BIRLA INSTITUTE OF TECHNOLOGY & SCIENCE, PILANI
Second Semester 2016-17
ME G631 Advanced Heat Transfer
End Semester

For Part -A maximum time will be 1.5 hours. You have to answer Part-A and Part B in two different answer scripts. Once you complete Part –A, return the answer script and collect a new one for Part-B

Max. Time: 3 hours **Max. Marks: 40**

Answer All the Questions

Make suitable assumptions and state them clearly

Part-A (Closed Book)

Q.1 Differentiate between constant density fluid, incompressible fluid and incompressible flow. Explain "variable density incompressible flow". What is bousinessq approximation and under what condition it is valid? Derive the condition under which a flow can be considered as incompressible? [1.5+1+1+1.5]

Q.2 The internal energy form of the first law of thermodynamics is given as follows. All the notations are same as discussed in the class.

$$\rho\frac{De}{Dt} = q''' + -\nabla.q - p\nabla.V + \mu\Phi$$

(a) Using the suitable thermodynamic relation and required constitutive relation derive the temperature form of the above equation.

Required Maxwell relation is given by: $\left(\frac{\partial s}{\partial p}\right)_T = -\left[\frac{\partial(1/\rho)}{\partial T}\right]_P$

(b) While deriving the internal energy form of the energy equation we have assumed that change in kinetic energy is negligible compared to change in internal energy. But if you include the change in kinetic energy term will your final expression change? Comment on it without deriving it.

(c) Write the special restricted versions of the change of temperature equation for the following cases omitting viscous dissipation and volumetric heat generation term and assuming constant thermal conductivity.

1. For an ideal gas.
2. For fluid flowing in a constant pressure system.
3. For a fluid with constant density.
4. For stationary solid. [6+2+2]

Q.3 The temperature profile of a semi infinite body subjected to following boundary and initial conditions: Boundary Conditions

$$T(0,t) = T_o$$
$$T(\infty,t) = T_i$$

Initial Condition $T(x,0) = T_i$

is found to be: $\frac{T(x,t) - T_i}{T_o - T_i} = 1 - erf\,\frac{x}{\sqrt{4\alpha t}}$, where α is the thermal diffusivity of the body.

Show that the temperature profile of the semi infinite body subjected to following boundary and initial conditions:

Boundary Condition: $q = q_o \quad at\; x = 0 \quad for\; t > 0$ Where q_o is the constant heat flux at the boundary

Initial Condition: $q = 0 \quad for\; x > 0 \quad for\; t = 0$

Will be: $T(x,t) = \frac{2q_o\sqrt{\alpha t}}{k}\, ierfc\left(\frac{x}{\sqrt{4\alpha t}}\right)$ where *ierfc* is the integral of the complementary error function

[5]

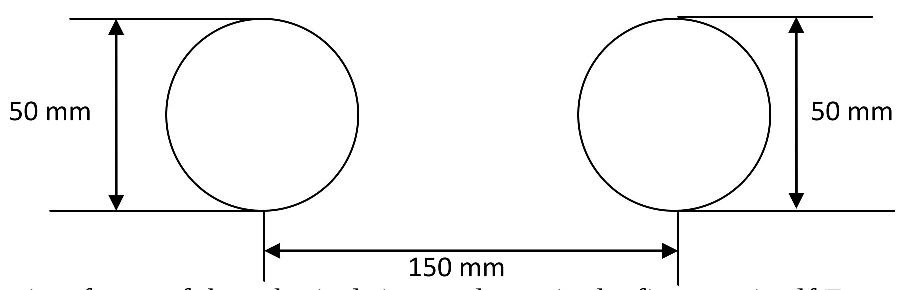
****

Answer All the Questions

Make suitable assumptions and state them clearly

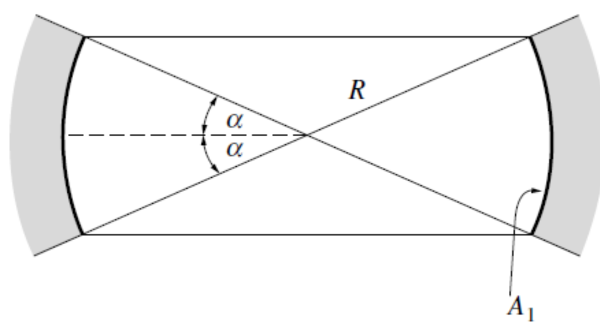
Part-B (Open Book)

Q.1 Calculate the view factor between two parallel tubes 10 m long, 50 mm diameter and separated centre to centre by 150 mm.



[3]

Q.2 Find the view factor of the spherical ring as shown in the figure to itself F_{1-1}.



[3]

Q.3 An absorbing an emitting gas at temperature of T_g =1100 K flows between two very long parallel plates. Both the plates have emissivity of 0.8 and are maintained at uniform temperature of T_1 = 400 K and T_2=400 K respectively. The spacing between the plates, L is 1.5m. Determine the absorption coefficient of the gas if amount of cooling required at each wall surface is q = 20 kW/m^2. Assume the medium to be optically thin. [3]

Q.4 Transient conduction in a semi-infinite region is used to determine the thermal diffusivity of material. The procedure is to experimentally heat the surface of a thick plate which is initially at uniform temperature such that the surface is maintained at constant temperature. Measurement of surface temperature and the temperature history at a fixed location in the region provides the necessary data to compute the thermal diffusivity.

(a) Show how the transient solution in a semi-infinite region can be used to determine the thermal diffusivity.

(b) Justify using the solution for a semi infinite region as a model for finite thickness plate.

(c) Compute the thermal conductivity of the material for the following data:

T_i = initial temperature = 20 ^{o}C,

T_o = surface temperature =150 ^{o}C,

T (x,t) = 72 ^{o}C at location x and time t

x = distance from surface =1.5 cm

t = time = 20 s.

Specific heat and density of the material are 2093 J/kg.K and 916.8 kg/m^3 respectively

[1+1+2]

Q.5 In Pilani during winter you plan to make ice in a cold day by keeping water in a pan outdoors. Heat transfer from water to ambient air is convection only. The ambient air temperature and the convective heat transfer coefficient is assumed to be constant at -5 ^{o}C and 15 W/m^2-^{o}C respectively. Initially water is at fusion temperature of 0^{o}C. Using quasi-steady model and the data given determine the thickness of ice layer after 10 hours. Also assume that the liquid in the pan is at uniform temperature equal to the fusion temperature throughout the process.

Properties of ice are: $c_{ps} = 2093$ J/kg$-^o$C, $k_s = 2.21$ W/m$-^o$C, latent heat of fusion $L = 333{,}730$ J/kg *and* $\rho_s = 916.8$ kg/m^3. Justify your quasi steady assumption using your numerical value given and prove that you are in a conservative side. [6+1]

Table 1: Values of exponential integral of order 3 $E_3(x)$

x	$E_3(x)$	x	$E_3(x)$
0.00	0.50000	0.60	0.19156
0.01	0.49029	0.65	0.17830
0.02	0.48098	0.70	0.16607
0.03	0.47201	0.75	0.15477
0.04	0.46333	0.80	0.14433
0.05	0.45493	0.85	0.13466
0.06	0.44677	0.90	0.12571
0.07	0.43884	0.95	0.11741
0.08	0.43113	1.00	0.10970
0.09	0.42362	1.20	0.08394
0.10	0.41630	1.40	0.06458
0.15	0.38228	1.60	0.04991
0.20	0.35195	1.80	0.03872
0.25	0.32469	2.00	0.03014
0.30	0.30005	2.25	0.02212
0.35	0.27768	2.50	0.01630
0.40	0.25729	2.75	0.01205
0.45	0.23867	3.00	0.00893
0.50	0.22161	3.25	0.00664
0.55	0.20595	3.50	0.00495

Table 2: Error function

η	erf η	η	erf η
0.0	0.00000	1.6	0.97635
0.1	0.11246	1.7	0.98379
0.2	0.22270	1.8	0.98909
0.3	0.32863	1.9	0.99279
0.4	0.42839	2.0	0.99432
0.5	0.52050	2.1	0.99702
0.6	0.60386	2.2	0.99814
0.7	0.67780	2.3	0.99886
0.8	0.74210	2.4	0.99931
0.9	0.79691	2.5	0.99959
1.0	0.84270	2.6	0.99976
1.1	0.88021	2.7	0.99987
1.2	0.91031	2.8	0.99992
1.3	0.93401	2.9	0.99996
1.4	0.95229	3.0	0.99998
1.5	0.96611		