Homework 1 – Model solution

a) FC power density is $u_{vol,FC} = 1$ kW/L or $u_{grav,FC} = 500$ W/kg, fuel tank energy density $u_{vol,tank} = 4$ MJ/L or $u_{grav,tank} = 8$MJ/kg. The vehicle needs to be able to run for t = 300miles/60mph = 5 h = 18 000 s. The power requirements for the vehicle are P = 30 kW and it's conversion efficiency is $\eta = 0.4$.

The mass and volume requirements for the tank and fuel cell can be calculated separately.

The required FC volume can be calculated from equation

$$V_{FC} = \frac{P}{u_{vol,FC}} = \frac{30 \cdot 10^3 W}{1 \cdot 10^3 W/L} = 30L \tag{1}$$

and the mass from equation

$$m_{FC} = \frac{P}{u_{grav,FC}} = \frac{30 \cdot 10^3 W}{500W/kg} = 60kg. \tag{2}$$

For the fuel tank the equivalent equation for volume is

$$V_{tank} = \frac{P*t}{\eta \cdot u_{vol,tank}} = \frac{30 \cdot 10^3 W \cdot 18000s}{0.4 \cdot 4 \cdot 10^6 J/L} = 337.5L \tag{3}$$

and for the mass

$$m_{tank} = \frac{P*t}{\eta \cdot u_{grav,tank}} = \frac{30 \cdot 10^3 W \cdot 18000s}{0.4 \cdot 8 \cdot 10^6 J/kg} = 168.75kg. \tag{4}$$

Therefore, the combined volume for the fuel cell is V≈370 liters and the mass m≈230 kilograms.

b) The volume of the cylindrical metal hydride container is

$$V = \pi r^2 h = \pi \cdot (4.5cm)^2 \cdot 42.5cm \approx 2700cm^3 = 2.7L. \tag{5}$$

1 mole of gas in standard conditions takes up a volume of 22.4 liters. The container has a capacity for 900 standard liters of hydrogen, which corresponds to $\frac{900L}{22.4L/mol} \approx 40.2mol$, which is the amount of hydrogen in the container.

Using the relation 1 kWh = 3600 kJ, the lower heating value of hydrogen is 244 kJ/mol = 0.06778 kWh/mol.

Therefore, the total energy of the hydrogen contained in the metal hydride per liter (volumetric energy density) is $\frac{0.06778kWh/mol \cdot 40.2mol}{2.7L}$ ≈1.0 kWh/L. The answer is thus **d)** 1.0 kWh/L.