

(1a)

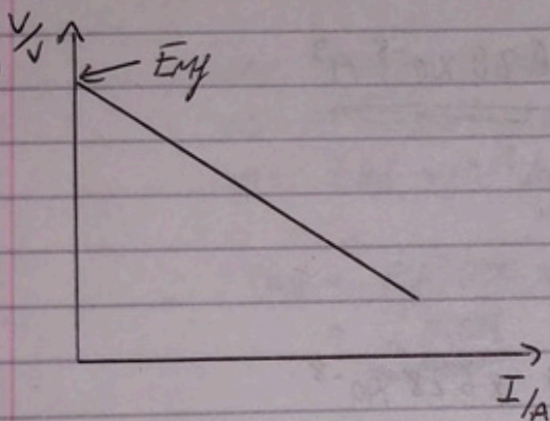
$$P = IV$$

$$P = I^2 R$$

$$P = \frac{V^2}{R}$$

$$P = \frac{12^2}{8} = \underline{\underline{18W}}$$

(b)



(c)

$$4 \Omega$$

Maximum power is achieved when the load resistance, R , is equal to the internal resistance, r , of the power supply.
 $\therefore$ Max. power $\rightarrow R = r$

(i)

$$\text{Resistivity, } \rho (\Omega m) = \frac{RA}{L}$$

$$A = \frac{\pi d^2}{4} = \frac{\pi (1 \times 10^{-4})^2}{4} = 7.85 \times 10^{-9} m^2$$

$$l = \frac{RA}{\rho} = \frac{100 \times 7.85 \times 10^{-9}}{9.81 \times 10^{-8}}$$

$$= \underline{\underline{8m}}$$

$$(ii) \quad V = \pi r^2 l = \frac{\pi d^2}{4} \times l$$

$$V = 7.85 \times 10^{-9} \times 8 = \underline{\underline{6.28 \times 10^{-8} m^3}}$$

$$(iii) \quad \text{density} = 21.45 \times 10^3 \text{ kg m}^{-3}$$

$$V = 6.28 \times 10^{-8} m^3$$

$$\therefore m = 21.45 \times 10^3 \text{ kg m}^{-3} \times 6.28 \times 10^{-8}$$

$$m = \underline{\underline{1.347 \times 10^{-3} \text{ kg}}}$$

$$\therefore \text{cost} = £10,000 \text{ kg}^{-1} \times 1.347 \times 10^{-3} \text{ kg}$$

$$= \underline{\underline{£13.47}}$$

$$(iv) \quad R = 125 \Omega$$

$$A = 3.50 \times 10^{-6} \text{ m} \times \text{thickness}$$

$$l = 0.75 \text{ m}$$

$$\rho = 9.81 \times 10^{-8} \Omega \text{ m}$$

$$R = \frac{\rho l}{A}$$

$$A = \frac{\rho l}{R}$$

$$3.50 \times 10^{-6} \times \text{Thickness} = \frac{9.81 \times 10^{-8} \times 0.75}{125}$$

$$3.50 \times 10^{-6} \times \text{Thickness} = 5.886 \times 10^{-10}$$

$$\text{Thickness} = \underline{\underline{1.68 \times 10^{-4} \text{ m}}}$$

$$(v) \quad V = 1.68 \times 10^{-4} \times 0.75 \times 3.50 \times 10^{-6}$$

$$V = 4.41 \times 10^{-10} \text{ m}^3$$

$$M = \text{density} \times \text{Volume}$$

$$M = 21.45 \times 10^3 \times 4.41 \times 10^{-10}$$

$$M = 9.46 \times 10^{-6} \text{ kg}$$

$$\therefore \text{Cost} = £10000 \text{ kg}^{-1} \times 9.46 \times 10^{-6} \text{ kg}$$

$$= \underline{\underline{£0.09}}$$

①(i) $R = 3.3 \Omega$
 $l = 1 \text{ km} = 1000 \text{ m}$

$d = 74 \text{ mm} = 7.4 \times 10^{-3} \text{ m}$

$$A = \frac{\pi d^2}{4} = \frac{\pi \times (7.4 \times 10^{-3})^2}{4}$$

$$= 4.30 \times 10^{-5} \text{ m}^2$$

$$R = \frac{\rho l}{A}$$

$$\rho = \frac{RA}{l} = \frac{3.3 \times 4.30 \times 10^{-5}}{1000}$$

$$= \underline{\underline{1.42 \times 10^{-7} \Omega \text{ m}}}$$

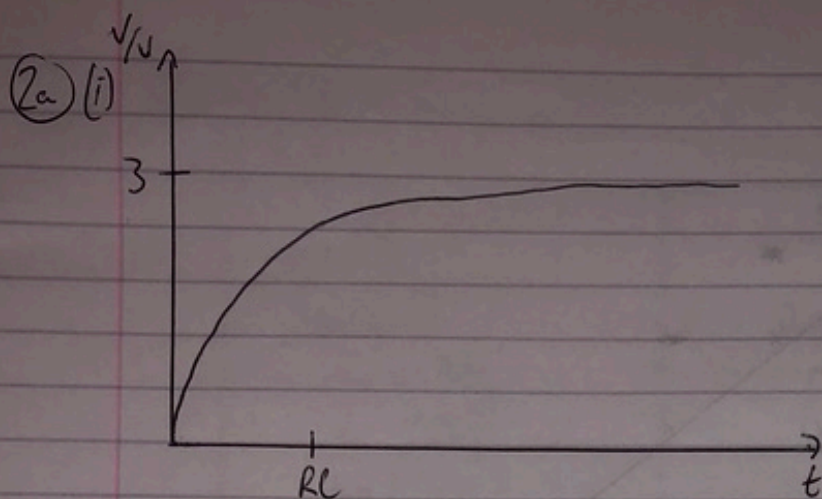
(ii) This is because the steel wire has a high resistivity. This is due to the steel having a higher resistance than the aluminium wires and a lower surface area to the total surface area of the aluminium wires.

(iii) Resistance in aluminium = $\frac{1.1}{6} = 0.183 \Omega$

Aluminium $\rightarrow P = \frac{V^2}{R} = \frac{75^2}{0.183} = 30.7 \text{ kW}$

Steel $\rightarrow P = \frac{V^2}{R} = \frac{75^2}{3.3} = 1.7 \text{ kW}$

Total Power loss = $1.7 + 30.7 = \underline{\underline{32.4 \text{ kW}}}$



(ii) When the diaphragm moves, the capacitance changes.

Using the equation $C = \frac{Q}{V}$, you can see when the capacitance, C , changes then so will the charge, Q , which travels through the resistor.

(b) $C = \frac{Q}{V}$

$V = 95 \text{ mV} = 0.095 \text{ V}$
 $C = 0.22 \text{ F}$

$Q = CV$

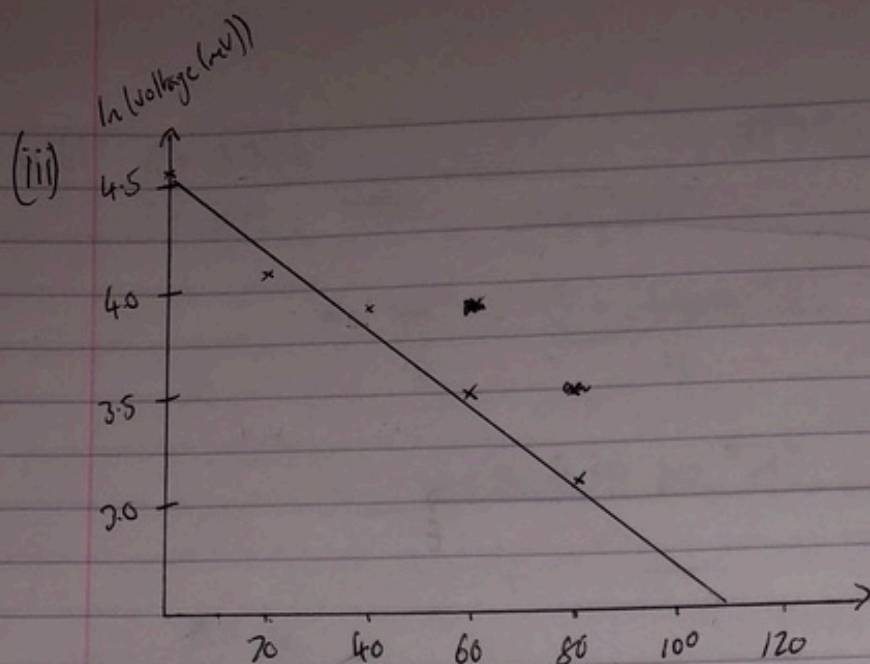
$Q = 0.22 \times 0.095$

$Q = 0.021 \text{ C}$

(i) It has a high resistance.

(ii)

Time (s)	Voltage (mV)	$\ln(\text{Voltage (mV)})$
0	95	4.55
20	67	4.20
40	46	3.83
60	33	3.50
80	22	3.09



(iv) The graph shows the voltage decreases exponentially as the gradient is negative and the line is straight.

(v) $95 \text{ mV} \times 0.37 = 35$

$\ln 35 = 3.55 \rightarrow \sim 60 \text{ s}$

time constant = $\frac{1}{2} RC$

$R = \frac{60}{0.22} = \underline{\underline{273 \Omega}}$

③ $\Delta U = Q - W$

<u>A</u>	<u>B</u>
Saturated	Superheated
$m_A = 3 \text{ kg}$	$m_B = 2.7 \text{ kg}$
$u_{A1} \text{ (J/kg)}$	$u_{B1} \text{ (J/kg)}$
$x_A = 0.4$	$T = 120^\circ\text{C}$
~~3 kg~~	
1.6 MPa (1600 kPa)	1.2 MPa (1200 kPa)

Q

<u>Stage 2</u>
$m_2 = m_A + m_B$
$u_2 \text{ (J/kg)}$
x_2
900 kPa

Q

$$U_1 = m \cdot u_1$$

$$U_2 - U_1 = Q - W$$

$$U_2 - (m_A \cdot u_{A1} + m_B \cdot u_{B1}) = Q - W$$

no work done

$$U_2 - (m_A \cdot u_{A1} + m_B \cdot u_{B1}) = Q - \cancel{W}$$

$$(m_A + m_B) u_2 - (m_A \cdot u_{A1} + m_B \cdot u_{B1}) = Q$$

$$m_2 = m_A + m_B$$

$$m_2 = 3 + 2.7 = \underline{5.7 \text{ kg}}$$

$$V_A + V_B = V_2$$

$$m_A v_A + m_B v_B = m_2 v_2$$

(a) Specific Volume

Tank A $\rightarrow$ Saturated @ 1600 kPa

$$v_A = v_f + x_A \cdot v_{fg}$$

$$v_{fg} = v_g - v_f$$

$$v_f = 0.00094 \text{ m}^3/\text{kg}$$

$$v_g = 0.012123 \text{ m}^3/\text{kg}$$

$$v_{fg} = 0.012123 - 0.00094 = 0.011183 \text{ m}^3/\text{kg}$$

$$\begin{aligned} \therefore v_A &= 0.00094 + (0.4 \times 0.011183) \\ &= \underline{5.4132 \times 10^{-3} \text{ m}^3/\text{kg}} \end{aligned}$$

Tank B $\rightarrow$ Superheated 1.2 MPa @ 120°C

$$\therefore \underline{v_B = 0.024228 \text{ m}^3/\text{kg}}$$

Final State $\rightarrow m_A v_A + m_B v_B = m_2 v_2$

$$(3 \times 5.4132 \times 10^{-3}) + (2.7 \times 0.024228) = 5.7 v_2$$

$$v_2 = \frac{0.0816552}{5.7}$$

$$\underline{v_2 = 0.0143 \text{ m}^3/\text{kg}}$$

@ 900 kPa

$$v_f = 0.0008580 \text{ m}^3/\text{kg}$$

$$v_g = 0.022683 \text{ m}^3/\text{kg}$$

$$v_{fg} = 0.022683 - 0.0008580 = 0.021825 \text{ m}^3/\text{kg}$$

$$v_2 = v_f + x_2 \cdot v_{fg}$$

$$x_2 = \frac{v_2 - v_f}{v_{fg}} = \frac{0.0143 - 0.0008580}{0.021825}$$

$$0.616 =$$

$$x_2 = \underline{\underline{0.62}}$$

$\therefore$ The quality of the refrigerant at final state is 0.62.

(b) Enthalpy

Tank A $\rightarrow$ 1600 kPa

$$h_f = 135.93 \text{ kJ/kg}$$

$$h_{fg} = 141.93 \text{ kJ/kg}$$

$$h_A = h_f + x_A \cdot h_{fg}$$

$$h_A = 135.93 + (0.4 \times 141.93)$$

$$\underline{h_A = 192.70 \text{ kJ/kg}}$$

Tank B $\rightarrow$ 1.2 MPa @ 120°C superheated

$$\therefore h_B = 354.11 \text{ kJ/kg}$$

Final State $\rightarrow$ 900 kPa

$$h_2 = h_f + x_2 \cdot h_{fg}$$

$$h_f = 101.61 \text{ kJ/kg}$$

$$h_{fg} = 167.66 \text{ kJ/kg}$$

$$h_2 = 101.61 + (0.616 \times 167.66)$$

$$h_2 = 204.89 \text{ kJ/kg}$$

Internal Energy

$$h = u + P \cdot v$$

$$u = h - P \cdot v$$

Tank A $\rightarrow$

$$u_{A1} = h_A - P \cdot v_A$$

$$= 192.70 \text{ kJ/kg} - (1.6 \times 5.4132 \times 10^{-3})$$

$$= 192.69 \text{ kJ/kg}$$

Tank B $\rightarrow$

$$u_{B1} = h_B - P \cdot v_B$$

$$= 354.11 \text{ kJ/kg} - (1.2 \times 0.024228)$$

$$= 354.08 \text{ kJ/kg}$$

Final

$$\text{State} \rightarrow u_2 = h_2 - P \cdot v_2$$

$$= 204.89 - (0.9 \times 0.0143)$$

$$= 204.88 \text{ kJ/kg}$$

$$Q = (m_A + m_B)u_2 - (m_A u_{A1} + m_B u_{B1})$$

$$Q = (3 + 2.7) \times 204.88 - ((3 \times 192.69) + (2.7 \times 354.08))$$

$$Q = -366.27 \text{ kJ}$$

$\therefore$ There is a heat loss from the tanks of 366.27 kJ.

④ Mass Balance

$$\sum \dot{m}_{in} = \sum \dot{m}_{out}$$

Energy Balance

$$\dot{Q} - \dot{W} = \sum \dot{m} \left(h + \frac{1}{2} c^2 + gz \right) - \sum \dot{m} \left(h + \frac{1}{2} c^2 + gz \right)$$

$$\dot{m}_1 = \dot{m}_2 \quad \underline{\text{AND}} \quad \dot{m}_3 = \dot{m}_4$$

SYSTEM	MASS BALANCE	ENERGY BALANCE
PIPE	$\dot{m}_3 = \dot{m}_4$ $\therefore = \dot{m}_p$	$\dot{Q}_s = \dot{m}_4 h_4 - \dot{m}_3 h_3$ $\dot{Q}_s = \dot{m}_p h_4 - \dot{m}_p h_3$ $\dot{Q}_s = \dot{m}_p (h_4 - h_3)$
TANK	$\dot{m}_1 = \dot{m}_2$ $\therefore = \dot{m}_T$	$\dot{Q}_L + \dot{Q}_s = \dot{m}_2 h_2 - \dot{m}_1 h_1$ $\dot{Q}_L + \dot{Q}_s = \dot{m}_T (h_2 - h_1)$
Entire heat exchanger	$\dot{m}_p$ AND $\dot{m}_T$	$\dot{Q}_L = (\dot{m}_2 h_2 + \dot{m}_4 h_4) - (\dot{m}_1 h_1 + \dot{m}_3 h_3)$

a) Enthalpy

Stage 3 $\rightarrow$ 50 kPa @ 200°C
0.05 MPa

$$\therefore h_3 = 2877.8 \text{ kJ/kg}$$

Stage 4 $\rightarrow$ 45 kPa

$$\therefore h_f @ 40 \text{ kPa} = 317.62$$

$$h_f @ 50 \text{ kPa} = 340.54$$

$$h_f @ 45 \text{ kPa} = 317 + \frac{(340.54 - 317.62)}{2}$$

$$= 329.08 \text{ kJ/kg}$$

$$h_{fg} @ 40 \text{ kPa} = 2318.4$$

$$h_{fg} @ 50 \text{ kPa} = 2304.7$$

$$h_{fg} @ 45 \text{ kPa} = 2304.7 + \frac{(2318.4 - 2304.7)}{2}$$

$$= 2311.55 \text{ kJ/kg}$$

$$h_4 = h_f + x_4 \cdot h_{fg}$$

$$= 329.08 + (0.15 \times 2311.55)$$

$$= \underline{675.81 \text{ kJ/kg}}$$

$$\dot{Q}_s = \dot{m}_p (h_4 - h_3)$$

$$\dot{Q}_s = 21.6 \times 10^3 (675.81 - 2877.8)$$

$$\dot{Q}_s = \frac{-47562984 \text{ kJ/h}}{3600}$$

$$= \underline{\underline{-13211.94 \text{ kJ/s}}}$$

$$\textcircled{b} \quad \dot{Q}_L = 6\% \text{ of } \dot{Q}_s$$

$$\therefore \dot{Q}_L = 0.06 \times 13211.94$$

$$= 792.72 \text{ kJ/s}$$

$$\dot{Q}_L + \dot{Q}_s = \dot{m}_w (h_2 - h_1)$$