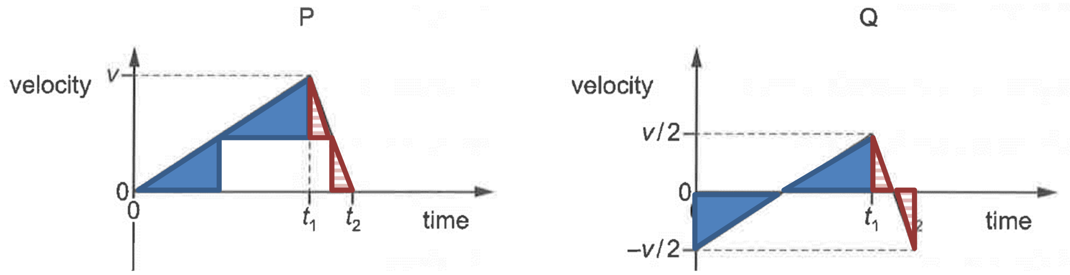
H2 Physics 9749 – 2018 A Level Exam

Paper 1

1	Essential Question(s):
	• How to calculate percentage uncertainty of a quantity from other quantities?
	  o Need an equation linking these quantities. Then apply the relevant rules to calculate the percentage uncertainty (product-quotient or addition-subtraction rule).
	  o Note that we are needed to *determine the percentage uncertainty* ***of g***. We therefore need to **make g the subject of the equation**.
	
	Make g the subject of the equation:
	$T=2\pi\sqrt{\frac{L}{g}}$
	$\frac{T^2}{4\pi^2}=\frac{L}{g}$
	$g=L\frac{4\pi^2}{T^2}$
	
	$\frac{\Delta g}{g}\times 100\% = \left(\frac{\Delta L}{L}+2\frac{\Delta T}{T}\right)\times 100\%$
	$\%g = \%L + 2\%T$
	$\%T = \frac{\%g - \%L}{2}$
	$\%T=\frac{\%g - \frac{0.05}{6.25}\times 100\%}{2}$
	$\%T=\frac{2\% - \frac{0.05}{6.25}\times 100\%}{2}$
	$= 0.6\%$ (1 s.f.)
	
	Answer: A
	
	Examiner's comments:
	Most candidates evaluated the percentage uncertainty in L correctly and also realised that there was a need to halve in order to deduce the percentage uncertainty in T from the percentage uncertainty in T^2. The difficulty that candidates had was in realising that **the percentage uncertainty in L needed to be subtracted from, rather than added to, the percentage uncertainty in g**.

2	Essential Question(s): • What is the difference between distance and displacement, and how can we deduce these quantities from the graphs? Integrating v with respect to t gives change in displacement. Unlike displacement, distance is a scalar, hence the magnitude of the integral is considered to find distance. Change in displacement for P is positive, while for Q it is zero. Hence displacements are different. → either option A or B. For P, the change in displacement is the same as the distance travelled, since the object is travelling on a straight line, in the same direction for the entire journey.

For Q, the distance travelled is shorter as the total area bounded by the graph and the time axis is smaller compared to the total area for P.



Therefore, both displacement and distance are different for P and Q.

Answer: A

Examiner's Comments:
Most candidates found this question challenging. The difficulty they experienced was in comparing the two graphs in terms of distance moved. Most candidates correctly deduced that the displacements were different. Only a minority of candidates correctly compared the total magnitudes of the areas of the triangles defined by the graph lines and the time axes to deduce that object P moves through a greater distance than object Q.

3 Essential Question(s):

- As momentum is a vector, how do we interpret the directions mathematically for vectors that are in opposite directions?
- How to calculate impulse?

impulse = Δp
$= p_f - p_i$
$= mv_f - mv_i$
$= m(v_f - v_i)$
$= m[v_f - (-18\ v_i)]$ Taking direction of final velocity as positive.
$= (80\times10^{-3})[23-(-18)]$
= 3.3 Ns

Answer: B

4 Essential Question(s):

- Is total momentum conserved? What is the condition for total momentum to be conserved?
- What kind of collision is this? (Elastic? Inelastic? Perfectly inelastic?)
- As momentum is a vector, how do we interpret the vector directions mathematically for vectors that are in opposite directions?

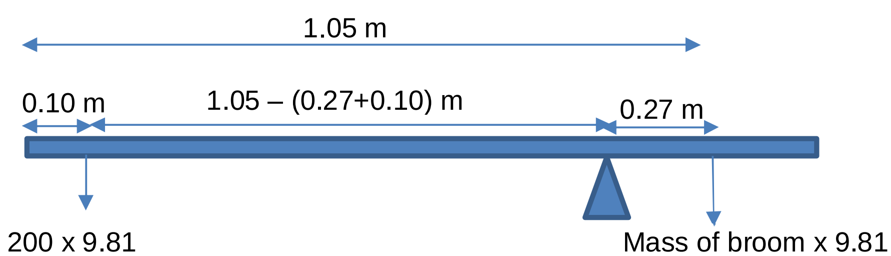
Not net external force acts on the system of two trolleys, hence total momentum remains constant throughout and equal to the total initial momentum.

Stick together → perfectly inelastic collision

Take direction to the right as positive.

Total initial momentum
$= p_{5.0\,kg} + p_{2.0\,kg}$
$= 5.0 \times 4.0 + (-2.0 \times 3.0)$
= 14 Ns

By conservation of momentum,
Total momentum at any instant = Total initial momentum = 14 Ns → either Option C or D

	Total final momentum = (5.0 + 2.0) V = 14 Ns V = 2.0 m s^{-1} (to the right) Answer: C
5	Keyword(s): ➔ Long-handed broom → non uniform → weight not at geometric centre ➔ “balances”….”horizontally” → broom is in equilibrium Essential Question(s): ➔ What are the conditions for the object to be in equilibrium, before and after mass is hung? ➔ What forces act on the broom before and after the mass is hung? → Draw 2 FBDs: before and after mass is hung. **Before mass is hung**, broom is in equilibrium which means that Weight acts through the pivot O initially → CG of the broom is thus 1.05 m from end X **After mass is hung,** and the broom is moved 0.27 m to the right, the CG is also shifted 0.27 m to the right. Pivot remains at the top of the chair.  Applying the principle of moments, taking moments about the pivot, Sum of anticlockwise moments = Sum of clockwise moments 200 x 9.81 x [1.05 – (0.27+0.10)] = Mass of broom x 9.81 x 0.27 Mass of broom = 504 g = 500 g (2sf) Answer: A
6	Keyword(s): ➔ “extra weight” – on top of what the bridge was already supporting Essential Question(s): ➔ What contributes to the total weight supported by the bridge? → water on the bridge and the barge ➔ How does the weight supported by the bridge change when the barge is on it? When barge enters the bridge, there is water displaced which in this case (according to principle of floatation) equals to the weight of the boat. Water displaced flowed away to both sides of the bridge. Hence, the water on the bridge is reduced by an amount of weight exactly equal to weight of the barge. Thus there is no change to the loading on the bridge. Watch: https://www.youtube.com/watch?v=sFdpyxWcKwo Answer: A
7	Keyword(s): ➔ Constant speed → no net force on car (resistive force equals to driving force of car) Essential Question(s):

	➔ How is power related to force? [$P_{output} = F_{driving}v$] ➔ How is force related to speed? [resistive force is proportional the square of its speed but since resistive force equals to driving force, driving force is also proportional to square of its speed.] ➔ How is speed varied? Speed has double from 20 m s^{-1} to 40 m s^{-1} $P_{output} = F_{driving}v$ $= kv^2.v$ $= kv^3$ When speed is doubled, power increases by a factor of $2^3 = 8$ Therefore, the new power required (output) is 8 x 23 = 184 kW Answer: C
8	Essential Question(s): ➔ What determine GPE? ➔ What determines EPE? GPE = mgh → S is at a lower height, hence GPE is lower at point S. → either option B or D. EPE, U = qV, where q = -e → U = -eV V is the electric potential at a point V_s is lower electric potential compared to V_R Therefore, the electric potential energy at S is higher (less negative / more positive) compared to electric potential at R (more negative / less positive). Answer: B
9	Essential Question(s): ➔ For a disc rotating at uniform circular motion, how does angular velocity vary for points on the disc? (all points on the same disc vary with same angular velocity) ➔ How does angular displacement vary with angular velocity? ($\omega = \frac{d\theta}{dt}$) After the same time duration of revolution, since dt is the same for both points and ω is the same for both, their angular displacement will be the same as well. Answer: D
10	Essential Question(s): ➔ What is required for circular motion? (centripetal force) ➔ What are the forces acing on the stone at the highest point? Which forces provide for the centripetal force required? Resultant force acting towards the centre = T + W This resultant force provides for the centripetal force required. T + W = centripetal force required $T + W = Mr\omega^2$ $T = Mr\omega^2 - W$ Answer: A

<table>
<tr><td>11</td><td>
Essential Question(s):
➔ What happens if the spacecraft fires its rockets <u>as</u> it follows the path?
➔ Without the spacecraft firing its rocket, what is currently affecting the spacecraft motion <u>as</u> it moves?

The context of the question is on “<u>as</u> it follows the path”. This means that the spacecraft is already moving initially.

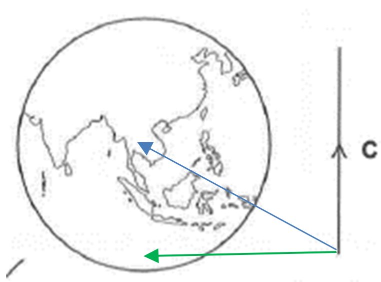
As the spacecraft is in the vicinity of the Earth, gravitational force (F_G) is currently acting on the spacecraft.

By Newton’s 3rd law, as the spacecraft exerts a force on the rocket as it fires the rocket, there will be an equal and opposite force on the spacecraft.

Options A and D are straight line paths passing through the centre of the Earth. These paths are possible without the need for additional force by the rocket since F_G acts along these paths, thus changing only the magnitude not the direction of velocity. Spacecraft follows path A with increasing speed. Spacecraft follows path D with decreasing speed.

Option B is a trace of a spacecraft in uniform circular motion. The path is possible without the force by rocket as F_G alone can provide for the centripetal force required since F_G acts towards the centre of this circular path.

Option C:
Along path C, a component of F_G acts perpendicular to the velocity of the spacecraft, and so tends to change the direction of the velocity. Therefore, in order to prevent a change in the direction of velocity and so remain in the same straight line path, an external force on the spacecraft by the rocket must act opposite to that component of F_G and equal in magnitude.



Component of F_G that acts perpendicular to spacecraft’s velocity. Should expect direction of velocity to change.

Answer: C
Examiner’s Report:
Many candidates chose option D, possibly as a result of assuming that the spacecraft was starting from rest.
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<tr><td>12</td><td>
Essential Question(s):
➔ What is the difference between graphs A, B, C, D?
➔ How does changes in amount of gas (n) & thermodynamic temperature (T) affect the difference identified in A, B, C, D?
➔ How are p, V, n and T related for an ideal gas?

By the ideal gas equation, pV = nRT, then,
$$\left(\frac{1}{p}\right)=\left(\frac{1}{nRT}\right)V$$
From the above equation, the gradient of the graph is m = nRT.
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	If n is doubled and T is also doubled, the new gradient m' is, $m' = \frac{1}{n'RT'}$ $m' = \frac{1}{(2n)R(2T)}$ $m' = \frac{1}{4}nRT = \frac{1}{4}m$ This means that the new gradient is 1/4 times of the gradient of the original graph. Answer: D
13	Essential Questions: • How temperatures of object and surrounding affects the net heat transfer between object and surrounding? • How is the net energy transfer represented using the arrows? X shows net transfer to the object. Y shows no net transfer of energy. Z shows net transfer of energy to surrounding. Answer: D
14	Essential Questions: • Which law involves heat supplied to system and work done by system? • Are Q and W positive or negative in each process? • What is meant by thermodynamic state? • What is meant by "back to (the same initial) thermodynamic state? First law of thermodynamic states that the increase in total internal energy ΔU of a system is the sum of the heat supplied to the system Q and work done ON the system W. Therefore, for process 1, Q = +2800 kJ and W = -600 kJ $\Delta U_1 = Q_1 + W_1$ $= 2800kJ + (-600kJ)$ $= 2200kJ$ Bringing back to initial state X would mean that the overall process of X → Y → X has no net change in internal energy. $\Delta U_{net} = 0$ $\Delta U_1 + \Delta U_2 = 0$ $Q_1 + W_1 + Q_2 + W_2 = 0$ $2800kJ + (-600kJ) + 1000kJ + W_2 = 0$ $W_2 = -3200kJ$ Therefore, the work done by gas is 3200 kJ. Answer: C

15	Essential Question(s):
	• What is the starting position of the oscillation from the information of the question that "the mass is pulled down and then released"?
	    o The mass starts oscillation at the Amplitude position, at t = 0, x = x_o
	• What do the points "100" and "30" represent?
	    o 2 amplitude positions

	• What is the amplitude of the oscillation?
	   o (100-30)/2 = 35 cm
	• Since the mass starts oscillation at Amplitude position, where is the mass for t = T/4 and t = T/2?
	   o At t = T/4, the mass will be at the Equilibrium position and at t=T/2, the mass will be at the other Amplitude position
	
	Not Option A because 70 cm is the peak-to-peak distance and not amplitude.
	
	Not Option B because at t=T/2, the mass is at Amplitude position where the speed is zero, therefore K.E. is zero and not maximum.
	
	Not Option C because the mass is moving from the Amplitude position to Equilibrium position, displacement x is decreasing. Since $\lvert a \rvert = \lvert w^2 x \rvert$, the restoring force decreases as x decreases.
	
	Option D is the correct because at t =T/4, the mass is at the Equilibrium position, where the speed is maximum.
	
	Answer: D

16	Essential Question(s):
	• What can deduced from waves X and Y are travelling through the same medium?
	   ➔ Waves X and Y have the same speed (assuming same type of waves).
	• What is the relationship between intensity of a wave and its amplitude?
	   ➔ Intensity is proportional to amplitude^2
	
	Amplitude of Wave X = 2 x Amplitude of Wave Y
	      Since Intensity is proportional to amplitude^2
	Intensity of Wave X = 4 x Intensity of Wave Y
	
	Since speed of Wave X = Speed of Wave Y, and speed = frequency x wavelength,
	For the same speed, wavelength is *inversely proportional* to frequency
	
	Frequency of Wave X = 2 x Frequency of Wave Y
	      Since wavelength is *inversely proportional* to frequency
	Wavelength of X = ½ x Wavelength of Wave Y
	
	Answer: C

17	Essential Question(s):
	• What does “monochromatic light, two narrow parallel slits and interference pattern observed” imply?
	   o Young Double slit two source interference of light
	• What is equation associated with Young Double Slit?
	   ➔ $x = \frac{\lambda D}{a}$
	• How is fringe separation x measure?
	   o Bright fringe to bright fringe or dark fringe to dark fringe
	• When the distance from the centre of the pattern to the centre of the first dark region is 1.2 mm, what is the value of x
	   o ½ x = 1.2 mm, therefore x = 2 x 1.2 = 2.4 mm
	
	When λ = 450 nm, $2.4 \times 10^{-3} = \frac{450 \times 10^{-9} \times D}{a} \Rightarrow \frac{D}{a} = \frac{2.4 \times 10^{-3}}{450 \times 10^{-9}} = \frac{16000}{3}$
	
	Therefore when λ = 600 nm, $x = \frac{\lambda D}{a} = 600 \times 10^{-9} \times \frac{16000}{3} = 3.2 \times 10^{-3}\, m = 3.2\, mm$

	Answer : D Examiner's report: Students who did not get the correct answer, were particularly attracted to option B. The likely reason for this was missing the fact that the question gave the centre-to-fringe distance but asked for a fringe-fringe distance, therefore requiring a doubling of the new centre-fringe distance.
18	Key words: • detects the **first** node at distance of 0.17 m from the end • microphone is fixed in this position • frequency…increased until..again detects a node Essential Questions: • Is it referring to a displacement node or pressure node? → nothing said, so referring to displacement node • How to relate frequency (the goal) to wave speed and length (the given information)? → use $v = f\lambda$, where λ can be found from the length given • How to find λ from the given length? → recall stationary wave formation in an open pipe → displacement antinode at the open end, hence for the **first node** detected, in the length of 0.17 m there is ¼ λ. • How much of a wavelength does 0.17 m correspond to at the next higher frequency? → The next time it is a node again (with an antinode remaining at the open end) is when 0.17 m corresponds to ¾ λ. $\frac{3}{4}\lambda = 0.17$ m $\lambda = 0.22667$ m $v = f\lambda$ $340 = f(0.22667)$ $f = 1500$ Hz Answer: C Examiner's Report: Many candidates struggled with this question. Options A and B were both popular incorrect answers, with option B proving particularly attractive to candidates who performed less well.
19	Essential Questions: • What is the definition of electric field strength? Answer: C
20	Essential Questions: • How to relate the goal (E-x graph) to the given information (equipotential lines)? → $E = - dV/dx$ → recall the significance: "-" indicates that the **direction of E** is in the direction of decreasing V. magnitude of dV/dx (potential gradient) gives the **magnitude of E**. $E = - dV/dx$ **Direction of E:** Since V decreases all the way from left to right, E is directed to the right; no change in direction of E along PQ, hence no change in the sign of E on the graph, i.e. either always positive or always negative. [In this case, all 4 options satisfy this.] **Magnitude of E:** dV/dx can be approximated by $\Delta V/\Delta x$ when Δx is small.

	ΔV between adjacent equipotential lines remain constant, so the changes in Δx gives a sense of changes in $\Delta V/\Delta x$ and hence magnitude of E. [smaller Δx → larger $\Delta V/\Delta x$ → larger $\lvert E \rvert$] Thus along PQ, $\lvert E \rvert$ decreases then increases back to original value. Answer: A
21	Essential Questions: 1. How do we identify which is length or area? 2. How do we relate current, power and resistivity? Since $P = I^2R$ $400 \times 10^{-3} = (40 \times 10^{-3})^2\ \rho\ (1.8 \times 10^{-2}) / [(1.2 \times 10^{-3})(1.5 \times 10^{-2})]$ $\rho = 0.25\ \Omega\ m$ Ans: A
22	Essential Questions: 1. What is the characteristic of parallel and series circuit? Effective e.m.f. of each branch = 1.5 x 3 = 4.5 V Since voltage across parallel circuit is the same, the overall effective e.m.f. is same = 4.5 V Effective resistance across each branch = 0.2 x 3 = 0.6 Ω Overall effective resistance = 0.6 / 2 = 0.3 Ω Ans: A
23	Essential Question: 1. What are some of the equations I can use to solve this problem? There are many ways to solve this question. Given that this is a MCQ, we would like to use the fastest way. We can use potential divider principle, but that might be tedious as there will be fraction of unknown. It might just be easier to use V = IR to find the potential difference across 1.0 Ω and 9.0 Ω resistors, and then the voltage across the 6.0 Ω resistor. Voltage across the 6.0 Ω resistor = 6.0 V – 0.5 A x 1.0 Ω – 0.5 A x 9.0 Ω = 1.0 V Therefore the current through the 6.0 Ω resistor = 1.0 V / 6.0 Ω = 0.167 A Current through R = 0.5 – 0.167 = 0.33 A R = 1.0 V / 0.33 A = 3.0 Ω Ans: D
24	Essential Question: 1. What are the concepts involved in this question? 2. What are the forces acting on the coil? 3. Is the coil in equilibrium? 4. What does the horizontal arrow on the diagram represent? This is an equilibrium system. We can approach it with two ways: no net resultant force and no net moment. With the free body diagram of the coil in mind, there is an unknown contact force at the pivot and hence we cannot solve the problem with the equation of zero resultant force. That leaves us no choice but to take moment at the pivot. The horizontal part of the coil (the lowest side of the coil going into the page) can be seen as many straight current-carrying wires, each with 0.4 A of current. Hence the total magnetic force on the wire = NBIL.

	By taking moment at the pivot, Total anticlockwise moment = Total clockwise moment 0.12 x [30 x 10^{-3} sin 30°] = [50 x B x 0.40 x 60 x 10^{-3}] x [60 x 10^{-3} x cos 30°] B = 0.029 T Ans: A Examiners' Report: Candidates found this question very challenging. The most popular option was option **B**, which involved omission of a factor of 2. This could have been either from omitting the sin 30 ° factor or from missing that the magnetic force is exerted on the coil at double the distance away from the pivot as is the weight. Option **D**, which involved treating the coil as consisting of a single turn rather than 50, was particularly appealing to some candidates.
25	Essential Question(s): • What is the effect that takes place when the magnet fall through the long coil of wire? • What is the Law that explains this effect? • What affects the magnitude of the induced e.m.f produced? When the magnet enters the long coil of wire, there will be a rate of change of magnetic flux linkage with the coil of wire. From Faraday's law, an induced e.m.f will be set up across the ends of the wire. As the magnet falls through while it is entirely within the coil there is no net change of magnetic flu linkage with the coil of wire. Only when it does leave the coil at the bottom, will the coil of wire experience a changing magnetic flux linkage. This sets up another induced e.m.f. As the two rates of change of e.m.f. are different, i.e. when entering the change is an increase while it decreases when leaving, the direction of induced e.m.f is opposite to each other. Also as the magnets is accelerating as it falls, the speed of entry is slower than the exit speed. This means the rate of change of magnetic flux linkage is faster at the bottom and consequently so will the magnitude of the e.m.f. Answer: A
26	Essential Question(s): • What is the formula that determines the magnitude of the magnetic flux density B within a long solenoid? What equation relates B to the given information? • Is the magnetic flux density a scalar or a vector quantity? • What determines the magnetic flux density at point X? When will it be zero? (resultant flux density at X is equal to the vector sum of the flux density due to P and due to Q) (resultant equals zero when B_P = B_Q in magnitude, since they act in opposite directions) B = $\mu_0 n I = \mu_0 \left(\frac{N}{L}\right) I$ where N is number of turns and L is the length of the solenoid. Since the resultant flux density at X = 0, and the flux density at X due to P is opposite direction to that due to Q, Magnitude of flux density at point X due to Q = Magnitude of flux density at point X due to P $\frac{\mu_0 N_Q I}{L} = \frac{\mu_0 N_P I}{L}$ $\frac{N_P}{N_Q}$ = 1 [Since μ_0, I and L are the same for solenoid P and Q] Note: Radius of the solenoid does not affect B. Answer: A

27	Essential Question(s): • What are the formulae available to calculate mean power? Which particular formula links to the given information of current and resistance? → <P> = $(I_{rms})^2R$ • What is the circuit diagram like? • What is the effect of a diode? • Is it a sinusoidal or non-sinusoidal AC? Hence what approach to use to find I_{rms}? → non-sinusoidal, so use graphical approach Determine I_{rms} then apply the formula <P> = $(I_{rms})^2R$ to determine mean power. Mean-square current, $I_{rms}^2 = \frac{I_0^2}{4}$ $I_{rms} = \frac{I_0}{2} = \frac{(7.6)}{2} = 3.8$ A <P> = $I_{rms}^2R = (3.8)^2(9.4) = 136$ W = 140 W (2 s.f.) Answer: C
28	Essential Questions: • How do you obtain the energy change from the given wavelength? • Which of the energy transition give raise to the amount of energy? Loss of electron excitation energy = Energy of emitted photon $\Delta E = E_P$ $\Delta E = \frac{hc}{\lambda}$ $= \frac{(6.63\times10^{-34})(3.00\times10^{-8})}{(633\times10^{-9})}$ $= 3.14\times10^{-19} J$ $\Delta E = 3.14\times10^{-19} J$ $= \frac{3.14\times10^{-19}}{1.6\times10^{-19}}$ $= 1.96 eV$ Answer: A
29	Atomic or Proton Number = 4 Mass or Nucleon Number = 4+5=9 Answer: C
30	Essential Questions: • How is half-life related to the activity and Number of atoms?

	$t_{1/2} = \frac{\ln 2}{\lambda}$ Equation1 $A = \lambda N$ $\lambda = \frac{A}{N}$ Equation2 $t_{1/2} = \frac{N \ln 2}{A}$ $\frac{t_{1/2,X}}{t_{1/2,Y}} = \frac{N_X A_Y}{A_X N_Y} = 0.25$ Answer: B

Paper 2

				Marks
1	a		The principle of moments states that for a body to be in equilibrium, the sum of clockwise moments about any pivot must be equal to the sum of anticlockwise moments about the same pivot. *Examiner's Comment:* *The need for the system to be in equilibrium and the sum of the moments about a point are essential for this definition.*	1
	b	i	Essential Question(s): ➔ What does ratio of the tensions mean? (It means that the tension in one of the supports is $\frac{3}{10}$ of the total tension and the tension in the other support is $\frac{7}{10}$ of the total tension.) ➔ What are the forces acting on the sign? (Tension at A, Tension at B, Weight of sign) ➔ Which tension is greater? Tension at A or Tension at B (If we apply the principle of moments, taking pivot at centre of mass, clockwise moment due to tension at A must balance anticlockwise moment due to tension at B. Judging from the diagram, line of action of the tension at A is closer to line of action of weight compared to line of action of tension at B. Therefore, tension due to A should be larger compared to tension due to B.) ➔ How to apply equilibrium of forces to determine the tension? Weight of sign = 4.5 x 9.81 = 44.145 N Since there is vertical equilibrium, Weight of sign = total tension = 44.145 N Tension at A = $\frac{7}{10}$ x Total tension = 30.9 N Tension at B = $\frac{3}{10}$ x Total tension = 13.2 N Examiners' Report:	 1 1

			A majority of candidates obtained the correct answer. A significant number gave the two values the wrong way round.	
		ii	Essential Question(s): ➔ For a system an equilibrium, when I need to determine horizontal distance, which condition is more appropriate to use here? [Principle of moments includes perpendicular distance from pivot, so will be more appropriate here.] ➔ Where should I take pivot to be? (Since the horizontal d is to be determined, pivot could be taken at the top left corner of the sign.) Taking pivot about the top-left corner, Sum of anticlockwise moment due to the tension and A and B = sum of clockwise moments due to weight of sign 30.9 x 0.20 + 13.2 x (1.00-0.2) = 44.145 x d d = 0.38 m	 **1** **1**
	c		Keyword(s): ➔ Horizontal wind → wind exerts a horizontal force Essential Question(s): ➔ Does the wind exert any force on the sign? If yes, which direction? ➔ What are the forces acting on the sign that can possibly balance the force exerted by the wind? Since the wind exerts a horizontal force on the sign, and **since the weight acts vertically, there needs to be a horizontal component of force by each support, where their vector sum is equal in magnitude and opposite direction to the force by wind, in order <u>to maintain the sign in horizontal equilibrium</u>**. *Examiner's report:* *The need for a horizontal force in the opposite direction to the wind to maintain equilibrium was not stated clearly by the majority of candidates. Many just repeated the question and said there was a horizontal force because the wind was horizontal. Misconceptions were evident as some candidates suggested the weight now had a horizontal component and some described the force was due to Newton's third law.*	 **1**

				Marks
2	**a**		Hooke's law states that force is proportional to its extension, provided the limit of proportionality has not been exceeded. *Examiner's Comments:* *There were some who wrote about resultant force and some who talked about displacement from an equilibrium position, both of which are incorrect.*	**1**
	b		Essential Question(s): ➔ How to determine EPE from the load - compression graph? (Area under the graph is the EPE stored) ➔ What is the corresponding value of force (load) for a compression of 85 mm? (6.8 N) EPE stored = Work done on spring = Area under graph until compression of 85 mm = ½ (85 x 10^{-3})(6.8) = 0.289 = 0.29 J	 **1** **1**

			Examiner's Comments: *This calculation proved to be straightforward. A few candidates missed out the half, or read to the end of the line on the graph, or mis-read the graph.*	
	c		Essential Question(s): ➔ How is energy converted from the point of release of ball till point P? (EPE is converted to both GPE and KE) At the start point, EPE = 0.289 J At point P, there is both KE and GPE GPE = mgh = 0.042 x 9.81 x 0.40 = 0.165 J EPE = GPE + KE $0.289 = 0.165 + ½\ m\ v^2$ $0.124 = ½\ (0.042)\ v^2$ $v = 2.430 = 2.4\ m\ s^{-1}$ *Examiner's Comments:* *There was a significant number of candidates that equated the elastic potential energy with the final kinetic energy and ignored the gravitational potential energy gained by the ball.*	**1** **1** **1**
	d	**i**	Essential Question(s): ➔ What does it mean for the ball not to fall off the track? (There is still a normal contact force on the ball at the top – point P.) ➔ Since the ball is in circular motion, what forces provide the centripetal force? (Sum of Weight and Normal contact force.) At P, the sum of the ball's weight (W) and the normal contact force (N) exerted by the track on the ball provide for the centripetal force required (F_c). For ball to remain in contact with track, N > 0. Hence at v_{min}, N just equals 0 and so W alone provides for F_c. $W + N = F_c$ $W + 0 = m\frac{v_{min}^2}{r}$ where m is ball's mass, and r is radius of the circular motion $mg + 0 = m\frac{v_{min}^2}{r}$ $v_{min} = \sqrt{rg} = \sqrt{(0.40 \div 2)x9.81} = 1.4\ m\ s^{-1}$ *Examiner's Comments:* *A majority obtained the correct answer. There were some that did not explain that at the minimum speed the normal contact force was zero and the centripetal force was therefore equal to the weight of the ball.*	**1** **1** **1**
		ii	Since $v_{min} = \sqrt{rg}$, v_{min} is independent of mass and hence v_{min} does not change.	**1**

				Marks
3	**a**		Diffraction is the <u>**spreading**</u> **of waves as they pass through an opening or around an obstacle into the geometrical shadow regions**. Examiner's comment:	**1**

There were many clear and concise explanations of diffraction. A number gave the unacceptable answer of describing the waves as spreading through an obstacle. Another issue was the poor use of correct language here, as the words bending, and splitting were sometimes used instead of spreading. ***→ Cannot replace 'spreading' with 'bending' or 'splitting'!***

b

Essential Question(s):

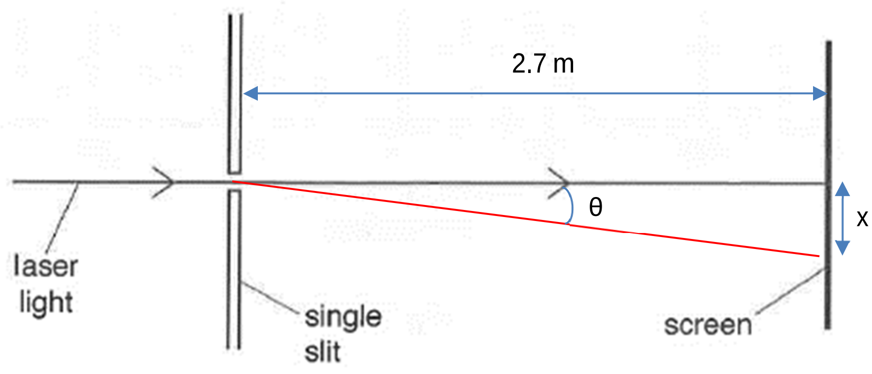
- ➔ Which equation represent the phenomenon of diffraction through a single slit?
- ➔ What information does the intensity against displacement graph give, in terms of the physical quantities required in the equation?

For single slit diffraction,

$$\sin\theta = m\frac{\lambda}{b}$$

Since the graph in Fig. 3.2 shows the first order minima, consider m = 1. So,

$$\sin\theta = \frac{\lambda}{b}$$



From Fig. 3.2, the first minima position, x, is about 14 cm.

Hence,

$$\lambda = b\sin\theta$$ **1**

$$\lambda = \left(12\times10^{-6}\right)\sin\left(\tan^{-1}\frac{14}{270}\right)$$ **1**

$$\lambda = 6.21\times10^{-7}\,m$$ **1**

Examiner's Comment:

This was well answered by many candidates. Some used inappropriate expressions for diffraction at a single slit. The Young's double slit formula and the diffraction grating formula were examples.

c

Essential Question(s):

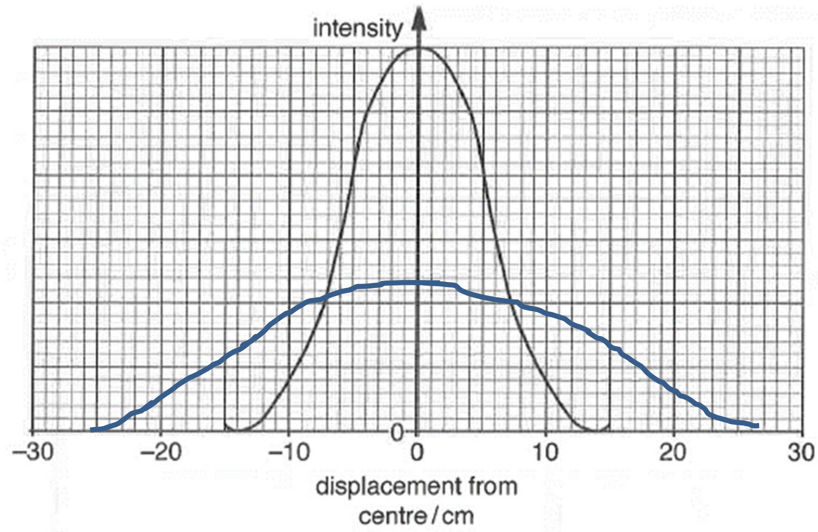
- When the slit is narrower, what happen to the angle of diffraction?
- What happen to the intensity of the light received at the screen?

According to the equation for the single slit diffraction,

$$\sin\theta = \frac{\lambda}{b}$$

For the same light of the same wavelength, when the slit width *b* decreases, the angle of diffraction increases.

However, since a narrower slit allows less light to pass through, the intensity decreases.



			Increase in displacement from centre – 1 mark Reduction in intensity – 1 mark Examiner's comment: It was common to see no variation in the intensity even though the slit was narrower than the original. A significant number thought there would be less spreading with a narrower slit.	
	d	**i**	Essential Question(s): • By the single slit diffraction equation, what will happen when the wavelength increases in terms of the angle of diffraction? The central maximum would broaden, with the first order minima further than 14 cm from the centre. Because with a longer wavelength <u>and</u> slit width unchanged, the angle of diffraction would increase. Examiner's comment: This proved to be one of the most challenging questions on the paper. Almost all of the candidates realised that the central maximum would broaden as drawn in the previous part of the question. Only about half gave a suitable justification for the broadening.	**1** **1**
		ii	Essential Question(s): • What does white light consist of? • What do you think is seen on the screen when visible light of more than one wavelength passes through a single slit? **White light consists of <u>all</u> colours of visible light, which is of a <u>continuous range of wavelengths</u>. The <u>longer the wavelength</u>, the <u>greater the degree of diffraction</u>, <u>producing a central fringe of larger width</u>.** **In the central region where <u>all</u> colours <u>overlap</u>, it is white.** **At the edges where not all colours are present, they are coloured.**	**1** **1**

			 OR White light consists of visible light of a continuous range of wavelengths. **Visible light of every wavelength meet with zero path difference at the centre, (thus meet in phase and undergo constructive interference,) thus all the overlapping colours produces a white region.** **At the edges, there are destructive interference of some light but not for others as the extent of diffraction increases with the wavelength. Hence the edges would not be white but be of the mixed colour of wavelengths that have non-zero intensity.** Examiner's Comments: This proved to be a challenging question. Only a small number were able to explain these two effects. The white light at the centre was often explained by there being no diffraction at the centre. The amount of spreading or diffraction being dependent on the wavelength was quoted by only a small number of candidates. Sometimes candidates did not use precise scientific terms here, for example not using interference or overlap.	

4	**a**		It is the the **<u>minimum</u> frequency of <u>electromagnetic</u> radiation required** for the **ejection of electrons** from a **metal <u>surface</u>** in a photoelectric effect process. Examiner's comment: The majority of candidates were able to explain the term threshold frequency. A significant number did not read the question carefully and gave a description of the photoelectric effect.	**1** **1**
	b		Essential Question(s): • What is the energy of the photoelectron when frequency of radiation equal threshold frequency? What equation relates E_{max} to f? ➔ State the Einstein's photoelectric equation in terms of hf, Φ and E_{max} ➔ Linearise the equation, and identify what represents the gradient and the x-intercept and y-intercept. • What is the gradient and intercepts of the graph of E_{max} against f for higher Φ? Do they change? If yes, how?	

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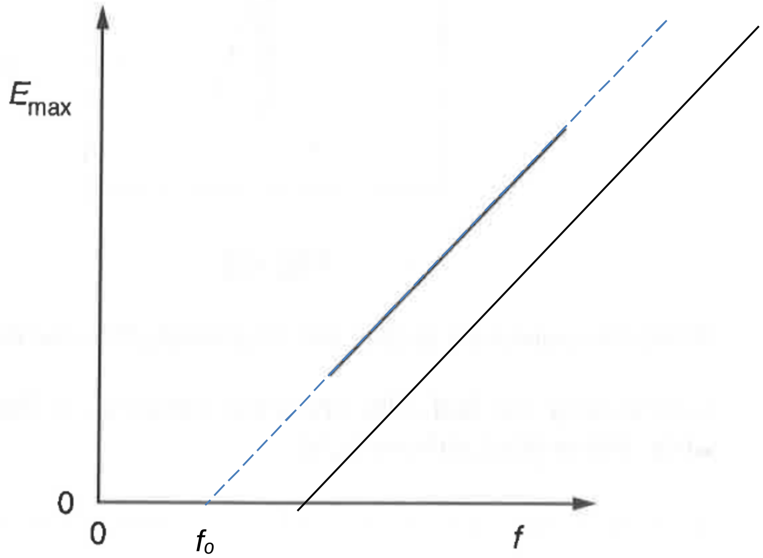

From Einstein's photoelectric equation:
$E_{max} = hf – \Phi$ where $\Phi = hf_o$
$E_{max} = hf – hf_o$
➔ Gradient = h, and y-intercept = $–\Phi$, and x-intercept = f_o

b (i) Extrapolate the line to the x-axis. The x-intercept is the threshold frequency f_o.

b (ii) Gradient gives the value of the Planck constant. ***Answer in words, following the command word "State".***

b (iii) For a metal surface with higher Φ,
gradient = h, which is a constant, remains unchanged, but
x-intercept = $f_o = \Phi/h$, since f_o proportional to Φ, f_o increase.
➔ Draw a second line with the same gradient, but greater x-intercept. Graph shifts to the right.

Examiner's Report:
A common fault was to drop a perpendicular from the end of the drawn line onto the *x*-axis rather than extrapolating the line to the *x*-axis to find *fo*. The majority correctly extrapolated the line back to the *x*-axis. Most gave the gradient as the Planck constant and most drew a suitable parallel line for the second metal.
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<td>c</td>
<td>(i)</td>
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Essential Question(s):
• State the Einstein's photoelectric equation in terms of hf, ϕ and KE_{max}

$E_{max} = ½ m v_{max}^2$
$f = c/ \lambda$

$E_{max} = hf - \phi$
$½ m v_{max}^2 = h c/\lambda - \phi$
$½ (9.11 \times 10^{-31}) v_{max}^2 = (6.63\times 10^{-34})(3.00 \times 10^{8}) / (490 \times 10^{-9}) – 2.5 \times 1.60 \times 10^{-19})$
$v_{max} = 1.14 \times 10^{5}\ m\ s^{-1}$

Examiner's Report:
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M1

M1
M1
A1
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			Candidates performed well in this multi-stage calculation. The correct value for v_{max} was obtained by most. There were some who converted the nm incorrectly to m and some who were not able to convert the energy in eV to J.	
	c	**(ii)** **(1)** **(2)**	Essential Question(s): • How does the gold leaf electroscope work? What causes the gold leaf to rise / fall? → when repulsion between the gold leaf and metal rod increases, leaf rises; when repulsion decreases, leaf falls • How does the charge on the gold leaf change? What phenomenon could occur when light is incident on metal? → photoelectric effect occurs if energy of the incident photons exceeds the work function energy of the europium surface. Net charge on the gold leaf and metal rod would then decrease, causing repulsion to decrease, and leaf falls. • ***Recall significance of photoelectric effect → highlights the quantum nature of light, and the 1-to-1 interaction between photon and electron in a metal. Therefore refer to 'photons' not simply 'EM radiation' in your answer.*** • What is the frequency of blue light as compared to red light? Which photon energy is higher? Blue light photons or red light photons? • **(1)** What happens to the gold leaf when electrons are liberated from the gold when the gold leaf is initially *negatively* charged? • **(2)** What happens to the gold leaf when electrons are liberated from the gold when the gold leaf is initially *positively* charged? **(1)** Frequency and hence **energy of photons** of blue light ($E_{p,b}$) is **greater** than that of red light ($E_{p,r}$) . **$E_{p,b}$ exceeds the work function energy of the europium metal surface but $E_{p,r}$ is lower**. *Note: must state red light photons have energy less than work function energy.* Therefore **only** blue light will **eject electrons from the europium surface, which then decreases the amount of negative charge in the gold leaf and metal rod and hence repulsion decreases and hence leaf falls**. (With red light, the amount of negative charge in the gold leaf electroscope remains the same. The leaf does not fall.) **(2)** Even for wavelengths of light that can cause photoelectric effect, when electrons are ejected from the europium surface, the amount of positive charge on the metal rod and gold leaf increases resulting in more repulsion and the gold leaf rises more. However, the leaf rises only momentarily. Because unlike charges attract, the ejected electrons will eventually be attracted back into the gold-leaf electroscope. Then the charge in the gold leaf electroscope returns to the original value. Leaf returns to the original angle of elevation. Examiner's Report: **(ii)1.** Candidates found this part and the next challenging. Weaker responses did not make good use of correct scientific terms. **(ii)2.** This part was only explained clearly by a small minority of candidates. Some suggested the leaf did not fall because the positive charge could not	**B1** **B1** **B1**

			be emitted. Generally, the effects with the gold leaf electroscope were poorly understood by the majority of candidates.	

5	**a**		Essential Question(s): • What is the meaning of "number density of charge carriers"? → number of mobile charge carriers per unit volume of copper. • How to relate the goal (number density of charge carriers) to the given information? Volume of **per mole** of copper = mass **per mole** / density = $(63.5 \times 10^{-3}) / 8960$ = 7.0871×10^{-6} m^3 Number of conduction (mobile) electrons **per mole** of copper = 1 electron per atom x number of atoms per mole = 1 electron per atom x Avogadro's constant = $1 \times (6.02 \times 10^{23}) = 6.02 \times 10^{23}$ Number density of charge carriers = $6.02 \times 10^{23} / 7.0871 \times 10^{-6}$ = 8.49×10^{28} m^{-3} (shown) Examiner's Report: The majority of answers were correct.	**M1** **M1** **M1** **A0**
	b		Essential Question(s): • How to relate the goal (drift velocity) to the given information? Use $I = nqAv$ where I is determined using $P = I^2R$ $P = I^2R$ $5.0 = I^2 (30)$ $I = 0.40825$ A $I = nqAv$ $0.40825 = (3.4 \times 10^{28}) (1.60 \times 10^{-19}) [\pi (0.36 \times 10^{-3})^2 / 4] v$ $v = 7.4 \times 10^{-4}$ m s^{-1} Examiner's Report: The majority of answers were correct. A small number calculated an incorrect value for the current and some used the number of charge carriers per unit volume for copper instead of tungsten. A few weaker responses had the misconception to multiply *n*, the number of charge carriers per unit volume, by the volume to obtain a number they can use in the calculation.	**M1** **M2** **A1**
	c		Key words: • another tungsten wire… same diameter…twice the length • p.d. across the wire is unchanged • temperature..same • State and explain…change to the drift velocity Essential Question(s): • What does changing the length affect? → resistance R; doubles R	

			• What does a constant diameter imply? → no effect on R, and no change to A • What does a constant p.d. imply? → use $P = V^2 / R$. Since V constant and R doubles, P halves • What does a constant temperature imply? → no changes to resistivity • Which variables (in part b) remains constant, and which variables changes? Change by how much? → R doubles and P halves, so in $P = I^2R$, I becomes half of that in first wire. → n, q, A are unchanged, so in I = nqAv, v becomes half of that in first wire. Solution: Since the two wires have the same temperature, they have the same resistivity ρ. With twice the length L and same cross-sectional area A (since same diameter), the second wire's resistance R (= ρL/A) will be double that of the first wire. With the same p.d. V, and double the R, current I will be half that of the first wire (since V = IR). For the same number density of charge carriers n, same A and same charge of electrons q, the electron drift velocity v (= I / nqA) is directly proportional to the current I and hence v will be half that of the first wire. Examiner's Report: There were many who gave a ***general*** description that involved increase or decrease of particular quantities**. The question describes a *particular* change to the length of the wire and not just that the length was increased, and hence more detail was required**. Some thought that the power would not change even though they had described correct changes to the resistance and the current with the voltage remaining constant. A small minority described changes to *n* due to the change in length of the wire. ➔ **The words in bold implies that candidates need to be specific in mentioning that the R will be doubled, I will be halved, v will be halved etc….Simply stating increase or decrease is considered too generic.**	**B1** **B1** **B1**

6	**(a)**	**(i)**	Essential questions: ➔ Is this a series or parallel circuit? ➔ How to relate the goal (V_{out}) to the given information (E, I, R)? Solution: Current in Q = Current in P = 27 mA V_{out} = p.d. across Q = IR = 0.027 x 90 =2.43 V Examiner's report: The vast majority gave the correct answer. A small minority calculated the total resistance of the circuit and equated this to the resistance of P. They then used the potential divider formula to calculate the potential difference for Q.	**A1**
		(ii)	Essential questions:	

			➔ Is this a series or parallel circuit? [thermistor & Q are in parallel, while these are in series with P] ➔ Which values from (a) are still applicable in this circuit? [resistance of Q applies**, but current no longer 27 mA**] ➔ Resistance of P is still unknown. Is there a way to find its resistance? [From (a), 9.0 – 2.43 = 6.57 V; resistance of P = 6.57 / 0.027] ➔ What various methods can be used to find p.d.? Effective resistance across parallel connection of thermistor and Q $= (1/120 + 1/90)^{-1} = 51.43\ \Omega$ In (a), p.d. across P = 9.0 – 2.43 = 6.57 V resistance of P = 6.57 / 0.027 = 243.3 Ω Apply potential divider principle to (b), New V_{out} = (51.43 / (51.43 + 243.3)) x 9.0 = 1.57 V Examiner's report: A significant number of candidates calculated the correct answer. There was evidence of a misconception here, as many answers assumed the current would remain the same as in the original circuit when the thermistor was connected in parallel to Q.	**M1** **M1** **A1**
		(iii)	Essential questions: ➔ How does the resistance of a NTC thermistor change with increasing temperature? ➔ How does the resistance of a parallel circuit of two resistors when the resistance of one of the resistors decreases? ➔ How do you calculate the p.d. across a resistor of potential divider circuit consisting of a few resistors? Solution: As temperature increases, resistance of the thermistor decreases. Hence the resistance of the parallel connection of thermistor and Q decreases. By potential divider principle, since e.m.f. and resistance of P unchanged, V_{out} will decrease. Examiner's report: The majority of answers were fully correct. There were a number of candidates who thought that the resistance of the thermistor increases when its temperature is increased.	**B1** **B1** **A1**
	(b)		Essential questions: ➔ How to determine the p.d. across a part of the resistance wire? [Apply potential divider formula.] ➔ What is the significance of zero internal resistance of the battery? ➔ How to determine the resistance of the resistance wire (or part of the wire)? What equation relates the resistance to the length? Solution: The circumference of the circle = 2π r = 2π x 1.2 cm Length of AB = (92°/360°) (2π x 1.2) = 1.927 cm *Notes:* - *If "s = rθ" is used, θ must be in radians not degrees.* - Circumference is not 6.5 cm, since wire is not a full circle! Resistance = ρ L / A Since ρ is the same for the wire of the same material	**C1**

			A is the same for the wire of the same cross section area → Resistance ∝ L Hence (resistance of wire AB / resistance of whole loop of wire) = (length of wire AB / length of resistance wire) V_{out} = (resistance of wire AB / resistance of whole loop of wire) x 9.0 = (length of wire AB / length of resistance wire) x 9.0 = (1.927/ **6.5**) x 9.0 = 2.67 V Examiner's report: This application of knowledge to a novel situation was well done. Some candidates thought that the wire was a full circle. There were also candidates who mixed up angles in radians and angles in degrees.	**M1** **A1**

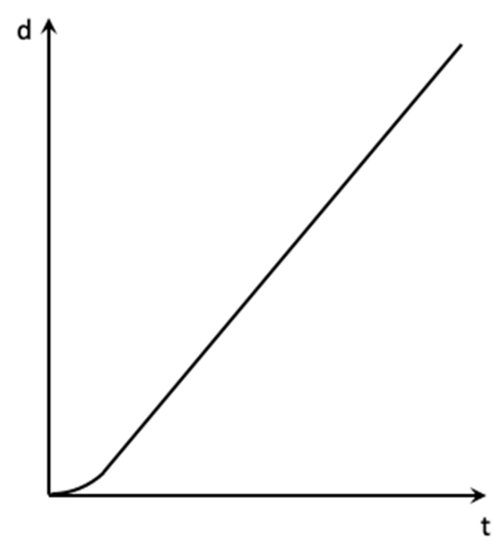
				Marks
7	**a**		Essential Question(s): • f increases as V increases…is it considered a 'proportional' relationship? **How to check if it is proportional? What odes proportional mean?** [If proportional, means linearly related and passing through origin, and ratio of f to V would remain constant.] • Which is the dependent variable, and which is the independent variable? [For the context, V is the IV and f is the DV.] Solution: **f increases as V increases**, but they are **not proportional**. *Note: It would sound illogical to swap 'f' and 'V' in the statement above, since V is the IV.* *Examiner's report:* *A significant number of candidates gave the relationship as (directly) proportional. The change in the frequency as the potential difference is changed is <u>not</u> proportional and it would seem that these candidates have an incorrect interpretation for a proportional relationship.*	**1**
	b	i	Plot to half the smallest division.	**1**
		ii	Draw the best fit line, in this case, it's a straight line.	**1**
		iii	Essential Question(s): • Is the equation given for the plotted graph? $V = kf^n$ $\lg V = \lg k + n \lg f$ Since the graph plotted is lg V against lg f, a straight line is expected where gradient gives value of n. n = gradient = (0.64 – 0) / (14.84 – 14.56) = 2.29 *Note: Get two coordinates far apart enough to calculate the gradient. Apply practical skills.*	**1** **1**

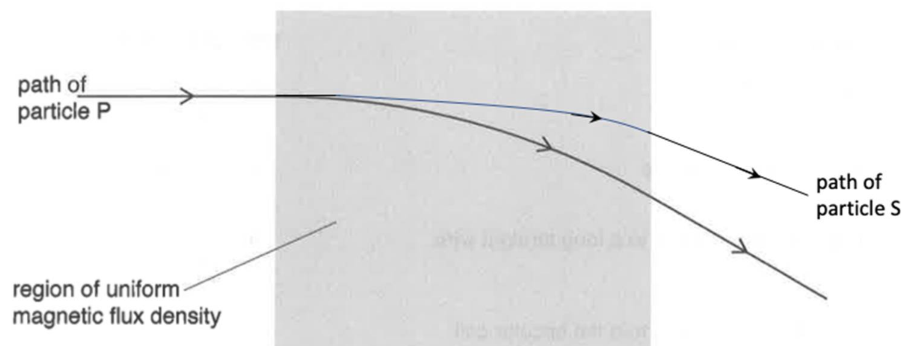
			Examiner's report for part (b): *The point was plotted correctly in general. There were some plots of the point that were inaccurate due to careless positioning of the centre of the cross that was drawn. The lines were drawn correctly in general. The calculation of the gradient and the link with the power n was correctly determined by the majority of candidates. There were a small number who calculated the reciprocal of the gradient. A smaller number gave a unit with their answer for n.*	
	c	i	Essential Question(s): • How to relate wavelength to the variables represent by the graph in Fig. 7.1? [wavelength is related to f] $f = c / \lambda = (3.00 \times 10^8) / (520 \times 10^{-9}) = 5.77 \times 10^{14}$ Hz $\lg f = \lg (5.77 \times 10^{14}) = 14.76$ From the best fit line plotted, $\lg V = 0.46$ ➔ V = 2.88 V *Examiner's report:* *Almost all candidates arrived at the correct answer. Some responses left the answer as the log of the value of potential difference; a few used e^x rather than 10^x to get the potential difference.*	**1** **1** **1**
		ii	Essential Question(s): • How to relate the goal (number of photons released) to the given information (Power, Energy per photon, Time interval)? • What is power? [Power = Total energy / Time interval] • How much electromagnetic energy is emitted from the 10W LED in 1.0 minute? Total amount of energy emitted in 1.0 minute = 10(60) = 600 J Each photon has 3.8×10^{-19} J of energy, therefore total number of photons released in 1.0 minute = $600 / 3.8 \times 10^{-19} = 1.6 \times 10^{21}$ *Examiner's report:* *The majority of answers were correct.*	**1** **1**
		iii	Essential Question(s): • What information from the passage can help us determine the answer? • What is the safe operating current in the circuit? • What is the potential difference across the resistor? For photons that have wavelength of 520 nm, the potential difference across is 2.88 V. (from (c)(i)) Power supply e.m.f. is 4.5 V, therefore the potential difference across the resistor is 4.5 – 2.88 = 1.62 V. Resistance of the resistor = 1.62 / 0.020 = 81 Ω *Examiner's report:* *There was a significant number of candidates who were able to calculate the potential difference across the series resistor using their answer to **(c)(i)**. A significant number used the potential difference of the power supply as the potential difference across the series resistor.*	**2**

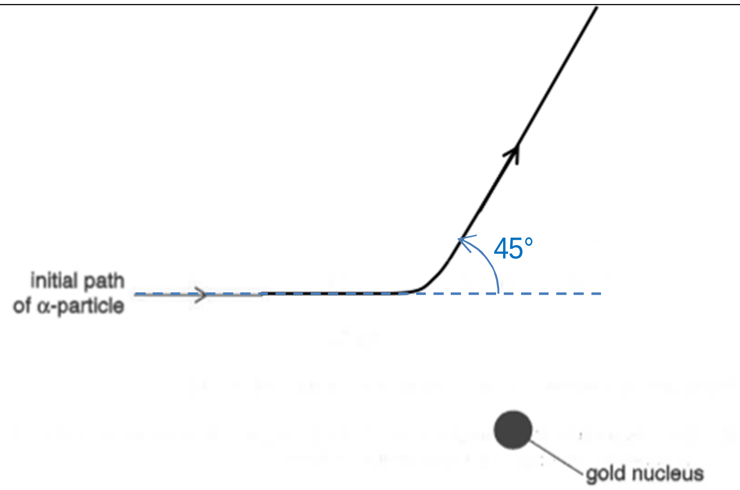
	d		Essential Question(s): • What quantities are represented by 'mA h' ? [Current and Time] • How to relate current, charge and time? [Q = It] A **power supply** of 730 mAh means that it is **able to deliver 730 mA of current over a period of 1 hour**, and **supplying a total charge of 0.730(3600) = 2630 C of charge**. *Examiner's report:* *A small number recognised the quantity of 730mAh as charge. There were fewer who described this quantity as the total amount of charge available from the supply. The majority gave an answer of the current of 730mA flowing for one hour. There seemed to be very little evidence that candidates understood that this was the total charge available and that the current and time could vary provided the total, when the product of current and time was calculated, gave 730mAh.*	**1** **1**
	e		Essential Question(s): • Which part of the passage mentions efficiency? (para. 4) • What is the definition of efficiency? (Useful power output / Total power input) Efficiency of LED = 800 / 10 = 80 lumens per watt Efficiency of Lamp = 840 / 60 = 14 lumens per watt Ratio = 80/14 = 5.7 *Examiner's Comments:* *The majority of answers were correct.*	**1** **1**
	f	**i**	Essential Question(s): • Which data and information is useful in determining why incandescent lamps are being replaced? Lamps have the highest power rating, meaning highest power consumption, and hence have the highest *running* cost for the same time span. Also, the projected lifetime is also the shortest, hence needs to be changed most frequently, hence have the highest *capital* cost for the same time span. Overall, it is the least power efficient and least cost efficient. *Examiner's Comments:* *The majority of candidates gave at least one of the reasons why incandescent lamps should be replaced. Better performing candidates realised that different types of bulbs do not use different amounts of energy, they use different amounts of power.*	**1** **1**
		ii	Essential Question(s): • Can we calculate the operating cost for one traffic light with either LED or CFL? Consider the same time span of 50 k hours, Operating cost for LED = [(0.010 kW)(50000 h) x $0.22]+ $35.95 = $145.95 Operating cost for CFL = [(0.014 kW)(50000 h) x $0.22] + 5 x $3.95 = $173.75	**M1**

			Operating cost for LED is slightly cheaper than CFL, and also the manpower and logistical costs when changing bulbs is 5 times less since lifespan is 5 times longer. Hence I support LTA's decision to switch to LEDs. *Note: A1 marks not awarded if M1 marks not gained.* *Examiner's report:* *This question proved to be challenging. There was a minority of candidates that showed the LED lamps were cost effective over a period of 50000 hours. A significant number compared only the cost of buying the lamps over this period. There were many errors in the calculation of the cost of the energy over this period of time. The cost given for the energy of a kWh was not used correctly. The energy used was calculated for a period in seconds and/or the power in W was used rather than kW.*	**M1** **A1**
		iii	Incandescent lamps have **lowest power efficiency** which implies that they **produce highest amount of thermal energy (or heat) per unit time** that could **melt the snow covering the traffic lights**. *Examiner's report:* *A small minority realised that the incandescent lamps were inefficient and gave large quantities of heat that could melt the snow. There were many answers that considered the small difference in brightness between the lamps was sufficient for the incandescent lamps to be more visible in the snow.*	**1**

Paper 3
Section A

1	**a**		Essential question: ➔ What does the gradient of a distance-time graph give? [speed v] ➔ How will d and v vary, in the presence of air resistance? [speed increases at a decreasing rate initially, and eventually terminal velocity is reached]  	

			Examiner's comment: A graph with an **increasing gradient, followed by a straight line** is expected. **At t = 0, gradient = 0 since ball initially at rest.** Many lines showed a decreasing gradient, which is wrong. **Note: use ruler to draw the straight line portion.**	**2**
b			Essential question: ➔ What determines the shape of the path of a charged particle moving through a uniform magnetic field? [Magnetic force acts perpendicular to the velocity at every instant, changing direction of velocity and not its magnitude. Constant speed in turn keeps the magnetic force constant in magnitude. Magnetic force thus causes the particle to move along a circular path of constant radius.] ➔ What is the shape of the path within the field? What affects the radius of curvature of the path? ➔ What is the shape of the path beyond the field? Since the magnetic force provides for the centripetal force on particle S when it is in the magnetic field, $Bqv = \frac{mv^2}{r}$ $r = \frac{mv}{Bq}$ With double the speed and mass, charge and flux density the same, the radius of the circular path is doubled. Thus, the deflection of particle S will be lesser than particle P. S and P have charge of the same sign, so deflect in the same direction. Sketch a path for S such that **within the field, it is a circular arc of larger radius than P**, and **beyond the field it is linear**. *[Use a ruler to draw the linear portion.]*  Examiner's comment: Lines indicating a smaller deflection were in a small majority. Frequently, sketches were poorly drawn with no deflection occurring before the particle was well into the region of the field.	**1** **1**
c				

			 Marking points: - Deflect away from the nucleus, since like charges repel. - Deviation through 45°. - Examiner's Comments: The great majority indicated a sudden change in direction and many of these did not show the deviation in an appropriate position relative to the nucleus.	1 1

2	**a**		It is a **<u>region</u> of space** where a **<u>mass</u> experiences a <u>gravitational</u> force** exerted by other mass(es). Examiner's Comments: Most answers were acceptable, with few referring to force on an object (or particle) rather than a mass. ➔ **Cannot replace 'mass' with 'object' or 'particle' or 'body'. 'mass' must be used.**	**2**
	b	**(i)**	Essential question: ➔ What is the criteria for which Newton's law of gravitation can be used? As the diameters of both stars are **very** small (or **much** smaller) **compared to** their separation, the stars may be considered as **point masses**, therefore allowing the usage of Newton's gravitational law. Examiner's Comments: Some quoted Newton's law of gravitation, but most emphasised the **very** large difference in the magnitudes of the diameters and the separation. ➔ **Comparative language is expected.** ➔ **'very' / 'much' is stated to emphasise the very large difference. Simply stating 'small' / 'smaller' is not accepted.**	**1**
	b	**(ii)**	$F = \frac{Gm_S m_{PC}}{r^2}$ $= \frac{(6.67\times10^{-11})(2.0\times10^{30})(2.4\times10^{29})}{(4.0\times10^{15})^2}$	**1** **1**

			$= 2.0\times10^{16}$ N Examiner's Comments: This was generally done well; power-of-ten errors were quite common. Despite giving a correct response in (b)(i), many included the radii of the stars in the denominator of the relevant expression.	
	c		Essential question: • What is the **effect** of a **force** on the **motion** of a body? [Apply N2L: net force causes acceleration, hence causes changes in velocity.] Although the magnitude of the force on the Sun is very large, the **mass of the Sun is also very large**. Thus, by Newton's second law of motion, the **acceleration of the Sun due to this force is very small ($2.0 \times 10^{16} / 2.0 \times 10^{30} = 1.0 \times 10^{-14}$ m s^{-2}).** Thus the effect of this force in terms of changing the velocity of the Sun is very insignificant. Examiner's Comments: • Many candidates attempted verbose explanations, rather than **calculate the acceleration**. ➔ ***When values are known, calculate out to substantiate your answer.*** • It was common to find that the mass of the Sun was said to be much greater than the gravitational force. ➔ ***Wrong! Because it doesn't make sense to compare unlike physical quantities (mass and force are different physical quantities; illogical to compare them).***	**1** **1**

3	**a**	**i**	Essential Question(s): • Which plate is at the higher potential? • What is the direction of the Electric field? • What is the sign of the charge of the particle? • What is the direction of the Electric force on the particle? • What is the direction of the particle's velocity relative to the electric field? Hence, what is the expected path of the particle in the uniform electric field? Note: In this "show" question, all quantities must be defined if not already defined. The electric force , F on the particle is $$F = qE$$ where q is the charge of the particle and E is magnitude of the uniform electric field strength. $$E = \frac{\Delta V}{d}$$ where d is the separation between the parallel plates and ΔV is the potential difference between the parallel plates.	**M1**

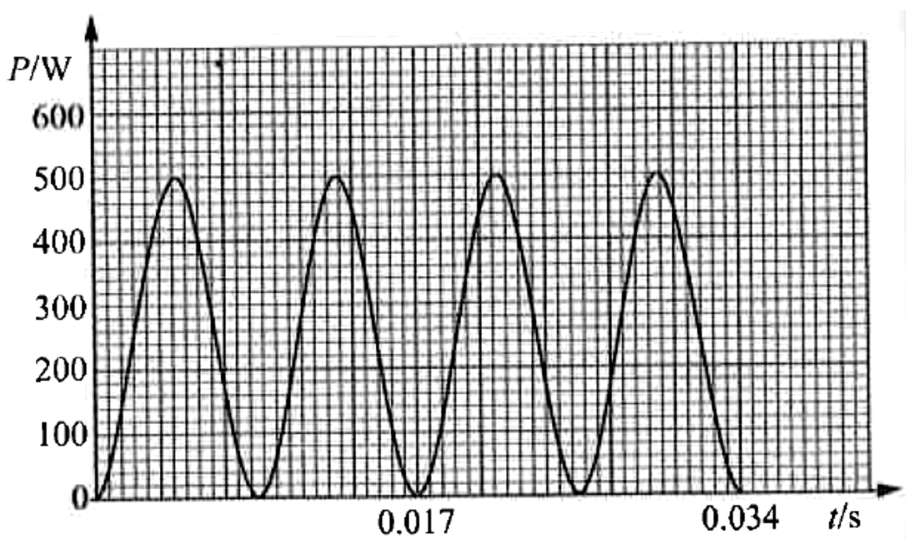
			Therefore, $$F = q\frac{\Delta V}{d} = (3.2\times10^{-19})\times\frac{(900-0)}{3.6\times10^{-2}}$$ $$= 8.0\times10^{-15}\ N$$ Examiner's Comments: With few exceptions, the calculation was completed correctly and an adequate explanation provided.	M1 A0
		ii	Essential Question(s) • Ignoring weight, what are the forces acting on the particle while the particle is inside the parallel plates? By Newton's 2nd Law, $$F_{net} = ma$$ $$a = \frac{F_{net}}{m} = \frac{8.0\times10^{-15}}{6.6\times10^{-27}}$$ $$= 1.2121\times10^{12} = 1.21\times10^{12}\ m\,s^{-2}$$ Examiner's Comments: The great majority arrived at the correct answer.	M1 A1
	b		Essential Question(s) • If you were to sketch the path of the particle from the beginning of the parallel plate to the end of the parallel plate, what is the expected path? ➔ How does the path look like if the particle hit the lower plate? ➔ How does the path look like if the particle travels beyond the parallel plates? • What would be the vertical displacement if the particle successfully travels through the full length of the plate? What is the criterion to determine if it hits the lower plate? [maximum vertical displacement before it hits the lower plate = 3.6 cm / 2 = 1.8 cm; compare with the vertical displacement if the particle could travel the full length of the plates] Consider the horizontal motion the particle, $$s_x = u_x t$$ where u_x = horizontal component of velocity of particle , s_x = length of plate, t = time for particle to travel though the full length of the plates $$t = \frac{s_x}{u_x} = \frac{7.5\times10^{-2}}{4.1\times10^{5}} = 1.8293\times10^{-7}\ s$$ Consider the vertical motion, $$s_y = u_y t + \frac{1}{2}a_y t^2$$	M1 M1

			where u_y = vertical component velocity of particle = 0 , s_y = vertical displacement of particle, t = time for particle to travel though the full length of the plates, a_y = acceleration of particle in the vertical direction $s_y = 0 + \frac{1}{2}(1.2121 \times 10^{12})(1.8293 \times 10^{-7})^2 = 2.0279 \times 10^{-2}\ m = 2.0\ cm$ Since 2.0 cm is more than 1.8 cm (half of plate separation of 3.6 cm), the particle will hit the lower plate Examiners' Comments: The most common approach to this problem was to calculate the time to travel between the plates and then to determine the possible vertical deflection. There were several other different and acceptable solutions. The majority of candidates arrived at the correct conclusion.	**A1**

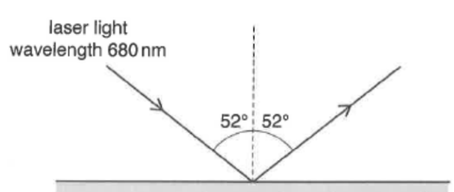
				Marks
4	**a**	**i**	The magnetic flux density B at a point is the magnetic force per unit current per unit length experienced by a straight current-carrying conductor placed at right angle to a uniform magnetic field. Examiner's report: Some attempted to define the tesla, rather than magnetic flux density.	**B1** **B1** **B1**
		ii	The magnetic flux through a coil is the product of the magnetic flux density **norma**l to the plane of the coil and the area of the plane of the coil. Magnetic flux *linkage* through a coil is the product of the magnetic flux through the coil and the number of turns on the coil. Examiner's Report: Many referred to the product of magnetic flux and number of turns, without defining magnetic flux.	**B1** **B1**
	b		Essential Question(s): • When the switch is closed, what is produced in the coil? • Is there an induced current in the aluminium ring? Why? • What forces act on the aluminium ring that causes it to move vertically? When the switch is closed, the current in the coil increases from zero. This increasing current produces a magnetic field that increases in flux density. The soft iron core becomes magnetised, thus increases the overall magnetic flux density experienced by the ring, causing a large increase in the magnetic flux and hence flux linkage through the aluminium ring. By Faraday's law, an e.m.f. of magnitude equal to the rate of change of magnetic flux linkage is induced in the ring. Since the ring is a conductor and a complete circuit, a current is induced in the ring. By Lenz's law, the induced current will flow in a direction to produce a magnetic field directed opposite to the coil's magnetic field in an attempt to reduce the increase in magnetic flux linkage.	**B1** **B1** **B1**

			This results in a magnetic force of repulsion between them. As the upward magnetic force on the ring exceeds the ring's weight, the upward net force causes the ring to accelerate upwards from rest and hence moves vertically. Examiner's report: Many answers commenced by quoting Faraday's and Lenz's laws. Most referred to the magnetic flux linking the ring but frequently, induced current was omitted. It was common to find that the induced e.m.f. gave rise to a magnetic field in the ring.	**B1**
	c		Essential Question(s): • Is there induced e.m.f. in an electrical insulator? [Yes] • Can an electrical insulator conduct current? [No] No current can flow through an insulator. Thus although there is an induced e.m.f. in the insulator ring, there is no induced current and hence no induced magnetic field and no magnetic force of repulsion is produced. Hence, the insulator ring does not move. Examiner's Report: A common misunderstanding was to assume that an e.m.f. would not be induced in the ring. ➔ ***In an insulator, there is a separation of the electron cloud from the individual nucleus which results in an induced e.m.f. However, the charge carriers are immobile and hence cannot flow.***	**M1** **A1**

				Marks
5	**a**		The root-mean-square of an alternating current is defined as the **value of steady direct current** that **dissipates *heat*** at the **same <u>rate</u> as the alternating current** in a **given resistance**. *Note: Replace 'energy' in the formal definition with 'heat' to answer the question specifically.* Examiner's comments: Frequently, reference was made to heating, without making it clear that it is the rate of heating that must be considered and that the heating takes place in a resistor.	
	b	**i**	Essential Question(s): • How to relate the goal (r.m.s. voltage) to the given info (resistance, give circuit diagram, given V-t equation)? • What do the values in the V-t equation represent? What is the general V-t equation for an a.c.? Compare with the general V-t equation for an a.c.: $V = V_o \sin(\omega t)$ ➔ $V_o = 170$ V ➔ $\omega = 377\ s^{-1}$ For a **sinusoidal a.c.**, $V_{rms} = V_o / \sqrt{2}$ $= 170 / \sqrt{2}$ $= 120$ V	 **B1**

		ii	$\omega = 2\pi f$ $377 = 2\pi f$ $f = 60$ Hz	 **M1** **A1**
		iii	$\langle P\rangle = V_{rms}^2 / R$ $= (120^2) / 58$ $= 248$ W $= 250$ W (2 s.f.)	 **M1** **A1**
			Examiners' Comments: **(b) (i)** to **(iii)** With few exceptions, all three parts of this section of the question were completed correctly.	
	c		Essential Question(s): • What are the significant features to represent on a graph? ➔ Shape of graph (function of P-t graph is a sine-squared) ➔ Axes labelling (Peak P, Mean P, period) ➔ Need to show for two periods as per question requirement. • How to calculate the peak P and the period? For **sinusoidal a.c.**, peak P, $P_o = 2\langle P\rangle = 2(250) = 500$ W Period, $T = 1 / f = 1 / 60 = 0.017$ s (2 s.f.)  Marking points: - Sine-squared graph (Note: gradient at all points on the t-axis equal zero; be careful not to draw as 'sharp' points) - two periods → 4 cycles of the power curve must be shown - units on both axes must be stated, since not yet stated. - Values on both axes must be labelled, with the following represented correctly: mean power, peak power, period - Good scale chosen Examiners' Comments: Sketches showing four cycles of the power curve were in a minority and the units were frequently omitted. The peak power was often shown as being '249' or '250'.	 **B1** **B1** **B1**

6	**a**		A photon is a **<u>quantum</u>** of **<u>electromagnetic radiation</u>** **<u>energy</u>**.	**B1**

			This amount of energy is equal to the product of the Planck constant and the frequency of the radiation. Examiners' Comments: Better performing candidates referred to a quantum of energy and that this energy is associated with electromagnetic radiation.	B1
	b	**i**	Energy of a photon = hc/λ $= 6.63 \times 10^{-34} \times 3.00 \times 10^{8} / 680 \times 10^{-9}$ $= 2.925 \times 10^{-19}$ J $= 2.9 \times 10^{-19}$ J (2 s.f.)	 C1 A1
		ii	Essential questions: • What are the quantities given and how does it relate to number of photons per unit time? • Since this is a 'show' question, explanation is required, including definition of symbols used that hasn't been defined in the question. $I = \frac{P}{A} = \frac{N\,E}{t\,A}$ where I: intensity P: power, which is equal to the total energy of all the photons incident per unit time (i.e. P = NE/t) N: total number of photons incident in time t E: energy per photon t: time elapsed A: cross-sectional area of the beam Hence number of photons per unit time, $\frac{N}{t}$ $= \frac{I\,A}{E}$ $= 3.1 \times 10^{3} \times \pi\,(1.2 / 2 \times 10^{-3})^{2} / 2.925 \times 10^{-19}$ $= 1.2 \times 10^{16}$ s^{-1}	 B1 M1 A0
	c		Essential Questions: • How does a force arise? [Force arise when 2 bodies interact and there is a rate of change of momentum of the bodies.] • Why is there a force exerted by the laser light? What laws to apply? [N2L and N3L] • Which photons will exert a force? Both reflected ones and absorbed ones, or, only one group of photons? [Both groups of photons will exert force, since both experience a non-zero rate of change of momentum normal to the surface.] • Which direction of momentum to consider? [Since question requires only the *normal* force to be calculated, consider the momentum of each group of photon in the direction *normal* to the surface, before and after striking the surface.\\  Each photon experiences a rate of change in momentum after striking the surface, hence by **Newton's 2nd law (N2L)** the photon will experience a net force exerted by the surface. And by **Newton's 3rd law (N3L)**, the photon will exert an equal and oppositely directed force on the surface.	

By N2L, Net force on a body = Rate of change in momentum of that body

To calculate the force **normal** to the surface, we need to determine the rate of change in momentum **normal** to the surface experienced by each photon.

Using de Broglie equation:
Initial momentum of each photon, p = h/λ
= $6.63 \times 10^{-34} / 680 \times 10^{-9} = 9.75 \times 10^{-28}$ kg m s^{-1}

Direction of momentum is along the path of the light.

<u>For the photons that are **reflected**:</u>
Since the magnitude of momentum of the photon after it strikes the surface does not change (since there is no change in the wavelength),
the **magnitude** of the **change in** momentum **normal** to the surface of <u>each</u> **C1**
photon is
Δp_r = **2 x** p cos 52° = 1.20×10^{-27} kg m s^{-1}
Direction is upwards

Hence by N2L,
the force **normal** to the surface exerted by the surface on <u>all</u> of the **reflected** photons
= 0.55 x (N / t) x Δp_r
= $0.55 \times 1.2 \times 10^{16} \times 1.20 \times 10^{-27}$ **C1**
= 7.9×10^{-12} N , **upwards**

By N3L, **C1**
the force **normal** to the surface exerted by <u>all</u> of the **reflected** photons on the surface = 7.9×10^{-12} N , **downwards**

<u>For the photons that are **absorbed**:</u>
Momentum after striking surface = 0, so
the **magnitude** of the **change in** momentum **normal** to the surface of <u>each</u>
photon is **C1**
Δp_a = p cos 52° - 0 = 6.00×10^{-28} kg m s^{-1}
Direction is upwards

Hence by N2L,
the force **normal** to the surface exerted by the surface on <u>all</u> of the **absorbed** photons
= 0.45 x (N / t) x Δp_a
= $0.45 \times 1.2 \times 10^{16} \times 6.00 \times 10^{-28}$
= 3.2×10^{-12} N , **upwards** **C1**

By N3L,
the force **normal** to the surface exerted by <u>all</u> of the **absorbed** photons on the surface = 3.2×10^{-12} N , **downwards**

Total normal force exerted **by both reflected and absorbed photons** on the surface
= $7.9 \times 10^{-12} + 3.2 \times 10^{-12}$
= 1.1×10^{-11} N , **downwards** **A1**

Examiners' Comments:
A significant minority did not appreciate the nature of the question. There were some complete correct answers but many only considered either the reflected photons or the absorbed photons.

7	a	i	**The points on a <u>count rate against time graph</u> <u>scatter about the (exponential) line of best fit</u>.** **OR** **<u>Measured count rate fluctuates</u>** from instant to instant in time**.** ***Answers must refer to an <u>observable measurement e.g. "measured count rate"</u>.*** ***Do not Accept "decay graph" / "rate of decay" / "activity" → these do not refer to the quantity being measured experimentally,*** ***Do not Accept "not constant" / "varies"→ not the same meaning as "fluctuates" which refer to count rates that can be higher or lower than the trend line. As the count rate is expected to decrease exponentially with time, it will be non-constant and will vary.***	**B1**
		ii	**The <u>rate of decrease of the measured count rate</u> is unaffected by external stimuli and changes in physical conditions.** **OR** **<u>Repeated experiments</u> under different physical conditions result in no change in the <u>rate of decrease of the measured count rate</u>.** ***Answers must refer to an <u>observable measurement e.g. "measured count rate"</u>.***	**B1**
			Examiner's comment: Many answers to both (i) and (ii) did not answer the question in that **experimental evidence** was required. **Answers referring to individual nuclei, such as probability of decay of a nucleus, did not constitute what is experimental observation.**	
	b	i	Essential Question(s): • How can the decay constant be represented in the activity against time graph? What is decay constant? **[λ is related to $t_{1/2}$, which can be determined from the graph]** • How to determine $t_{1/2}$ from such a graph? **[Recall: Firstly, if best-fit line is not given, you must draw it first. In this case, it is given. Secondly, the half-life must be determined from the average of at least 2 half-lives.]** $\lambda = \frac{\ln 2}{t_{1/2}}$ The graph in Fig. 7.1 allows reading to the maximum of two half-lives. Initial A = 5.8 x 10^5 s^{-1} After 1^{st} half-life, A = 2.9 x 10^5 s^{-1} → t = 15 days After 2^{nd} half-life, A = 1.45 x 10^5 s^{-1} → t = 30 days Therefore, **average** $t_{1/2}$ = [15 + (30 - 15)] / 2 = 15 days	**M1** **M1**

			$\lambda = \dfrac{\ln 2}{t_{1/2}} = \dfrac{\ln 2}{15 \times 24 \times 60 \times 60}$ $\lambda = 5.3 \times 10^{-7} s^{-1}$ Examiners' Report: The graph extended over 40 days, which is several half-lives. For a full answer, candidates were expected to use good experimental practice, taking more than just one measurement of the half-life.	**M1** **A0**
	b	**ii**	Essential Question(s): • How is the decay constant linked with the mass of 1.0 mol of a sample? • Which equation connects the quantities represented through the graph and the quantities given in the text? $A = \lambda N$ $A_o = \lambda N_o$ 5.8 x 10^5 = $5.3 \times 10^{-7}\ N_o$ $N_o = 1.08x10^{12}$ nuclei $m_o = N_o$ x (atomic mass) $= \left(1.08x10^{12}\right)\left(\dfrac{32g}{6.02 \times 10^{23}}\right)$ $= 5.8 \times 10^{-11} g$ Examiner's Comments: This was generally answered correctly, with adequate explanation. In some answers, the Avogadro constant had been omitted, leading to astronomic masses.	 **M1** **M1** **A1**

Section B

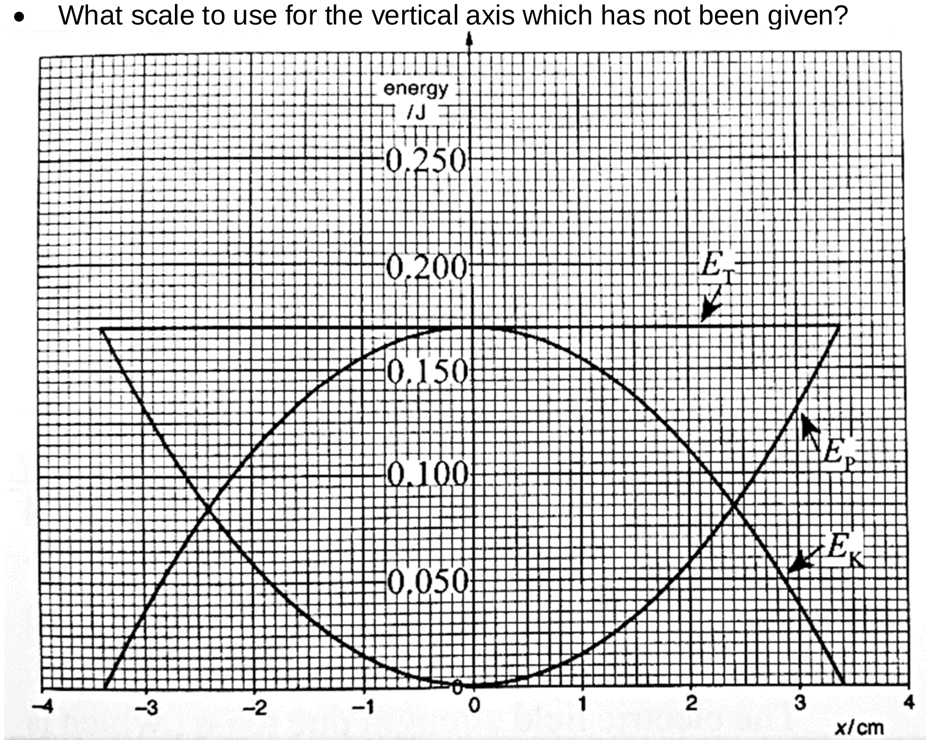
8	**a**	**i**	Internal energy of a system is the **sum of** the **random kinetic energy and potential energy** of the **individual atoms or molecules** of the system. *Examiners' Report:* *In general, reference was made to both kinetic energy and to potential energy of molecules. Frequently, it was not clear that the kinetic energy is associated with random motion of the molecules.*	**B1** **B1**
		ii	Essential Question(s): ➔ Recall Qn. Must memorise +*q*: the heat **supplied to** the system +w: work done **on** the system *Examiners' Report:* *This was answered correctly by the great majority of candidates.*	 **B1** **B1**
	b	**i**	Essential Question(s): ➔ Definition of ideal gas.	

			A gas that **obeys the gas laws or the ideal gas law, pV = nRT, <u>for all values of volume, V, pressure, p, and absolute temperature, T</u>. n is the number of moles while R is the molar gas constant**. *Examiners' Report:* *There was confusion here in that many answers listed the assumptions of the kinetic theory of gases and did not include the equation of state for an ideal gas. Furthermore, where the equation of state was given, many did not explain fully the symbols used.*	**B1** **B1**
	b	**ii**	**1.** Essential Question(s): • What equations can we use to relate the quantities provided to determine the number of molecules. Using pV = NkT $N = \frac{pV}{kT}$ $= \frac{(5.4 \times 10^{5})(1.2 \times 10^{4} \times 10^{-6})}{(1.38 \times 10^{-23})(57+273.15)}$ $= 1.42 \times 10^{24}$ molecules **2.** Essential Question(s): • What are the equations that relates to the mean kinetic energy? • Is it for the entire gas or 1 mole or 1 molecule? Mean kinetic energy, $\langle E_K \rangle = \frac{3}{2}kT = \frac{3}{2}(1.38 \times 10^{-23})(57 + 273.15)$ $= 6.83 \times 10^{-21}$ J **3.** Essential Question(s): • What is total internal energy made up of for an ideal gas? Since the intermolecular forces of attraction in an ideal gas is assumed to be zero, **the potential energy of the molecules/atoms is zero**. Hence the internal energy of an ideal gas is **<u>only</u>** made up of the total kinetic energy of the gas molecules/atoms. Total internal energy = total number of gas molecules x mean kinetic energy per gas molecule $= N \times \langle E_K \rangle$ $= (1.42 \times 10^{24})(6.83 \times 10^{-21})$ $= 9.70 \times 10^{3}$ J *Examiners' Report:* *Answers to **(ii)1.** and to **(ii)3.** were, in the most part, completed correctly, with very few confusing Celsius and kelvin temperatures. In **(ii)3.**, some did not make it clear that the potential energy of the molecules is zero.*	**B1** **M1** **A1** **M1** **A1** **B1** **A1**
	c	**i**	Essential Question(s): • What is the new internal energy of the gas when temperature increases?	

			Internal energy of gas at 155°C = $\frac{3}{2}$NkT $= \frac{3}{2}(1.42 \times 10^{24})(1.38 \times 10^{-23})(155 + 273.15)$ = 1.26×10^4 J Total **increase in** internal energy = $1.26 \times 10^4 - 9.70 \times 10^3$ = 2.90×10^3 J Examiners' Report: *Apart from a minority confusing energy of one molecule with energy of the gas, the calculation was completed correctly.*	M1 M1 A1
	c	ii	**1.** Essential Question(s): • What are the quantities that are present in the calculation for an ideal gas? It is only pressure/volume/temperature/number of moles of gas. • Which equation can be used to link the idea of heat supplied to internal energy of the gas From the first law of thermodynamics, if the increase in internal energy of the gas is due to the thermal energy supplied to the gas, then the work done on the gas has to be zero. $\Delta U = +q$. For work done to be zero, the volume of the gas must have remained constant. *Examiners' Report:* *There were some very full answers here. Candidates suggesting either constant pressure or number of molecules were in a minority.* **2.** Essential Question(s): • How do you link your knowledge on specific heat capacity to one with the term molar heat capacity? [$Q = mc\Delta T \rightarrow Q = nc_m\Delta T$] Given: Thermal energy supplied = Increase in total internal energy = 2.90×10^3 J Molar heat capacity, *C* $= \frac{\text{Thermal energy supplied}}{\text{number of moles of gas molecules x change in temperature}}$ $= \frac{2.90 \times 10^3}{\frac{1.42 \times 10^{24}}{6.02 \times 10^{23}} \times (155 - 57)}$ = 12.5 J mol^{-1} K^{-1} *Examiners' Report:* *An explanation of molar heat capacity was explained in the question, nevertheless a significant numbers of answers omitted to include n.*	M1 A1 M1 A1

9	**a**	**(i)**	It 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 (i.e. acceleration is always directed towards the equilibrium position). Examiner's Comments: The definition had been learned carefully by most candidates.	**1** **1**
9	**a**	**(ii)**	**1.** 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. **2.** The a-x graph is not always linear, showing that acceleration is not always proportional to the displacement, hence not simple harmonic motion. Examiners' Report: **1.** There were few correct responses, in that simple harmonic motion was defined again, rather than **using evidence from the graph**. Positive and negative displacements indicate the mass is oscillating. **2.** Better performing candidates made reference to the curvature of the line, as **evidence from the graph**. Many others discussed proportionality of the displacement and the acceleration without mentioning the line.	 **1** **1**
	b	**i**	Essential Question(s): • What does 'lose contact' imply about the force on the sand? [N becomes 0] • How does N vary during the oscillation? What is the free body diagram of the sand at various instants during the oscillation? • When is N most likely to be zero? Why? What is required for a body to be in SHM? [For a body to be in SHM, it must experience a net force towards the equilibrium position. So what provides for the net force on the sand in this scenario?] • How does net force / acceleration vary with the position of the sand? So at which position will N first become zero? Solution: **1.** At the highest/uppermost position. ***Do not accept: 'At amplitude position' or 'At maximum displacement'. Need to answer in context. Furthermore, these could refer to the lowest position too which is wrong.*** ***Do not accept: 'At maximum amplitude'. This makes no sense. Amplitude refers to the maximum displacement from equilibrium position.*** **2.** Loses contact → Normal contact force (N) between sand and plate = 0 So at this instant, Net force on a sand grain = Weight of sand grain Mass x Acceleration = Mass x Gravitational field strength Acceleration = Gravitational field strength Sand's weight (W) remains constant throughout.	 **1**

			N can only become zero *above* the equilibrium position, where N acts away from the equilibrium position and W must be greater than N to provide a net force towards the equilibrium position. N cannot be zero *below* the equilibrium position, since N must be greater that W to provide a net force towards the equilibrium position. Since acceleration is maximum at the amplitude position, N becomes zero first at the highest position. Hence, at this instant, Maximum acceleration = Gravitational field strength $\omega^2 x_o = g$ $(2\pi f)^2 x_o = g$ $(2\pi(13))^2 x_o = 9.81$ $x_o = 1.47mm$ Examiners' Report: **(i)1.** A common answer was 'at maximum amplitude', without reference to the upper position. **(i)2.** This was completed correctly in the large majority of answers, including the conversion to mm.	**1** **1**
		ii	Essential Question(s): • What does the loss of contact depends on? • Is mass part of the equation? The minimum amplitude for the loss of the contact will be the same. This is because the minimum amplitude is independent of the mass / volume of the object. Examiners' Report: There were very few clear explanations. Many answers involved dependence on frequency.	**1** **1**
9	**c**	**i1**	Essential Question(s): • What equations can be used to calculate the total energy of oscillations? Which equation relates E_T to the given information? $E_T = \frac{1}{2} m\omega^2 x_o^2$ $= \frac{1}{2} m(2\pi f)^2 x_o^2$ $= \frac{1}{2}(1.2)(2\pi(2.5))^2(0.034)^2$ $= 0.17J$ Examiners' Report: **(i)1.** This was completed correctly by most candidates. A minority attempted to include gravitational potential energy by including the expression *mgh*. ***→ No need to include GPE because E_P refers to the potential energy 'of oscillations'. Likewise, E_T refers to the total energy 'of oscillations'.***	**1** **1**
9	**c**	**i2.**	Essential Question(s):	

			• What is the relationship between total energy, kinetic energy and potential energy in SHM? • What equations relate E_T, E_P and E_K to displacement in SHM? $E_P + E_K = E_T$ When the potential energy and the kinetic energy are equal, the potential energy is half of the total energy. $E_P = \frac{1}{2} E_T$ $\frac{1}{2} m\omega^2 x^2 = \frac{1}{2}\left(\frac{1}{2} m\omega^2 x_o^2\right)$ $\therefore$ $x = \frac{x_o}{\sqrt{2}} = \frac{3.4}{\sqrt{2}} = 2.4cm$	1 1
	c	**ii.**	Essential Question(s): • What is the shape of the graphs? What equations relate E_T, E_P and E_K to x in SHM? • What is the relationship between E_T, E_P and E_K ? • What values should you take note of to draw the graphs more precisely? (What values are given in the question? What values are found in previous parts?) • What scale to use for the vertical axis which has not been given?  Marking points: • Labelled vertical axis & Good scale **[1]** • Shape of E_T – horizontal line, since E_T = constant; Constant Value of E_T at 0.17J **[1]** • Shape of E_P – positive quadratic curve, since $E_P = ½ m\omega^2x^2$ **[1]**	

			• Shape of E_k – negative quadratic curve, since $E_K = ½ m\omega^2 (x_o^2 – x^2)$ OR $E_K = E_T – E_P$ = constant – (positive quad) = (negative quad); maximum point at (0 cm, 0.17 J). **[1]** • E_p and E_K intersect at points where $E_P = E_K$, so use answer in (c)(i)(2) $\rightarrow$ 0.17 / 2 = 0.085J $\rightarrow$ intersection points at (- 2.4 cm, 0.085 J) and (+2.4 cm, 0.085 J). **[1]** • Amplitude positions at x = ± 3.4 cm $\rightarrow$ All three graphs should only span within x = ± 3.4 cm (NOT ± 4 cm!!) **[1]** • Deduct 1 mark if graphs are not labelled “E_T”, “E_P”, “E_K“. • Deduct 1 mark if the three graphs do not approximately show the relationship $E_P + E_K = E_T$. Examiners’ Report: There were some good sketches; many others lacked sufficient care when drawing curves. Sharp changes in direction do not indicate the nature of the variation of kinetic energy and potential energy. It was not uncommon to find that the line for total energy was drawn from –4 cm to +4 cm. The line for kinetic energy usually had the correct *x*-axis intercepts. Many ‘curves’ had peculiar shapes where candidates had made the lines for potential energy and kinetic energy cross at the points calculated in **(i)2**.	