GCE

Physics A

Advanced GCE **2825/04**

Nuclear and Particle Physics

Mark Scheme for June 2010

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Annesley
NOTTINGHAM
NG15 0DL

Telephone: 0870 770 6622
Facsimile: 01223 552610
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Abbreviations, annotations and conventions used in the Mark Scheme	
	/ = 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

Question	Expected Answers	Marks
1 (a)	repulsion / attraction correctly labelled on axis;	1 [1]
(b)(i)	correct point N - where strong line crosses distance axis;	1
	at N (resultant) force is zero; (1)	
	so neutrons must be at equilibrium; (1)	
	neutrons do not experience an electrostatic force (1)	
	strong force graph same for protons and neutrons (1)	
	any 1	1 [2]
	not just 'forces equal'	
(ii)	correct point P;	1
	at P electrostatic and strong forces balance (or AW);	1 [2]
(c)	crosses axis at P;	1
	crosses e/s force line at point vertically above N;	1
	generally correct shape, entirely above strong line;	1 [3]
(d)(i)	(F =) $Q^2/[4\pi\varepsilon_0(x)^2]$ allow (F =) $Q_1 Q_2/[4\pi\varepsilon_0(x)^2]$	1 [1]
(ii)	$25 = (1.6 \times 10^{-19})^2 / (4\pi \times 8.85 \times 10^{-12} [d]^2)$ subs.	1
	d = $3.0(3) \times 10^{-15}$ m allow 3×10^{-15} m	1 [2]
		11

2 (a)(i)	(neutrons) having energies comparable with thermal energies / slow moving / low kinetic energy / energy in range 6 - 100 eV / energy similar to (energy of) atoms of surroundings ;	1	[1]
(ii)	*either* thermal neutrons will be captured / absorbed (by U-235 nuclei) *or* higher energy neutrons do not get absorbed;	1	[1]
(b)(i)	3 points plotted correctly;	1	[1]
(ii)	curve through 3 points and heads down towards zero; line peaks between Kr and origin;	1 1	[2]
(iii)	BE per *nucleus* of $^{235}_{92}U$ = 7.60 x 235 (= 1786 MeV) BE of products = 8.0 x 145 + 8.4 x 88 both lines (= 1160 + 739 MeV) so energy released = (1160 + 739) - 1786 = 113 MeV omits multiplication by nucleon number to get 8.8 MeV gets 0,1,0 = 1	 1 1 1	[3]
(c)(i)	speed after collision = 0.93 x speed before collision so after 120 collisions, final speed = $(0.93)^{120}$ x speed before collision = 2.48×10^{3} m s^{-1}	1 1	[2]
(ii)	this is collision is head-on but other collisions may not be;	1	[1] **11**

3(a)	**energy-generating reaction**		
1	*either* equation $^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n$ (+ energy) (2)		
2	*or* $^{2}_{1}H$ fuses with $^{3}_{1}H$ (1)		
3	*and* detail e.g. why the deuterium-tritium reaction was chosen D-T reaction works at lower temperature D-T reaction releases more energy; (1) any 2	2	
	confinement		
4	by magnetic field(s) (<u>not</u> inertial or gravitational);	1	
5	detail: *either* what produces magnetic field - field coils/ current in plasma; *or* ions / nuclei spiral along magnetic field lines;	1	
	energy supply		
	methods of energy supply:		
6	pass (high) current through plasma; (1)		
7	radio frequency / RF heating by electromagnetic / radio waves (1)		
8	injection of high energy particles; (1)		
9	self-heating (of plasma) by He nuclei; (1) any 2	2	
10	appropriate detail		
11	plasma current causes (ohmic) heating effect (1)		
12	RF frequency approx. same as freq. rotation of ions/nuclei round *B* lines (1)		
13	neutral particles collide with plasma ions, transferring energy; (1)		
14	He nuclei collide with ions / nuclei, transferring energy; (1) any 1 (relevant) detail	1	
	high temperatures		
15	*either* (give nuclei enough energy) to overcome coulomb barrier/mutual repulsion;		
	or nuclei have more k.e. at higher temperature *or* AW;	1	[8]

(b)	**advantages of fusion**			
A	greater energy per unit mass of fuel (1)			
B	no / little radioactive waste (1)			
C	materials in JET structure will not become radioactive over long period (1)			
D	fuel / reactants (virtually) limitless (1)			
E	no chance of runaway / meltdown (1)	any 2	2	
	corresponding explanation			
F	greater change of binding energy / nucleon for fusion than fission (1)			
G	by-product is (stable) helium (1)			
H	tritium has short half-life (and is used anyway) (1)			
I	deuterium available from water (1)			
J	deuterium easily separated from normal hydrogen (1)			
K	lithium is a common / abundant material (1)			
L	only minute quantities of reactants (in vessel) (1)			
M	reaction ceases immediately (temperature falls) (1)			
	but <u>not</u> tritium is widely available	any 2	2	[4]
				12

4(a)(i)	energy = 50 + 10 x 40 = 450 keV	1	[1]
(ii)	$\frac{1}{2} m v^2 = V e$	1	
	$\frac{1}{2} \times 1.67 \times 10^{-27} v^2 = 450 \times 10^3 \times 1.6 \times 10^{-19}$	1	
	$v = 9.29 \times 10^6$ m s^{-1}	1	[3]
	omits 10^3 and gets 2.9×10^5 2/3 omits 1.6×10^{-19} and gets 2.3×10^{16} 1/3 omits 1.67×10^{-27} and gets 3.8×10^{-7} 1/3		
(b)(i)	4.3×10^8 m s^{-1} is greater than speed of light;	1	
	nothing can travel faster than light;	1	[2]
(ii)	protons accelerate so travel greater distance in same time (1)		
	positrons (much) less massive than protons; (1)		
	so same energy means greater speed (for positrons); (1)		
	positrons reach / cannot exceed speed of light; (1)		
	either electrodes of equal length means (positron) speeds are constant *or* electrodes of increasing length because (proton) speed increasing; (1) any 3	3	[3]
(c)	rest energy (1) + kinetic energy (1) = $2hf$	2	
	$2 \times (9.11 \times 10^{-31})(3 \times 10^8)^2 + 850 \times 10^3 \times 1.6 \times 10^{-19} = 2 \times 6.63 \times 10^{-34} f$	1	
	$f = 2.26 \times 10^{20}$ Hz	1	[4]
	omits rest energy and gets 1.03×10^{20} Hz 2/4		
	omits kinetic energy and gets 1.24×10^{20} Hz 2/4		
	any further error (-1), to zero		**13**

5(a)

	hadron	baryon	lepton
neutron	✓	✓	
proton	✓	✓	
electron			✓
neutrino			✓

4 lines correct 2/2: 3 lines correct 1/2: 2 or 1 line correct 0/2 | 2 | [2]

(b)(i)	10 -15 minutes - any value within range	1	[1]
(ii)	d -> u + e^- + ν (-bar) omits e^- or ν loses 1 each (u) (u) (d) (d)	2	[2]
(iii)	charge: $-^1/_3$ (+ $^2/_3$ $-^1/_3$) -> $^2/_3$ (+$^2/_3$ $-^1/_3$) -1 (+0)	1	
	baryon number: $^1/_3$ (+$^1/_3$ + $^1/_3$) -> $^1/_3$ (+$^1/_3$ + $^1/_3$) + 0 (+0)	1	[2]
	nuclear values: charge 0 = 1 - 1 (+ 0) *and* baryon no. 1 = 1 + 0 gets 1/2		
(c)(i)	arrowed line plus 'resultant' / p_r label	1	[1]
(ii)	anti- (1) neutrino (1) is emitted		
	carries away some momentum (1)		
	shows labelled neutrino momentum vector (1) any 3	3	[3]
			11

6(a)	*either* (produced) in a nuclear (fission) reactor *or* bombard (natural) uranium with neutrons (1) uranium 238 (nucleus) absorbs / captures a neutron (1) product (uranium 239) undergoes β-decay (1) any 2	2	[2]
(b)(i)	alpha (particle)	1	[1]
(ii)	${}^{239}_{94}Pu \rightarrow {}^{4}_{2}He + {}^{235}_{92}U$ each correct product nucleus gets (1)	2	[2]
(c)(i)	24000 years / 7.57×10^{11} s	1	[1]
(ii)	*either* $\lambda = 0.693/24000$ *or* $N = N_0 (½)^{9000/24000}$ equation(s) $= 2.89 \times 10^{-5}\ y^{-1}$ $= 5 \times 10^{20} (½)^{0.375}$ subs. $N = N_0 e^{-\lambda t}$ $(= 3.85 \times 10^{20})$ $= 5 \times 10^{20} \exp(-2.89 \times 10^{-5} \times 9000)$ $(= 3.85 \times 10^{20})$	1 1	[2]
(d)(i)	ratio = 4.0	1	[1]
(ii)	original ratio $N_{240}/N_{239} = 40 \times 10^{20}/(5 \times 10^{20}) = 8$ (ratio after 9000 years = 4) equal numbers after another 9000 + 9000 = 18000 years so total time = 9000 + 18000 = 27000 years	1 1 1	[3] **12**

7

(a) <u>mgΔh</u> / gravitational potential energy / of upper carriage decreases /is converted
into...B1
gravitational energy of lower carriage...B1
and E_k of carriage(s)...B1
allow for the third mark ref. to heat in brakes / work done against friction

(b) T_1 = mg sinθ
T_1 = 10000 x 9.81 x 150 / 260 or 10000 x 9.81 x sin 35...................................B1
T_1 = 5.7 x 10^4 N or 5.66, 5.63, 5.62 x 10^4 N B1

(c)(i) m=F/a , 8.7 x 10^3 / 1.5 ....C1
= 5.8 x 10^3 kg...C1
m = 10000 – 5800 = 4200 kg C1
V = m / □
V = 4.2 x 10^3 / 1000 = 4.2 m^3 ....A1

(ii) t = (v-u) / a
t = 6.6 / 1.5 ....C1
t = 4.4 s A1

(iii) s = ut + 0.5 x a x t^2
= 0 + 0.5 x 1.5 x 4.4^2 ....C1
= 14.5 m or 15 m...A1

(d) (i) 3800 x 9.81 x 150 = change in gpe...B1
= 5.6 or 5.59 MJ B1

(ii) E = m c ΔT...C1

5.5 x 10^6 = 6 x 25 x 470 x ΔT C1
ΔT = 78 K allow 79 K if 5.6 MJ used A1

(iii) some <u>thermal</u> energy is lost <u>to the surroundings</u> / brakes lose heat.........................B1
sensible explanation, ...B1
e.g. mechanism e.g. radiation, by which energy is transferred or
to where the thermal energy might also be transferred e.g. cable or pulley

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1 Hills Road
Cambridge
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