1.

- A system at 20^{0}C has to achieve 10^{-9} mbar after prolonged pumping with a turbo molecular pump (S_{EFF} = 300 Ls^{-1}, independent of the gas type). What is the maximum allowable leakage?

1. ANSWER

- $q_{Leak,tot} \leq 10\,\% \times S_{Eff}$

- $q_{Max} = 0.1 \times 10^{-9} mbar \times 300\ Ls^{-1} = 3 \times 10^{-8}\ mbar\ L\ s^{-1}$

2.

- A diffusion pump vacuum system with a chamber of 0.75 m^3 is isolated from its pumps. The pressure increases from $2 \cdot 10^{-3}$ mbar to $5 \cdot 10^{-1}$ mbar in 10 minutes.

- A. What is the leakage rate, assuming no other gas source?

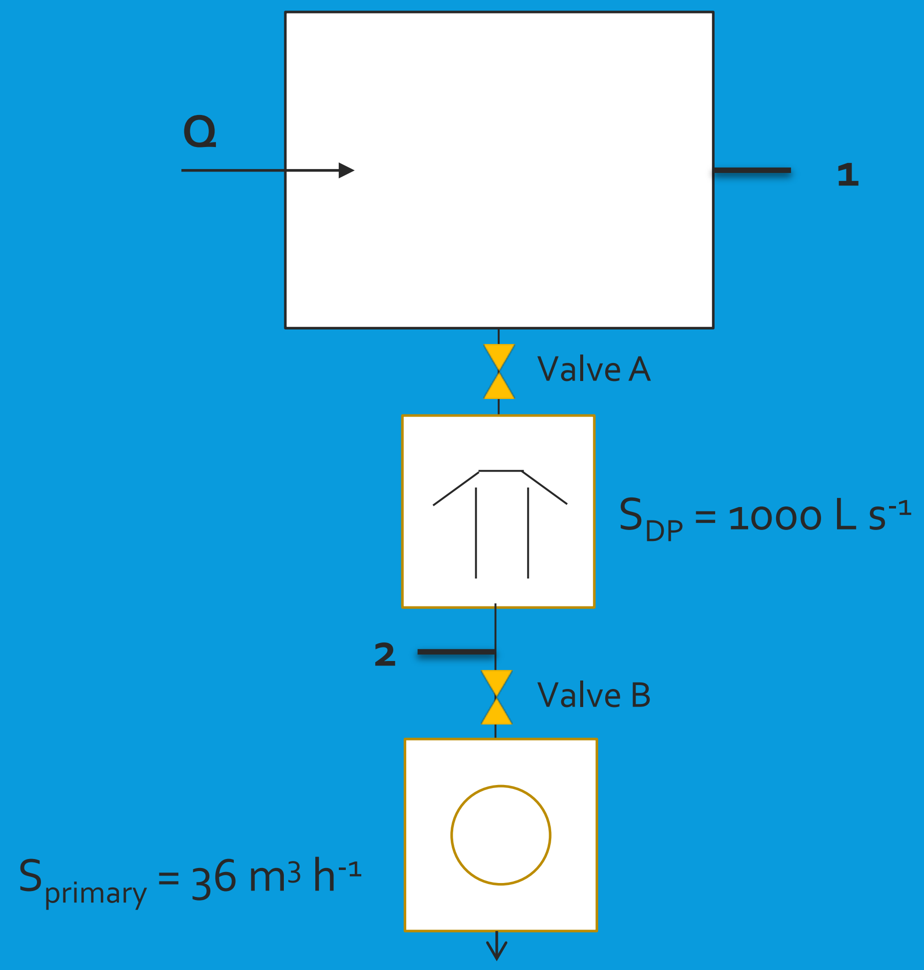
- B. After repairing a significant leak, the system could be evacuated to $5 \cdot 10^{-5}$ mbar with the diffusion pump (S_{EFF} = 2000 Ls^{-1}). What leakage remains?

2. ANSWER

- 1. $q_L = V\frac{\Delta P}{\Delta t} = \frac{750\ L \times 0.498\ mbar}{600\ s} = 0.62\ mbar\ L\ s^{-1}$

- 2. $p = \frac{q_{in}}{S_{eff}} \rightarrow\ q_{in} = 5 \times 10^{-5}\ mbar\ \times 2000\ Ls^{-1} = 0.1\ mbar\ L\ s^{-1}$

3.



The vacuum vessel has a volume of 5 m^3. An air leak of 1.05 E-6 mbarl/s is present.

Calculate the response time for 95% of the final signal on the leak detector when it is connected in position 1 with and without valve A open and the position 2 with and without valve B open.

For each case, what is the signal on the detector when the leak is pocketed with helium ?

Which of the 4 configurations is best for the leak test

$S_{LeakDetector\ at\ Inlet} = 1\ L\ s^{-1}$

3.ANSWER

- In position 1, valve A closed:
  - $t_{95\%} = 3 \times \frac{V}{S} = \frac{3{\times}5000\ L}{1Ls^{-1}} = 15000\ s$ He leak signal $1.10^{-6} mbarLs^{-1}$ x 2.7
- In position 1, valve A open:
  - $t_{95\%} = 3 \times \frac{V}{S} = \frac{3{\times}5000L}{(10^3Ls^{-1}+1Ls^{-1})} = 14.99\ s$ He leak signal $1.10^{-9} mbarLs^{-1}$ x 2.7
- In position 2, valve B closed:
  - $t_{95\%} = 3 \times \frac{V}{S} = \frac{3{\times}5000L}{10^3Ls^{-1}} = 15\ s$ He leak signal $1.10^{-6} mbarLs^{-1}$ x 2.7
- In position 2, valve B open:
  - $t_{95\%} = 3 \times \frac{V}{S} = \frac{3{\times}5000L}{10^3Ls^{-1}} = 15\ s$ He leak signal $9.10^{-8} mbarLs^{-1}$ x 2.7
- Position 2 with valve B closed is best configuration, but leak detector might not be able to accept the full gas load

4.

- A human hair is trapped across an O-ring on a vacuum system where the internal; pressure is 10^{-4} mbar and the external pressure is 10^{3} mbar. The temperature is 20°C. Leakage of air into the vacuum system is occurring:

- A. If the trapped hair is a leak that can be regarded as a uniform tube of 70 um diameter (approximate diameter of a human hair) and length of about 8mm with the above pressure the exit and entrance, respectively, what is the nature of the flow across the leak?
- B. Estimate the leakage (q_L)

SUPPORT TO QUESTION 4 EXERCISE

Mean free path of gases at T= 293 K:

Gas	$\bar{l}$lp (m mbar) (x 10[5])
N2	6.4
Air	6.5
O2	6.5
He	19
H2	12.2
Ar	6.8

Dependence of flow type on Kn

K values	***FLow type***
Kn < 0.01	Viscous
Air0.01 < Kn < 0.5	Transitional
Kn> 0.5	Molecular

4. ANSWER

- The type of flow can be determined by the Knudsen number *Kn*
- $\bar{l}p = 6.5x10^{-5}\ m\ mbar\ \rightarrow 6.5x10^{-3}\ cm\ mbar$
- ***At the leak inlet***, *p = 10³ mbar* → $\bar{l}p = 6.5x10^{-5}$
- *As the d=70 µm (7x10⁻³ cm)*
- *Kn* = $\frac{\bar{l}}{d} = 9.3x10^{-4}$
- *Kn <<< 0.01 viscous flow will predominate*
- ***At the leak outlet***, *p = 10⁻⁴ mbar* → $\bar{l}p = 65$
- *As the d=70 µm (7x10⁻³ cm)*
- *Kn* = $\frac{\bar{l}}{d} = 9286$
- *Kn >> 0.5 Molecular flow will predominate*

4. ANSWER

- *If we assume that viscous, laminar flow of air occurs in the leak then:*
- $q_L = 135 \times \frac{d^4}{l}\left(\frac{p_{ext}^2 - p_{vac}^2}{2}\right) mbarLs^{-1} = 0.2mbarLs^{-1}$
- *If we assume that molecular flow occurs in the leak:*
- $C_{Leak} = \frac{12.1 \times d^3}{l}\ Ls^{-1}$
- $q_L = C_{Leak} \times (p_{EXT} - p_{vac})$ = $5.2 \times 10^{-3}\ mbarLs^{-1}$