MASENO UNIVERSITY

UNIVERSITY EXAMINATIONS 2012/2013

FIRST YEAR SECOND SEMESTER EXAMINATIONS FOR THE DEGREE OF MASTER OF SCIENCE IN PHYSICS (MAIN CAMPUS)

SPH 834: HEAT AND MASS TRANSFER

Date: 29th July, 2013 *Time: 9.00 – 12.00 noon*

INSTRUCTIONS

- Answer ANY THREE questions

SPH 834: HEAT AND MASS TRANSFER

MSc second semester 2012/2013 examination.

Attempt any THREE questions

Useful quantities:

Air properties at $300 \leq T \leq 400K$: $\upsilon = 2.076 \times 10^{-5}\ m^2 s^{-1}$; $k = 0.03\ Wm^{-1}K^{-1}$

Oil: $\upsilon = 0.75 \times 10^{-4}\ m^2s^{-1}$; $\rho = 868\ kg\ m^{-3}$

Copper: $k = 380\ Wm^{-1}K^{-1}$, Brick: $k = 1.2\ Wm^{-1}K^{-1}$

Stone: $k = 0.8\ Wm^{-1}K^{-1}$, Plaster: $k = 0.4\ Wm^{-1}K^{-1}$

Qn1.(a). A blackbody is radiating at temperature T K. What fraction of the total hemispherical emissive power is radiated into a solid angle subtended by : $0 \leq \theta \leq 30^o$ and $0 \leq \varphi \leq 2\pi$

(6mks)

(b). Small surfaces $dA_1 = 6cm^2$ and $dA_2 = 12cm^2$ are separated by a distance r as indicated in Fig 1 below. If r = 60cm, calculate the view factor between the surfaces. (6mks)

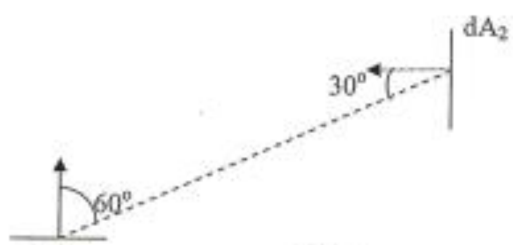

Fig.1

(c). Determine analytically the view factors from an elemental surface dA_1 to a circular disc A_2 of radius r which are parallel to each other and positioned at a distance L as shown in Fig 2 below. Re-draw Fig.2 and indicate details used in your determination view factor.

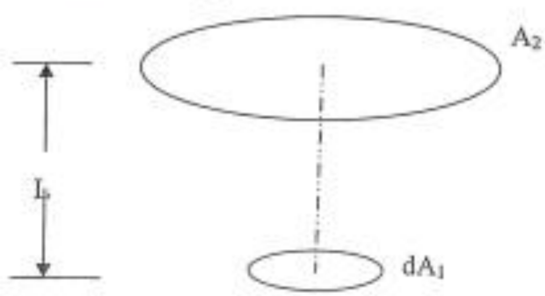

Fig.2

(6mks)

(d). A perfect blackbody may not exist but geometrical blackbodies that perform close to the ideal blackbody can be constructed. Give an example of such geometrical blackbody and explain how it functions. (2mks)

Qn.2 (a). The velocity profile for a developed laminar flow inside a circular tube is given by

$$U(r) = 2u_m\left[1 - (r/R)^2\right]$$

where R is the inside radius of the tube and u_m is the mean flow velocity. Develop an expression for friction factor f for flow inside the tube. (8mks)

(b). Oil is pumped with a mean velocity of $u_m = 0.6\ ms^{-1}$ through a bundle of 80 tubes each of inside diameter D = 2.5 cm and length L = 10 m. Calculate the pressure drop across each tube and the total power required for pumping the oil through 80 tubes to overcome the friction. (8mks)

(c). Heating of atmospheric air inside a thin-walled tube can be done either by condensing steam on the outer surface thus maintaining a uniform surface temperature or by electric resistance heating to maintain uniform surface heat flux. If the diameter of the tube is 2.5 cm and air velocity $u_m = 0.5\ ms^{-1}$ in the hydrodynamically and thermally developed region, calculate the heat transfer coefficient for both heating conditions. Use the given air properties. (4mks)

Qn.3.(a). Wrought iron pipe of inside radius r_1 = 5.04 cm and outside radius r_2 = 5.7 cm is covered with magnesia insulation of thickness Δr = 2.55 cm. If thermal conductivities of iron and magnesia are $k_i = 55.4\ Wm^{-1}K^{-1}$ and $k_m = 0.07\ Wm^{-1}K^{-1}$ respectively, find heat loss per meter length of the pipe when inside pipe temperature is 150^0C and the outer surface of the insulation is at 30^0C. (4mks)

(b). A copper rod 0.5 cm in diameter and 0.3 m long has its two ends maintained at 22^0C while the rest of the surface is thoroughly insulated so that heat flow is in one direction only. Find the maximum electrical current that the rod may carry if the temperature is not to exceed 122^0C at any point when electrical resistivity of the rod is 1.73×10^{-6} ohm-cm

(8mks)

(c). The wall of Otieno's building consists of an outside layer of bricks 10 cm thick followed by a layer of common building stones 15 cm thick which is then plastered with cement 1.2 cm thick. Taking outside convective heat transfer coefficient to be $31 Wm^{-2}K^{-1}$ and the inside one to be $8\ Wm^{-2}K^{-1}$, determine the rate of heat gain per unit area of the wall surface when the outside air temperature is at 35°C while the inside one is at 22°C. What is the temperature of the plaster? (8mks)

Qn.4. Given that for laminar flow of uniform stream past a flat surface, the local wall shear stress and local heat transfer coefficient vary with distance from the leading edge in the following ways:

$$\tau_o = 0.332\mu U\left(U/\upsilon x\right)^{1/2}$$

$$h_x = 0.332kPr^{1/3}\left(U/\upsilon x\right)^{1/2}$$

where the quantities μ, υ and k are dynamic viscosity, kinematic viscosity and thermal conductivity of the fluid, respectively. If at x = 0.25 m from the leading edge, the free stream velocity U = 20 ms^{-1} and temperature Ta = 40°C while surface temperature is 80°C.

(a) Verify that the flow is laminar (6mks)

(b) Calculate the local wall shear, heat transfer coefficient and heat flux (7mks)

(c) Calculate the local skin friction coefficient and local Nusselt number. (7mks)

Use the following properties of air at 1 atm: $\mu = 20 \times 10^{-6}$ kg $m^{-1}s^{-1}$, $\rho = 1.06$ kg m^{-3}, $\upsilon = 19 \times 10^{-6} m^2s^{-1}$, $k = 28.5 \times 10^{-3} Wm^{-1}K^{-1}$, Pr = 0.708.

Qn.5. (a). A vertical [plate 10 cm high and 5 cm wide is cooled by natural convection. The rate of heat transfer is 5.55 W and the fluid temperature is 38°C. Assuming that the flow of the fluid on the plate is laminar and that the properties of the fluid are $\upsilon = 1.67 \times 10^{-5} m^2s^{-1}$, Pr = 0.72, k = 0.027 $Wm^{-1}K^{-1}$, estimate the maximum temperature of the plate. (12mks)

(b). Determine the total rate of heat transfer by natural convection between vertical parallel plates which are 5cm apart, 1m high and 1m wide. The walls are maintained at 134°C and the air temperature is at 20°C. The following information about the air are given: Pr = 0.7, average Nu = 7, k = 0.03 $Wm^{-1}K^{-1}$, $\upsilon = 20.8 \times 10^{-6} m^2s^{-1}$. (8mks)