Answers to Coursebook questions – Chapter 1.1

1 Taking the diameter of a proton to be of the order 10^{-15} m we find

$$\frac{10^{-15}}{3\times10^{8}} = 0.3 \times 10^{-23} = 3 \times 10^{-24} \approx 10^{-24} \text{ s.}$$

2 The mass of the earth is about 6×10^{24} kg and the mass of a hydrogen atom is about 2×10^{-27} kg, so we need $\frac{6\times10^{24}}{2\times10^{-27}} = 3 \times 10^{51} \approx 10^{51}$.

3 From the table on page 5 in *Physics for the IB Diploma*: $\frac{10^{17}}{10^{-43}} = 10^{60}$.

4 $\frac{6.380\times10^{6}}{10^{-35}} = 6.380 \times 10^{41} \approx 10^{42}$

5 A heartbeat lasts about 1 s, so $\frac{75\times365\times24\times3600}{1} = 2.4 \times 10^{9} \approx 10^{9}$.

6 Using the table on page 4 in *Physics for the IB Diploma*: $\frac{10^{41}}{10^{30}} = 10^{11}$.

7 From the table on page 4 in *Physics for the IB Diploma*: $\frac{10^{21}}{1.5\times10^{11}} \approx 10^{10}$.

8 There are 300 g of water in the glass and hence $\frac{300}{18} = 17$ moles of water.

The number of molecules is $17 \times 6.0 \times 10^{23} \approx 10^{25}$.

9 A body of 60 kg mass is made up of 6.0×10^{4} g water.

$\frac{6.0\times10^{4}}{18} = 3.3 \times 10^{3}$ moles.

The number of molecules is $3.3 \times 10^{3} \times 6.0 \times 10^{23} \approx 10^{27}$.

10 Taking a mass of 10^{53} kg for the universe and 3.4×10^{-27} kg ($2 \times 1.7 \times 10^{-27}$ kg) for a hydrogen molecule, we get $\frac{10^{53}}{3.4\times10^{-27}} = 2.9 \times 10^{79} \approx 10^{79}$.

11 The mass of a proton is about 1.7×10^{-27} kg and the radius is about 10^{-15} m, so the density is

$$\frac{1.7\times10^{-27}}{\frac{4\pi}{3}\times(10^{-15})^{3}} \approx \frac{1.7\times10^{-27}}{4.2\times10^{-45}} = 4.1 \times 10^{17} \text{ kg m}^{-3}$$

12 The distance to be travelled is 1.5×10^{11} m and so the time of travel is $\frac{1.5 \times 10^{11}}{3 \times 10^{8}} = 0.5 \times 10^{3} = 500$ s.

$\frac{500}{60} = 8.3$ min.

13 Assuming a mass of 4000 kg for the elephant and 0.150 kg for the apples,

$\frac{4000}{0.15} = 2.7 \times 10^{4}$ apples.

14 Assume a 200 m^2 house with 100 m^2 on each storey (10 × 10 m). Take the height of a floor to be 3 m. Divide each floor into four rooms. The wall area is thus:

10 m (length of wall) × 3 m (height of wall) × 6 (walls per storey) × 2 (number of storeys) = 360 m^2

Subtract about 80 m^2 for doors and windows to give 280 m^2 wall area.

Assume a brick size of 20 cm × 5 cm = 10^{-2} m^2 area.

Number of bricks = $\frac{280}{10^{-2}} = 2.8 \times 10^{4}$.

No corridors etc. have been taken into account.

15 **a** 5.356×10^{-9} m

b 1.2×10^{-15} m

c 3.4×10^{-3} m

16 **a** 4.834×10^{6} J

b 2.23×10^{-12} J

c 3.64×10^{11} J

17 **a** 4.76×10^{-9} s

b 2.4×10^{-2} s

c 8.5×10^{-18} s

18 $v = \frac{15.68 \times 10^{-3}}{87.50 \times 10^{-9}} = 1.792 \times 10^{5}$ m s^{-1}.

19 **a** $E = 2.5 \times 1.6 \times 10^{-19} = 4.0 \times 10^{-19}$ J.

b $E = \dfrac{8.6 \times 10^{-18}}{1.6 \times 10^{-19}} = 54$ eV.

20 $V = (2.8 \times 10^{-2})^3 = 2.2 \times 10^{-5}$ m^3.

21 $a = (588 \times 10^{-9})^{1/3} = 8.38 \times 10^{-3}$ m.

22 $g = 9.8 \dfrac{\text{m}}{\text{s}^2} = 9.8 \dfrac{100 \times \dfrac{1}{2.54} \times \dfrac{1}{12} \text{ft}}{\text{s}^2} = 32 \text{ ft s}^{-2}$.

23 $V = 125 \times 2.96 \times 10^{-5}$ m^3 and so

$a = V^{1/3} = (125 \times 2.96 \times 10^{-5})^{1/3} = 0.155 \text{ m} = 15.5 \text{ cm}$.

$\dfrac{15.5}{2.54} = 6.09$ in.

24 $P = \dfrac{224 \times 10^3}{746} = 300$ hp.

25 **a** 200 g

b 2 kg

c 400 g

26 The distance to be travelled is 10^{21} m, so the time of travel is $\dfrac{10^{21}}{3 \times 10^8} = 3 \times 10^{12}$ s.

$\dfrac{3 \times 10^{12}}{365 \times 24 \times 3600} = 10^5$ yr.

27 The mass is of the order 10^{30} kg and the radius of order 10^6 m, so the density is of order

$\dfrac{10^{30}}{\dfrac{4\pi}{3}(10^7)^3} = 2 \times 10^8 \text{ kg m}^{-3}$

28 In SI units the acceleration is $\dfrac{100 \times \dfrac{10^3}{3600}}{4} = 7 \text{ m s}^{-2}$, which is about 0.7 g.

29 Assuming a mass of 70 kg made out of water, we have 7×10^4 g of water in the body and hence $\frac{7 \times 10^4}{18} = 4 \times 10^3$ moles of water.

Number of molecules = $4 \times 10^3 \times 6 \times 10^{23} = 2 \times 10^{27}$.

Each molecule contains 2 electrons from hydrogen and 8 from oxygen for a total of

$10 \times 2 \times 10^{27} = 2 \times 10^{28}$ electrons.

30 Assuming masses of 50 kg we have

$$F = \frac{GM_1M_2}{r^2} = \frac{6.7 \times 10^{-11} \times 50^2}{1^2} = 1.7 \times 10^{-7}\ \text{N} \approx 10^{-7}\ \text{N}.$$

31 The ratio is

$$\frac{F_e}{F_g} = \frac{ke^2}{Gm^2} = \frac{9 \times 10^9 \times (1.6 \times 10^{-19})^2}{6.7 \times 10^{-11} \times (9.1 \times 10^{-31})^2} = 4 \times 10^{42}.$$

32 $f = cm^x k^y$.

The unit of m is kg, i.e. M.

The units of k are $\frac{\text{N}}{\text{m}} = \frac{\text{kg m s}^{-2}}{\text{m}} = \text{kg s}^{-2} = \text{M T}^{-2}$.

Entering these units into the equation gives $\text{T}^{-1} = \text{M}^x(\text{M T}^{-2})^y = \text{M}^{x+y}\text{T}^{-2y}$.

From this we deduce that

$x + y = 0$.

$-2y = -1$, therefore $y = \frac{1}{2}$ and $x = -\frac{1}{2}$

Thus, $f = c\sqrt{\frac{k}{m}}$.

33 **a** $\frac{243}{43} \approx \frac{250}{50} = 5$

b $2.80 \times 1.90 \approx 3 \times 2 = 6$

c $\frac{312 \times 480}{160} \approx \frac{3 \times 10^2 \times 5 \times 10^2}{1.5 \times 10^2} = \frac{15}{1.5} \times 10^2 = 10^3$

d $\frac{8.99 \times 10^9 \times 7 \times 10^{-6} \times 7 \times 10^{-6}}{(8 \times 10^2)^2} \approx \frac{10 \times 10^9 \times 5 \times 10^{-6} \times 5 \times 10^{-6}}{64 \times 10^4} = \frac{25 \times 10^{-2}}{64 \times 10^4} \times 3 \times 10^{-7}$

e $\frac{6.6 \times 10^{-11} \times 6 \times 10^{24}}{(6.4 \times 10^6)^2} \approx \frac{7 \times 10^{-11} \times 6 \times 10^{24}}{(6 \times 10^6)^2} \approx \frac{40 \times 10^{13}}{36 \times 10^{12}} \approx 10$