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) $= 7 \cdot 5$ MeV[/nucleon] (1) [or $1 \cdot 2 \times 10^{-14}$ J [/nucleon]] ((**unit**))	4
	(b)		$13 \cdot 99995 - 13 \cdot 999234 - 0 \cdot 000549$ i.e. attempt at mass defect (1) × 931 MeV **or** use of $E = mc^2$ (1) $= 0 \cdot 155$ MeV **or** $2 \cdot 5 \times 10^{-14}$ J (1)	3
	(c)		(from conservation of mom) $v_\beta > v_N$ (1) **or** $v_\beta = 26000 v_N$ (since) $M_N > M_\beta$ (1) **or** $M_N = 26000 M_\beta$ since $E_k = \frac{1}{2}mv^2$, β particle has most of the energy (1) or $E_\beta = 26000 E_N$	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) $\lambda = \frac{\ln 2}{30 \times 365 \times 24 \times 60 \times 60}$ (1) $\left[= 7.3 \times 10^{10}\right]$	2
	(c)		$A = \pm \lambda N$ stated or used (1) $= 7.3 \times 10^{-10}$ (e.c.f.) $\times \frac{1}{0.137} \times 6 \times 10^{23}$ (1) [= 3.2 × 10^{15} Bq]	2
	(d)		[All] β absorbed [however expressed] ✓ **or** no γ present [implies β absorbed]	1
	(e)		$A = A_0 e^{-\lambda t}$ [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. $t\left[= \frac{1}{\lambda} \ln 3.2 \times 10^{15}\right]$ = 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)		$F = Eq$ $a = \frac{F}{m}$ $E = \frac{V}{d}$ 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 × 10^{17} 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)	
		(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 × 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)	$v = u + a\,t$ (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**

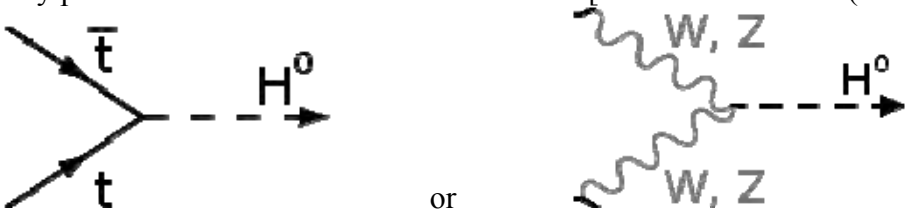
Question			Marking details	Marks Available
A4	*(a)*		force on electrons is downwards [**or** electron deficiency on top] (1) due to Fleming's LHR [**or** stating that current is to the right] (1)	2
	(b)		Voltmeter symbol shown connected between top and bottom faces ✓	1
	(c)		$Bqv = Eq$ (1) [**not** $Blv = Eq$, but accept $Bev = Eq$] $Bqv = \frac{V_H}{d} q$ (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 ÷ 2 (1) $I\left[= \frac{B}{\mu_0 n}\right]$ = 2.3 A (1) [allow 1 mark for $1{\cdot}15A$ 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) ∴ 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 $\frac{\mathrm{d}}{\mathrm{d}t}(N\Phi)$ 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) $v = \sqrt{\frac{2\times 50\times 10^6\times 1.6\times 10^{-19}}{1.67\times 10^{-27}}} = 9.8 \times 10^7$ m s^{-1} (1) [ans]	2
		(ii)	$v = 3\cdot 7\times 10^{10}\ ms^{-1}$ ✓	
		(iii)	2nd calculation not valid [**or** 1st is 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 $\rightarrow$ ~10^{-3} mm [be generous] (1) $V = 10^{-12}$ m^3 $\rightarrow 10^{-9}$ 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) $V = 2.4 \times 10^{-11}$ 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 × 10^{-6} × (3 × 10^8)^2]= 5.6 × 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]



(i.e. means of production)

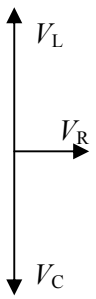
- Possible solution to dark matter problem
- Possibly more than one Higgs predicted

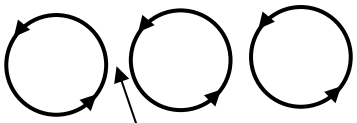
Dark energy/dark matter

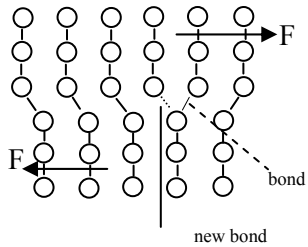
- Dark matter related to 'missing' mass (of Universe)
- Evidence from motion of (spiral) galaxies (ph4) {accept from clusters, gravitational lensing etc.)
- Possibly affects anisotropy of cosmic microwave background
- Possible role in galaxy formation
- Does not interact with light (e-m radiation) – 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) **or** $P = 50 = I_1 \times 240$ (1) $I_1 \left[= \frac{12}{240} \times 4.17\right] = 0.21$ A (1) $I_1 \left[= \frac{50}{240}\right] = 0.21$ 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 $\perp^r$ 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) zero 'motion' or 'idler' (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 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	4 **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 sqs (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)	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_{air} = 442 kg m^2 s^{-1}; $Z_{skin} = 1.7 \times 10^6$ 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)	$\frac{1}{2} I_0 = I_0 e^{-\mu x}$ [i.e. substitution] (1) $e^{\mu X_{\frac{1}{2}}} = 2 \rightarrow \ln 2 = \mu X_{½}$ (1) [convincing manipulation]	2
		(iii)	μ = 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)	$E = ½\ mv^2$ 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_{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