

Markscheme

May 2023

Physics

Higher level

Paper 2

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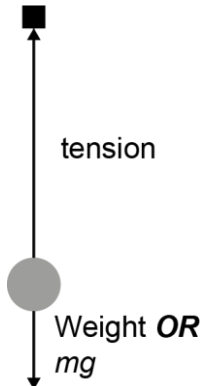
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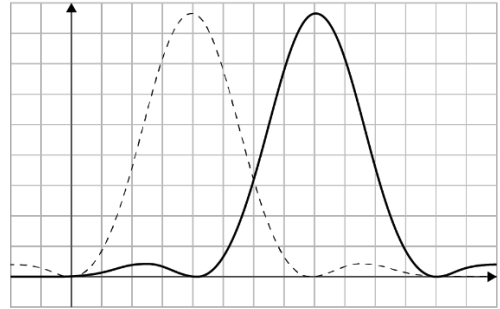
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Question			Answers	Notes	Total
1.	a	i	Tension upwards, weight downwards ✓ Tension is clearly longer than weight ✓	Look for: 	2
1	a	ii	$v = \sqrt{2 \times 9.81 \times 0.95}$ OR $= 4.32 \text{ «ms}^{-1}\text{»}$ ✓	Must see either full substitution or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

Question			Answers	Notes	Total
1	b	ii	<p>ALTERNATIVE 1 Rebound speed is halved so energy less by a factor of 4 ✓ Hence height is $\frac{95}{4} = 23.8$ «cm» ✓</p> <p>ALTERNATIVE 2 Use of conservation of energy / $\frac{1}{2} \times 0.800 \times 2.16^2 = 0.800 \times 9.8 \times h$</p> <p>OR Use of proper kinematics equation (e.g. $0 = 2.16^2 - 2 \times 9.8 \times h$) ✓ $h = 23.8$ «cm» ✓</p>	Allow ECF from b(i)	2
1	c		<p>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» ✓</p> <p>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» ✓</p>		3

Question		Answers	Notes	Total
2.	a	<p>Reads change in temperature to be 45 – 31 OR 14 °C ✓</p> <p>$Q = 0.082 \times 1.6 \times 10^3 \times 14 = 1.84 \times 10^3$ «J» ✓</p> <p>$P = \frac{1.84 \times 10^3}{2.0 \times 60} = 15.3 \approx 15$ «W» ✓</p>	<p><i>Must see either full substitution OR answer to at least 3 s.f. in MP3</i></p>	3
2	b	<p>$Q = 15.3 \times 4.0 \times 60 = 3.67 \times 10^3$ «J» ✓</p> <p>$L = \frac{3.67 \times 10^3}{0.082} = 4.5 \times 10^4$ «J kg⁻¹» ✓</p>		2
2	c	<p>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» ✓</p> <p>Because kinetic energy «of the molecules» is the same AND potential energy «of the molecules» has increased / OWTTE ✓</p>		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 ✓	<i>Allow medium, material, water, molecules, or atoms for particles.</i>	1
3	a	ii	$v = \llcorner 0.50 \times 16 \Rightarrow \llcorner 8.0 \llcorner \text{ms}^{-1} \llcorner$ ✓		1
3	a	iii	P at (8,1.2) ✓		1
3	a	iv	<p>ALTERNATIVE 1</p> <p>Phase difference is $\frac{2\pi}{\lambda} \times \frac{\lambda}{2}$ ✓</p> <p>«= π »</p> <p>ALTERNATIVE 2</p> <p>One wavelength/period represents «phase difference» of 2π and «corks» are $\frac{1}{2}$ wavelength/period apart so phase difference is π/OWTTE ✓</p>		1
3	b		<p>light acts as a wave «and not a particle in this situation» ✓</p> <p>light at slits will diffract / create a diffraction pattern ✓</p> <p>light passing through slits will interfere / create an interference pattern «creating bright and dark spots» ✓</p>		2 max

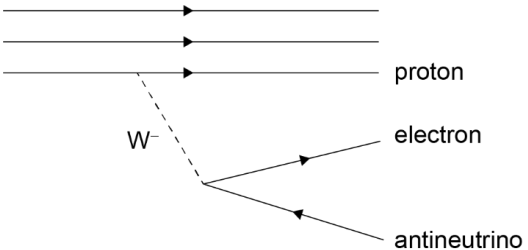
Question			Answers	Notes	Total
3	c	i	The amplitude «at $x = 0$ » will be doubled ✓ intensity is proportional to amplitude squared / $I \propto A^2$ ✓		2
3	c	ii	Use of $s = \frac{\lambda D}{d} \Rightarrow \lambda = \frac{sd}{D}$ OR $s = \frac{n\lambda D}{d} \Rightarrow \lambda = \frac{sd}{nD}$ ✓ $\lambda = \left\langle \frac{0.567 \times 10^{-2} \times 0.18 \times 10^{-3}}{2.2} \right\rangle \Rightarrow 4.6 \times 10^{-7}$ «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 ✓	<p>intensity</p>  <p>Allow a graph drawn to the left of the original graph with these same characteristics.</p>	1

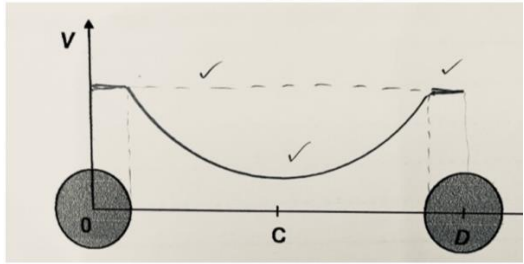
Question			Answers	Notes	Total
3	d	ii	<p>ALTERNATIVE 1</p> $\frac{d}{D} = 1.22 \times \frac{\lambda}{b} \text{ therefore } d = \frac{1.22 \times \lambda \times D}{b} \checkmark$ $\llcorner d \approx 1.22 \times \frac{3.2 \times 10^{-2} \times 1.1 \times 10^{23}}{300} \llcorner = 1.4 \times 10^{19} \text{ «m» } \checkmark$ <p>ALTERNATIVE 2</p> $\theta = \llcorner 1.22 \frac{\lambda}{b} = 1.22 \times \frac{3.2 \times 10^{-2}}{300} \llcorner = 1.3 \times 10^{-4} \text{ «radians» } \checkmark$ $d = \llcorner (1.1 \times 10^{23})(1.3 \times 10^{-4}) \llcorner = 1.4 \times 10^{19} \text{ «m» } \checkmark$		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	$\langle \mu \rangle = 2.0141 + 3.0160 - (4.0026 + 1.008665) \langle = 0.0188 \text{ u} \rangle$ OR <i>In MeV:</i> $1876.13415 + 2809.404 - (3728.4219 + 939.5714475) \checkmark$ $= 0.0188 \times 931.5 \text{ OR } = 17.512 \langle \text{MeV} \rangle \checkmark$	<i>Must see either clear substitutions or answer to at least 3 s.f. for MP2.</i>	2

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

5	d	i	3 ✓	<i>Do not accept ${}^3_2\text{He}$ by itself.</i>	1
5	d	ii	Proton shown ✓ W- shown ✓ Produces electron/e ⁻ / β ⁻ and antineutrino / $\bar{\nu}$ with proper arrow directions. ✓	 <p><i>Allow solid, dashed, or wavy line for W-particle.</i> <i>Must see bar on antineutrino if symbol used.</i></p>	3
5	d	iii	$\lambda = \left\langle \frac{\ln 2}{12.3} \right\rangle 0.056 \text{ «y}^{-1}\text{» OR } 0.5^{\frac{1}{12.3}} \text{ OR } e^{-1 \times \frac{\ln 2}{12.3}} \checkmark$ 0.945 OR 94.5% ✓	<i>Allow ECF from MP1</i>	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 ✓	 <p>Do not allow a bowl shaped down curve for MP3.</p>	3
6	a	ii	$V = 2 \times \frac{8.99 \times 10^9 \times 2.0 \times 10^{-3}}{0.60} = 6.0 \times 10^7 \text{ «V» } \checkmark$ $W = \text{«}qV = 6.0 \times 10^7 \times 4.0 \times 10^{-9} \text{»} = 0.24 \text{ «J» } \checkmark$	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	$\omega = \sqrt{\frac{32kQq}{mD^3}} \text{ OR use of } F = m\omega^2 r \text{ OR } F = 1.33x \text{ OR } a = 53.3x \checkmark$ $\text{«} = \sqrt{\frac{32 \times 8.99 \times 10^9 \times 2.0 \times 10^{-3} \times 4.0 \times 10^{-9}}{0.025 \times 1.2^3}} \text{»} = 7.299 \text{ «s}^{-1}\text{» } \checkmark$		2

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

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

7	c	iii	<p>ALTERNATE 1</p> <p>Voltage across C_2 is half that across C_1 ✓</p> <p>So voltage across C_2 is 4.0 V ✓</p> <p>Charge is «$C_2 V_2 = 2.0 \times 10^{-6} \times 4.0$» 8.0×10^{-6} «C» ✓</p> <p>ALTERNATE 2</p> <p>Charge on C_1 is «$C_1 V_1 = 2.0 \times 10^{-6} \times 12$» 24 «μC» ✓</p> <p>So voltage across C_1 is «$\frac{24}{3.0}$» 8.0 «V» ✓</p> <p>Charge on C_2 is «$C_2 V_2 = 2.0 \times 10^{-6} \times 4.0$» 8.0×10^{-6} «C» ✓</p> <p>ALTERNATE 3</p> <p>«$C_3 = 2C_2$ leading to » $q_3 = 2q_2$ ✓</p> <p>Total charge in parallel = «$q_2 + q_3 = q_2 + 2q_2 =$» $3q_2$ ✓</p> <p>$3q_2 = 24$ leading to $q_2 = 8 \times 10^{-6}$ «C» ✓</p>	<p><i>ECF for MP3 allowed in ALT 1 and ALT 2</i></p>	3
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Question			Answers	Notes	Total
8.	a	i	Use of $E_{\max} = \frac{hc}{\lambda} - \phi \Rightarrow \phi = \frac{hc}{\lambda} - E_{\max} \checkmark$ $\phi = \left\langle \frac{hc}{\lambda} - E_{\max} = \frac{(6.63 \times 10^{-34})(3 \times 10^8)}{(468 \times 10^{-9})(1.6 \times 10^{-19})} - 1.8 \right\rangle = 0.85625 \approx 0.86 \text{ «eV»} \checkmark$		2
8	a	ii	Use of $\frac{hc}{\lambda} = \phi \Rightarrow \lambda = \frac{hc}{\phi} \checkmark$ $\lambda = \left\langle \frac{(6.63 \times 10^{-34})(3 \times 10^8)}{(468 \times 10^{-9})(1.6 \times 10^{-19})} \right\rangle = 1.45 \times 10^{-6} \text{ «m»} \checkmark$	Allow ECF from a(i)	2
8	b	i	2e AND 82e seen OR 3.2x10 ⁻¹⁹ «C» AND 1.312x10 ⁻¹⁷ «C» seen \checkmark $d = \frac{8.99 \times 10^9 \times (2e)(82e)}{5.9 \times 10^6 \times e} = 3.998 \times 10^{-14} \approx 4 \times 10^{-14} \text{ «m»} \checkmark$	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 . \checkmark «Therefore» the strong nuclear force will not act on the alpha particle. \checkmark		2