t2 – t1) = ½ T = ½ (1.1976×10^{-3}) = 5.99×10^{-4} s (3 s.f.) Examiner's report: Many candidates gave the time interval as the period which is wrong.	**A1**
		3.	Essential questions: 1) How to determine vmax from the graph? • $E_{max} = ½ m v_{max}^2$ 2) But we don't know the value of E_{max}. Question expects a numerical answer. So how? → What other information in the question is v_{max} related to? • For SHM, $v_{max} = \omega x_o = 2\pi f x_o$ Solution: $v_{max} = \omega x_o = 2\pi f x_o = 2\pi\ (835)\ (610 \times 10^{-9})$ $= 3.2003 \times 10^{-3} = 3.20 \times 10^{-3}$ m s^{-1} (3 s.f.)	**M1** **A1**
		4.	Essential questions: 1) See part 3 Solution: Emax = $½ m v_{max}^2 = ½ (5.3 \times 10^{-26}) (3.2003 \times 10^{-3})^2$ $= 2.7 \times 10^{-31}$ J (2 s.f.)	**M1** **A1**
		(iii)	Essential questions: 1) What is the speed of sound in a gas? 2) How is 'speed of sound' different from 'maximum speed v_{max}'? Solution: The speed of sound in a gas at room temperature is about 330 m s^{-1} which is more than 100, 000 times the speed found in (ii)3. They differ because 'speed of sound' is the speed of transfer of energy, while 'v_{max}' is the maximum speed of each gas molecule's simple harmonic motion. Energy is transferred from molecule to molecule the instant they interact and is independent of the frequency and amplitude of vibration of the wave source. Whereas v_{max} is proportional to the frequency and amplitude of vibration of the wave source. Examiner's report: Nil.	**B1** **B1**
	(c)	**(i)**	Essential questions: 1) What type of wave is a sound wave? • Mechanical wave 2) How is sound wave produced? • By a vibrating object in contact with the gas Solution:	

			The source is the mechanical energy of a vibrating object that is in contact with the gas. Examiner's report: The majority of candidates did not state the origin of the energy of the wave.	**B1**
		(ii)	Essential questions: 1) What type(s) of force(s) act on each molecule? [note: restoring force is not the name of a type of force, it is a net force.] Solution: The restoring force arises from the pressure difference in the wave due to the differences in separation between molecules in the wave (alternating regions of compression and rarefactions). Examiner's report: It was common to find that the nature of a restoring force was described, rather than its origin. Personal note: *At the microscopic level, pressure is the result of electrostatic forces between the molecules. But just like how we explain why diffusion occurs (due to differences in concentration), it suffices to explain why pressure equilibrates in nature from the macroscopic perspective.	**B1**