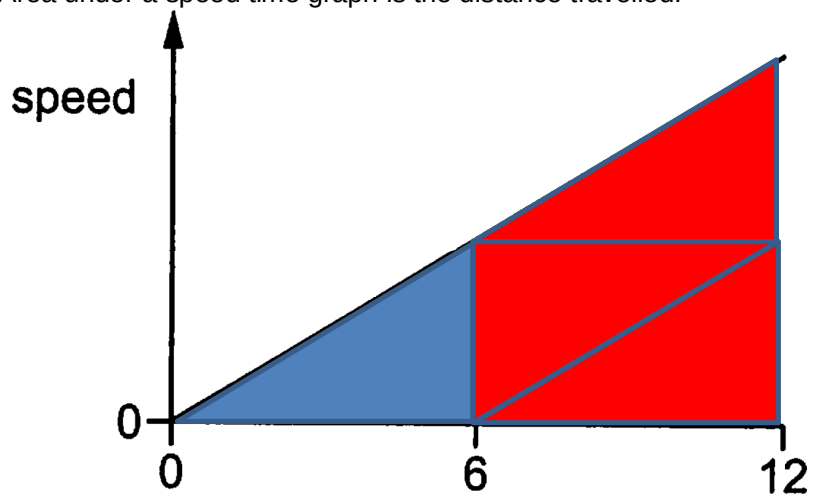
H2 Physics 9749 – 2017 A Level Exam

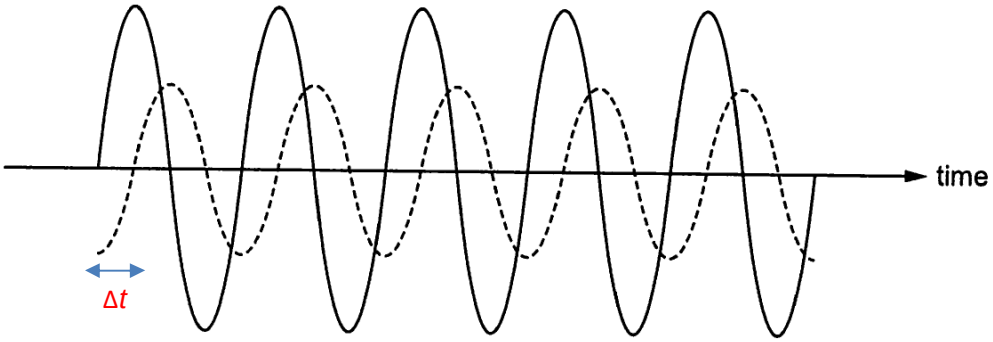
Paper 1

1	Essential Question(s): • What are the 7 base units? → Just memorise! (Base units vs Derived units) Answer: A
2	Essential Question(s): • Question asks for "uncertainty" – In which form? Absolute, Fractional or Percentage? ➔ Percentage uncertainty • How to compute the percentage uncertainty of a derived quantity (i.e. xy^2 / z) from the individual percentage uncertainties (i.e. x, y and z)? ➔ Apply Product-Quotient Rule of combining uncertainties. $Percentage\ uncertainty\ of \frac{xy^2}{z} = \left(\frac{\Delta x}{x} + \mathbf{2}\frac{\Delta y}{y} + \frac{\Delta z}{z}\right) x100\% = 6\%$ For options A to D, substitute the values in the 3 columns into the expression above. See which gives 6%. Note that the effect of $\frac{\Delta y}{y}$ is **doubled**. Option A: 1 + **2**(1) + 4 = 7% Option B: 2 + **2**(1) + 2 = 6% Option C: 3 + **2**(2) + 2 = 9% Option D: 4 + **2**(1) + 1 = 7% Answer: B
3	Essential Question(s): • What remain constant/the same over the period of 12 s? • Which are the variables that are involved in the question? ➔ Distance, S ➔ Time, t ➔ Initial Speed, u = 0 • Which kinematic equations links up all these variables? $s = ut + ½ at^2$ According to the examiner's report, student performed well for this question. Approach 1: Acceleration is constant as can be seen from the gradient of this single line graph. Therefore, valid to use the kinematics equation. $s = ut + ½ at^2$ where a = gradient and u = 0. $\frac{s_{0-6}}{s_{0-12}} = \frac{at_{0-6}{}^2}{at_{0-12}{}^2} = \frac{6^2}{12^2} = \frac{1}{4}$ Therefore, $s_{6-12} = s_{0-12} - s_{0-6}$ Since it is ratio, we can subtract the parts : $s_{6-12} = 3$ $\frac{s_{6-12}}{s_{0-6}} = \frac{3}{1}$

	Approach 2: Area under a speed time graph is the distance travelled.  Red area is 3 times the blue area. Answer : C
4	Essential Question(s): • How will the object's velocity change as it falls? (it continues to increase until terminal velocity is reached) • What are the forces acting on the object? (weight downwards and air resistance upwards) • Under what conditions will object reach max velocity? (when air resistance equals and opposite to weight) To find v_{max}, Air resistance = Weight 0.60 x v_{max} = 3 x 9.81 v = 49 m s^{-1} acc when v = 12 m s^{-1}, R = 0.6 x 12 = 7.2 N To find acc, equate resultant force = mass x acc mg – R = ma 3 x 9.81 – 7.2 = 3a a = 7.4 m s^{-2} Answer: D
5	Essential Question(s): • Ball collides inelastically – What happens to the ball's KE? (decreases) • What happens to the magnitude of momentum after collision? (reduces) • How to determine change in momentum? ($p_f - p_i$; Note that these are vector quantities) Max Change in momentum (if elastic) = $p_f - p_i$ = p – (-p) = 2.0 p (cannot be option D since collision is inelastic and p_f less than p) If object comes to rest after collision and p_i = 0 Then change in momentum = $p_f - p_i$ = 0 – (-p) = 1.0 p (cannot be option B since object rebounds upwards so it has some momentum after collision) Change in momentum should fall between 1.0 to 2.0 p for this scenario, therefore option C is a possible option). Option A means that ball continues to move in the same direction as before, after collision which is not the case.

	Answer: C
6	Essential Question(s): • Which are the objects in interaction? (earth with brick; floor with brick) W, weight of brick = force the earth exerts on the brick Newton's 3rd law pair = force the brick exerts on the earth S, support force from floor on brick Newton's 3rd law pair = force from brick on the floor Answer: A
7	Essential Questions: • What kind of motion will the golf ball undergo when it is hit? • What are the characteristic of this motion? Since the golf ball is undergoing a projectile motion, acceleration (or rate of change of vertical component of velocity) is always constant (i.e. downward acceleration due to gravity) and horizontal velocity will always stay constant as there are no horizontal forces. However, since the velocity (& speed) of golf ball changes, the total kinetic energy will change. Answer: D
8	Essential Questions: • What does the total energy of the satellite comprise of? Total energy of a satellite = GPE of satellite + KE of satellite in the orbit = $-\frac{1}{2}\frac{GMm}{R}$ Therefore, change of total energy = final total energy at the smaller orbital radius – initial total energy at the higher orbital radius. = - 2 x 10^9 J Negative sign implies that energy is lost. Answer: C
9	Essential Question(s): • What kind of motion is this? • Which physical quantities remain the same for both position of P and Q? ➔ Angular Velocity • Which quantity changes between point P and point Q? ➔ Radius • Which is the relevant equation to use for this question? Angular velocity at P and Q is the same, because when P rotate 1 round, Q also rotate 1 round. $a = m\omega^2 r$ $\frac{a_Q}{a_P} = \frac{r_Q}{r_P} = \frac{1}{2}$ $a_Q = 8$ Answer: D

10	Essential Question(s): ➔ What is the formula for gravitational potential? ➔ How to apply it using some mathematical manipulation. $\phi = -\frac{GM}{r_E}$ $-6.257 \times 10^7 = -\frac{GM}{r_E}$ $\Rightarrow -6.257 \times 10^7 r_E = -GM$ So $\phi_{new} = -\frac{GM}{r_E + 50000}$ $= \frac{-6.257 \times 10^7 r_E}{r_E + 50000}$ $= \frac{-6.257 \times 10^7 \left(6.371 \times 10^6\right)}{\left(6.371 \times 10^6\right) + 50000}$ $= -6.208 \times 10^7 \text{ J kg}^{-1}$ Answer: A
11	Essential Question(s): ➔ What equation links the temperature in the Kelvin scale to the degrees Celsius scale? ➔ How to apply it using some mathematical manipulation. $T/K = \theta/ °C + 273$ Hence by linearising the equation, the gradient is 1 and the y-intercept is 273. Answer: D
12	Essential Question(s): ➔ What is the question requirement for Thermal Physics? (Is it just Internal Energy = Sum of all KE and PE of atoms/molecules/particles of the system?) ➔ If not then is the first law of thermodynamics required? Since the answers in the table provides the headings as internal energy/heat supplied and work done, therefore it must be agreed that the First Law of Thermodynamics must be used. As there is an increase in temperature, internal energy must increase. As the container is insulated, no heat is supplied. And when stirring happens, work is done on the system hence work done increases. Answer: B
13	Essential Questions: • What are the different degrees of damping? • How to represent the different degrees of damping through graphs? • Which degree of damping is best for a car suspension system? Option A: Light damping oscillations. An “oscillation” is seen from the graph alternating between the positive and negative displacement throughout time. Option B: Heavy damping. It takes relatively a longer time to reach the equilibrium position as compared to option D. Option C” Also a light damping oscillation, but is more damped than option A.

	Option D: Critical damping. Reaches equilibrium position is relatively the shortest time. A critical damping is required for a car suspension system. Whenever the car goes over a hump, it is expected that the car returns to the equilibrium position as soon as possible. Answer: D
14	Essential Questions: • How do we know whether a wave profile is a representation of the whole wave or the oscillation at one point in space? • How do I calculate the phase difference when the time axis is shown? ➔ $\Delta\theta = \frac{\Delta t}{T} \times 2\pi$  From the graph, the dotted graph lags the solid graph by one-quarter of the wave. Therefore, ➔ $\Delta\theta = \frac{\frac{1}{4}T}{T} \times 2\pi = \frac{\pi}{2}$ The graph can also be interpreted as the solid graph lags the dotted graph by three-quarter of the wave. ➔ $\Delta\theta = \frac{\frac{3}{4}T}{T} \times 2\pi = \frac{3\pi}{2}$ Other learning points: ➔ Phase difference is independent on the amplitude of oscillation ➔ It is not meaningful in this case to ask if there is a $\frac{\pi}{2}$ rad as one of the options, which is the correct answer? Both answers are essentially the same. o Exception: IF the question already made which graph is leading / lagging, then only one of the answers is right. Answer: D Examiner's report: Weaker candidates chose option B, presumably not realizing that one full wavelength corresponds to a rotation of 2π radians.
15	Essential Questions: • What is the relationship between intensity and amplitude? ➔ $I \propto a^2$ • When travelling through a boundary, which quantity(ies) remains constant? ➔ Frequency Since the amplitude is halved, the intensity is reduced to $0.25I$. As the frequency of the light remains the same, the wavelength of the wave will be halved when the speed of the wave is halved. Answer: B Examiner's report:

Weaker candidates chose option **A** instead of the key, not realizing that frequency is constant as a wave moves from one medium to another.

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Essential Questions:

- How do the intensity of maxima vary from the central maximum of a diffraction grating where the slit is not infinitely small?
- Does the angle of diffraction vary proportionally with the order of maxima?

a) For a diffraction grating, the intensities of the maxima decrease with distance from the central maximum.

Option B and D are incorrect

b) The angle of diffraction does not varies proportionally with the order of maxima.

Option A is incorrect

By elimination, Option C is the correct answer.

Answer: C

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Essential Questions:

- How is the tension related with the mass?
- How do you calculate the value of constant of proportionality?
- What is the relationship of length of string and wavelength in the stationary waves form by a stretched string? For any stationary wave formed, Length of string = integer number of half-wavelengths

At L = 90 cm = 0.9 m, this is 1st harmonic ie. $L = \frac{\lambda}{2} \implies \lambda = 2 \times 0.9 = 0.18\, m$

$$v = k\sqrt{T} = k\sqrt{mg}$$

At m = 400 g = 0.4 kg and f = 15 Hz

$$v = f\lambda = k\sqrt{mg}$$

$$15 \times 0.18 = k\sqrt{0.4 \times 9.81}$$
$$k = 13.63$$

Option	m /g	f /Hz	$v = k\sqrt{mg}$ / m s^{-1}	$\lambda = \frac{v}{f}$ / m
A	500	30	30.187	1.006
B	600	40	33.068	0.8267
C	800	60	38.183	0.63638
D	900	90	40.500	0.45

Only Option D gives an integer of (λ/2) for the length of 90 cm.

Answer : D

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Essential Questions:

- What is the relationship between electric field strength and radial distance?
- What is the relationship between electric field strength direction and the charge of the body?
- Negative Charge Field strength is towards itself. (to the right in this case)
- Positive Charge Field strength is away from itself. (to the right in this case)

	$E_q = \frac{q}{4\pi\varepsilon_o r^2} = \frac{q}{4\pi\varepsilon_o 0.3^2} = 10$ $E_{-q} = \frac{-q}{4\pi\varepsilon_o r^2} = \frac{-q}{4\pi\varepsilon_o 0.6^2}$ $= \frac{-q}{4\pi\varepsilon_o (0.3\times 2)^2} = \frac{1}{4}\times\frac{-q}{4\pi\varepsilon_o 0.3^2} = \frac{1}{4}\times -10 = -2.5$ The Electric field strength at P is 10 N C^{-1} to the right by the +q charge and 2.5 N C^{-1} to the right by the –q charge. The net Electric Field is 12.5 N C^{-1} to the right. Answer: C
19	Essential Qn: • What is the IV characteristics of an ideal semicon. Ans B ,Simple recall of the IV characteristics of an ideal semiconductor
20	Essential Qn: • P = VI. • P_o = n P_i, where n is the efficiency. Anc C, P_{out} = 0.9 P_{input} = 0.9 x 280 x 5.7 = 1436 W. Thus I_{output} = 1436 / 230 = 6.2 A
21	Essential Qn: • Recall R = ρd/A, and o how R varies linearly w d and o inversely proportional with A (cross sectional area) Ans A, Concept R = ρd/A .As the length d increases, R increases, thus C and D are out. As the wire moves from a larger diameter to a smaller diameter, the cross sectional area A decreases and hence the resistance experience a faster rate of increment for R for the section of the diameter, thus option A is the answer. ER: Weaker candidates chose option **C**, not recognising that the question asked about the resistance between X and a point at distance *d*.
22	Essential Question(s): • What happens at the junction above the bottom resistor? • How is potential related to potential difference? Which is at a higher potential? How do we know? Current flowing through the bottom resistor = 2A + 4A = 6A Therefore, potential drop across the bottom resistor = (6A)(30Ω) = 180 V Potential drop across the top resistor = (4A) (30Ω) = 120 V Therefore potential at P = 0 + 120 + 180 = 300 V Answer: D Examiner's Report: Weaker candidates showed a slight preference for option B, which was obtained by not realising that the 2 A current is added to the 4 A current to give 6 A through the bottom 30 Ω resistor.

23	Essential Question(s): • How is the direction of the force related to that direction of the B field? $F = Bqv(\sin 20)$ $v = \frac{F}{Bq(\sin 20)}$ $= \frac{4.3 \times 10^{-14}}{0.088 \times 1.6 \times 10^{-19} (\sin 20)}$ $= 8.9 \times 10^{6}\ \text{m s}^{-1}$ Answer: D
24	Essential Question(s): • Which sides of the frame induce(s) emf? What is the area swept and by which side of the frame? Using Fleming's Left Hand Rule, and treating the frame as 4 individual rods, emf will be induced in both MN and QP. Answer: C
25	Essential Question(s): • How to determine r.m.s. value for a **non**-sinusoidal AC? →Use a Graphical Approach to determine the r.m.s. value of V from the given graph. • How to related r.m.s. V to r.m.s. I? • How to calculate the mean power dissipated in a resistor for a varying current / voltage? Answer: A
26	Essential Question(s): • Is 32 W the peak power dissipated or mean power dissipated in R? ➔ Mean power, <P> • How to relate <P> to the peak value of the primary voltage? • How to relate R to the known information? ➔ $\langle P \rangle = V_{rms,s}^2 / R$ ➔ $V_{rms,s}$ can be found from $V_{rms,p}$ using the turns ratio of the transformer ➔ $V_{rms,p}$ can be found from $V_{o,p}$ using the formula for a sinusoidal AC Answer: B
27	Essential Question(s): • What is the photoelectric effect about? Answer: D
28	Using de Broglie's wavelength, $\lambda = \frac{h}{p} = \frac{6.63\ x\ 10^{-34}}{(9.11\ x\ 10^{-31})(2.00\ x\ 10^{7})} = 3.64\ x\ 10^{-11}\ m$ Answer: C
29	Essential Questions: • What is the nuclide notation for alpha particle? • What is the nuclear equation for this decay? Mass number for nuclide X is 145 + 94 = 239 Proton number for nuclide X is 94 Mass number for alpha particle is 4 Proton number for alpha particle is 2

	Therefore, after decay, Proton number of the new nuclide is 94 – 2 = 92 Mass number of the new nuclide is 239 – 4 = 235 , neutron number = 235 – 92 = 143 Answer: B
30	We can determine the decay constant using the decay law. $$A = \lambda N$$ $$\lambda = \frac{3.7\ x\ 10^{7}}{4.8\ x\ 10^{20}} = 7.71\ x\ 10^{-14}$$ Using the radioactive decay equation, $$N = N_o e^{-\lambda t}$$ $$\frac{N}{N_o} = e^{-\lambda t}$$ $$\frac{1.5\ x\ 10^{19}}{4.8\ x\ 10^{20}} = e^{-(7.7\ x\ 10^{-14})t}$$ $$t = 4.5\ x\ 10^{13}\ s$$ Answer: C

Paper 2

1	**a**		Essential Question(s): • How to relate 'force constant of spring' to the given information? ➔ Apply Hooke's Law equation, F = kx → k = F/x • What do the symbols in this equation mean? ➔ F is the force applied to the spring; x is the extension. extension, x = 10.8 – 8.0 = 2.8 cm k = F/x = mg / x = (0.140)(9.81) / (0.028) = 49.05 = 49.1 N m^{-1}	**1** **1**
	b	**i**	Essential Question(s): • How was 'force constant' obtained? Is it from raw measurement or a derived quantity? ➔ Derived quantity (see part (a)) • How to determine the percentage uncertainty of a derived quantity? ➔ In this case, apply Product-Quotient Rule since k = mg / x k = mg / x Thus, $\frac{\Delta k}{k} x100\% = \left(\frac{\Delta m}{m} + \frac{\Delta g}{g} + \frac{\Delta x}{x}\right) x100\%$ $\frac{\Delta m}{m} x100\%$ = 1.0% is given. Since no information, assume $\frac{\Delta g}{g}$ is negligible. Given $\Delta(measured\ spring\ length, L)$ = 1 mm, and since x = $L_2 – L_1$ ➔ Apply Addition-Subtraction Rule, $\Delta x = 2\ \Delta L = 2$ x 1 mm = 2 mm = 0.2 cm	**1**

			$\frac{\Delta k}{k} x100\% = \left(\frac{\Delta m}{m} + \frac{\Delta x}{x}\right) x100\%$ $= 1.0\% + \frac{0.2\ cm}{2.8\ cm} x100\%$ = 8.1 % (2 s.f.) *Examiners' Report:* *This calculation was less well done. Some candidates used an error of 1 mm for the extension.*	**1**
		ii	$\frac{\Delta k}{k} x100\% = 8.1\%$ $\Delta k = \frac{8.1}{100} x\ 49.05 = 4\ N\ m^{-1}$ $(\mathbf{1}\ \boldsymbol{s.f.})$ **Δk must be rounded off to 1 s.f.* *k must be expressed to the same precision as Δk, hence* $(k \pm \Delta k) = (49 \pm 4)\ N\ m^{-1}$	**1**
	c	**i**	Essential Question(s): • What are the forces acting on the mass? (Weight downwards, upthrust upwards and force on spring upwards) • System is in equilibrium Difference in force on spring = upthrust $kx_1 - kx_2$ = upthrust $49.05(10.8\text{-}8)x10^{-2} - 49.05(10.3 - 8)x10^{-2}$ = Upthrust Upthrust = 0.245 N	**B1**
		ii	Essential Question(s): • Which physical quantities links up the upthrust in (ci) to the density of the liquid as requested by this question? ➔ Upthrust = weight of liquid displaced. ➔ Upthrust = mass x g ➔ Upthrust = ρVg • With g and upthrust known, ρ to be found out, V is the only unknown variable. • How is the volume of the liquid displaced related to the volume of the block? Mass of the block is 0.140 kg. Volume of the block = 0.140/ 7750 = 1.806×10^{-5} Volume of the block = Volume of Fluid displaced = 1.806×10^{-5} Upthrust = Weight of Fluid displaced Upthrust is found in Part (i) 0.245 =ρVg $0.245 = \rho \times 1.806 \times 10^{-5} \times 9.81$ =1380 kg m^{-3} Examiner's Comments: Power of ten errors were common here.	**M1** **M1** **A1**

2	**a**	**i**	Essential Question(s): • How is the moon able to orbit about another body?	

			• What could the same period *T* suggest about how the moon is viewed with respect to Pluto? • What is the relationship between orbital speed and orbital radius? • What is the relationship between angular velocity and period? • What relevant information do we extract from the table? Note: In this "show" question, all quantities must be defined if not already defined. Since moon is in circular motion, $v=r_o\omega$ where *v* is the orbital speed of Charon, ω is the angular velocity of Charon and r_o is the orbital radius of Charon around Pluto. Angular velocity, $\omega = \frac{v}{r_o} = \frac{2\pi}{T}$ $T = \frac{2\pi r_o}{v}$ $= \frac{2\pi(1.75x10^4 x10^3)}{0.2x10^3} = 549779s$ $= \frac{549779}{60x60x24}$ = 6.36 days Examiner's Comments: Better answers showed how seconds were converted to days.	**B1** **B1**
		ii1.	Essential Question(s) • Space probe on surface of Pluto observes Charon – what does it observe given same period of rotation about Pluto's axis? (focus is rotation about Pluto's axis) Charon will be above the same place on surface of Pluto (at all times). **Note:** Charon appears to be in the same permanent location in the sky with respect to the space probe. (Just like the geostationary satellite as seen on Earth).	**B1**
		ii2.	Essential Question(s) • Space probe on surface of Pluto observes Charon – what does it observe given equal periods of rotation? (focus is rotation about each of their axes) – note that Charon is rotating around Pluto but both are also rotating about their own axes. The space probe **observes the same side/face of Charon** as Charon's side closest to Pluto will face the space probe permanently. Examiners' Comments: Answers to this part (ii) were generally poor, with significant number repeating statements given in the question rather than what is observed from the space probe. Other candidates assumed that the space probe was orbiting Pluto rather than on the surface of Pluto.	**B1**
	b		Essential Question(s) • Use data – values to be used in calculations	

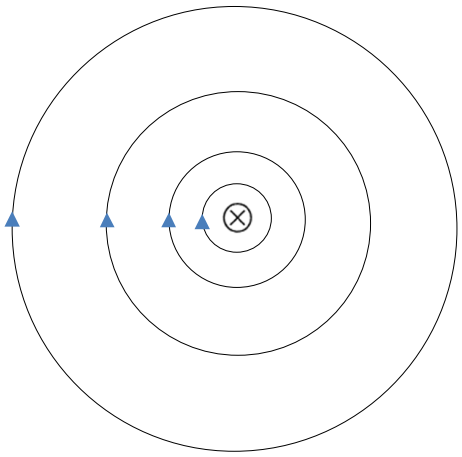
			• What is the equation for gravitational field strength? Grav field strength at surface, g_p = $\frac{Gm}{r^2} = \frac{6.67x10^{-11}x1.31x10^{22}}{\left(1.2x10^3x10^3\right)^2}$ $=0.607\ N\ kg^{-1}$ Examiner's Comments: There were a significant number of power of ten errors. Some candidates did not square the radius.	**M1** **A1**
	c	**i**	Essential Question(s): • What concept can be used to determine the speed? Dynamics/Kinematics or Energy approach? ➔ Since non-constant acceleration, Energy approach is most convenient. Let KE: kinetic energy; GPE: gravitational potential energy By conservation of energy, Total initial energy of rock at infinity = Total final energy of rock just before it hits Pluto's surface $KE_i + GPE_i = KE_f + GPE_f$ $0 + 0 = \frac{1}{2}Mv^2 + \left(-\frac{GmM}{r}\right)$ where m: mass of Pluto Since it is released at rest at inifinity, the KE is 0 and the GPE at infinity is also zero by definition. $\frac{1}{2}Mv^2 = \left(\frac{GmM}{r}\right)$ $v^2 = \frac{2Gm}{r} = \frac{2Gm}{r^2}r = 2g_Pr$, since $g_P = \frac{Gm}{r^2}$ $v = \sqrt{2\,g_Pr}$ Examiners' Comments: The majority of responses started by equating the gravitational potential energy lost to the kinetic energy gained. The step that required the substitution of the expression for the gravitational field strength of the surface of Pluto was often not explicitly stated but hidden in the algebra. Note also that M had been pre-defined in the question to represent the mass of the rock, so candidates should not use M for mass of Pluto. Symbol r was also defined in the first part of the question.	**1** **1** **1**
		ii	Essential Question(s) • What is the energy conversion of a rock going from the surface to infinity? (it loses KE to gain GPE) – Unlike ci, the rock is now going from surface of Pluto to infinity By conservation of energy, Total energy of rock at surface = total energy of rock at infinity GPE + KE = GPE + KE $\frac{-GMm}{R} + \frac{1}{2}M_{min}v^2 = 0 + 0$ $v_{min} = \sqrt{2\left(\frac{Gm}{r}\right)}$ $= \sqrt{2\left(\frac{Gm}{r^2}\right)r}$	

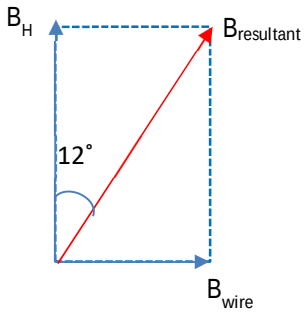
			----------Start of answer---------- Using expression from (b), info from Table 2.1 and g_p value calculated in (c)(i). $v_{min}=\sqrt{2g_p r}$ $=\sqrt{2(0.607)1.2x10^3 x10^3}$ $=1210\ m\ s^{-1}$ Examiner's Comments: Power of ten errors were common here.	**A1**

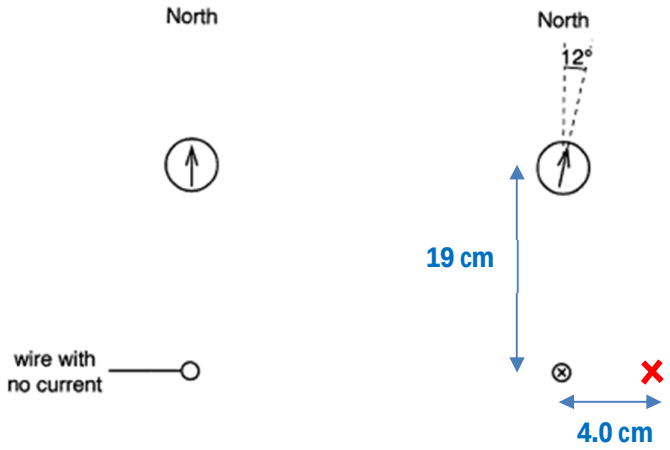
				Marks
3	**a**		Polarisation is a phenomenon where the oscillations in a transverse wave are confined to one direction only, the direction being at right angles to the direction of propagation of the wave. Examiner's report: The relationship between the direction of vibration and the direction of propagation of the wave should be clearly described.	**1** **1**
	b		Essential Question(s): • From lecture notes. Derivation that needs to be memorized. No two ways about it. Speed of wave, $v = \frac{\text{distance travelled by a wave profile in one period, } \lambda}{\text{one period, T}}$ $= \frac{\lambda}{T}$ $= f\lambda$ Examiner's Report: Better answers followed the instructions in the question to start with the definition of speed and used recognised symbols to deduce the wave equation. Some did not start with a definition of speed.	**M1** **M1** **A0**
	c	**i**	State: **Constructive interference** occurs at point P. Explain: Since ***path* difference** between the waves is **1 km**, which is **4 times the wavelength (250 m) <u>and</u> sources were in phase**, the **two waves will meet in phase at point P** and **hence interfere constructively**. Examiner's report: There were many answers that simply described the conditions for constructive or destructive interference. Better answers went on to use the data given to explain their answer. Some suggested that, as the waves were emitted in phase, they would produce constructive interference. There were many good answers with the wavelength of the waves being correctly linked to the path difference.	**1** **1** **1**

	c	**ii**	Essential Question(s): • What would be detected by the car when 2 waves interfere? • What happens when 2 waves interfere? → Apply Principle of Superposition. Analysis: This is 2-source interference. So with steady interference, alternating regions of constructive & destructive interference would occur. Dotted line along which the car travels is like the 'screen'. So as the car travels, it should detect alternating regions of constructive & destructive interference, which by Principle of Superposition, implies that the amplitude of the resultant wave at these points would be maximum and minimum respectively, and since the car is travelling at constant speed, these would be detected alternately at regular time intervals. *Question command word here is simply **"Describe"** not "Describe and explain", so the following answer would suffice:* **The amplitude of the resultant wave detected by the car as it travels would <u>vary alternately between maximum and minimum</u> at <u>regular time intervals</u>.** ***IF** question command word were **"Describe and explain"**: answer is* **Since the 2 radiowaves are <u>coherent and overlap</u>, <u>steady interference</u> occurs. So as the car travels, it should detect <u>alternating regions of constructive & destructive interference</u>, which <u>by Principle of Superposition</u>, implies that the <u>amplitude of the resultant wave at these points would be maximum and minimum respectively</u>, and <u>since the car is travelling at constant speed</u>, these would be <u>detected alternately at regular time intervals</u>.** Examiner's Report: Most candidates wrote clearly about variations between maxima and minima.	**B1**
	c	**iii**	Essential Question(s): • When will there be no more interference pattern? • What do you need to have for observable interference pattern to form? (same nature & overlap/coherent/similar amplitude/transverse waves unpolarised or polarized in the same direction) ➔ So if any of this is not achieved then interference would not occur. There can be a polariser placed in front of both transmitters such that the wave emitted after passing through the polariser will be orthogonal/perpendicular to the other wave emitted from the other transmitter. In doing so the interference pattern will no longer be observable as the resultant amplitude will no longer fluctuate but instead remain constant. Examiner's Report: Better performing candidates realised that polarisation was the solution; some wanted to polarize one transmitter only. Some candidates suggested that the waves be polarised in different directions.	**B1** **B1**
3	**d**		Essential Question(s) • What constitute to the change in the intensity of the radio wave?	

			➔ A longer distance away from the source will mean a smaller intensity. • What is the relationship between intensity and distance? Let Po and r be the power of the transmitter and the distance from the transmitter respectively. Intensity of radio wave from transmitter A Intensity of radio wave from transmitter B $= \frac{\frac{p_o}{4\pi(AP)^2}}{\frac{p_o}{4\pi(BP)^2}} = \frac{BP^2}{AP^2} = \frac{13^2}{12^2}$ =1.2 (2 s f) *Examiners' Report:* Significant number of students left the answer as 169/144 rather than as a decimal. There was some confusion between A for amplitude and A for area.	**M2** **A1**

4	**(a)**		Essential Question: • How do we represent magnetic field? o Directions with arrow heads o Strengths with how close the lines are o No field lines to cross one another • How do we determine the direction of the magnetic field? o Use Right Hand Grip Rule  • Circular Field Lines • "Clockwise" direction • Spacing between adjacent field lines increases as the distance from the wire increases. [Draw at least 4 field lines to show this increasing trend at least 3 times.] *Examiners' Report:* *A minority of candidates omitted clockwise arrows on their circles. Most indicated a weakening field with radial distance.*	**1** **1**
	(b)		Magnetic flux density at a point from a straight wire,	

			$B = \frac{\mu_0 I}{2\pi r}$ $B = \frac{(4\pi \times 10^{-7})(8.5)}{2\pi(0.19)} = 8.95 \times 10^{-6}\text{T}$ Examiners' Report: Generally, the calculation was well answered. The vast majority made the conversion from cm to m for the distance from the wire. A few incorrectly doubled the distance.	**1** **1**
	(c)	**(i)**	Essential Questions: • How will the needle of a compass align itself in an external magnetic field? • What is causing the needle to deflect by 12˚ when there is a current flowing in the wire? • How to determine the direction of the magnetic field at a point by the long conducting wire? As the compass arrow aligns itself to the direction of the external resultant magnetic field $B_{resultant}$,  B_H is pointing in the direction when there is no current in the wire. Since the compass is placed exactly North of the wire and the direction of the magnetic field due to the wire is a tangent to the circular field lines, B_{wire} points to the right. In (b), $B_{wire} = 8.95 \times 10^{-6}$ T. Therefore, $\tan 12° = \frac{B_{wire}}{B_H}$ $B_H = \frac{B_{wire}}{\tan 12°} = \frac{8.95 \times 10^{-6}}{\tan 12°} = 4.21 \times 10^{-5}\text{T}$ *Examiners' Report:* *This was not well answered. Very few vector diagrams were seen showing the combination of the two fields and the included angle.*	**1** **1**

		(ii)	 **Fig. 4.3a** **Fig. 4.3b** Resultant magnetic flux density equals zero at the location where the flux density due to the Earth's field is equal in magnitude and opposite in direction to the wire's field. Only on the East side of the wire, at distance of 0.895/4.21 x 19 cm = 4.0 cm from wire, will both the above conditions be satisfied. *Further explanation:* Since direction of Earth's field is always towards North, X must be on the East side of the wire where the wire's field is towards South (i.e. opposite of North). Also, at 19cm, from (b) and (c)(i), flux density due to Earth is greater than that due to the wire in magnitude. Since flux density due to the wire is inversely proportional to distance from the wire, and since the Earth's flux density is relatively similar in the same region, X must be closer than 19 cm, at distance of 0.895/4.21 x 19 cm = 4.0 cm from wire. Examiners' Report: This was answered poorly. Many candidates merely said the two fields would cancel out and did not explain how this would occur.	**1** **1**

5	**a**	**i**	Essential Question(s): • Recall the equation for resistance and resistivity of a conductor. ➔ Apply $R = \frac{\rho l}{A}$ • Note that diameter of wire is given and units of diameter is given in "mm". • What is the cross sectional area of the thin copper wire? o Since diameter is given, this implies cross-sectional area is circular, $A = \pi r^2$ Given ρ = 1.7 x 10^{-8} Ω m, l = 96m, d = 0.18 mm = 0.18 x 10^{-3} m $A = \pi r^2 = \pi\left(\frac{d}{2}\right)^2 = \pi\left(\frac{0.18 \times 10^{-3}}{2}\right)^2$ $R = \frac{\rho l}{A}$ $R = \frac{(1.7 \times 10^{-8}) \times 96}{\pi \times \left(\frac{0.18 \times 10^{-3}}{2}\right)^2}$	**1** **1**

			R = 64.1335 Ω R = 64.1 Ω	**1**
		ii	Essential Question(s): • What are the keywords/phrase in the question? ➔ Wire hangs vertically ➔ Stretches slightly under its own weight • Does the stretching affects cross-sectional area of wire? o It is not logical for length of wire to increase uniformly, when stretched, without affecting the cross sectional area. As the wire stretches under its own weight, it length increases and its cross-sectional area decreases. Since $R = \frac{\rho l}{A}$, resistance will increase. Examiner's report: The main error was not to consider the reduction in the cross-sectional area as a result of the stretching.	**1**
		iii	Essential Question(s): • How does the 16 strands of wire being form into a cable? ➔ The 16 strands of wire are in parallel inside the cable. Since the 16 strands of wire are parallel inside the cable, $\frac{1}{R_{eff}} = \frac{1}{R} \times 16$ $R_{eff} = \frac{R}{16} = \frac{64.1335}{16} = 4.0083 = 4.01\ \Omega$	**1**
	b	**i**	Essential Question(s): • Recall equations to calculate power: $P = IV, P = I^2R$ and $P = \frac{V^2}{R}$. Which equation should be used? ➔ Since current is given in the equation and resistance calculated in 5(a)(iii), $P = I^2R$ will be used. Using $P = I^2R$ $P = (2.5)^2 \times 4.0083$ P = 25.052 = 25.01 W	**1** **1**
		ii	• What is the keywords/phrase in the question? o Each strand of wire o The current 2.5 A is current in the cable. Therefore the each strand of wire will be $\frac{2.5}{16}\ A$. • Note that the number density n is given in SI units. No conversion of units is needed. • Recall equation relating current and drift velocity : $I = qnAV_d$ • How many strands of wires are there? Current in each strand is 2.5/16 A Using $I = qnAV_d$	

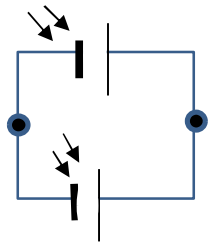
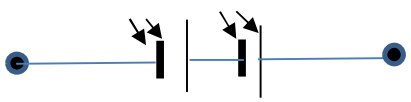
			$\frac{2.5}{16} = (1.6 \times 10^{-19}) \times (8.5 \times 10^{28}) \times \pi \left(\frac{0.18 \times 10^{-3}}{2}\right)^2 V_d$ $V_d = 4.5149 \times 10^{-4} = 4.51 \times 10^{-4}\ m\ s^{-1}$ Examiner's Report: The majority of answers did not consider that the current in each strand is a sixteenth of the total current or that the total area was sixteen times the area of one wire.	**1** **1**

6	**a**		Essential Questions: • Is this related the some of the ideas that what taught in class? ➔ Diffraction grating. • What are the features in diffraction grating that must exist for the graphite film to behave like a grating? Graphite's crystal structure acts like a grating. The diffraction rings are caused by the electrons exhibiting wave-like behavior (wave-particle duality) and thus diffracting as they pass through the regular crystal structure of graphite. Examiner's Comments: The majority of candidates described the diffraction of electrons at the graphite film. Some thought the diffraction occurred at the gap in the anode. The main misconceptions were to consider the rings being due to the production of photons when the electrons collided with the graphite or the emission of photons from the atom's electron energy levels.	**A1**
	b		Essential Qn: • Since applied voltage is increased without change in polarity, what will happen to the momentum of the electrons? • What is the relationship between momentum and wavelength? • How to relate wavelength to angle of diffraction? • How does angle of diffraction affect the physical appearance of the rings? As the p.d is increased, the kinetic energy of the electrons would increase, resulting in the average velocity of the electrons to increase too. This would result in the increase of the momentum of the electrons, ρ and hence from de Broglie equation $\lambda = \frac{h}{\rho}$, the wavelength produced would decrease. Since the wavelength decreases, the angle of diffraction decreases too and hence diameter of a given ring gets smaller. ER The majority stated that the energy of the electrons would increase. Many went on to state that an increase in the energy of the electrons would increase the energy of emitted photons. A small minority considered the effect on the momentum of the electrons.	M1 M1 A1
	c		Essential Qn: • Recall formula $E_k = eV$, and de Broglie equation. • Competent mathematical skills	

			E_k = e V = 1.6 x 10^{-19} x 1.2 x 10^3 = 1.92 x 10^{-16} J ½ mv^2 = eV v = √(2eV/m) = 2.05 x 10^7 m s^{-1} therefore, from de Broglie eqn, $\lambda = \frac{h}{mv}$, λ = 6.63 x 10^{-34} / (1.87 x 10^{-23}) = 3.5 x 10^{-11} m ER This was answered well. Some did not correctly calculate the energy gained by the electron due to the accelerating potential difference. A significant number considered the energy from the accelerating potential difference being converted into the energy of a photon.	C1 C1 M1 A1

				Marks
7	**a**	i	Essential Question(s): • How do you relate "gliding" to any of the info in the question? • What does "vertical drop" mean? What is the difference in the vertical distance between the gliding at night and cruising altitude? Let gliding ratio be R. $R = \frac{d_{horzontal}}{vertical\ drop}$ $d_{horzontal} = R(vertical\ drop)$ = 40×(8500-1500) = 280 000 m Examiner's report: This was generally well answered. A small number ignored the glide ratio and gave the distance as the difference between the cruising altitude and night-time altitude.	**1**
		ii	Essential Question(s): • How to reduce drag force and/or increase lift force experienced by the glider? Design features that enable Solar Impulse 2 to have a large glide ratio: 1. Large wing span (71.9 m) suggests a large wing area → increases Lift 2. Relatively small mass (2300 kg) suggests a small cross-sectional area of its body (called fuselage) → decrease Drag Examiner's report: <u>Better performing candidates were able to link the data of the features given for this aircraft with the features necessary to give a good glide ratio.</u> Many quoted numerical values or interpreted the feature in the opposite way to what is needed. Many answers gave vague descriptions of area.	
		iii	Essential Question(s): • What does constant speed imply about the forces acting in the horizontal and vertical directions? • What does "horizontal flight" imply about the forces acting on the aircraft vertically?	

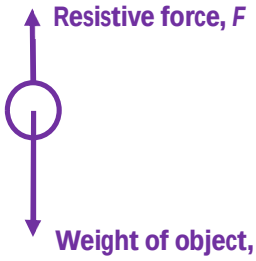
			$\text{glide ratio, } R = \frac{Lift}{Drag\ Force}$ $\text{Drag force} = \frac{Lift}{R}$ In horizontal flight, aircraft is in vertical equilibrium, thus Upward lift on aircraft = Weight of aircraft $\text{Drag force} = \frac{Weight\ of\ aircraft}{R}$ $= \frac{2300 \times 9.81}{40}$ =564 N Examiner's report: Most candidates realised that weight equals lift. A few included the mass of the batteries.	1 1
	b	i	Essential Question(s): • What physical quantities are revealed by the units involved? • What does a battery do? It is the amount of energy stored per unit mass of the battery. Examiner's report: Many responses mixed units with quantities, for example, giving the energy per kg or included a time of one hour by stating energy per unit mass for one hour.	1
		ii	Essential Question(s): • How much is 1 kW h of energy? Since each battery can store 41 kW h of energy, 4 batteries can store $4 \times (41 \times 1000 \times 60^2) = 5.90 \times 10^8$ J OR $633 \times 0.260 \times (1000 \times 60^2) = 5.92 \times 10^8$ J Examiner's report: Some candidates were able to calculate this value. The number of batteries was often omitted, or the conversion from kWh to J was incorrect.	1
		iii	Essential Question(s): • What does constant horizontal velocity suggest about the forces, and about GPE and KE? • How can the energy of the batteries calculated before be used in this part to calculate distance? • How is energy related to force? → through Work Done! Method 1: Constant horizontal velocity → no net force horizontally ➔ Forward driving force = Backward Drag ➔ Work done by driving force = Work done against Drag Since, Energy converted from energy stored in batteries = Work done by driving force Energy converted from energy stored in batteries = Work done against Drag $5.90 \times 10^8 = 564 \times$ horizontal distance moved horizontal distance moved	1

			$= \frac{5.90\times10^{8}}{564}$ $= 1.05\times10^{6}$m Method 2: Constant horizontal velocity → no change in GPE and no change in KE → Energy converted from energy stored in batteries = Work done against Drag 5.90×10^{8} = 564 x horizontal distance moved horizontal distance moved $= \frac{5.90\times10^{8}}{564}$ $= 1.05\times10^{6}$m Examiner's report: Some answers obtained were unrealistic.	1
7	**c**		Essential Question(s): • What factors affect the sunlight reaching the cells? • How does altitude affect these factors? At lower altitude, clouds and air pollutants block the sunlight more so less energy is collected by the cells. Examiner's report: Most candidates neglected to take into account that the energy of light is absorbed as it travels through the atmosphere. Many proposed the idea the aircraft would be nearer the Sun. *[Using the hyperbolic relationship Intensity proportional to distance-squared, very far away from the Sun where the aircraft flying in Earth's atmosphere is, the differences in intensity due to differences in distance from the Sun is less significant.]*	**1**
	d		Essential Question(s): ➔ How to supply energy when there is no sunlight? Some energy collected by the panels must be stored in the batteries for use during the night when there is no sunlight for the cells to generate electrical energy.	**1**
	e		Essential Question(s): ➔ What is the combined e.m.f. and current of cells connected in series and parallel 1. 	**1**
			2. 	**1**

			Examiner's Comments: There were many incomplete symbols and cells short-circuited by a connecting wire or an ammeter. Details were often omitted for the parallel pair.	
	f	**i**	Power is directly proportional to area	**1**
		ii	Power of the sunlight **collected** per unit area by the photovoltaic cells. (= Intensity of the **collected** sunlight) Examiner's report Some candidates did not refer to the collected light or stated that it was the incident light.	**1**
		iii	Intensity = P / A = 73000 / 300 = 243 W m^{-2}	1
	g	**i**	When $\theta = 50°$, M = 1 / cos 50° = 1.556 $k = M^{0.678} = (1.556)^{0.678}$ =1.349 $I_i = 1.353 \times 0.700^{k} = 1.353 \times 0.700^{1.349} = 0.836$	 1
		ii	Ensure that the cross at θ = 50° is not bigger than the smallest square of the grid.	1
		iii	Take note that even though the question states 'best-fit line', a best-fit curve is expected to be drawn. (Smooth curve touching all points) Examiner's comment states that candidates are expected to draw a curve and extend the curve to the final point in the graph grid.	1
		iv	From Fig. 7.4, at θ = 36°, read off the I_i coordinate accurately to half the smallest division. Incident intensity I_i = 0.895 kW m^{-2}	 1
		v	Efficiency = $\frac{I_c}{I_i} x$ 100% Using data for the same location, i.e. Japan, Efficiency = $\frac{243\ W\ m^{-2}}{0.895\ x\ 10^3\ W\ m^{-2}}\ x$ 100% = 27.2 % Examiner's Comment: Candidates are expected to use their own value for the required point above Japan and avoid using a value from the table (the maximum value of 0.947 was common).	1
	h		Any of the two points (refer to given data in the question or earlier calculations): • Passenger aircrafts are rather heavy, and so much more lift needs to be generated. From (g)(v), efficiency of photovoltaic cells is currently very low. Thus more photovoltaic cells / batteries would be needed to provide enough energy. These batteries themselves are heavy and take up a significant percentage of the aircraft's weight, thus limiting the payload of the solar powered aircraft. *(Payload refers to the load carried by a vehicle exclusive of what is necessary for its operation.)* • As photovoltaic cells have relatively low energy density, their mass takes up a large percentage of the aircraft's weight, thus limiting the total mass of passengers that it can carry.	2

			• From paragraph 2, average speed of a solar powered aircraft is estimated to be less than 20 m s^{-1}. This speed is too slow for most passenger flights as it means very long journey times. • Pure solar powered aircraft requires longer wingspan (to accommodate enough photovoltaic cells to capture enough sunlight). However this increases drag as well, lowering energy efficiency and increasing running costs for airline operators. Examiner's Comment: Most candidates wrote about problems that will affect all types of solar aircraft, not simply **passenger** aircraft as specified in the question.	

Paper 3
Section A

				Marks
1	**a**		Essential questions: • When is constant velocity achieved? ➔ Zero acceleration → zero net force • What are the forces acting on the object? What is the free body diagram of the object? • How do these forces vary as the object falls? Initially, the weight of the object is greater than the air resistance acting on the object. The net force downwards causes the object's speed to increase as it falls. Air resistance acting on the object increases as speed increases. **The weight of the object however remains constant.** Since air resistance acts opposite in direction to the weight, the net force downwards decreases. Eventually, air resistance becomes equal in magnitude to the weight, causing net force on the object to be zero. Hence acceleration of the object also becomes zero, leading to constant velocity.	B1 B1 B1
	b	**i**	Consider the free-body diagram of the object:  **Net** downward force on object = mg – F where F = kv By Newton's second law of motion, Net downward force object = mass of object x acceleration of object mg – kv = ma mg – ma = kv m (g – a) = kv g – a = kv / m Examiner's Comments: Candidates are expected to commence their explanations by stating that the resultant force would be equal to *ma*. Candidates must take note that symbols are pre-defined in the question and because this is a show type of question,	B1 M1 A0

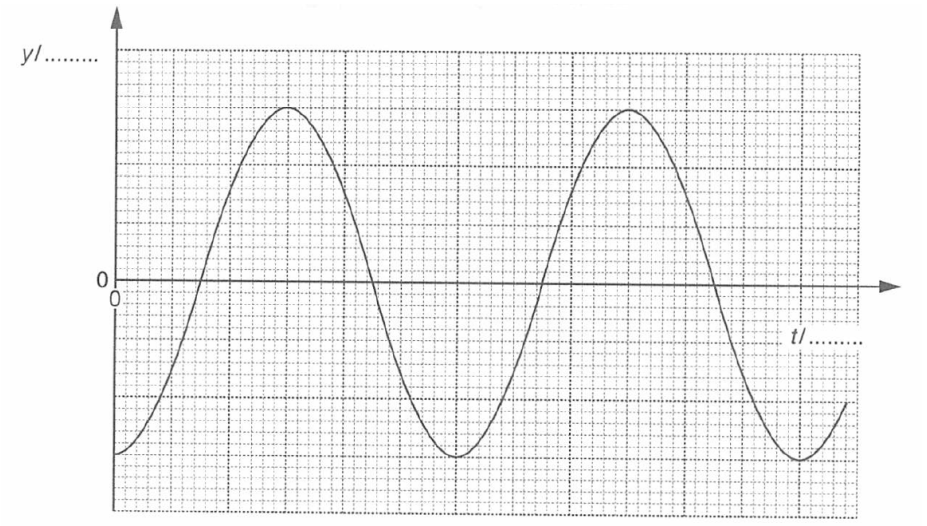
			new symbols used in the solution must be defined. Common mistake was ' F = ma ' since F is already defined in the question as resistive force.	
		ii	Essential points: Acceleration of the object is obtained from the velocity against time graph. At time, t = 0 s, where the velocity is also 0 m s^{-1}, the only vertical force acted on the object is the gravitational force, therefore the acceleration is 9.81 m s^{-2}. The value of (g – a) is 0 m s^{-2} When the velocity is 30 m s^{-1}, acceleration = $\frac{40.0-15.0}{5.30-1.00}$ = 5.8 $m\ s^{-2}$ Accepted range is ± 0.2 m s^{-1} The value of (g – a) is 4.0 m s^{-2} When the velocity is 40 m s^{-1}, the acceleration is zero as the gradient of the v-t graph is zero. Therefore, the (g – a) value is 9.8 m s^{-2} Examiner's Comment: A common error was to attempt to calculate the acceleration at *t* = 0 from the gradient of the graph, rather than realising that the value must be 9.8 m s^{-2}. The acceleration at speed 30 m s^{-1} was usually determined within acceptable limits.	**A1** **A2** **A1**
		iii	Re-arrange the equation from b(i) $$\frac{(g-a)}{v} = constant = \frac{k}{m}$$ For v = 20 m s^{-1}, $$\frac{(g-a)}{v} = \frac{1.6}{20} = 0.080\ s^{-1}$$ For v = 30 m s^{-1}, $$\frac{(g-a)}{v} = \frac{4.0}{30} = 0.13\ s^{-1}$$ Since the values for $\frac{k}{m}$ are not equal, the student's suggestion is not correct.	**M1** **A1**

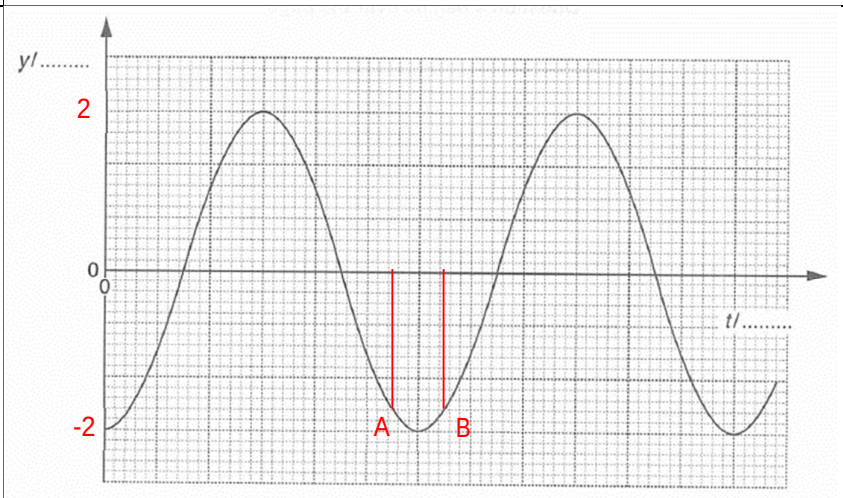
2	**a**	**i**	Essential Question(s): • What was the momentum of the system before collision? No. The total momentum of the system of the two trolleys before collision is non-zero (1.29 kg m s^{-1} to the left). Hence by Principle of Conservation of Momentum, since no net external force acts on the system, there cannot be any instant when both trolleys are stationary as the total momentum will be zero rather than 1.29 kg m s^{-1} to the left.	**B1** **B1**
		ii	Essential Question(s): • How is force linked to momentum? Consider the momentum **change** of trolley A and **taking leftwards to be positive**,	

			$F = \frac{\Delta p}{\Delta t}$ = 1.5 [0.70-(-0.90)] / 0.30 = 8.0 N	**M1** **A1**
	b	**i**	Essential Question(s): • How does trolley B experience a change in speed? By Newton's 3rd Law, the force experience by trolley B is equal and opposite to that of trolley A, - 8.0 x 0.30 = 1.2 (v_B – 2.2) v_B = 0.20 m s^{-1}	**M1** **A1**
		ii	Essential Question(s): • What direction is the force exerted on B? • What direction will B move in after the collision? It is moving to the left since the average force experienced by trolley B is only sufficient to reduce its speed from 2.2 m s^{-1} to 0.20 m s^{-1} as shown in (b)(i) without any change in its initial direction.	**B1**
	c		Essential questions: • When do we use relative speed of approach equals relative speed of separation? ➔ Only for elastic collisions. For a collision to be elastic, the relative speed of approach must be equal to the relative speed of separation. **Take velocity to the left as positive**. Relative speed of **approach** = U_A- U_B = (-0.90) – 2.2 = -3.1 m s^{-1} Relative speed of **separation** = V_B – V_A = 0.20 – 0.70 = -0.5 m s^{-1} Since the relative speed of approach not equal to the relative speed of separation, it is not an elastic collision. *Examiners' reports:* A common error was to give the relative speed of approach as 1.3 m s^{-1}	**M1** **A1**

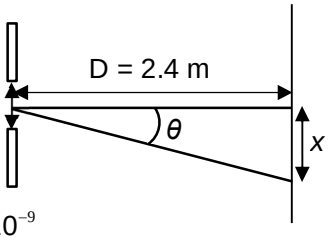
3	**a**		A gravitational field is a region in space where an object with mass experiences a gravitational force. Examiner's Comments: Some candidates' answers simply repeated part of the question. A large number of answers neglected to mention that the force is on a mass. Others confused gravitational field with gravitational field strength.	**1**
	b	**i**	Essential Question: • How is the sun able to travel around in a circular orbit? • What must be presented in this "show" question? The gravitational force acting on the sun, F_G by the galaxy provides for the centripetal force on the sun, F_C. $F_G = F_C$	1

			$\frac{GM_{Sun}M}{r^2} = \frac{M_{Sun}v^2}{r}$ $v = \sqrt{\frac{GM}{r}}$	1
		ii	Essential Question: • How do I make use of the answers in the previous part? From 3bi, $v = \sqrt{\frac{GM}{r}}$ $M = \frac{v^2 r}{G}$ Thus, $\frac{\text{effective mass M at centre of galaxy}}{\text{mass of Sun}} = \frac{\frac{v^2 r}{G}}{M_{Sun}}$ $= \frac{\frac{\left(230\times10^3\right)^2\left(2.4\times10^{20}\right)}{6.67\times10^{-11}}}{2.0\times10^{30}}$ $=9.52\times10^{10}$ Examiner's Comments: The most usual error was omitting to square the speed.	**2** **1**

4	**(a)**		Essential Questions: • What is the questions trying to find out about the student? ➔ Whether student is able to make sense of the amplitude and period information given. Amplitude = 1.5cm Period = 12.0 / 20 = 0.6 s  Fig. 4.2	**B1** **B1**

			Examiners' Report: With few exceptions, the axes were labelled with correct units. It was usual to find that values had not been written on the axes.	
4	**(b)**	**(i)**	Essential Questions: • What equation links displacement to t? For simple harmonic motion, the time taken from +2.0 mm to equilibrium is the same time taken from 0 to -2.0 mm. Therefore, we can Use $x = -x_o \sin\left(\frac{2\pi}{T}t\right)$ to find time taken to move from x=0 to x= -2.0 mm. $-2.0 \times 10^{-3} = -1.5 \times 10^{-2} \sin\left(\frac{2\pi}{12.0 \div 20}t\right)$ $\sin^{-1}\frac{2.0 \times 10^{-3}}{1.5 \times 10^{-2}} = \left(\frac{2\pi}{12.0 \div 20}t\right)$ t = 0.01277s Therefore, the time taken from +2.0 mm to -2.0mm is 2x0.01277 = 0.0255 s Examiners' Report: The majority of candidates used the expression $y = y_0 \cos \omega t$, substituting to obtain the times for displacements of -2.0 mm and +2.0 mm. Some added together the two displacements and then substituted y = 4.0 mm into the expression $y = y_0 \cos \omega t$. Others used the expression $y = y_0 \sin \omega t$. Despite the curve in Fig. 4.2 being that for a cosine. *[→ But in the working above, we are making use of the symmetry of motion about x = 0, so using sine is alright since explanation is also stated in the opening statement.]*	**1** **1** **1**
		(ii)	 Fig. 4.2 A is a point when the cube is at a displacement of x = -1.3 cm and moving downwards, t_A = 0.55 s. B is a point when the cube is at a displacement of x = -1.3 cm and moving upwards, t_B = 0.65 s. $\Delta t = t_B - t_A$ = 0.65 – 0.55 = 0.10 s (estimated) *Examiners' Report:* *Answers varied between 0.02 s and 2.0 s but majority were correct.*	**1**
	(c)		The timing should be made from the zero displacement.	**A0**

			The cube spends a **shorter time near the zero displacement region**. Hence the **uncertainty in timing** from the zero displacement position is **smaller.** Whereas, **for the same distance moved**, the cube **lingers near the maximum displacement region for a longer time**. Thus there is greater uncertainty in determining the exact time it has reached the maximum displacement position. *Examiners' Report:* *Better performing candidates found the calculation provided some theoretical backing for good practice in experimental work.*	**B1** **B1**

5	**a**	**i**	Essential Question(s): • What does width of the central bright fringe mean? • Is there a direct formula from the single slit diffraction equation that can be used to determine this value? ➔ If there isn't how can the equation be manipulated to do so? From the single slit diffraction, $\sin\theta = \frac{\lambda}{b} = \frac{590 \times 10^{-9}}{0.60 \times 10^{-3}}$ b = 0.60 mm  but since θ is small then $\sin\theta = \tan\theta \approx \theta$ $\frac{x}{2.4} = \frac{590 \times 10^{-9}}{0.60 \times 10^{-3}}$ $x = 2.4 \times \frac{590 \times 10^{-9}}{0.60 \times 10^{-3}}$ Therefore width of central bright fringe = 2*x* $= 2 \times 2.4 \times \frac{590 \times 10^{-9}}{0.60 \times 10^{-3}}$ $= 4.72 \times 10^{-3}$ m = 4.72 mm Examiner's Report: A variety of expressions were used to calculate the distance between the centre of the pattern and the first minimum. Candidates who performed less well did not realise that this distance is one half of the width of the central maximum.	**1** **1** **1**
		ii	Essential Question(s): • What is required to be drawn? • What are the critical information for the single slit diffraction pattern? ➔ No choice but to memorise.  	

			Main points to note: 1. Smooth curve with 2 maximas on either side. So 5 maximas in total when central maxima is included. [3 maximas is insufficient to show a 'trend'!] 2. Width of central fringe must be twice that of the other maxima fringes. 3. Maxima intensity must reduce on either side as it gets further from central maxima fringe. (Intensity of central maxima must be shown to be significantly higher than the higher order maxima.) 4. Minimas must touch zero intensity. 5. Take note of the x-axis label. It is not angle but distance from central maxima. 6. Exact values of intensity or horizontal axis labelling with values are not required. Examiner's Report: A minority of drawn curves were good. Many sketches showed only two subsidiary maxima with all fringes of the same width. (Must show at least 5 maximas in total for a 'trend' to be represented.)	**B1** **B1** **B1**
	b	**i**	Essential Question(s): • Definition. ➔ No choice but to memorise. For the two patterns to be (just) distinguishable, the central maximum of one image must lie on the first minimum of the other image. Examiner's Report: Most candidates referred to the patterns being resolved, without giving any explanation as to the meaning of resolution in this context. Candidates who performed less well did not include the words central and/or first in their descriptions. *cannot replace "distinguishable" with "just resolved".	**B1** **B1**
		ii	Essential Question(s): • What is the formula for the Rayleigh Criterion? ➔ If there is how can the equation be manipulated to do so? Applying the Rayleigh Criterion, (when λ<<b) $\theta \approx \frac{\lambda}{b}$ $= \frac{590 \times 10^{-9}}{0.60 \times 10^{-3}}$ $= 9.83 \times 10^{-4}$ rad	**B1** **A1**

			Examiner's Report: Few candidates were unable to quote the expression $\theta \approx \frac{\lambda}{b}$. The most frequent error was to use the screen-slit distance for the value of b.	

6	**a**		Essential Question(s): • What are the key words/info in the question? ➔ Parallel plates → uniform field ➔ Potentials of plates A and B → Direction of electric field is vertically downwards ➔ Alpha-particle → Helium-4 nucleus → charge = + 2e, mass = 4u ➔ GPE is negligible compare to EPE ➔ Alpha-particle initially stationary and in contact with plate B ➔ x is measured from plate B ➔ Hence in considering the motion from x = d/3 to 2d/3, the speed at x = d/3 is NON-zero. • In question (a), what type of energy is gained? What is the energy change taking place as it moves from x = d/3 to 2d/3? ➔ Loses EPE; Gains KE. • What is the command word in the question? ➔ "Show" → define all symbols or short-forms used in derivation clearly; ensure working and reasoning clear to the examiner. Solution: Energy gained = Kinetic energy (KE) gained = Electric potential energy (EPE) lost [by conservation of energy] Magnitude of Electric field strength, E = (potential difference across plates) / d = (750 – 0) / d = 750 / d EPE lost = charge (q) x change in electric potential (ΔV) = (2e) x (Magnitude of E).(displacement moved in the direction of E) = (2e) x (750 / d).(2d / 3 – d / 3) = (2e) x (750 / d).(d / 3) = (2e) x (750 / 3) = 500e which is independent of d (shown). Examiners' Report: Many candidates did not explain the symbols they used. Some candidates demonstrated a loose use of symbols such as E, where E could represent energy or field strength. It was quite usual to find that the energy associated with moving the total distance between the plates was calculated, rather than showing an independence from d.	**1** **1**
	b		By conservation of energy, Gain in KE = Loss in EPE For the motion from x = d / 3 to 2d / 3, ½ m ($v_2^2 - v_1^2$) = 500e → m = 4u, but v_1 and v_2 are unknown. --------(1)	**1**

			**** KE at x = d / 3 and 2d / 3 are unknown while KE at x = 0 is known to be zero.*** For the motion from x = 0 to d / 3, Loss in EPE is also 500e, while gain in KE = ½ m (v_1^2 – 0) = ½ m v_1^2 ➔ ½ m v_1^2 = 500e ➔ ½ (4u) v_1^2 = 500e ➔ v_1^2 = 250e / u = 250 (1.60 x 10^{-19}) / (1.66 x 10^{-27}) = 2.4096 x 10^{10} --- (2) ➔ v_1 = 1.5523 x 10^5 m s^{-1} Sub (2) into (1) to find v_2: ➔ ½ (4u) (v_2^2 – 2.4096 x 10^{10}) = 500e ➔ (v_2^2 – 2.4096 x 10^{10}) = 250e / u ➔ (v_2^2 – 2.4096 x 10^{10}) = 2.4096 x 10^{10} ➔ v_2^2 = 4.8192 x 10^{10} ➔ v_2 = 2.1953 x 10^5 m s^{-1} Change in speed = v_2 – v_1 = (2.1953 – 1.5523) x 10^5 = 6.43 x 10^4 m s^{-1}	**1** **1** **1** **1**

7	**a**		Essential Questions: • What is the difference between uv light and red light? - comparisons to be made between individual photons (UV photons have higher energy/ frequency compared to red light photons) • What is this phenomenon? (photoelectric effect) – to explain conditions to observe phenomenon Note: The phenomenon, which is the photoelectric effect, requires that photons incident on the metal surface have energies that are equal or greater than the work function energy of the metal surface for electrons to be ejected. Solution: Energy per ultraviolet light photon is greater or equal to the work function energy of the zinc plate which is why electrons are ejected from the surface of the zinc plate. Energy per red light photon is less than the work function energy of the zinc plate, therefore no electrons are emitted. *****refer to 'photon', and not simply 'e.m. radiation' and worse still 'e.m. wave'.*** Examiner's Comments: Most candidates wrote about the energy of the incident e.m. radiation without mentioning individual photons. The terminology used was frequently confused. Answers frequently concentrated on one type of radiation with only a passing reference to the other.	**B1** **B1**
	b		Similar question in Nov 2012 / III / 8diii Key Words: • β-particles • X-ray Essential Questions:	

			1) What are β-particles? 2) What happens when β-particles collides with the lead container (which is a metal target)? 3) How are X-ray photons produced? (recall content knowledge on X-ray production) Solution: β-particles are **high speed** electrons Either: These are stopped **suddenly** by the aluminium container. When **charged** particles (electrons in this case) undergo **large acceleration/deceleration**, X-ray photons are produced (Bremsstrahlung radiation). Or: These excite **inner electrons** in the aluminium atoms. When these inner electrons de-excite, X-ray photons are emitted. ****CIE examiners highlighted the importance of words in bold during their visit to Singapore in 2018!*** Examiners' Report: Few candidates identified β-particles as being **fast-moving** electrons. Consequently, very few opted for an explanation where there would be **large** accelerations or decelerations of electrons.	**1** **1** **1** **(1)** **(1)**
	c		Essential Question(s): • A small proportion deflected through angles greater than 90 degree→ What conclusions about the nucleus can we draw from these observations? • Why is there a deflection? • Why only a small proportion deflected by angles greater than 90 degree? Atoms contain a **positively-charged** nucleus and this nucleus is **very small compared to the overall size of the atom**, so only a small proportion of alpha particles approach closely the nucleus. **(electrostatic) repulsion** can give large deflections of angles greater than 90° since alpha particles are also positively-charged. Examiner's Comments: Many answers were based on the atom is mostly empty space or the nucleus is very small. Fewer answers **compared the atom with its nucleus (you need to make that comparison!)**. Where this comparison was made, a minority went on to refer to the proportion of α-particles passing close by the nucleus. Few candidates mentioned electrostatic repulsion.	**B1** **B1** **B1**

Section B

8	**(a)**	**(i)**	The two bodies are at the same temperature. *Examiners' Report:* *With very few exceptions, it was stated that the temperature would be equal.*	**1**
		(ii)	When two bodies are in thermal equilibrium, there are no **net** heat transfer between the two bodies. *Examiners' Report:* *A small number of candidates stated that the bodies would have the same thermal energy. Whilst most did consider no transfer of thermal energy, some omitted to refer to net transfer.*	**1** **1**
	b	**i**	Essential Question(s): • What is thermal equilibrium? There must be a net transfer of thermal energy <u>from the surroundings to the ice</u> to melt the ice. So not in thermal equilibrium. ***Direction of heat transfer must be mentioned for full marks to be awarded.*** *Examiners' Report:* There were some references to energy transfer from the heater to the ice but, in general, this was well answered.	**A1**
		ii	Essential Question(s): • What is the ice in interaction with? What will it gain heat from? Heat lost from the atmosphere + heat lost from heater = heat gained by ice $R\ t + I\ V\ t = m\ L_f$ $R\ (5 \times 60) + 6.3 \times 12.0 \times (5 \times 60) = (114.0 - 32.4) \times 330$ $R = 14.2\ W$ (3 s.f.)	**1** **1** **1**
	c	**i**	Essential Question(s): • What is an ideal gas? • What is the energy associated with an ideal gas? An ideal gas has **no intermolecular forces**, **therefore potential energy between the molecules is 0**. Hence, **internal energy equals to total kinetic energy of the molecules only** and **this kinetic energy is proportional to thermodynamic temperature.** Therefore internal energy is proportional to its thermodynamic temperature. Examiner's Comments: Most candidates included a reference to the potential energy of the molecules being zero; many did not provide any reasoning in support. There was often no reference to the proportionality of kinetic energy to thermodynamic temperature.	**M1** **A1** **B1** **B1**
	c	**ii1**	Essential Questions: • Since gas behaves like an ideal gas, which equations can we use?	

			Initial P/T = 1.0 x 10^5 / (25 + 273.15) = 335.40 Pa K^{-1} Final P/T = 1.5 x 10^5 / (174 + 273.15) = 335.46 Pa K^{-1} Since P/T value is constant and V also constant, hence number of moles of gas is constant, and thus mass of gas is constant.	**M1** **M1** **A1**
		ii2	Essential Questions: • How is the specific heat capacity of the gas determined? Q = m c ΔT 1220 = $\frac{pV}{RT} \times m_R \times c \times \Delta T$ 1220 = $\frac{335.43 \times 2.0 \times 10^{-2}}{8.31} \times 20 \times c \times (174 - 25)$ c = 0.507 J g^{-1} K^{-1}	 **1** **1** **1**
		iii	Essential Question(s): • What are the key words/phrase in the question? o Use first law of thermodynamics. The answers must make reference to this law. o Specific heat capacity. o Larger. There must be comparison made between the two context, constant pressure and constant volume, in the answer. o Heating at constant pressure and heating at constant volume.. • 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 ΔU α ΔT 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). From the first law of thermodynamics, $\Delta U = Q + W$ Therefore, $Q = \Delta U - W$ **Change in internal energy is the same in both processes.** **At constant volume, no work done by gas. But at constant pressure, work is done by gas as it expands / work is done against external pressure.** **Hence additional thermal energy must be supplied.** *Examiner's Report:* *Most candidates stated that, at constant pressure, external work would be done; it was not always made clear that this work would be done by the gas.*	 **B1** **M1** **A1**

9	**a**		Essential Question(s): • What are the key words/phrase in the question? o Heating effect. Recall the definition of root-mean-square value.	

			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 Report:* *The wording in many answers did not make it clear that it is the value of the direct current that is relevant. Many did refer to heating but did not make it clear that it is the rate of heating in a resistor.*	**1** **1**
	b	**i**	Essential Question(s): • What are the key info in the question? o Voltage supply between terminals of heater o The equation V = 240sin337t → V_o = 240 V, ω = 377 rad s^{-1} o Resistance of heater, 38 Ω Using the equation V =240sin377t $\omega = 377$ $2\pi f = 377$ $f = 377/(2\pi) = 60.001 = 60$ Hz	**1** **1**
		ii	Essential Question(s): • Recall power in AC, $\langle P \rangle = I_{rms}V_{rms} = I_{rms}^2 R = \frac{V_{rms}^2}{R}$ • Since V_{rms} is not given, how is V_{rms} related to V_o? o $V_{rms} = \frac{V_o}{\sqrt{2}}$ Using $V_{rms} = \frac{V_o}{\sqrt{2}} = \frac{240}{\sqrt{2}}$ Therefore, power dissipated , $\langle P \rangle = \frac{V_{rms}^2}{R} = \frac{\left(\frac{240}{\sqrt{2}}\right)^2}{38}$ $= 757.89 = 758\ W$	 **1** **1** **1**
9	**c**	**i1.**	Essential Question(s): • What is the definition of Faraday's Law of electromagnetic induction? Faraday's Law of electromagnetic induction states that the magnitude of the electromotive force (e.m.f.) induced in a conductor is <u>proportional</u> to the <u>rate of change of magnetic flux linkage</u> of the conductor Examiner's Comments: Faraday's law was known widely. A minority did not refer to *rate of change*.	 **B1** **B1**
9	**c**	**i2.**	Essential Question(s): ➔ How does an e.m.f. produced in the secondary coil ➔ What is the relation between the e.m.f. induced and the change in the magnetic flux linkage The alternating current in the primary coil varies sinusoidally and it produces a sinusoidal (alternating) magnetic flux density which is linked to the secondary coil through the core.	 **B1** **B1** **B1**

			The magnetic flux linkage of the secondary coil is proportional to the magnetic flux density it experiences and thus varies sinusoidally as well. According to Faraday's law, the e.m.f. induced in the secondary coil is proportional to the rate of change of the magnetic flux linkage of the secondary coil. Hence the e.m.f. in the secondary coil also varies sinusoidally and thus alternating. Examiner's report: Many candidates made a statement that the alternating current causes a changing flux; many candidates did not make any reference to flux changes *in the core*.	**B1**
	c	**ii1.**	Essential Question(s): • What is ideal associate with? ➔ No power loss. An ideal transformer is 100% efficient which imply that there are no power loss due to the transformer which means that the input power (primary side) is equal to the output power (secondary side). Examiner's Comments: Better performing candidates made reference to both input and output power.	**B1**
	c	**ii2**	$N_s / N_p = V_{s,rms} / V_{p,rms}$ $N_s = N_p \times V_{s,rms} / V_{p,rms}$ $N_s = 5000 \times 12 / (240/\sqrt{2})$ = 354	**1** **1**
	c	**iii1**	Essential Question(s): ➔ What factors cause the transformer to be less efficient? ➔ How is the design of the transformer improve efficiency? So that the magnetic fields in the soft iron core can be changed efficiently alternately according to the alternating current in the input with little energy loss due to hysteresis effect. In addition, the soft iron core allows good flux linkage, from the primary coil to the secondary coil, and reduce loss in magnetic flux. Examiner's report Very few candidates not using either r.m.s. or peak values.	**1** **1**
	c	**iii2**	Essential Question(s): ➔ What factors cause the transformer to be less efficient? ➔ How is the design of the transformer improve efficiency? Lamination increases the effective resistance of the core (by limiting the current paths) and reduces the induced current (known as eddy current) in it. As a result the energy loss as heat is reduced. Examiner's report Many answers only stated that the laminations prevent thermal energy loss from the core without stated that the size of eddy currents would be reduced and this would reduce thermal energy losses.	**1** **1**