MASENO UNIVERSITY

UNIVERSITY EXAMINATIONS 2015/2016

FIRST YEAR SECOND SEMESTER EXAMINATIONS FOR THE DEGREE OF MASTER OF SCIENCE IN PHYSICS

MAIN CAMPUS

SPH 834: HEAT AND MASS TRANSFER

Date: 10th May, 2016 Time: 2.00 - 5.00 pm

INSTRUCTIONS:

- Answer ANY THREE questions.

SPH 834: HEAT AND MASS TRANSFER

MSc second semester 2015/2016 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: $\upsilon = 0.75 \times 10^{-4}\ m^2 s^{-1}$; $\rho = 868\ kg\ m^{-3}$

$\sigma = 5.67 \times 10^{-8} W\ m^{-2} K^{-1}$

Qn1(a). Give the general equations for one-dimensional steady state heat conduction for constant thermal conductivity and constant internal heat generation rate for:

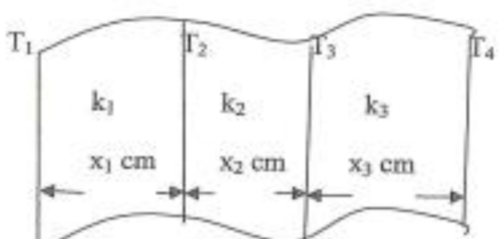
i. Rectangular block (heat flow in x-direction) (4mks)

ii. Cylindrical rod (heat flow radially) (4mks)

iii. Spherical object (heat flow radially) (4mks)

Take q_g *to* be heat energy generated per unit volume in Wm^{-3}.

(b). Consider the composite slab as shown



If heat flowing through the slab per unit area in the x-direction is q, derive an expression for this one dimensional heat conduction. (8mks)

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

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

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. (6mks)

(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. (7mks)

(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. (7mks)

Qn.3.(a). Take the inside base surface of a cube to be surface 1 while the top is surface 2. If the view factor $F_{1\text{-}2} = 0.2$, determine the view factors from surface 1 to the other surfaces i.e. $F_{1\text{-}3}$, $F_{1\text{-}4}$, $F_{1\text{-}5}$, $F_{1\text{-}6}$.

(4mks)

(b). A flat plate has one surface insulated while the other surface is exposed to 800 W of sunshine. If the ambient air is at 300°K and the emissivity of the plate is 0.9 . Determine the equilibrium temperature of the plate if the convective heat transfer coefficient is 12 $Wm^{-1}K^{-1}$. Assume that emissivities of the plate and ambient air are equal. (4mks)

(c). (i). A blackbody radiator is at 2000 K. What fraction of the total radiation emitted is in the following wavelength bands: $\lambda = 1$ to 5 μm; $\lambda = 10$ to 15 μm. (6mks)

(ii). Calculate the rate of emission per unit area through a solid angle subtended by $0° \leq \Theta \leq 30°$, $0 \leq \Phi \leq 2\pi$ over all wavelengths (6mks)

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:

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

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

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 $Ta = 40^oC$ while surface temperature is 80^oC.

(a) Verify that the flow is laminar (4mks)

(b) Calculate the local wall shear, heat transfer coefficient and heat flux (8mks)

(c) Calculate the local skin friction coefficient and local Nusselt number. (8mks)

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

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^oC. 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. (10mks)

(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^oC and the air temperature is at 20^oC. The following information about the air are given: $Pr = 0.7$, average $Nu = 7$, $k = 0.03\ Wm^{-1}K^{-1}$, $\upsilon = 20.8 \times 10^{-6} m^2 s^{-1}$. (10mks)