EASTERN UNIVERSITY, SRI LANKA

SPECIAL DEGREE EXAMINATION IN SCIENCE - 2004/2005

Experimental Techniques in Low Temperature Physics

PH 409

Answer ALL questions.

Time: 2 hours

1. Explain how you could design a Liquid-Helium glass dewar for research cryostat. Draw the schematic diagram showing the process of transferring liquid helium from storage dewar to the helium cryostat. Write the precautions that you should take while transferring the liquid.

   (a) Consider the transfer tube having an inner tube of 3mm diameter, 2m long and has its emissivity as $\epsilon \approx 0.05$. If this transfer tube is exposed to room temperature radiation from surrounding black body calculate the heat inflow.

   (b) If the quantity of heat transferred per unit time due to radiation effect in a helium cryostat is 5 *Watts*, calculate the time to boil off one litre of helium due radiation effect. You may assume the Latent heat of liquid helium as 3000 *joule litre*$^{-1}$

2. Write the general means of heat transfer in a system. Define the thermal conductivity of a material and describe the heat flow in uniform cross-section of a solid.

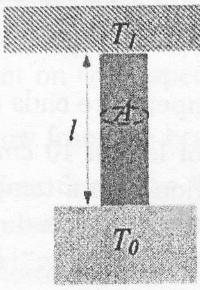


Figure 1

Consider a solid having a length l, uniform cross-section A and having the temperature ends of T_1 and T_0 as shown in the Figure 1. If $\bar{\kappa}$ is the mean heat conductivity show that the heat flow $\dot{Q}$ through the solid as

$$\dot{Q} = \bar{\kappa}\frac{A}{l}(T_1 - T_0)$$

Hence show that the resultant heat flow $\dot{Q}$ of a thermal conductor with discrete steps using a material having the same mean heat conductivity

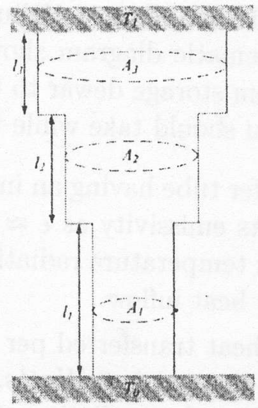


Figure 2

and of uniform cross-section area A_1, A_2, A_3 with corresponding lengths of l_1, l_2, l_3 as shown in the Figure 2, as

$$\dot{Q} = \frac{\bar{\kappa}(T_1 - T_0)}{\frac{l_1}{A_1} + \frac{l_2}{A_2} + \frac{l_3}{A_3}}$$

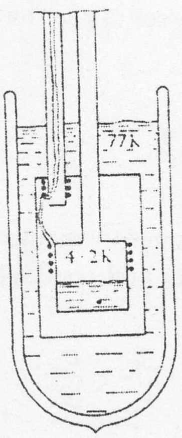
Here T_1 and T_0 are the temperature ends of the conductor.

A stainless steel cylinder of length 10 cm, diameter 0.5 cm and wall thickness 0.25 mm is positioned in a temperature ends of $T_1 = 4.2\ K$ and $T_0 = 2\ K$. If the mean heat conductivity of the stainless steel between T_1 and T_0 is 0.002 $Watts\ m^{-1}K^{-1}$ calculate the heat flow through the cylinder.

3. Consider two plane parallel surface each of area A and emissivities ϵ_1 and ϵ_2 and at respective temperature T_1 and T_2, if σ is the Stefan's constant. Show that the radiation per unit time $\dot{Q}$ is given by the equation

$$\dot{Q} = \sigma A(T_1^4 - T_2^4)\frac{\epsilon_1\epsilon_2}{\epsilon_1 + \epsilon_2 - \epsilon_1\epsilon_2}$$

The figure shows a cryostat having a polished copper inner chamber of surface area of 0.05 m^2 supported by a German silver tube of 2.0 cm diameter and 0.3 mm wall thickness is positioned inside a tarnished brass vacuum chamber. The length of the tube separating the two



chamber is 6 cm. Eight copper electrical leads of 0.1 mm diameter and four constantan electrical leads of 0.2 mm is enter the outer chamber through the pumping tube and are effectively thermally anchored on a copper bush at 77 K as shown in the figure. The leads are then taken to the inner chamber, each lead having a length of about 12 cm between its points of attachment on the respective chambers. Calculate

(a) Radiant heat inflow from the brass to the copper chamber

(b) Radiant heat inflow down the German silver tube to the inner chamber when no radiation baffle is present.

(c) Heat conducted down the electrical leads from one chamber to he other.

You may assume that mean heat conductivity of German silver, copper and constantan are 12 $Watts\ m^{-1}K^{-1}$, 980 $Watts\ m^{-1}K^{-1}$ and 14 $Watts\ m^{-1}K^{-1}$ respectively.

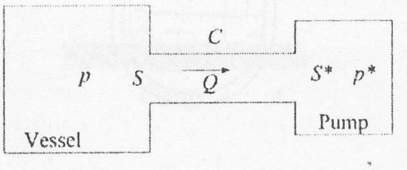
4. Describe the following sources of gas that present as a load to the pump.

   (a) Leaks

   (b) Vaporisation

   (c) Outgassing

   Define the term 'conductance' in vacuum technology. Derive expression for conductance in parallel and conductance in series.



   The figure shows a pump of speed S^* connected via a pipe of conductance C to a vessel where the pressure is p. If S is the speed at the vessel and Q is the throughput show that the speed at the vessel S is given by

$$S = \frac{S^* C}{S^* + C}$$

   Suppose a pump of speed 100 $l\ s^{-1}$ is connected to a vessel by a pipe of conductance 400 $l\ s^{-1}$. Find the speed at the vessel. If the pressure at the pump is 1.0×10^{-5} $mbar$ what is the pressure in the vessel.