WJEC
CBAC

GCE MARKING SCHEME

PHYSICS
AS/Advanced

JANUARY 2011

INTRODUCTION

The marking schemes which follow were the ones used by the WJEC for the January 2011 papers in the GCE PHYSICS examination. They were finalised after detailed discussion at an 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 scheme was 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' conference, teachers may have different views on certain matters of detail or interpretation.

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

Notes on the interpretation of these marking schemes

The marking schemes, whilst reasonably complete do not give **all** the answers which were credited by the examiners. It is hoped that the schemes are self-explanatory, though they will need to be read alongside the question papers. The following clarifications may be of use:

Statements in brackets [ ] are exemplification, alternatives, acceptable ranges, e.g. 3.8 [$\pm$ 0.3] $\times 10^{-19}$ J **or** statements which, whilst desirable in an answer were not required on this occasion for full marks. [accept….] indicates that, whilst not a good answer, it was accepted on this occasion.

The numbers in parentheses ( ) are the marks, usually 1, for each response.

e.c.f. stands for *error carried forward*, and indicates that the results of a previous (incorrect) calculation will be treated as correct for the current section. i.e. the mistake will only be penalised once.

The expression [or by impl.] indicates that the mark is credited when subsequent credit-worthy working or answer demonstrates that this idea/equation has been used.

In general the physics of the answer needs to be correct but specific expressions or methods are often not required. The expression [or equiv.] emphasises that the particular idea, could be expressed in several different ways.

Incorrect or absent units are not always penalised, but they are present in the mark scheme for completeness. Where ((**unit**)) appears it indicates that the unit is required for the mark to be awarded but attracts no separate mark. A (1) following the unit, in addition to a (1) following the numerical part of the answer, indicates that the unit itself attracts a mark.

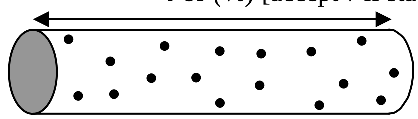
Example: 25 GPa (1) ((**unit**)) indicates that the unit (or correct alternative. e.g. $2{\cdot}5 \times 10^{10}$ N m^{-2}) is a requirement for the mark;

25 (1) GPa (1) indicates that the numerical part of the answer [$2{\cdot}5 \times 10^{10}$] and the unit Pa each attract a mark. In this case, an answer of 25 GN would be awarded the first mark but not the second, it being considered that the SI multiplier is numerical.

Unless otherwise stated, no penalties for excessive significant figures are applied in these papers. Significant figures are usually assessed only in the practical units.
N.B. This Mark Scheme is not a set of Model Answers.

PH1 Mark Scheme – January 2011

Question			Marking details	Marks Available
1	*(a)*	(i)	[Rate of] flow of charge / $I = \frac{Q}{t}$ or $\frac{dQ}{dt}$ <u>with *Q* defined</u>	1
		(ii)	C s^{-1}	1
	(b)	(i)	$x = y + z$	1
		(ii)	charge	1
	(c)	(i)	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$ or $R = \frac{R_1 R_2}{R_1 + R_2}$ of by impl. (1) $R_{\|\|}$ = 30 Ω (1); R_{Total} = 40 Ω (1) [no e.c.f.]	3
		(ii)	[Current *x* =] 0.15 A e.c.f. [Accept equiv., e.g. $^{6}/_{40}$, but not 0.2A without working]	1
		(iii)	V_1 = 0.15 × 10 [= 1.5 V] (1) [e.c.f.] V_2 = 6 – 1.5 [= 4.5 V] [or 30 × 0.15 = 4.5 V] (1) [e.c.f.]	2
		(iv)	$y = \frac{4.5}{120}$ [= 0.038 A] (1) *z* = 0.15 – 0.038e.c.f. [= 0.11 A] $\left[\text{or } \frac{4.5}{40} \text{ [= 0.11 A]}\right]$ (1) [Accept solutions based upon ratios, e.g. $y = \frac{0.15}{4}$ …]	2 **[12]**
2.	*(a)*	(i)	$R = \frac{1.6}{15 \times 10^{-3}}$ (1) (reading from graph, accept 14 × 10^{-3}) *R*= 107 Ω [answers in range 107 – 114 Ω]	2
		(ii)	[Very] high [accept infinite]	1
	(b)	(i)	*V* not proportion to *I* / not a straight line [through the origin] [“Not through origin” insufficient on its own]	1
		(ii)	Bulb / thermistor [Not wire or superconductor, but accept superconducting device, e.g. superconducting electromagnet coil]	1
	(c)		$R = \frac{V}{I}$ (1) ; $R = \frac{10.4 (1)}{15 \times 10^{-3}}$ = 693 Ω (1) **Alt 1**: $10.4 = \frac{R}{R + 107} \times 12$ [or equiv.] (1) manipulation e.g. 10.4*R* + 112.8= 12(1); *R* = 696 Ω (1) **Alt 2**: $R_T = \frac{V}{I}$ or $\frac{12}{1.5 \times 10^{-3}}$ (1) = 800 Ω (1); *R* 800 – 107 = 693 Ω (1)	3 **[8]**

Question			Marking details	Marks Available
3	*(a)*		*l* or *(vt)* [accept *v* if stated dist travelled in 1 s] (1)  [NB free electrons not required to be labelled] Number of free electrons = *nAvt* [**or** *nAl*] (1) Total change = *nAvte* [**or** *nAle*] (1) $I = \frac{nAvte}{t}$ with cancelling shown [or $\frac{nAle}{t}$, where $\frac{l}{t} = v$ shown] (1)	4
	(b)		$2.0 = 1.0 \times 10^{29} \times 1.7 \times 10^{-6} v \times 1.6 \times 10^{-19}$ (1) [substitution] $v = 7.4 \times 10^{-5}$ m s^{-1} ((**unit**))(1)	2
	(c)		collisions [accept obstructions](1) between <u>free electrons and copper atoms / ions / lattice</u> (1) [accept: delocalised / moving / conducting electrons]	2
	(d)		$R = \frac{P}{I^2}$ [or $P = I^2R$] (1); $R = \frac{0.1}{4}$ [=0.025 Ω] (1) $\rho = \frac{0.025\text{[e.c.f.]} \times 1.7 \times 10^{-6}}{2.5}$ (1) [manipulation i.e $\rho = \frac{RA}{l}$ or with figures] $\rho = 1.7 \times 10^{-8}$ Ω m. (1)	4
	(e)		cross-sectional area — smaller (1) *n* — the same (1) resistivity — the same (1)	3 **[15]**
4.	*(a)*	(i)	To overcome the frictional / drag force or because the applied force is insufficient.	1
		(ii)	$\frac{1}{\text{gradient}}$ attempted (1); Correct substitution, e.g. $\frac{3.0 - 0.5}{3.0}$ (1) *m* = 0.8(3) kg ((**unit**)) (1)	3
	(b)	(i)	A = contact force of surface on body [accept <u>normal</u> reaction](1) B = gravitational force of Earth on body (1) [accept: weight / *mg*]	2
		(ii)	<u>Gravitation force of body (mass)</u> (1) on Earth (1)	2 **[8]**

Question			Marking details	Marks Available
5.		(i)	$[\pi \times 22^2]$(1) [accept πr^2] × 14 (1) [=21 287 $m^3\ s^{-1}$] [21 287 → 1 mark]	2
		(ii)	mass every second = 1.2 × 21000 [or as calculated in (i)] [= 25 200] kg s^{-1}	1
		(iii)	Initial E_{k1} = ½ × 25 200 × 14^2 (1) e.c.f. from (ii) Final E_{k2} = ½ × 25 200 × 14^2 (1) e.c.f. from (ii) Δ E_k = 945 × 10^3 J s^{-1} (1) e.c.f. from E_{k1} and E_{k2} NB. "Solutions" based upon ½ *m* × $(14 - 11)^2$ → 0	3
		(iv)	Useful power available = 614 250 J s^{-1} (1) e.c.f. from (iii) $N_{\text{turbines}} = \frac{1000 \times 10^6}{614\,250}$ [=1628] (1)	2 **[8]**
6	*(a)*		Velocity = $\frac{\text{Displacement}}{\text{time}}$ / displacement per unit time / rate of change of displacement [but **not** per unit time] / $\frac{ds}{dt}$ with *s* defined]	1
	(b)	(i)	*v* + 1 [or equiv]	1
		(ii)	$t = \frac{s}{v}$ used [or by impl.](1) → $t = \frac{12(1)}{15}$ [= 8 s]	2
		(iii)	$v + 1 = \frac{28}{8}$ (1) [allow e.c.f. from (i) only on *v* – 1 or 1 – *v*] manipulation (1) *v* = 2.5 m s^{-1} (1) **Alt 1**: Distance moved by Stacey in 8 s = 8 m ✓ Distance moved by walkway in 8 s = 28 – 8 = 20 m ✓ Speed of walkway = $\frac{20}{8}$ = 2.5 m s^{-1} ✓ **Alt 2**: Velocity of Stacey on walkway = $\frac{28}{8}$ = 3.5 m s^{-1} ✓ Velocity of walkway = 3.5 – 1.0 ✓= 2.5 m s^{-1} ✓	3
		(iv)	5.0 m s^{-1} e.c.f. from (iii), i.e. ans = 2.5 + (iii)	1 **[8]**

Question			Marking details	Marks Available
7.	*(a)*		Use of cos 70° (1) $2T\cos 70° = 800$ (1) [$\rightarrow T = 1170$ N] [Accept mysterious division by 2 (b.o.d.)]	2
	(b)	(i)	Area under graph attempted or ½ Fx or ½ kx^2 (1) 240 J (1)	2
		(ii)	Initial energy stored in bow converted entirely to E_k of arrow (1) 240 e.c.f. = ½ $50 \times 10^{-3} v^2$ (1) [subst] manipulation leading to $v = 98$ m s^{-1} shown. (1) [Final mark not available if incorrect E_k used]	3
	(c)	(i)	$x = ut + \frac{1}{2}at^2$ (1); $u = 0$ (1) $t = 0.55$ s [accept 0.6 s] (1)	2
		(ii)	$D = V_H t$ [or by imp.] (1) e.c.f. of t $D = 98$ [or 100] × 0.55 [or 0.6] [e.c.f.] $\therefore D = 54$ m (1)	3
		(iii)	$v_{vertical} = u + at$ **and** $u = 0$ (1) [or equiv or by impl.] $v_v = 5.4$ m s^{-1} (1) $v_{resultant} = \sqrt{5.4^2 + 98.0^2}$ (1) or $v^2 = 5.4^2 + 98.0^2$ $v_{resultant} = 98.1$ m s^{-1} (1) Angle to horizontal [clearly identified] = $\sin^{-1}\frac{5.4}{98.1} = 3°$ (1) [Or equivalent correct application of other trig function]	5
	(d)		Greater [initial] force [or equiv.] required to pull the Turkish bow string [through a given distance] (1) [or more work / energy needed] Greater area under the Turkish bow curve (1) [leading to] more [elastic] potential energy stored (1). Arrows will leave Turkish bow with a greater speed / velocity (1) [Accept converse arguments]. [Alt to 2nd marking point: linking to 1st marking point …. because gradient of graph greater for Turkish bow]	4
				[21]

PH2 Mark scheme – January 2011

Question			Marking details	Marks Available
1	*(a)*	(i)	0.20 m	1
		(ii)	I. 10 m s^{-1} [e.c.f.]	1
			II. 0.02 s	1
			III. Displaced wave drawn with same amp and wavelength (1) As 1st marking point with displacement 0.05 m to right (1)	2
		(iii)	Direction of [particle] oscillation [accept <u>particle</u> movement] and direction of travel [or direction of energy propagation] (1) at right angles (1).	2
	(b)	(i)	Progressive waves transfer energy through medium; stationary waves do not.	1
		(ii)	For progressive waves the amplitude doesn't change [or falls gradually] (1) For stationary waves the amplitude increases, decreases and increases (1) [or drops to zero at equally spaced points / nodes]	2
				[10]
2.	*(a)*	(i)	Spreads out [or equiv. but not just "bends"]	1
		(ii)	constant phase relationship (1) [between light from slits / sources]	1
	(b)		re-arrangement of formula at any stage (1) [or by impl.] answer correct except, perhaps, for powers of 10 (1) 1.9 m (1)	3
	(c)		Dark fringes caused by destructive interference (1). With one slit closed, light from the other slit not cancelled [or equiv.](1)	2
				[7]

Question			Marking details	Marks Available
3	*(a)*	(i)	Formula correctly transposed at any stage (1). n = 2 (1); d = 2.2 μm (1)	3
		(ii)	Uncertainty [accept error] in measuring angle makes lower uncertainty [accept error] in d.	1
	(b)	(i)	$2\lambda = 2.2 \times 10^{-6} \sin 35.1°$ [e.c.f.] (1) [or by impl.] λ = 633 nm (1)	2
		(ii)	**Either** $\frac{d}{\lambda} = 3.5$ [or < 4] **or** $\frac{3\lambda}{d}$ and $\frac{4\lambda}{d}$ evaluated [in an attempt to find $\sin\theta$]. (1) [e.c.f. on d or λ] 3rd order deduced by valid reasoning (1).	2 **[8]**
4.	*(a)*		$n_{\text{clad}} \sin 90° = 1.540 \sin 77°$ **or** $n_{\text{clad}} = 1.540 \sin 77°$ [or by impl.] (1) $n_{\text{clad}} = 1.50[1]$ [accept 1.5] (1)	2
	(b)	(i)	speed = $\frac{3.00 \times 10^8}{1.54}$ (1) time = $\frac{\text{distance}}{\text{speed}}$ (1) [transposed at any stage] = 1.027×10^{-5} s (1) [omission of 1.54 loses just 1 mark]	3
		(ii)	I. AB = $\frac{AC}{\sin 77°}$ **or** AB = $\frac{AC}{\cos 13°}$ **or** equiv. (1)	1
			II. Zigzag time = $1.027 \times 10^{-5} \times 1.026$ s (1) [**or** Extra time = $1.027 \times 10^{-5} \times 0.026$ or by impl.] Extra time = 2.7×10^{-7} s [e.c.f. on speed] (1)	2
		(iii)	Bit of data arrives spread out over a period of time [accept: data smeared or multimode dispersion] (1). Data bits could overlap on arrival / can't distinguish (1)	2 **[10]**

Question			Marking details	Marks Available
5.	*(a)*		[minimum] energy needed to eject an electron [from surface]	1
	(b)	(i)	$hf_{min} = \phi$ [or equiv. or by impl.] (1) f_{min} = 5.7 10^{14} Hz (1)	2
		(ii)	$E_{k\ max} = 6.63 \times 10^{-34} \times 7.0 \times 10^{14} - 3.8 \times 10^{-19}$ [or equiv or by impl.] (1) $= 8.4 \times 10^{-20}$ J (1)	2
	(c)	(i)	Increasing intensity increases number of photons per second [or "photons cannot co-operate"]. (1) But individual photon energy unchanged [or "frequency unchanged"] (1).	2
		(ii)	No. of emitted electrons per second [accept current].	1
	(d)		Increase p.d. from zero (1) until ammeter reads zero (1). Take voltmeter reading, *V*. (1) Evaluate *eV*. (1)	4
				[12]
6	*(a)*	(i)	$\lambda = \frac{hc}{E}$ [any orientation] [**or** $E = hf$ **and** $f = \frac{c}{\lambda}$] (1) $\lambda = 6.33 \times 10^{-7}$ m ((**unit**))(1)	2
		(ii)	Red or orange.	1
		(iii)	Arrow shown from top energy level to middle level	1
	(b)	(i)	[Incident or passing] photon (1) of energy 3.14×10^{-19} J [or equiv. but not just "of the right energy"] (1)	2
		(ii)	Any 2 × 1 of: • coherent ✓ • beam nearly parallel ✓ • [almost] monochromatic [or same frequency] ✓ • polarised ✓	2
	(c)	(i)	[photons reflected by M_2 per second =] 6.3×10^{-15} [s^{-1}] **and** [photons transmitted per second =] 0.7×10^{15} [s^{-1}]	1
		(ii)	$0.7 \times 10^{15}\ s^{-1} \times 3.14 \times 10^{-19}$ J [or by impl.] (1) = 0.22 mW ((**unit**))(1) [1 mark lost if wrong number of photons used]	2
		(iii)	Stimulated emission event gives 2 photons out for 1 photon in. (1) Many such events as photons traverse amplifying medium [twice] (1) [**or** other true **and** relevant observation]	2
				[13]

Question			Marking details	Marks Available
7.	*(a)*	(i)	LHS: lepton number [= 0 + 0] = 0 (1) RHS: lepton number = [0] – 1 + 1 (1) [= 0]	2
		(ii)	I. $4 \rightarrow 3$ II. $2 \rightarrow 3$	1 1
	(b)		weak (1) because of neutrino involvement [**or** change in quark flavour] (1)	2
	(c)		takes place in the Sun (1) first stage in fusion chain [**or** ultimately leads to sunshine] (1) **Alternatively:** has taken place in stars (✓) leading to the formation of heavy elements (✓)	2
	(d)		electro-magnetic	1
				[9]
8	*(a)*	(i)	Power $= \text{intensity} \times 4\pi r^2$ (1) $= 3.8[5] \times 10^{26}$ W (1) [1 mark lost for factors of 2, 3 or 10^n adrift]	2
		(ii)	absorption by atmosphere.	1
	(b)	(i)	$A = \frac{3.85 \times 10^{26}}{5.67 \times 10^{-8} \times 5780^4}$ m^2 [e.c.f.] (1) $= 6.1 \times 10^{18}$ m^2 (1) [6.08×10^{18} m^2]	2
		(ii)	***Either*** $d = 2\sqrt{\frac{A}{4\pi}}$ [or equiv.] (1) $= 1.39 \times 10^9$ m (1) **Or** $A = 4\pi\left[\frac{d}{2}\right]^2$ (1) $= 6.15 \times 10^{18}$ m^2 (1)	2
	(c)		$\lambda_{\text{I max}} = \frac{W}{T} = \frac{2.90 \times 10^{-3}\ \text{mK}}{5780\ \text{K}}$ (1) = 500 nm [which is in the visible] (1) Sketch graph of correct general shape (1) with peak at 500 nm [e.c.f.] (1)	4
				[11]

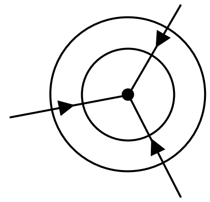
PH4 Mark scheme – January 2011

Question			Marking details	Marks Available
1.	*(a)*	(i)	$pV = \frac{1}{3}Nm\overline{c^2}$ or $p = \frac{1}{3}\rho\overline{c^2}$ <u>used</u>. (1) Correct use of N and m **or** ρ = 11.0 kg m^{-3} (1) $c_{\text{r.m.s.}}$ = 286 m s^{-1} (1)	3
		(ii)	$M_r = \frac{1.39\times10^{-25}}{1.66\times10^{-27}}$ (1) = 84 (1)[or $M_r = m/\text{g} \times N_A$] [No unit penalty] [N.B. Alternatives available: 1 mark method; 1 mark answer – factor of 10^3 error → method mark available]]	2
		(iii)	$pV = nRT$ <u>used</u> (1) $n = \frac{1.7\times10^{20}}{6.02\times10^{23}}$ (1) [N.B. The mark might be earned in (ii)] T = 275 K (1)	3
	(b)		Gets bigger (1) because pressure decreases [and T is ~ constant] (1). [Accept: …. because it collects dissolved gas(es) or because temperature increases as bubble rises]]	2 **[10]**
2.	*(a)*		ΔV = 0 / no change in volume	1
	(b)		Work done = area under graph or by impl. [i.e. area calc attempt] (1) Work done [= [–]1.5 × 10^5 × 4.0 × 10^{-3}]= [–] 600 J (1) Minus sign (1) [free-standing mark] [NB Any reasonable method of determining area, including counting squares ✓]	3
	(c)		ΔU: <u>change</u> [or <u>increase</u>] in <u>internal energy</u> of …(1) Q: <u>heat supplied</u> ["heat in" etc. – direction must be indicated] to ……(1) W: <u>work</u> done <u>by</u> …..(1) [NB: **not** "by or on"] [Subtract 1 mark if "gas" or "system" not mentioned at least once].	3
	(d)		Attempt at area inside the cycle or Area $_{BC}$ – Area $_{DA}$ (1) Area / W [= 0.675× 10^5 × 4.0 × 10^{-3} – 600] = – 350 J (1) ∴ Q = –350 J (1) [NB final step must be explicit – leaving answer for W doesn't gain the final mark]	3 **[10]**

Question			Marking details	Marks Available
3			Sample answer: Microwave oven [although away from central resonance] (1). Driving force: the [e-m fields of the] microwaves (1) Oscillating System: rotation [accept vibration] of <u>water</u> molecules (1) Result: Increased [accept large amplitude] rotational k.e. (1) General scheme: 4 distinct points needed → 4 × (1) Diagram / statement of application [e.g. bridge, car rattle…] ✓ Description of plausible oscillating driving force ✓ Description of plausible system ✓ Large <u>amplitude</u> because of same frequency [or graph showing resonance, with labelled axes]✓	4 **[4]**
4.	*(a)*		$r_1 = \frac{m_2}{m_1 + m_2} d$ <u>used</u> [or $m_1 r_1 = m_2 r_2$] (1) $r_1 = 7.43 \times 10^8$ m (1)	2
	(b)		<u>Use</u> of relevant eq^n: $T = 2\pi\sqrt{\frac{d^3}{G(m_1 + m_2)}}$ or $2\pi\sqrt{\frac{d^3}{GM}}$ or $\frac{GM}{r^2} = \frac{mv^2}{r}$ (1) $T = 3.75 \times 10^8$ s (1) Division by (24 × 60 × 60 × 365[.25]) or equiv (1) [=11.88 year]	3
	(c)		$v = \frac{2\pi r}{T}$ [or $v = \omega r$ **and** $\omega = \frac{2\pi}{T}$] (1) $v = \frac{2\pi \times \text{ answer } (a)}{\text{answer } (b)}$ (1) [= 12.46 m s^{-1}]	2
	(d)		Doppler shift calculated: $\frac{\Delta\lambda}{\lambda} = \frac{v}{c} \rightarrow \Delta\lambda = \frac{v\lambda}{c}$ = 5.3 × 10^{-14} m (1) Upper λ value labelled: 1.28 μm / $\lambda_{[0]}$ + 5.3 × 10^{-14} m (1) Lower λ value labelled: 1.28 μm / $\lambda_{[0]}$ − 5.3 × 10^{-14} m (1) [Alternatively for 2nd and 3rd marks, indication on the graph that the amplitude of the variation is 5.3 × 10^{-14} m, e.g. peak to peak $\Delta\lambda$ is shown as 10.6 × 10^{-14} m] Period labelled: 12 years / 3.75 × 10^8 s (1)	4 **[11]**

Question			Marking details	Marks Available
5.	*(a)*		[centripetal force =] $m\omega^2 r$ [or $\omega^2 r$ and ma] (1) $F = 32.5 \times 1.4^2\ r$ [= 63.7 r] (1) Friction [of the surface on the shoes] provides centripetal force [or is the resultant etc.] (1) [Accept $F = m\omega r^2$ for 1st and 3rd marks as F is defined in the question]	3
	(b)		63.7 r = 114 [N] (1) r = 1.79 **and** relevant comment, e.g. if r greater, F > 114 N (1) [Alt: Subst r = 1.8 m and comment that F > 114 N]	2
	(c)		$T = \frac{2\pi}{\omega}$ [or by impl.] (1) = [$\frac{2\pi}{1.4}$ =] 4.49 s (1)	2
	(d)		$v = \omega A$ [or by impl.] (1) = [1.4 × 1.8 =] 2.52 m s^{-1} (1) [If $v = A\omega \cos \omega t$, or equiv, then $\cos \omega t$ = 1must be stated for 1st mark]	2
	(e)		$a = \omega^2 A$ [or by impl.] (1) = [1.4^2 × 1.8 =] 3.53 m s^{-2} (1) occurs at the extremities / when $x = \pm A$ etc. (1) [If $a = A\omega^2 \cos \omega t$, or equiv, then $\cos \omega t$ = 1must be stated for 1st mark]	3
	(f)		At least one cycle of wave drawn with correct amplitude [1.8 m e.c.f.] (1) Reasonable shape of sinusoid + correct period + correct phase [i.e. sin wave] (1)	2
	(g)		Use of – 1.00 = sin ωt (1) $1.4t = \sin^{-1}\left(\frac{-1}{1.8}\right)$ (1) [= – 0.59] t = – 0.42 s (1) [Mysterious loss of – sign loses 1 mark] $t_1 = \frac{T}{2} + 0.42$ [2.42 s] **and** $t_2 = T - 0.42$ [4.07 s] (1) Max 2 marks for reading from graph ± 0.1 s, i.e 2.6, 2.7 s ✓ 4.0, 4.1 s ✓	4 **[18]**

Question			Marking details	Marks Available
6.	*(a)*		$p = \frac{h}{\lambda} = \frac{6.63\times10^{-34}}{519.8\times10^{-9}}$ = 1.275 × 10^{-27} kg m s^{-1} / Ns ((**unit**))	1
	(b)		$p = mv$ = 9.11 × 10^{-31} × 1400 (1) = 1.275 × 10^{-27} kg m s^{-1} ∴ momenta cancel or sum = 0. [Comment needed] (1)	2
	(c)		Yes – momenta cancel afterwards also. [i.e. Yes + sensible comment, e.g. reflection symmetry, e.g. wavelength and speed unchanged. Accept mention of C of M frame]	1
	(d)		Loss of photon energy (1) = gain in kinetic energy [of electron] (1) ["Photon energy decreases; Electron KE increases" → 1 mark]	2
				[6]
7.	*(a)*		<u>Use</u> of $\frac{GMm}{r^2}$ (1)[or by impl.] = $\frac{6.67\times10^{-11}\times1.99\times10^{30}\times1.31\times10^{22}}{(7.38\times10^{12})^2}$ Force = 3.19 × 10^{16} N (1)	2
	(b)		$\frac{GM_1}{r_1^2} = \frac{GM_2}{r_2^2}$ (1) $\frac{r_2^2}{r_1^2} = \frac{m_2}{m_1}$ (1) $\frac{r_2}{r_1}$ = 8.11 × 10^{-5} (1) → r_2 = 6 × 10^8 m (1) [Alt: $\frac{GM_1}{r_1^2} = \frac{GM_2}{(d_1 - r_1)^2}$ (1) $M_1(d - r_1)^2 = M_2 r_1^2$ (1) remaining algebra (1)]	4
	(c)		GPE = [–]$\frac{GMm}{r}$ [or V = [–]$\frac{GM}{r}$ **and** GPE = $m\Delta V$] (1) Attempt at calculating 2 PEs or 2 Vs (1) [PEs: –2.36 × 10^{29} and –3.92 × 10^{29}, Vs: 1.8 × 10^7 and 3.0 × 10^7] ΔE_k = [–]ΔE_p = 1.56 × 10^{29} J (1) e.c.f. i.e. the mark is for equating the gain of KE to the loss in PE.	3
				[9]

Question			Marking details	Marks Available
8.	*(a)*		At least 2 field lines shown with correct direction (1) At least two equipotentials surfaces shown [reasonable sketch circles centred on –Q] (1) Labelling (1)  	3
	(b)	(i)	<u>Use</u> of $F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r^2}$ (1) = 5.62 N (1)	2
		(ii)	<u>Use</u> of $V = \frac{1}{4\pi\varepsilon_0}\frac{Q_1}{r}$ **and** $\Delta E_p = q\Delta V$ **or** use of $E_p = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{r}$ (1) ΔE_p = [–] 0.45 J (1) $\therefore E_{k\,[max]}$ = 0.45 J [explicit] (1)[NB Free-standing mark – awarded if KE gain = PE loss stated]	3
	(c)		<u>Use</u> of $E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$ (1) = 2.81 × 10^6 V m^{-1}(1) Horizontal cpts cancel ∴ direction down [could be in diagram] or stated algebraically, e.g. $2E\cos\theta$ (1) E_{res} [= $2E\sin\theta = 2\times\frac{3}{5}\times 2.81\times10^6$]= 8.6 × 10^6 V m^{-1} [or N C^{-1}] (1) ((**unit**))	4 **[12]**