Heat and Thermodynamics Supplementary Questions

Study Guide 23

Part 1 - Specific Heat Capacity

1. $\Delta E = mc\Delta\theta$

$= 2.0 \times 2300 \times (50 - 20)$

$= \underline{\underline{1.38 \times 10^5 \text{ J}}}$

2. $\Delta E = mc\Delta\theta$

$= 3.5 \times 510 \times 23.4$

$= 41769 \text{ J}$

$= \underline{\underline{4.18 \times 10^4 \text{ J}}}$

3. $\Delta E = mc\Delta\theta$

$$m = \frac{\Delta E}{c\Delta\theta}$$

$$= \frac{60}{385 \times 10.4}$$

$= 0.014985 \ldots$ kg

$= \underline{\underline{0.0150 \text{ kg}}}$

4. $\Delta E = mc\Delta\theta$

$= 750 \times 4200 \times (60 - 25)$

$= \underline{\underline{1.10 \times 10^8 \text{ J}}}$

5. $\Delta E = mc\,\Delta\theta$

$$\therefore\ P = \frac{\Delta E}{\Delta t} = mc \cdot \frac{\Delta\theta}{\Delta t}.$$

$45\,\text{K}/\text{min}$

$= \underline{\underline{0{\cdot}75\ \text{K}/\text{sec}}}$

$P = 2{\cdot}5 \times 4200 \times 0{\cdot}75$

$= 7875\ \text{W}$

$= \underline{\underline{7880\ \text{W}}}$

6. $\Delta E = mc\Delta\theta$ and $\Delta E = p\Delta t.$

$\therefore p\Delta t = mc\Delta\theta$

$$\therefore \Delta t = \frac{mc\Delta\theta}{p}$$

$m = \rho V$

$= 1.2 \times \underbrace{(5 \times 7 \times 2.5)}_{V}$

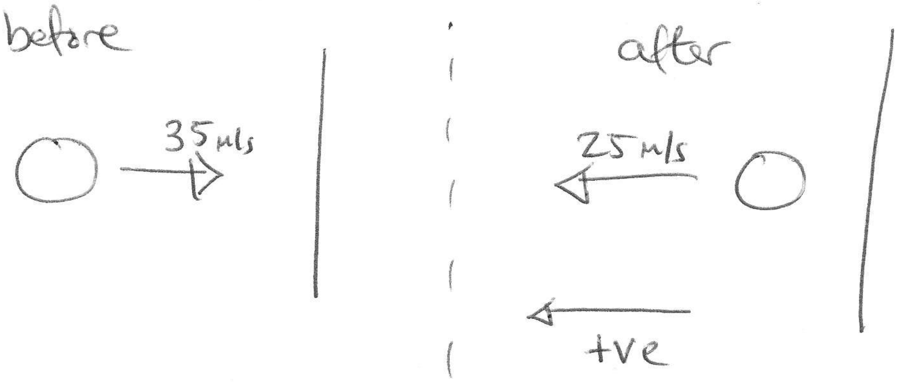
$= 105$ kg of air in the room.

$$\Delta t = \frac{105 \times 1100 \times (21-6)}{2.4 \times 10^3}$$

$\Delta t = \underline{\underline{722 \text{ seconds}}}$

(= 12 minutes 2 seconds)

7. i)



$\Delta p = 0.05(25 - (-35))$

$= \underline{\underline{3 \text{ kg m/s}}}$

ii) before : $E_K = \frac{1}{2}mv^2$

$= 0.5 \times 0.05 \times 35^2$

$= \underline{\underline{30.625 \text{ J}}}$

after : $E_K = \frac{1}{2}mv^2$

$= 0.5 \times 0.05 \times 25^2$

$= \underline{\underline{15.625 \text{ J}}}$

$\Delta E_K = 30.625 - 15.625$

$= \underline{\underline{15 \text{ J}}}$

iii) loss in KE = rise in internal energy

$$\therefore \Delta E_k = mc\Delta\theta$$

$$\therefore \Delta\theta = \frac{\Delta E_k}{mc}$$

$$= \frac{15}{0.05 \times 1880}$$

$$= \underline{\underline{0.160 \text{ K}}}$$

8. $\Delta E = ItV$

$= 2.5 \times (8 \times 60) \times 14$

$= \underline{\underline{16800\ J}}$

$\Delta E = mc\Delta\theta$

$\therefore \quad c = \dfrac{\Delta E}{m\Delta\theta}$

$= \dfrac{16800}{4 \times 17}$

$\therefore \quad \underline{\underline{c = 247\ J\ kg^{-1}\ K^{-1}}}$

9. $\Delta E_p = mg\Delta h$

$= mc \cdot \Delta\theta$

$\therefore \quad mc\Delta\theta = mg\Delta h.$

$\therefore \quad \Delta\theta = \dfrac{g\Delta h}{c}$

$= \dfrac{9.81 \times 25}{4200}$

$\therefore \quad \underline{\underline{\Delta\theta = 0.0584\,K}}$

10.

$$\Delta E = ItV$$

$$= 1.1 \times (5.5 \times 60) \times 7.5$$

$$= \underline{\underline{2722.5\,J}}$$

$$\Delta E = mc\Delta\theta$$

$$c = \frac{\Delta E}{m\Delta\theta}$$

$$= \frac{2722.5}{0.045 \times (25-13)}$$

$$= 5042\ J\ Kg^{-1}\ K^{-1}$$

$$= \underline{\underline{5040\ J\ kg^{-1}\ K^{-1}}}$$

11.

$$E_K = \frac{1}{2} M V^2$$

$3 \times$ Kinetic energy $\times 0.65$

$$= 0.975 \, m v^2$$

* Each disc will receive a 1/4 of this energy:

$$\Delta E = m_{disc} c \, \Delta\theta = \frac{1}{4} \times 0.975 \, m_{car} v^2$$

$$\Delta\theta = \frac{0.24375 \times 1350 \times 25^2}{2 \times 435}$$

$$\underline{\underline{\Delta\theta = 236 \text{ K}}}$$

12.

Mass of water $= 672 - 150$

$= \underline{\underline{522g}}$

$= \underline{\underline{0.522\,kg}}$

$\Delta E = ItV$

$= 3.9 \times (13 \times 60) \times 11.4$

$= \underline{\underline{34678.8\,J}}$

$\Delta E = mc\Delta\theta$

$$\therefore c = \frac{\Delta E}{m\Delta\theta}$$

$$= \frac{34678.8}{0.522 \times (30.2 - 18.5)}$$

$= 5678\ J\,kg^{-1}\,K^{-1}$

$= \underline{\underline{5680\ J\,kg^{-1}\,K^{-1}}}$

13.*

$$\Delta E = \underbrace{mc}_{\text{heat capacity } = C} \Delta\theta$$

$$\Delta E = ItV = C\,\Delta\theta$$

$$\Delta\theta = \frac{ItV}{C}$$

$$= \frac{0{\cdot}25 \times (2 \times 60) \times 6}{15}$$

$$\underline{\underline{\Delta\theta = 12\,K}}$$

14.* i) 8 litres = 50 cups.

1 litre = $0.001 \, m^3$

$\therefore$ $0.008 \, m^3 = 50$ cups

$\therefore$ $\underline{\underline{1 \text{ cup} = 1.6 \times 10^{-4} \, m^3}}$

ii) Mass of water brought to boil

$$= \underbrace{190}_{\text{no. of cups}} \times \underbrace{1.6 \times 10^{-4}}_{\text{Volume of 1 cup}} \times \underbrace{1000}_{\text{density of water}}$$

$$= \underline{\underline{30.4 \text{ kg}}}$$

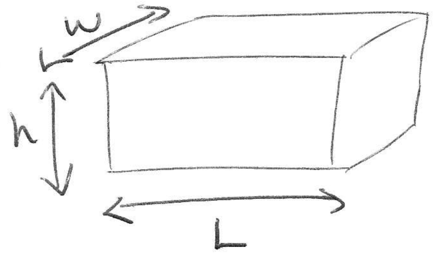
$$\Delta E = p \cdot \Delta t = mc\Delta\theta$$

$$\therefore \; p = \frac{mc\Delta\theta}{\Delta t} = \frac{30.4 \times 4200 \times (100-20)}{60 \times 60}$$

$$= \underline{\underline{2.84 \text{ kW}}}$$

15.*

$m = \rho V = \rho w h L$



$\therefore \Delta E = p \cdot \Delta t = mc \cdot \Delta\theta$

$= \rho w h L \cdot c \cdot \Delta\theta$

let $\frac{L}{\Delta t} = v$ = speed of flow.

$\therefore p = \rho w h v c \Delta\theta$

$$\therefore \Delta\theta = \frac{p}{\rho w h v c} = \frac{750 \times 10^6}{1000 \times 25 \times 4 \times 0.9 \times 4200}$$

$\Delta\theta = 1.98\,K$

16.*

$$\Delta E = m_w c_w \Delta\theta + C_{HE}\,\Delta\theta$$

$$= p\Delta t.$$

$$\therefore \quad p\Delta t = \Delta\theta\left(M_w C_w + C_{HE}\right).$$

$$\therefore \quad \frac{\Delta\theta}{\underbrace{\Delta t}_{\text{per second}}} = \frac{P}{M_w C_w + C_{HE}}$$

to make per min

$$= \frac{2.5\times10^{3}}{1.2\times4200 + 500} \times 60$$

$$= \underline{\underline{27.1\ \text{K/min}}}$$

17.* i)

$$\Delta E_w = mc_w \Delta\theta$$

$$= 0{\cdot}120 \times 4200 \times 8$$

$$= \underline{\underline{4032\ \text{J}}}$$

ii) $\Delta E_{can} = 0{\cdot}025 \times c \times 8$

$$= \underline{\underline{0{\cdot}2c}}$$

iii) $\Delta E_{Metal} = 0{\cdot}1 \times c \times (100 - 28)$

$$= \underline{\underline{7{\cdot}2c}}$$

iv) $\Delta E_{Metal} = \Delta E_w + \Delta E_{can}$

$$\therefore 7{\cdot}2c = 0{\cdot}2c + 4032$$

$$\therefore 7c = 4032$$

$$\underline{\underline{c = 576\ \text{J kg}^{-1}\text{K}^{-1}}}$$

18.* Thermal equilibrium is reached when energy lost by 250g of "hot" water equals energy gained by 100g of "Cold" water: let this happen at a temperature T:

$$250\text{g} \quad : \quad \Delta E_{250} = \underbrace{\overset{m}{0.25} \times \overset{c}{4200}}_{=1050} \times \left(T - \overset{\substack{50^\circ\text{c in k} \\ \downarrow}}{323}\right)$$

$$100\text{g} \quad : \quad \Delta E_{100} = \underbrace{0.1 \times 4200}_{=420} \times (T - 283)$$

$$-\Delta E_{250} = \Delta E_{100}$$

$$-1050\,(T - 323) = 420 \times (T - 283)$$

$$339150 - 1050T = 420T - 118860.$$

$$458010 = 1470T$$

$$\therefore T = 311.6\,\text{K}$$

$$= \underline{\underline{38.6\ ^\circ\text{C}}}$$

19.*

$$\Delta E_L = m_L c_L (T - 338)$$

$$\Delta E_W = M_W C_W (T - 283)$$

$$-\Delta E_L = \Delta E_W$$

$$\therefore m_L c_L (338 - T) = M_W C_W (T - 283)$$

$$\therefore -M_L C_L T + 338 M_L C_L = M_W C_W T - 283 M_W C_W$$

$$T(M_L C_L + M_W C_W) = 283 M_W C_W + 338 M_L C_L$$

$$\therefore T = \frac{283 M_W C_W + 338 M_L C_L}{M_L C_L + M_W C_W}$$

$$= \frac{283 \times 0.12 \times 4200 + 338 \times 0.022 \times 4000}{0.022 \times 4000 + 0.12 \times 4200}$$

$$T = 291.2$$

$$= \underline{\underline{18.2^\circ C}}$$

20.*

$$\Delta E = mc\Delta\theta$$

$$p.\Delta t = mc\Delta\theta$$

$$\frac{m}{\Delta t} = \frac{p}{c\Delta\theta}$$

$$= \frac{70}{4200 \times 2}$$

$$= \underline{\underline{0.00833 \text{ kg/s}}}$$

21.**

$$\Delta E_1 = m_1 c_1 (T_1 - T)$$ ← loses energ

$$\Delta E = m_2 C_2 (T - T_2)$$ ← gains energy

$$M_1 C_1 (T_1 - T) = M_2 C_2 (T - T_2)$$

$$M_1 C_1 T_1 - M_1 C_1 T = M_2 C_2 T - M_2 C_2 T_2$$

$$M_1 C_1 T_1 + M_2 C_2 t_2 = M_1 C_1 T + M_2 C_2 T$$

$$= T (M_1 C_1 + M_2 C_2)$$

$$\therefore T = \frac{M_1 C_1 T_1 + M_2 C_2 T_2}{M_1 C_1 + M_2 C_2}$$

* All the energy that the first liquid loses is gained by the second liquid; no energy is wasted.