PH5

Question			Marking details	Marks Available
1	*(a)*	(i)	Attempt at 6n + 6p - mass of carbon nucleus (1) × 931 and ÷12 **or** $E = mc^2$ and ÷12 (1) Correct answer = 7.7 [MeV/nucleon] **or** 1.23×10^{-12} [J] (1)	3
		(ii)	Conversion of 7.16 MeV to mass = 0.00769 [u] (1) Conservation of mass-energy 4.0015 + 11.9967 - 0.00769 (1) Answer approx correct e.g. 15.99 u accept (16.07 ± 0.08) [u] **or** $(2.67 \pm 0.02) \times 10^{-26}$ [kg] (1) 15.9905 (accuracy mark, also available for 16.0059 and without unit) (1)	4
	(b)	(i)	Neutron absorber **or** high melting point (**or** other valid response)	1
		(ii)	Light nucleus **or** poor neutron absorber **or** slows down neutrons (**or** other valid response)	1
		(iii)	High heat capacity **or** poor neutron absorber **or** doesn't become radioactive (**or** other valid response) Don't accept must be a fluid **or** good ability to conduct heat away	1
			Question 1 Total	**[10]**

Question			Marking details	Marks Available
2	*(a)*	(i)	Mass number = 206 (1) Atomic number = 82 (1)	2
		(ii)	Gas can be <u>inhaled</u> (1) (Don't accept if state both ingest and inhale) **Any 2 (×1) from:** • Dense gas **or** stays in basements • Alpha <u>highly</u> ionising • Multiple emissions i.e. more than 1 alpha (do not accept emits alpha and beta by itself) • Short half-life • Contaminates wells • Enters through cracks Don't accept high activity **or** contaminates water supply **or** alpha particles are breathed in **or** causing cancer	3
	(b)		Use of $\lambda = \frac{ln2}{T_{1/2}}$ e.g. $\lambda = 0.182$ [day^{-1}] (2.11×10^{-6} s^{-1}) **or** $\boldsymbol{t = nT_{1/2}}$ (1) Logs taken correctly e.g. $\ln A = \ln A_0 - \lambda t$ **or** $\ln A = \ln A_0 - n\ln 2$ (1) Algebra correct e.g. $t = \frac{1}{\lambda}\ln\frac{A_0}{A}$ **or** $n = \frac{1}{\ln 2}\ln\frac{A_0}{A}$ **or** implied (1) Correct answer 13.2 [days] (1.14×10^6 [s]) (1)	4
	(c)		Daughter nuclei give added activity	1
			Question 2 Total	**[10]**

Question			Marking details	Marks Available
3	*(a)*	(i)	Values substituted into $C = \frac{\varepsilon_0 A}{d}$ (= 7.32 × 10^{-9} F) (1) $Q = CV$ (**or** implied) note $C = \frac{Q}{V}$ not good enough (1) Answer = 9.37 × 10^{-7} [C] (1)	3
		(ii)	Answer = 6.0 × 10^{-5} [J] (**ecf**)	1
		(iii)	$E = \frac{V}{d}$ (1) Answer = 2 170 000 [V m^{-1}] (1)	2
	(b)	(i)	Capacitance decreases (1) Energy stored increases (1)	2
		(ii)	Work done by separating plates **or** work done against field **or** increase in potential energy (1) (accept energy used instead of work done) Equal to increase in stored energy (1)	2
			Question 3 Total	**[10]**

Question			Marking details	Marks Available
4	(a)		$n = \frac{9560}{1.45}$ (1) Correct answer = 2.65×10^{-3} T **UNIT mark** (1)	2
	(b)		$B = \frac{\mu_0 I}{2\pi a}$ used (e.g. 2.82×10^{-6} [T] **or** 4.35×10^{-6} [T] **or** 10^{x} slips) (1) Subtracting **or** adding fields (1) 1.53×10^{-6} [T] no **ecf** (1) Out of paper (1)	4
	(c)		Equating fields e.g. $\frac{\mu_0 \times 0.24}{2\pi \times a} = \frac{\mu_0 \times 0.37}{2\pi \times (0.034 - a)}$ **or** $\frac{\mu_0 \times I_1}{2\pi \times a} = \frac{\mu_0 \times I_2}{2\pi \times b}$ (1) (Accept $\frac{a_1}{a_2} = \frac{0.37}{0.24}$ (= 1.54 or 0.65 reciprocal)) Algebra $\frac{0.24 \times 0.034}{(0.37+0.24)} = a$ **or** $\frac{0.37 \times 0.034}{(0.37+0.24)} = a$ **or** $a = \frac{1.54}{2.54} \times 0.034$ etc (1) Answer = 0.0134 [m] **or** 0.0206 [m] but must be clear from algebra, working **or** statement that the point is nearer the upper wire (1)	3
			Question 4 Total	**[9]**

Question			Marking details	Marks Available
5	(a)		$F = Eq$ (**or** eE) used **or** implied (1) $E = \frac{V}{d}$ **quoted or** implied (1) $a = \frac{F}{m}$ used **or** implied (1) $a = \frac{11.2\text{x}1.6\text{x}10^{-19}}{9.11\text{x}10^{-31}\text{x}7.6\text{x}10^{-3}}$ $[= 2.588 \times 10^{14}]$ (1) N.B. Use of $a = \frac{Eq}{m}$ **or** $F = \frac{Vq}{d}$ **award 2 marks or** $a = \frac{Vq}{md}$ **award 3 marks**	4
	(b)	(i)	No horizontal forces (don't accept no horizontal acceleration **or** because it's in a vacuum)	1
		(ii)	Constant vertical force **or** uniform electric field	1
	(c)		Valid method for obtaining time e.g. $s = ut + \frac{1}{2}at^2$ (1) Time correct = 5.4×10^{-9} [s] (1) Answer = $8.00 \times 10^7 \times 5.4$ ns = 43 [cm] **(ecf)** (1) (factors of 10 or $\sqrt{10}$ slips only penalised 1 mark)	3
	(d)		Valid method e.g. definition of eV, force × distance, getting resultant velocity and finding change in $\frac{1}{2}mv^2$ (1) Answer = 5.6 [eV] (which can simply be written for full marks) **or** 8.96×10^{-19} [J] **(ecf)** (1) (answer of 11.2 eV gets 1/2 marks)	2
			Question 5 Total	**[11]**

Question			Marking details	Marks Available
6	*(a)*	(i)	Flux linkage = $NBA\cos\theta$ used (1) 0.251 [Wb] [and 0.251 Wb] (1)	2
		(ii)	No change in flux [linkage] **or** field lines cut in one direction and then the opposite direction Don't accept rate of change of flux is 0	1
	(b)		Flux linkage = 0.0443 **or** -0.0443 (1) Time = $\frac{20}{360} \times 0.1$ (1) Attempt at change of flux (linkage) divided by time (1) Answer = [-] 15.9 [V] (1)	4
	(c)		Peak emf = 17 [V] Sinusoid with peak of 3.4 squares high **(ecf)** (1) Sinusoid with period of 4 squares (1)	3
			Question 6 total	**[10]**

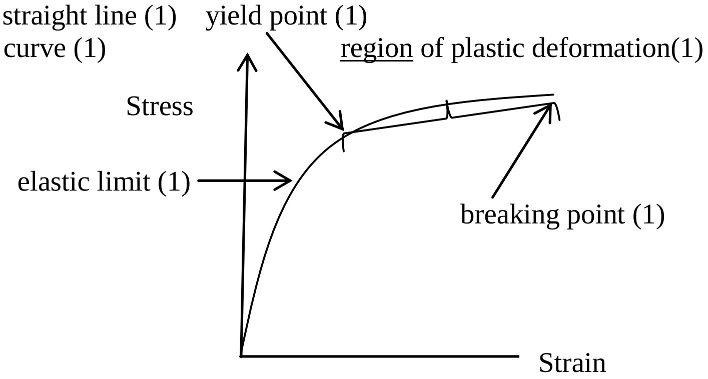
Question			Marking details	Marks Available
7	(a)		**Any 2 (×1) from:** • Near stars move relative to distant stars [due to Earth orbit] • More movement (or larger angle) means stars nearer (inversely proportional etc.) or accept parsec = 1/arcsec • Parallax (or distance) can be measured from readings 6 months apart (or accept readings where Earth movement is known etc.)	2
	(b)		4 parsec **or** angle = $1.5 \times 10^{11}/d$ (1) $4 \times 3.25 = 13$ [light year] (1)	2
	(c)		10× distance gives <u>100 times</u> less intensity (1) Substituting 1 and 0.1 into equation **accept 1 and 10** (1) $m = M - 5$ and $m = M$ shown (1) **Alternative:** 2.5^5 roughly equal to 100 **award 2 marks**	3
	(d)		1[%] Accept 0.01 but not 0.01 %	1
	(e)		Electrons need to be in the high energy levels (1) They need to be in $n = 3$ (1st mark can be implied in the 2nd mark) (1) Not possible because no ultraviolet to absorb **or** collisions don't have enough KE (1)	3
	(f)		Comparison with $4\pi r^2 \sigma T^4$ **or** $b = 4\pi\sigma$ (1) Answer $b = 7.13 \times 10^{-7}$ (1) Unit = W m^{-2} K^{-4} **or** equivalent (1)	3

Question			Marking details	Marks Available
	(g)	(i)	T = 1 (year) and a = 1 (AU) and M = 1 Accept because everything = 1	1
		(ii)	Assuming $M + m \approx 0.32\ M_{\text{Sun}}$ (1) $a = \sqrt[3]{0.32 \times 0.46^2} = 0.41$ [AU] (1)	2
	(h)		Drop when large eclipses small (1) And small eclipses large (1) Bigger drop when the <u>hotter/brighter</u> star is blocked (1) **Award 3 marks** for bigger drop when small in front of large	3
			Question 7 Total	**[20]**

Question			Marking details	Marks Available
8	*(a)*	(i)	Sinusoidal reading on voltmeter @ 0.9 Hz (or across resistor) (1) Sinusoidal (or changing) *B*-field in primary (1) Leads to *B*-field cutting secondary **or** flux changing in secondary (1) emf induced in secondary due to Faraday's (1)	4
		(ii)	Lost flux **or** no iron core **or** low frequency **or** low turns	1
	(b)	(i)	$\omega L = \frac{1}{\omega C}$ **or** $f = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$ (1) Answer = 4 490 [Hz] (1)	2
		(ii)	V_R = 12 [V] (1) I = 0.067 [A] (1) $V_L = \mathrm{I} \times \omega L$ **or** $V_C = \mathrm{I} \times \frac{1}{\omega C}$ (1) V_L = 71.5 [V] **and** V_C = 71.5 [V] **or** implied e.g. V_C = same (1)	4
8	*(c)*	(i)	$Z = \sqrt{(X_L - X_C)^2 + R^2}$ (1) Z = 581 [Ω] or implied (1) Current $= \frac{12}{581}$ = 21 [mA] (1)	3
		(ii)	Phasor diagram (1) $\tan\theta = \frac{X_L - X_C}{R}$ (this step implies vector diagram if omitted) (1) Answer = 72° **(ecf)** (1) (18° and similar slips gain 1/2)	3
	(d)		$\frac{R}{X_C} = \frac{3}{4}$ (1) $X_C = \frac{1}{2\pi f C}$ **or** $X_C = \frac{1}{\omega C}$ and $\omega = 2\pi f$ **used** (1) Answer = 20 [kHz] (1)	3
			Question 8 Total	**[20]**

Question			Marking details	Marks Available
9	*(a)*	(i)	Ørsted **or** Oersted (accept Orsted)	1
		(ii)	Battery (not cell)	1
		(iii)	**Any 3 (×1) from:** • Current passed through wire **or** pile connected across wire • Compass turned [nearly] at right angles to wire • When compass above wire points in opposite direction • Compass points according to rh grip (or screw) rule • Field lines circle around wire	3
		(iv)	Electric effect arising from magnetism (or from magnet)	1
	(b)	(i)	Vortices shown separated by (smaller) idlers (1) Vortices and/or idlers labelled (1) Rotation shown or stated (1)	3
		(ii)	**Any 2 (×1) from:** • Maxwell used it to predict e-m waves • Maxwell used it to explain magnetic field due to a wire • Maxwell used it to explain [any other e-m effect!] • Its existence is irrelevant / Maxwell didn't suppose it existed	2

Question			Marking details	Marks Available
9	*(c)*	(i)	Produced when sparks occurred between [ball-ended] rods [connected to an induction coil or high voltage]. (1) Detected by sparks occurring across spark-gap between rods or across break in ring. (1)	2
		(ii)	He found spark intensity varied according to orientation of detector rods [relative to transmitter rods]. **or** he interposed metal grille between transmitter and detector, finding spark intensity varied with grille orientation.	1
		(iii)	He used metal reflector to produce stationary wave. (1) He measured distance between nodes [and doubled it]. (1)	2
	(d)	(i)	Time between events in a frame in which the events occur at the same place. **or** time between events as measured by a clock present at both events.	1
		(ii)	$\gamma = 1.01$ (1) $t_B - t_A = 0.5000\,\gamma$ (1) despite mistakes in γ $t_B - t_A = 0.5050$ [s] (1) allow **ecf** on γ arising from slips.	3
			Question 9 total	**[20]**

Question			Marking details	Marks Available
10	*(a)*			6
	(b)	(i)	DE broken **or** E bonds with B (1) HG broken **or** H bonds with D (1) Movement of dislocations stated (1) Or all clearly seen from diagrams	3
		(ii)	No dislocations (or equivalent) **or** no grain boundaries Don't accept addition of foreign atoms Don't accept single crystal (stated in question)	1
		(iii)	Any valid use e.g. Turbine blades (don't accept wind turbines), combustion chambers, nuclear reactors, wear resistant materials, rocket engines etc.	1
	(c)	(i)	$\dfrac{Fl}{2\times10^{11}A_{steel}} = \dfrac{Fl}{1\times10^{11}A_{brass}}$ (1) Convincing algebra to show $A_{brass} = 2\times A_{steel}$ (1) (**alternative:** force, length and extension all the same 1 mark so brass must have twice the CSA 1 mark only – not fully shown as required)	2
		(ii)	50 [N]	1
		(iii)	$\Delta x = \dfrac{50\times2}{\left(2.8\times10^{-7}\right)\times2\times10^{11}}$ (1) – substitution (**ecf** on 50 N) Δx = 1.8 [mm] (1) (correct unit required m or mm)	2
		(iv)	$E = ½\, Fx$ (1) (accept $\boldsymbol{E} = \frac{1}{2}\sigma\varepsilon\boldsymbol{V}$) E = 0.044 [J] (1) (**ecf** on Δx only)	2
		(v)	Same (1) F and Δx same (1)	2
			Question 10 total	**[20]**

Question				Marking details	Marks Available
11	*(a)*	(i)		Both background and line spectra labelled clearly	1
		(ii)	I	[Inner] electrons [of target element] knocked out / ionised (1)	4
				Electrons from higher energy levels fall to take their place (1)	
			II	Rapid deceleration of <u>electrons</u> (1)	
				On collision with target element / nucleus (1)	
		(iii)		$\lambda = \frac{hc}{eV}$ (or rearrangement in figures) (1)	2
				$\lambda = 2.07 \times 10^{-11}$ [m] (1) Accept 2.1×10^{-11} [m]	
	(b)	(i)		Ultrasound B-scan (1)	6
				Moving pictures/ see organ development **not** 'give a 2D image' (1)	
		(ii)		CT scan (1)	
				Distinguishes soft tissue well (1)	
				Accept MRI cannot be used because of pacemaker	
		(iii)		MRI scan (1)	
				Gives high quality images of soft tissue (1)	
	(c)			Time taken from scale 5 ± 1 [μs] (1)	3
				Distance = 8.2×10^{-3} [m] (1) **(ecf)**	
				Thickness = $\frac{8.2\text{x}10^{-3}}{2} = 4.1 \times 10^{-3}$ [m] (1)	

Question			Marking details	Marks Available
11	*(d)*	(i)	QRS wave / R / central spike (1) Bigger / higher /more spiked (1)	2
		(ii)	P wave flatter / P wave extended/ prolonged PR interval / no P wave / smaller P wave / P wider / P lower amplitude	1
		(iii)	Deepening of Q wave / T wave inversion / ST elevation / ST depression {Irregular interval / inverted waves / bigger distance P to QRS to T wave} N.B. any incorrect statement negates the mark	1
			Question 11 total	**[20]**

Question			Marking details	Marks Available
12	*(a)*	(i)	**Any 2 ×(1) from:** • Possible second use as a bridge • Cheap electricity after build • Zero or low CO_2 after built • High output • Predictable output • Sustainable/renewable/reliable energy source that will not run out	2
		(ii)	**Any 2 ×(1) from:** • Only available twice a day (i.e. not a constant output) • Possible huge impact on Severn estuary wildlife • High CO_2 costs to build • Expensive to build (£3k per kW as opposed to £1k per kW coal)	2
	(b)		GPE (PE not good enough) to KE **or** GPE to electrical (1) KE / mechanical to electrical **or** const KE when running (1)	2
	(c)		Mean height increase = 0.5 h must be stated **not** implied (1) Either volume = Ah **or** mass = $Ah\rho$ (1) Correct substitution into mgh **(ecf)** (1)	3
	(d)		Values substituted into equation (1.38×10^{14} J) (1) ×2 (or using time as 12 hrs) and × 0.75 (1) Dividing by time or $P = E/t$ etc. (1) Answer = 2.4 [GW] **(no ecf)** (1)	4

Question			Marking details	Marks Available
12	(e)	(i)	**Any 2 ×(1) from:** • Continuous electricity not twice a day • Less damage to environment • Less impact on shipping	2
		(ii)	Mass per second = $A\rho v$ (or implied) (1) KE per second = 0.5 $A\rho v\ v^2$ (or good attempt at 0.5mv^2) (1) × 0.75 (1) Answer = 3.1 [GW] **(no ecf)** (1)	4
		(iii)	Because $\propto \lvert v^3 \rvert$(accept v^2, v^3 *etc.*) and we need $\lvert \overline{v^3} \rvert$ not $\lvert \bar{v} \rvert$ Wordy answers also valid e.g. 'if speed is 1.5 and 4.5 say, 4.5^2 will be far more significant than 1.5^2 or 'the power output for high speeds will be far greater than for low speeds increasing the mean power' etc.	1
			Question 12 total	**[20]**