Solutions problems chapter 2 and 3

- Chapter 2: 2.5, 2.8, 2.12, 2.27, 2.28, 2.37

2.5: What is the weight of an object with a mass of 150 kg on a planet where g = 4.1 m/s^2?

The definition of the weight is given by equation 2.5 on p. 22 of Chapter 2:

$$F_w = mg$$

$$F_w = 150 \times 4.1 = \mathbf{615\ N}$$

2.8: A 5 kg box sliding across the floor with an initial velocity of 8 m/s is decelerated by friction to 3 m/s over 5 s. What is the force of friction acting on it?

The definition of the acceleration is in the equation 2.13, p. 28.

$$a = \frac{\Delta V}{\Delta t} = \frac{3-8}{5} = -1\ m/s^2$$

The frictional is the only force acting on the box. We can use equation 2.5:

$$F_w = mg = 5 \times (-1) = -5\ N$$

The force is in opposite direction of the sliding of the box, that is why we obtain a negative value, but we can say that the force decelerating the box is **5 N**.

2.12: Acceleration due to gravity at Earth's surface is g = 9.80665 m/s^2 and decreases by approximately 3.3×10^{-6} m/s^2 for each metre of height above the ground. What is the potential energy of a 100 kg mass raised to an altitude of 1000 m: (a) assuming constant g, (b) accounting for the decrease in g with height?

(a) Assuming the g is constant we have only one variable: the height. We can use equation 2.11, on p. 25.

$$\Delta PE = mg\Delta z = 100 \times 9.80665 \times 1000 = \mathbf{980\ 665\ J}$$

(b) When taking into account that g decreases with height, we have 2 variables, therefore, we have to use equation 2.10 from p. 25.

$$d(PE) = d(mgz)$$

$$\Delta PE = m\int_0^h g dz = 100 \times \int_0^h (9.80665 - 3.3 \times 10^{-6} \times \mathrm{z})\mathrm{dz}$$

$$\Delta \mathrm{PE} = 100 \times (9.80665\ \mathrm{h} - 1.65 \times 10^{-6}\ \mathrm{h}^2) = \mathbf{980550\ \boldsymbol{J}}$$

2.27: Tank A has a volume of 0.5 m3 and contains air with density 1.2 kg / m3 while tank B has a volume of 0.8 m3 and contains air with density 0.9 kg / m3. The two tanks are connected to each other and their contents mixed. What is the final air density in the tanks?

First, we have to calculate the mass of air in each tank:

$$m_A = \rho_A V_A = 1.2\ \times 0.5 = 0.6\ kg$$

$$m_B = \rho_B V_B = 0.9\ \times 0.8 = 0.72\ kg$$

The total mass of air, combining the two tanks, is:

$$m_t = m_A + m_B = 0.6 + 0.72 = 1.32\ kg$$

The total volume is:

$$V_t = V_A + V_B = 0.5 + 0.8 = 1.3\ m^3$$

The density of air in the combined tank is then:

$$\rho = \frac{m_t}{V_t} = \frac{1.32}{1.3} = \mathbf{1.02\ kg/m^3}$$

2.28: A 0.5 m3 container is filled with a mixture of 10% by volume ethanol and 90% by volume water at 25 °C. Find the weight of the liquid.

The masses of each liquid in the container are:

$$m_{water} = \rho_{water} V \times 0.9 = 1000\ \times 0.5\ \times 0.9 = 450\ kg$$

$$m_{ethanol} = \rho_{ethanol} V \times 0.1 = 783\ \times 0.5\ \times 0.1 = 39.15\ kg$$

The total mass is :

$$m_t = m_{water} + m_{ethanol} = 450 + 39.15 = 489.15\ kg$$

$$F_w = m_t g = 489.15\ \times 9.81 = \mathbf{4\ 798.6\ N}$$

2.37: The inside of a house is at 20 °C while the exterior air is at –5 °C. The temperature of the walls of the house does not change with time. Are the walls at equilibrium?

On pages 35 and 36, you can find the definition of steady state and equilibrium.

As the temperatures inside the house and outside are different and the system is not isolated, there is heat transfer from the inside to the outside of the house at a constant rate. As the walls keep interacting with the inside and outside of the house, the walls are in **steady state but do not reach equilibrium** (it is illustrated on Figure 2.13 (b) on p. 35 and Figure 2.14 p. 36). Heat must be constantly added to maintain the temperature difference.

- Chapter 3: 3.3, 3.7 , 3.9, 3.15, 3.20, 3.27, 3.39

3.3: If 5 g of methane is burned in the chemical reaction $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$, what mass of oxygen is consumed and what are the masses of the combustion products?

On p. 52, you can find the relation between mass, moles and molar mass:

$$m = N \times M$$

As we have the mass of methane we can calculate the mole of methane:

$$N_{CH_4} = \frac{m_{CH_4}}{M_{CH_4}} = \frac{5}{16} = 0.31\ gmol$$

From the equation we know that for one mole of methane, two moles of oxygen was used and one mole of carbon dioxyde was produced and two moles of water.

$$N_{O_2} = 2 \times N_{CH_4} = 0.62\ gmol$$

$$N_{CO_2} = N_{CH_4} = 0.31\ gmol$$

$$N_{H_2O} = 2 \times N_{CH_4} = 0.62\ gmol$$

$$m_{O_2} = N_{O_2} \times M_{O_2} = \mathbf{19.9\ g}$$

$$m_{CO_2} = N_{CO_2} \times M_{CO_2} = \mathbf{13.7\ g}$$

$$m_{H_2O} = N_{H_2O} \times M_{H_2O} = \mathbf{11.2\ g}$$

3.7: A cubical container, 10 cm long along each edge, is filled with a gas at a pressure of 350 kPa. Determine the force that the gas exerts on each wall of the container.

First, we calculate the surface area of each wall of the container:

$$A = 0.1^2 = 0.01\ m^2$$

Then, to find the force that the gas exerts on each wall of the container we use the formula 3.2 on p. 54.

$$P = \frac{F}{A}$$

$$F = P \times A = 350 \times 10^3 \times 0.01 = \mathbf{3500\ N}$$

3.9: A cylindrical drum, 1 m high, is filled with water (ρ = 1000 kg/m^3) to a depth of 0.2 m. The rest of the drum is then filled with oil (ρ = 850 kg/m^3). What is the gauge pressure on the bottom of the drum?

The gauge pressure is in this case the sum of the pressure exerted by water and oil:

$$P = \rho_{water} g h_{water} + \rho_{oil} g h_{oil} = 9.81 \times (1000 \times 0.2 + 850 \times 0.8) = \mathbf{8632.8\ Pa}$$

3.15: What is the volume in liters of 1 gmol of an ideal gas at standard temperature and pressure, defined as 0 °C and 101.325 kPa?

The ideal gas equation has to be used, it can be found on p. 58, equation 3.10:

$$V = \frac{NRT}{P} = \frac{10^{-3} \times 8.314 \times 10^3 \times 273.15}{101325} = 0.0224\, m^3 = \mathbf{22.4\ L}$$

3.20: An air bubble, 1 mm in diameter, is released at the bottom of a lake 20 m deep where the temperature is 10 °C. It rises to the surface of the lake where the temperature is 25 °C. What will the radius of the bubble be at the surface?

The pressure at the bottom of the lake is calculated as follow:

$$P_{20} = P_{atm} + \rho_{water} g h = 297.53\ kPa$$

Pressure at the top of the lake is the atmospheric pressure: P_0 = 101.325 kPa
The air bubble is supposed to be an ideal gas with constant mass:

$$\frac{P_{20} V_{20}}{T_{20}} = \frac{P_0 V_0}{T_0}$$

$$\frac{V_0}{V_{20}} = \frac{P_{20} T_0}{P_0 T_{20}} = 3.09$$

The volume of a sphere is:

$$V = \frac{4}{3} \pi r^3$$

Therefore:

$$r_0 = \sqrt[3]{3.09} \times r_{20} = \mathbf{0.73\ mm}$$

3.27: An evacuated 20 L container is filled with gas until the pressure inside reaches 800 kPa at 25 °C. By weighing the container before and after filling it is determined that its mass increased by 26 g. What gas was it filled with?

$$M = \frac{mRT}{PV} = \frac{26 \times 10^{-3} \times 8314 \times 298.15}{800 \times 10^3 \times 20 \times 10^{-3}} = \mathbf{4.03\ kg/kmol}$$

3.39: Five kilograms of air, initially at 0 °C, are heated until the temperature reaches 50 °C. The internal energy increases by 180 kJ during this process. Find the specific heat of air.

The relation between internal energy and specific heat is given by equation 3.30, p. 65.

$$U_2 - U_1 = mc(T_2 - T_1)$$

$$c = \frac{U_2 - U_1}{m(T_2 - T_1)} = \frac{180\ kJ}{5\ kg\ (50\ C - 0\ C)} = \mathbf{0.72}\ \frac{\boldsymbol{kJ}}{\boldsymbol{kg\ C}}$$