CHAPTER 3

Gravity, orbits and space travel

Answers to revision questions

1. See Chapter 1.

2. (a) See Chapter 3.

(b) In the context of the slingshot effect, the law of conservation of angular momentum refers to the fact that when a probe undergoes the slingshot effect it will gain angular momentum in one direction, and at the same time the planet will lose an equal amount of angular momentum. In simple terms, angular momentum is the term used to describe the momentum while something is carving an arc of a circle (angular momentum = mvr). The momentum gained by the probe results in an increase in its velocity and the loss of momentum by the planet results in a decrease in its velocity. However, due to the fact that the mass of the planet is much greater than the mass of the probe, the velocity lost by the planet is much smaller compared to that of the probe.

3. (a) Using Kepler's third law:

$$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$

Known quantities:

$$T = 365 \text{ days} = 365 \times 24 \times 3600 = 31536000 \text{ s}$$
$$M = 1.99 \times 10^{30} \text{ kg}$$
$$G = 6.67 \times 10^{-11}$$
$$\frac{r^3}{(31536000)^2} = \frac{6.67 \times 10^{-11} \times 1.99 \times 10^{30}}{4\pi^2}$$
$$r = 1.495 \times 10^{11} \text{m}$$

$\therefore$ The distance $= 1.495 \times 10^{11} - 696000000 - 6378000 = 1.488 \times 10^{11}$ m

(b) Using the universal gravitational equation:

$$\boldsymbol{F} = \frac{Gm_1m_2}{\boldsymbol{d}^2}$$

Known quantities:

$$G = 6.67 \times 10^{-11}$$
$$m_1 = 6.0 \times 10^{24} \text{kg}$$
$$m_2 = 1.99 \times 10^{30} \text{kg}$$
$$\boldsymbol{d} = 1.495 \times 10^{11} \text{m}$$
$$\boldsymbol{F} = \frac{6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times 1.99 \times 10^{30}}{(1.495 \times 10^{11})^2}$$
$$= 3.56 \times 10^{22} \text{N}$$