GCE MARKING SCHEME

PHYSICS
AS/Advanced

SUMMER 2010

INTRODUCTION

The marking schemes which follow were those used by WJEC for the Summer 2010 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 [± 0.3] × 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.

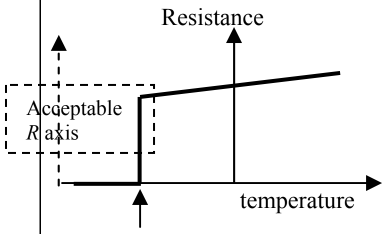
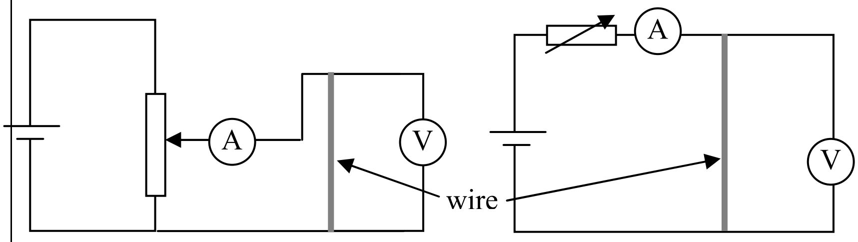
Example: 25 GPa (1) ((**unit**)) indicates that the unit (or correct alternative. e.g. $2{\cdot}5 \times 10^{10}$ N m^{-2}) is a requirement for the mark;

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

<table>
<tr><th colspan="3">Question</th><th>Marking details</th><th>Marks Available</th></tr>
<tr><td>1</td><td><i>(a)</i></td><td>(i)</td><td>Vectors have magnitude and direction; scalars have only magnitude
[Reference to vectors and scalars required for complete answer, e.g. vectors have direction and scalars do not is enough]</td><td>1</td></tr>
<tr><td></td><td></td><td>(ii)</td><td><table><tr><th>Vector</th><th>Scalar</th></tr><tr><td>velocity
force</td><td>distance
time
temperature
density</td></tr></table>All correct → 2
One incorrect → 1
Two or more incorrect → 0</td><td>2</td></tr>
<tr><td></td><td><i>(b)</i></td><td>(i)</td><td>1600 cos 25° (1) = 1450 N (1)</td><td>2</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>Long (1) because greater component in the direction of motion (1)
[NB Decrease angle only – not enough. 2nd mark for reference to component either in direction of motion or perpendicular to it]</td><td>2
[7]</td></tr>
<tr><td>2.</td><td><i>(a)</i></td><td></td><td>No net / resultant force [accept ‘total’](1)
No net / resultant moment (1)
[1 mark max if ‘net’ or equiv missing]</td><td>2</td></tr>
<tr><td></td><td><i>(b)</i></td><td>(i)</td><td>Downward vertical arrow indicated ± 1 cm of centre of bar [halfway between 30 N and 25 N forces], labelled 20 N</td><td>1</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>$T_A \times 3(1) = 20 \times 1.5(1) + 40 \times 2.35 + 30 \times 1.75 + 25 \times 0.85\,(1)$
[Note: LHS →(1); RHS: moment of bar (1), all other moments (1)]
T_A = 65.9 N (1)</td><td>4</td></tr>
<tr><td></td><td></td><td>(iii)</td><td>115 N (1) – 65.9 N (e.c.f.) = 49.1 N (1)
[Accept solution based on taking moments about chain A or other equiv method]</td><td>2
[9]</td></tr>
</table>

Question			Marking details	Marks Available
3	*(a)*		A material which has zero [electrical] resistance [or equiv.]	1
	(b)		 Axes (1) Line (not nec straight above T_C)(1) Temperature at which resistance [of material] drops [suddenly] to zero [or label on graph] (1)	3
	(c)		No [accept little] heat [accept energy] lost / generated (1) [Accept – large current can be produced from zero /small pd] Any application, e.g. nuclear fusion / tokamaks, particle accelerators / LHC, MRI scanners / large motors or generators (1)	2
				[6]
4.	*(a)*		 Wire in functioning circuit with both meters correctly connected (1) Method of varying current / pd (1)	2
	(b)	(i)	Resistance values / Ω: 4.00,4.00, 4.33, 4.75, 6.00 [all correct]	1
		(ii)	Graph: Axes [scales, labels, units] (1), plots (1) line (1) [axes – no s.f. penalty; line – produced to *R* axis – accept extrapolation]	3
	(c)	(i)	0 → 0.2 A ['at start', 'to begin with'] no change / constant (1) 0.2 A → 0.5 A ['then'] increasing with current (1)	2
		(ii)	0 → 0.2 A [e.c.f. from graph]	1
		(iii)	Temperature wire not constant / increases [accept changes] [with current]	1
	(d)		Current / ammeter reading would [rapidly rise from 0 then] decrease (1) and then stabilise (1)	2
				[12]

Question			Marking details	Marks Available
5.	*(a)*		E = total energy transferred [per unit charge passed] in the source (1) V = energy [per unit charge passed] converted [accept 'lost'] in the internal resistance (1) Correct use of "per unit charge" in definitions of both E and V. (1)	3
	(b)	(i)	$Q = 0.22 \times 3600$ [= 792 C]	1
		(ii)	$E = \frac{4750}{792(\text{e.c.f.})}$ [= 6.0 V]	1
		(iii)	$V = \frac{4500}{792(\text{e.c.f.})}$ (1) [= 5.7 V] or $\left[P = \frac{4500}{3600} = 1.25W.V = \frac{1.25}{0.22} = 5.7\right]$ V	1
		(iv)	r = 0.3 V [= ans (ii) – ans (iii) e.c.f.]	1
		(v)	0.32 (e.c.f.) = 0.22 r (1) [or by impl] r = 1.45 Ω (1) [e.c.f. based upon (i) to (iv)]	2
				[9]
6	*(a)*		Accept answers in range [–] 9.6 to [–] 10.0 [m/s^2] [no unit or sign penalty] (1) Acceleration due to gravity (1)	2
	(b)		4.0 m s^{-1} [accept 3.9 or 4]	1
	(c)		[Constant] deceleration from 4 m s^{-1} to zero / rest in 0.4[1] s (1) [Constant] accel from rest to – 4 m s^{-1} from 0.4[1] s to 0.8[2] s (1) [Momentarily] stationary [or at its max height] at 0.4[1] s (1) [NB or equivalent wordings to the same effect]	3
	(d)	(i)	Area shaded between graph and abscissa from 0.8[2] to 3.2 s	1
		(ii)	Shaded area: ½ × 2.8 × 2.7 – ½ × 0.4 × 4 (1) = 37 m (1) [or ½ (4 + 27) × (3.2 – 0.8) (1) = 37.2 m (1) or equiv. using equations of motion, eg. $x = ut + \frac{1}{2}at^2$] [37.5 ± 1.5✓]	2
			Directly beneath (1) Horizontal speed constant (1) ….because .. no horizontal force[s] acting on stone (1) [NB 'no' required; horizontal only needed once]	3
				[12]

Question			Marking details	Marks Available
7.	*(a)*	(i)	Force × distance (1) moved in direction of force (1) [or equiv, eg component of force in direction of movement × distance moved, or $\underline{W = Fd}$ (1) $\underline{\cos\theta}$ (1) - explanation for 2nd mark] [Work is done when a force moves its point of application → 1 only]	2
		(ii)	kg m s^{-2} (1) × m → kg m^{2} s^{-2} (1)	2
	(b)	(i)	E_P lost = 70 × 9.81 × $\underline{120 \sin 20°}$ (1) [or by impl.] = 28 000 J [28148] (1) [Use of 10 for g – 1st mark lost]	2
		(ii)	At A, $E_k = ½ × 70 × 6^2$ (1) [= 1260 J] At B, $E_k = ½ × 70 × 21^2$ (1) [=15435 J] ΔE_k = 14175 J (1) [If $(21 – 6)^2$ calculated → 1 mark only]	3
	(c)	(i)	Energy cannot be created or destroyed only changed from one form to another	1
		(ii)	Energy is converted to [accept: lost as] internal energy heat / sound / ke of air (1) Detail: Molecules of air gain E_k as skier moves / molecules of of snow / skis gain E_k / vibrational energy (1)	2
	(d)		$\underline{\text{Use}}$ of $W = Fd$ (1) [or by impl.] 28184 – 14175 (1) (e.c.f. on both) = F × $\underline{120}$ (1) [or by impl.] F = 117 N (1) [Accept answer based upon force components]	4 **[16]**

Question			Marking details	Marks Available
8	*(a)*		[A conductor is] a material through which charge / electrons [accept ions / holes] can flow / move **or** which contains free / delocalised electrons.	1
	(b)	(i)	Volume = $2.0 \times 10^{-6} \times 2.0$ (1) [or by impl] mass = $8920 \times 4.0 \times 10^{-6}$ (1) [= 0.0357 kg] ((**unit**))	2
		(ii)	$\frac{0.0357\text{(e.c.f.)}}{1.05\times10^{25}}$ (1) $\underline{\times 1.5}$ (1) [= 5.1×10^{23} electrons]	2
		(iii)	$n = \frac{5.1\times10^{23}\text{(e.c.f.)}}{4.0\times10^{-6}\text{(e.c.f.)}}$ (1) [= 1.28×10^{29} m^{-3}] $v = \frac{I}{nAe}$ [manipulation at any stage] (1) $v = \frac{1.2}{1.28\times10^{29}\times2.0\times10^{-6}\times1.6\times10^{-19}}$ (subst) (1) [e.c.f. on n] $v = 2.9 \times 10^{-5}$ m s^{-1} (1) [NB use of 5.1×10^{23} for $n \rightarrow 7.3(5)$ m s^{-1}]	4 **[9]**

PH2

Question			Marking details	Marks Available
1	*(a)*	(i)	$v = \frac{0.15\text{ m}}{0.0030\text{ s}}$ (1) [or equiv. or by impl.] = 50 m s^{-1} ((**unit**)) (1)	1
		(ii)	**Either**: $T = 0.012$ s (1) $f = \frac{1}{T}$ [or by impl.] (1) = 83 Hz (1) **Or**: $\lambda = 0.60$ m (1) $f = \frac{v}{\lambda}$ [in this form – or by impl] (1) = 83 Hz (1) [e.c.f. on v from (i)]	2
	(b)	(i)	<u>Two of</u>: 0.90 m, 1.20 m, 1.50 m, 1.80 m	1
		(ii)	I. Varies [smoothly] between maxima and minima / zeroes (1); Maxima midway between minima [**or** maxima 0.30 m / $\lambda/2$ apart; minima 0.30 m / $\lambda/2$ apart] (1)	2
			II. No – for a progressive wave the amplitude is constant along string [or falls gradually]	1
	(c)		Waves reflected by wall (1) Reflected wave interferes with wave straight from generator [or equivalent, e.g. the two waves travelling in opposite directions interfere] (1) Nodes occur where interference is destructive [accept: where the two waves cancel] (1)	3
				[12]
2.	*(a)*	(i)	$\lambda = \frac{2.0 \times 1.8}{12.0}$ m (1) [or by impl.] = 0.30 m (1)	2
		(ii)	Reflected sound [would affect the pattern].	1
	(b)		Previously, sound from the two speakers superposed / interfered [or by implication](1) destructively [accept: cancel] at that point (1) as it arrived in antiphase [accept: exactly out of phase] (1)	3
	(c)		Quiet spots are where loud sounds used to be [or equiv.]	1
	(d)	(i)	$y = \frac{D\lambda}{a}$ (1) <u>thus</u> [or other qualification, e.g. recalculation] y halves (1) [or equiv] [because a doubles] [Qual. answer “y decreases” + correct qual reasoning → 1 mark]	2
		(ii)	Wavelength halves [or equiv] (1) Separation halves (1)	2 **[11]**

Question			Marking details	Marks Available
3	*(a)*	(i)	$[1.00]\sin x = 1.52\sin 25^\circ$ [or by impl, or equiv with data inserted] (1) $\sin x = 0.642$ [or by impl.] (1) $x = 40°$ (1)	3
		(ii)	65°	1
		(iii)	**Either:** $[1.52\sin c = 1.00\sin 90^\circ$ so] $c = 41°$ (1). 65°>c so no escape (1) [No penalty for omission of last point if first mark awarded] **Or:** $\sin^{-1}\left(1.52\sin 65^\circ\right)$ / 1.38 (1) doesn't exist (1) [so refraction doesn't occur].	2
		(iv)	I. total internal reflection [not: TIR, total or internal] reflection] II. equal	1 1
	(b)	(i)	beam confined to small angle to axis [or damage avoided to reflecting surface] [accept: fewer int. refl^{s}]	1
		(ii)	small (1); equal to a few wavelengths (1)	2
		(iii)	light propagates parallel to axis [or without being reflected **or** along only one path]. [Not – 'only one beam']	1
				[12]
4.	*(a)*	(i)	When e-m radn^{n} [accept: light, u-v, photons] [of high enough frequency] falls on a surface [or metal] (1) electrons are emitted (1)	2
		(ii)	Photon knocks out electron [or not] **or** gives energy to e(1). Photon carries energy hf (1). Electron needs [a minimum] energy ϕ to escape (1) Remainder of photon's energy given to electron as KE (1) [KE$_{\text{max}}$ corresponds to minimum energy ϕ to escape]	4
	(b)	(i)	$E_{\text{k max}} = 6.63\times10^{-34}\times7.99\times10^{14} - 4.97\times10^{-19}$ J (1) [or photon energy shown to be greater than ϕ] $E_{\text{k max}} = 3.27\times10^{-20}$ J (1)	2
		(ii)	Photon energy = 4.47×10^{-19} J < ϕ [or equiv], so no emission	1
		(iii)	3.27×10^{-20} J(1) Photons don't co-operate releasing electron [or equiv] (1)	2
				[11]

Question			Marking details	Marks Available
5.	*(a)*	(i)	Fraction = $\frac{\left[3.297\times10^{-18}-2.983\times10^{-18}\right](1)}{3.297\times10^{-18}}$ = 0.095 (1) [accept $\frac{2}{21}$]	2
		(ii)	$\lambda = \frac{hc}{E_{\text{photon}}}$ (1) [or $\lambda = \frac{c}{f}$ **and** $f = \frac{E_{\text{photon}}}{h}$] (1) [or by impl.] λ = 633 nm (1)	2
	(b)	(i)	A[n incident] photon (1) of energy equal to ($E_U - E_L$) (1) [or equiv.]	2
		(ii)	Now 2 photons [original and emitted] [or by impl.] (1) Photons in phase / travel in same dir^n / have same f, λ or E (1)	2
		(iii)	Fewer electrons in L than U (1) [accept pop^n inversion] [So] stimulated emission commoner than absorption (1) [**or** less pumping needed]	2
		(iv)	Mirrors cause light to traverse cavity [or HeNe etc] to and fro (1) increasing chances of stimulated emission / increases amplification / increases intensity (1) [or any other correct point, e.g. resonant selection of particular λ]. [No credit for light escaping from r.h. mirror]	2
				[12]
6	*(a)*		A surface / body that absorbs all radiation incident / falling on it.	1
	(b)		$\lambda_{\text{I max}}$ = 250 [± 10] nm (1) $T = \frac{W}{\lambda_{\text{I max}}}$ (1)[thus or by impl.] = 11500 K (1) [e.c.f. on $\lambda_{\text{I max}}$]	3
	(c)	(i)	$A = \frac{\text{power}}{\sigma T^4}$ [transposition at any stage] (1) $= \frac{2.53\times10^{31}}{5.67\times10^{-8}\times11500^4}$ (e.c.f.) (1) = 2.55 × 10^{22} m^2 ((**unit**)) [e.c.f. on T, e.g. 10^4 K → 4.46 × 10^{22} m^2]	3
	(d)	(ii)	**Either** $A_{\text{Sun}} = 4\pi r_{\text{Sun}}^2$ [or by impl.] (1) = 6.1 × 10^{18} m^2 « A_{Rigel} (1) e.c.f over slips in 4 or π **Or** $r_{\text{Rigel}} = A_{\text{Rigel}} / 4\pi$ (1) = 4.5 × 10^{10} m » r_{Sun} (1) e.c.f over slips in 4 or π	2
		(iii)	Spectral intensity higher at 400 nm than at 700 nm (1) 400 nm is at violet end of visible spectrum (1) [or converse] So Rigel not a red giant [Not a freestanding mark] [NB – “Peak closer to violet than red,” unsupported by figures, loses first mark]	3
				[12]

Question			Marking details	Marks Available
7.	*(a)*	(i)	e	1
		(ii)	zero	1
	(b)		baryon	1
	(c)		p = uud (1) u quark number for x = 4 – 3 [= 1][or equiv] (1) d quark number for x = 2 – 1 – (–1) [=2] [or equiv] (1) So x is a neutron (1) [or Δ^0]	4
	(d)		Lepton number zero before and after	1
	(e)		Any 1 × (1) of • High KE means short contact time ✓ • u and d numbers separately conserved [so not weak] ✓ • no γ involvement [suggests not e-m] ✓ So strong (1)	2
				[10]

Question			Marking details	Marks Available
1	*(a)*		Acceleration towards a fixed point [or central / equilibrium](1) and [directly] proportional to the distance from that point (1) Accept $a = -kx$ (1) with x defined	2
	(b)		Smooth curve drawn which extends at least to ± 19.5 mm [i.e. beyond the extreme points] symmetrically on at least 2 extremes.	1
	(c)		$\omega = \frac{2\pi}{T} = \frac{2\pi}{0.5}$ [= 12.57 rad s^{-1}]	1
	(d)		**Either** $v_{\text{max}} = r\omega$ [or by impl.] (1) $= 20 \times 10^{-3} \times 12.57$ [r range 19.5 – 21 mm] $= 0.25$ m s^{-1} (1) **Or** tangent drawn (1) $v_{\text{max}} = \frac{(30-(-30))\times 10^{-3}}{0.67-0.42}$ $= 0.24$ m s^{-1} (1)	2
	(e)		Squaring $T = 2\pi\sqrt{\frac{m}{k}}$ i.e $T^2 = 4\pi^2 \frac{m}{k}$ or following substitution (1) Substitution (1) Rearranging and answer: k = 6.32 N m^{-1}	2
				[8]

Question			Marking details	Marks Available
2.	*(a)*		Any 2 × (1) of: • forces between molecules negligible [or no forces…] / molecules travel in straight lines between collisions ✓ • volume [allow "size"] of molecules negligible / collision time small [cf time between collisions] ✓ • molecules behave like perfectly elastically / have elastic collisions ✓ • molecules exert forces [or pressure] on walls of container during collisions ✓ • gasses consist of a large number of particles / molecules in random motion	
	(b)		amount of gas, $n = \left[\frac{pV}{RT} = \frac{1.01\times10^5\times(6\times5\times3)}{8.31\times293} = \right]$ 3730 mol (1) no. of molecules $N = nN_A = 3730 \times 6.02 \times 10^{23} = 2.2 \times 10^{27}$ (1)	2
	(c)		$c_{\text{rms}} = \sqrt{\frac{350^2+420^2+550^2}{3}}$ (1) [or by impl.] = 448 m s^{-1} (1)	2
	(d)		Density ρ = (1) $\frac{M}{V} = \frac{3733\times\frac{29}{1000}(1)}{90}$ [= 1.203 kg m^{-3}]. Use of $p = \frac{1}{3}\rho\overline{c^2}$ (1). [c_{rms} = 502 m s^{-1}]. (1) (i.e. use of *M/V* (1); inserting ~3733 for *n* (1); relating *M* to *Mr* (1); use of $p = \frac{1}{3}\rho\overline{c^2}$ and substitution [or by impl.] (1))	2 4
	(e)	(i)	Time of travel ~ 0.01 – 0.02 s	1
		(ii)	No – time estimated is [far] too short (1) e.c.f from (i) Relay is much longer because of collisions between molecules [or equiv. eg takes time to diffuse / mean free path is very short] (1)	2 **[13]**

Question			Marking details	Marks Available
3	*(a)*		ΔU = increase [accept change / difference] in <u>internal</u> energy [of the gas](1) Q = heat <u>supplied</u> [to] the gas (1) U = work done <u>by</u> the gas (1)	3
	(b)		Readings from graph: $p = 120 \pm 2.5$ kPa; $V = 2.0 \times 10^{-3}$ m (1) $T = \frac{pV}{nR}$ (1)= $\frac{120\times10^{3}\times2.0\times10^{-3}}{0.1\times8.31}$ (1) [= 289 / 290 K]	3
	(c)		Work Done = 'area' under graph (1) Any reasonable method used correctly to estimate area, (1) e.g 27 × 1 cm squares × 'area' of 1 cm square → 169 J **or** [approximating AB to straight line] area ~ 1.0 × ½ × [120 + 240] → 180 $\therefore$ a bit less than 180 J ~ 170 J.	2
	(d)	(i)	$\Delta V = 0$ along AP (1) So $W = p\Delta V = 0$ (1)	2
		(ii)	Work done **on** gas (1) = $p\Delta V$ = 240 J (1)	2
	(e)		Temperature at A and B are the same: $U_A = U_B$ so $\Delta U = 0$, so $Q = W$ [from 1st law] (1) W is different for the two paths so Q is different. (1)	2 **14**
4.	*(a)*		Concentric equipotentials drawn (1) At least 3 outward radial electric field lines drawn symmetrically(1) [No labelling →–1; no arrows on field lines → –1]	2
	(b)	(i)	KE = 8.3×10^{-14} J	1
		(ii)	At closest approach, all KE lost [or by impl.] (1) KE lost [or PE gained] = $q\Delta V_E$ (1) $\Delta V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$ (1) Subst, manip + ans → $r = 1.6 \times 10^{-13}$ m (1) [e.c.f. on KE from (i)]	4
		(iii)	[It retraces its path] with electric PE decreasing (1) and KE increasing (1) or equiv.	2
		(iv)	Smooth symmetric curve drawn curving away from nucleus	1 **10**

Question			Marking details	Marks Available
5.	*(a)*	(i)	N m^{-2} / Pa [or equiv.]	1
		(ii)	Mass = $1.2 \times 2.0 \times 10^{-4} \times 1.00 \times 10^{3}$ [= 0.24 kg]	1
		(iii)	Change in momentum = [0 –] 0.24 × 1.2✓ [= –0.29 N s ~ 0.3 N s]	1
		(iv)	Force = $\frac{\Delta mv}{t} = \frac{0.3(\text{e.c.f.})}{1}$ / 0.3 N [equal and opposite force on wall implied] (1) Pressure = $\frac{F}{A} = \frac{0.3}{2.0 \times 10^{-4}}$ = 1500 Pa [1450 Pa if 0.29 N s used] (1)	2
	(b)	(i)	$\lambda = 660 \times 10^{-9}$ m [or equiv – unit conversion] (1) $p = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}}{660 \times 10^{-9}}$ (1) [e.c.f. on unit conv.] = 1.0×10^{-27} N s (1)	3
		(ii)	Photon energy $E = hf = \frac{hc}{\lambda}$ (1) = 3.01×10^{-19} J [or by impl.] Number of photons in 1 s = $\frac{\text{Power}}{\text{energy of 1 photon}}$ (1) [= 3.32×10^{13}] Force = $\frac{\Delta p}{t}$ = 3.32×10^{-12} N (1) [e.c.f. if only 1 photon used] Pressure = 3.3×10^{-6} Pa (1) [NB $F = \frac{P}{c}$ → 1st 3 marks by impl] [If pressure = 1×10^{-21} Pa given specified “per photon” – or equiv – then 1 mark]	4
				[12]

Question			Marking details	Marks Available
6	*(a)*		$r = 1.0 \times 10^8$ m [unit conversion] (1) $g = \frac{GM_E}{r^2} = \frac{6.67\times10^{-11}\times6.0\times10^{24}}{(1.0\times10^8)^2}$ (1) [e.c.f. for this mark only] $= 0.04$ N kg^{-1} , Statement "agreement with graph" or equiv (1)	2
	(b)		Moon has a [much] smaller <u>mass</u> than the Earth. [or converse]	1
	(c)		3.45 [± 0.05] <u>× 10^5 km</u> (from graph) (1) No resultant gravitational field [or fields of Earth and Moon equal <u>and opposite</u>] or fields balance at this point. [or equiv](1)	2
	(d)		From M to point of intersection / at start $F_{moon}>F_{earth}$ (1) At point of intersection: $F_{moon}=F_{earth}$ (1) From point of intersection to earth / at end $F_{earth}>F_{moon}$ (1) [– 1 for fields rather than forces; – 1 not using resultant at least once]	3
	(e)		More (1) because gravitational fields of Earth and Moon <u>reinforce</u> [or equiv] and act towards centre of moon <u>opposite to rocket motion</u>. (1) Or [if considering escape from the E/M system] Less because of initial greater PE [less negative] due to Earth's field.	2
				[11]

Question			Marking details	Marks Available
7.	*(a)*		T = 1090 × 24 × 60 × 60 [= 9.42 × 10^7 s] [unit conversion] (1) $r_{\mathrm{S}} = \frac{Tv_{\mathrm{S}}}{2\pi}$ (1) or equiv e.g. $v = \frac{d}{t}$ and d πr = 6.82 × 10^8 m (1)	3
	(b)	(i)	$T = 2\pi\sqrt{\frac{d^3}{G\left(M_{\mathrm{S}} + M_{\mathrm{P}}\right)}}$ (equation selection) (1) [or by impl] ($M_{\mathrm{S}} >> M_{\mathrm{P}}$) [or by impl]→ $T = 2\pi\sqrt{\frac{d^3}{GM_{\mathrm{S}}}}$ (1) $d = \sqrt[3]{\frac{T^2GM_{\mathrm{S}}}{4\pi^2}}$ (rearrangement) (1) [or with numbers] Substitution and convincing calculation(1) [to give = 3.21 × 10^{11}m]	4
		(ii)	Use of $M_{\mathrm{P}} = \frac{M_s r_s}{d}$ [in any orientation] or $m_1r_1 = m_2r_2$ (1) $= \frac{2.2\times10^{30}\times6.8\times10^{8}}{3.2\times10^{11}}$ = 4.7 × 10^{27} kg (1)	2
	(c)		Find $\Delta\lambda$ in star's spectral lines arising from motion of star / Doppler shift (1) Find velocity of star using $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$	2
				[11]

PH5

Question			Marking details	Marks Available
A1	*(a)*		${}^{14}_{6}C$ has 8n + 6p [or implied] (1) [8p + 6n → slip, allow e.c.f.] attempt at 8n + 6p – 13.99995 (1) [=0.113026] × 931 and ÷ 14 **or** use of $E = mc^2$ and ÷ 14 (1) $= 7\cdot5$ MeV[/nucleon] (1) [or $1\cdot2\times10^{-14}$ J [/nucleon]] ((**unit**))	4
	(b)		$13\cdot99995 - 13\cdot999234 - 0\cdot000549$ i.e. attempt at mass defect (1) × 931 MeV **or** use of $E = mc^2$ (1) $= 0\cdot155$ MeV **or** $2\cdot5\times10^{-14}$ J (1)	3
	(c)		(from conservation of mom) $v_\beta > v_N$ (1) **or** $v_\beta = 26000v_N$ (since) $M_N > M_\beta$ (1) **or** $M_N = 26000M_\beta$ since $E_k = \frac{1}{2}mv^2$, β particle has most of the energy (1) or $E_\beta = 26000E_N$	3
				10
A2	*(a)*		137 0 56 -1 Conservation of A and Z (1) All figures correct (1)	2
	(b)		$\lambda = \frac{\ln 2}{T_{\frac{1}{2}}}$ (**or** $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$) either eq^n by <u>itself</u> or used [e.g. $\frac{0.69}{30}$] (1) $\lambda = \frac{\ln 2}{30\times365\times24\times60\times60}$ (1) $\left[= 7.3\times10^{10}\right]$	2
	(c)		$A = \pm\lambda N$ stated or used (1) $= 7.3\times10^{-10}(\text{e.c.f.})\times\frac{1}{0.137}\times6\times10^{23}$ (1) [= 3.2 × 10^{15} Bq]	2
	(d)		[All] β absorbed [however expressed] ✓ **or** no γ present [implies β absorbed]	1
	(e)		$A = A_0e^{-\lambda t}$ [or $A = A_0 2^{-n}$] 1000 = 3.2 × 10^{15} $e^{-\lambda t}$ or 3 × 10^{15} $e^{-\lambda t}$ (1) [or 1000 = 3 × 10^{15} × 2^{-n}] taking logs correctly(1) e.g. ln 1000 = ln [3.2 × 10^{15}] – λt or equiv. $t\left[= \frac{1}{\lambda}\ln 3.2\times10^{15}\right]$ = 4.1 – 4.9 × 10^{10} s [1240 – 1544 years] (1)	3
				10

Question			Marking details	Marks Available
A3	*(a)*		$C=\frac{\varepsilon_0 A}{d}$ used [2 quantities inserted, e.g. $C=\frac{\varepsilon_0\times 0.163}{0.35}$](1) $C=$ 4.1 nF (1)	2
	(b)	(i)	5 μC ✓	1
		(ii)	3mJ ✓	1
	(c)		$t_{\frac{1}{2}}$ [= CR] = 2.77 ms (1) $\frac{1}{2}Q_0=Q_0 e^{-\frac{t}{CR}}$ (1) T = 1.92 ms (1)	3
	(d)		Since $E=\frac{1}{2}CV^2$ or $\frac{1}{2}\frac{Q^2}{C}$ or $\frac{1}{2}QV$ (1) E drops off more quickly (1)	2
	(e)		$\left.\begin{array}{l}F=Eq\\ a=\frac{F}{m}\\ E=\frac{V}{d}\end{array}\right\}$ all three → 2 marks 2 → 1 mark also, subtract 1 mark for for each 2 useless unused eq^{ns} NB. $a=\frac{Ee}{m}=\frac{eV}{md}$ ✓✓ $a=\frac{1200\times1.6\times10^{-19}}{9.1\times10^{-31}\times0.35\times10^{-3}}$ (1) [= 6.03 × 10^{17} m s^{-2}]	3
	(f)	(i)	$v^2=u^2+2ax$ **or** other combinations e.g. $x=ut+\frac{1}{2}at^2$ and $v=u+at$ (1) **(do not award mark if all 4 eq^{ns} by themselves only)** v [= $\sqrt{2\times6\times10^{17}\times0.175\times10^{-3}}$]=1.45 × 10^7 m s^{-1} (1)	2
		(ii)	$E=\frac{1}{2}mv^2$ used (1) → 9.6 × 10^{-12} J ÷ e [gives 600 eV] (1) Alternative method is using $E=Vq$, V = 0.6 kV [and $q=e$] – **or** other convincing argument] (1)	3
		(iii)	$v=u+at$ (1) 1.45 × 10^7 = 0 + 6 × $10^{17}t$ (1) ∴ t = 24.2 ps (1) **or** $x=ut+\frac{1}{2}at^2$ (1) 0.175 × 10^{-3} =0 +$\frac{1}{2}$ 6×10^{17} t^2 (1) ∴ t = 24.2 ps (1) [**or** equivalent solution based upon $x=vt-\frac{1}{2}at^2$] NB. Use of $t=\frac{v}{d}$ =12.1 ps → 0 marks	3 **20**

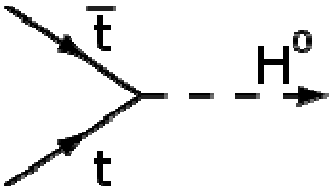
Question			Marking details	Marks Available
A4	*(a)*		force on electrons is downwards [**or** electron deficiency on top] (1) due to Fleming's LHR [**or** stating that current is to the right] (1)	2
	(b)		Voltmeter symbol shown connected between top and bottom faces ✓	1
	(c)		$Bqv = Eq$ (1) [**not** $Blv = Eq$, but accept $Bev = Eq$] $Bqv = \frac{V_\text{H}}{d} q$ (1) [i.e. using $E = \frac{V_\text{H}}{d}$] + convincing algebra (1) [from above step the answer alone suffices]	3
	(d)	(i)	n = 15 000 ÷ 2 (1) $I\left[= \frac{B}{\mu_0 n}\right]$ = 2.3 A (1) [allow 1 mark for $1\cdot15A$ missing first step]	2
		(ii)	In the middle / inside [of the solenoid] (1) with front face $\perp^{r}$ (1)[to axis of solenoid or B-field] [NB: "inside current" ×, "between the coils" ×]	2
				9
A5	*(a)*		Area (inside hoop) changes (1) Magnetic flux changes (1) **or** [sides of] hoop cut (1) [B-]field lines (1) $\therefore$ *EMF* induced according to Faraday's Law (Neumann) – **or** law or equation quoted] (1)	3
	(b)		Using Fleming RHR (1) goes left at top **and** right at bottom (1) **or** correct use of r.h. grip rule (1)for flux to oppose **or** Lenz's law (1)	2
	(c)		$[\Delta]\Phi = B[\Delta]A$ (1) $A = \pi r^2$ (1) $I = \frac{V}{R}$ (1) $V = \frac{\Delta\Phi}{t}$ or $\frac{\Phi}{t}$ or $\frac{\text{d}}{\text{d}t}(N\Phi)$ or similar (1) $I = \frac{B\pi r^2 / t}{R} = \frac{58\times10^{-3}\times\pi(0.31)^2}{0.063\times0.44}$ = 0.63 A (1)	5
				10

Question			Marking details	Marks Available
B6	*(a)*		See next page for details 3 × (1) points for Higg’s Boson or 3 × (1) points for Dark energy / dark matter or 3 × (1) points for Grand Unified Theories	3
	(b)	(i)	$\frac{1}{2}mv^2 = 50$ MeV (1) $v = \sqrt{\dfrac{2\times 50\times 10^6\times 1.6\times 10^{-19}}{1.67\times 10^{-27}}} = 9.8\times 10^7$ m s^{-1} (1) [ans]	2
		(ii)	$v = 3\cdot 7\times 10^{10}\ ms^{-1}$ ✓	
		(iii)	2nd calculation not valid [**or** 1st <u>is</u> valid] (1) Because $v_2 > 3\times 10^8$ m s^{-1} [**or** c] (1)	1
	(c)		Keeps superconductors at low temperature (1) so that high currents [are maintained] (1)	2
	(d)	(i)	Accept ~ 10^{-4} m → ~10^{-3} mm [be generous] (1) $V = 10^{-12}$ m^3 → 10^{-9} mm^3 [ecf on side] (1)	2
		(ii)	$pV = nRT$ (1) number of moles = $\dfrac{1\times 10^{-9}}{1}$ [accept $\dfrac{1\times 10^{-9}}{2}$] (1) $V = 2.4\times 10^{-11}$ m^3 and compared with d(ii) (1) (large range: check)	2
	(e)		Any 2 × (1) from • Gravitational pull small (only 2 protons) ✓ • Tiny probability of collision (with small object) ✓ • Shrinks in size ✓ due to Hawking radiation ✓ • etc. [any sensible answer]	3
	(f)		(protons would) collide with soot particles	2
	(g)		Annihilated mass = 2 × 3.1 × 10^{-6} kg [**or** by implication] (1) E [$= mc^2 = 6.2\times 10^{-6}\times (3\times 10^8)^2$]$= 5.6\times 10^{11}$ J (1) [1 mark for 2.8 × 10^{11} J]	1
				2
				20

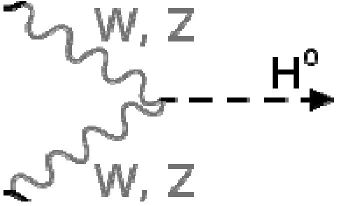
In each case, any 3 × (1) – no combining marks for different subjects

Higgs Boson Marking Points

- Last particle of standard model
- Related to mass (origin of mass of Universe etc.) / gives mass to matter
- Breaking electroweak gauge symmetry
- Has no spin/angular momentum
- Any prediction for mass with the unit GeV/c^2 [100–300 GeV/c^2 or(100–300)m_p or m_n]



or



(i.e. means of production)

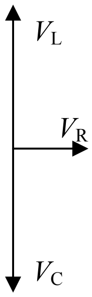
- Possible solution to dark matter problem
- Possibly more than one Higgs predicted

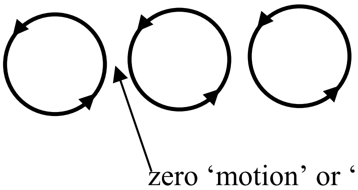
Dark energy/dark matter

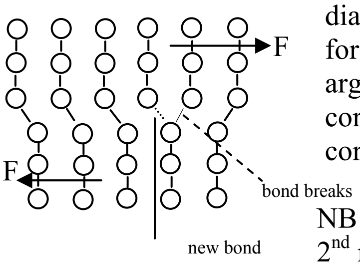
- Dark matter related to ‘missing’ mass (of Universe)
- Evidence from motion of (spiral) galaxies (ph4) {accept from clusters, gravitational lensing etc.)
- Possibly affects anisotropy of cosmic microwave background
- Possible role in galaxy formation
- Does not interact with light (e-m radiation) – not “can’t be seen”, but “can’t be detected
- Possibly accounts for 80% [majority]of mass of Universe
- Higgs boson could be responsible for dark matter
- Dark energy possibly related to accelerated expansion of Universe
- Universe made of ~74% [majority] dark energy
- Evidence for accelerated expansion from (class 1a) supernovae
- Recent evidence also for dark ‘flow’ or ‘fluid’ – any mention
- Dark flow/fluid possibly explains both dark matter/dark energy (no marks for details)

Grand Unification Theories

- Based on unification of force [l]aws
- Specifically weak, strong and electromagnetic (accept gravity as well even though this is theory of everything TOE)
- Electric & magnetic already unified (Einstein)
- Electro-weak unification
- Anything to do with greater gauge symmetry or unified coupling constant
- Unification at high energies
- Not possible to check with particle colliders (i.e. too high an energy)
- Observation through proton decay or neutrino properties

Question			Marking details	Marks Available
C7	*(a)*		Any 4 × (1) from - alternating / changing p.d. or current in primary ✓ - [alternating] B-field / flux inside primary or core ✓ - <u>core</u> takes B-field to secondary / links with secondary ✓ - alternating / changing flux inside secondary ✓ - alternating EMF induced in sec^{y} according to Faraday's Law, or equation given ✓	4
	(b)	(i)	$\frac{N_1}{N_2}=\frac{V_1}{V_2}$; $N_1\left[=\frac{240}{12}\times 280\right]$ (manipulation)(1) = 5600 [turns] (1)	2
		(ii)	use of $P = IV$ (1); so $50 = I_2 \times 12 \rightarrow I_2 = 4.17$ A (1) I_1 [$=\frac{12}{240}\times 4.17$] = 0.21 A (1) **or** $P = 50 = I_1 \times 240$ (1) I_1 [$=\frac{50}{240}$] = 0.21 A (1)	3
	(c)	(i)	Because V_c and V_c cancel **or** all 30 V across R <u>stated</u> (1) $I=\frac{V}{R}=\frac{30}{6.7}$ [= 0.448 A] (1)	2
		(ii)	$V_L = IX_L$ (1) = [0.45 × 2π × 1000 × 0.035 =] 98.5 V (1)	2
		(iii)	98.5 V e.c.f.✓	1
		(iv)	$\frac{98.5}{30}$ **or** $\frac{\omega L}{R}$ **or** $\frac{1}{\omega CR}$ (1) = 3.3 (1)	2
		(v)	 V_L , V_C , V_R all ⊥^{r} with V_L and V_C opposite (1) $V_L = V_C$ [by eye] >>V_R (1) NB. Diagram in any orientation / reflection	2
	(d)		at high freq, X_C very small (1) **and** V_{OUT} small (1) [**or** at low freq, X_C very large (1) ∴ V_{OUT} large (1)] 2nd mark only given if statement that it is a low pass filter.	2 **20**

Question			Marking details	Marks Available
C8	*(a)*		correct use of the word 'wavelength' [not breadth of undulations] (1) correct statement using path, path length or path difference (1) [e.g. light from the slits have a path difference of a whole number of wavelengths (for a bright fringe)]	2
	(b)		correct multiplication by 0.0254 (1) 700 nm – 420 nm (1)	2
	(c)		Any 4 × (1) from: • Contradicted Newton ✓ • Newton – almost god-like status ✓ • Previously accepted particle or corpuscular theory ✓ • Young didn't publish 'raw' data ✓ • Young didn't explain his working ✓ • Brougham's review (not encouraging) ✓	4
	(d)		Knife cuts lines of force induces emf in circuit containing knife	1
	(e)		Vibrations travel along lines of force (1) as a transverse wave (1) **[or** like waves in a stretched string]	2
	(f)	(i)	Cells of fluid spin (1) axes [of rotation] along lines of force (1)	2
		(ii)	Clash of vortices [moving against each other at points of contact] (1) separating vortices by idlers (1) **or** by diagram  diagram (1)	2
	(g)		Any 3 × (1) from: • failure to detect either (or implied) ✓ • Michelson-Morley experiment ✓ • No *motion* detected relative to ether ✓ (different from • Success of (special theory of) relativity ✓ detecting ether) • Based on *no* special frame of reference ✓ (i.e. no ether) • Any detail of Michelson-Morley experiment e.g. diagram of interferometer ✓ **or** anything explaining two branches of light in interferrometer (at right angles) to compare motion through ether etc. + 1 mark – standard of English and argument	4
			Penalise: average SPaG / too much writing (if irrelevant) Reward: good writing even if SPAG borderline / confident argument e.g. The whole consept (sic) of the ether was nonsense **and** no experiment confirmed it's (sic) existence. [Good writing though borderline SPaG. First marking point → 2 marks	**20**

Question			Marking details	Marks Available
C9	*(a)*	(i)	 diagram showing dislocation (1) forces <u>in opposition</u> shown **or** implied in argument (1) correct breaking bond shown (1) correct 'making' bond shown (1) NB Slipping planes of atoms can get only 2nd mark	4
		(ii)	foreign atoms **or** other dislocations **or** grain boundaries (1) stop dislocations from moving (1) [accept work hardening etc for max 1 mark]	2
	(b)	(i)	Hysteresis	1
		(ii)	Greater for loading because area greater (1). [difference] goes to heat [in tendon] (1)	2
		(iii)	Attempt at working out area (s) (1) Good attempt at working out both areas (1) e.g. below loading ~ ½ × 0.006 × 1200 = 3.6 J + below unloading ~ ½+ 1½+ 2½ + 3½ + 5½ = 13½ big sq^{s} (1) [or equivalent method, e.g. trapezoidal rule] Efficiency = $\frac{2.7}{3.6}$ × 100 = 75 % [eq^{n} + calc–e.c.f. on work values] (1)	3
		(iv)	I. $W = \frac{1}{2}Fe$ [**or** W = ½ × stress × strain × volume] (1) $E = \frac{Fl}{Ae}$ (1) or $E = \frac{\sigma}{\varepsilon}$ **and** $\sigma = \frac{F}{A}$ **and** $\varepsilon = \frac{\Delta l}{l}$ <u>Convincing</u> substitution + algebra (1)	3
			II. F = 1200 N and W = 3.6 J e.c.f. from (iii) [other possibilities] / **or** other values from graph (1) l = 0.3 m and $A = 0.55 \times 10^{-4}$ m^{2} [i.e. unit conversions] (1) E [= $\frac{1200^2 \times 0.3}{2 \times 0.55 \times 10^{-4} \times 3.6}$]= 1.1 GPa / **or** $E = \frac{Fl}{Ae} \rightarrow$ 1.1 GPa (1)	3
			Any 2 × (1) from: • Large Young modulus [accept stiff] ✓ • Large strains without breaking [accept 'elastic', 'flexible'] ✓ • Large stress without breaking/high [ultimate] tensile strength [accept 'strong']✓	2
				20

Question			Marking details	Marks Available
C10	*(a)*	(i)	A = piezoelectric [crystal] ✓	1
		(ii)	Stop reflection inside probe [or equiv., e.g. stops waves being cancelled etc.]/ absorb wave going to left / allows short pulses to be generated ✓	1
		(iii)	Correct substitution into $Z = \rho v$ once (1) [$Z_{\text{air}} = 442$ kg m^2 s^{-1}; $Z_{\text{skin}} = 1.7 \times 10^6$ kg m^2 s^{-1}] $R = 0.99[897]$ (1) [accept 1, with evidence of good substitution]	2
		(iv)	No [independent mark] – too much reflection [or implied – e.g. 'nearly all reflected from first boundary'] (1)	1
	(b)	(i)	Isotope of / [chemically] the same as the element it replaces (1) Suitable half life **or** stable daughter nuclide **or** γ emitter (1)	2
		(ii)	[Activity] rises <u>then falls</u> ✓	1
	(c)	(i)	X-ray output increases / intensity increases [accept: more X-rays] [because of more electrons per second]	1
		(ii)	$\frac{1}{2}I_0 = I_0e^{-\mu x}$ [i.e. substitution] (1) $e^{\mu X_{\frac{1}{2}}} = 2 \rightarrow \ln 2 = \mu X_{½}$ (1) [convincing manipulation]	2
		(iii)	$\mu = 57.8$ m^{-1} [or 0.0578 mm^{-1}]	1
		(iv)	$0.05\ I_0 = I_0\ e^{-\mu x}$ [or equiv or by impl] (1) [$\mu x = \ln 20 \rightarrow$] $x = 0.052$ m (1)	2
	(d)	(i)	Units on Potential axis / [m]V and time axis / [m]s(1) Large pulse (1) Small pulse before and after (1)	3
		(ii)	So voltage not lost [due to resistance of body] / because can only supply a v small current etc.	1
		(iii)	Any 2 × (1) of: • Large [voltage] gain ✓ • Reliable / robust / cheap ✓ • Even frequency response ✓ • high SNR ✓	2
				20

Question			Marking details	Marks Available
C11	*(a)*	(i)	$E = \frac{1}{2} mv^2$ used (1) Power = $\frac{E}{t}$ used (1) $= \frac{\frac{1}{2}\times 1200\times 28^2}{13}$ (1) [= 36.2 kW] $P = Fv$ **and** $F = ma$ **and** $v = u + at$ (1) P = 72 kW (1) → (2$_{\text{max}}$) NB. Full marks available for mean power = ½ max power → 36 kW	3
		(ii)	Any 2 × (1) sensible points, e.g. • friction in gears / links / engine / wheels [**not** tyres] ✓ • air resistance / drag [**not** heat / sound – too unspecific] ✓ • tyre hysteresis / internal energy [heat] <u>in tyres</u> ✓	2
		(iii)	2nd Law of Thermodynamics (1) … heat must be wasted (1) [accept: [ideal] efficiency = $1 - \frac{T_2}{T_1}$]	2
		(iv)	$\left[\frac{42}{5.8}\times 100 = \right]$ 724 km	1
		(v)	mass of carbon in tank = 0.042 × 780 × 0.85 kg (1) ratio of carbon to CO_2 is 12:44 [or used or by impl.] (1) mass of CO_2 [= 0.042 × 780 × 0.85 × $\frac{44}{12}$] = 102 kg (1)	3
		(vi)	$\frac{102}{724}$ [e.c.f. on (iv) and (v)] = 0.141 kg km^{-1} (1) Appropriate comment: e.g quite good agreement / nearly all carbon is burned (1)	2
		(vii)	greenhouse gas / [probably causes] global warming	1
	(b)	(i)	350 TWh = 350 × 10^{12} × [60 × 60 (1)] = 1.26 × 10^{18} J (1)	2
		(ii)	40 GW	1
		(ii)	To cope with peak / winter demand **or** at 6 o'clock everyone boils a kettle etc.	1
		(iv)	pump water to higher level / pump storage scheme (1) release when required to produce electricity [via turbines and generator] (1)	2
				20

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