L-Università ta' Malta

MATSEC
Examinations Board

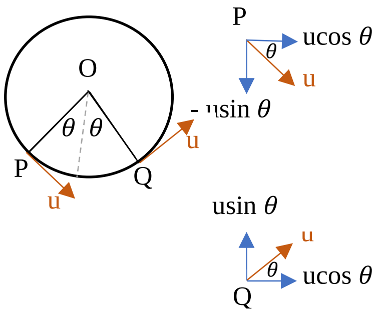
Marking Scheme

AM Physics

First Session 2024

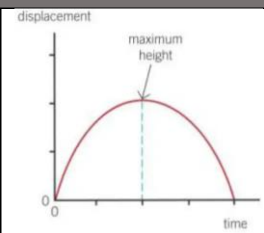
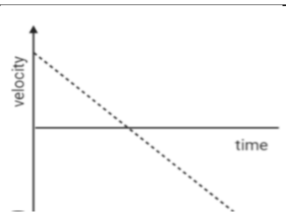
SECTION 'A'

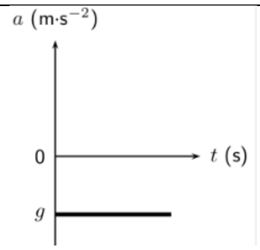
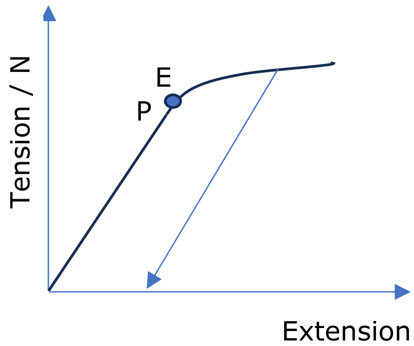
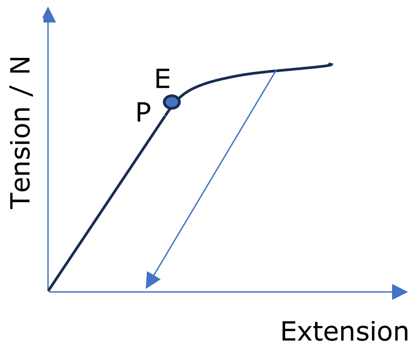
Qn No			Solution	Marks Distribution	Marks
1	a		Base units cannot be expressed in simple units. Example: m, s, A Derived units are made up of base units. Example: Newton, Joule	The definition and example must both be correct for the marks to be awarded.	(1) (1)
	b	i	$\mu_0 = \frac{2\,\pi\,r\,F}{I_1\ I_2\,l}$ Base units of force using force = (mass)(acceleration) = (kg)(m s^{-2}) Base units of radius r = m Base units of 2 π = unitless Base units of 2 $\pi\,r\,F = m\,kg\,m\,s^{-2}$ Base units of length l = m Base units of currents $I_1 = \ I_2$ = A Base units of $I_1\ I_2\,l = A\,A\,m$ Thus, the units of μ_0 are $\frac{r\,F}{I_1\ I_2\,l} = \frac{m\,kg\,m\,s^{-2}}{A\,A\,m} = kg\,m\,s^{-2}\,A^{-2}$		(1) (1) (1)
		ii	A homogeneous equation is an equation whose terms in the equation have the same units. If the dimensionless constants such as π in the above equation were to missing, the equation would still be homogeneous but physically incorrect.	The first mark must be allotted for the definition of a homogeneous equation. The second mark must be allotted for how the equation can become physically incorrect but still homogeneous.	(1) (1)
	c	i	Firstly, 2Tcos(θ) = mg If the wire is shorter, the angle is larger and thus cos(θ) is smaller which infers that T is larger. If the wire is longer, the angle is smaller and thus cos(θ) is larger which infers that T is smaller.	The first mark must be allotted for the equation describing an equilibrium of forces. The second mark should be allotted for a shorter wire inferring a larger tension.	(1) (1)
		ii	Thus, a longer wire is ideal to minimize tension.	The third mark should be allotted for a longer wire inferring a smaller tension.	(1)
Total:					10

2	a		Consider a particle moving in a circular path of radius R with uniform speed u.  Let A and B be two points on the circle which are very close to each other such that the corresponding radii OP and OQ make up a small angle θ Consider the velocity components at points P and Q At point P: The horizontal component is ucos θ and the vertical component is - usin θ At point Q: The horizontal component is ucos θ and the vertical component is usin θ The resultant change in horizontal velocity is 0 and the resultant change in vertical velocity = 2 usin θ The acceleration is a = 2 usin θ/ t but u = s/t = R(2θ)/t which implies t = R(2θ)/u Thus, a = 2 usin θ/t= 2 usin θ / (R(2θ)/u) = u^2/R since sin $\theta \approx \theta$	The first mark must be allotted for the diagram and the description of the diagram. The second mark should be allotted for the horizontal and vertical velocity components at each point. The third mark should be allotted for the resultant horizontal and vertical velocity components. The fourth mark should be allotted for the relation of time t in terms of θ and u. The fifth mark should be allotted for the correct relation of the acceleration in terms of u and R	(5)
	b		The acceleration increases by a factor of velocity squared and the sharper the curve, the smaller the radius, and thus, more acceleration would be needed to turn, and this could cause the car to skid.	The first mark should be allotted for using the relation of the acceleration in terms of u and r and how the greater the vel. and the greater the accel. The second mark should be allotted for stating that the sharper the curve the smaller the radius and thus, further increasing the accel. and this could cause the car to skid.	(1) (1)
	c		Angular velocity is $\omega = \frac{v}{r}$ The maximum frictional force = centripetal acceleration	The first mark should be allotted for obtaining the relation between friction and the centripetal acceleration.	(1)

			$\frac{mg}{2} = \frac{mv^2}{r}$ $v = \sqrt{\frac{rg}{2}}$ $\omega = \frac{v}{r} = \frac{1}{r}\sqrt{\frac{rg}{2}} = \sqrt{\frac{g}{2r}}$	The second mark should be allotted for the correct expression for ω.	(1)
	d		$\omega = \sqrt{\frac{g}{2r}}$ $\omega = \sqrt{\frac{9.81\ ms^{-2}}{2\ (4m)}}$ = 1.107 s^{-1}	The mark should be allotted for the correct answer	(1)
Total:					**10**
3	a	i	Required to find v : $average\ velocity = \frac{s}{t}$ $s = \left(\frac{u+v}{2}\right)t$ $5\ m = \left(\frac{0\ ms^{-1} + v}{2}\right)\ 15\ s$ $v = 0.66\ ms^{-1}$	The first mark must be allotted for the correct working. The second mark should be allotted for the correct velocity.	(1) (1)
		ii	$\omega = \frac{v}{r} = \frac{0.66\ m\ s^{-1}}{0.3\ m} = 2.2\ rad\ s^{-1}$ From the conservation of energy : Potential energy at the top = Kinetic energy at the bottom $mgh = \frac{1}{2}\ m\ v^2 + \frac{1}{2}\ I\ \omega^2$ $(7\ kg)(9.81\ ms^{-2})(0.05\ m) = \frac{1}{2}\ (7\ kg)\ (0.66\ ms^{-1})^2 + \frac{1}{2}\ I\ (2.2\ rad\ s^{-1})^2$ $3.43\ J - 1.52\ J = \frac{1}{2}\ I\ (2.2\ rad\ s^{-1})^2$ $I = 0.79\ kg\ m^2$	The first mark should be allotted for the correct calculation of the angular velocity. The second mark must be allotted for stating the conservation of energy principle. The third mark should be allotted for the correct calculation of the moment of inertia.	(1) (1) (1)
		iii	$v^2 = u^2 + 2as$ $(0.66\ ms^{-1})^2 = (0\ ms^{-1})^2 + 2a(5m)$ $a = 0.066\ ms^{-2}$	1 mark for a correct answer	(1)

	b		$L_i = L_f$ **provided that there are no external torques** $I_{disk}\omega_{disk} = (I_{disk} + I_{ring})\omega_{system}$ $\omega_{system} = \frac{I_{disk}\omega_{disk}}{(I_{disk} + I_{ring})}$ $\omega_{system} = \frac{(\frac{1}{2}M_{disk}R_{disk}{}^2)\omega_{disk}}{(\frac{1}{2}M_{disk}R_{disk}{}^2 + M_{ring}R_{ring}{}^2)}$ ω_{system} $= \frac{(\frac{1}{2}(25\,kg)(0.20m)^2)(10\,rad\,s^{-1})}{(\frac{1}{2}(25\,kg)(0.20m)^2 + (10\,kg)(0.05m)^2)}$ $\omega_{system} = \frac{5\,kg\,m^2 rad\,s^{-1}}{0.5\,kg\,m^2 + 0.025\,kg\,m^2}$ $\omega_{system} = 9.524\,rad\,s^{-1}$	The first mark must be allotted for stating the conservation of angular momentum principle. The second mark should be allotted for correctly expressing the initial and final angular momentums. The third mark should be allotted for the correct expression of the angular velocity. The fourth mark should be allotted for the correct answer.	(1) (1) (1) (1)
Total:					**10**
4	a		The principle of the potentiometer is based on the comparison of emfs related to the comparison of balance lengths (wire lengths at null deflection). When the emf of a cell is measured using the potentiometer, no current passes through the cell at zero galvo deflection and thus the emf of the cell can be calculated correctly. Placing a voltmeter across the cell would in fact measure the pd across the cell and not the emf.		(2)
	b		Change the value of the resistance of the variable resistor R so that the pd across wire AB would be a better match for the unknown emf of the cell. That way, the balance position on the wire will be closer towards B and the wire length for use to calculate the emf would be larger, thus increasing accuracy.		(1) (1)
	c		For zero galvo deflection: 4= I (2+2.4); I = (4/4.4) A and pd across AB is (8/4.4) V = 1.8 V But 100/82.5 = 1.8 / emf of X Therefore emf of X = (1.8 x 82.5) / 100 = 1.5 V		(1) (1) (1)

	d		Resistance AC = resistance CB = 1Ω 1/1 + 1/20 = 21/20; Resistance in parallel for V and AC = 20/21 Ω R total = 20/21 + 1+1 =62/21 Ω V=IR thus 4 = I x 62/21 implying I = 84/62 A; so pd across V = 84/62 x 20/21 = 1.29 V		(1) (1) (1)
Total:					**10**
5	a		The resistance of a conductor is the ratio of the p.d. across the conductor to the current flowing through it.		(2)
	b		The resistance of the thermistor may be found by reading the y coordinate at point Z. Also reading the x coordinate at A. Then dividing these 2 values.		(2)
	c		Experiment to find internal resistance r. **Circuit Diagram**: Series circuit including a cell, ammeter, a variable resistor and switch. A voltmeter connected in parallel with the resistor. **Take reading**s of I vs V. **Plot** graph of V against I. **V = E - Ir** **The slope** is negative and equal to -r from where r can be calculated.		(1) (1) (1) (1)
	d		No. It is not the best circuit to use. With R and V having a similar value, the ammeter reads double the current through R and the percentage error in the resistance calculation will be large.		(2)
Total:					**10**
6	a				(2)
	b		 maximum height reached when v = 0	upwards taken as positive direction	(2)

	c				(2)
	d		S= ut + ½ a t^2 0 = 10 t + ½ (-9.81) t^2 t= (10x 2) / 9.81 = 2.04 s =total time of flight	Accept any other valid way that gives this answer.	(2)
	e		To find the maximum height reached: Time = half the value found in (iv) S= ut + ½ a t^2 S = (10 x 1.02) – (½ x 9.81 x 1.02^2) S = 5.2 m		(2)
Total:					**10**
7	a		Hooke's Law states that tension is proportional to extension, as long as the **proportionality** limit is not exceeded.		(1)
	b	i	P is proportionality Limit E is elastic limit; elastic from origin to E; Plastic from E onwards. 	Award no marks if only P is shown to delineate the regions, when it should be the elastic limit.	(2)
		ii	Yes. A permanent extension will result since the wire was loaded beyond the elastic limit. 		(1) (1)

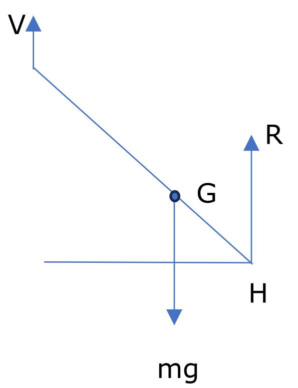
		iii	Work done to extend the wire to the proportionality limit is found from the area under the graph. This is a triangle: Work done in Joules = ½ Force in N x extension up to proportionality limit	Accept ½ base x height	(1) (1)
		iv	Work done represented by one square = 1 N x 1 x 10^{-2} m = 1 x 10^{-2} J. There are approximately 16 squares below the line up to Q. Thus the work done to extend the strip to Q = 1 x 10^{-2} x 16 = 16 x 10^{-2} J (Full squares are counted as usual. Count areas larger than half a square area as 1, those less than a square area are not counted.)	Accept number of squares: 16 or 15	(1) (1) (1)
Total:					**10**
8	a		The half-life of a radioactive isotope is the time taken for the total number of radioactive atoms to decay to half their original number. The relationship between the decay constant λ and the half-life can be defined as : $T_{1/2}$ = ln(2)/λ $N = N_0 e^{-\lambda t}$ $N_0 / 2 = N_0 e^{-\lambda T_{1/2}}$ $1/2 = e^{-\lambda T_{1/2}}$ $\ln\left(\frac{1}{2}\right) = -\lambda T_{1/2}$ $\ln(2) = \lambda T_{1/2}$ $T_{1/2} = \ln(2)/\lambda$	The first 1 mark should be allotted for the correct definition of half-life. The second mark should be allotted for the substitution of N_0 and $N_0/2$ and the third mark should be allotted for the correct derivation.	(1) (1) (1)
	b		1 year = (365.25 days)(24 hours)(60)(60)s = 31557600 s 5370 years = 169464312000 s Thus, λ = 4.09 × 10^{-12} s^{-1}	The first mark should be allotted the correct number of half-lives. The second mark should be allotted for the correct answer.	(1)

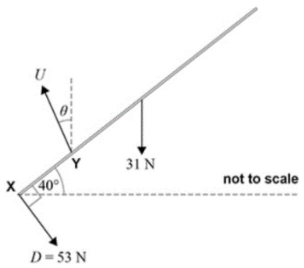
	c		The half-life of Carbon-14 is approximately 5730 years which infers that 17,190 years is equivalent to 3 half-lives and thus, N = (0.5)(0.5)(0.5)(25000) = 3125 Thus, (3125/25000)(100)=12.5% Alternatively, $N = N_0 e^{-\lambda t}$ $N = (25000)e^{-(169464312000 \text{ s})(4.09 \times 10^{-12} s^{-1})}$ $= 12500$ $N = (12500)e^{-(169464312000 \text{ s})(4.09 \times 10^{-12} s^{-1})}$ $= 6250$ $N = (6250)e^{-(169464312000 \text{ s})(4.09 \times 10^{-12} s^{-1})}$ $= 3125$ Thus, (3125/25000)(100)=12.5%		(1) (1)
	d		$500 = (0.5)^n(25000)$ $1/50 = (0.5)^n$ Taking logarithms on both sides and simplifying infers that n = 5.644 and thus, the total number of half-lives required is 6. Alternatively, $N = N_0 e^{-\lambda t}$ $N = (25000)e^{-(169464312000 \text{ s})(4.09 \times 10^{-12} s^{-1})}$ $= 12500 \, nuclei$ $N = (12500)e^{-(169464312000 \text{ s})(4.09 \times 10^{-12} s^{-1})} = 6250 \, nuclei$ $N = (6250)e^{-(169464312000 \text{ s})(4.09 \times 10^{-12} s^{-1})}$ $= 3125 \, nuclei$ $N = (3125)e^{-(169464312000 \text{ s})(4.09 \times 10^{-12} s^{-1})}$ $= 1562.5 \, nuclei$ $N = (1562.5)e^{-(169464312000 \text{ s})(4.09 \times 10^{-12} s^{-1})}$ $= 781.25 \, nuclei$ $N = (25000)e^{-(169464312000 \text{ s})(4.09 \times 10^{-12} s^{-1})}$ $= 390.625 \, nuclei$ Thus, the total number of half-lives required is 6.	The first mark should be allotted for the correct answer. The second mark should be allotted for the correct answer.	(1) (1)
	e		Carbon dating solely works for things that were once alive and in equilibrium with atmospheric carbon. Carbon-14 levels vary over time. Nuclear testing has caused an increase in Carbon-14 levels disrupting Carbon dating. Sample contamination.	Accept any two causes. 1 mark per cause of uncertainty.	(1) (1)
Total:					**10**

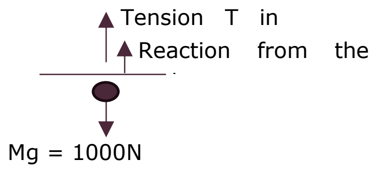
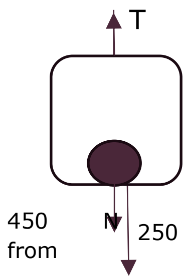
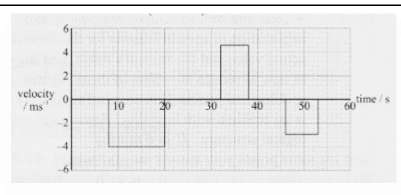
SECTION B

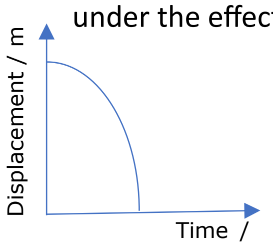
9	a		The moment of inertia of a rigid body, I, is the rotational equivalent of mass and the reluctance of a body to start rotating if it is at rest and stop rotating if it is already rotating.	The first mark should be allotted for the rotational equivalent of mass and the second mark should be allotted for the reluctance of a body to start rotating if it is at rest and stop rotating if it is already rotating	(1) (1)
	b	i	Moment of inertia of the combined system = Moment of inertia of satellite body + 2 × Moment of inertia of sensor Assumption : Each sensor should be treated as a point mass $I_{sensor} = M_{sensor} R_{sensor}^2 = (7\ \text{kg})(3.3\ \text{m})^2 = 76.23\ \text{kg m}^2$ Moment of inertia of the combined system = $250\ \text{kg m}^2 + (2 \times 76.23\ \text{kg m}^2) = 402.46\ \text{kg m}^2$	The first mark should be allotted for the correct expression of the total oment of inertia of the combined system. The second mark should be allotted for the correct assumption. The third mark should be allotted for the correct calculation and final answer.	(1) (1) (1)
		ii	The total angular momentum of the system $L = I\ \omega = (402.46\ \text{kg}\ m^2)(0.3\ \text{rad}\ s^{-1})$ $= 120.74\ kg\ m^2\ s^{-1}$ and the kinetic energy of the system is $KE = \frac{1}{2} I\ \omega^2$ $= \frac{1}{2}\ (402.46\ \text{kg}\ m^2)(0.3\ \text{rad}\ s^{-1})^2$ $= 18.11\ J$	The first mark should be allotted for the correct working of the angular momentum calculation and the second mark should be allotted for the correct answer. The first mark should be allotted for the correct working of the kinetic energy calculation and the second mark should be allotted for the correct answer.	(2) (2)
		iii	By the principle of conservation of angular momentum, $I_{oldsystem}\omega_{oldsystem} = I_{newsystem}\omega_{newsystem}$ (no external torque) where the old system refers to the satellite with	The first mark should the system's conservation of angular momentum of momentum.	(1)

	c		fully extended arms and the old system refers to the satellite with retracted arms. When the telescopic booms are retracted, the distance of the sensors from the axis of rotation decreases and the moment of inertia of the combined system decreases. Thus, by the conservation of angular momentum, the angular velocity of the satellite with the retracted telescopic booms increases.	The second mark should be allotted for the decreasing moment of inertia due to the retracted telescopic booms. The third mark should be allotted for the increasing angular velocity due to the decreasing mom. of inertia.	(1) (1)
	c	i	The rotational kinetic energy is equal to the potential energy of the swinging rod. $$KE = \frac{1}{2} I\,\omega^2 = mgh_{com} = PE$$ $$\omega^2 = \frac{2mg\frac{l}{2}}{\frac{ml^2}{3}}$$ $$\omega = \sqrt{\frac{3g}{l}}$$ $$\omega = \sqrt{\frac{3(9.81\,m\,s^{-2})}{(1.7\,m)}} = 4.16\,rad\,s^{-1}$$	The first mark should be allotted for correctly expressing the conservation of energy for the system. The second mark should be allotted for the correct answer	(1) (1)
		ii	$KE_{before\ collision} = KE_{after\ collision}$ $$\frac{1}{2} m_{point\ mass}\, v_{before}{}^2 = \frac{1}{2} m_{point\ mass} v_{after}{}^2 + \frac{1}{2}\frac{1}{3} m_{rod}\ l^2 \omega_{rod}{}^2$$ $$v_{after} = \sqrt{\frac{m_{point\ mass}\, v_{before}{}^2 - \frac{1}{3} m_{point\ mass}\ l^2 \omega_{rod}{}^2}{m_{point\ mass}}}$$ $$v_{after} = \sqrt{\frac{(0.5\,kg)(15\,m\,s^{-1})^2 - \frac{1}{3}(4.5\,kg)\ (1.7m)^2(4.16\,rad\,s^{-1})^2 6}{(0.5\,kg)}}$$ $v_{after} = 8.65\,m\,s^{-1}$	The first mark should be allotted for correctly expressing the conservation of kinetic energy. The second mark should be allotted for the velocity calculation.	(1) (1)

		iii	$L = mvr = (0.5\text{ kg})(15\, m\, s^{-1})(1.7\, m)$ $= 12.75\text{ kg}\, m^2\, s^{-1}$	The mark should be allotted for the correct answer	(1)
		iv	By the conservation of angular momentum, $L_{before} = L_{after}$ provided that no external torques are acting on the system. Note that by (iii) $L_{before} = 12.75\text{ kg}\, m^2\, s^{-1}$. $L_{after} = I\omega + m(v\, cos\theta)r$ $cos\theta = \dfrac{12.75\text{ kg}\, m^2\, s^{-1} - (4.16\, rad\, s^{-1})\frac{1}{3}(4.5\, kg)\,(1.7m)^2}{(0.5\, kg)(8.66\, m\, s^{-1})(1.7\, m)}$ $= -0.719$ $\theta = 135.943°$	The first 2 marks should be allotted for correctly stating and expressing the conservation of angular momentum respectively. The second mark should be allotted for the correct angle	(1) (1) (1)
Total:					**20**
10	a		For a rigid body to be in equilibrium: 1) the net force on the body must be zero; the net moment about any arbitrary point must be equal to zero.		(1) (1)
	b	i		1 for the weight 2 for the reaction at the hinge for being drawn vertically upwards	(1) (2)
		ii	Taking moments about the Hinge H: Vx 0.90 cos 45° = 25 x 0.35 cos 45° V = 9.7 N		(1) (1) (1)

	c	i	Figure 2  Forces upwards + Forces downwards (53 cos 40°) +31 = U cos θ.....i Horizontal forces are equal: 53 sin 40° = U sin θ………….ii Dividing ii by i : tan θ = (53 sin 40°) / (53 cos 40°) +31 thus θ = 25.4° Using equation ii: 53 sin 40° = U sin 25.4° and U = 79.29 N		(1) (1) (1) (1) (1) (1)
		ii	V = S + 31 V must be vertically upwards since the other forces are both acting downwards		(1) (1)
		iii	The moment of the weight about point X is **larger** in the 2nd diagram, since the perpendicular distance from X is larger.		(2) (2)
Total:					**20**
11	a		1. Every body continues in its state of rest or uniform motion in a straight line, as long as no external forces acts upon it. 2. The rate of change of momentum is proportional to the applied force and takes place in the same direction as the force. 3. For every action there is an equal and opposite reaction.		(3)
	b		The newton 2nd law of motion defines the Newton. From F=ma, 1 Newton is the force which when acting on a mass of 1 kg creates and acceleration on $1ms^{-2}$.		(2)

	c	i	Free body diagram of the painter: 		(2)
		ii	Free body diagram of the crate: 		(2)
		iii	Forces acting on painter: T + 450 – 1000 = ma = 100a……..i Considering forces on the crate: T – (450+250)=ma = 25a…………..ii Solving these equations for a gives a= 2 ms^{-2}		(1) (1) (2)
	d	i	Average velocity = Δ displacement/ Δ time = (-6 – 36) / 60 = - 0.7 ms^{-1}		(2)
		ii	Average speed = total distance /total time = (36 +12+ 12+ 15+ 15+ 6)/ 60 = 96/60 = 1.6 ms^{-1}		(2)
		iii			(3)
Total:					**20**
12	a	i	For the nut: u = 4 ms^{-1} , g = 9.81 ms^{-2}, t= 6 s, and s is unknown. Using $s= ut + ½ a t^2 = (4 \times 6) + (1/2 \times 9.81 \times 6^2)=$ 200.58 m		(1) (1)

		ii	Displacement / time graph is a curve with increasing slope as time increases. The slope indicates the increase of the velocity of the nut, as the nut falls under the effect of g.  	A graph showing increasing displacement with time should also be counted as correct...reviewer suggestion.	(2) (1)
	b	i	Impulse is defined as the product of the Force acting on a body and the time for which the force acts. Impulse = F . Δt	Award mark even if the equation only is provided.	(1)
		ii	Impulse = 0.15 Ns = F. Δt = mv Thus v = 0.15 / (0.6 x 10 $^{-3}$) = 250 m/s		(2)
		iii	Pellet fired horizontally from 1.4m above ground. Horizontally : v = d/t; 250 = 100/t and t= 0.4 s Vertically: u=0, g= 9.81 and t= 0.4 s S = 0 + (1/2 x 9.81 x 0.4^2) = 0.784m But this is larger than 0.6m which is the radius of the target below the level at which the pellet is fired at start. Therefore the pellet does not hit the target.		(2) (2) (1)
		iv	The pellet is projected at an angle θ to the horizontal from the same level off the ground as the centre of the target. Horizontally : v = d/t, 250 cos θ = 100/t and t = 100/250 cos θ Vertically : a = - g, s=0, u = 250 sin θ and t= 100/250 cos θ So 0 = (250 sin θ . 100/250 cos θ) + (½ . -g. (100/250 cos θ)^2); Sin θ. Cos θ = ½ . g .100/ 250^2 = 0.0008 g		(2) (2) (2) (1)
Total:					**20**
13	a		Glass is brittle and breaks upon an impact force/ breaks with little or no plastic deformation Aluminium is hard/strong/tough/malleable and a large force is required to break/returns to its	Brittle (1) an impact force/ breaks with little or no plastic deformation (1)	(4)

			original shape after the stress is removed/absorbs energy upon impact.	hard / strong / tough / malleable (1) a large force is required to break/returns to its original shape after the stress is removed/absorbs energy upon impact(1)	
	b	i	$Young's\ Modulus\ E = \frac{stress}{strain}$ $2 \times 10^{11}\ Pa = \frac{stress}{3.0 \times 10^{-4} m^2}$ $stress = 6 \times 10^7 N\ m^{-2}$ $6 \times 10^7 N\ m^{-2} = \frac{Force}{7.7 \times 10^{-3}\ m^2}$ $Force = 4.62 \times 10^5 N$ $strain = \frac{extension\ \Delta l}{length\ l}$ $3.0 \times 10^{-4}\mathrm{m} = \frac{extension\ \Delta l}{72\ m}$ $\Delta l = 2.16 \times 10^{-2}\mathrm{m}$ $Stored\ Energy = \frac{1}{2} F \Delta l$ $Stored\ Energy = \frac{1}{2}(4.62 \times 10^5 N)(2.16 \times 10^{-2}\mathrm{m})$ $Stored\ Energy = 4.99 \times 10^3\ J$	The first mark shall be allotted for the correct stress calculation. The second mark shall be allotted for the correct force calculation. The third mark shall be allotted for the correct extension calculation. The fourth mark shall be allocated for the correct extension The final 2 marks shall be allocated for the working and correct calculation.	(1) (1) (1) (1) (2)
		ii	The highest observed temperature should not be used to calculate the pre-strain as the rail should not be under constant stress and reduce the time under which the rail is at its highest temperature.	The highest observed temperature should not be used (1) the rail should not be under constant stress (1) reduce the time under which the rail is at its highest temperature (1)	(1) (1) (1)
	c	i	Let E_s and E_b be the Young's moduli of the steel wire and brass wire respectively. Let F_s and F_b be the forces of the steel wire and brass wire respectively. $E_s = \frac{\sigma_s}{\varepsilon_s}$ and $E_b = \frac{\sigma_b}{\varepsilon_b}$ $\sigma_s = \frac{F_s}{A}$ and $\sigma_b = \frac{F_b}{A}$	The first mark should be allocated for the correct assumption. The second mark should be allocated for the working of the derivation.	(1) (1)

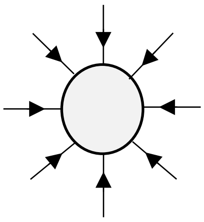
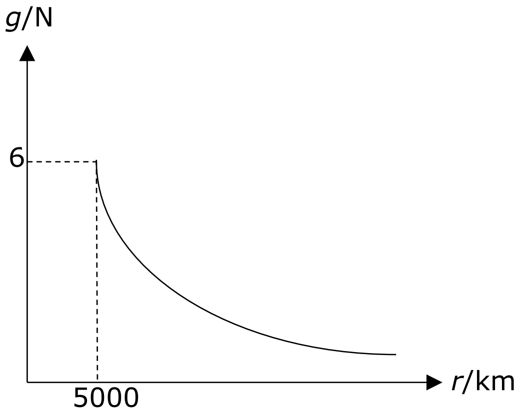
			$A = \frac{F_s}{\sigma_s} = \frac{F_b}{\sigma_b}$ Assumption: The extension of each wire is the same, that is, $\varepsilon_s = \varepsilon_b = \varepsilon$ $E_s = \frac{\sigma_s}{\varepsilon}$ and $E_b = \frac{\sigma_b}{\varepsilon}$ Thus, $\sigma_s = \varepsilon E_s$ and $\sigma_b = \varepsilon E_b$ $\frac{F_s}{\varepsilon E_s} = \frac{F_b}{\varepsilon E_b}$ $\frac{E_b}{E_s} = \frac{F_b}{F_s}$	The third mark shall be allocated for the correct result.	(1)
		ii	$\frac{200 \times 10^9\ Pa}{100 \times 10^9\ Pa} = \frac{F_b}{F_s}$ $F_b = 2F_s$ But $F_b + F_s = 15N$ $2F_s + F_s = 15N$ $F_b = 10N$ $Stored\ Energy = \frac{1}{2} F\Delta l$ $stress = \frac{Force}{Area} = \frac{10\ N}{1.35 \times 10^{-6}\ m^2}$ $stress = 7.4 \times 10^6\ N\ m^{-2}$ $Young's\ Modulus\ E = \frac{stress}{strain}$ $1 \times 10^{11}\ Pa = \frac{7.4 \times 10^6\ N\ m^{-2}}{strain}$ $strain = 7.4 \times 10^{-5}$ $strain = 7.4 \times 10^{-5} = \frac{extension\ \Delta l}{length\ l} = \frac{\Delta l}{1.3m}$ $\Delta l = 9.62 \times 10^{-5} m$ $Stored\ Energy = \frac{1}{2} F\Delta l$ $Stored\ Energy = \frac{1}{2}(10N)(9.62 \times 10^{-5} m)$ $Stored\ Energy = 4.81 \times 10^{-4}\ J$	The first mark shall be allocated for the correct calculation of the force experienced by the brass wire. The second mark shall be allocated for the correct stress calculation. The third mark shall be allocated for the correct strain calculation. The fourth mark shall be allocated for the correct energy calculation.	(1) (1) (1) (1)
Total:					**20**

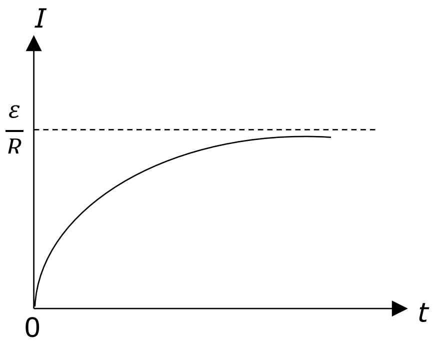
14	a		C $P = I^2 R$ Thus P changes with the square of I.		(1) (2)
	b	i	Supply of energy from the cell = 2.4 $Js^{-1} = I^2 R$ R_{total} = 9+6 = 15 Ω so 2.4 = I^2 . 15 and I =0.4 A Thus p.d. across R = 0.4 x 9 = 3.6 V		(2) (2) (2)
		ii	Filament lamp connected in parallel to the thermistor.		(1)
			When θ decreases, R thermistor increases and thus more current flows through the lamp connected in parallel, thus lighting up the lamp.		(2)
			Adding another cell in series increases the p.d. across R and Thermistor. The ratio of pd_R to pd_T is however still the same. So pd_T will be larger. The current will be larger and the thermistor heats up more quickly. So the lamp can light up when θ is much lower.		(1) (2) (3)
			Using cells with internal resistance would decrease the current in the circuit. The lamp will be less bright.		(2)
Total:					**20**
15	a	i	Mass defect is the difference between the mass of nucleus and the total mass of the individual masses of the protons and the neutrons forming the nucleus.	The 2 marks shall be allotted for the correct definition.	(2)
		ii	Total mass of nucleus = Total mass of 26 protons + Total mass of 30 neutrons Mass of 1 proton = 1.0073 u Total mass of 26 protons = 26 × 1.0073 u = 26.1898 u Mass of 1 neutron = 1.0087 u Total mass of 30 neutrons = 30 × 1.0087 u = 30.261 u Total mass of nucleus = 26.1898 u + 30.261 u = 56.4508 u Mass defect Δm = 56.4508 u – 55.9349 u = 0.5159 u Binding Energy = $\Delta m\, c^2 = (0.5159 \times 1.66054 \times 10^{-27}\ kg)(3\times 10^8\ ms^{-1})^2 = 7.71 \times 10^{-11}$ J = 4.81878×10^8 eV = 481.88 MeV	The first 2 marks should be allotted for the correct total mass of neutrons and protons and their sum. The third mark should be allotted for the correct mass defect. The fourth mark shall be allotted for the correct binding energy.	(1) (1) (1) (1)

	b	i	The minimum frequency of the incident electromagnetic radiation at which the metal surface emits photoelectrons. At this frequency, the kinetic energy of the electrons is zero.		(1) (1)
		ii	Einstein's equation for the photoelectric effect is $KE = hf - \phi$ At the cutoff frequency K.E = 0 and thus, $\phi = hf = \frac{hc}{\lambda_c}$ Thus, $\lambda_c = \frac{hc}{\phi} = \frac{(6.63\times10^{-34} J\,s)(3\times10^8 m\,s^{-1})}{(4.52\ eV)(1.6\times10^{-19} J/eV)} =$ $2.75 \times 10^{-7} m$	The first mark shall be allotted for KE = 0 and deducing the correct relation. The second mark shall be allotted for the correct answer.	(1) (1) (1)
		iii	Einstein's equation for the photoelectric effect is $KE = hf - \phi KE = \frac{hc}{\lambda_c} - \phi =$ $\frac{(6.63\times10^{-34} J\,s)(3\times10^8 m\,s^{-1})}{(198\times10^{-9} m)} -$ $(4.52\ eV)\left(1.6 \times \frac{10^{-19} J}{eV}\right) = 1.75\ eV$	The first mark shall be allotted for the correct equation. The second mark shall be allotted for the correct answer.	(1) (1) (1)
		iv	$V_{stopping} = \frac{KE_{max}}{e} = \frac{1.75\ eV}{1\ e} = 1.75\text{V}$	$V_{stopping} = \frac{KE_{max}}{e}$ (1) for correct final answer (1)	(2)
	c	i	Nuclear fusion is a reaction in which two or more atomic nuclei, combine to form one or more stable atomic nuclei. Nuclear fusion examples : Naturally occurring in stars, fusion of two hydrogen atoms into one helium atom Nuclear fission occurs when a neutron hits a larger atom, causing it to excite itself and split into two smaller atoms. Nuclear fission examples : Nuclear reactors in nuclear power plants	The first mark should be allotted for the correct nuclear fusion definition and the correct example. The second mark should be allotted for the correct nuclear fusion definition and the correct example.	(1) (1)
		ii	The nuclear binding energy curve has a peak in the stability region which means that fission, that is, the breakup of heavier nuclei and fusion, the merge of lighter nuclei will yield more tightly bound nuclei.	The 2 marks shall be allotted for the understanding of the nuclear binding energy curve in relation to the fission and fusion processes.	(2)
Total:					**20**

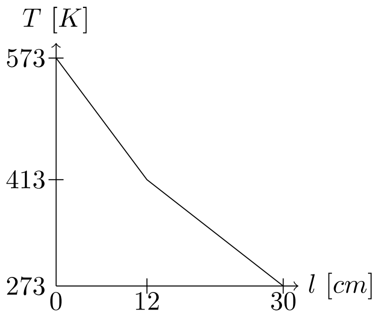
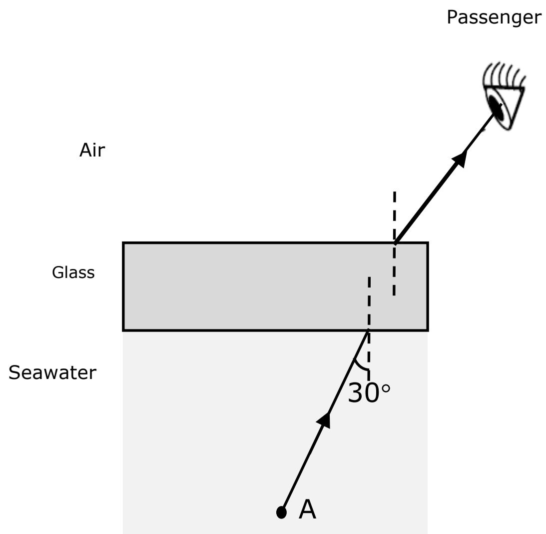
Paper II

Section A

Question No			Solution	Marks Distribution	Marks
1	a			1 mark for radial lines, 1 mark for direction	(2)
	b			Deduct 1 mark if graph starts at r = 0. Deduct 1 mark if axes labels are absent.	(3)
	c		For a circular orbit, $mr\omega^2 = \frac{GMm}{r^2} \rightarrow \omega^2 = \frac{GM}{r^3}$ Since the angular frequency is independent of mass, both satellites have the same orbital period.		(2) (1)
	d		The potential is $V = -\frac{GM}{r}$. Since satellites are found at different altitudes, they do not have the same potential so cannot be in the same equipotential surface.		(1) (1)
Total:					**10**
2	a		$-L\frac{\mathrm{d}I}{\mathrm{d}t}$ corresponds to the emf produced by the inductor. The term is associated to Faraday's law and Lenz's law.		(1) (1)
	b	i	At $t = 0$, the change in current is the greatest causing a large back emf in the inductor. This leads to a very small current in the circuit.		(1) (1)
		ii	As time passes, the change in current starts to decrease causing a smaller back emf produced in the inductor. This leads to a growth in current in the circuit.		(1) (1)
	c		The max current is thus $I = \varepsilon/R$. After a long time, the current will have approached a steady value, hence creating no back emf.		(1) (1)

	d			Deduct 1 mark if axes labelling are absent.	(2)
Total:					**10**
3	a		The root mean square voltage characterizes a alternating current source through the square root of the time average of the voltage squared. $V_{rms} = V_0/\sqrt{2}$ $V_{rms} = \frac{325}{\sqrt{2}} = 230\text{ V}$		(1) (1) (1)
	b		$X_L = 2\pi f L$ $X_L = 2\pi \times 50\text{ Hz} \times 1.6\text{ H} = 0.50\text{ k}\Omega$ $R = X_L = 0.50\text{ k}\Omega$		(1) (1) (1)
	c		$I_{rms} = \frac{V_{rms}}{X_L}$ $I_{rms} = \frac{230V}{0.50\text{ k}\Omega} = 0.46\text{ mA}$		(1) (1)
	d		($X_L = 2\pi f L$ linear with frequency $\Rightarrow \widetilde{X_L} = 2X_L$) The opposition to the alternating current doubles (because the reactance doubles too). The induced voltage in the inductor which opposes its origin according to Lenz's law increases.		(1) (1)
Total:					**10**
4	a		The **Universe's expansion** causes the galaxies to separate away from each other in a similar way to **points on a balloon or ribbons on a rubber band**.		(1) (1)
	b		Hubble's law: $v = H_0 d$ Value of H_0 is computed either via gradient or using any point from the line. As an example: $H_0 = \frac{v}{d} = \frac{2 \times 10^4}{9 \times 10^8} = 2.22 \times 10^{-5}\text{ km s}^{-1}\text{ ly}^{-1}$		(1) (1) (1)

	c		$f = f_0\left(1 - \frac{v}{c}\right)$ $\frac{c}{\lambda} = \frac{c}{\lambda_0}\left(1 - \frac{v}{c}\right)$ $\lambda_0 = \lambda\left(1 - \frac{v}{c}\right)$ $= 490\text{ nm}\left(1 - \frac{1.4 \times 10^4 \times 1000}{3 \times 10^8}\right)$ $= 467.13\text{ nm}$		(1) (1) (1)
	d		Blueshift is the phenomenon when the wavelength (frequency) of a signal appears shorter (with a higher frequency) when an observer approaches the source of the signal. As the signal is blueshifted, the galaxy is approaching towards Earth.		(1) (1)
Total:					**10**
5	a		ΔU: change of internal energy ΔQ: heat supplied to the system ΔW: work done by the system	Equivalent definitions in terms of heat withdrawn or work done on the system are valid.	(1)
	b		i: Isochoric means constant volume. Constant volume means vertical line, therefore $i \cong AB$ ii: Adiabatic means $pV^{\gamma} = const.$ Adiabatic means $p = const./V^{\gamma}$, therefore $ii \cong BC$ iii: isobaric means constant pressure. Constant pressure means horizontal line, thus $iii \cong CA$	Accept adiabatic means constant heat.	(1) (1) (1) (1) (1) (1)
	c		$i: Q_i > 0; W_i = 0$ $ii: Q_{ii} = 0; W_{ii} > 0$ $iii: Q_{iii} < 0; W_{iii} < 0$	Summary for ΔU is not required	(1) (1) (1)
Total:					**10**
6	a		$\frac{\Delta Q}{\Delta t} = \frac{k_1 A(\theta_{high} - \theta_{interface})}{l_1}$		(1)
	b		$\frac{\Delta Q}{\Delta t} = \frac{k_1 A(\theta_{high} - \theta_{interface})}{l_1} \Rightarrow \theta_{interface} = \theta_{high} - \frac{l_1}{k_1 A}\frac{\Delta Q}{\Delta t}$ $\theta_{interface} = 573\text{ K} - \frac{0.12\text{ m}}{239\text{ W m}^{-1}\text{K}^{-1}\,\pi(0.0050\text{ m})^2} 25\text{ W}$ $\theta_{interface} \approx 413\text{ K}$		(1) (1) (1)
	c		$\frac{\Delta Q}{\Delta t} = \frac{k_2 A(\theta_{interface} - \theta_{end})}{l_2} \Rightarrow k_2 = \frac{\Delta Q}{\Delta t} \cdot \frac{l_2}{(\theta_{interface} - \theta_{end})A}$ $k_2 = 25\text{ W} \cdot \frac{0.18\text{ m}}{140\text{ K}\,\pi(0.0050\text{ m})^2}$ $k_2 \approx 410\text{ W m}^{-1}\text{ K}^{-1}$		(1) (1) (1)

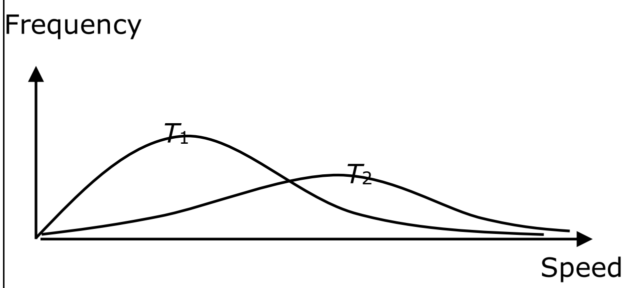
	d		 Sketch has correct axes: x stands for length of cylinder and exceeds 30 cm, y has temperature and contains range from 0°C to 300°C or equivalently 273K to 573K. Graph contains correct points (0,273+300), (12,273+140), (30,273+0); graph is continuous at interface; points connected linearly		(1) (1) (1)
Total:					10
7	a		By making use of Snell's law: $\boldsymbol{\eta_{\text{seawater}} \sin \theta_i = \eta_{\text{glass}} \sin \theta_r}$ $\mathbf{1.34 \sin 30 = 1.52 \sin \boldsymbol{\theta_r}}$ $\boldsymbol{\theta_r} = \mathbf{26.15}\ °$ Repeating for the glass-air boundary: $\eta_{\text{glass}} \sin \theta_i = \eta_{\text{air}} \sin \theta_r$ $1.52 \sin 26.15 = 1 \sin \theta_r$ $\theta_r = 42.07\ °$	Accept the shortcut approach $\eta_{\text{seawater}} \sin \theta_i = \eta_{\text{air}} \sin \theta_r$ provided candidate shows appropriate reasoning and explanations.	(1) (1) (1) (1)
	b		 	1 mark per light ray. Mark is awarded if light ray is clearly shown to move towards/away from normal. Deduct 1 mark if glass-air boundary normal is not drawn. Marking of angles is not required.	(2)

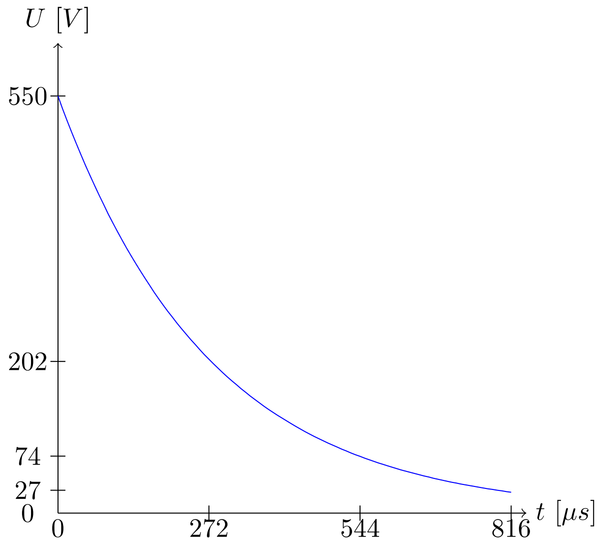
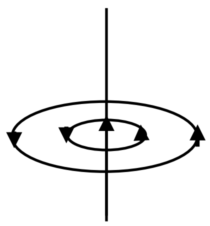
	c		By making use of Snell's law: $\eta_{\text{seawater}} \sin\theta_i = \eta_{\text{glass}} \sin\theta_r$ $1.34 \sin 60 = 1.52 \sin\theta_r$ $\theta_r = 49.77\,°$ Since the incident angle on the glass-air boundary is greater than the critical angle, the ray will be totally internally reflected. Thus, the passenger will not be able to view the coral.		(1) (1) (1)
	d		Due to $\eta = \frac{\text{Real Depth}}{\text{Apparent Depth}} \rightarrow \text{Apparent Depth} = \frac{\text{Real Depth}}{\eta}$, for an optically denser medium, the apparent depth decreases making the object appear closer to the observer.		(1)
Total:					10
8	a		A mechanical wave is produced by oscillation of matter which leads neighbouring matter to oscillate as well causing transport of energy. In the guitar string, the oscillation starts where the string is plucked which causes the neighbouring metal of the guitar string to oscillate as well which transports energy along the string.		(1) (1)
	b		Longitudinal: Matter oscillates parallel to direction of energy transport Transverse: Matter oscillates perpendicular to direction of energy transport		(1)
	c		Guitar string vibration is a transverse wave		(1)
	d		$f_1 = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$ $T = \mu(2Lf)^2$ $T = 0.00031 \text{ kg m}^{-1} (2 \times 0.65 \text{ m} \times 330 \text{ Hz})^2 \approx 57 \text{ N}$ $c = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{57}{0.00031}} \text{ m s}^{-1} \approx 428.8 \text{ m s}^{-1}$		(1) (1) (1) (1)
	e		$\lambda = \frac{c}{f}$ $\lambda = \frac{330 \text{ m/s}}{330 \text{ Hz}} \approx 1.00 \text{ m}$		(1) (1)
Total:					**10**

Section B

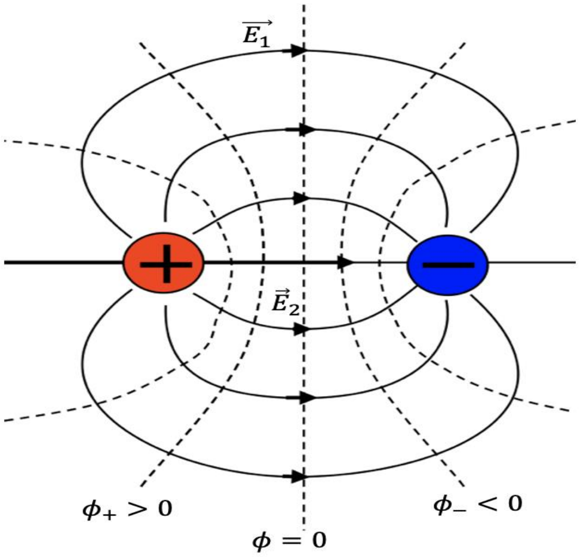
9	a		Heat is a measure of energy stored in a substance. Temperature is a measure of the average kinetic energy of the particles in a substance.		(1) (1)
	b		As thermocouple is inserted, **due to a temperature difference causes heat energy to be transferred** causing the thermocouple's **temperature to change**. After some time, the **thermocouple's temperature matches the temperature of the water causing no exchange of heat.**		(2) (1)
	c		To use: $\theta = \frac{X_\theta - X_0}{X_{100} - X_0} \times 100\ °\mathrm{C}.$ Given: $X_0 = 100\ \Omega$ and $X_{100} = 138.5\ \Omega$. Hence: $\theta = \frac{120 - 100}{138.5 - 100} \times 100\ °\mathrm{C} = 51.95\ °\mathrm{C}$		(1) (1), (1)
	d		Triple point of water		(1)
	e		$Q = mc\Delta\theta$ $Pt = mc\Delta\theta$ $100 \times 4 \times 60 = 0.2 \times c \times (52 - 24)$ $c = 4285.7\ \mathrm{J\ kg^{-1}\ °C^{-1}}$		(1) (2) (1)
	f		The ice in the ice-water mixture is receiving heat energy to melt. This does not cause a change in temperature until the ice has completely melted.		(1) (1)
	g		$Q = mL$ $m = \frac{Q}{L} = \frac{Pt}{L}$ $m = \frac{75 \times 11 \times 60}{3.34 \times 10^5} = 0.148\ \mathrm{kg}$		(1) (1), (1)
	h		Heat transfer is **largest at the beginning causing the greatest change in temperature**. As the **temperature difference decreases, heat transfer happens slower** causing a slower increase in temperature.		(1) (1)
Total:					**20**

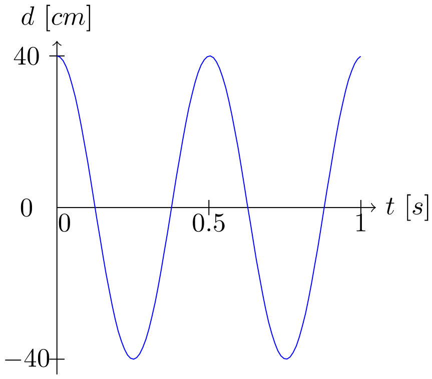
10	a		Monochromatic light means a light source emitting a singular wavelength (or frequency).		(1)
	b		For a single slit, $\theta \approx \frac{\lambda}{a} = \frac{650\times10^{-9}}{0.1\times10^{-3}} = 6.5 \times 10^{-3}$.		(1), (1)
	c		For small angles, $\theta \approx \tan\theta = \frac{y}{D}$, where y is the separation from central maximum to first minimum. From the graph, $y \approx 32\ \mathrm{mm}$. Hence: $\frac{32 \times 10^{-3}}{D} = 6.5 \times 10^{-3}$ $D = 4.9\ \mathrm{m}$		(1) (1) (1) (1)
	d	i	The dark fringes move further away from the central maximum. The intensity of central maximum diminishes.		(1) (1)
		ii	Blue light has a smaller wavelength, making the dark fringes closer to the central maximum. The intensity of central maximum increases.		(1) (1)
	e		By virtue of $\theta_{\min} = 1.22\frac{\lambda}{a}$, for the same aperture diameter and wavelength, the **angle increases**, causing the first dark fringe to **shift further away** from the central maximum when compared to the rectangular slit.		(1) (1) (1)
	f		A bright maximum is obtained when light rays from the two apertures interfere constructively with each other. This occurs when the rays are in phase. A dark minimum is obtained when light rays from the two apertures interfere destructively with each other. This occurs when the rays are out of phase with each other.		(1) (1) (1) (1)
	g		By virtue of $y = \frac{\lambda D}{d}$, if the separation of the slits increases, the fringe separation decreases.		(1) (1)
Total:					**20**
11	a		Following Archimedes' principle, the upthrust force is equal to the weight of the mass displaced, i.e. $\rho_o V g$. This lift is against the weight of the cargo, and the weight of the heated air, $\rho_i V g$. Hence, resolving forces: $\rho_o V g = mg + \rho_i V g$		(1) (1) (1)
	b		The pressures are equal. The bottom of the balloon is open to the external atmospheric pressure.	The specification that the balloon is open is sufficient.	(1) (1)

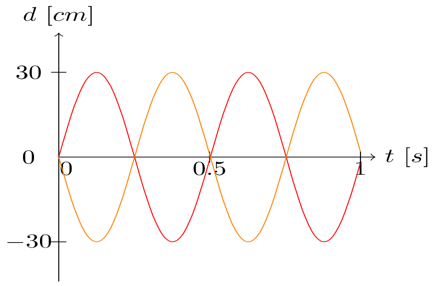
	c		$T_i = \frac{P_i}{P_o}\frac{T_o}{\left(1-\frac{mRT_o}{P_0MV}\right)}$ $= \frac{300}{1-\frac{500\times 8.31\times 300}{101000\times\frac{29}{1000}\times 2000}} = 381\ \mathrm{K}$		(1), (1)
	d		The temperature should be decreased. Decreasing the temperature **increases the density** of the gas making the balloon **sink due to having a larger density than the external air**.		(1) (1) (1)
	e		1. particles are in constant, random motion 2. the particles do not exert forces on one another 3. all collisions are perfectly elastic 4. the particles are considered as hard spheres and their volume is negligible 5. the average kinetic energy of the particles is directly proportional to the temperature of the gas	Any three of the assumptions.	(3)
	f	i	$\langle c^2\rangle$ represents the mean square speed of the particles.		(1)
		ii	$P = \frac{nRT}{V} = \frac{1}{3}\rho\langle c^2\rangle$ $\frac{nRT}{V} = \frac{1}{3}\frac{nM}{V}\langle c^2\rangle$ $\langle c^2\rangle = \frac{3RT}{M}$		(1) (1) (1)
	g			1 mark per graph 1 mark for labelling	(3)
Total:					**20**
12	a		$C = \frac{Q}{V}$ $C = \frac{0.00150}{550} \approx 2.72\ \mu\mathrm{F}$ $E = \frac{1}{2}CV^2$ $E = \frac{0.00000272\cdot 550^2}{2} \approx 411\ \mathrm{mJ}$		(1) (1), (1) (1), (1)
	b		It is hazardous to get shocked by an eel because the electric energy 411 mJ is larger than the threshold 350 mJ and 550 V is larger than the threshold 60 V.		(1) (1)

	c		By $C = \frac{\varepsilon A}{d}$, minimising the distance of the plates increases the capacitance. By $E = \frac{V}{d}$, while keeping the voltage constant the electric field strength inside the capacitor is maximised.		(1) (1) (1)
	d	i	$T = RC$ $T = 100\ \Omega \cdot 0.00000272$ F $T \approx 272\ \mu s$	.	(1) (1) (1)
		ii	 Graph has correct axes: at least 3 time constants in *x*-axis direction and *y*-intercept has 550 V Graph contains correct points (0,550V), (T, 202V), (2T,74V), (3T, 27V) and looks exponential		(1) (1) (1)
	e		Choosing diagram a) with “eels” having heads/positive poles side by side and tails/negative poles side by side. The eels enlarge the area of the plates of the capacitor and therefore the volume inside the plate capacitor is enlarged/increasing the capacitance Enlarging the hazardous space for the prey		(1) (1) (1) (1)
Total:					**20**
13	a			1 mark for circular loops around wire 1 mark for direction	(2)

	b	i	The **voltage decreases**. This is due to a **decrease in the magnetic field strength** as the probe is moved away from the wire.		(1) (1)
		ii	The **voltage is zero.** This is due to the **probe being parallel to the magnetic field**.		(1) (1)
	c		For the same position, the **voltage decreases.** This is by virtue of the equation $V_H = \frac{BI}{nqt}$ where the Hall voltage is inversely proportional to the thickness.		(1) (1)
	d		By virtue of $V_H = \frac{BI}{nqt}$, a metal has a **large number of free charge carriers** which **reduces the hall voltage significantly** making it **unsuitable to measure** magnic flux densities.		(1) (1) (1)
	e	i	For A, the current must be of the same magnitude and same direction.	Accept working through $B = \frac{\mu_0 I}{2\pi r}$	(1) (1)
		ii	For B, the magnetic flux density due to the first wire is $B = \frac{\mu_0 I}{2\pi\times 0.5}$ where due to second wire, $B = \frac{\mu_0 I_2}{2\pi\times 1.5}$. To obtain a zero magnetic flux density, the second current must point in the opposite direction with a magnitude: $\frac{\mu_0 I}{\pi} = \frac{\mu_0 I_2}{3\pi} \rightarrow I_2 = 3I$		(1) (1) (1)
	f		The wire carrying the current *I* experiences a magnetic force to the left due to the magnetic field of the second wire. Similarly, the one with 2I experiences a force to the right due to the field of the left wire. The wires end up repelling each other. Fleming's left hand rule and right-hand grip rule were used.		(1) (1) (1) (1)
Total:					**20**

14	a			$\vec{E}$ may equally be called $\vec{F}$. Entire graph can be mirrored along $\phi = 0$	
		i	Positive charge and negative charge $\phi = 0$ line perpendicular and central between charges $\phi_+ > 0$ can be any of the dashed lines in the left half $\phi_- < 0$ has to be symmetric reflection of ϕ_+		(1) (1) (1) (1)
		ii	Any two of the solid lines with arrows Separate statement: electric lines of force for positive charge start at positive charge (repelling) and point towards negative charge (attracting)		(1) (1)
	b		$F = \frac{Q_1 Q_2}{4\pi\epsilon r^2}$ Q_1 and Q_2 are electric charges of the objects that encounter electric force ϵ is the electric permittivity r is the distance between the two charges		(1) (1) (1) (1)
	c		$\lvert F\rvert = \frac{Q^2}{4\pi\epsilon_0\epsilon_r r^2}$ $\lvert F\rvert = \frac{0.0017^2}{4\pi \cdot 40 \cdot 8.85 \cdot 10^{-12}(0.20)^2}$ $\lvert F\rvert \approx 16\ kN$		(1) (1) (1)
	d		$\lvert E_{tot}\rvert = 2\frac{Q}{4\pi\epsilon r^2}$ $\lvert E_{tot}\rvert = 2\frac{0.0017}{4\pi \cdot 40 \cdot 8.85 \cdot 10^{-12} \cdot 0.10}$ $\lvert E_{tot}\rvert \approx 2 * 3.8 \cdot 10^6\ \mathrm{V\ m^{-1}}$ $\lvert E_{tot}\rvert \approx 7.6 \cdot 10^6\ \mathrm{V\ m^{-1}}$		(1) (1) (1) (1)

	e		$W = V \cdot q$ The potential difference V is 0 because its motion is along an equipotential line. $W = 0$		(1) (1) (1)
Total:					**20**
15	a		$a = -\omega^2 x$	Accept equivalent qualitative statement	(1)
	b		$(m \cdot a = -kx \Rightarrow)\ \ a = -\frac{k}{m}x$ $\omega^2 = \frac{k}{m}$ $\omega = \frac{2\pi}{T}$ $T = 2\pi\sqrt{\frac{m}{k}}$ $T \approx 0.5\ s$	$\omega = \sqrt{\frac{k}{m}}$ is good This line needn't be written out. Implicit use ok.	(1) (1) (1) (1) (1)
	c		 x-axis is time ranging from 0s to at least 1s or equivalently time/T and then ranging from 0 to 2; y-axis is displacement ranging from -40 cm to + 40 cm or equivalently displacement/x_0 and then ranges from -1 to 1. Graph contains points (0s,40cm), (0.125s,0cm), (0.25s,-40cm), (0.375s,0cm), (0.5s,40cm), (0.625s,0cm), (0.75s,-40cm), (0.875s,0cm),(1s,40cm). Graph has cosine shape between the points	Use marking scheme in next row.	(1) (1) (1)
	d		Every peak of the yoyo's motion coincides with a trough of the mass's motion And every trough of the yoyo's motion coincides with a peak of the mass's motion	Equivalent statements with vice versa formulation are acceptable	(1) (1)

	e		 x-axis is time ranging from 0s to at least 1s or equivalently time/T and then ranging from 0 to 2; y-axis is displacement ranging from -30 cm to + 30 cm or equivalently displacement/30cm and then ranges from -1 to 1. Graph contains points (0s, 0cm), (0.125s,$\pm$30cm), (0.25s,0cm), (0.375s, $\mp$30cm), (0.5s,0cm), (0.625s, $\pm$30cm), (0.75s,0cm), (0.875s, $\mp$30cm),(1s,0cm). Graph has sine or negative sine shape between the points	Use marking scheme in next row. Only one of those graphs is required, both are equally valid.	(1) (1) (1)
	f		The student is using his hand shaking motion to force the mass spring system His forcing is periodic (at some frequency potentially different from the system's frequency) The mass system shows (forced) vibrations at the forcing frequency		(1) (1) (1)
	g		The forcing starts at a frequency much larger than the resonant frequency and reaches the resonant frequency at the end. The mass starts off with some (small) amplitude which increases to a bigger amplitude at the end because of resonance		(1) (1) (1)
Total:					**20**

Paper 3

Section A

4

Given that the springs are connected in series, the force acting on each spring is equal to the weight attached.

$\boldsymbol{F = m_T g} = [(\mathbf{2} \times \mathbf{0.0252}) + \mathbf{0.0085}] \times \mathbf{9.81}$

$\boldsymbol{F = 0.578}\ \mathbf{N}$ (1)

Total: 1

5

Let x_T be the total extension of the two-spring system.

$x_T = x_1 + x_2$ where x_1 and x_2 are the extensions of the first and second spring. (1)

$\frac{F}{k_{eq}} = \frac{F}{k_1} + \frac{F}{k_2}$, where k_{eq} is the equivalent spring constant of the two-spring system, k_1 is the spring constant of the first spring and k_2 is the spring constant of the second spring. (1)

Since springs are identical $k_1 = k_2$ (1)

$$\frac{1}{k_{eq}} = \frac{1}{k_1} + \frac{1}{k_2} = \frac{2}{k} \to k_{eq} = \frac{k}{2}$$

Total: 3

6

				1st	2nd	3rd			
n	m /kg	m_H /kg	m_T /kg	T_{20}/s	T_{20} /s	T_{20} /s	$\overline{T_{20}}$ /s	T /s	T^2 /s^2
2				12.91					
3									

(1)

Total: 1

7

				1st	2nd	3rd			
n	m /kg	m_H /kg	m_T /kg	T_{20}/s	T_{20}/s	T_{20}/s	$\overline{T_{20}}$/s	T /s	T^2 /s^2
2				12.91	12.94	13.09			
3									

(2)

Total: 2

8

				1st	2nd	3rd			
n	m /kg	m_H /kg	m_T /kg	T_{20}/s	T_{20}/s	T_{20}/s	$\overline{T_{20}}$/s	T /s	T^2 /s^2
2				12.91	12.94	13.09			
3				15.38	15.38	15.37			
4				17.50	17.54	17.38			
5				19.19	19.31	19.25			
6				20.97	20.87	20.94			

(12)

Total: 12

9

n	m/kg	m_H/kg	m_T/kg	1st T_{20}/s	2nd T_{20}/s	3rd T_{20}/s	$\overline{T_{20}}$/s	T /s	T^2 /s^2
2	0.0504	0.0107	0.0611	12.91	12.94	13.09	12.98	0.649	0.42
3	0.0756	0.0107	0.0863	15.38	15.38	15.37	15.38	0.769	0.59
4	0.1008	0.0107	0.1115	17.50	17.54	17.38	17.47	0.874	0.76
5	0.1260	0.0107	0.1367	19.19	19.31	19.25	19.25	0.963	0.93
6	0.1512	0.0107	0.1619	20.97	20.87	20.94	20.93	1.046	1.09

(5)

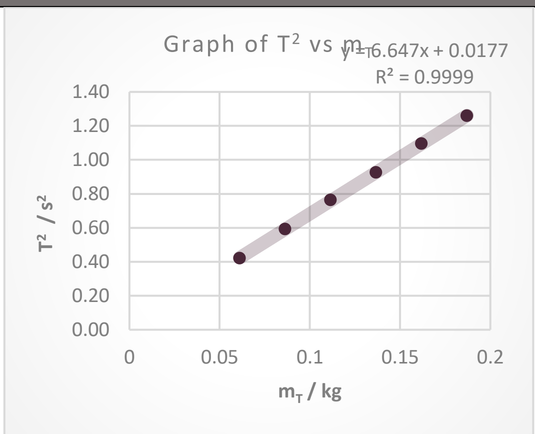
Total: 5

11

Squaring both sides: $T^2 = \frac{4\pi^2 m_T}{k_{eq}}$ (1)

Total: 1

12



Even if data used for the graph from previous table was not correct but candidate plotted a correct graph (subject to mark deductions as indicated above), full marks are given for the correct plot, etc..

Titles and Axis Labels Including Units (2)
Correct Usage of space (2)
Correct Plot (2)
Correct Best Straight Line (2)

Total: 8

13

$$T^2 = \frac{4\pi^2 m_T}{k_{eq}}$$

By comparison with $y = mx + c$

$$Gradient = \frac{4\pi^2}{k_{eq}} \rightarrow k_{eq} = \frac{4\pi^2}{Gradient}$$ (2)

From graph $Gradient = 6.647\ \mathrm{s^2 kg^{-1}}$ (1)

$$k_{eq} = \frac{4\pi^2}{6.647} = 5.94\ \mathrm{N\ m^{-1}}$$

Total: 3

14			$k_{eq} = \frac{k}{2} \rightarrow k = k_{eq} \times 2 = 5.94 \times 2 =$ $11.88\ \text{N m}^{-1}$		(1)
Total:					**1**
15			$\kappa_{wire} = kR^2$ The radius of the coils forming the spring needs to be obtained through direct measurement of the diameter of the coils themselves. From direct measurement $D = 0.015\ \text{m}$ $\rightarrow R = 0.0075\ \text{m}$ $\kappa_{wire} = 11.88 \times 0.0075^2 = 0.000668\ \text{N m}$		(1) (1)
Total:					**2**

Section B

19			Figure 4(a) is the setup with the largest moment of inertia of the stud. Since the moment of inertia depends on the <u>mass</u> and the <u>distance from the axis of rotation</u>, the nuts in Figure 4(a) are further from the axis of rotation than in Figure 4(b). Hence the moment of inertia is larger.		(1)
Total:					**1**
22			(table below)		(1)

		1st	2nd	3rd			
s /m	$d = \frac{s}{2}$ /m	T_{20}/s	T_{20}/s	T_{20}/s	$\overline{T_{20}}/\text{s}$	T/s	T^2/s
0.085		31.59					
0.075							
0.065							
0.055							
0.045							

Total: **1**

23			(table below)		(2)

		1st	2nd	3rd			
s /m	$d = \frac{s}{2}$ / m	T_{20}/s	T_{20}/s	T_{20}/s	$\overline{T_{20}}/\text{s}$	T/s	T^2/s
0.085		31.59	31.75	31.81			
0.075							
0.065							
0.055							
0.045							

Total: **2**

24

		1st	2nd	3rd			
s /m	$d = \frac{s}{2}$ / m	T_{20}/s	T_{20}/s	T_{20}/s	$\overline{T_{20}}/\text{s}$	T/s	T^2/s
0.085		31.59	31.75	31.81			
0.075		29.43	29.47	29.40			
0.065		27.22	27.06	27.06			
0.055		25.25	25.09	25.09			
0.045		23.31	23.28	23.21			

(12)

Total: 12

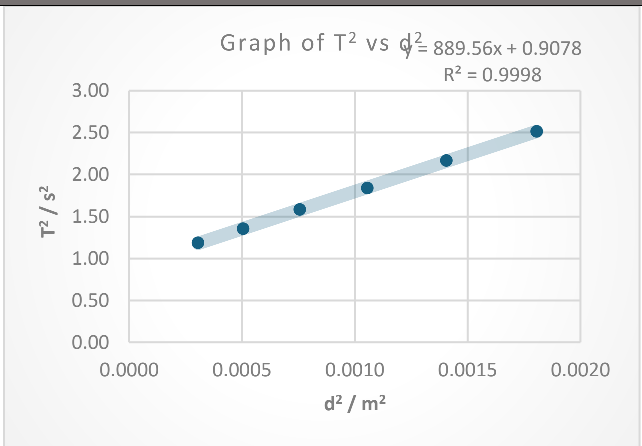
25

			1st	2nd	3rd			
s /m	d /m	d^2 /m^2	T_{20}/s	T_{20}/s	T_{20}/s	$\overline{T_{20}}/\text{s}$	T/s	T^2/s
0.085	0.0425	0.0018	31.59	31.75	31.81	31.72	1.59	2.51
0.075	0.0375	0.0014	29.43	29.47	29.40	29.43	1.47	2.17
0.065	0.0325	0.0011	27.22	27.06	27.06	27.11	1.6	1.84
0.055	0.0275	0.0008	25.25	25.09	25.09	25.14	1.26	1.58
0.045	0.0225	0.0005	23.31	23.28	23.21	23.27	1.16	1.35
0.035	0.0175	0.0003	21.91	21.75	21.72	21.72	1.09	1.19

(5)

Total: 5

27



Titles and Axis Labels Including Units (2)
Correct Usage of space (2)
Correct Plot (2)
Correct Best Straight Line (2)

Even if data used for the graph from previous table was not correct but candidate plotted a correct graph (subject to mark deductions as indicated above), full marks are given for the correct plot, etc..

Total: 8

28

The constant I_0 could represent the combined moment of inertia of the nuts at the centre that are holding the spring and the moment of inertia of the stud itself. (1)

Total: 1

29			$T^2 = \frac{16\pi^2 md^2}{\kappa_{spring}} + \frac{4\pi^2 I_0}{\kappa_{spring}}$ By comparison with $y = mx + c$ $Gradient = \frac{16\pi^2 m}{\kappa_{spring}}$ From graph $Gradient = 889.56\ \mathrm{s^2\ m^{-2}}$ $\rightarrow 889.56 = \frac{16\pi^2 m}{\kappa_{spring}}$ $\rightarrow \kappa_{spring} = \frac{16\pi^2 \times 0.00477}{889.56}$ $= 0.000846\ \mathrm{kg\ m^2\ s^{-2}}$		(2) (1)
Total:					**3**
31			From direct measurement $l = 0.022\ \mathrm{m}$ From direct measurement $N = 31$ $t = \frac{0.022}{31} = 0.00071\ \mathrm{m}$		(1) (1) (1)
Total:					**3**
32			$\kappa_{spring} = \frac{Yt^4}{64DN}$ $\kappa_{spring} = \frac{99.5 \times 10^9 \times 0.00071^4}{64 \times 0.015 \times 31}$ $\kappa_{spring} = 0.000849\ \mathrm{kg\ m^2\ s^{-2}}$		(1) (1)
Total:					**2**
33			There is <u>no</u> relationship between the torsional constant of the wire itself and the torsional spring constant. The torsional constant of the wire is the amount of torque needed to rotate one end of a wire by 1 radian about the longitudinal axis of the wire with the other end being fixed whereas the torsional spring constant is analogous to the spring constant of a linear spring – equivalent to the ratio of the applied torque to an angular 'extension'.	Accept Sources of Error and Corresponding Precautions that make sense.	(2)
Total:					**2**
34			The value of t greatly effects the value of κ_{spring} given that it is to the order of 4.		(1)
Total:					**1**