CHAPTER 17

Applications of nuclear physics and the standard model of matter

Answers to revision questions

1. (a) The primary coolant is usually a material that is very efficient in carrying heat away from the nuclear reactor core to the heat exchanger; some suitable materials include molten sodium and molten sodium chloride. The primary coolant also forms a closed loop, and thus does not mix with the steam. This design minimises the chance of the nuclear waste leaking out into the external environment.

   (b) A heat exchanger is where the heated primary coolant circulates out of the nuclear reactor core to heat up water to make steam, which is in turn used to operate the generator to produce electricity.

   (c) The secondary coolant cools the used steam to warm water, which is then re-circulated back into the heat exchanger so that more steam is produced. The cooling pond is used to prevent thermal pollution by avoiding discharging warm water directly into the environment.

   (d) From nuclear energy to heat energy, then to electrical energy.

2. The nuclear reactor at Lucas Heights acts as a rich source of neutrons. These neutrons can be used to cause transmutation reactions via neutron bombardment and capturing. They can also be used to probe the interior structure of matter.

3. See Chapter 17.

4. (a) See Chapter 17.

   (b) For detail, see Chapter 17. Neutrons are good for probing organic matter because they interact with the nucleus of the atoms rather than their electrons, which organic matter lacks. The neutral charge of the neutrons is the reason for them to not be affected by the magnetic field when they are used to probe objects with magnetic properties.

5. (a) The trigger was concern from refugees from Nazi Germany about the possibility that Germany was utilising the nuclear fission technology to develop nuclear weapons. In 1939, Leo Szilard, Edward Teller and Eugene Wigner convinced Albert Einstein to write a letter to the American President Franklin D. Roosevelt to advocate the development of atomic bombs.

   (b) For detail, see Chapter 17. The two methods were gaseous diffusion separation and electromagnetic separation.

   (c) The project was carried out under the pressure of the war. The speed for the project to progress outweighed all other aspects. One implication was that the atomic bombs were able to be developed much faster than if the fuel preparation and weapon design were carried out separately. However, it also meant that a huge risk was taken, because if one aspect did not work, then the entire project would fail.

   (d) See Chapter 17.

6. (a) See Chapter 17.

(b) Yes. Particle accelerators work for all charged particles.

(c)
$$F_B = F_c$$
$$qvB = \frac{mv^2}{r}$$
$$v = \frac{qBr}{m}$$
$$v = \frac{1.602 \times 10^{-19} \times 0.005 \times (100)}{1.673 \times 10^{-27}}$$
$$v = 4.79 \times 10^{7}\ \text{m s}^{-1}$$

7. (a) Quarks are particles with charges that are sub-multiples of electron charges. They are fundamental particles.

(b) Up, down, charm, strange, top and bottom; anti-up, anti-down, anti-charm, anti-strange, anti-top and anti-bottom.

(c) Leptons are another type of fundamental particle that have either very little or no mass.

(d) Electron, electron-neutrino, muon, muon-neutrino, tau and tau-neutrino; anti-electron (positron), anti-electron-neutrino, anti-muon, anti-muon-neutrino, anti-tau and anti-tau-neutrino.

(e) See Chapter 17.