

PH5

Question		Marking details	Marks Available
A1	(a)	${}^{14}_6\text{C}$ has $8n + 6p$ [or implied] (1) [$8p + 6n \rightarrow$ slip, allow e.c.f.] attempt at $8n + 6p - 13.99995$ (1) [=0.113026] $\times 931$ and $\div 14$ or use of $E=mc^2$ and $\div 14$ (1) $= 7.5 \text{ MeV}[\text{nucleon}]$ (1) [or $1.2 \times 10^{-14} \text{ J}[\text{nucleon}]$] ((unit))	4
	(b)	$13.99995 - 13.999234 - 0.000549$ i.e. attempt at mass defect (1) $\times 931 \text{ MeV}$ or use of $E = mc^2$ (1) $= 0.155 \text{ MeV}$ or $2.5 \times 10^{-14} \text{ J}$ (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)	${}^{137}_{56}\text{Ba}$ ${}^0_{-1}\text{e}$ 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) $\lambda = \frac{\ln 2}{30 \times 365 \times 24 \times 60 \times 60}$ (1) [= 7.3×10^{10}]	2
	(c)	$A = \pm \lambda N$ stated or used (1) $= 7.3 \times 10^{-10} \text{ (e.c.f.)} \times \frac{1}{0.137} \times 6 \times 10^{23}$ (1) [= $3.2 \times 10^{15} \text{ Bq}$]	2
	(d)	[All] β absorbed [however expressed] \checkmark or no γ present [implies β absorbed]	1
	(e)	$A = A_0 e^{-\lambda t}$ [or $A = A_0 2^{-n}$] $1000 = 3.2 \times 10^{15} e^{-\lambda t}$ or $3 \times 10^{15} e^{-\lambda t}$ (1) [or $1000 = 3 \times 10^{15} \times 2^{-n}$] taking logs correctly(1) e.g. $\ln 1000 = \ln [3.2 \times 10^{15}] - \lambda t$ or equiv. $t \left[= \frac{1}{\lambda} \ln 3.2 \times 10^{15} \right] = 4.1 - 4.9 \times 10^{10} \text{ s}$ [1240 – 1544 years] (1)	3
10			

Question		Marking details	Marks Available
A3	(a)	$C = \frac{\epsilon_0 A}{d}$ used [2 quantities inserted, e.g. $C = \frac{\epsilon_0 \times 0.163}{0.35}$] (1) $C = 4.1 \text{ nF}$ (1)	2
	(b)	(i) $5 \mu\text{C}$ ✓ (ii) 3mJ ✓	1 1
	(c)	$t_{\frac{1}{2}} [= CR] = 2.77 \text{ ms}$ (1) $\frac{1}{2}Q_0 = Q_0 e^{-\frac{t}{CR}}$ (1) $T = 1.92 \text{ ms}$ (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)	$F = Eq$ $a = \frac{F}{m}$ $E = \frac{V}{d}$	all three → 2 marks 2 → 1 mark also, subtract 1 mark for for each 2 useless unused eq ^{ns}
		NB. $a = \frac{Ee}{m} = \frac{eV}{md}$ ✓✓	
		$a = \frac{1200 \times 1.6 \times 10^{-19}}{9.1 \times 10^{-31} \times 0.35 \times 10^{-3}}$ (1) [= $6.03 \times 10^{17} \text{ m s}^{-2}$]	3
	(f)	$v^2 = u^2 + 2ax$ or other combinations e.g. $x = ut + \frac{1}{2}at^2$ and $v = u + at$ (1)	2
	(i)	(do not award mark if all 4 eq^{ns} by themselves only) $v [= \sqrt{2 \times 6 \times 10^{17} \times 0.175 \times 10^{-3}}] = 1.45 \times 10^7 \text{ m s}^{-1}$ (1)	
	(ii)	$E = \frac{1}{2}mv^2$ used (1) → $9.6 \times 10^{-12} \text{ J}$ $\div e$ [gives 600 eV] (1) Alternative method is using $E = Vq$, $V = 0.6 \text{ kV}$ [and $q = e$] – or other convincing argument] (1)	3
	(iii)	$v = u + at$ (1) $1.45 \times 10^7 = 0 + 6 \times 10^{17}t$ (1) $\therefore t = 24.2 \text{ ps}$ (1)	3
		or $x = ut + \frac{1}{2}at^2$ (1) $0.175 \times 10^{-3} = 0 + \frac{1}{2}6 \times 10^{17}t^2$ (1) $\therefore t = 24.2 \text{ ps}$ (1) [or equivalent solution based upon $x = vt - \frac{1}{2}at^2$]	
		NB. Use of $t = \frac{v}{d} = 12.1 \text{ ps}$ → 0 marks	3
			20

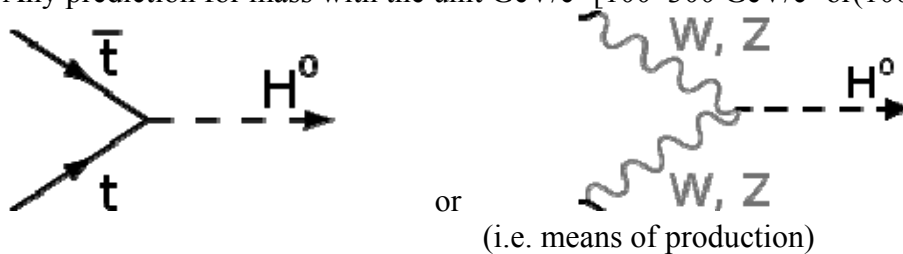
Question		Marking details	Marks Available
A4	(a)	force on electrons is downwards [or electron deficiency on top] (1) due to Fleming's LHR [or stating that current is to the right] (1)	2
	(b)	Voltmeter symbol shown connected between top and bottom faces ✓	1
	(c)	$Bqv = Eq$ (1) [not $Blv = Eq$, but accept $Bev = Eq$] $Bqv = \frac{V_H}{d} q$ (1) [i.e. using $E = \frac{V_H}{d}$] + convincing algebra (1) [from above step the answer alone suffices]	3
	(d)	(i) $n = 15\,000 \div 2$ (1) $I \left[= \frac{B}{\mu_0 n} \right] = 2.3 \text{ A}$ (1) [allow 1 mark for $1.15A$ missing first step]	2
	(ii) In the middle / inside [of the solenoid] (1) with front face \perp (1) [to axis of solenoid or B-field] [NB: "inside current" ✗, "between the coils" ✗]	2	
		9	
A5	(a)	Area (inside hoop) changes (1) or [sides of] hoop cut (1) Magnetic flux changes (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) or correct use of r.h. grip rule (1) for flux to oppose goes left at top and right at bottom (1) 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 $\frac{d}{dt}(N\Phi)$ or similar (1) $I = \frac{B\pi r^2}{R} = \frac{58 \times 10^{-3} \times \pi (0.31)^2}{0.063 \times 0.44} = 0.63 \text{ A}$ (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) $\frac{1}{2}mv^2 = 50 \text{ MeV}$ (1) $v = \sqrt{\frac{2 \times 50 \times 10^6 \times 1.6 \times 10^{-19}}{1.67 \times 10^{-27}}} = 9.8 \times 10^7 \text{ m s}^{-1}$ (1) [ans]	2
		(ii) $v = 3.7 \times 10^{10} \text{ ms}^{-1}$ ✓	
		(iii) 2 nd calculation not valid [or 1 st is valid] (1) Because $v_2 > 3 \times 10^8 \text{ m s}^{-1}$ [or c] (1)	1
	(c)	Keeps superconductors at low temperature (1) so that high currents [are maintained] (1)	2
	(d)	(i) Accept $\sim 10^{-4} \text{ m} \rightarrow \sim 10^{-3} \text{ mm}$ [be generous] (1) $V = 10^{-12} \text{ m}^3 \rightarrow 10^{-9} \text{ mm}^3$ [ecf on side] (1)	2
		(ii) $pV = nRT$ (1) number of moles = $\frac{1 \times 10^{-9}}{1}$ [accept $\frac{1 \times 10^{-9}}{2}$] (1) $V = 2.4 \times 10^{-11} \text{ m}^3$ and compared with d(ii) (1) (large range: check)	2
	(e)	Any 2 × (1) from <ul style="list-style-type: none"> • 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 = $2 \times 3.1 \times 10^{-6} \text{ kg}$ [or by implication] (1) $E [= mc^2 = 6.2 \times 10^{-6} \times (3 \times 10^8)^2] = 5.6 \times 10^{11} \text{ J}$ (1) [1 mark for $2.8 \times 10^{11} \text{ J}$]	1
			2
			20

In each case, any $3 \times (1)$ – 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 [$100\text{--}300 \text{ GeV}/c^2$ or $(100\text{--}300)m_p$ or m_n]



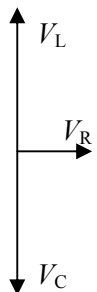
- Possible solution to dark matter problem
- Possibly more than one Higgs predicted

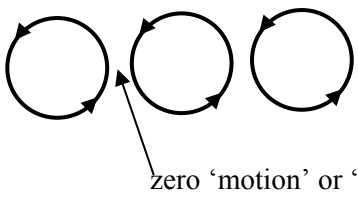
Dark energy/dark matter

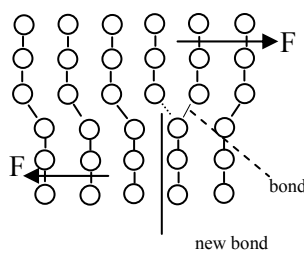
- Dark matter related to ‘missing’ mass (of Universe)
- Evidence from motion of (spiral) galaxies (ph4) {accept from clusters, gravitational lensing etc.}
- Possibly affects anisotropy of cosmic microwave background
- Possible role in galaxy formation
- Does not interact with light (e-m radiation) – 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 $\sim 74\%$ [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 [1]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)	<p>Any 4 × (1) from</p> <ul style="list-style-type: none"> • alternating / changing p.d. or current in primary ✓ • [alternating] <i>B</i>-field / flux inside primary or core ✓ • <u>core</u> takes <i>B</i>-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)	<p>(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)</p> <p>(ii) use of $P = IV$ (1); so $50 = I_2 \times 12 \rightarrow I_2 = 4.17 \text{ A}$ (1) or $P = 50 = I_1 \times 240$ (1) $I_1 \left[= \frac{12}{240} \times 4.17 \right] = 0.21 \text{ A}$ (1) $I_1 \left[= \frac{50}{240} \right] = 0.21 \text{ A}$ (1)</p>	2 3
	(c)	<p>(i) Because V_c and V_c cancel or all 30 V across <i>R</i> <u>stated</u> (1) $I = \frac{V}{R} = \frac{30}{6.7} [= 0.448 \text{ A}]$ (1)</p> <p>(ii) $V_L = IX_L$ (1) $= [0.45 \times 2\pi \times 1000 \times 0.035 =] 98.5 \text{ V}$ (1)</p> <p>(iii) 98.5 V e.c.f. ✓</p> <p>(iv) $\frac{98.5}{30}$ or $\frac{\omega L}{R}$ or $\frac{1}{\omega CR}$ (1) = 3.3 (1)</p> <p>(v) </p> <p>V_L, V_C, V_R all \perp^r with V_L and V_C opposite (1) $V_L = V_C$ [by eye] $\gg V_R$ (1)</p> <p>NB. Diagram in any orientation / reflection</p>	2 2 1 2
	(d)	<p>at high freq, X_C very small (1) and V_{OUT} small (1) [or at low freq, X_C very large (1) $\therefore V_{OUT}$ large (1)] 2nd mark only given if statement that it is a low pass filter.</p>	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: <ul style="list-style-type: none"> • 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 	2
	(g)	Any 3 × (1) from: <ul style="list-style-type: none"> • failure to detect either (or implied) ✓ • Michelson-Morley experiment ✓ • No <i>motion</i> detected relative to ether ✓ (different from detecting ether) • Success of (special theory of) relativity ✓ (i.e. no ether) • Based on <i>no</i> special frame of reference ✓ • Any detail of Michelson-Morley experiment e.g. diagram of interferometer ✓ or anything explaining two branches of light in interferometer (at right angles) to compare motion through ether etc. + 1 mark – standard of English and argument Penalise: average SPaG / too much writing (if irrelevant) Reward: good writing even if SPAG borderline / confident argument e.g. The whole concept (sic) of the ether was nonsense and no experiment confirmed it’s (sic) existence. [Good writing though borderline SPaG. First marking point → 2 marks	4
		20	

Question	Marking details	Marks Available
C9	<p>(a)</p> <p>(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</p> <p>(ii) foreign atoms or other dislocations or grain boundaries (1) stop dislocations from moving (1) [accept work hardening etc for max 1 mark]</p> <p>(b)</p> <p>(i) Hysteresis</p> <p>(ii) Greater for loading because area greater (1). [difference] goes to heat [in tendon] (1)</p> <p>(iii) Attempt at working out area (s) (1) Good attempt at working out both areas (1) e.g. below loading $\sim \frac{1}{2} \times 0.006 \times 1200 = 3.6 \text{ J}$ + below unloading $\sim \frac{1}{2} + 1\frac{1}{2} + 2\frac{1}{2} + 3\frac{1}{2} + 5\frac{1}{2} = 13\frac{1}{2}$ big sq^s (1) [or equivalent method, e.g. trapezoidal rule] Efficiency = $\frac{2.7}{3.6} \times 100 = 75 \%$ [eqⁿ + calc–e.c.f. on work values] (1)</p> <p>(iv) I. $W = \frac{1}{2} Fe$ [or $W = \frac{1}{2} \times \text{stress} \times \text{strain} \times \text{volume}$] (1) $E = \frac{Fl}{Ae}$ (1) or $E = \frac{\sigma}{\epsilon}$ and $\sigma = \frac{F}{A}$ and $\epsilon = \frac{\Delta l}{l}$ <u>Convincing</u> substitution + algebra (1)</p> <p>II. $F = 1200 \text{ N}$ and $W = 3.6 \text{ J}$ e.c.f. from (iii) [other possibilities] / or other values from graph (1) $l = 0.3 \text{ m}$ and $A = 0.55 \times 10^{-4} \text{ m}^2$ [i.e. unit conversions] (1) $E [= \frac{1200^2 \times 0.3}{2 \times 0.55 \times 10^{-4} \times 3.6}] = 1.1 \text{ GPa}$ / or $E = \frac{Fl}{Ae} \rightarrow 1.1 \text{ GPa}$ (1)</p> <p>Any 2 \times (1) from:</p> <ul style="list-style-type: none"> • Large Young modulus [accept stiff] ✓ • Large strains without breaking [accept 'elastic', 'flexible'] ✓ • Large stress without breaking/high [ultimate] tensile strength [accept 'strong'] ✓ 	<p>4</p> <p>2</p> <p>1</p> <p>2</p> <p>3</p> <p>3</p> <p>3</p> <p>2</p> <p>20</p>

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) [$Z_{\text{air}} = 442 \text{ kg m}^2 \text{ s}^{-1}$; $Z_{\text{skin}} = 1.7 \times 10^6 \text{ kg m}^2 \text{ s}^{-1}$] $R = 0.99[897]$ (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) $\frac{1}{2} I_0 = I_0 e^{-\mu x}$ [i.e. substitution] (1) $e^{\frac{\mu x}{2}} = 2 \rightarrow \ln 2 = \mu x_{\frac{1}{2}}$ (1) [convincing manipulation]	2	
		(iii) $\mu = 57.8 \text{ m}^{-1}$ [or 0.0578 mm^{-1}]	1	
		(iv) $0.05 I_0 = I_0 e^{-\mu x}$ [or equiv or by impl] (1) [$\mu x = \ln 20 \rightarrow x = 0.052 \text{ m}$] (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 \times (1) of: <ul style="list-style-type: none"> • 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]	<div style="border: 1px dashed black; padding: 5px;"> $P = Fv$ and $F = ma$ and $v = u + at$ (1) $P = 72 \text{ kW}$ (1) $\rightarrow (2_{\text{max}})$ NB. Full marks available for mean power = $\frac{1}{2}$ max power $\rightarrow 36 \text{ kW}$ </div>	3
		(ii) Any 2 \times (1) sensible points, e.g. <ul style="list-style-type: none"> • friction in gears / links / engine / wheels [not tyres] ✓ • air resistance / drag [not heat / sound – too unspecific] ✓ • tyre hysteresis / internal energy [heat] <u>in</u> tyres ✓ 		2
		(iii) 2 nd 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 = $0.042 \times 780 \times 0.85 \text{ kg}$ (1) ratio of carbon to CO ₂ is 12:44 [or used or by impl.] (1) mass of CO ₂ [= $0.042 \times 780 \times 0.85 \times \frac{44}{12}$] = 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 = $350 \times 10^{12} \times [60 \times 60 \text{ (1)}] = 1.26 \times 10^{18} \text{ J}$ (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			