Markscheme

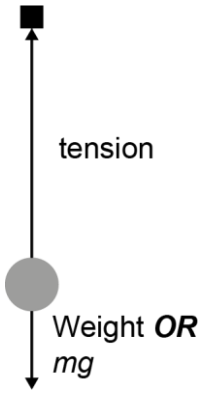
May 2023

Physics

Higher level

Paper 2

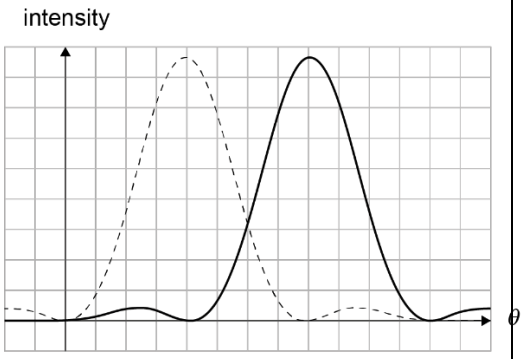
17 pages

Question			Answers	Notes	Total
1.	**a**	**i**	Tension upwards, weight downwards✓ Tension is clearly longer than weight✓	*Look for:*  	**2**
1	**a**	**ii**	$v = \sqrt{2 \times 9.81 \times 0.95}$ ***OR*** $= 4.32$ **«**m s^{-1}**»** ✓	*Must see either full substitution or answer to at least 3 s.f.*	**1**
1	**a**	**iii**	$T\text{-}mg = F_{\text{net}}$ ***OR*** $T - mg = \frac{mv^2}{r}$ ✓ T **«**$= 0.800 \times 9.81 + \frac{0.800 \times 4.317^2}{0.95}$**»** $= 23.5$ **«**N**»** ✓		**2**
1	**b**	**i**	Use of conservation of momentum. ✓ Rebound speed = 2.16 **«** m s^{-1}**»** ✓ Calculation of initial KE = **«** $\frac{1}{2} \times 0.800 \times 4.317^2$ **»** = 7.46 **«** J **»** ✓ Calculation of final KE = **«** $\frac{1}{2} \times 0.800 \times 2.16^2 + \frac{1}{2} \times 2.40 \times 2.16^2$ **»** = 7.46 **«**J**»** ✓ **«**hence elastic**»**		**4**

Question			Answers	Notes	Total
1	b	ii	***ALTERNATIVE 1*** Rebound speed is halved so energy less by a factor of 4 ✓ Hence height is $\frac{95}{4}$ =23.8 **«**cm**»** ✓ ***ALTERNATIVE 2*** Use of conservation of energy / $\frac{1}{2}\times 0.800\times 2.16^2 = 0.800\times 9.8\times h$ ***OR*** Use of proper kinematics equation (e.g. 0 = 2.16^2 - 2 x 9.8 x h) ✓ *h* = 23.8 **«**cm**»** ✓	*Allow **ECF** from **b(i)***	**2**
1	c		***ALTERNATIVE 1*** Frictional force is f **«**$= 0.400\times 2.40\times 9.81$**»** $= 9.42$ **«**N**»** ✓ $9.42\times d = \frac{1}{2}\times 2.40\times 2.16^2$ ***OR*** $d = \frac{5.5987}{9.42}$ ✓ $d = 0.594$**«**m**»** ✓ ***ALTERNATIVE 2*** $a =$ **«**$\frac{f}{m} = \mu g = 0.4\times 9.81$**=»** 3.924 «m s^{-2}» ✓ Proper use of kinematics equation(s) to determine ✓ *d* = 0.594 «m» ✓		**3**

Question			Answers	Notes	Total
2.	**a**		Reads change in temperature to be 45 – 31 ***OR*** 14 °C ✓ $Q = 0.082 \times 1.6 \times 10^3 \times 14 = 1.84 \times 10^3$ **«J»** ✓ $P = \frac{1.84 \times 10^3}{2.0 \times 60} = 15.3 \approx 15$**«W»** ✓	*Must see either full substitution* ***OR*** *answer to at least 3 s.f. in* ***MP3***	**3**
2	**b**		$Q = 15.3 \times 4.0 \times 60 = 3.67 \times 10^3$ **«J»** ✓ $L = \frac{3.67 \times 10^3}{0.082} = 4.5 \times 10^4$ **«J kg^{-1}»** ✓		**2**
2	**c**		Internal energy is greater at t = 6 min ***OR*** internal energy is lower at t = 2 min ***OR*** internal energy increases **«**as energy is added to the system**»** ✓ Because kinetic energy **«**of the molecules**»** is the same ***AND*** potential energy **«**of the molecules**»** has increased / ***OWTTE*** ✓		**2**

Question			Answers	Notes	Total
3.	**a**	**i**	**«**A wave where the**»** displacement of particles/oscillations of particles/movement of particles/vibrations of particles is perpendicular/normal to the direction of energy transfer/wave travel/wave velocity/wave movement/wave propagation ✓	*Allow medium, material, water, molecules, or atoms for particles.*	**1**
3	**a**	**ii**	$v = «0.50 \times 16 =» 8.0$ **«**m s^{-1}**»** ✓		**1**
3	**a**	**iii**	P at (8,1.2) ✓		**1**
3	**a**	**iv**	***ALTERNATIVE 1*** Phase difference is $\frac{2\pi}{\lambda} \times \frac{\lambda}{2}$ ✓ **«**= π » ***ALTERNATIVE 2*** One wavelength/period represents **«**phase difference**»** of 2π and **«**corks**»** are ½ wavelength/period apart so phase difference is π/***OWTTE*** ✓		**1**
3	**b**		light acts as a wave **«**and not a particle in this situation**»** ✓ light at slits will diffract / create a diffraction pattern ✓ light passing through slits will interfere / create an interference pattern **«**creating bright and dark spots**»** ✓		**2 max**

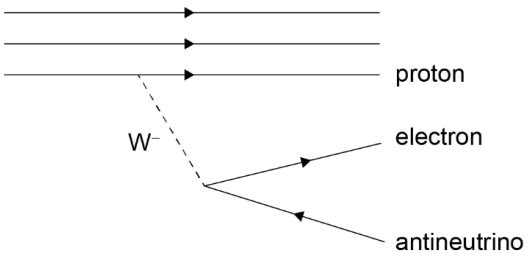
Question			Answers	Notes	Total
3	c	i	The amplitude «at $x = 0$» will be doubled ✓ intensity is proportional to amplitude squared / $I \propto A^2$ ✓		2
3	c	ii	Use of $s = \frac{\lambda D}{d} \Rightarrow \lambda = \frac{sd}{D}$ ***OR*** $s = \frac{n\lambda D}{d} \Rightarrow \lambda = \frac{sd}{nD}$ ✓ $\lambda =$ «$\frac{0.567\times10^{-2}\times0.18\times10^{-3}}{2.2}$ =»4.6×10^{-7} «m» ✓		2
3	c	iii	Stays the same: Position/location of maxima/distance/separation between maxima «will be the same» ***/ OWTTE***✓ Changes: Intensity/brightness/width/sharpness «of maxima will change»***/ OWTTE***✓	*Allow other phrasing for maxima (fringes, spots, etc).*	2
3	d	i	Maximum coinciding with first minimum ***AND*** minimum coinciding with maximum✓	 *Allow a graph drawn to the left of the original graph with these same characteristics.*	1

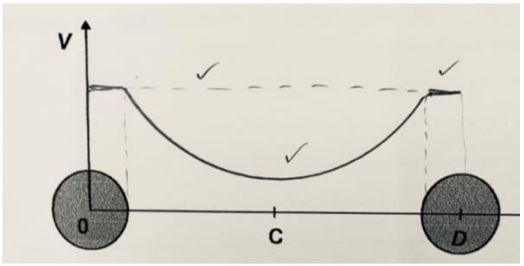
Question			Answers	Notes	Total
3	d	ii	***ALTERNATIVE 1*** $\frac{d}{D} = 1.22 \times \frac{\lambda}{b}$ therefore $d = \frac{1.22 \times \lambda \times D}{b}$ ✓ **«**$d \approx 1.22 \times \frac{3.2 \times 10^{-2} \times 1.1 \times 10^{23}}{300}$**»** $= 1.4 \times 10^{19}$ **«**m**»** ✓ ***ALTERNATIVE 2*** $\theta =$ **«**$1.22 \frac{\lambda}{b} = 1.22 \times \frac{3.2 \times 10^{-2}}{300}$ **=»** 1.3 x 10^{-4} **«**radians**»** ✓ d = «(1.1 x 10^{23})(1.3 x 10^{-4}) **=»** 1.4 x 10^{19} «m» ✓		2

Question			Answers	Notes	Total
4.	**a**	**i**	Voltage across P is 1.4 **«**V**»** ✓ Voltage across Q is 4.6 **«**V**»** ✓ And 6 – 1.4 = 4.6 **«**V**»** ✓	*Need to see a calculation involving the two voltages and the total voltage in the circuit for **MP3** (e.g. 1.4 + 4.6 = 6).*	**3**
4	**a**	**ii**	Current in R is **«(**0.45 - 0.4)=**»** 0.05 A ✓ So resistance is **«**$\frac{1.4}{0.05}$**»** $= 28$ **«**Ω**»** ✓	*Allow **ECF** from **a(i)*** *Allow **ECF** from **MP1***	**2**
4	**a**	**iii**	**«**0.45×6.0**»** $= 2.7$ **«**W **»** ✓		**1**
4	**b**		Q will have a smaller resistance ✓ **«**Because total resistance in the circuit is now larger so**»** the current **«**through the circuit/Q**»** is smaller / ***OWTTE*** ✓	*Allow similar argument for **MP2** based on voltage across* Q *becoming smaller.*	**2**

Question			Answers	Notes	Total
5.	**a**		Weak nuclear: 2 ticks ✓ Strong nuclear: quarks only ✓		**2**
5	**b**	**i**	**«**μ**»** = 2.0141 + 3.0160 - (4.0026 + 1.008665) **«**= 0.0188 u**»** ***OR*** *In* MeV*:* 1876.13415 + 2809.404 - (3728.4219 + 939.5714475) ✓ $=0.0188\times931.5$ ***OR*** $=17.512$ **«**MeV**»** ✓	*Must see either clear substitutions or answer to at least 3 s.f. for* ***MP2****.*	**2**

Question			Answers	Notes	Total
5	b	ii	***ALTERNATIVE 1*** 0.40 kg of deuterium is **«**$\frac{400}{2}\times 6.02\times 10^{23}$**»** $= 1.2\times 10^{26}$ nuclei **«**0.60 kg of tritium is the same number**»** ✓ So specific energy **«**$\frac{1.2\times 10^{26}\times 17.51\times 10^{6}\times 1.6\times 10^{-19}}{0.4+0.6}$**»** = 3.4 x 10^{14} «J kg^{-1} » ✓ ***ALTERNATIVE 2*** «17.51x10^{6} x 1.6x10^{-19} =» 2.8x10^{-12} «J» ***AND*** «(2.0141 + 3.0160) x 1.66x10^{-27} =» 8.35x10^{-27} ✓ **«**$\frac{2.8\times 10^{-12}}{8.35\times 10^{-37}}$**»** $= 3.4\times 10^{14}$ **«**Jkg^{-1}**»** ✓	*Allow ~2.1 x 10^{27}* MeV kg^{-1} *for **MP2**.* *Allow **ECF** from **MP1** for both **ALTs.***	**2**
5	c	i	Requires high temp/pressure ✓ Must overcome Coulomb/intermolecular repulsion ✓ Difficult to contain / control «at high temp/pressure» ✓ Difficult to produce excess energy/often energy input greater than output / ***OWTTE*** ✓ Difficult to capture energy from fusion reactions ✓ Difficult to maintain/sustain a constant reaction rate ✓		**2 max**
5	c	ii	Plentiful fuel supplies ***OR*** larger specific energy ***OR*** larger energy density ***OR*** little or no **«**major radioactive**»** waste products ✓	*Allow descriptions such as "more energy per unit mass" or "more energy per unit volume"*	**1**

5	**d**	**i**	3 ✓	*Do **not** accept* $^{3}_{2}He$ *by itself.*	**1**
5	**d**	**ii**	Proton shown ✓ W- shown ✓ Produces electron/e $^{-}$ / β^{-} and antineutrino / $\overline{\upsilon}$ with proper arrow directions. ✓	 *Allow solid, dashed, or wavy line for* W- *particle.* *Must see bar on antineutrino if symbol used.*	**3**
5	**d**	**iii**	$\lambda = \frac{\ln 2}{12.3}$ **«»** $0.056\ «y^{-1}»$ ***OR*** $0.5^{\frac{1}{12.3}}$ ***OR*** $e^{-1\times\frac{\ln 2}{12.3}}$ ✓ 0.945 ***OR*** 94.5% ✓	*Allow **ECF** from **MP1***	**2**

Question			Answers	Notes	Total
6.	**a**	**i**	Constant, non-zero within spheres ✓ A clear, non-zero positive minimum at C ✓ Symmetric bowl shaped up curved shape in between ✓	 *Do **not** allow a bowl shaped down curve for **MP3.***	**3**
6	**a**	**ii**	V «$= 2\times\frac{8.99\times10^{9}\times2.0\times10^{-3}}{0.60}$» $= 6.0\times10^{7}$ «V» ✓ W = «qV = 6.0x10^{7} x 4.0x10^{-9} =» 0.24 «J» ✓	*Allow **ECF** from **MP1***	**2**
6	**b**	**i**	The restoring force/acceleration is opposite to the displacement/towards equilibrium / ***OWTTE*** ✓ and proportional to displacement from equilibrium / ***OWTTE***✓	*Allow discussions based on the diagram (such as towards C for towards equilibrium).* *Accept $F \propto x$ **OR** $a \propto x$ for **MP2***	**2**
6	**b**	**ii**	$\omega = \sqrt{\frac{32kQq}{mD^3}}$ ***OR*** use of $F = m\omega^2 r$ ***OR*** F = 1.33x ***OR*** a = 53.3x ✓ «$= \sqrt{\frac{32\times8.99\times10^{9}\times2.0\times10^{-3}\times4.0\times10^{-9}}{0.025\times1.2^{3}}}$» $= 7.299$ «s^{-1}» ✓		**2**

Question			Answers	Notes	Total
6	**c**		the net force will no longer be a restoring force/directed towards equilibrium ***OR*** the gravitational force is attractive/neutral mass would be pulled towards larger masses/***OWTTE*** ✓ **«**and so**»** no, motion will not be the same/no longer be SHM / ***OWTTE*** ✓		**2**

Question			Answers	Notes	Total
7.	**a**		The induced emf is equal/proportional/related to the **«**rate of**»** change of **«**magnetic**»** flux/flux linkage ✓ Flux is changing because the area pierced/enclosed by magnetic field lines changes **«**decreases**»** ***OR*** Flux is changing because the loop is leaving/moving out of the **«**magnetic**»** field**.** ✓	*Need to see a connection between the EMF and change in flux for **MP1**.* *Need to see a connection between the area changing or leaving the field and the change in flux for **MP2***	**2**
7	**b**		$mg = BIL$ ***OR*** I = 0.33 **«**A**»** ✓ $BvL=IR$ ***OR*** $\mathcal{E}$ = 8.25x10^{-3} **«**V**»** ***OR*** $\mathcal{E} = 0.12v$ ✓ Combining results to get $v = \frac{mgR}{B^2L^2}$ ✓ $v = \text{«}\frac{0.0040 \times 9.81 \times 0.025}{0.80^2 \times 0.15^2} \text{=»} 0.068$ **«**m s^{-1}**»** ✓	*Allow **ECF** **b**etween steps if clear work is shown.*	**4**
7	**c**	**i**	The 2 in parallel give a total of 6.0 «μF» ✓ The total is $\text{«}\left(\frac{1}{3}+\frac{1}{6}\right)^{-1}\text{»} = 2.0$ «μF» ✓	*Allow **ECF** from **MP1*** *Accept other powers of 10 for capacitances with proper unit included.*	**2**
7	**c**	**ii**	$E = \text{«}\frac{1}{2}CV^2 = \frac{1}{2} \times 2.0 \times 10^{-6} \times 12^2 \text{»} 1.44 \times 10^{-4}$ **«**J**»** ✓	*Allow **ECF** from **c(i)** (=72 x **c(i)**)*	**1**

7	**c**	**iii**	***ALTERNATE 1*** Voltage across C_2 is half that across C_1 ✓ So voltage across C_2 is 4.0 V ✓ Charge is «$C_2V_2 = 2.0\times10^{-6}\times4.0$»$8.0\times10^{-6}$ «C» ✓ ***ALTERNATE 2*** Charge on C_1 is «$C_TV_T = 2.0\times10^{-6}\times12$»24«μC» ✓ So voltage across C_1 is «$\frac{24}{3.0}$»8.0«V» ✓ Charge on C_2 is «$C_2V_2 = 2.0\times10^{-6}\times4.0$» 8.0×10^{-6} «C» ✓ ***ALTERNATE 3*** «$C_3 = 2C_2$ leading to » $q_3 = 2q_2$ ✓ Total charge in parallel = «$q_2 + q_3 = q_2 + 2q_2$ =» $3q_2$ ✓ $3q_2 = 24$ leading to $q_2 = 8 \times 10^{-6}$ «C» ✓	***ECF*** *for* ***MP3*** *allowed in* ***ALT 1*** *and* ***ALT 2***	**3**

Question			Answers	Notes	Total
8.	**a**	**i**	Use of $E_{max} = \frac{hc}{\lambda} - \phi \Rightarrow \phi = \frac{hc}{\lambda} - E_{max}$ ✓ $\phi = \text{«}\frac{hc}{\lambda} - E_{max} = \frac{\left(6.63\times10^{-34}\right)\left(3\times10^{8}\right)}{\left(468\times10^{-9}\right)\left(1.6\times10^{-19}\right)} - 1.8\text{»} = 0.85625 \approx 0.86$ **«**eV**»** ✓		**2**
8	**a**	**ii**	Use of $\frac{hc}{\lambda} = \phi \Rightarrow \lambda = \frac{hc}{\phi}$ ✓ $\lambda = \text{«}\frac{\left(6.63\times10^{-34}\right)\left(3\times10^{8}\right)}{\left(468\times10^{-9}\right)\left(1.6\times10^{-19}\right)} = \text{»}1.45\times10^{-6}$ **«**m**»** ✓	*Allow **ECF** from **a(i)***	**2**
8	**b**	**i**	2e ***AND*** 82e seen ***OR*** $3.2\text{x}10^{-19}$ **«**C**»** ***AND*** $1.312\text{x}10^{-17}$ **«**C**»** seen ✓ $d = \frac{8.99\times10^{9}\times(2e)(82e)}{5.9\times10^{6}\times e} = 3.998\times10^{-14} \approx 4\times10^{-14}$ **«**m**»** ✓	*Must see either clear substitutions or answer to at least 4 s.f. for **MP2**.*	**2**
8	**b**	**ii**	The closest approach is **«**significantly**»** larger than the radius of the nucleus / far away from the nucleus/***OWTTE*****.** ✓ **«**Therefore**»** the strong nuclear force will not act on the alpha particle.✓		**2**