L-Università ta' Malta

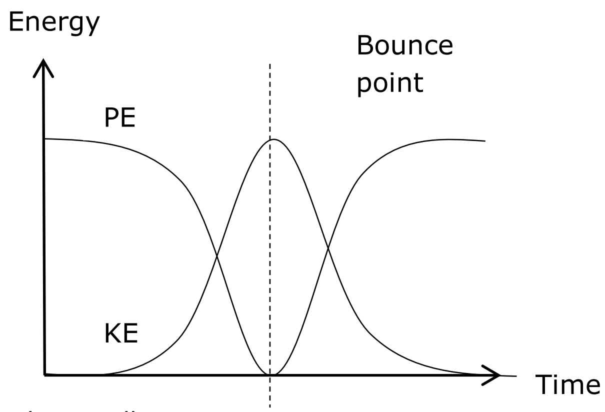
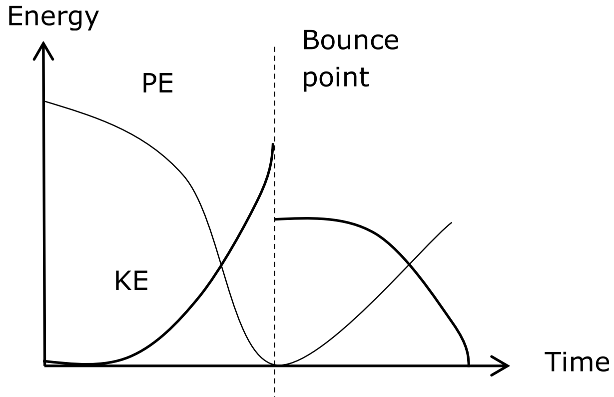
MATSEC
Examinations Board

Marking Scheme

AM Physics

Main Session 2019

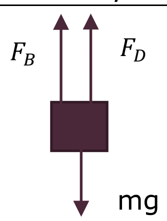
Question				Mark	Additional Guidelines
Paper 1					
Section A					
1	a	i	Units of v: m s^{-1} Units of g: $\mathrm{m\,s^{-2}}$ Units of λ: m	1 1 1	
		ii	If equation is homogeneous units on LHS must be equal to units on RHS. $$m\,s^{-1} = (m\,s^{-2})^p \times m^q$$ By observing the equation p must be equal to $\frac{1}{2}$ and q must also be equal to $\frac{1}{2}$.	1 2	
	b	i	Speed is a scalar which determines the distance travelled per second. Velocity is a vector whose magnitude is the speed but it also describes the direction of this speed.	1 1	
		ii	The wind and water currents must be north westerly. Let v be the combined velocity of wind and current. In the East direction $$v_x = 22\cos 10 - 20 = 1.67\ \mathrm{m\,s^{-1}}$$ In the South Direction $$v_y = 22\sin 10 = 3.82\ \mathrm{m\,s^{-1}}$$ Magnitude of v is $\sqrt{1.67^2 + 3.82^2} = 4.17\ \mathrm{m\,s^{-1}}$ Let θ be the angle this velocity makes with the horizontal $$\tan\theta = \frac{3.82}{1.67} \to \theta = 66.41°$$ $\therefore$ Angle with the Northern direction is $90 + 66.41 = 156.41°$	1 1 1 1	
			Total:	**12**	
2	a		Solving vertically: $v_y^2 = u_y^2 + 2as_y$ At maximum height $v_y = 0\ \mathrm{m\,s^{-1}}$ $0 = u_y^2 - 2g \times 2.4$ $u_y^2 = 4.8g = 47.088$ $u_y = \sqrt{47.088} = 6.86\ \mathrm{m\,s^{-1}}$	1 1 1	
	b		$v_y = u_y + at$ At maximum height $v_y = 0\ \mathrm{m\,s^{-1}}$ $0 = u_y - gt$ $t = \frac{u_y}{g} = \frac{6.86}{9.81} = 0.7\ \mathrm{s}$	1 1 1	
	c		Consider the velocity of the rock has magnitude v and makes an angle θ to the ground. From a): $$v\sin\theta = \sqrt{4.8g}$$ Resolving horizontally, $$v\cos\theta = \frac{d}{t} = \frac{dg}{u}$$ Dividing yields: $$\tan\theta = \sqrt{4.8g}\frac{u}{dg} = \sqrt{4.8g}\frac{\sqrt{4.8g}}{dg} = \frac{4.8}{d}$$	1 1 1	

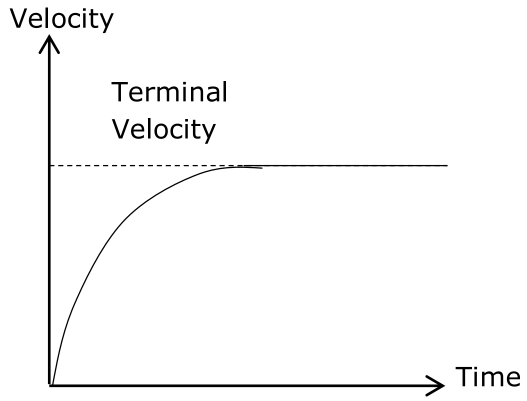
			Using Pythagoras: $$v^2 = 4.8g + \frac{d^2g^2}{u^2}$$ $$v^2 = 4.8g + \frac{d^2g^2}{4.8g}$$ $$v^2 = 4.8g + \frac{d^2g}{4.8}$$	1 1 1	
			Total:	**12**	
3	a		The principle of conservation of energy states that energy cannot be created nor destroyed but it can change from one form to another.	2	
	b		During an elastic collision, all the kinetic energy is conserved whilst in an inelastic collection, some of the kinetic energy is lost to other forms of energy. In this ball example, in an elastic collision, the ball will reach the original drop height whilst in an inelastic collision, the ball will bounce to a smaller height.	2 2	
	c		Elastic collision  Inelastic collision 	3 3	Elastic graph should be symmetrical. 1 mark each for PE and KE, an extra mark to indicate bounce point. For inelastic, same rules apply. A clear drop in KE at bounce point should be evident with PE not reaching a maximum after bounce point to be given full marks. In case these features are not shown, marks should not be awarded.
	d		By conservation of energy: $$\text{Energy at maximum} = \text{Energy at minimum}$$ $$\text{Max PE} = \text{Max KE}$$ $$mgh = \frac{1}{2}mv^2$$ $$v^2 = 2gh$$ $$v = \sqrt{2gh}$$	1 1	
			Total:	**14**	

4	a		Let T_2 be the tension in the lower string. Let θ be the angle between a string and the horizontal (by symmetry/isosceles triangle, this holds for both strings). Resolving vertically: $T_1 \sin\theta = T_2 \sin\theta + mg$ $T_2 = \frac{T_1 \sin\theta - mg}{\sin\theta} = T_1 - \frac{mg}{\sin\theta}$ But $\sin\theta = \frac{d}{2L}$. Hence, $T_2 = T_1 - \frac{2mgL}{d}$	1 2 1 1	
	b		Let r be the radius of rotation and ω the angular speed. Resolving horizontally: $mr\omega^2 = T_1 \cos\theta + T_2 \cos\theta$ $mr\omega^2 = \left(T_1 + T_1 - \frac{2mgL}{d}\right)\cos\theta = 2\left(T_1 - \frac{mgL}{d}\right)\cos\theta$ But $\cos\theta = \frac{r}{L}$. Hence: $mr\omega^2 = 2\left(T - \frac{mgL}{d}\right)\frac{r}{L}$ $\omega = \sqrt{\left(T - \frac{mgL}{d}\right)\frac{2}{mL}}$	1 1 1 1 1	
	c		If d increases, from the angular speed relation in b), $1/d$ increases thus $T - \frac{mgL}{d}$ decreases. Therefore, the angular speed decreases.	1 1	
			Total:	**12**	
5	a		The resultant forces acting on the system is zero; The **total clockwise moment is equal to the total anticlockwise moment** about a pivot point.	1 1	
	b		Let θ be the angle between the cable and the rod and T be the tension in the cable. As the rod is uniform, its centre of mass is at the centre (2.0 m away from hinge) and similarly, the centre of mass of the sign is at the centre (4 m – 0.5 m = 3.5 m away from hinge). By principle of moments: $T \sin\theta \times 4 = m_{\text{rod}}g \times 2.0 + m_{\text{sign}}g \times 3.5$ Now, $\sin\theta = \frac{3}{5} = 0.60$. Thus, $T = \frac{2 \times g \times 2.0 + 20 \times g \times 3.5}{4 \times 0.6} = 302.48\ \text{N}$	1 1 1 1	
	c		Consider a reaction force R making an angle α to the horizontal. Resolving vertically and horizontally yields: $R \sin\alpha + T \sin\theta = m_{\text{rod}}g + m_{\text{sign}}g$ $R \cos\alpha = T \cos\theta$ The angle can be found through: $\tan\alpha = \frac{m_{\text{rod}}g + m_{\text{sign}}g - T \sin\theta}{T \cos\theta}$ $\tan\alpha = 0.142$ $\alpha = 8.08\,°$ Hence, $R = \frac{T\cos\theta}{\cos\alpha} = 244.41\ \text{N}$	1 1 1 1	

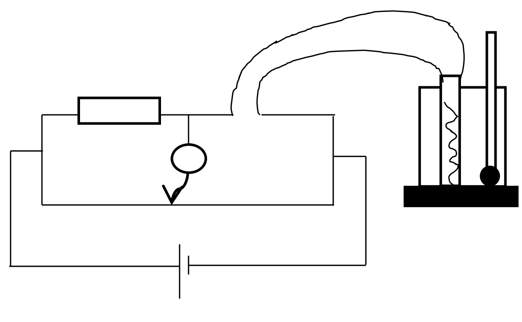
			OR Using Pythagoras, $$R^2 = \left(m_{\text{rod}}g + m_{\text{sign}}g - T\sin\theta\right)^2 + (T\cos\theta)^2$$ Then the angle could be found through: $$\alpha = \arccos\left(\frac{T\cos\theta}{R}\right)$$		
	d		From the principle of moments equation, if the cable is attached closer to the hinge, the tension in the cable has to increase making it more likely to break. Thus, the further away from the hinge is attached, the less likely it will break.	1 1	
			Total:	**12**	
6	a		Work function is the minimum energy required to take a free electron out of a metal against the attractive forces of the surrounding positive ions. Threshold frequency is the minimum frequency required to free the electrons out of a metal (or equivalently, is the minimum frequency required for the photoelectric effect to occur).	2 1	
	b		The photoelectric equation is $$hf = eV_s + hf_0$$ $$\frac{hc}{\lambda} = eV_s + hf_0$$ $$V_s = \frac{hc}{e} \times \frac{1}{\lambda} - \frac{hf_0}{e}$$ This is a straight line equation of the form $Y = MX + C$, with $Y = V_s$, $M = \frac{hc}{e}$, $X = \frac{1}{\lambda}$ and $C = -\frac{hf_0}{e}$. Thus, Planck's constant be found through $h = \frac{eM}{c}$. From the gradient: $$\frac{hc}{e} = \frac{\Delta y}{\Delta x} = \frac{-1.1 - (-0.6)}{(0.0031 - 0.0027) \times 10^9}$$ $$= -1.25 \times 10^{-6}\ \text{V m}^{-1}$$ $$\therefore h = \frac{-1.25 \times 10^{-6} \times -1.6 \times 10^{-19}}{3 \times 10^8}$$ $$= 6.67 \times 10^{-34}\ \text{J s}$$	1 1 1 1 1 1	
	c		When the stopping voltage is zero: $$f = f_0$$ $$f_0 = \frac{c}{\lambda_0} = 3 \times 10^8 \times 0.022 \times 10^9 = 6.66 \times 10^{15}\ \text{Hz}$$	1 1	
	d		For wavelength 312.5 nm, $$\frac{1}{\lambda} = 0.0032\ \text{nm}^{-1}.$$ From the graph, the corresponding stopping voltage is −1.2 V. Using the fact that $$eV_s = \frac{1}{2}mv^2$$ $$v = \sqrt{\frac{2eV_s}{m}} = 6.5 \times 10^5\ \text{m s}^{-1}$$	1 1 1	
			Total:	**14**	

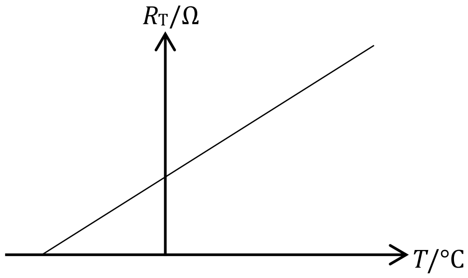
7	a		Kirchhoff's first law states that the sum of currents at a junction point is zero. Kirchhoff's second law states that in a circuit loop, the sum of emfs is equal to the sum of potential differences across the resistances of that loop.	2 2	
	b		The first law is based on the conservation of charge. The second law is based on the conservation of energy.	1 1	
	c		Assume that the 3 A current splits into a current I_1 flowing in the direction of the 3 Ω resistor and current I_2 flowing through the positive side of the unknown emf *E*. Taking the upper loop of the circuit, by Kirchhoff's second law: $12 + 10 = 2 \times 3 + 3I_1$ $I_1 = \frac{16}{3}$ A By Kirchhoff's first law: $3 = I_1 + I_2$ $I_2 = -\frac{7}{3}$ A Thus, direction of current I_2 is reversed. Taking the lower loop of circuit, by second law: $10 + E = 3I_1 + 1\,I_2$ $E = \frac{25}{3}$ V	 1 1 1 1 1	Other loops can be used. Direction of currents could be taken differently as long as the final directions are correct.
	d		$Q = It$ $Q = 3 \times 10 = 30$ C	1	
			Total:	**12**	
8	a		The atomic spectra of different elements are uniquely distinguishable from one another as only specific frequencies are emitted during transitions. In the case of composite objects, various spectral lines are observed which then have to be compared with the spectral lines of the pure elements to determine the composition of the object. For instance, in the case of stars, only a set of spectral lines are visible allowing for the determination of its composition by cataloguing each individual spectral line to those emitted by the elements.	1 2	
	b	i	Ground state is the lowest energy level that an electron can occupy. Excited state is a higher energy level than the ground state. Ionisation energy is the minimal energy required to remove an electron from its energy state to leave the atom, leaving the atom ionised.	1 1 1	
		ii	$E_1 - E_2 = hf$ $-5.5 \text{ eV} - (-10.4 \text{ eV}) = hf$ $4.9 \text{ eV} = hf$ Converting eV to J: $hf = 4.9 \times 1.602 \times 10^{-19} = 7.85 \times 10^{-19}$ J $\therefore f = 1.18 \times 10^{15}$ Hz	1 1 1	

		iii	$c = \lambda f$ $\lambda = \frac{c}{f} = 2.53 \times 10^{-7}$ m	1	
		iv	From de Broglie's formula: $\lambda = \frac{h}{p}$ $p = \frac{h}{\lambda} = 2.62 \times 10^{-27}$ kg m s^{-1} OR Use of momentum relation for photons: $E = pc$, where the energy is obtained from part ii)	1 1	
			Total:	**12**	
			Section B		
9	a	i	For an object submerged in a fluid, the buoyant force F_B is a force which opposes the weight of the object. OR The buoyant force acting on an object submerged in a fluid is the upward force which is equal to the weight of the fluid displaced by the object.	2	
		ii	For the cube to float, $\rho > \rho_f$	1	
		iii	From definition $F_B = mg = Weight\ of\ Liquid\ Displaced$ $F_B = \rho V g$ $F_B = \rho L^3 g$ At equilibrium, the buoyancy is equal to the weight. $Weight\ of\ Block = mg = \rho_f L^3 g$ $Weight\ of\ Liquid\ Displaced = \rho V g$ $\rho_f L^3 g = \rho V g$ $V = \frac{\rho_f L^3}{\rho}$	1 1 1 1 1	
	b	i	Terminal velocity	1	
		ii		3	1 mark for each correct force drawn
		iii	Initially, the drag force is zero as the object is at rest. Since the object is sinking, the weight of the cube is greater than the buoyancy force. By Newton's second law, this results into a downward acceleration. As the object starts to sink, the drag force increases since the velocity of the cube increases. By Newton's second law, the acceleration decreases as given by $F_D + F_B - mg = ma$,	2 2	

			where *a* is the acceleration of the cube. As the velocity continues to increase, the drag force continues to increase until the force is large enough to achieve the condition $$F_D + F_B = mg$$ This nets zero acceleration and the velocity becomes constant. By Newton's first law, this object will continue to sick at constant velocity unless external forces act on it.	2	
		iv	 	3	
		v	As shown in e), the condition for terminal velocity is $$F_D + F_B = mg$$ $$\frac{1}{2}\rho A v^2 C_D + \rho L^3 g = \rho_M L^3 g$$ $$v^2 = \frac{2gL^3(\rho_M - \rho)}{\rho A C_D}$$ Now, the area in direction of flow is the square base of the cube i.e. $A = L^2$. Thus: $$v^2 = \frac{2gL^3(\rho_M - \rho)}{\rho L^2 C_D} \rightarrow v = \sqrt{\frac{2gL(\rho_M - \rho)}{\rho C_D}}$$	1 1 2	
			Total:	**25**	
10	a	i	Total emf for a row = 10*n* V (emf in series are additive) Total emf of battery is = 10*n* V (emf in parallel is equal) Row resistance = *n* Ω (resistor in series is additive) Total resistance of battery $$\frac{1}{R} = \frac{1}{n} + \frac{1}{n} + \frac{1}{n} \rightarrow R = \frac{n}{3}$$ Therefore, current through external resistor is $$10n = I\left(5 + \frac{n}{3}\right)$$ $$I = \frac{30n}{15 + n}$$	1 1 1 1 1 1	
		ii	Voltage across resistor: $$V = IR = \frac{30n}{15 + n} \times 5 = \frac{150n}{15 + n}$$ For voltage across each internal resistance, voltage across resistor is the voltage across the battery. Across each row, this voltage remains the same.	1 1	

			Current through each row is 1/3 current through external resistor $$I = \frac{1}{3}\left(\frac{30n}{15+n}\right)$$ Voltage acroos each internal resistance is $$V = IR = \frac{1}{3}\left(\frac{30n}{15+n}\right) \times 1 = \left(\frac{10n}{15+n}\right)$$	1 1	
	b	i	P and Q open, open circuit hence 0 V.	1	
		ii	P closed and Q open $$\varepsilon = I(R + 0.5R)$$ $$\varepsilon = 1.5IR$$ Voltage is $V = IR = \frac{\varepsilon R}{1.5R} = \frac{2\varepsilon}{3} = 8\text{ V}$	1 1	
		iii	P open and Q closed $$\varepsilon = I(R + 3R) = 4IR$$ Voltage is $V = IR = \frac{\varepsilon}{4} = 3\text{ V}$	1 1	
		iv	P and Q closed $$\varepsilon = I\left(R + \frac{1}{\frac{1}{0.5R} + \frac{1}{3R}}\right) = IR\left(1 + \frac{3}{7}\right) = \frac{10IR}{7}$$ Voltage is $V = \frac{7\varepsilon}{10} = 8.4\text{ V}$	2 1	
		v	1. P and Q open 2. P is open, Q is closed 3. P and Q closed 4. P closed and Q open 5. P and Q open	1 1 1 1 1	.
		vi	$$\varepsilon = IR = \frac{QR}{t}$$ $$Q = \frac{Vt}{R}$$ Thus, the charge can be determined by taking the **area under the graph** and then **dividing by *R***.	1 1	
			Total:	**25**	
11	a	i	C to B Since at $t = 0$ s tension in the string as sphere moves from C to B starts to increase. It will reach maximum at B. Otherwise from B to A graph for tension should start from a maximum and then decrease.	1 1 1 1	
		ii	At P Splitting the weight of the sphere in to components parallel to the tension in the string and perpendicular to it we get. $$T - mg\cos(90-\theta) = mr\omega^2$$ $$T = mr\omega^2 + mg\sin\theta$$	1 2 1	
		iii	At points A or C the tension is independent of the weight. Tension at one of these points is equal to $mr\omega^2 = 5\text{ N}$. At point B, tension is maximum and given by $$T_{\max} = mr\omega^2 + mg$$ $$7 = 5 + mg$$ $$mg = 2$$ $$m = \frac{2}{9.81} = 0.204\text{ kg}$$	2 1 1	

		iv	Time for one revolution is time between two peaks, or two through or time taken to return to its original position. From graph it is approximately 1.2 s. Frequency is $$f = \frac{1}{T} = 0.8\ \text{Hz}$$	1 1	
		v	$\omega = 2\pi f = 5.2\ \text{rad s}^{-1}$	2	
		vi	From ii), taking at maximum for example: $7 + 0.2 \times 9.81 = 0.2r\omega^2 = 0.2 \times 5.2^2 r$ $r = 1.7\ \text{m}$	2 1	
	b		Let T be the tension in the cable and let m be the mass of a person sitting on the chair. Resolving vertically and horizontally: $T\cos 50 = mg$ $T\sin 50 = \frac{mv^2}{r}$ Dividing the relations: $\tan 50 = \frac{v^2}{rg} = \frac{r\omega^2}{g} \rightarrow r = \frac{g\tan 50}{\omega^2}$ Now, $r = L + 4\sin 50$. Therefore: $r = \frac{g\tan 50}{1.5^2} = L + 4\sin 50$ $L = 2.1\ \text{m}$	1 1 1 1 1 1	
			Total:	**25**	
12	a	i	The temperature coefficient of resistance is a constant which determines the change in resistance of a material per degree Celsius/Kelvin change in temperature. When it is positive, the resistance increases with temperature and resistance decreases when it is negative.	2 1	
		ii	Apparatus: Material under testing, beaker, thermometer, hot plate, a 1 m long wire used as a metre bridge, metre ruler, a known resistor, jockey and a galvanometer, leads, stirrer, water, cell and connecting wires. Diagram:  Procedure: i. Set up the experiment as shown in the diagram. ii. Switch on the burner and heat the mixture until it reaches a specific temperature say 20 °C.	2 2 2	A mark for every half of the components mentioned. Connecting wires, water and cell can be left out. Diagram should be properly labelled. One mark for general idea of what measurements to take, another mark for the full process.

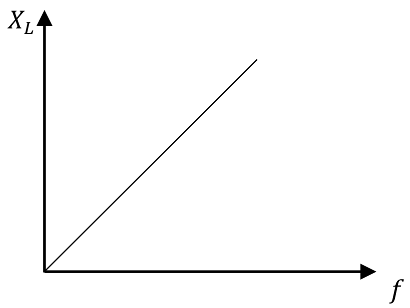
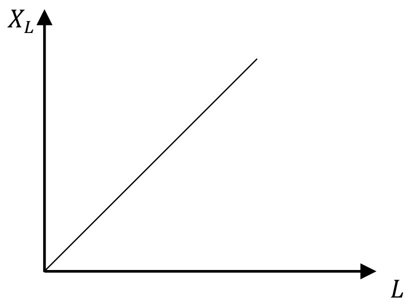
			iii. For this temperature, determine the length *l* of the wire when the galvanometer gives zero deflection and obtain the value of resistance of the material under testing. iv. Repeat process for various temperatures. Table of results: *l*/m *T*/°C R_T/Ω	2	
			Graph:  	2	The graph does not need to be extrapolated towards *x*-axis.
			From definition of temperature coefficient: $$R_T = R_0[1+\alpha(T-T_0)]$$ Plotting R_T against *T* and taking R_0 to be the resistance at T_0 = 0 °C, α can be obtained either from the gradient with R_0 obtained from the intercept or by extrapolating the graph to the value of the *x*-intercept.	2	One method to determine α is sufficient for marks.
	b	i	Component P is the LDR and component Q is the thermistor.	1	Award 1 mark if both are correct.
		ii	Initially, the switch S is open. The voltage across the LDR is $$V_L = IR_L$$ where *I* is the current. The voltage across the thermistor is $$V_T = I\left(\frac{1}{\frac{1}{R_0}+\frac{1}{R_1}}\right) = \frac{IR_1R_0}{R_1+R_0}$$ As the currents are equal $$\frac{V_L}{V_T} = R_L\left(\frac{1}{R_0}+\frac{1}{R_1}\right)$$	1 1 1	
		iii	• When LDR is covered, the resistance increases (less light) and hence the ratio increases. • When temperature increases, the thermistor resistance decreases (negative coefficient) and hence the ratio increases.	1 1 1	
		iv	When S is closed, a current also flows in R_2. If the ammeter does not read any current, this is a balancing of potentials. This is a Wheatstone bridge arrangement and hence the following condition holds: $$\frac{R_L}{R_2} = \frac{R_T}{R_1} \to R_T = \frac{R_1R_L}{R_2}$$ where R_T is the resistance of the thermistor.	1 2	One mark for balancing condition, one mark for final resistance result.
			Total:	**25**	

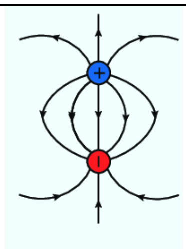
13	a		When a substance is 'elastic', any applied force/stress will result in a temporary deformation of the substance in size or shape.	2	
	b	i	Tensile stress is defined as the tensile force per unit cross-sectional area. Tensile strain is defined as the ratio of the extension per unit length of wire. Stress strain curves are intrinsic property of material and it will be same for all specimen sizes. The force extension curve will be specimen dependent and thus it will not be a true representation of material property.	1 1 2	
		ii	Q For the same force wire Q extends more than wire P. Since cross-sectional area is inversely proportional to the extension, the larger the extension the smaller the cross-sectional area.	1 2	
		iii	The additional measurements that would be needed are the cross-sectional area A and the original length of the wire. Using the equation $Y=\frac{\sigma}{\varepsilon}=\frac{F}{A}\times\frac{l_0}{\Delta l}$ Would give the Young modulus of copper.	2 1	
		iv	The area under the force-extension graph is equal to the work done in stretching the wire. Area $=\frac{1}{2}F\Delta x=\frac{1}{2}k\Delta x^2$	2 1	
	c	i	$Y=\frac{\sigma}{\varepsilon}=\frac{F}{A}\times\frac{l_0}{\Delta l}$ $\Delta l=\frac{Fl_0}{AY}=\frac{750\times 9.81\times 25}{4.00\times 10^{-4}\times 20\times 10^{10}}=0.0023\text{ m}$	1 2	
		ii	$T-mg=ma$ $T=mg+ma=750\times 9.81+750\times 3=9607.5\text{ N}$ $\Delta l=\frac{Fl_0}{AY}=\frac{9607.5\times 25}{4.00\times 10^{-4}\times 20\times 10^{10}}=0.003\text{ m}$ Additional extension $0.003-0.0023=0.0007\text{ m}$	1 1 1 1	
		iii	$\sigma=\frac{F}{A}\rightarrow\sigma A=F=2.2\times 10^{8}\times 4\times 10^{-4}=88000\text{ N}$ $88000=m(g+a)\rightarrow m=6869.63\text{ kg}$	2 1	
			Total:	**25**	
14	a	i	Although the tube is not incident to the incoming radiation, a non-zero count is observed due to surrounding and external sources, which could be cosmological (e.g. cosmic background radiation) or terrestrial (e.g. atmospheric, radioactive elements in the earth, etc.).	2	
		ii	This is the inverse square law property of γ radiation. For this type of radiation, as soon as it leaves the source, the radiation starts to open up spherically causing the intensity to decrease inversely with the square of the distance.	1 2	
		iii	This will <u>not hold</u> as most of the incident radiation would be absorbed in the surrounding air.	1 1	

		iv	By inverse square law: $$\frac{C_1}{C_2}=\frac{r_2^2}{r_1^2}$$ $$C_1=1500\times\frac{0.2^2}{0.5^2}=240\ \mathrm{s}^{-1}$$	1 2	
	b	i	By definition of absorption coefficient: $$C=C_0e^{-\mu d}$$ From iv), the incident count rate is 240 s^{-1}. Hence: $$226=240\ e^{-\mu\times4\times10^{-3}}$$ $$\mu=-\frac{1}{4\times10^{-3}}\ln\frac{226}{240}=15\ \mathrm{m}^{-1}$$	1 1 1	
		ii	Half-value thickness is the required thickness for the incident intensity to be reduced to half of its original value. This is related to the absorption through $$d_{\frac{1}{2}}=\frac{\ln 2}{\mu}=0.046\ \mathrm{m}$$	1 2	One mark for relation, one mark for correct answer.
	c	i	Decay constant is a constant which determines the rate of decay of a radioactive material to its population at a given time. Time constant is the time required for the population of a given radioactive material to reduce to half its original value. The quantities are related by $$t_{\frac{1}{2}}=\frac{\ln 2}{\lambda}$$	1 1 2	
		ii	The rate of disintegration is related by $$A=\frac{dN}{dt}=\lambda N$$ Therefore, we have $$\frac{dN_{\mathrm{old}}}{dt}=\lambda N_{\mathrm{old}},\qquad \frac{dN_{\mathrm{living}}}{dt}=\lambda N_{\mathrm{living}}$$ Thus, we have $$N_{\mathrm{old}}=N_{\mathrm{living}}e^{-\lambda t}$$ $$\frac{1}{\lambda}\frac{dN_{\mathrm{old}}}{dt}=\frac{1}{\lambda}\frac{dN_{\mathrm{living}}}{dt}\ e^{-\lambda t}$$ $$\frac{dN_{\mathrm{old}}}{dt}=\frac{dN_{\mathrm{living}}}{dt}\ e^{-\lambda t}$$ $$t=-\frac{1}{\lambda}\ln\frac{\frac{dN_{\mathrm{old}}}{dt}}{\frac{dN_{\mathrm{living}}}{dt}}=-\frac{t_{\frac{1}{2}}}{\ln 2}\ln\frac{\frac{dN_{\mathrm{old}}}{dt}}{\frac{dN_{\mathrm{living}}}{dt}}$$ $$=-\frac{5700}{\ln 2}\ln\frac{6}{15}=7535\ \mathrm{yr}$$	1 1 1 1 1	
			Total:	**25**	

15	a		The moment of inertia of a body is the degree of reluctance of the body to change its rotational motion.	2	
	b		The principle of conservation of angular momentum states that the total angular momentum of a system is conserved as long as **no external forces** act on the system.	2	No marks to be awarded if no external forces is not included.
	c	i	By principle of conservation of energy: $\text{Energy at bottom} = \text{Energy at top}$ $\frac{1}{2}mv_b^2 + \frac{1}{2}I\omega^2 = mgh + \frac{1}{2}mv_t{}^2 + \frac{1}{2}I\omega_t{}^2$ $\frac{1}{2}mv_b^2 + \frac{1}{2}\left(\frac{2}{5}mr^2\omega_b^2\right) = mgh + \frac{1}{2}mv_t{}^2 + \frac{1}{2}\frac{2}{5}mr^2\omega_t{}^2$ $\frac{1}{2}mv_b^2 + \frac{1}{5}mv_b^2 = mgh + \frac{1}{2}mv_t{}^2 + \frac{1}{5}mv_t{}^2$ $\frac{7}{10}v_b^2 = gh + \frac{7}{10}v_t{}^2$ $v_t{}^2 = v_b^2 - \frac{10gh}{7} = v_b^2 - \frac{10 \times 9.81 \times 2}{7} = v_b^2 - 28$	3 1 1	One mark for KE, one for PE and one for Rot KE.
		ii	Time taken for fall: $s_y = u_y t + \frac{1}{2}at^2$ $s_y = \frac{1}{2}at^2$ (since no vertical velocity) $t = \sqrt{\frac{2s}{a}} = \sqrt{\frac{2s}{g}} = \sqrt{2 \times \frac{0.75}{9.81}} = 0.4\ \text{s}$	1 1	
		iii	To obtain the velocity on top of track: $v = \frac{d}{t} = \frac{4}{0.4} = 10\ \text{m s}^{-1}$	2	
		iv	From i) $v_t{}^2 = v_b^2 - 28 = 100 - 28 = 74$ $v = 8.6\ \text{m s}^{-1}$	1 1	
	d	i	$I = mr^2 + mr^2 = 2mr^2$ $I = 2 \times 60 \times 0.6^2 = 43.2\ \text{kg m}^2$	1 1	
		ii	Kinetic energy is $\text{KE} = \frac{1}{2}I\omega^2 = \frac{1}{2}I\frac{v^4}{r^2} = \frac{1}{2} \times 43.2 \times \frac{2^4}{0.6^2} = 960\text{J}$	2	One for formula, one for result
		iii	By conservation of angular momentum: $I_1\omega_1 = I_2\omega_2$ New inertia is $I_2 = 60 \times 0.4^2 + 60 \times 0.4^2 = 19.2\ \text{kg m}^2$ Thus $\omega_2 = \frac{I_1\omega_1}{I_2} = 25\ \text{rad s}^{-1}$ New kinetic energy is $\text{KE} = \frac{1}{2}I\omega^2 = 6000\ \text{J}$	1 1 1 1	
		iv	The kinetic energy is greater since the skaters have to do work in bringing themselves closer to fight against the centripetal force which is keeping them apart.	2	
			Total:	**25**	

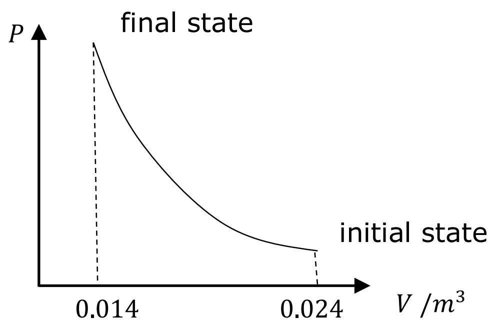
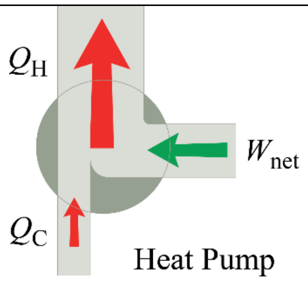
Paper 2

Question				Mark	Additional Guidelines
Section A					
1	a		The statement means that after long enough time the two objects A and B which are not in thermal equilibrium reach thermal equilibrium and this is achieved when no heat flows between the two objects.	2	
	b		The statement in (a) can be used to measure temperature. This is the basis of the zeroth law of thermodynamics. If Object A is in thermal equilibrium with object B and object B is in thermal equilibrium with object C then object A and Object C have the same temperature.	1 1	
	c		A good thermometric property of matter should vary: • continuously with temperature • uniquely over the range of temperature to be measured • its variation should be measurable.	 1 1 1	
	d	i	$P = \rho g h = 13600 \times 9.81 \times 0.31 = 41358.96 \text{ Pa}$	2	
		ii	$T = \frac{P}{P_{triple}} \times 273.16$ $T = \frac{0.405}{0.310} \times 273.16 = 356.87 \text{ K}$ $\theta = 356.87 - 273.16 = 83.71°\text{C}$	1 1 1	
		iii	This may be due to the fact that the variation of gas pressure with temperature at constant volume is different from the variation of the expansion of liquid with temperature.	2	
			Total:	**14**	
2	a		The root mean square value of an alternating current is defined as that value of steady current which would dissipate heat at the same rate in a given resistance.	1 1	
	b	i	The peak value of the current is 0.05 A	1	
		ii	$I_{rms} = \frac{I_0}{\sqrt{2}} = \frac{0.05}{\sqrt{2}} = 0.035 \text{ A}$	2	
		iii	 	2 2	

		iv	$2\pi f t = 280000\pi t$ $X_L = 2\pi f L = 280000\pi \times 0.11 \times 10^{-3} = 96.76\ \Omega$	1 1	
		v	$V_{rms} = I_{rms} X_L$ $V_{rms} = 0.035 \times 96.76 = 3.39\ \text{V}$ $V_{peak} = 3.39 \times \sqrt{2} = 4.79\ \text{V}$	1 1 1	
			Total:	**14**	
3	a		Specific heat capacity of a substance is the heat required to raise the temperature of 1 kg of it through 1 degree. Specific latent heat of fusion is the heat required to convert unit mass of it, at its melting-point, into liquid at the same temperature.	2 2	
	b	i	$Heat\ Lost\ by\ metal\ pieces = Heat\ Gained$ $0.05 \times 387 \times (80 - 20) + 0.07 \times c_{unknown} \times (100 - 20) =$ $0.25 \times 4.19 \times 10^3 \times (20 - 10) + 0.10 \times 900 \times (20 - 10)$ $1161 + 5.6 c_{unknwon} = 10475 + 900$ $c_{unknown} = 1823.93\ \text{J kg}^{-1}\ \text{K}^{-1}$	1 1 1 1 1	
		ii	It might be beryllium. The material might be an unknown alloy or a material not listed in the table that has the same specific heat capacity.	1 1 1	
			Total:	**12**	
4	a		The strength of an electric field at any point is defined as the force per unit charge which it exerts at that point.	1	
	b			2	
	c		$E_{total} = E_A + E_B$ $E_{total} = \frac{q_A}{4\pi\varepsilon_0 r^2} + \frac{q_B}{4\pi\varepsilon_0 r^2}$ $E_{total} = \frac{(0.80 - 0.60) \times 10^{-6}}{4\pi\varepsilon_0 \times 0.04^2} = 1.124 \times 10^6\ \text{N C}^{-1}$	1 2	
	d	i	$F_{BA} = \frac{q_B q_A}{4\pi\varepsilon_0 r_{AB}^2} = 0.674\ \text{N}$ $F_{BC} = \frac{q_B q_C}{4\pi\varepsilon_0 r_{BC}^2} = 1.499\ \text{N}$ Resultant force= $1.644\ \text{N}$	1 1 2	
		ii	$\tan\theta = \frac{0.674}{1.499} \rightarrow \theta = 24.2°$	2	
			Total:	**12**	

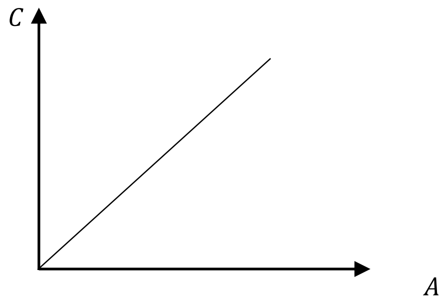
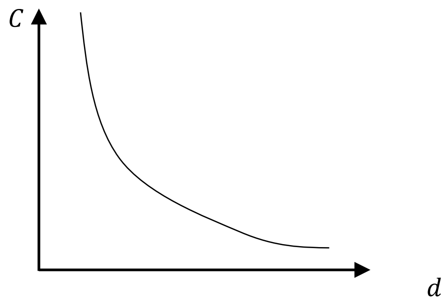
5	a		Simple harmonic motion is the motion of an object whose acceleration is always directed towards a fixed point; and is also directly proportional to its distance from that point.	1 1	
	b		Let the extension be e when sphere is placed on spring. In equilibrium $mg = ke$ When sphere is pulled down, the tension in the string is $T = k(e+x)$ where x is the extension in the spring. Resultant force downwards is $F = mg - k(e+x)$ But $mg = ke$ $F = -kx$ $\therefore ma = -kx$ $a = -\frac{k}{m}x = -\omega^2 x$ $T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{k}}$ The acceleration is directly proportional to the distance from equilibrium position and is directed towards a fixed point. The system therefore performs SHM.	1 1 1 1 1	
	c	i	$0.04\ \mathrm{m}$	1	
		ii	$2\pi f t = 0.7t$ $\frac{2\pi}{T} = 0.7 \rightarrow T = 8.98\ \mathrm{s}$	1 1	
		iii	$y = 0.04\sin(0.7\,t + 2.245)$	2	
			Total:	**12**	
6	a		Snell's law states that the ratio of the sines of the angles of incidence and refraction is equivalent to the ratio of phase velocities in the two media, or equivalent to the reciprocal of the ratio of the indices of refraction: $\frac{\sin\theta_2}{\sin\theta_1} = \frac{v_2}{v_1} = \frac{n_2}{n_1}$	2	
	b		• The index of refraction must decrease across the boundary in the direction of light refraction. • The angle of incidence of the light ray must exceed the critical angle of the interface.	1 1	
	c	i	$\frac{\lambda_1}{\lambda_2} = \frac{n_2}{n_1} = 1.5 \rightarrow \lambda_2 = \frac{590\ \mathrm{nm}}{1.5} = 393.33\ \mathrm{nm}$	2	
		ii	Angle of incidence$= 90 - 75 = 15°$ $\frac{n_1}{n_2} = \frac{\sin\theta_1}{\sin\theta_2} \rightarrow r = 9.94°$ Angle refracted ray makes with horizontal inside prism $= 90 - 75 - 9.94 = 5.06°$ Angle refracted ray makes with normal at second boundary $= 90 - (180 - 5.06 - 105) = 20.06°$ $\frac{n_1}{n_2} = \frac{\sin\theta_1}{\sin\theta_2} = \frac{1}{1.5} = \frac{\sin 20.06}{\sin\theta_1} = 30.96°$ Angle between extended emergent ray and internal refracted ray $= 30.96 - 20.06 = 10.9°$ $180 - 5.06 - 10.9 = 164.04°$ $\delta = 180 - 164.04 = 15.96°$	1 1 1 1 1 1	
			Total:	**12**	

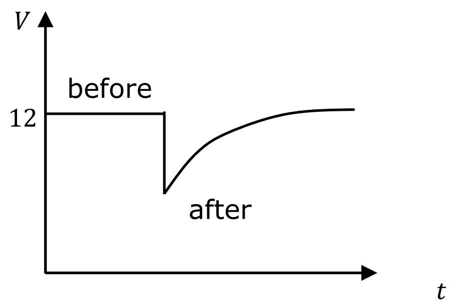
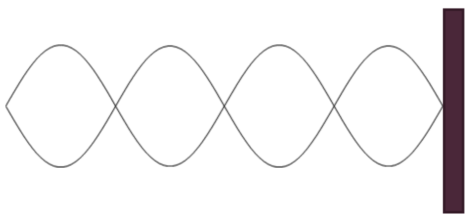
7	a		Galaxies are receding from Earth at a velocity which is proportional to their distance from Earth. The greater the distance, the greater is their velocity. It also implies that the universe is expanding. $$d = \frac{v}{H}$$	2 1	
	b	i	It is assumed that v and D were proportional throughout the history of the Universe when this may not always be the case.	1 1	
		ii	(A) According to Hubble, $t = \frac{1}{16 \times 10^{-18}}\,\text{s} = 2.0$ billion years. (B) According to the modern value of H_o, $t = \frac{1}{2.184\times10^{-18}}\,\text{s} = 14.5$ billion years.	2 2	
	c	i	Light from stars which are travelling away from us is red shifted, while light from stars travelling away from us is blue shifted. The magnitude of the red shift is a measure of the velocity of the source of light. Measurement of galactic red shift shows that the velocity of galaxies due to Universal expansion is proportional to their distance from us.	1 1	
		Ii	The Cosmic Microwave Background radiation which permeates the whole of space which can be explained by assuming that the burst of short wavelength radiation produced by the Big Bang is another piece of evidence that backs the Big Bang theory.	1	
			Total:	**12**	
8	a		For heat to flow there must be a temperature difference between the hot object and its surroundings.	1	
	b		Foam contains pockets of air. Since air is a good insulator, this makes the substance a good insulator.	2	
	c		$$\frac{dQ}{dt} = -kA\left(\frac{d\theta}{dx}\right)$$ Since the rate of flow of heat across both materials must be equal $$-0.022A \times \frac{20-\theta}{dx} = -0.13A \times \frac{\theta - 0}{dx}$$ $$0.169(20-\theta) = \theta \rightarrow \theta = 2.89°\text{C}$$	1 1 2	
	d		$$\frac{dQ}{dt} = -kA\left(\frac{d\theta}{dx}\right)$$ Since the rate of flow of heat across both materials must be equal $$-0.13A \times \frac{20-\theta}{dx} = -0.022A \times \frac{\theta - 0}{dx}$$ $$5.91(20-\theta) = \theta \rightarrow \theta = 17.10°\text{C}$$	1 1 2	
	e		No it does not matter. Rate of heat flow through both materials placed either way is the same.	1	
			Total:	**12**	

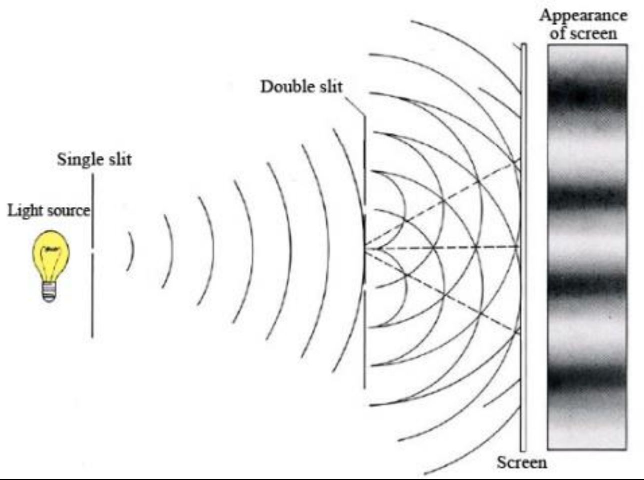
Section B					
9	a	i	Work is being done on the coffee. Since coffee is contained in a vacuum flask, the flask reduces the amount of heat that is transferred from the coffee. The work done increases the internal energy of the coffee and hence its temperature.	2	
		ii	A temperature increase is a direct consequence of an increase in internal energy. This means that internal energy increased as well.	1	
	b		First Law of Thermodynamics $\Delta U = \Delta Q + \Delta W$ Where ΔU is the change in internal energy ΔQ is the transfer of heat to or from the system and ΔW is the work done by or on the system.	1 1 1 1	
	c	i		4	
		ii	Area to be shaded is the area under the graph bounded by the x-axis.	2	
		iii	$\Delta U = \Delta Q + \Delta W$ Since the temperature did not change along the isotherm $\Delta U = 0$ $0 = \Delta Q + 5000\ \mathrm{J}$ $\Delta Q = -5000\ \mathrm{J}$ ∴ 5000 J of heat flow from the container to the reservoir since the container must lose 5000 J of heat.	1 1 1	
		iv	$PV = nRT$ $3 \times 1.01 \times 10^5 \times 0.024 = n \times 8.31 \times 300$ $n = 2.81\ moles$	1 1	
		v	$P_1V_1 = P_2V_2$ $3 \times 1.01 \times 10^5 \times \frac{0.024}{0.014} = 5.19 \times 105\ \mathrm{Pa}$	1 1	
	d		 The second law of thermodynamics says that heat cannot spontaneously flow from a colder body to a hotter body; but heat pumps can make that happen. In a heat pump, heat flows from cold to hot, with work as the input.	2	

	e		$\eta = 1 - \frac{T_C}{T_H} = 1 - \frac{27 + 273.16}{127 + 273.16} = 0.25 = \frac{W}{Q_H}$ $Q_H = \frac{6.2 \times 10^3}{0.25} = 24800\ \text{J}$ $Q_C = Q_H - W = 24800 - 6200 = 18600\ \text{J}$	1 1 1	
			Total:	**25**	
10	a	i	Student will observe the random motion of particles suspended in a fluid.	2	
		ii	The random motion of particles suspended in a fluid (a liquid or a gas) result from their collision with the fast-moving molecules in the fluid. This explanation of Brownian motion served as convincing evidence that atoms and molecules exist and that they are moving at high-speeds and in random directions.	1 2	
	b	i	The molecule travels from face A to opposite side and back (2L) between collisions. Speed $u_x = \frac{2L}{t}$ so that $t = \frac{2L}{u_x}$ Change in momentum $= mu_x - (-mu_x) = 2mu_x$	2 1	
		ii	Force = rate of change of momentum $F = \frac{2mu_x}{t}$ $F = \frac{2mu_x}{\frac{2L}{u_x}}$ $F = \frac{mu_x^2}{L}$	1 1 1	
		iii	Total Force by N molecules $F = \frac{Nmu_x^2}{L}$	1	
		iv	Let $\langle u^2 \rangle = \langle u_x^2 \rangle + \langle u_y^2 \rangle + \langle u_z^2 \rangle$ Since molecular motion is random there is no preferred direction. Therefore, $\langle u_x^2 \rangle = \langle u_y^2 \rangle = \langle u_z^2 \rangle = \frac{\langle u^2 \rangle}{3}$ and $F = \frac{mN\langle u^2 \rangle}{3L}$ So that $P = \frac{1}{3} \frac{mN\langle u^2 \rangle}{V}$ where $V = L^3$, the volume of the cube.	1 1 1 1	
	c		$PV = \frac{1}{3} mN\langle u^2 \rangle = RT$ $\frac{1}{2} \times \frac{2}{3} mN\langle u^2 \rangle = RT$ $\frac{1}{2} m\langle u^2 \rangle = \frac{3RT}{2N} = \frac{3}{2} kT$ $\langle u^2 \rangle = \frac{3kT}{m}$ $u_{rms} = \sqrt{\frac{3kT}{m}}$	1 1 1 1	

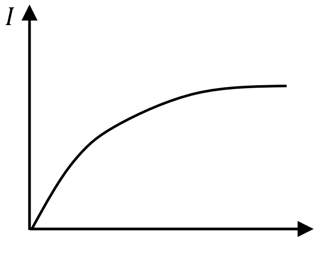
	d	i	$PV = nRT \rightarrow n = \frac{PV}{RT} = \frac{0.9 \times 10^4 \times 0.002}{8.31 \times 300} = 0.0072 \text{ moles}$	1 1	
		ii	Number of molecules per mole = N_A Number of molecules $= 0.0072 \times 6.02 \times 10^{23} = 4.33 \times 10^{21}$ molecules	1	
		iii	$u_{rms} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3 \times 1.38 \times 10^{-23} \times 300}{\frac{0.032}{6.02 \times 10^{23}}}}$ $u_{rms} = 483.37 \text{ m s}^{-1}$	1 1	
			Total:	**25**	
11	a	i	Gravitational Force	1	
		ii	$F = \frac{GM_S M_E}{R^2}$	2	
		iii	The strength of a gravitational field at any point is defined as the force per unit mass which it exerts at that point.	2	
		iv	$g = \frac{F}{m} = \frac{GM_E m}{mR_E^2}$ $g = \frac{GM_E}{R_E^2}$ $g = \frac{G\rho}{R_E^2} \times \frac{4}{3}\pi R_E^3$ $g = \frac{4}{3}\pi G\rho R_E^2$	1 1 1 1	
		v	$T = \frac{2\pi R}{v}$ $\frac{GM_S M_E}{R^2} = \frac{M_E v^2}{R} \rightarrow v = \sqrt{\frac{GM_S}{R}}$ $T^2 = 4\pi^2 R^2 \times \frac{R}{GM_S} = \frac{4\pi^2}{GM_S} R^3$	1 1 2	
		vi	$T^2 = \frac{4\pi^2}{GM_S} R^3 \rightarrow M_S = \frac{4\pi^2}{GT^2} R^3$ $M_S = \frac{4\pi^2 \times (1.50 \times 10^{11})^3}{6.67 \times 10^{-11} \times (365 \times 24 \times 60 \times 60)^2}$ $M_S = 2 \times 10^{30} \text{ kg}$	1 1 1	
	b	i	Gravitational potential at a point is numerically equal to the work done in taking a unit mass from infinity to that point.	1 1	
		ii	$\frac{1}{2}mv^2 = \frac{GM_E m}{R_E}$ $\rightarrow v = \sqrt{2gR_E}$	2 1	
		iii	The escape speed from other planet $\sqrt{2} \times \sqrt{2gR_E}$ $\sqrt{2} \times 11.2 = 15.84 \text{ km s}^{-1}$	2 2	
			Total:	**25**	

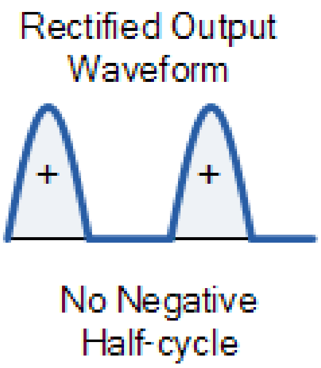
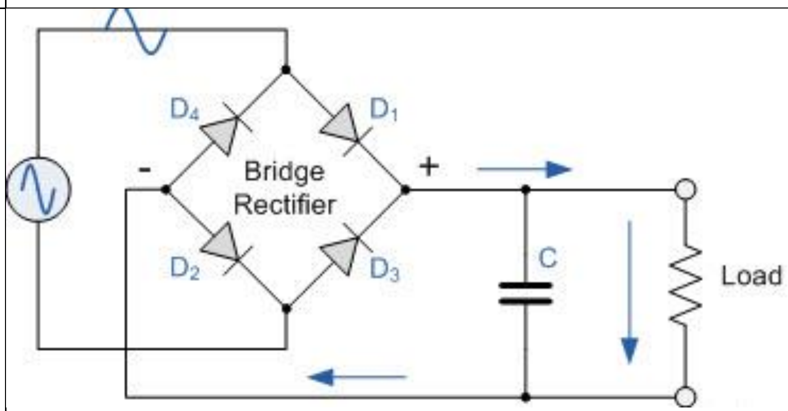
12	a	i	Capacitance is defined as the ability of a system to store charge.	2	
		ii	 	1 1	
		iii	Good dielectric constant Dielectric strength Low loss factor Temperature stability Storage stability Behaviour over temperature range Frequency response Amenable to industrial process	2	Accept any two
	b	i	Having any other dielectric would reduce the ability of the moveable plate to move. Furthermore the sensitivity to air pressure waves would be reduced.	2	
		ii	$C = \frac{\varepsilon_0 \varepsilon_r A}{d} = 8.85 \times 10^{-12} \times \frac{\pi \times 0.003^2}{0.001}$ $C = 2.5 \times 10^{-13}\mathrm{F}$	1 1	
		iii	$Q = Q_0\left(1 - e^{-\left(\frac{t}{RC}\right)}\right)$ $RC = 1 \times 10^6 \times 2.5 \times 10^{-13} = 0.25 \times 10^{-6}\ s$ $0.9 = \left(1 - e^{-\left(\frac{t}{0.25 \times 10^{-6}}\right)}\right)$ $t = \ln 0.1 \times -RC = 0.57 \times 10^{-6}\ \mathrm{s}$	1 1 1	
		iv	$Q = CV = 2.5 \times 10^{-13} \times 12 = 3 \times 10^{-12}\mathrm{C}$	2	
		v	Decreasing the separation by half means doubling the capacitance, from capacitor equation. If the capacitance is instantaneously doubled and no charge is lost, the voltage on the capacitor will temporarily decrease to 6 V. Temporarily because it will start charging again with the new increase capacitance.	1 2	
		vi	Current will flow anti-clockwise as the capacitor needs to charge again.	1	

		vii		3	
		viii	As the moveable plate is moved outward, the distance between the plates increases. The capacitance decreases and the surplus charge on the capacitor is discharged through the circuit. The current now flows from the capacitor into the battery and hence in a clockwise direction.	1 1 1	
			Total:	**25**	
13	a		Standing waves are confined in a given region of space; Progressive waves are free to propagate, to progress; The net transfer of energy in standing waves is zero; Progressive waves transfer energy; Standing waves have frequency restrictions; The energy spectrum of progressive waves is continuous;	1 1 1	
	b		The principle of superposition may be applied to two (or more) waves travelling through the same medium at the same time. The waves pass through each other without being disturbed. The net displacement of the medium at any point in space or time, is simply the sum of the individual wave displacements.	1 1	
	c	i		2	
		ii	The minimum in microwave radiation detected by the detector correspond to the nodes of the standing wave. $\therefore \frac{\lambda}{2} = 0.025\text{ m}$ $\lambda = 0.05\text{ m}$ $c = f\lambda \rightarrow f = \frac{c}{\lambda} = 6 \times 10^9\text{ Hz}$	1 1	
	d	i	Let Δx be the dot-to-dot separation and D be the viewing distance. Since $\Delta x \ll D$, the angular separation of the dots $\sin\theta = \theta = \frac{\Delta x}{D}$ In order for the dots to merge, the angular separation $\Delta\theta$ must be smaller than the angle given by the Rayleigh criterion for resolution. The minimum $\Delta\theta$ for resolution is given by $a\Delta\theta = 1.22\lambda$	1	

<table>
<tr><td></td><td></td><td></td><td>Since we do not want the dots to merge
$$a\Delta\theta < 1.22\lambda$$
$$\frac{a\Delta x}{D} < 1.22\lambda$$
$$\Delta x < \frac{1.22 \times 400 \times 10^{-9} \times 0.40}{0.0025} = 0.0781 \text{ mm}$$</td><td>1
1
1</td><td></td></tr>
<tr><td></td><td></td><td>ii</td><td>Since the violet wavelength is the smallest in the visible light spectrum, the Δx calculated holds for larger wavelengths as well.</td><td>1</td><td></td></tr>
<tr><td></td><td>e</td><td>i</td><td>A monochromatic source of light,
A single slit,
A double slit
A screen</td><td>2</td><td></td></tr>
<tr><td></td><td></td><td>ii</td><td>
</td><td>2</td><td></td></tr>
<tr><td></td><td></td><td>iii</td><td>Description of Young's double slit experiment
Monochromatic light shown onto a double slit
This causes two sources of light to interfere both constructively and destructively with one another
Results projected onto a screen
The height of a bright fringes d is measured for every different slit to screen separation D.
<table><tr><td>d /m</td><td>D/m</td></tr><tr><td></td><td></td></tr></table></td><td>2
1</td><td></td></tr>
<tr><td></td><td></td><td>iv</td><td>Graph of d/m against D/m</td><td>2</td><td></td></tr>
<tr><td></td><td></td><td>v</td><td>The gradient of the graph plotted is equal to the $\frac{s}{\lambda}$. Given the value of the slit separation, the value of the wavelength can be calculated.</td><td>1</td><td></td></tr>
<tr><td colspan="4">Total:</td><td>25</td><td></td></tr>
<tr><td>14</td><td>a</td><td></td><td>The particles have positive charge. They are accelerated in the direction of the field between the metal plates.</td><td>2</td><td></td></tr>
<tr><td></td><td>b</td><td></td><td>Magnetic flux density is the magnetic flux per unit area
$$B = \frac{\phi}{A}$$
Where ϕ is the magnetic flux and A is the surface area.</td><td>1
2</td><td></td></tr>
<tr><td></td><td>c</td><td>i</td><td>The Kinetic Energy will be equal to the work done by the field.
Since all particles will pass through the electric field, they will all exit with the same kinetic energy.</td><td>1
1</td><td></td></tr>
</table>

		ii	$qV = \frac{1}{2}mv^2$ $v = \sqrt{\frac{2qV}{m}}$	1 2	
	d	i	Similar to what happens to a current carrying conductor in a magnetic field, the moving particles in the magnetic field constitute a current and hence also a magnetic field. The magnetic field generated by the particles and the magnetic field present interact and the particles are forced in a direction parallel to their direction of travel. Fleming's left hand rule is used to determine the force on the moving charged particles.	2 1	
		ii	Imagine the path of the charged particle as a wire. The current flowing through this path in a period of time (t) would be Q/t. The speed would be equal to the length of this path (L) per unit time. Therefore, $v = L/t$, which can also be expressed as $L = tv$. Substitute $I = Q/t$ and $L = tv$ into $F = BIL$ to get $F = B \times \left(\frac{Q}{t}\right) \times (tv)$. This can be simplified to $F = BQv$.	1 1 2	
		iii	$F = \frac{mv^2}{r} = Bqv$ $r = \frac{mv}{Bq}$	1 1	
	e		Since B, v and q are the same for both particles: $r \propto m$ $\frac{r_1}{r_2} = \frac{m_1}{m_2}$ $r_2 = \frac{m_2 r_1}{m_1} = \frac{7.016 \times 8.4}{6.015} = 9.80 \text{ cm}$	1 1 1	
	f		$Bqv = \frac{mv^2}{r}$ $Bq = \frac{mv}{r} = \frac{m2\pi r}{tr} = 2\pi mf$ $f = \frac{Bq}{2\pi m}$	1 1 1	
			Total:	**25**	
15	a		The total number of magnetic field lines that pass perpendicularly through an area.	1	
	b		Faraday's law states that the induced emf in a conductor is proportional to the rate of change of the magnetic flux linking the conductor. Lenz's law states that an induced electromotive force (emf) always gives rise to a current whose magnetic field opposes the change in original magnetic flux.	2 2	

	c	i		3	
		ii	$L = \frac{E_{back}}{\frac{dI}{dt}} = \frac{12}{0.5} = 24\ \mathrm{H}$	2	
		Iii	$E = \frac{1}{2}LI_0^2 = \frac{1}{2} \times 24 \times \left(\frac{12}{6}\right)^2 = 48\ \mathrm{J}$	1	
		iv	A South pole is generated in the primary coil on the LHS. A south pole is induced on the RHS of the secondary coil. Current flows from Q to P.	2	
	d	i	The potential barrier in the pn junction is the barrier which does not allow charge flow across the junction normally. This barrier is created by the charge present in the space charge region. When a p-type material is brought in contact to a n-type material charge flow across the junction takes place due to concentration gradient between the two sides (n and p type). After some time, the immobile ions are created near the contact which create electric field which opposes flow of current. This resistance to the flow of charge is known as barrier potential. In semiconductor physics, the depletion region, also called depletion layer, depletion zone, junction region, space charge region or space charge layer, is an insulating region within a conductive, doped semiconductor material where the mobile charge carriers have been diffused away, or have been forced away by an electric field. The only elements left in the depletion region are ionized donor or acceptor impurities.	2 2	
		ii	When the voltage is applied in the opposite direction across the diode, the depletion region begins to shrink. In a reverse-biased diode, the electrons and holes would be pulled away from the junction, but a forward-biased scenario ensures that the electrons and holes move toward the junction as they are repelled from the positive and negative terminals of the voltage source respectively. Given a great enough applied voltage, both the holes and the electrons would overcome the depletion region and meet near the junction, where they could combine in a continuous process, closing the circuit and allowing current flow.	1 2	One for formula, one for result

		iii		2	
		iv		3	
			Total:	**25**	