MEL804 Radiation and Conduction Heat Transfer
Major Test
(Open Notes Only: Books not allowed)

Date: 03.05.07

Time: 2 hours — Total Marks: 40+20

Answer All Questions. Answer parts A and B in ***separate*** answer books. Part A carries 40 marks and part B carries 20 marks.

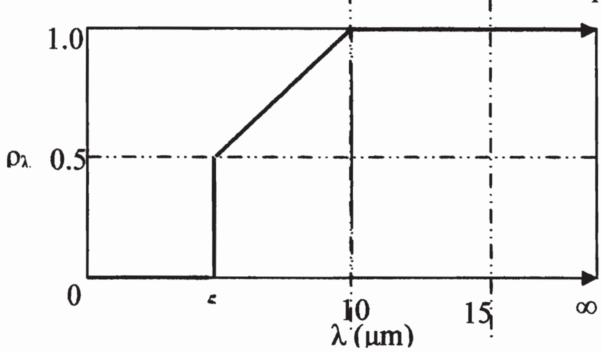
Part-A: Radiation Heat Transfer

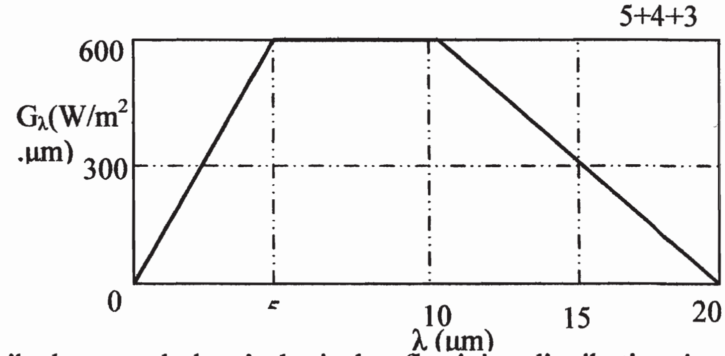
1. Show mathematically that for a gray medium at radiative equilibrium there is no distinction (i.e. same source function) between an absorbing-emitting medium and an absorbing, emitting and isotropic scattering medium. 2
2. The extinction coefficient between two infinitely long plane-parallel plates (1-D Cartesian) of L distant apart varies linearly between 0 and 1. Calculate the maximum optical depth where the extinction coefficient is 1. 2
3. Consider a radiative equilibrium situation of a planar medium (1-D Cartesian) with the two black boundaries at different finite temperature T_1 and T_2. What will be trend of radiative heat flux (increasing/decreasing) with optical thicknesses? Justify your statement. If the optical thickness of the medium is zero, what will be the radiative heat flux? 3
4. Explain the different terms of the expression for divergence of radiative heat flux. Why the scattering term is not appearing even if scattering is present in the medium? 3
5. How do the discrete ordinates and finite volume methods differ from each other? 2
6. What are the variables with which intensity varies for a gray planar medium? 2
7. (a) A spherical radiation shield (area A_3, temperature T_3) is placed between two concentric spheres of temperature, area, and emissivity as T_1, A_1, ε_1 (inner sphere) and T_2, A_2, ε_2 (outer sphere). If the emissivity of the shield ε_3 is same in both sides, using network analysis deduce an expression for the radiative heat transfer rate between the two spheres.

   (b) A spherical tank with diameter D_1 = 40 cm filled with a cryogenic fluid at T_1 = 100K is placed inside a spherical container of diameter D_2 = 60 cm and temperature T_2 = 300K. The emissivities of the inner and outer tanks are ε_1 = 0.15 and ε_2 = 0.2, respectively. A spherical radiation shield of diameter D_3 = 50 cm and having an emissivity ε_3 = 0.05 on both surfaces is placed between the spheres.

   Using the expression deduced in (a), Calculate the rate of heat loss from the system by radiation. Then find the rate of evaporation of the cryogenic liquid for $h_{fg} = 2.1 \times 10^5$ J/kg.

   5+4+3





8. An opaque surface with the prescribed spectral, hemispherical reflectivity distribution is subjected to the spectral irradiation as shown below.
   (a) Sketch the spectral, hemispherical absorptivity distribution.
   (b) Determine the total irradiation on the surface.
   (c) Determine the radiant flux that is absorbed by the surface.
   (d) What is the total, hemispherical absorptivity of this surface? 3+4+4+3

Part B. Conduction Heat Transfer

1. A long thick-walled cylindrical pipe of inner diameter 50 mm and outer diameter 75 mm is electrically heated. The current i is 10 A, and the resistance R' per unit length of the pipe can be taken as 2.454 ohm/m. Heat generation is calculated using i^2R' per unit length, and correspondingly converted to unit volume basis as required. The thermal conductivity of the wall of the pipe is known to vary linearly with radius, and can be taken to be given by $k=2r$. The outer and inner surfaces of the pipe are maintained at constant temperatures of 400°C and 300°C respectively.
   a. Derive the expression for the steady state temperature profile in the wall of the cylinder.
   b. Evaluate the heat transfer rates at the inner surface and the outer surface, and verify the steady state energy balance for the pipe per unit length. 7+3

2. Figure P2 shows the cross-section of a long triangular bar. The diagonal of the triangular section is perfectly insulated. It is desired to solve for steady state temperature distribution in the bar for the boundary conditions shown in the figure.
   a. Suggest the steps to convert this into a problem of the kind we have solved in the class and assignments during this semester, which is physically and mathematically equivalent to the given problem.
   b. State the governing equation and boundary conditions for the equivalent problem.
   c. Write the steps towards solving this problem using method of separation of variables. (Write only steps, need not solve the problem). 5+3+2

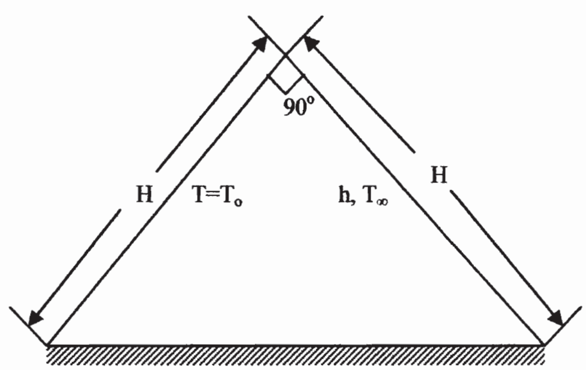


Figure P2