GCE MARKING SCHEME

PHYSICS
AS/Advanced

SUMMER 2012

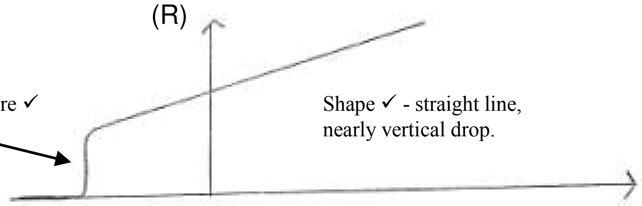
INTRODUCTION

The marking schemes which follow were those used by WJEC for the Summer 2012 examination in GCE PHYSICS. They were finalised after detailed discussion at examiners' conferences by all the examiners involved in the assessment. The conferences were held shortly after the papers were taken so that reference could be made to the full range of candidates' responses, with photocopied scripts forming the basis of discussion. The aim of the conferences was to ensure that the marking schemes were interpreted and applied in the same way by all examiners.

It is hoped that this information will be of assistance to centres but it is recognised at the same time that, without the benefit of participation in the examiners' conferences, teachers may have different views on certain matters of detail or interpretation.

WJEC regrets that it cannot enter into any discussion or correspondence about these marking schemes.

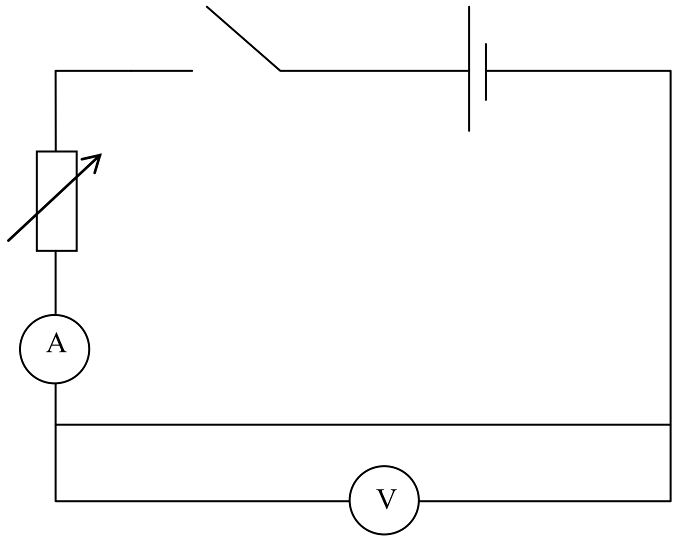
Question			Marking details	Marks Available
1	*(a)*	(i)	$I \propto V$ (1) Providing the temperature / physical conditions remain constant (1)	2
		(ii)	V A^{-1} circled	1
	(b)	(i)	**Switch combination** / **P** / **Q** / **S** **X** open, **Y** open: On, On, Off **X** closed, **Y** open: Off, On, Off (1) **X** open, **Y** closed: On, On, On (1) **X** closed, **Y** closed: Off, On, On (1)	3
		(ii)	**Either** $R = \frac{9}{0.18}$ (1) (= 50 Ω) → $R_P + R_Q = 50$ (1) R_{each} buzzer = 25[Ω] (1) ecf between 2nd and 3rd marks **Or** $R = \frac{4.5\ (1)}{0.18}$ (1) = 25[Ω] (1)	3
		(iii)	$R_{Total} = 16\frac{2}{3}$ [Ω] (1) $I = \frac{9}{16\frac{2}{3}}$ = 0.54 [A] (1) ecf from (b)(ii) / no ecf for R_{Total}	2
		(iv)	<u>**Either**</u> ecf from (b)(ii) or (b)(iii) or both $P_S = \left(\frac{2}{3} \times 0.54\right)^2 \times 25$ (1) $P_S = 3.24$ [W] $P_Q = \left(\frac{1}{3} \times 0.54\right)^2 \times 25$ (1) $P_Q = 0.81$ [W] <u>**Or**</u> $P_S = \frac{9^2}{25}$ (1) = 3.24 [W] $P_Q = \frac{4.5^2}{25}$ (1) = 0.81 [W] <u>**Or**</u> $P_S = \frac{2}{3} \times 0.54 \times 9$ (1)= 3.24 [W] $P_Q = \frac{1}{3} \times 0.54 \times 4.5$ (1) = 0.81 [W] → $\frac{3.24}{0.81} = 4$ (1) or any correct algebraic solution = 3 marks	3
			Question 1 total	**[14]**

Question			Marking details	Marks Available
2	*(a)*		A material with zero/negligible resistance	1
	(b)	(i)	Transition temperature (accept critical temperature)	1
		(ii)	 If axes labelled, must be correct.	2
		(iii)	0 / negligible / almost zero	1
	(c)		Collisions between free/delocalised/flowing/conducting electrons and ions/atoms in lattice/atoms/particles (1) increase vibrations of ions /atoms / particles **or** electrons transfer KE to ions (1)	2
			Question 2 Total	**[7]**

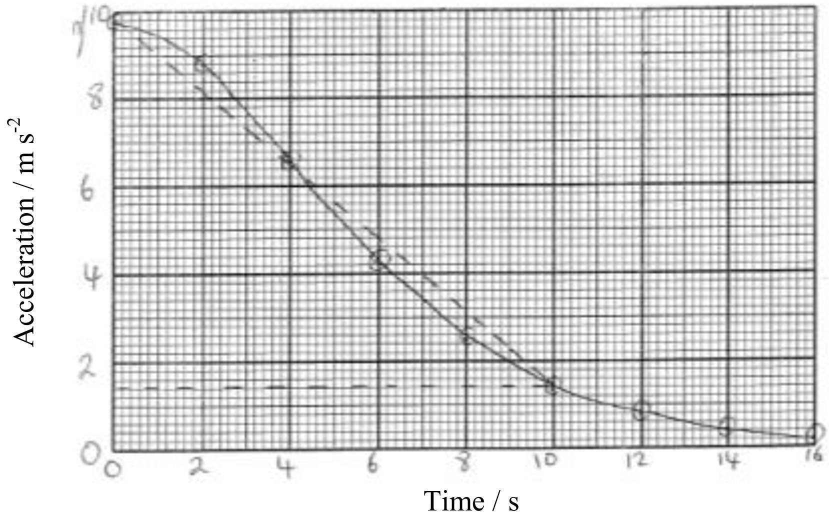
Question			Marking details	Marks Available
3	*(a)*	(i)	12 Joules per coulomb (1) Supplied from cell / source / battery / chemical to electrical (1)	2
		(ii)	Energy lost in the resistance of cell	1
	(b)		$\left\{\frac{3.6(1)}{120}\right\}$ = 0.03 [Ω] (1)	2
	(c)		$I = \frac{12}{0.03} =$ 400 [A] ecf from (b)	1
	(d)	(i)	$Q = 3 \times [(16 \times 60^2)$ or 57 600 (1)] = 172800 [C] (1)	2
		(ii)	$t = \frac{172{,}800}{120}$ = 1440 seconds / 24 mins **UNIT mark** Allow ecf from (d) (i)	1
			Question 3 Total	**[9]**

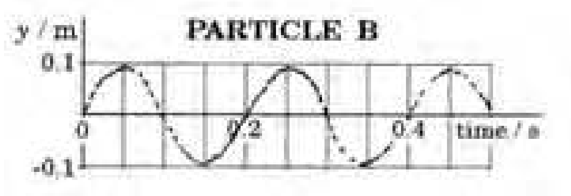
Question			Marking details	Marks Available
4	*(a)*		**<u>All 4 positions considered, 2 relevant statements per position</u>** At start (A): E_{Grav} – max; E_k – zero; $E_{Elastic}$ – zero (1) Free fall, Cord slack(B): E_{Grav} – decreasing; E_k – increasing; $E_{Elastic}$ – zero (1) Cord stretching (C): E_{Grav} – decreasing; E_k – increasing or decreasing; $E_{Elastic}$ – increasing (1) At lowest point (D): E_{Grav} – minimum (accept zero if explained); E_k – zero; $E_{Elastic}$ – maximum (1) 5th mark available for other general comment e.g. Some of initial energy lost due to air resistance / rope gets hot (1) Don't accept statement of the conservation of energy on its own.	5
	(b)	(i)	$E_{p\text{ loss}}$ = 70 x 9.8[1] x 130 (1) substitution (not $g = 10\text{ m s}^{-2}$) = 89 271 [J] (1) (accept 89 300 or 89 000)	2
		(ii)	$89271 = \frac{1}{2}k(50)^2$ (2) [1 mark for $E_{p\text{ loss}} = \frac{1}{2}kx^2$; 1 mark for 50 [m]] $k = 71.4$ [N m^{-1}] (1) ecf from (b)(i)	3
		(iii)	$mg = kx$ (1) $= \frac{70 \times 9.81}{71.4}$ = 9.6 [m] (1) ecf on k from (b)(ii) N.B. Only penalise once for use of $g = 10\text{ m s}^{-2}$	2
			Question 4 total	**[12]**

Question			Marking details	Marks Available
5	*(a)*	(i)	$v_H = 16\cos 40°$ (1) = 12.3 [m s^{-1}]	
			$v_V = 16\sin 40°$ (1) = 10.3 [m s^{-1}]	2
		(ii)	Horizontal: constant velocity Vertical: acceleration / changing (both statements required)	1
	(b)	(i)	0 = 10.3 – 1.6 *t* (1) ecf from (a)(i) penalise only once for use of 9.8 m s^{-2}	
			t = 6.4 [s] (1)	
			t_{flight} = 12.8 [s] (1) ecf between 2nd and 3rd marks **Or** any other alternative method used to gain correct answer = 3 marks	3
		(ii)	D_H = 12.3 x 12.8 = 157 [m] ecf from (b)(i)	1
		(iii)	$0 = (10.3)^2 – 2 \times 1.6$ s (1) ecf from (a)(i)	
			S = 33.2[m] (1)	2
	(c)		Air resistance on Earth (1)	
			g on Earth different (accept greater) than on the Moon (1)	2
			Question 5 Total	**[11]**

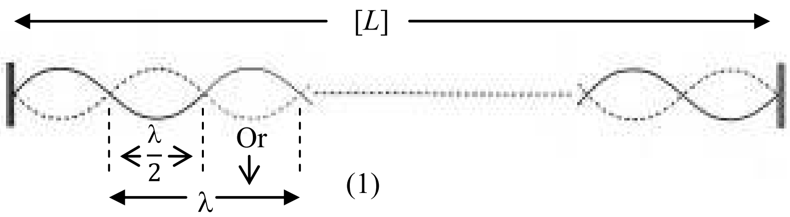
Question			Marking details	Marks Available
6	*(a)*	(i)		
			Circuit (without voltmeter and ammeter) (1)	
			Voltmeter and Ammeter correctly positioned (1)	2
		(ii)	$R = \frac{10}{0.9}$ = 11.11 [Ω] (1)	
			$A = 3.14\text{x}10^{-8}$ [m^2] (1)	
			$\rho = \frac{11.11 \text{ x } 3.14\text{x}10^{-8}}{3.2}$ (1) substitution $\rho = 1.09\text{x}10^{-7}$ [Ω m] (1) ecf for R and A	4
		(iii)	Platinum and Tin	1
	(b)		$\rho = \frac{0.74\text{x}10^{-3}}{(3.14\text{x}10^{-8} \text{ x } 3.2)(1)}$ = 7365 [kg m^{-3}] (1) ecf for A	
			Tin (1) ecf from density value	3
			Question 6 Total	**[10]**

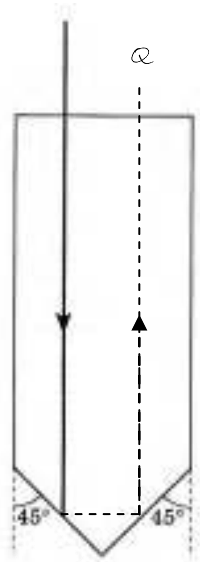
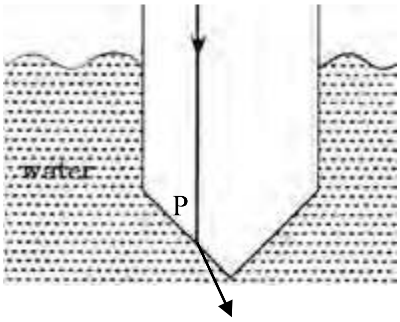
Question			Marking details	Marks Available
7	*(a)*		$F \rightarrow$ kg m s^{-2} (1) $\rho \rightarrow$ kg m^{-3} (1), $v^2 \rightarrow$ m^2 s^{-2} (1) Correct manipulation / cancelling seen $\rightarrow$ m^2 (1)	4
	(b)	(i)	Correct statement of Newton's 3rd Law	1
		(ii)	• <u>May</u> not have same magnitude • Forces act on same object • Forces not of same type (e.g. not two '*g*' forces or contact forces) Don't accept : They are not equal unless qualified Only one statement required.	1
	(c)	(i)	60 x 9.8 = 588 N **unit mark**	1
		(ii)	$F_{\text{res}} = W - F_{\text{drag}}$ implied in any correct form (1) F_{drag} = 588 –[(60 x 1.4) (1)] ecf from (c)(i) F_{drag} = 504 [N] (1)	3

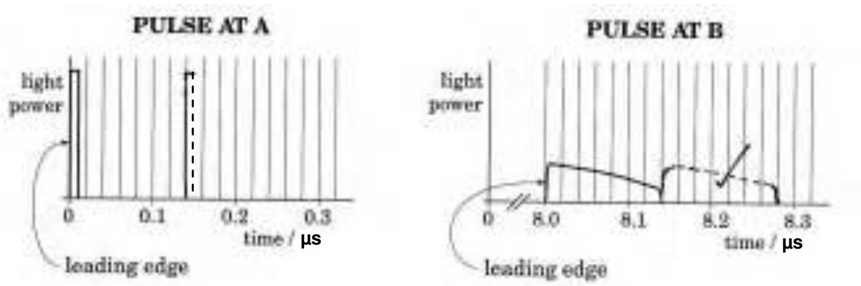
Question			Marking details	Marks Available
	(d)	(i)		
			Axes labelled with units (1); Points plotted correctly to within ±½ square division (1); Line (1)	3
		(ii)	Area attempted (1)	
			(1.4 x 10) + (½ x 10 x [9.8-14])	
			14 + 42 = 56 [m s^{-1}] (1) (accept range 52 – 60)	2
		(iii)	$504 = \frac{1.2 \times D \times 56^2}{2}$ substitution (1) allow ecf on F_{drag} and v	
			D = 0.27 [m^2] (1) (accept range 0.23 – 0.31)	2
			Question 7 total	**[17]**

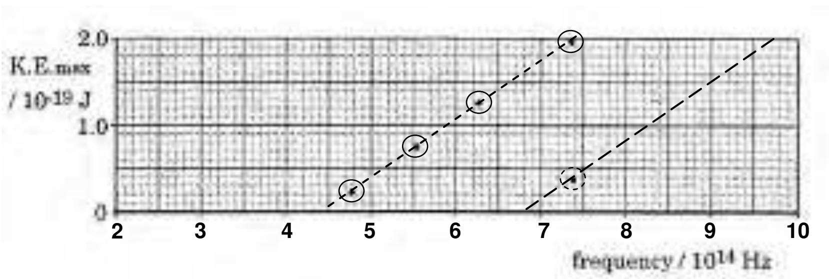
Question			Marking details	Marks Available
1	*(a)*	(i)	I. 2.0 [m] / 2.5 or <u>clear</u> equivalent	1
			II. The same	1
		(ii)	I. 5.0 Hz / s^{-1} **UNIT**	1
			II. 	
			Same *f* and *A* (1) Delayed by $\frac{1}{4}$ cycle (1)	2
		(iii)	4.0 [m s^{-1}] **ecf**	1
	(b)		Statement that *f* doesn't change (1), or working based on this principle (e.g. *v* = 5.0 [Hz] x 0.60 [m]) *v* = 3.0 [m s^{-1}] (1) **ecf**	2
			Question 1 total	**[8]**

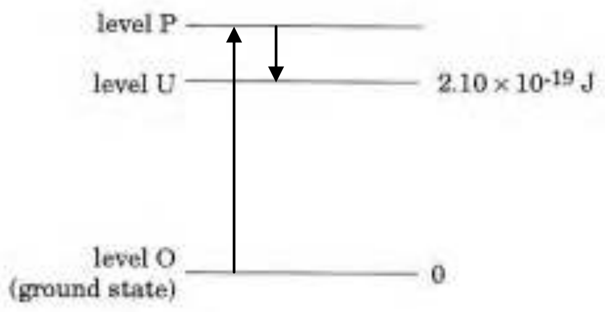
Question			Marking details	Marks Available
2	*(a)*		Waves arrive in phase at P. (1) Accept twin graphs: displacement along paths or displacement versus time at P.	
			This occurs if path difference = [0], λ, 2λ ……… (1) Accept $n\lambda$	2
	(b)	(i)	Insertion of *a*, *D* and *y* into $\lambda = \frac{ay}{D}$, <u>even if powers of 10 incorrect</u>. (1)	
			λ = 600 n[m] (1)	2
		(ii)	Beams (fringes, orders) :	
			brighter / sharper or more defined or narrower / further apart / slit separation more accurately known (Any 2 x (1))	2
			Question 2 total	**[6]**

Question			Marking details	Marks Available
3	*(a)*		 (1) Convincing algebra, e.g. $n\frac{\lambda}{2} = L$ (1)	2
	(b)	(i)	When λ = 820.0 nm, $\frac{2L}{\lambda} = 500$ (1) When λ = 821.0 nm, $\frac{2L}{\lambda} = 499.4$ (1) (Give 1 mark if same arithmetical error in both)	2
		(ii)	$n = 499.00$ (1) **ecf** [or by implication] λ = 821.60 [nm] (1) No mark if previous mark not given.	2
	(c)		Less amplitude [or fewer photons…] reflected back from [partially reflecting] mirror than arrive at it. (1) + (1) of the following: • Mirror not a proper node • Amplitudes of progressive waves travelling in opposite directions not equal. (Except near fully reflecting mirror).	2
			Question 3 total	**[8]**

Question			Marking details	Marks Available
4	*(a)*	(i)	1.55 $\sin c$ = 1.00 $\sin 90°$ (1) [or equivalent, or by implication]	
			c = 40° (1)	2
		(ii)	First reflection (1) **No ecf**	2
			Rest of path (1) 	
	(b)	(i)	1.55 $\sin 45°$ = 1.33 $\sin w$ (1) [or equivalent, or by implication]	
			w = 56° (1)	2
		(ii)	Bends as shown 	1
		(iii)	[Sensor at] Q receives more light when water level drops and exposes lower end of rod to the air. No ecf if paths badly wrong.	1
			Question 4 Total	**[8]**

Question			Marking details	Marks Available
5	*(a)*	(i)	$d = v \times t$ (1) [Attempt to use, or by implication] $v = \frac{3.00\text{x}10^8}{1.50}$ [m s^{-1}] (1) d = 1600 [m] (1) [Omission of n (giving 2400 [m]) loses 1] Arithmetical error loses 1 mark.	3
		(ii)	Zig-zag routes [take] longer than straight. (1) (1) For one of the following: • <u>Good</u> diagram (angles equal by eye) • A continuous <u>range</u> of zig-zag routes, all of different lengths	2
	(b)	(i)	0.14 [µs] [± 0.02µs]	1
		(ii)	 1 mark for the correct pulse on each graph. **ecf from (b)(i)**	2
			Question 5 Total	**[8]**

Question			Marking details	Marks Available
6	*(a)*	(i)	Maximum k.e. of <u>emitted / photo electrons</u>	1
		(ii)	Energy of a photon[s]	1
		(iii)	[Minimum] energy needed to remove electron [from surface]. Don't accept from an atom	1
	(b)	(i)	I. Gradient calculation attempted (1) – no penalty for wrong powers of 10. 6.6 [± 0.3] x10^{-34} [J s] (1) <u>agreeing with working</u>	2
			II. f_{thresh} = 4.4x10^{14} Hz (1) [± 0.1x10^{14} Hz] <u>or</u> valid algebraic method ϕ = 2.9x10^{-19} J **UNIT** (1) **ecf**	2
		(ii)	I.  Correct point (1), parallel line (1)	2
			II. Ultraviolet [or UV]	1
			III. Lithium has higher work function / needs more energy to remove an electron	1
			Question 6 Total	**[11]**

Question			Marking details	Marks Available
7	*(a)*	(i)	P and U : zero <u>or</u> very low and / or O : 100%	1
		(ii)	Absorption (accept excitation) (1) : electron promoted from O to U (1)	2
	(b)	(i)	More electrons in U than O or more electrons in higher level	1
		(ii)		1
		(iii)	Incident (or by implication) <u>photons</u> (1) causes an electron to drop (1). Emitting photon: so two photons where one previously (or by implication) (1). (1) For one of the following: • Atom / electron drops [from U] to O. • Incident photon energy must be 2.10 x 10^{-19} J or equivalent • Process happens repeatedly as photons traverse cavity to and fro • Stimulated photon in phase with incident photon	4
		(iv)	$\lambda = \frac{hc}{\Delta E}$ <u>or</u> $\lambda = \frac{c}{f}$ and $f = \frac{\Delta E}{h}$ <u>or</u> equivalent or by implication (1) λ = 950 n[m] (1)	2
	(c)		Electrons in lower level drop [spontaneously] to ground state (1) (accept de-excite) Making population inversion easier to maintain or lowering number of electrons in lower level or making photon absorption less likely. (1) [**or equivalent**]	2
			Question 7 Total	**[13]**

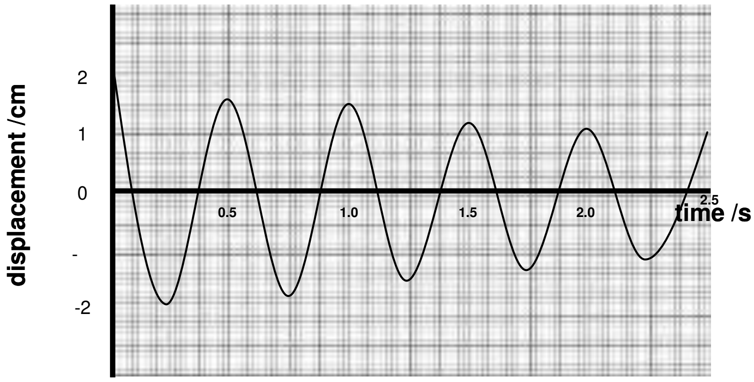
Question			Marking details	Marks Available
8	*(a)*	(i)	= 5.4 [± 0.2] [day] (1)	
			P = 0.70 [± 0.1] x10^{30} [W] (1) **ecf**	2
		(ii)	$I = \frac{P}{4\pi r^2}$ (1) [or equivalent, or by implication]	
			r = 2.6x10^{20} [m] (1) **ecf**	2
			[1 mark only lost if factor of 4 omitted]	
	(b)	(i)	λ_{peak} = 450 n[m] (1) [±10 nm]	
			T = 6400 [K] (1) [ecf on λ_{peak}]	2
		(ii)	$A = \frac{P}{\sigma T^4}$ (1) [transposition at any stage]	
			= 10 x 10^{21} [m^2] (1) [or by implication] **ecf on *T***	
			$r = \sqrt{\frac{A}{4\pi}}$ (1) [= 2.8 x 10^{10} [m]] [or by implication]	
			d = 5.6 x 10^{10} [m] (1) **ecf** (missing factor of 4 loses 1 mark)	4
			Question 8 Total	**[10]**

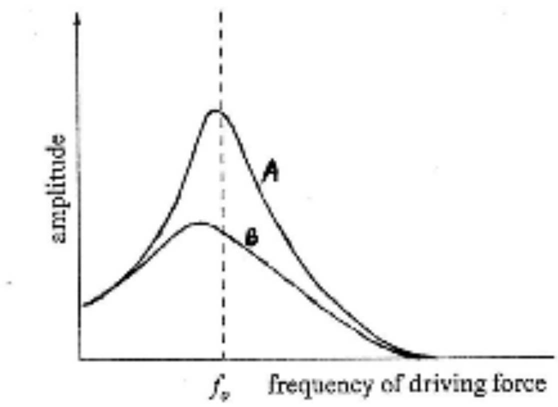
Question			Marking details	Marks Available
9	*(a)*	(i)	e^- : +1 e^+ : -1 (1) γ : 0 (1)	2
		(ii)	electromagnetic : γ involvement (1) both	1
	(b)		π^- (1) because either charge of x = -e [accept -1] and x must be a hadron / can't be a lepton Or u number = 0 - 1 = -1, d number = 0- (-1) = 1 or equivalent (1)	2
	(c)	(i)	e^+ or positron	1
		(ii)	Weak	1
	(d)		π^- [accept μ or $\bar{u}d$] → $e^- + \bar{\nu}_e$ (accept $+ \bar{\nu}$) [In fact, π^- → $\mu^- + \bar{\nu}_\mu$ much more likely]	1
			Question 8 Total	**[8]**

Question			Marking details	Marks Available
1	*(a)*	(i)	Increase (change) in the internal energy [of the system]	1
		(ii)	Heat supplied to (flowing into) [the system]	1
		(iii)	Work done by the system	1
	(b)		$PV = nRT$	
			$T = \frac{PV}{nR}$ (1) $= \frac{(1.01 \times 10^5)(1.3 \times 1.00 \times 10^{-2})}{(0.4)(8.31)}$ = 395 K (1)**unit mark**	2
	(c)	(i)	$(1.01 \times 10^5)(0.3 \times 1.00 \times 10^{-2})$ = 303 [J] **on gas** (1)	
		(ii)	0 / No work (1)	
		(iii)	$\frac{1}{2}(0.3 \times 1.00 \times 10^{-2})(0.2 \times 1.01 \times 10^5) + (0.3 \times 1.00 \times 10^{-2})(1.01 \times 10^5)$	
			= 30 + 303	
			= 333 [J] (1) by gas ecf from (c)(i) (1)	4
	(d)		Convincing evidence of multiplication by 3 for the 3 cycles (1)	
			$\Delta U = 0$ (1)	
			$Q = \Delta U + W$ = 0 + 90 = 90[J] into gas (1) ecf from (c)(iii)	3
			Question 1 total	**[12]**

Question			Marking details	Marks Available
2	*(a)*	(i)	$Ft = \Delta(mv)$ $\therefore$ 3 (0.15) = 0.200 v v = 2.25 [m s^{-1}] Or equivalent but clear method must be shown	1
		(ii)	(0.200) (2.25) = (0.200 + m_B) (1.20) (attempting to use conservation of momentum) (1) $m_B = \frac{(0.200)(2.25) - (0.200)(1.20)}{120}$ (1) = 0.175 [kg]	2
		(iii)	KE before collision = $\frac{1}{2}$(0.200) (2.25)^2 = 0.506[J] (1) KE after collision = $\frac{1}{2}$(0.200) (0.15)^2 + $\frac{1}{2}$(0.175) (2.40)^2 = 0.506 [J] (1) KE before collision = KE after collision [so collision is elastic] (1)	3
	(b)	(i)	$E = hf = \frac{hc}{\lambda}$ (1) $= \frac{6.63x10^{-34} x3x10^{8}}{500x10^{-9}} = 3.98x10^{-19}$ [J] (1)	2
		(ii)	N^o arriving each second = $\frac{(1500)(100)}{(3.98 x10^{-19})}$ = 3.77 x10^{23} **allow ecf for *E* from (i)**	1
		(iii)	Momentum of 1 photon $= \frac{h}{\lambda} = \frac{(6.63x10^{-34})}{(500 x10^{-9})}$ (1) = 1.33x10^{-27} [kg m s^{-1}] Change of momentum of 1 photon 2 (1) x 1.33x10^{-27} = 2.65x10^{-27} [kg m s^{-1}] Total change of momentum of photon in 1 s = (2.65x10^{-27}) (3.77x10^{23}) = 9.99x10^{-4} [kg m s^{-1}] (1) **Allow ecfs from (b)(i) and (ii)** Force = Change of momentum per second = 9.99x10^{-4} = 1.0x10^{-3}[N] (force on sail is equal and opposite to force on photons)	3
			Question 2 total	**[12]**

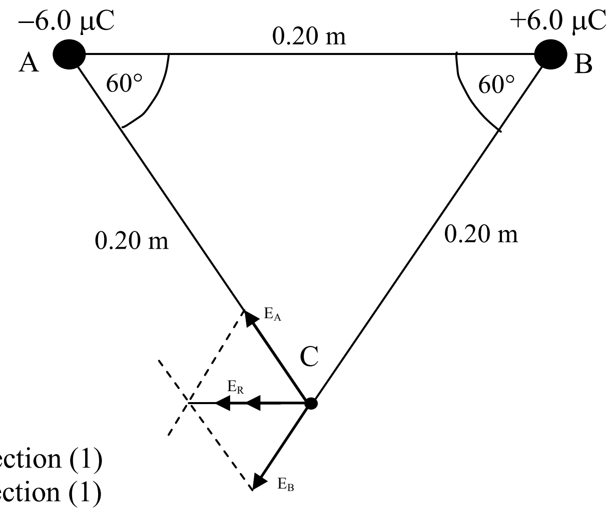
Question			Marking details	Marks Available
3	*(a)*		Acceleration α displacement from central (fixed) point (1) is directed towards the central (fixed) point (1)	2
	(b)	(i)	$\omega = \frac{2\pi}{T} = \frac{2\pi}{0.40} = 15.7$ [rad s^{-1}] (1) $v_{max} = \omega A = (15.7)(0.05) = 0.79$ [m s^{-1}] (1)	2
		(ii)	$a_{max} = \omega^2 A$ (1) = $(15.7)^2 (0.05) = 12.3$ [m s^{-2}] (1)	2 2
	(c)		$x = 0.05 \sin\left(15.7t - \frac{\pi}{2}\right)$ [m] 0.05 (1) 15.7 (1) $-\frac{\pi}{2}$ (1) or accept $-90°$	3
	(d)		Loses contact when $a = -g$ (1) $-\omega^2 x = -g$ $x = \frac{9.81}{(15.7)^2} = 0.04$ [m] (1)	2
			Question 3 total	**[11]**

<table>
<tr><th colspan="3">Question</th><th>Marking details</th><th>Marks Available</th></tr>
<tr><td>4</td><td>(a)</td><td>(i)</td><td>

Scales on both axes (1)
Period and shape (1)
Amplitude (1)</td><td>3</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>e.g. air resistance
magnetic damping
friction by itself is not enough - needs either reference or implication to air resistance</td><td>1</td></tr>
<tr><td></td><td>(b)</td><td>(i)</td><td>

General shape with label (accept if peak on or just to left of f_o)</td><td>1</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>Smaller values than A with peak not to the right and correct shape</td><td>1</td></tr>
<tr><td></td><td></td><td>(iii)</td><td>At a <u>certain</u> driving <u>frequency</u> there is a <u>maximum</u> (peak) in the <u>amplitude</u> of the oscillating load. At this frequency the system is at resonance.</td><td>1</td></tr>
<tr><td></td><td></td><td>(iv)</td><td>e.g. microwave cooking (1)
driving force : by microwave radiation (1)
responding oscillator : water molecules (1)</td><td>3</td></tr>
<tr><td></td><td></td><td></td><td>Question 4 Total</td><td>[10]</td></tr>
</table>

Question			Marking details	Marks Available
5	*(a)*	(i)	$PV = n\,RT$ $n = \frac{PV}{RT} = \frac{(3.04\times 10^5)(0.025)}{(8.31)(280)} = 3.27$[mol]	1
		(ii)	$N = n\,N_A = (3.27)\,(6.02\text{x}10^{23}) = 1.97\text{x}10^{24}$ **allow ecf from (i)**	1
		(iii)	$\rho = \frac{(m_r \times 10^{-3})n}{V} = \frac{(4\text{x}10^{-3})(3.27)}{0.025} = 0.52$[kg m^{-3}] (1) formula with m_r (1)	2
		(iv)	$P = \frac{1}{3}\rho\overline{c^2}$ $\sqrt{\overline{c^2}} = \sqrt{\frac{3P}{\rho}} = \sqrt{\frac{3(3.04x10^5)}{0.52}} = 1324[ms^{-1}]$ (1) **allow ecf from (iii)** Rearrange equation (1)	2
	(b)	(i)	(Combining of the two given equations to give) $\frac{1}{3}Nm\overline{c^2} = nRT$ (1) KE of gas (i.e. of the N molecules) = $\frac{1}{2}Nm\overline{c^2}$ [= number of atoms x $\frac{1}{2}m\overline{c^2}$] (1) (can award for K.E. of one molecule i.e. K.E. = $\frac{1}{2}m\overline{c^2}$ only if it is clearly noted that it is for one molecule) $\therefore$ KE of gas [$\frac{1}{2}Nm\overline{c^2}$] = $\frac{3}{2}nRT$ manipulation mark (1) Internal energy of gas (U) = KE + PE and PE = 0 (for ideal gas) (1) [or internal energy is only the KE] (so $U = \frac{3}{2}n\,RT$)	4
		(ii)	$U = \frac{3}{2}n\,RT = \frac{3}{2}(3.27)\,(8.31)\,(280) = 11\,413$ [J]	1
			Question 5 Total	**[11]**

<table>
<tr><th colspan="3">Question</th><th>Marking details</th><th>Marks Available</th></tr>
<tr><td>6</td><td>(a)</td><td>(i)
(ii)
(iii)</td><td>


E_A – direction (1)
E_B – direction (1)
E_R – “horizontal” and to the left (1) ecf from (i) & (ii)</td><td>1
1
1</td></tr>
<tr><td></td><td>(b)</td><td></td><td>$E = 2 \; \frac{1}{4\pi\varepsilon_0} \; \frac{6\times10^{-6}}{(0.2)^2} \; \cos 60°$

$E = 2 \; \frac{1}{4\pi 8.85\times10^{-12}} \; \frac{6\times10^{-6}}{(0.2)^2} \cdot \frac{1}{2} = 1.35\times10^{6}$ N C^{-1}
Substitution of Q and r (1) factor of 2 (1) answer with unit (1)
Allow ecf from (a)</td><td>3</td></tr>
<tr><td></td><td>(c)</td><td>(i)</td><td>$V = -\frac{1}{4\pi\varepsilon_0} \; \frac{6\times10^{-6}}{(0.6)}$ (1) $+ \frac{1}{4\pi\varepsilon_0} \; \frac{6\times10^{-6}}{(0.4)}$ (1) $= -8.99\times10^{4} + 13.49\times10^{4}$

$= 4.5\times10^{4}$ [V] (1)</td><td>3</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>$W = q\,\Delta V = (2\times10^{-6})\,(4.5\times10^{4}) = 0.09$ [J] (1) ecf from (c)(i)

formula and substitution (1)</td><td>2</td></tr>
<tr><td></td><td></td><td>(iii)</td><td>$\frac{1}{2}\,m\,v^2 = 0.09$ (1) (PE →KE) allow ecf from (c)(ii)

$v = \sqrt{\frac{2\,(0.09)}{5\times10^{-3}}} = 6$ [m s^{-1}] (1)</td><td>2</td></tr>
<tr><td></td><td></td><td></td><td>Question 6 Total</td><td>[13]</td></tr>
</table>

Question			Marking details	Marks Available
7	*(a)*		1. Planets move in elliptical orbits with the Sun at one focus (1) 2. Line joining a planet to the Sun sweeps out equal areas in equal time[intervals]. (1) 3. $r^3 \propto T^2$ r- semi major axis (or accept radius), T- period of orbit (1)	3
	(b)		Consider $\frac{r^3}{T^2}$, For Earth $\frac{(149.6\text{ x}10^9)^3}{(1.00\text{x}365.25\text{x}24\text{x}60\text{x}60)^2} = 3.36\text{x}10^{18}$ [$\text{m}^3\ \text{s}^{-2}$] (1) For Jupiter $\frac{(778.6\text{ x}10^9)^3}{(11.86\text{x}365.25\text{x}24\text{x}60\text{x}60)^2} = 3.37\text{x}10^{18}$ [$\text{m}^3\ \text{s}^{-2}$] (1) Both essentially **equal** so data consistent with Kepler's third law. (1) (accept answers in other units e.g. $\text{m}^3\ \text{yr}^{-2}$)	3
	(c)		A body moving in a circular motion experiences an acceleration towards the centre of the circle. This is known as centripetal acceleration.	1
	(d)		$\frac{G M_s m}{r^2} = \frac{m v^2}{r}$ (1) m: mass of planet or equivalent method $v^2 = \frac{G M_s}{r}$ also $v = \frac{2\pi r}{T}$ (1) Combine $\left(\frac{2\pi r}{T}\right)^2 = \frac{G M_s}{r}$ (1) $\frac{4\pi^2 r^2}{T^2} = \frac{G M_s}{r}$ $M_s = \frac{4\pi^2}{G} \frac{r^3}{T^2} = \frac{4\pi^2}{(6.67\text{x}10^{-11})} (3.36\text{x}10^{18}) = 2\text{x}10^{30}$ [kg] (1)	4
			Question 7 Total	**[11]**

Question			Marking details	Marks Available
1	*(a)*		All α absorbed / stopped by paper (1) (nearly) all γ passes through (1)	2
	(b)		${}^{0}_{-1}[\beta]$ correct (1) Conservation of A and Z (but not for trivial ${}^{0}_{0}\beta$) (1)	2
	(c)		$\lambda = \frac{\ln 2}{T_{1/2}}$ used (1) $\frac{\ln 2}{28.8 \times 365 \times 24 \times 3600}$ $[= 7.63 \times 10^{-10}\ \text{s}^{-1}]$ (1)	2
	(d)		Correct equation used i.e. some understanding of $A = A_0 e^{-\lambda t}$ or $A = \frac{A_0}{2^n}$ (1) Answer correct (110 GBq **ecf** on λ) (1)	2
	(e)		$A = \pm\lambda N$ used (e.g. $140 = 7.6 \times 10^{-10}\ N$ is ok) (1) $N = 1.83 \times 10^{20}$ (1) Mass = 90 u x 1.83×10^{20} = 27.4×10^{-6} kg (27.4 mg) **ecf** on N (1) **UNIT mark**	3
			Question 1 total	**[11]**

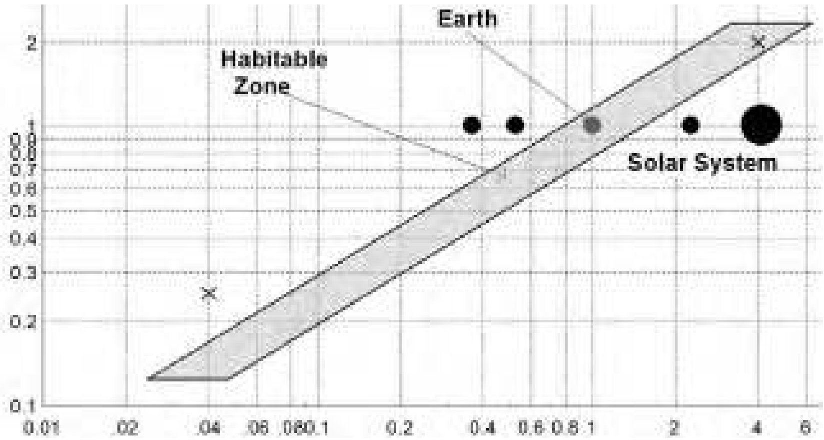
Question			Marking details	Marks Available
2	*(a)*		LHS - RHS attempted (0.1859 u) (1)	
			x 931 or $E=mc^2$ used (must have u to kg conversion) (1)	
			173.1 [MeV] / 2.78 x 10^{-11} [J](1)	3
	(b)		[more or 3] <u>neutrons</u> are released (1)	
			These can produce fission (or, on average one of these....) (1)	2
	(c)		Control rods stop or absorb neutrons (1)	
			Moderator slows neutrons (1)	
			To increase [probability of] fission (or increase capture X-section) (1)	3
	(d)		[Highly] radioactive for many years / long half life (1) Any sensible **A level standard** comment relating to - storage, leakage, transportation, cost, dirty bombs etc. (1)	2
			Question 2 Total	**[10]**

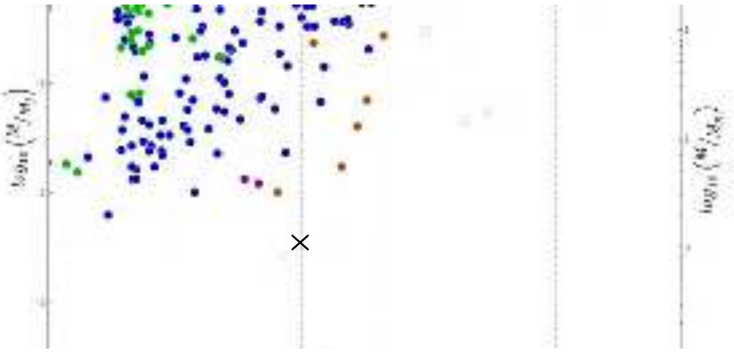
Question			Marking details	Marks Available
3	*(a)*	(i)	$C = \frac{\varepsilon_0 A}{d}$ used $\left(= \frac{8.85\times10^{-12}\times 8.2\times10^{-4}}{0.77\times10^{-3}}\right)$ (1)	
			Answer correct (9.42 x 10^{-12} F) (1) **UNIT mark**	2
		(ii)	Dielectric accept solid insulator	1
	(b)	(i)	$Q = CV$ (used or implied) (1)	
			Answer correct (5.35 x 10^{-8} [C]) (1)	2
		(ii)	$Q = Q_0 \exp\left(\frac{-t}{RC}\right)$ used e.g. $Q_0 \exp\left(\frac{-50\times10^{-6}}{47\times33\times10^{-9}}\right)$ (1)	
			= 5.3 x 10^{-22} [C] (1)	
			<u>Comment</u> e.g. v. small or completely discharged etc. (1) **ecf**	3
		(iii)	$I = \frac{Q}{t}$ and $T = \frac{1}{f}$ (or implied) or $I = Q$ x 20 000 (1)	
			= 20 000 x 5.35 x 10^{-8} = 1.07 x 10^{-3} [A] (1) **ecf**	2
			Question 3 Total	**[10]**

Question			Marking details	Marks Available
4	*(a)*		Concentric circle / ellipse with wire @ centre (1)	
			Direction correct and unambiguous (1)	2
	(b)	(i)	$B = \frac{\mu_0 I}{2\pi a}$ used (1)	
			$B_1 = 2.4\text{x}10^{-6}$ [T] **and** $B_2 = 3.6\text{x}10^{-6}$ [T] (1)	
			Answer $B = 1.2\text{x}10^{-6}$ [T] (1) **ecf**	
			Out of paper (1)	4
		(ii)	One wire is in the magnetic field of another (can be implied)(1)	
			Field due to I_2 out of paper at I_1 (1)	
			Force to left due to LHR (1) Other wire is opposite due to N3 or opposite field or equivalent (1)	
			AWARD a maximum of 3 marks	
			OR One wire is in the magnetic field of another (can be implied) (1)	
			Field due to I_1 out of paper at I_2 (1)	
			Force to right due to LHR (1) Other wire is opposite due to N3 or opposite field or equivalent (1)	
			AWARD a maximum of 3 marks	3
			Question 4 Total	**[9]**

Question			Marking details	Marks Available
5	*(a)*		The right side (independent mark) (1)	
			Force [on electrons (can be implied)] is to the right (1)	
			Due to LHR or current back to front face (1)	3
	(b)		$V = Ed$ *(or $E=V/d$)* (1) Quoted only or implied	
			= $3.2\text{x}10^{-6}$ x $2.6\text{x}10^{-3}$(**ecf** from a) = $8.32 \text{ x } 10^{-9}$ [V] (1)	2
	(c)		eE = electrical force **and** Bev = magnetic force (1)	
			equilibrium is reached or electrons pass through unaffected etc. (1)	2
	(d)		Substituting $v = \frac{I}{nAe}$ in $eE = Bev$ **or** calculating $v = 3.93 \text{ x } 10^{-5}$ m s^{-1}(1)	
			Rearranging i.e. $B = \frac{EnAe}{I}$ (1)	
			Answer = 0.081 T (1) **UNIT mark**	3
			Or rearranging $V_H = \frac{BI}{nte}$ (1) $\left\{B = \frac{nteV}{I}\right\}$	
			Correct substitution (including t = 0.85 mm and V = 8.32 nV **ecf**) (1)	
			Answer correct (1)	
			Question 5 Total	**[10]**

Question			Marking details	Marks Available
6	*(a)*		Valid complete statement - 2 marks e.g. Induced emf is proportional to (or equal to) the rate of change (or cutting) of flux (linkage). e.g. Accept induced emf = change of flux / time e.g. Accept emf = rate of flux cutting (bod - missing induced) Nearly complete statement - 1 mark e.g. $\mathcal{E} = [-]\frac{[d]\phi}{[d]t}$ (terms not defined) e.g. Induced emf is proportional to change of flux (missing rate of)	2
	(b)	(i)	$\mathcal{E} = -\frac{d\varphi}{dt}$ or $\frac{\varphi}{t}$ or $\frac{BA}{t}$ or $\frac{BAN}{t}$ (1) $A = \pi r^2$ used (1) Use of $I = \frac{V}{R}$ (1) Correct answer (1)	4
		(ii)	$\div\sqrt{2}$ (1) = 1410 [A] (1)	2
		(iii)	$P = IV$ or I^2R or V^2/R used (1) = 456 [W] (1)	2
			Question 6 Total	**[10]**

Question			Marking details	Marks Available
7	*(a)*		Because their star is the Sun **or** they all orbit the Sun **or** $\frac{M_{star}}{M_{sun}} = 1$ Accept M_{star} is the same	1
	(b)	(i)	 	1
		(ii)		1
		(c)	(i) yes **because** it's in the habitable zone **ecf** (1) (ii)[no] **because** it is too hot **or** too close to star **ecf** (1)	2
		(d)	Eliminating r_S (1) $\frac{M_S v_S^2}{r_S} = \frac{GM_S M_p}{d^2} \rightarrow \frac{v_S^2}{M_p d / M_S} = \frac{GM_p}{d^2}$ or $M_S v_S^2 = \frac{GM_S r_S M_p}{d^2} = \frac{GM_p d M_p}{d^2}$ Remainder of algebra convincing (1)	2
		(e)	Because Doppler shift $\propto v_S$ (accept depends on) (1) and $v_S \propto M_p$ or v_S increases with M_p (1) and $v_S \propto M_S^{-0.5}$ or v_S decreases with M_S (1) and $v_S \propto d^{-0.5}$ or v_S decreases with d (1)	4

Question			Marking details	Marks Available
7	*(f)*		Some comment about most planets being large mass e.g. nearly all masses greater than M_E or average/median mass is close to mass of Jupiter etc. (1) Some comment about *d* being quite small on average e.g. mean/median *d* is only about 1 AU (not 0 AU!) or nearly all planets inside 10 AU etc. (1) The graph says nothing about the size of the star (1) **Award a maximum of 2 marks only** Most planets towards top left of graph (by itself) scores 1 mark	2
	(g)		 Accept a circle around the correct planet x correct – 1 mark, y correct – 1 mark	2
	(h)		$\frac{\pi r_1^2}{\pi r_2^2} = 20^2$ (1) Drops by 0.25% or drops **to** 99.75% or drops by $^1/_{400}$ (1) (correct answer implies first step)	2
	(i)		Radial velocity gives mass (1) Transit gives radius **or** area **or** diameter (1) Density = $\frac{mass}{volume}$ and volume from area or diameter or radius (1)	3
			Question 7 Total	**[20]**

Question			Marking details	Marks Available
8	*(a)*	(i)	$\omega L = \frac{1}{\omega C}$ or $f = \frac{1}{2\pi\sqrt{LC}}$ (1)	
			$\omega = 2\pi f$ or algebra i.e. $L = \frac{1}{4\pi^2 C f^2}$ (1)	
			L = 0.247 H **UNIT mark** (1)	3
		(ii)	$I = \frac{240}{150}$ (1)	
			Because V_L and V_C cancel or because all voltage across R etc. (1)	2
		(iii)	$V = IX_C$ (1)	
			$= I\omega L$ (1)	
			= 6360 [V] (1)	3
		(iv)	6360 [V] (1)	
			0 (1)	
			0 (1)	
			0 (1)	4

Question			Marking details	Marks Available
8	*(b)*		E - **induced** emf L - (self) inductance (1) For both $\frac{\Delta I}{\Delta t}$ - rate of change of current (1)	2
	(c)		$\mathcal{E} = (-)\frac{d}{dt}(BAN)$ or $\mathcal{E} = (-)\frac{BAN}{t}$ (1) $B = \mu_0 nI$ substituted i.e. $\mathcal{E} = (-)\frac{\mu_0 nIAN}{t}$ (1) $N = nl$ substituted i.e. $\mathcal{E} = (-)\frac{d}{dt}(\mu_0 nIAnl)$ (1) Final arrangement and 'comment' e.g. $\mathcal{E} = (-)\overbrace{\mu_0 n^2 Al}\frac{I}{t}$ (1)	4
	(d)		$L = \mu_0 n^2 \pi r^2 l$ i.e. using πr^2 and $\mu_0 n^2 Al$ (1) Answer [=0.25 H] (1)	2
			Question 8 Total	**[20]**

Question			Marking details	Marks Available
9	*(a)*	(i)	Either in words or on diagram, for first mark 2 of; for second 3 of: Interference mentioned, 2 sources mentioned or labelled, wavefronts labelled, lines of constructive or destructive interference labelled.	2
		(ii)	**Newton**: Light is moving [or flow of] corpuscles [particles](1) **Huygens**: Light is a wave. (1) But H had no notion of periodic nature of wave (1) [**or** of wavelength **or** of interference]	3
	(b)	(i)	Two coils and iron core shown on diagram. (1) When current switched on or off [accept either] in one coil, (1) Current flowed [or equivalent] in other coil. (1) Detected by deflection of compass needle close to a [long] wire connected across the secondary. (1)	4
		(ii)	Any Two of Lines shown by compass needle or iron filings. Cutting by conductor induces emf [accept current] in conductor **or** emf induced in a circuit if number of lines linking it changes. Lines under tension **or** light/radiation is a wave propagating along the lines.	2

Question			Marking details	Marks Available
9	*(b)*	(iii)	spinning 'beads' [**or** cells, vortices…] (1)	
			axis of spin along lines of force. (1)	2
	(c)	(i)	Laws of Physics the same in all inertial frames. [Accept: No privileged (special) frame of reference.] (1)	
			Speed of light independent of the motion of its source. [Accept: speed of light always the same.] (1)	2
		(ii)I	time of flight = 0.36 [m] / 0.60 x 3.0 x 10^8 [s] [= 2.0 ns] [or by implication](1)	
			attempt to use this as Δt in time dilation formula (1)	
			Correct evaluation of $\sqrt{(1 - v^2/c^2)}$ or its reciprocal [0.8 or 1.25] [or by implication] (1)	
			= 1.6 [ns] time (1)	4
		II	Time [between events] as found by clock moving with pion **or** by clock present at both events. Accept : time as experienced by pion.	1
			Question 9 Total	**[20]**

Question			Marking details	Marks Available
10	*(a)*		(2x1) from: crystalline- long range, regular (unit cell repeated) Amorphous- short range, irregular Polymeric- long chain molecules (no order between, only within molecules) 2 examples given (1)	3
	(b)	(i)	Equation applied to both sections correctly i.e. $\frac{F\frac{L_0}{2}}{AY}$ and $\frac{F\frac{L_0}{2}}{2AY}$ (1) Extensions added i.e. $\frac{F\frac{L_0}{2}}{AY}+\frac{F\frac{L_0}{2}}{2AY}$ (1) Convincing algebra (1)	3
		(ii)I	Line drawn correctly	1
		II	Re-arrange for ***A*** bar, **2*A*** bar or **combination (1)** Correct force-extension combination for each of above (1) Answer = 2×10^{11} [N m^{-2}] (1)	3
		III	Both extensions correct i.e. 2 μm and 4 μm (ecf on line) (1) Correct method of finding energy e.g. $\frac{1}{2}Fx$ or $\frac{1}{2}\sigma\varepsilon\times V$ or area (1) Answer correct $E_p = 6 \times 10^{-4}$ [J] (**ecf** on line usually 12×10^{-4} [J]) (1) Alternative: Areas under graph lines - same method applies	3

Question			Marking details	Marks Available
10	*(c)*	(i)	Hysteresis labelled/described correctly (1)	
			Permanent set labelled/described correctly (1)	
			Correct sketch (1)	3
		(ii)I	Untangling of molecules (rotation about single bonds) (1)	
			Small force causes large extension (1)	2
		II	Increasing temperature increases random rotation about single bond (molecules 'ravel' up and become shorter) (1)	
			(Given) force produces smaller extension (1)	2
			Question 10 Total	**[20]**

Question			Marking details	Marks Available
11	*(a)*	(i)	A-scan measures distances / depths (1)	
			B-scan provides images (moving) pictures (1)	2
		(ii)	Any valid application	1
			e.g. development of foetus, scanning young (born) babies' skulls imaging liver, kidneys, heart locating arteries/veins/nerves locating fluid (puss, blood etc.) inside body (esp abdomen&lungs)	
		(iii)I	Time = 7.5 x 2 μs (1)	
			Distance = time x 1.45 x 10^3 (=21.8 mm) (1)	
			Thickness = 0.5 x distance (=10.9 mm) (1)	3
		II	Both pulses at start or only the first pulse	1
			(accept second pulse very faint)	
	(b)	(i)	More electrons emitted or hit target (1)	
			Output higher **intensity** (1)	2
		(ii)I	2.8 x 10^{18}	1
		II	80000 x 1.6 x 10^{-19} = 1.28 x 10^{-14} J	1
			(accept 80 keV)	

Question			Marking details	Marks Available
11	*(b)*	(iii)	High X-ray dose / high exposure / expensive / CT scanner in high demand	1
	(c)		*y*-axis pd or voltage etc. **and** x-axis time (1)	
			y- axis units – mV (1)	
			x-axis unit – s (1)	3
	(d)		Nuclei precess/wobble around field lines (1)	
			Radio waves at resonance frequency change/flip orientation of nuclei (1)	
			Orientation goes back to field direction (while emitting radio waves) (1)	3
	(e)		Lower (1)	
			Alpha are more damaging/ionising (to tissue) (1)	2
			Question 11 Total	**[20]**

Question			Marking details	Marks Available
12	*(a)*		3 valid points for/against coal & nuclear 3 marks 2 valid points for/against coal & nuclear 2 marks 1 valid point for/against coal & nuclear 1 mark Coal Acid rain, global warming/CO_2 emitting, other specified pollution e.g. smog & carcinogenic particulates, causes asthma, can be very high output power Nuclear Danger of accident/leak in high population area, decommissioning very expensive, waste radioactive for many years **and** must be contained, expensive in general, no CO_2 emission, can be very high output power 2 valid local points 2 marks 1 valid local point 1 mark Local points Large number of local jobs (and plenty of people to fill vacancies), plenty of water available (Thames), less need for long power cables, good rail links, very expensive land prices, causes asthma (but cannot be counted twice), risk of radioactive leak in high population area (but cannot be counted twice), reduces already poor air quality in London etc.	5
	(b)		Substitution of $\frac{Q_2}{Q_1}=\frac{T_2}{T_1}$ (1) Rest of algebra $\frac{Q_1-Q_2}{Q_1}=1-\frac{Q_2}{Q_1}=1-\frac{T_2}{T_1}$ (1)	2
	(c)		$1-\frac{T_2}{T_1}=1-\frac{323}{773}=0.58$ or 58%	1

Question			Marking details	Marks Available
12	*(d)*	(i)	$\times \frac{100}{35}$ (i.e. $3.6 \times \frac{100}{35} = 10.3$ GW) (1) $\div 25$ (i.e. $10.3 \div 25$) (1) Answer = 0.411 [tonnes s^{-1}] (1)	3
		(ii)	Method correct i.e. (1) $\times 2.1 \times 24 \times 60 \times 60$ (even if 10.3 GW$\times 2.1 \times 24 \times 60 \times 60$) Answer = 653 tonne ($653 \times 10^3$ kg) (1)	2
	(e)	(i)	$A = 2\pi rl$ used (allow 1st mark for πdl) (1) Correct answer = 90 [m^2] (1)	2
		(ii)	$\frac{\Delta Q}{\Delta t} = -Ak\frac{\Delta\theta}{\Delta x}$ used (1) Values substituted correctly i.e. $7.24 \times 77 \frac{45}{0.0254}$ (1) Answer correct = 9.87×10^5 [W] (1)	3
		(iii)	Lagging (or description of equivalent) (1) With material of high *k* (or *U*) (1) (accept apt material e.g. fibre glass, rockwool etc.) i.e. wrap fibre glass around the pipe - 2 marks	2
			Question 12 Total	**[20]**

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