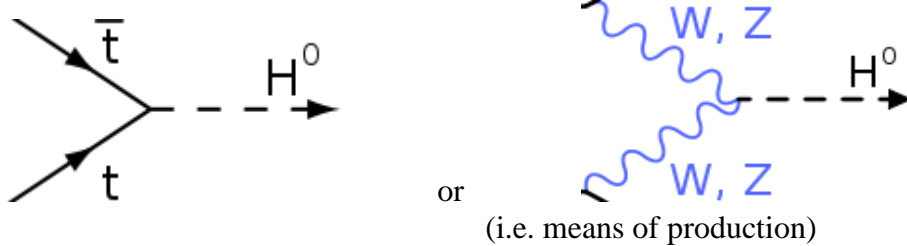


Question			Marking details	Marks Available
B6	(a)		See next page for details 3 × (1) points for Higg's Boson or 3 × (1) points for Dark energy / dark matter or 3 × (1) points for Grand Unified Theories	3
	(b)	(i)	$\frac{1}{2}mv^2 = 50 \text{ MeV}$ (1) $v = \sqrt{\frac{2 \times 50 \times 10^6 \times 1.6 \times 10^{-19}}{1.67 \times 10^{-27}}} = 9.8 \times 10^7 \text{ m s}^{-1}$ (1) [ans]	2
		(ii)	$v = 3.7 \times 10^{10} \text{ ms}^{-1}$ ✓	
		(iii)	2 <sup>nd</sup> calculation not valid [or 1 <sup>st</sup> 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"> <li>• Gravitational pull small (only 2 protons) ✓</li> <li>• Tiny probability of collision (with small object) ✓</li> <li>• Shrinks in size ✓ due to Hawking radiation ✓</li> <li>• etc. [any sensible answer]</li> </ul>	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
				<b>20</b>

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  $\text{GeV}/c^2$  [ $100\text{--}300 \text{ GeV}/c^2$  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