GCE MARKING SCHEME

PHYSICS
AS/Advanced

SUMMER 2011

INTRODUCTION

The marking schemes which follow were those used by WJEC for the Summer 2011 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.

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.

<u>Example</u>: 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.

Question			Marking details	Marks Available
1	*(a)*		Use of cos 40° [or sin 50°] (1) [or by impl.] $\left(\frac{200}{\cos 40}\right)$(1)= 260 N [subst or ans]	2
	(b)	(i)	Work done = Force × distance (1) in direction of force (1) There is no movement in the vertical direction [or equiv.] (1)	3
		(ii)	I. Work done = 200 (1) × 2000 = 4.0 × 10^5 J ((**unit**)) [or 400 kJ] (1) II. $P = \frac{4\times10^5\text{(ecf)}}{30\times60\text{(1)}}$ (1) [NB or use of $P=Fv$]	2 2
	(c)		Attempt at resultant force calculation (1) ΣF = 261 (ecf) – 200 (1) [=61 N] [correct sign needed] $a = \frac{61}{40}$ [=1.53 m s^{-2}] [no ecf on use of 261 N] (1)	3 **[12]**
2	*(a)*		Ammeter shown in series with bulb [or in series with bulb/voltmeter parallel combination] (1) Voltmeter shown in parallel with bulb [or across bulb/ammeter series combination] (1)	2
	(b)	(i)	2.0 A	1
		(ii)	6.0 Ω	1
	(c)		**Either:** $\frac{1}{18}+\frac{1}{6\text{(ecf)}}=\frac{1}{R_{\parallel}}$ (1); R_{par} = 4.5 Ω (1) Subst into pot div equations: $12 = \frac{4.5}{4.5+R}\times16$ (1) R = 1.5 Ω (1) **Or**: $I_{18\,\Omega} = \frac{12}{18}$ [=0.67 A] (1); So I_{total} = 2.67 A [ecf from *(a)*](1) $R = \frac{4\text{(1)}}{2.67\text{(ecf)}}$ = 1.5 Ω (1)	4
	(d)		Graph shown with positive gradient and linear through the origin for low values (1) and smoothly reducing gradient for higher values [NB – **not** negative gradients at end](1)	2 **[10]**

Question			Marking details	Marks Available
3	*(a)*		Moment [or torque / couple]	1
	(b)	(i)	4.0 × 0.40 = Δ × 0.20 (1) [or by impl.] Wt of Δ = 8.0 N (1)	2
		(ii)	12.0 N (1)[ecf = 4.0 + *(b)*(i)]	1
	(c)	(i)	12(ecf)x (1) = 9.0(0.8 – x)(1) x = 0.34 m (1)	3
		(ii)	x needs to stay the same (1) because force/weight [and hence the moment] at C are unchanged (1) N.B. Ecf from *(b)*(ii)	2 **[9]**
4	*(a)*	(i)	[gradient =] $\frac{v-u}{t}$ (1); represents acceleration [accept: a] (1)	2
		(ii)	[Area =] $ut+\frac{1}{2}t(v-u)$ **or** $\frac{1}{2}(u+v)t$ (1) Represents displacement [accept: distance [travelled in a given direction]] (1)	2
		(iii)	Either: $v = u + at$ (1) $x = ut + ½t(ut)$ shown (1) [or other convincing working] Or: $v = u + at$ (1) $x = ½(u + u + at)t$(1) [or other convincing working]	2
	(b)	(i)	x = ut + ½at^2 used with u = 0 (1) x = 36 m (1)	2
		(ii)	$v = u + at$ used with u = 0 (1) [or $v^2 = u^2 + 2ax$ used with u = 0] v = 6 m s^{-1} (1)	2
	(c)	(i)	$x = \frac{1}{2}(u+v)t$ used (1) t = 40 s (1) [Use of u = 0 seen → 1 mark penalty]	2
		(ii)	Use of $a = \frac{v-u}{t}$ (1) [Use of u = 0 seen → 1 mark penalty] a = [–] 0.15 m s^{-2} (1)	2
	(d)		Axes [inc + and – acceleration; time; labelling] (1) Horizontal line from 0 s at 0.5 m s^{-2}(1) Horizontal line from at – 0.15 m s^{-2} [ecf from *(c)*(ii)] (1) Change of a at 12 s and cease at 52 s (1)	4
	(e)	(i)	157 N	1
		(ii)	$\left(\frac{157(\text{ecf})}{4(1)}+8\right)$ [= 47 N] (1) [or equivalent working.] NB Use of factor of 2 → 0 marks	2 **[21]**

Question			Marking details	Marks Available
5	*(a)*		Rearrangement of $R = \frac{\rho l}{A}$ seen [or implied by 2nd mark]. (1) $\frac{\Omega\ \text{m}^2}{\text{m}}$ seen (1) Accept equivalent working in terms of showing homogeneity: 1st mark insertion of units in equation; 2nd mark explicit conclusion	2
	(b)	(i)	Convincing demonstration, e.g $\pi\left(\frac{1.3\times10^{-3}}{2}\right)^2$ seen [Ans = 1.327×10^{-9} m^2]	1
		(ii)	$R = \frac{1.7\times10^{-8}\times20}{1.3(\text{or } 1.33)\times10^{-6}}$ [=0.26 Ω]	1
		(iii)	$\frac{0.26(\text{ecf})}{14}$ [or correct use of parallel formula] (1) = 0.019 Ω (1) If resistivity formula used, 1st mark for A × 14.	2
		(iv)	Use of $P = I^2R$ [or equiv, e.g. $P = IV$ and $V = IR$] (1) $\left(\frac{9\times0.26}{9\times0.19}\right)$[NB 9 not 3] **or** $\left(\frac{I^2R}{I^2 R/14}\right)$ (1) Answer in range 13 – 14.5 : 1 (1)	3
		(v)	I. Less power loss in whole / larger cable [for a given current] / or smaller resistance [accept: if 1 strand breaks there will still be continuity.]	1
			II. More flexible [or less prone to snap with repeat bending] /if 1 strand breaks there will still be continuity [accept only once]	1
	(c)	(i)	7.52 – 7.7 × 10^{28} m^{-3}	1
		(ii)	Substitution in or re-arrangement of $I = nAve$ to give v: $v = \frac{I}{nAe}$ or 3.0 = 7.7 × 10^{28}(ecf) × 1.3 × 10^{-6} × 1.6 × $10^{-19}v$(1) [NB No ecf on n if 2.0 × 10^{24} used] v = 1.9 × 10^{-4} m s^{-1} (1)	2
		(iii)	I, n and e do not change (1) A increased by × 14 (1) v reduced by same ration → 1.36 [1.4] × 10^{-5}m s^{-1}.(1)	3
				[17]

Question			Marking details	Marks Available
6	*(a)*	(i)	*V* is the terminal p.d. – or clear explanation in energy terms: energy per coulomb delivered to external circuit / [NB "per coulomb" / "per unit charge" required on one of (i) and (ii) if energy explanation given]	1
		(ii)	P.D. across the internal resistance [accept lost volts – "bod"] / energy per coulomb lost / dissipated in the internal resistance / cell	1
	(b)	(i)	2.4 V	1
		(ii)	0.4 Ω [allow e.c.f. from *(b)*(i)]	1
		(iii)	e.g. "Drains" the cell quickly, Cell gets hot	1
	(c)		Correct use of $I = \frac{E}{R_{\text{Tot}}}$ $I = 1.0$ A	2
	(d)		Trial and error acceptable: Use of 1 ×, 2 ×, 3 × … (1); corresponding total resistance (1); use of $\frac{V}{R}$ (1) leading to 5 cells (1) Nice answer: Subst in $I = \frac{E}{R+r}$: $3.0 = \frac{2.4n}{2.0+0.4n}$ [ecf on n × 2](1) Re-arrangement: $6.0 + 1.2n = 2.4n \rightarrow n = 5$ Marking points with analytical answer: $n \times 2.4$ (1) Use of total resistance = $2.0 + 0.4\,n$ (1) Application of $I = \frac{V}{R}$ (1); $n = 5$ (1)	4
				[11]

Question			Marking details	Marks Available
1	*(a)*	(i)	Longitudinal waves: Directions of [particle **or** molecule or air] oscillations and direction of travel of wave [or energy] [NB **not** particles travelling](1) are parallel [or parallel / antiparallel or the same] (1) [Independent marks]	2
		(ii)	Wavelength: [Shortest] distance [along the direction of propagation] between air layers [or particles or molecules or points] oscillating in phase (✓) **or** distance between [the centre of successive] compressions [or rarefactions]. [NB **not** 'peaks' and 'troughs']	1
	(b)	(i)	Interference between [or superposition of] [progressive] waves (1) travelling <u>in opposite directions</u>. (1) [Not 'constructive' or 'destructive' interference only]	2
		(ii)	N.B. Working must be shown. λ = 0.44 m (1) $v = f\lambda$ correctly applied (1) [**or** $v = \lambda/T$ correctly applied] v = 330 m s^{-1} ((**unit**)) (1) [Correct answer only → 1 mark] [No ecf unless wrong answer commented upon!]	3
		(iii)	$\frac{\lambda}{2}$ = 3.3 m or λ = 6.6 m (1). So nodes must be further apart than 2 m [or equiv] (1) [ecf from incorrect v]	2
				[10]
2	*(a)*	(i)	$v_{air} > v_{glass}$ (1), $f_{air} = f_{glass}$ **and** $\lambda_{air} > \lambda_{glass}$ (1)	2
		(ii)	Cycles [or oscillation] can't appear or disappear [at boundary] **or** equiv. / frequency determined by the source [**not** just f is constant]	1
	(b)	(i)	$[1.00]\sin 40^\circ = 1.52 \sin\phi$ [where ϕ = angle of refraction] (1) ϕ = 25° (1); θ = 90° – 25° (1) = [65°]	3
		(ii)	$\sin c = \frac{1}{1.52}$ [or equiv] c = 41° (1) 65° > 41° or remark (1)[free standing] **or**: $\sin^{-1}\left(1.52\sin 65^\circ\right)$ gives "error" (1), so refraction not possible (1)	2
		(iii)	I. Diagram: Reasonable path drawn [no gross departure from law of reflection] with emergent ray in correct quadrant (1)	1
			II. 2 sensible parallel paths inside block labelled (1) Emergent ray labelled as parallel to incident ray. (1)	2
	(c)		Any 2× (1) from: • minimises <u>multimode</u> dispersion [or equiv](✓) • cuts down range of path lengths (✓) • less pulse broadening **or** less likelihood of overlapping **or** more rapid data [allow: smearing and jumbling] sequence possible (✓) [not interfere or distorted]	2
				[13]

Question			Marking details	Marks Available
3	*(a)*		Electrons are emitted [from tin] (1). Electrons are negatively charged [**or** plate originally neutral] **or** electrons knocked out by photons (1) Plate left with a positive charge (1)	3
	(b)	(i)	Work function: [Minimum] energy [or work] needed for an electron to escape [from metal surface]	1
		(ii)	$hf_{min} = \phi$ [or by impl.] or $0 = 6.63 \times 10^{-34} f_{min} - 7.1 \times 10^{-19}$ (1) $f_{min} = 1.07 \times 10^{15}$ Hz (1)	2
		(iii)	$1.5 \times 10^{-19} = hf - 7.1 \times 10^{-19}$ [or equiv. or by impl.] (1) $f = 1.3 \times 10^{15}$ Hz (1)	2
	(c)	(i)	number per second = $\frac{0.64\times10^{-6}[\text{C s}^{-1}]}{1.6\times10^{-19}[\text{C}]}$	1
		(ii)	Number of photons per second = $4.0 \times 10^{12} \times 1200$ Multiplication by 1200 at any stage [or by impl.](1) Photon energy = 8.6×10^{-19} J [or by impl.] (1) UV energy per second = 4.1 m(1)W(1) [4.1×10^{-3} J s^{-1} ✓✓]	4
				[13]
4	*(a)*	(i)	Ground state to level T labelled I or *pumping* (1) Level U to level L labelled II or *stimulated emission* (1)	2
		(ii)	$E_{phot} = \frac{hc}{\lambda}$ [or $E_{phot} = hf$ **and** $f = \frac{c}{\lambda}$] [or by impl.](1) $E_{phot} = 1.9[0] \times 10^{-19}$ J (1) Energy of level U $= 2.2 \times 10^{-19}$ J (1)	3
		(iii)	I. [Stimulated emission is triggered by an incident] photon (1) with energy 1.9×10^{-19} J [ecf but **not** 2.2×10^{-19}] **or** equal to the difference between levels U and L (1) [no ecf from incorrect identification of transition in *(a)*(i)]	2
			II. Photon emitted together with the original photon [accept: there are now 2 photons where there was previously 1; also accept correct answer given in I.]	1
			III. Stimulated photon and incident photon <u>in phase</u>.	1
		(iv)	Promotes population inversion [between levels U and L] (1) **Either** less pumping needed, **or** population inversion needed so that stimulated emission predominates over absorption (1)	2
	(b)		Less energy input needed for a given [light] energy output (1) [**or** more efficient]	1
				[12]

Question			Marking details	Marks Available
5	*(a)*	(i)	Diffraction	1
		(ii)	[Slit width much] greater than the wavelength (1) [Angular] spread [of central maximum] is small. (1)	2
		(iii)	[Width of] spread decreases (1) [accept: less diffraction] <u>Peak</u> intensity increases (1)[**or** intensity increases because more light is let through].	2
	(b)	(i)	1.25 mm	1
		(ii)	Use of $\lambda = \frac{ay}{D}$ with symbols correctly interpreted (1) λ = 625 nm [ecf on *y*] (1)	2
		(iii)	When path difference is a whole number of wavelengths [not just: path difference = 0] (1), waves from the slits <u>arrive</u> [or equiv.] in phase (1) and interfere constructively (1)	3
		(iv)	Less light diffracted at greater angles / intensity envelope the same as the diffraction graph.	1
	(c)		Any 2 × (1) from: • Light from laser may be brighter ✓ [not just collimated] • Light from laser coherent / no need for single slit / light source need not be distant ✓ • light [more nearly] monochromatic ✓	2
				[14]

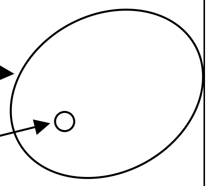
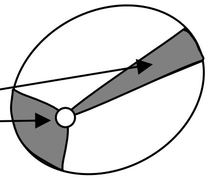
Question			Marking details	Marks Available
6	*(a)*	(i)	Quark-antiquark combination [or equiv.]	1
		(ii)	Only $u\bar{d}$ combination [in the 1st generation] gives a charge of +e [or $\frac{2}{3}+\frac{1}{3}=1$]	1
	(b)	(i)	I. [$u\bar{d}$ + uud + udd → uud + uud] u numbers: LHS = 4; RHS = 4, so conserved	1
			II. d numbers: LHS = 2; RHS = 2, so conserved	1
		(ii)	Strong force (1) Any 1 × (1) of: • 'high energies' suggests strong ✓ • separate conservation of u and d ✓ • no neutrino / lepton involvement ✓ • quark regrouping / only quarks involved ✓	2
	(c)	(i)	Any intelligible method [e.g. baryon and charge conservation **or** u and d numbers conservation, **or** quark counting to give 9u+9d in X, **or** comparison with equation in *(b)* noting that π^+ + n → p] (1) [or by impl.] A = 6 **and** Z = 3 (1)	2
		(ii)	Proton number / atomic number [accept: chemical element]	1
				[11]
7	*(a)*	(i)	$T=\frac{W}{260\times10^{-9}}$ (1 – trans) [or by impl.][allow this mark even if 10^{-9} omitted] = 11 × 10^3 K (1) ((**unit**))	2
		(ii)	Black body [accept: non-reflecting surface / radiates <u>equally</u> in all directions]	1
	(b)		Radius is × 70 so area is × 70^2 [or equiv, or by impl.] (1) Temperature is × 2, so T^4 is 2^4 [or equiv. or by impl.] (1) [So] Power is × 80 000 (1)	3
	(c)		Absorption [by atoms in the stellar atmosphere or in interstellar gas] of specific wavelengths from the star's continuous spectrum [or from star's radiation / star's light] (1) Any 2 × (1) from: • ….. because photons of specific <u>energy</u> abso rbed ✓ • Photon energies correspond to transitions between [atoms'] energy levels ✓ • Absorbed radiation re-emitted but in all directions ✓	3
				[9]

Question			Marking details	Marks Available
1.	*(a)*		[In any interaction] the [vector] sum of bodies' *momenta* [accept 'total momentum'] stays constant (1), provided no [resultant] external force acts [accept: in a closed system] (1) NB. Separate marks but statement of conservation of energy loses both marks.	2
	(b)	(i)	$1.67 \times [10^{-27}] \times 3150 \pm 9.98 \times [10^{-27}] \times 225 = 11.6 \times [10^{-27}]v$ (1) [10^{-27} consistently dropped or masses given as 1, 6, 7 ✓] With minus sign (i.e. signs correct) (1) $v = 260\ \text{m s}^{-1}$ (1) [no ecf] Arrow to right (1)	4
		(ii)	Σ KE initially = 8.54×10^{-21} J (1) Σ KE finally = 3.92×10^{-21} J (1) [Correct answer other than powers of 10 → 1 mark]	2
	(c)		$\Delta mv = \frac{h}{\lambda}$ or $v = \frac{h}{\lambda m}$ (1) [or $\frac{h}{\lambda} = 3.88 \times 10^{-21}$ [Ns]] $v = 3.3 \times 10^{5}\ \text{m s}^{-1}$ (1) [No penalty for attempts to include initial momentum (which is 3.0×10^{-24} Ns)]	2
				10

Question			Marking details	Marks Available
2.	*(a)*	(i)	Relevant comment, e.g. stem suggests not at equilibrium when released / graph shows equilibrium at t = 0 / graph contradicts stem	1
		(ii)	I. 0.08 m (1) II. 1.2 s (1)	1 1
	(b)		$k = \frac{4\pi^2 m}{T^2}$ (1) [correct transposition at any stage] $= 11\text{ N m}^{-1}$ (1) ((**unit** including any SI equivalent))	2
	(c)	(i)	{$\omega = 5.24\text{ rad s}^{-1}$} **or** {use of $v_{\text{max}} = \frac{2\pi A}{T}$ [or equiv]}(1) $v_{\text{max}} = 0.42\text{ m s}^{-1}$ [accept $v_{\text{max}} = 0.080 \times 5.24$] + comment (1) [Full marks available for use of tangent → $T = 0.42 \pm 0.7\text{ m s}^{-1}$]	2
		(ii)	Correct sequence of v values (i.e. correct phase) (1) t values correct, and reasonable curve plotted (1)	2
	(d)	(i)	I. – [or "decrease"] (1) 0.035 J [± 0.003 J] (1) II. – 0.31 J [±0.01 J] NB Correct sign required.	2 1
		(ii)	[0.35J of] elastic [potential] energy gained (1) [Accept: [more] energy stored in spring [at 0.9s]]	1
	(e)	(i)	ordinate labelled "amplitude" and abscissa labelled "frequency"	1
		(ii)	ϕ is [close to] the natural frequency [or by implication] (1) [NB **not** resonant frequency] 0.83 Hz (1) [e.c.f. from *(a)*(ii)(II)]	2
				16

Question			Marking details	Marks Available
3.	*(a)*	(i)	I. $\overline{c^2} = \frac{3p}{\rho}$ (1) [transposition at any stage] $= \frac{3\times100\times10^3\times1.5\times10^{-3}}{2.4\times10^{-3}}$ (1) [correct substitution or by implication] $\sqrt{\overline{c^2}}$ = 433 m s^{-1} (1) [Wrong attempts based on $pV = \frac{1}{3}Nm\overline{c^2}$ can score the last mark if $\sqrt{\ }$ correctly taken]	3
			II. collisions [“random process” not enough]	1
			III. $935^2 + 743^2 + 312^2$ [= 1.52 × 10^6] (1) Division of sum by 3 even if $\frac{935+743+312}{3}$ [= 663 m s^{-1}] (1) C_{rms} = 712 m s^{-1} (1) [no ecf]	3
		(ii)	I. T = $\frac{pV}{nR}$ (1) [transposition at any stage] T = 301 K **or** { $\frac{100\times10^3\times1.5\times10^{-3}}{0.050\times8.31}$ = 300 K or 301 K} (1)	2
			II. $N = 3.6\times10^{22}$	1
			III. rmm = $\frac{2.4}{0.0600}$ (1) [award mark even if 2.4× 10^{-3} used] = 40 (1) [NB no unit penalty]	2
	(b)	(i)	Attempt to find area under AB / use of $p\Delta V$ [or by implication] (1) 100 J (1)	2
		(ii)	Either T_B = 500 K (1) [or by impl.] U_B = 374 J **or** U_A = 224 J (1) [or by impl.] ΔU = 150 J (1) Or $U = \frac{3}{2}pV$ (1) [or by impl] $\Delta U = \frac{3}{2}p\Delta U$ (1)[or by impl.] = 150 J (1)	3
		(iii)	250 J [e.c.f.]	1
		(iv)	[U falls by 150 J and because the volume doesn’t change] no work involved / $Q = \Delta U$ (1) 150 J (1) [ecf on answer to (ii)]	2
				20

Question			Marking details	Marks Available
4.	*(a)*	(i)	Arrows shown at **P** away from **both** the two charges [Resultant shown → ignore; other arrows shown in other directions → s.i.f.]	1
		(ii)	E at P due to one charge = $\dfrac{7.0\times10^{-12}}{4\pi\times8.85\times10^{-12}\times(0.38)^2}$ N C^{-1} (1) [= 0.44 N C^{-1}] [Accept 9.0×10^9 [F^{-1}m] for $\dfrac{1}{4\pi\varepsilon_0}$; treat 0.31m as slip: give first mark] Multiplication by cos 55° (1) Multiplication by 2 (1) NB These 2 marks available for clear working to calculate <u>force</u> on a charge placed at P ; 0.38 m must be used. E_{res} = 0.50 N C^{-1} **or** 0.50 V m^{-1} ((**unit**)) (1) [Award last mark for 0.25 N C^{-1} but not for other mistake] NB. Direction **not** required. Use of 45° rather than 55° [i.e. *E*s at right angles → 1st and 3rd marks available].	4
		(iii)	I. Fields from charges cancel (1) [or equivalent, e.g. fields from charges are equal and opposite] II. Coulomb's law or inverse square law (however stated) [holds for individual charges]	1 1
	(b)	(i)	Force on ion = 4.8×10^{-19} C × 0.50 N C^{-1} (1) (ecf) [or by impl.] [= 2.4×10^{-19} N] Acceleration $\left[=\dfrac{2.4\times10^{-19}\text{ N}}{4.5\times10^{-26}\text{ kg}}\right]$ = 5.3×10^{6} m s^{-2} (1) ((**unit**)) (ecf applies within this calculation on the incorrect force)	2
		(ii)	Speed never decreases [accept: always accelerates](1) [or by implication] Speed increases at greatest rate where E_{res} graph peaks (1) [or equivalent]	2
		(iii)	PE = $q\dfrac{Q}{4\pi\varepsilon_0 r}\times 2$ (1) [or by implication] = 1.95×10^{-19} J (1) [or by implication] KE = 9.0×10^{-20} J (1) [independent mark] Total = 2.85×10^{-19} J (1) [no general e.c.f. but use of r^2 → no ecf; use of 0.38 m only loses 2nd mark; use of incorrect charge loses 1st and 2nd marks] [Omission of factor of 2 penalised only once → 1.88×10^{-19} J]	4
		(iv)	At large distance, PE negligible / KE_{max} = Total energy at 0 (1) [or by impl.] $\frac{1}{2}mv^2 = 2.85\times10^{-19}$ J (1) e.c.f. [or by impl.] v_{max} = 3600 m s^{-1} (1)	3
				18

Question			Marking details	Marks Available
5.	*(a)*	(i)	I. …Ellipse stated **and** shown (1) …with star at one focus stated **or** shown (1) 	2
			II. Faster when closer to the star (1) Equal areas in equal intervals of time stated **and** shown (1) 	2
		(ii)	I. $\frac{GMm}{r^2} = \frac{mv^2}{r}$ [Accept $\frac{GM}{r^2} = \frac{v^2}{r}$] [$\frac{GMm}{r^2} = mr\omega^2$ acceptable only if $\omega = \frac{v}{r}$ explicitly involved, with clear algebra]	1
		(iii)	II. Planet wouldn't orbit centre of star / planet [and star] orbit centre of mass [or equiv.] (1) We'd need $\frac{GMm}{d^2} = \frac{mv^2}{r}$ [in which $d \neq r$] (1) [or equivalent]	2
	(b)	(i)	I. $v = c\frac{\Delta\lambda}{\lambda}$ with evidence of correct use (1) [e.g. substitutions with no more than numerical slips] v_A = 9.5[1] × 10^5 m s^{-1}, **and** v_B = 5.3[0] × 10^5 m s^{-1} (1)	2
		(ii)	II. $\bar{v}$ = 7.4 × 10^5 m s^{-1}	1
		(iii)	III. v_{rot} = 2.1 × 10^5 m s^{-1}	1
	(c)		I. $M = \frac{v^2 r}{G}$ (1) [transposition at any stage] Substitution of *v*, *r* pair from dotted graph (1) *M* = 1.1 × 10^{41} kg (1) [e.c.f on slips in reading dotted graph] Slips in powers of 10 penalised by only 1 mark.	3
			II. Any 2 × (1) from Mass larger than 1.1 × 10^{41} kg / actual mass large than theoretical [**or** *M*] (✓) $v = \sqrt{\frac{GM}{r}}$ assumes the mass is central (✓) Mass distributed [however expressed] (✓)	2
				18

Question			Marking details	Marks Available
SECTION A				
1	*(a)*	(i)	$C = \frac{Q}{V}$ understood (1) [or by impl.] i.e Rearranging to give $V = Q/C$ or substitution of capacitance for C and charge for Q V = 12.5(3) V (1)	2
		(ii)	$C = \frac{\varepsilon_0 A}{d}$ understood [simply quoting is not enough] (1) [substitution of all quantities except d] $d = 9.44 \times 10^{-4}$ m [accept 0.9 mm] (1)	2
	(b)		$Q = Q_o \exp\left(\frac{-t}{RC}\right)$ understood (1) [substitution] Taking logs correctly e.g. $\ln Q = \ln Q_o - \frac{t}{RC}$ (1) Algebra e.g. $-1.9 = \frac{-t}{15\times10^{6}\times375\times10^{-12}}$ (1) t = 0.01 [0.007] s (1) [Use of $\log_{10}$ → 0.47: treat as calculator slip → 3 marks] [Mysterious vanishing of minus sign → slip]	4
	(c)		[Dielectric (or water)] increases C **or** allows more Q to be stored [accept: store more energy **or** time constant increased] (1) so change in C or Q means fog **or** use coulometer to measure Q **or** use multi(meter) to measure C [or voltage] } (1) NB. 0 marks awarded for answers referring to conduction by water.	2
				[10]

Question			Marking details	Marks Available
SECTION A				
2	*(a)*		$B = \frac{\mu_0 I}{2\pi a}$ understood [or $B = 4.8 \times 10^{-7}$ T] (1) [not $\mu_0 nI$] either $5 \times 4.8 \times 10^{-7}$ **or** $B = \frac{4\pi \times 10^{-7} \times 1.5}{2\pi \times 0.125}$ (1)	2
	(b)	(i)	$\sin\theta = 0^\circ$ **or** $\theta = 0^\circ$ **or** $\theta = 180, \pi$ etc (1) Travels along [parallel or opposite to] field lines (1) [NB: 2nd mark implies first] "to the right" → 0 "to the right parallel to field" → 1 bod.	2
		(ii)	$F = Bq\sin\theta$ understood (1) [or by impl.] , i.e. θ = 90° calculated [by using q = 1e] → 1 mark $\theta = 30^\circ$ / 0.52 radian (1)	2
	(c)	(i)	Arrow anti-clockwise ✓	1
		(ii)	$Bqv = \frac{mv^2}{r}$ [or $mr\omega^2$] [accept $r = \frac{mv}{Bq}$] (1) $m = 4 \times 1.66 \times 10^{-27}$ kg and q = <u>2e</u> [e.c.f. on q] (1) r = 76.08 km (1) Allow ecf on q = 1e i.e. → r = 157 km [→ 2/3 marks]	3
				[10]

Question			Marking details	Marks Available
SECTION A				
3	*(a)*		**Either** Flux changes (1) <u>hence</u> emf <u>induced</u> (1) [Because of RH rule or Faraday → 2nd mark, but not 1st mark] flux increases and decreases [implies 1st mark] [i.e. $\frac{d\Phi}{dt}$ alternates implied](1) NB. "Change in field" not 1st mark but others available] **Or** B-lines being cut (1) <u>hence</u> emf <u>induced</u> (1) [Because of RH rule or Faraday → 2nd mark, but not 1st mark] direction of cutting changing (1) [Not "magnet oscillating" accept "magnet changing direction [of motion]"]	3
	(b)	(i)	$V_{\text{rms}} = \frac{Vo}{\sqrt{2}} = 0.5\,\text{V}$	1
		(ii)	Rate of change of flux (linkage) = 0.707 [V] (1) from Faraday's [or Neuman's] law or $E = N\frac{d\Phi}{dt}$ [allow $E = \frac{\Phi}{t}$](1) [Independent mark – must be stated] For 1 turn = $\frac{0.707}{200} = 0.0035(35)\,\text{Wb}\,\text{s}^{-1}$ (1) NB. 0.0025 Wb s^{-1} [from use of V = 0.5 V]→ 2 if 2nd mark awarded.	3
	(c)		Stating or implying that there is a magnetic field set up in the coil (1) Opposes motion / due to Lenz's law (1) Detail given, e.g. loss (dissipation) of energy due to current or resistance, polarity of coil discussed [can imply 1st mark], work done against resistive force (1)	3
				[10]

Question			Marking details	Marks Available
SECTION A				
4	*(a)*		γ (1) Needs high penetration (1) [**or** to irradiate shielded side of metal**, or** because α and β not penetrating enough etc.] [NB. 2nd mark cannot be given if 1st mark not awarded]	2
	(b)	(i)	$\lambda = \frac{\ln 2}{T_{\frac{1}{2}}}$ understood (1) λ = 0.1[308] year^{-1} / 4[.14] × 10^{-9} s^{-1} ((**unit**)) [accept Bq] (1) [allow ecf on $\log_{10}$ used → 1.8 × 10^{-9} s^{-1} / 0.057 year $^{-1}$] [NB per year or per second]	2
		(ii)	Attempt at using $A = \lambda N$ (1) [allow use of number of moles for N] 1 mg = $\frac{1}{60}$ × 10^{-3} mol or N = 10^{19} (1) A = 4.16 × 10^{10} Bq [or 1.31 × 10^{18} year^{-1}] (1) [NB No unit penalty]	3
		(iii)	$\frac{A}{A_o} = \frac{1}{4}$ (1) 2 half lives (implies above) (1) t = 10. 6 year (1) Or $2^n = \frac{A_0}{A}$ n = 2 (1) t = 10. 6 year (1) Or or $A = A_0 e^{-\lambda t}$ (1) [used] taking logs (1) t = 10. 6 year (1) NB 3.3 × 10^8 → 2 marks, i.e. answer quoted in seconds.	3 **[10]**

Question			Marking details	Marks Available
SECTION A				
5	*(a)*		Conservation of *A* **and** *Z* (1) $^{241}_{95}\text{Am} \rightarrow {}^{237}_{93}\text{Np} + {}^{4}_{2}\alpha$ (1) $^{241}_{95}\text{Am} \rightarrow {}^{241}_{96}\text{Np} + {}^{0}_{1}\alpha$ → 1 mark But **not** $^{241}_{95}\text{Am} \rightarrow {}^{237}_{93}\text{Np} + {}^{0}_{0}\alpha$	2
	(b)		Attempt at LHS – RHS [= 0.00608 but allow slips] (1) Mass in u × 931 (1) or $E = mc^2$ [with mass in kg] (1) = 5.66 MeV (1) ((**unit**)) or 9.06×10^{-12} J ((**unit**))	3
	(c)	(i)	attempt at total mass of p + n (1) [e.g. = 95 m_p + 146m_n] – 241.00471 (1) [1.95125] ×931 and ÷ 241 (1) or $E = mc^2$ and ÷ 241 = 7.5[378] MeV / nucleon (1) or 1.206×10^{-12} J/nucleon [Slips in total mass can get first 3 marks] NB mixing up number of protons and neutrons → 7.27 MeV/nucleon	4
		(ii)	Plot answer on graph e.c.f. ± ½ square [7.4 – 7.6 MeV/nucleon and 238-244 for nucleon number]	1
				10

Question			Marking details	Marks Available
SECTION A				
6.	*(a)*		Insert a voltmeter [V in a circle] on the diagram between front and back faces	1
	(b)		<u>Electrons</u> feel force due to B-field [or *Bqv* or FLHR; accept *BIl*] (1) Force towards rear face [accept electrons move to rear face or into the page] (1) <u>Leaving</u> / <u>hence</u> front positive (or shortage of electrons) (1)	3
	(c)		$E = \frac{V}{d}$ (1) [or by impl.] = $\frac{8.5\times10^{-3}}{0.004} = 2.125\,\text{V m}^{-1}$ (1)	2
	(d)		$Bqv = Eq$ (1) $v = \frac{I}{nAe}$ (rearrange) (1) $E = \frac{BI}{nAe}$ (1) [subst] $n = \frac{BI}{EAe}$ (1)= $5.15 \times 10^{21}\ \text{m}^{-3}$ ((**unit**)) or $V_H = \frac{BI}{ntq}$ (1) → $n = 5.15 \times 10^{21}\ \text{m}^{-3}$ ((**unit**)) (1) Max 2/4 for remembering equation	4
				10

Question			Marking details	Marks Available
SECTION B				
7	*(a)*		Correct substation into speed = $\frac{\text{distance}}{\text{time}}$ (1) $\left[t = \frac{8\times10^8}{3\times10^8}\right]$ = 2.67 s (1) [Accept fraction $^8/_3$]	2
	(b)		After travelling both ways extra distance is $\lambda/2$ (1) Hence destructive **interference** or **antiphase / completely out of phase(1)**	2
	(c)		use of $n\lambda = d\sin\theta$ e.g. $7\times640=815\sin\theta$ (1) $d = 1.23 \times 10^{-5}$ m (1) [accept $^1/_{81\,500}$] any 2 of $\theta_1 = 2.99$, $\theta_2 = 5.99$, $\theta_3 = 9.00$ (1) Sensible comment, e.g. true, nearly true **or** wrong[if qualified, e.g. separation increases slightly etc.] [e.c.f.](1) [1st mark required for 3rd mark to be awarded]	4
	(d)		$N\times\frac{1}{2}mc^2 = \frac{3}{2}nRT$ **or** $\frac{1}{2}mc^2 = \frac{3}{2}kT$ (1) [or by impl.] Algebra $\overline{c^2} = \frac{3kT}{m}$ (1) [or by impl.] $\sqrt{\overline{c^2}} = \sqrt{\frac{3\times1.38\times10^{-23}\times300}{23\times1.66\times10^{-27}}}$ = [570.35 m s^{-1}] (1) NB. Mixing up *m*/*M* and *n* / *N* with correct algebra → 1.	3
	(e)		Any 3 × (1) from • 0.97 GHz corresponds to Doppler shift [due to 570 m s^{-1}] / red shift / blue shift✓ • Sodium atom moving towards laser we get resonant absorption / wavelength [or frequency or energy] is exactly right ✓ • ∴ slowing down is tuned or more probable etc ✓ • If atom moving away there is a shift <u>away from</u> resonance / absorption less probable ✓ [NB "more strongly absorbed", "Doppler-shifted up 0.97 GHz", "Match the resonance frequency" are phrases in the passage.]	3

Question			Marking details	Marks Available
SECTION B				
7	*(f)*		Photon energy = $\dfrac{hc}{\lambda}$ **or** *hf* and $c = \dfrac{f}{\lambda}$ (1) [$= 3.825 \times 10^{-19}$ J] No. of photos/sec = power $\div$ photon energy (1.93×10^{10}) (1) Momentum of 1 photon = $h / \lambda = 1.275 \times 10^{-27}$ kg ms^{-1} (1) [indep. mark] Force = $1.93 \times 10^{10} \times 1.275 \times 10^{-27} \times \sin 30 = 1.23 \times 10^{-17}$ N (1) [Slip with nm / m → allow ecf] **Alternative Method**: Force = $\dfrac{\text{Power}}{c}$ (1) [or by impl.] = 2.467×10^{-17} N (1) Force upwards (on particle) = Force down on light **or** reference to *F* = rate of change of momentum(1) $= 2.467 \times 10^{-17} \times \sin 30^{\circ} = 123 \times 10^{-17}$ N (1)	4
	(g)		**<u>Good</u>** • Lasts long time [accept: sustainable / renewable, lasts 000s years] • No nuclear waste [accept: no harmful waste but **not** “no waste”] • High concentration of energy e.g. per kilogram • No carbon emissions / use less non-renewables • Abundance of fuel / deuterium [and lithium] [**not** tritium → sif] • Could be profitable soon **<u>Bad</u>** • Tritium from where / needs generation • Does not work yet / huge energy in for little out [needs slightly more than “hasn’t got to breakeven”] • Induced nuclear waste. • Set-up / research costs • Possible military use Any 2 or 3 advantages and/or disadvantage → 1 4 statements with at least 1 of each (1)	2 **[20]**

Question			Marking details	Marks Available
SECTION C				
8	*(a)*		Laminated (or equivalent) (1) to prevent eddy currents (1) Suitable material for core (1) to avoid magnetising/hysterises losses (1)	4
	(b)	(i)	First mark for diagram with V_L, V_C, V_R perpendicular with V_L, opposite V_C [or impedances] (1) resultant reactive impedance is $\omega L - \frac{1}{\omega C}$ [or $V_{react} = V_L - V_C$], shown on the diagram(1) Resultant [justified] = $\sqrt{\ }$ etc.(1) or $V = \sqrt{(V_L - V_C)^2 + V_R^{\ 2}}$ **and** $V = \sqrt{\left(I\omega L - \frac{I}{\omega C}\right)^2 + I^2R^2}$	3
		(ii)	$f = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$ or $\omega = \sqrt{\frac{1}{LC}}$ or $\omega L = \frac{1}{\omega C}$ (1) Convincing substitution and/or algebra (1)	2
		(iii)	$\left[I = \frac{V}{R} = \right]\frac{12}{280}$ (1) Since all voltage across *R* **<u>or</u>** V_L and V_C cancel (or X_L and X_C) (1)	2
		(iv)	Equation used e.g. $Q = \frac{\omega L}{R}$ or $\frac{1}{\omega CR}$ used (1) Answer = 2.97 or (3) (1)	2
		(v)	Attempt at substitution e.g. accept $\sqrt{\left(10.35 \times 64 - \frac{1}{10.35 \times 9.2}\right)^2 + 280^2}$ *Z* = 1286 Ω (1) $I = \frac{V}{Z}$ (1) [independent mark]= 9.3 mA (1)	4
		(vi)	ωL doubled and $\frac{I}{\omega C}$ halved(1) X_C and X_L switched (1)(cf(v)) $(416–1671)^2 = (1671–416)^2$ or equivalent –ve number squared. (1) Alternative: X_C =1671 and X_L = 416 and *R*=280 [used or implied](1) Z = 1286(Ω) – **<u>clearly</u>** shown (1) 3rd mark – noticing X_C and X_L swapped.(1)	3
				[20]

Question			Marking details	Marks Available
9	*(a)*	(i)	I. Studied reflected light (from glass plate) (1) Reflection from 2nd plate depends on orientation (not just angle of inc.) / Light asymmetrical about direction of travel / Reflected light polarised (1)	2
			II. Developed wave theory mathematically (1) accounted for polarisation by reflection **or** double refraction **or** diffraction patterns of various obstacles **or** why we cannot see around corners (1)	2
		(ii)	• Requires stiff (or solid) medium (where light travels) (1) • which would also support longitudinal waves but not observed **or** would prevent movement of 'ordinary' objects. (1)	2
	(b)	(i)	Magnetic fields – rotating vortices (1) Electric fields – stress (or strain) in vortex material (1)	2
		(ii)	Density and stiffness	1
		(iii)	His ether (or equations) predicted $c = \sqrt{\frac{1}{\varepsilon_0 \mu_0}}$ (1) Experiment confirmed this (within uncertainties).(1)	
		(iv)	Oscillating *E* and *B* fields. (1) *E* and *B* at right angles to each other and to the propagation direction. (1)	2
	(c)	(i)	*Principle of Relativity* understood (either by statement or implied) (1) Not consistent as laws [of E-M] would have special form in this frame (also implies first mark). (1)	2
		(ii)	I. 6.39 μs	1
			II. $\Delta\tau = \Delta t\sqrt{1-\frac{v^2}{c^2}}$ (1) = 0.625 μs (1) [65.3 μs → 0 marks]	2
			III. 0.706 μs (1) approximately 10% (or 13%) out (1) [or any other correct and relevant remark]	2
				[20]

Question			Marking details	Marks Available
10 A	*(a)*	(i)	LCS – largest plastic deformation	1
		(ii)	QAS – highest breaking stress	1
	(b)		All are same / similar from initial gradients.	1
	(c)		HCS has greater strength and stiffness (1) Carbon in (crystal) lattice (1) Hinders/opposes/stops dislocation movement (1) Hence more opposition to plastic deformation in HCS (1)	4
	(d)	(i)	$\frac{1}{2}mv^2 = \frac{1}{2}Fx$ (1) × ¼ (1) $m = \rho Al$ (1) + convincing algebra (1)	4
		(ii)	$\varepsilon = 0.002$ (1) $v = \frac{1}{2}\sqrt{\frac{700\times10^6\times0.002}{8000}}$ = 6.6 m s^{-1} [answer] (1)	2
		(iii)	Accept either LCS or QAS with sensible reason: e.g. LCS has a higher breaking speed (1) because the area under the graph is greater / ε at breaking is much bigger (1) **or** QAS has a higher speed (1) because the area under the graph in the elastic region is bigger (1)	2
B	*(a)*		2.6→2.7 GPa from the graph (1) 8.3→8.65 kg (1)	2
	(b)		Thin fibres have fewer surface imperfections (1) Very thin fibres have no surface imperfections (1)	2
	(c)		Thin glass fibres encased in resin / epoxy / plastic material	1
				[20]

Question			Marking details	Marks Available
11	*(a)*	(i)	Same shape, below and longer minimum λ_0 (1) peaks in same place (1)	2
		(ii)	Peaks/spikes/line spectrum **move.**	1
		(iii)	$eV = \frac{hc}{\lambda}$ (1) $\lambda = 1.66 \times 10^{-11}$ m (1)	2
		(iv)	$P = IV = 9375$ W (1) 99.5% heat = $0.995 \times 9375 = 9328$W (1) **Or** comment that roughly all 9375W dissipated as heat.	2
	(b)		CT detector(s) rotate (1) about patient / analysis point. Multiple detectors output to computer (1) Series of 2D images obtained or 3D image obtained (1)	3
	(c)		Radio waves [2-100 MHz] (1) Resonate or Same/match frequency of [hydrogen] nuclear rotation [or precession]. (1) Causes them to flip/change (1) [Not just: change spin]	3
	(d)	(i)	crystal deforms / vibrates [when alternating p.d. applied]	1
		(ii)	$\frac{\Delta\lambda}{\lambda} = \frac{2v}{c}$ (1) $v = 0.9$ m s^{-1} (1) [e.c.f. on missing factor of 2]	2
	(e)	(i)	Mention of free radicals (1) [or equivalent, e.g. produces chemicals/ions/atoms which react/are highly reactive]. Damages DNA/cells/molecules (1)	2
		(ii)	Absorbed dose = energy (absorbed) per unit mass. Dose equivalent = absorbed dose $\times$Q[uality] factor.	2
				[20]

Question			Marking details	Marks Available
12	*(a)*	(i)	Power = solar constant $\times$ area [or by impl.] (1) $= 1.0686 \times 10^{10}$ W / 1.0686×10^{7} kW / 10.7 GW or equiv (1).	2
		(ii)	$P = \sigma A T^4$ understood [accept $5.67 \times 10^{-8} \times A \times 5778$] – i.e. 2 terms identified although missing (1) $P = 4\pi r^2$ quoted (1) $P = 3.85 \times 10^{26}$ W (1) Solar constant = $\dfrac{3.85 \times 10^{26}}{4\pi \times \left(1.496 \times 10^{11}\right)^2}$ [=1368 W m^{-2}]	4
	(b)		Hours in one year = $24 \times 365[.25]$ [or by impl.] (1) Total units = $1.0686 \times 10^{7} \times 24 \times 365 \times 0.4$ [or by impl.] (1) Money = units $\times 0.2$ = £7.5 billion / 7.5×10^{11} p /£7.489 $\times$ 10^{9} (1)	
	(c)		Volume = area $\times$ thickness [or by impl.] (1) Mass = density $\times$ volume [or by impl.] (1) [manip] Mass = 4.95×10^{6} kg (1)	
	(d)		$4.95 \times 10^{6} \div 2500 = 198$ missions [or by impl.] (1) [ecf from *(c)*] $\times\ 350 \times 10^{6}$ = £ 69.3 bn [or equiv.] (1)	2
	(e)		Heat engines inefficient [or by impl.] (1) Since $1 - \dfrac{T_1}{T_2} \simeq 1 - \dfrac{300}{400} \simeq 0.25$ (1) "which is poor" implies first mark. NB. T_2 in range 373 – 1700 K and T_1 in range 273 – 900 K [< T_2]	2
	(f)		Reasonable since costs recovered in 9/10 years (1) (ignoring time for 200 shuttle missions) + Any 3 × (1) **good** points: • Not weather dependant ✓ • Solar power at night ✓ • Less/no atmospheric absorption by microwaves ✓ • Time for 200 shuttle missions ✓ • Shuttle program ended ✓	4 **[20]**

WJEC
245 Western Avenue
Cardiff CF5 2YX
Tel No 029 2026 5000
Fax 029 2057 5994
E-mail: exams@wjec.co.uk
website: www.wjec.co.uk