m	= method mark
s	= substitution mark
/	= alternative and acceptable answers for the same marking point
;	= separates marking points
NOT	= answers which are not worthy of credit
( )	= words which are not essential to gain credit
____	= (underlining) key words which **must** be used to gain credit
ecf	= error carried forward
AW	= alternative wording
ora	= or reverse argument

Qn	Expected Answers	Marks	Additional Guidance
1(a)	A	1	
1(b)	D	1	
2	B	1	
3	C	1	
4(a)	Amplitude = 1.5 mm ✓	1	
4(b)	Frequency = 1/0.02 ✓ = 50 Hz ✓	2	If 20 s is used as period the answer will be 0.05 Hz. This is worth one mark.
5(a)	s = 500 x 3 x 10^8/2 ✓ = 7.5 x 10^{10} m	1	
5(b)	take two distance measurements at known time interval t ✓ average velocity = s/t ✓ (OR doppler effect ✓ arguments leading to v/c = $\Delta\lambda/2\lambda$ ✓)	2	The first mark is for statement of a measured time interval.
6	C = Q/V = 2.0 x 10^{-3} / 4.5 ✓ = 4.4 x 10^{-4} F ✓	2	μF ok
7	C = Q/V units of Cap = coulombs/volts ✓; 1V = 1 J/C✓ Leading to $C^2 J^{-1}$ OR Capacitance = Q^2 / 2E C^2 J^{-1}	2	
8(a)	$-\varepsilon/KT$ = - 3 x 10^{-20}/1.38 x 10^{-23} x 300 ✓ = -7.2 factor = $e^{-7.2}$ = 7.1 x 10^{-4} ✓	2	
8(b)	joules (J) OR eV ✓	1	
9	pV/T = constant ✓ (OR pV = nRT ✓) 1.0 x 10^5 x 5.0/298 = P x 10.8/257 ✓ P = 4 x 10^4 Pa ✓	3	
10 (a)(i)	2.0, 1.0 ✓ 0.5, 0.25 ✓ (x 10^{10})	2	
(a)(ii)	points ✓ line ✓	2	
(b)(i)	1/(4 x 10^{-12}) ✓ = 2.5 x 10^{11}	1	
(b)(ii)	(65/600) x 2.5 x 10^{11} = 2.7 x 10^{10} ✓	1	
(b)(iii)	from graph, 3000 ± 500 years (ecf from (ii) poss) ✓	1	
(c)(i)	relevant comment (eg no living organism, no calibration, **NO** carbon etc) ✓	1	
(c)(ii)	relevant comment (eg low count rate) ✓ no carbon-14	1	
(c)(iii)	too little difference (in count rate) ✓	1	

11 (a)	energy required = 4200 J ✓ no. of neutrons = 4200/3.5 x 10^{-16} ✓ = 1.2 x 10^{19}	2	Method **must** be clear
(b)	One interaction would cause only a small temp rise ✓ beyond resolution of instruments or heat loss considerations of calculation showing increase in T due to one particle or length of time to reach a measurable Temp. ✓	2	
(c)(i)	$\Delta\theta$ = Q/mc = 3.5 x 10^{-16} / 8.0 x 10^{-6} x 7.0 x 10^{-8} ✓ 6.3 = 10^{-4} K	1	
(c)(ii)	a particle will be trapped very rarely because of the small mass of detector OWTTE ✓ many detectors ✓	2	Both points needed
12 (a)	Δ p = 11.0 x (75 – 0.0 x 75) ✓ = 825 kg m s^{-1} ✓	2	
(b)	F = Δp/Δt = 825/0.14 = 5890 N ✓ 5890/750 = 7.8 times body weight ✓ can use F = ma. possible ecf from (a)	2	Correct calculation of F or acceleration ✓ Comparison with weight ✓
(c)	longer time / distance (ie deceleration less) ✓ therefore force less ✓ head will not bounce ✓	2	Any 2 from 3 for 2 marks
(d)(i)	graph shows that max force is lower ✓ statement to this effect ✓	2	
(d)(ii)	graph shows same area under line ✓ statement to this effect ✓	2	
13 (a)	Y and Z at same potential ✓ therefore energy required is independent of route in moving from X (OWTTE – sensible statements) ✓	2	
(b)(i)	change in energy = 2.8 x 10^6 ✓ x 28 x 10^{-3} ✓ 78000 J	2	
(b)(ii)	energy per molecule = 78000/(6.0 x 10^{23}) = 1.3 x 10^{-19} J ✓ 1.3 x 10^{-19} = ½ m v^2 = ½ 4.7 x 10^{-26} ✓ v^2 = m^2 s^{-2} ✓ v=2352 m s^{-1} (OR ½ mv^2 = mΔVg ✓ v^2=(2x2.8x10^6) ✓ v=(5.5 x 10^6)$^{1/2}$m s^{-1} ✓)	3	2352 or similar only 1 mark
(c)	n R T = 1/3 Nm c^2 ✓ for one mole n = 1, N = N_A so Nm = M_m ✓ RT = 1/3 M_m c^2 ✓	3	
(d)	$V_{r.m.s.}$ = (3 x 8.31 x 290 / 0.028)$^{1/2}$ ✓ = 510 m s^{-1} ✓ (2 or 3 SF)	2	
(e)	although mean speed lower than escape velocity ✓ molecules will gradually escape because distribution of speeds around mean / lunar temperature goes higher than 290K / Boltzmann Factor ✓	2	ecf incorrect mean speed> V_{esc} 1 mark
14 (a)	Correct test carried out ✓ supporting statement ✓	1 1	
(b)	Equating apparent brightness ✓ 1500/ (1 x 10^{21})^2 = 200/ s^2 ✓ s = 3.7 x 10^{20} m ✓	3	If distances are not squared 1 mark max

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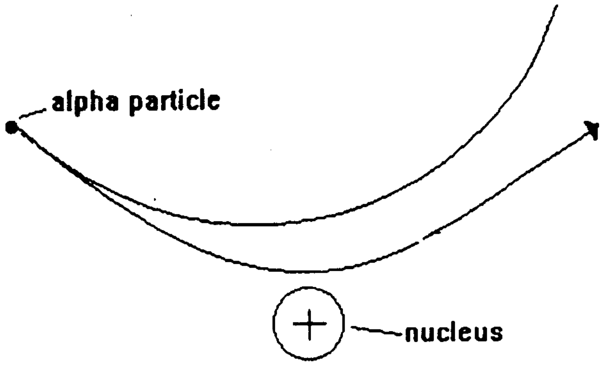
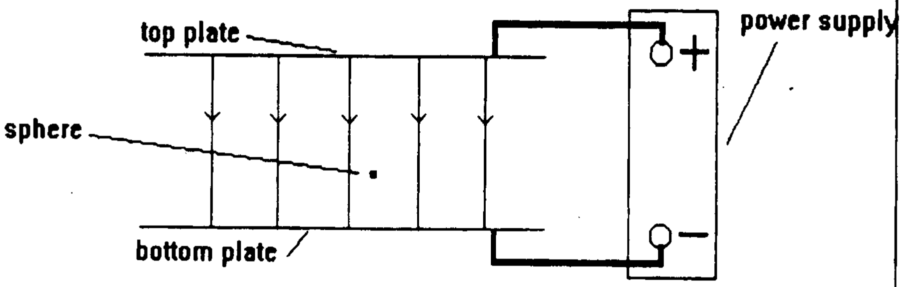
1(a) 1(b) 1(c)	Wb T V	1 1 1
2	$\frac{V_p}{V_s} = \frac{n_p}{n_s}$ 20	1 1
3	C	1
4	$A = \lambda N$ $A = 5.4\times10^{-5} \times 6.0\times10^{14} = 3.2\times10^{10}$ Bq	1 1
5	neutron	1
6	$E = mc^2$ $E = 1.2\times10^{6} \times 1.6\times10^{-19} = 1.92\times10^{-13}$ J ecf: $m = E/c^2 = 1.92\times10^{-13}/9\times10^{16} = 2.1\times10^{-30}$ kg	1 1 1

7	 further away from nucleus on closest approach more overall deflection	 1 1
8	total dose = 0.01 x 30 = 0.3Sv risk = 5 × 0.3 = 1.5%	1 1
9	B	1
10(a) 10(b)	DF correct units conversion ecf incorrect units: substitution and calculation $F = B/I$ $F = 500\times10^{-3} \times 420\times10^{-3} \times 8\times10^{-2}$ $F = 1.7\times10^{-2}$ N	1 1 1

11(a)	any of the following, maximum [2] • has a very high permeability • easily magnetised (owtte) • offers low reluctance path for flux • small flux in coil gives much larger flux in iron • iron atoms have a magnetic moment	2
11(b)	any of the following, maximum [3] • iron is a conductor • so emf induced as it moves through magnetic field of stator • (eddy) currents in solid iron • heat up the rotor • and provide a braking force on the rotor (wtte) • large resistance between iron sheets • so (eddy) currents are small • minimising waste heat and braking force	3
11(c)	any pair of the following suggestions and explanations decrease gap between rotor and stator to increase flux density / reduce permeability of magnetic circuit increase turns of wire on rotor to increase force / couple on rotor increase turns of wire on stator to increase magnetic field on rotor coils increase thickness of wire in coils to reduce resistance / increase conductance	4 9

12(a)(i)	$V = kQ/r$ $r = 7.4\times10^{-15} + 1.9\times10^{-15} = 9.3\times10^{-15}$ ecf incorrect r: $V = 9.0\times10^{9} \times 1.5\times10^{-17} / 9.3\times10^{-15} = 1.45\times10^{7}$ V	 1 1
12(a)(ii)	$E_p = qV$ ecf incorrect V: $E_p = 3.2\times10^{-19} \times 1.45\times10^{7} = 4.64\times10^{-12}$ J	1 1
12(b)(i)	$4.6\times10^{-12} / 1.6\times10^{-19} = 2.9\times10^{7}$ eV = 29 MeV	1
12(b)(ii)	any of the following reasons: strong force between hadrons (wtte) provides attraction of alpha particle to nucleus (charge distribution) nucleus is not spherical (wtte) because of electrostatic interaction with alpha particle model is too simple to give correct answer (wtte) quantum ideas should be used alpha particle loses energy as it leaves the <u>atom</u> (wtte) because of attraction to / collisions with electrons around nucleus	2 7

13(a)	 five vertical lines between plates equally spaced (by eye) with downwards arrow on each ACCEPT correct edge effects	1 1 1
13(b)	negative attraction to top plate / repulsion from bottom plate / force in field opposite to gravity / weight	1 1 1
13(c)	$n = Q/e = 4.8\times10^{-14} / 1.6\times10^{-19} = 300\,000\ (3.0\times10^{5})$	1
13(d)(i)	$F = qE$ $F = mg = 7.4\times10^{-9} \times 9.8 = 7.25\times10^{-8}$ N ecf incorrect F: $E = F/q = 7.25\times10^{-8} / 4.8\times10^{-14} = 1.5\times10^{6}$ V m^{-1}	1 1 1
13(d)(ii)	$E = V/d$ (eor) $V = Ed = 1.5\times10^{6} \times 1.0\times10^{-2} = 1.5\times10^{4}$ V	1 1
13(e)	any of the following, maximum [3] beta particles are electrons / charged particles which cause ionisation (of air) ions attracted to (charged) sphere transferring charge to it on contact	3
		15

14(a)	$I = 50\times10^{-12}$ A ecf incorrect I: $I = ne/t$ $n = It/e = 50\times10^{-12} / 1.6\times10^{-19} = 3.13\times10^{8}$	1 1
14(b)(i)	$E_0 = mc^2$ $E_0 = 9.11\times10^{-31} \times (3.0\times10^{8})^2$ $E_0 = 8.2\times10^{-14}$ **J** ecf incorrect E_0: $E_0 = 8.2\times10^{-14} / 1.6\times10^{-19} = 5.12\times10^{5}$ **eV** (<< 8.00×10^{8} eV)	1 1 1
14(b)(ii)	$E = 800\times10^{6} \times 1.6\times10^{-19} = 1.28\times10^{-10}$ **J** $p = E/c = 1.28\times10^{-10} / 3.0\times10^{8} = 4.27\times10^{-19}$ **Ns** ecf incorrect p: $\lambda = h/p = 6.63\times10^{-34} / 4.27\times10^{-19} = 1.6\times10^{-15}$ m (800×10^{6} **J** gives 2.5×10^{-34} m for [1])	 1 1
14(b)(iii)	proton can be modelled as a sphere / plate diffraction minimum (at 25°) EITHER $\lambda = b\sin\theta$ OR $\lambda \approx b$ proton diameter approximately 1.6×10^{-15} m (ecf)	1 1 1 1
14(c)	any of the following, maximum [4] proton contains quarks two **up** (+2/3e) and one **down** (-1/3e) held together by gluons which come in three colours which electrons can hit if they have short enough wavelength electron energy must be enough to create mesons which are made from quark pairs	4 **15**

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