Questions on Particle Physics MS

1. Charge on strange quark = – 1/3 (1)
   Conservation law:
   Charge – (–1) + (+1) → (0) + X by charge conservation (1)
   X is neutral (1)
   Particle X is a meson (1)
   Baryon number conservation (0) + (+1) → (+1) + (0) (1)
   OR discussion in terms of total number of q + \( \bar{q} \) = 5 OR \( \Sigma q - \bar{q} = 3 \)
   Composition of X is s \( \bar{d} \) [0/3 if not q\( \bar{q} \)] (1)
   Justify S quark:
   This is not a weak interaction/only a weak interaction can change quark type/this is a strong interaction/strangeness is conserved/ quark flavour cannot change (1)
   Justify \( \bar{d} \) quark:
   X neutral; \( s - 1/3; \bar{d} + 1/3 \). [e.e.f. if \( s = -1/3 \) in first line.]
   For the third mark accept any q\( \bar{q} \) pair that creates a meson
   of the charge deduced for X above. (1)
   [The justification for both q and \( \bar{q} \) can be done also by tracking individual quarks]

2. Gluon
   Weak
   Electromagnetic
   Gravitational
   Gravitational circled

3. \( \Omega^- \) is a baryon [no mark]
   p is a baryon/need to conserve baryon number
   Strangeness – 3 needs three quarks (2)
   p is uud
   \( \Omega^- \) is sss
   All Ks quark-antiquark pairs
   \( K^- \) is \( \bar{u}s \) \( K^+ \) is \( u\bar{s} \) \( K^0 \) is \( d\bar{s} \) [all right] (4)

4. (a) Lots of energy needed to produce the extra mass (2)
   (b) Conservation laws:
      charge
      lepton number
      baryon number (3)
   (c) They annihilate one another giving rise to \( \gamma \) ray/\( \gamma \) photon
Energy of $\gamma$ ray
= $2(0.00055)$ (930 MeV)
= 1.0/1.02/1.023 MeV

5. How properties of particles and antiparticles compare

Same mass/properties, opposite charge (1)

Energy

$E = mc^2 = 1.67 \times 10^{-27} \times (3 \times 10^8)^2$ J [m or c subbed correctly] (1)
= $1.503 \times 10^{-10}$ J [u.e. if comparison made here]
= $1.503 \times 10^{-10}/10^9 \times 1.6 \times 10^{-19}$ GeV (1)
= 0.94 GeV (1)

[jump to “$\approx 1$ GeV” omitting last line scores (1)(1)x]

Survival of anti-atom

Anti–proton meets proton OR positron meets electron OR (anti-atom) meets atom (1)
(leads to) annihilation (1)

Table

<table>
<thead>
<tr>
<th></th>
<th>Meson</th>
<th>Baryon</th>
<th>Lepton</th>
</tr>
</thead>
<tbody>
<tr>
<td>proton</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>antiproton</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>electron</td>
<td>✓</td>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>positron</td>
<td>✓</td>
<td></td>
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</tbody>
</table>

Quark structure

Antiproton: $2 \times -2/3$ (anti u) + $1 \times +1/3$ (anti d) (1)
= $-1$ (e not needed) (1)

[3 $\times$ d $\Rightarrow$ $-1$ scores $\ast\ast$]

6. Explanation

energy gained by electron accelerated through 1 V/W = QV (1)

$W = 1.6 \times 10^{-19}$ C $\times$ 1 V = $1.6 \times 10^{-19}$ J (1)

Unit of mass

$\Delta E = c^2 \Delta m$ so $\Delta m = \Delta E/c^2$ (1)

GeV is energy $\Rightarrow$ GeV/c$^2$ is mass (1)

Mass of Higgs boson

$m = 115 \times [10^9] \times 1.6 \times 10^{-19}/(3 \times 10^8)^2$ (1)
= $2.04 \times 10^{-25}$ kg (1)

Antiparticle

Same mass and opposite charge (1)

[Accept Particle and its antiparticle annihilate (→ photons)]
Explanation of need for a magnetic field and why it can be small
Force deflects particles/force produces circular motion (1)
Force is perpendicular to motion/force provides centripetal force (1)
r is large or curvature is small/gentle (1)
reference to $B = p/rQ$ to show why small $B$ is needed (1)

7. “The standard model”
Everyday matter/atoms: p,n, e [maybe in two places] (1)
Protons / neutrons are made from quarks (1)
p: uud and n:udd (1)
show charge of either [p: u(+2/3) u(+2/3) d(–1/3) ⇒ + 1 OR n: u
(+2/3) d(–1/3) d(–1/3) ⇒ 0] (1)
All baryons have three quarks (1)

8. Description of production of a beam of electrons
Hot filament / cathode / plate (1)
Thermionic emission (1)
Anode/other electrode positive wrt source (can be dia) (1)
Collimator/hole/focusing detail (1)
Control of beam (e.g. with $E$ or $B$) (1)
Vacuum (1)
Cyclotron:
Magnetic field → circles (1)
Acceleration across gap (1)
Repeated accelerations / details of voltage variation (1)
LINAC:
At least 2 sections connected to a.c. (1)
Details of variation of voltage with time / synchronisation (1)
Acceleration across each gap / attraction to + section (1)
Detail of lengths of tubes (1)
High energy needed to break particles into constituents and/or create new particles (1)
High energy linked to short wavelength, e.g. $\lambda = h/p$ (1)
Short wavelength comparable to dimensions of structures / mention of diffraction (1)
Electrons easily detected because charged (1)
High energy needed to get close to nuclei (1)