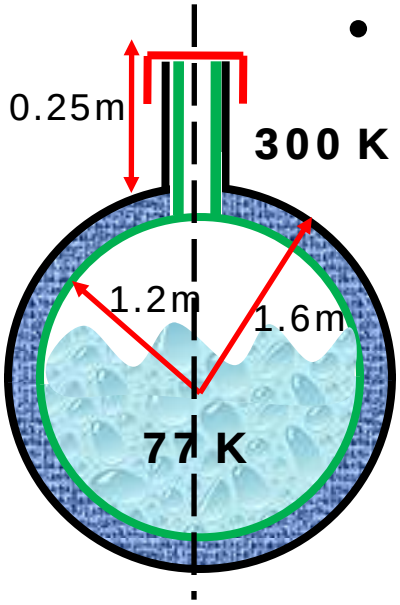
Tutorial



- A spherical **LN2** vessel (**e**=0.8) is as shown. The inner and outer radii are 1.2m and 1.6m respectively. Compare and comment on the heat in leak for the following cases.

  - Perlite (26 mW/mK)
  - Less Vacuum (1.5mPa)
  - Vacuum alone
  - Vacuum + 10 shields ($\mathbf{e_s}$=0.05)
  - Evacuated Fine Perlite (0.95 mW/mK)
  - 50/50 Cu – Santocel (0.33 mW/mK)

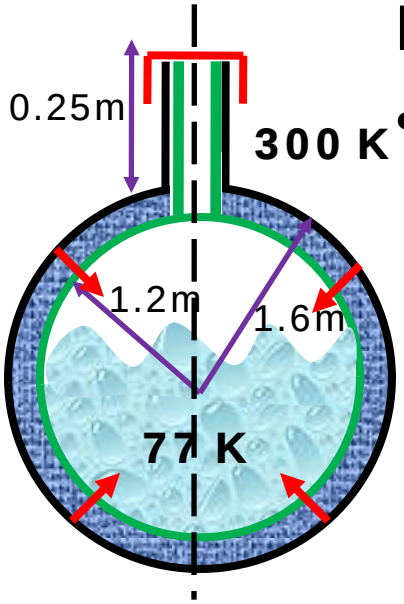
Tutorial

Given
Apparatus : Spherical vessel (**e**=0.8)
Working Fluid : Liquid Nitrogen
Temperature : 77 K (inner), 300 K (outer)

Calculate heat in leak	
1	Perlite (26 mW/mK)
2	Less Vacuum (1.5mPa)
3	Vacuum alone
4	Vacuum + 10 shields
5	Evacuated Fine Perlite (0.95 mW/mK)
6	50/50 Cu – Santocel (0.33 mW/mK)

- The shape factor between the two containers is assumed to be 1.

Tutorial



Perlite (k_A = 26mW/m-K)

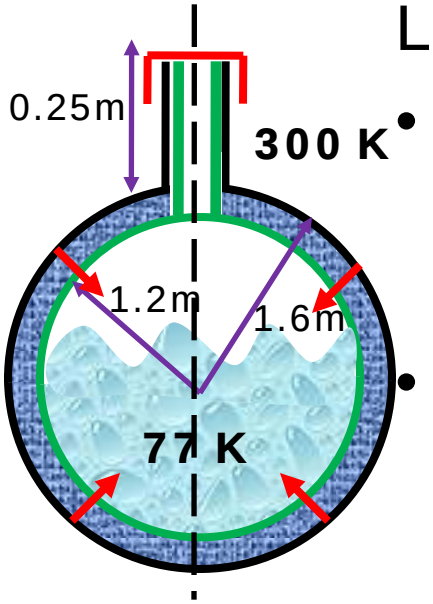
- **Sphere** - R_1=1.6m, R_2=1.2m, k_A, ΔT=(300-77)=223.

$$Q = \frac{4\pi k_A R_1 R_2 \Delta T}{(R_2 - R_1)}$$

$$Q = \frac{4\pi (26)(10^{-3})(1.6)(1.2)(223)}{(1.6 - 1.2)}$$

$$Q = 349.7W$$

Tutorial



Less Vacuum (1.5mPa)

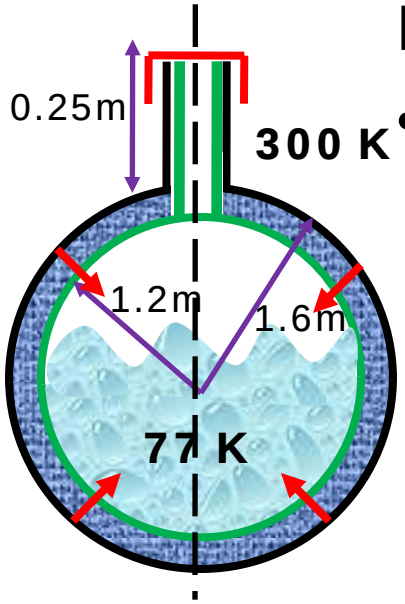
- **Sphere** - $R_1 = 1.6\text{m}$, $R_2 = 1.2\text{m}$, $e_1 = e_2 = 0.8$, $T_1 = 77$ K, $T_2 = 300$ K.

- The net heat transfer is due to both radiation and residual gas conduction.

$$F_e = \left(\frac{1}{e_1} + \left(\frac{A_1}{A_2} \right) \left(\frac{1}{e_2} - 1 \right) \right)^{-1}$$

$$F_e = \left(\frac{1}{0.8} + \left(\frac{1.2}{1.6} \right)^2 \left(\frac{1}{0.8} - 1 \right) \right)^{-1} = 0.72$$

Tutorial



Less Vacuum (1.5mPa)

- **Sphere** - $R_1 = 1.6\text{m}$, $R_2 = 1.2\text{m}$, $e_1 = e_2 = 0.8$, $T_1 = 77\ \text{K}$, $T_2 = 300\ \text{K}$.

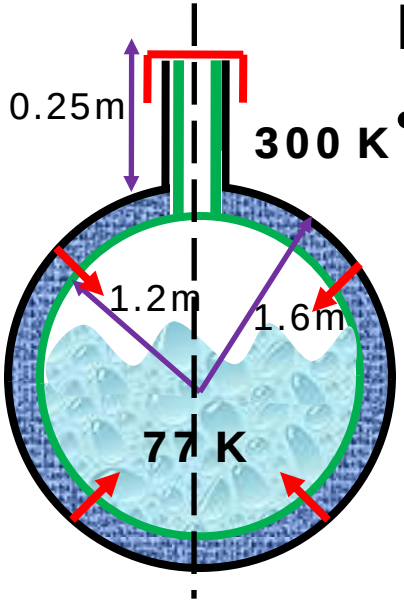
$$Q = F_e F_{1\to 2} \sigma A_1 \left(T_2^4 - T_1^4\right)$$

$$F_e = 0.72$$

$$Q = (0.72)(1)(5.67)\left(10^{-8}\right)\pi\left(1.6^2\right)\left(300^4 - 77^4\right)$$

$$Q_r = 2648W$$

Tutorial



Less Vacuum (1.5mPa)

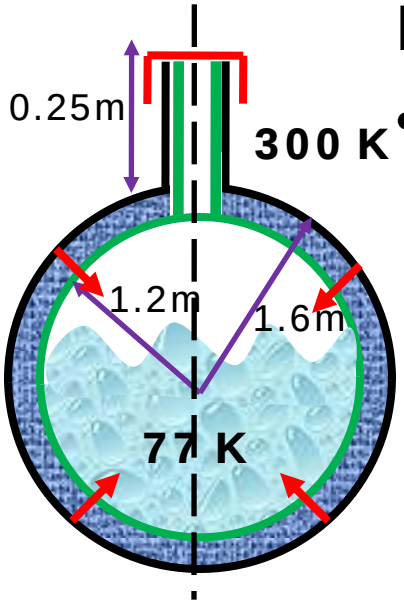
- **Sphere** - $R_1 = 1.6$m, $R_2 = 1.2$m, $T_1 = 77$ K, $T_2 = 300$ K, $p = 1.5$ mPa.

$$\lambda = \frac{\mu}{p}\left(\frac{\pi RT}{2}\right)^{0.5}$$

$$\lambda = \frac{(18.47)(10^{-6})}{(1.5)(10^{-3})}\left(\frac{\pi(287.6)(300)}{2}\right)^{0.5} = 4.53$$

- It is clear that the mean free path (λ) is greater than distance between the surfaces (0.4m).

Tutorial



Less Vacuum (1.5mPa)

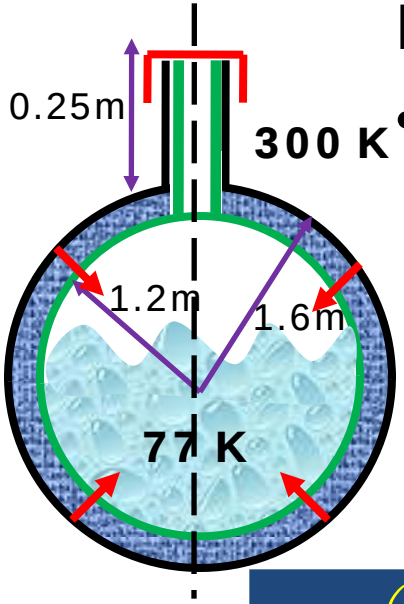
- **Sphere** - $R_1 = 1.6$m, $R_2 = 1.2$m, $T_1 = 77$ K, $T_2 = 300$ K, $p = 1.5$ mPa.

$$F_a = \left(\frac{1}{\alpha_1} + \left(\frac{A_1}{A_2} \right) \left(\frac{1}{\alpha_2} - 1 \right) \right)^{-1}$$

$$F_e = \left(\frac{1}{1} + \left(\frac{1.2}{1.6} \right)^2 \left(\frac{1}{0.85} - 1 \right) \right)^{-1} = 0.91$$

T (K)	Air
300	0.8-0.9
78	1.0
20	1.0

Tutorial



Less Vacuum (1.5mPa)

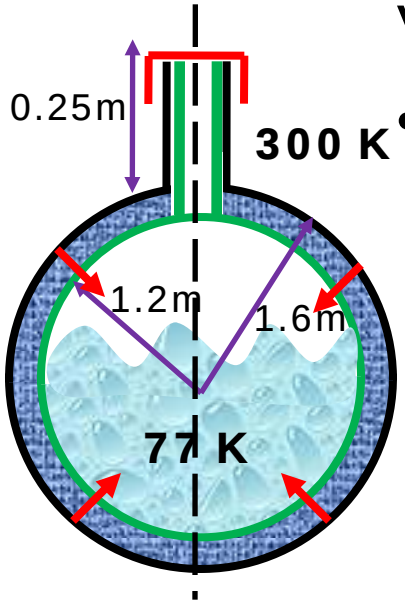
- **Sphere** - $R_1 = 1.6\,m$, $R_2 = 1.2\,m$, $T_1 = 77\ K$, $T_2 = 300\ K$, $p = 1.5\ mPa$.

$$\dot{Q} = \left(\left(\frac{\gamma + 1}{\gamma - 1} \right) \left(\frac{R}{8\pi T} \right)^{0.5} F_a \right) pA(T_2 - T_1)$$

$$\dot{Q} = \left(\left(\frac{1.4 + 1}{1.4 - 1} \right) \left(\frac{287.6}{8\pi (300)} \right)^{0.5} (0.91) \right) (1.5)\left(10^{-3}\right)(300 - 77)$$

$$Q_{gc} = 0.356W$$

Tutorial



Vacuum alone

- **Sphere** - $R_1 = 1.6m$, $R_2 = 1.2m$, k_A, $T_1 = 77K$, $T_2 = 300K$, e_1, $e_2 = 0.8$, $F_{1\to2} = 1$.

$$Q = F_e F_{1\to2} \sigma A_1 \left(T_2^4 - T_1^4\right) \qquad F_e = 0.72$$

$$Q = (0.667)(1)(5.67)(10^{-8})\pi(1.6^2)(300^4 - 77^4)$$

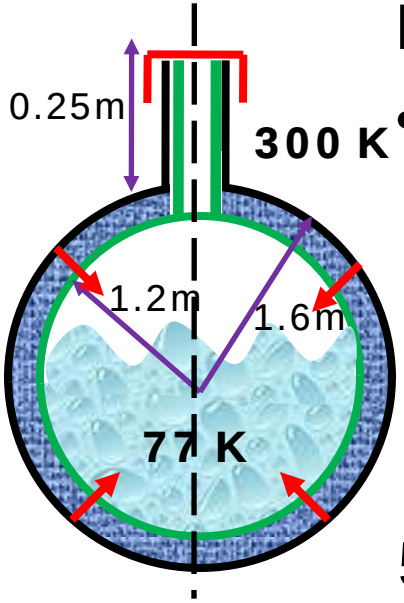
$$Q = 2648W$$

Vacuum + 10 shields

- e_1, $e_2 = 0.8$, $e_s = 0.05$. $\qquad F_e = 0.003$

$$Q = 11.02W$$

Tutorial



Evacuated Fine Perlite (k_A = 0.95mW/mK)

- **Sphere** - R_1=1.6m, R_2=1.2m, k_A, ΔT=(300-77)=223.

$$Q = \frac{4\pi k_A R_1 R_2 \Delta T}{(R_2 - R_1)}$$

$$Q = 12.7W$$

50/50 Cu – Santocel (k_A = 0.33mW/m-K)

- **Sphere** - R_1=1.6m, R_2=1.2m, k_A, ΔT=(300-77)=223.

$$Q = \frac{4\pi k_A R_1 R_2 \Delta T}{(R_2 - R_1)}$$

$$Q = 4.41W$$

Tutorial

Heat in leak (Q)	
Perlite	349.7 W
Less Vacuum (1.5mPa)	Q_r=2648 W Q_{gc}=0.356 W
Vacuum alone	2648 W
Vacuum + 10 shields	11.02 W
Evacuated Fine Perlite	12.7 W
50/50 Cu – Santocel	4.41 W