Seat No.: ________ Enrolment No. ________

GUJARAT TECHNOLOGICAL UNIVERSITY

BE - SEMESTER–VII (NEW) EXAMINATION – WINTER 2017

Subject Code: 2171911 **Date:02/11/2017**

Subject Name: Advance Heat Transfer(Department Elective - I)

Time: 10:30 AM TO 01:00 PM **Total Marks: 70**

Instructions:

1. **Attempt all questions.**
2. **Make suitable assumptions wherever necessary.**
3. **Figures to the right indicate full marks.**
4. **Use of Heisler chart and Correction factor chart for temperature history are permitted.**

Q.1 **(a)** Define fin. List at least six practical and specific examples of use of fin in heat transfer. **03**

(b) Prove that the temperature of a body at any time τ during newtonian heating or cooling is given by the relation $\frac{t - t_a}{t_i - t_a} = exp[-B_i, F_o]$ where B_i and F_o are the Biot and Fourier modulus respectively; t_a is the ambient temperature and t_i is the initial temperature of the body. **04**

(c) A two dimensional square isotropic plate is provided with constant edge temperature given in Fig.–1. Determine the temperature at point 1, 2, 3 and 4 for two-dimensional steady heat conduction without heat generation using finite difference method. **07**

Q.2 **(a)** Define non-dimensional B_i (Biot) number. State its importance in transient heat conduction analysis. **03**

(b) Interpret Grashof number and Rayleigh number with mathematical formula. Explain their significance in natural convection heat transfer analysis in 100 words. **04**

(c) Develop the numerical formulation and solution of two-dimensional steady heat conduction with heat generation in rectangular coordinates using the finite difference method. Prove that finite difference formulation of an interior node is obtained by adding the temperatures of the four nearest neighbors of the node, subtracting four times the temperature of the node itself, and adding the heat generation term. **07**

OR

(c) Steam in a heating system flows through tubes whose outer diameter is D_1 = 3 cm and whose walls are maintained at a temperature of 120°C. Circular aluminum fins (k = 180 W/m-deg) of outer diameter D_2 = 6 cm and constant thickness t = 2 mm are attached to the tube, as shown in Fig. 2. The space between the fins is 3 mm, and thus there are 200 fins per meter length of the tube. Heat is transferred to the surrounding air at T_∞ = 25°C, with a combined heat transfer coefficient of h = 60 W/m^2-deg. Determine the increase in heat transfer from the tube per meter of its length as a result of adding fins under steady operating conditions and neglecting heat transfer by radiation. Assume: 1. The heat transfer coefficient is uniform over the entire fin surfaces. 2. Thermal conductivity is constant. **07**

Q.3 **(a)** Define following terms **03**
i) Boiling
ii) Optically thick medium
iii) Monochromatic transmissivity of gas (spectral transmissivity of a medium)

(b) Prove that fully developed flow in a tube subjected to constant surface heat flux, the temperature gradient is independent of x and thus the shape of the temperature profile does not change along the tube. **04**

(c) Derive the governing differential equation for steady state condition for temperature distribution of constant area heat extended surface in the following forms: $\frac{d^2t}{dx^2} - m^2\theta = 0, \quad where \;\; m = \sqrt{\frac{hP}{kA_c}}$ **07**
where θ is excess temperature above the ambient air of the fin temperature at distance x from the root; P is the perimeter; A_c the cross sectional area of the fin; h is the heat transfer coefficient and k is the thermal conductivity of the material. State clearly assumption consider in derivation of formula.

OR

Q.3 **(a)** Mention at least four cases where heat is generated internally at uniform rate in the conducting medium itself. **03**

(b) State eight assumptions of Nusselt theory of condensation. (Laminar film condensation on a vertical plate) **04**

(c) A large steel plate 50 mm thick is initially at a uniform temperature of 425^0C. It is suddenly exposed on both sides to an environment with convective coefficient 285 W/m^2-K and temperature 65^0C. Determine the centre line temperature and the temperature inside the plate 12.5 mm from the mid plane after 3 minutes. **07**
For steel:
Thermal conductivity, k = 42.5 W/m-K
Thermal diffusivity, α = 0.043 m^2/hr
Heisler chart for temperature history at the centre of a plane and Correction factor chart for temperature history in a plate are given in Fig. 3 and Fig.4 respectively.
t_o = temperature t the mid plane
t_a = ambient temperature.

Q.4 **(a)** Define following: **03**
i) Efficiency of fin
ii) Effectiveness of fin.
Write mathematical formula for both performance parameters. Express mathematical formula which correlate them.

(b) Explain heat transfer from the human body in 200 words. **04**

(c) A 25-cm-diameter stainless steel ball (ρ = 8055 kg/m^3, C_p = 480 J/kg-deg) is removed from the oven at a uniform temperature of 300°C (Fig. 5). The ball is then subjected to the flow of air at 1 atm pressure and 25°C with a velocity of 3 m/s. The surface temperature of the ball eventually drops to 200°C. Determine the average convection heat transfer coefficient during this cooling process and estimate how long the process will take. **07**
The dynamic viscosity of air at the average surface temperature is $\mu_s = \mu_{@250\ °C}$ = 2.76 × 10^{-5} kg/m-s. The properties of air at the free-stream temperature of 25°C and 1 atm are

k = 0.02551 W/m-deg ν = 1.562 × 10^{-5} m^2 /s
μ = 1.849 × 10^{-5} kg/m-s Pr = 0.7296

Use the following correlation.

$$Nu = 2 + \left[0.4\,Re^{1/2} + 0.06\,Re^{2/3}\right] Pr^{0.4}\left(\frac{\mu_\infty}{\mu_s}\right)^{1/4}$$

Following assumption to be considered during cooling of ball for simplicity.
(1) Steady operating conditions exist. (2) Radiation effects are negligible. (3) Air is an ideal gas. (4) The outer surface temperature of the ball is uniform at all times. (5) The surface temperature of the ball during cooling is changing. Therefore, the convection heat transfer coefficient between the ball and the air will also change. To avoid this complexity, take the surface temperature of the ball to be constant at the average temperature of (300 + 200)/2 = 250°C in the evaluation of the heat transfer coefficient.

OR

Q.4 (a) State six practical example of transient heat conduction occurs. **03**

(b) Define shape factor or view factor. Explain minimum six salient features of shape factor. **04**

(c) Consider a 0.6 m × 0.6 m thin square plate in a room at 30˚C. One side of the plate is maintained at a temperature of 90˚C, while the other side is insulated. Consider steady operating conditions exist, air is an ideal gas and local atmospheric pressure is 1 atm. **07**
Determine the rate of heat transfer from the plate by natural convection if the plate is (a) horizontal with hot surface facing up, and (b) horizontal with hot surface facing down.
In which case natural convection heat transfer is the lower? Explain it.

The properties of air at the film temperature of $T_f = (T_s + T_\infty) / 2 = (90 + 30)/2 = 60$˚C and 1 atm are

$k = 0.02808$ W/m-deg $\qquad \nu = 1.896 \times 10^{-5}$ m^2/s
$\beta = 1/T_f = 1/333$ K $\qquad Pr = 0.7202$

Use the following correlation for horizontal with hot surface facing up

$$Nu = 0.54\,Ra_L^{1/4}$$

Use the following correlation for horizontal with hot surface facing down.

$$Nu = 0.27\,Ra_L^{1/4}$$

where Ra = Rayleigh number

Q.5 (a) State Beer's law. Derive a mathematical expression for radiation beam while passing through an absorbing medium of thickness L in following forms : $\dfrac{I_{\lambda,L}}{I_{\lambda,0}} = e^{-\kappa_\lambda L}$ where **03**
$I_{\lambda,0}$ = A spectral radiation beam of intensity when it is incident on the medium, L = participating medium of thickness, κ_λ = spectral absorption coefficient of the medium whose unit is m^{-1}, $I_{\lambda,L}$ = A spectral radiation beam of intensity at medium thickness L

(b) A thermocouple used to measure the temperature of hot air flowing in a duct whose walls are maintained at T_w = 400 K shows a temperature reading of T_{th} = 650 K (Fig. 6). Assuming the emissivity of the thermocouple junction to be ε = 0.6 and the convection heat transfer **04**

coefficient to be $h = 80$ W/m^2-deg, determine the actual temperature of the air. The surfaces are opaque, diffuse, and gray.

(c) Explain Nusselt theory of condensation for Laminar film condensation on a vertical plate and obtain an expression for local value of condensing heat transfer coefficient over a vertical flat plate length l, Also show that average value of heat transfer coefficient is equal to 4/3 times the local value of condensing heat transfer coefficient at $x = l$. **07**

OR

Q.5 **(a)** State three special features of radiation from gases. **03**

(b) An electric wire of 1.25 mm diameter and 250 mm long is laid horizontally and submerged in water at 7 bar. The wire has an applied voltage of 2.2 V and carries a current of 130 amperes. If the surface of the wire is maintained at 200^{0}C, make calculation for the heat flux and boiling heat transfer coefficient. Saturation temperature corresponding to 7 bar is 165^{0}C. **04**

(c) Discuss in detail the various regimes in boiling with sketch in 500 words. **07**

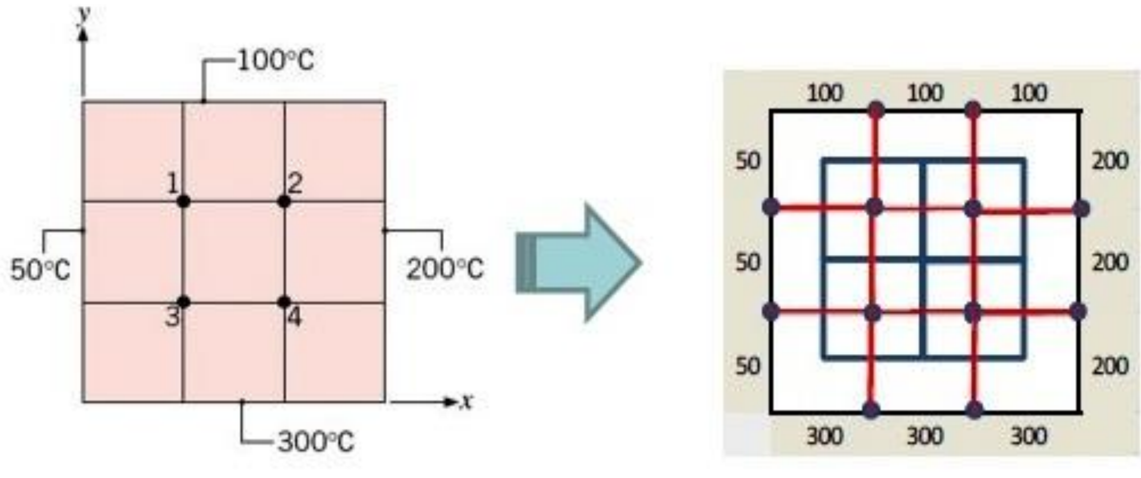

Fig. 1

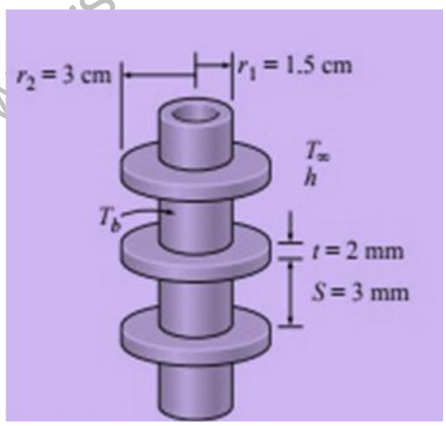

Fig. 2

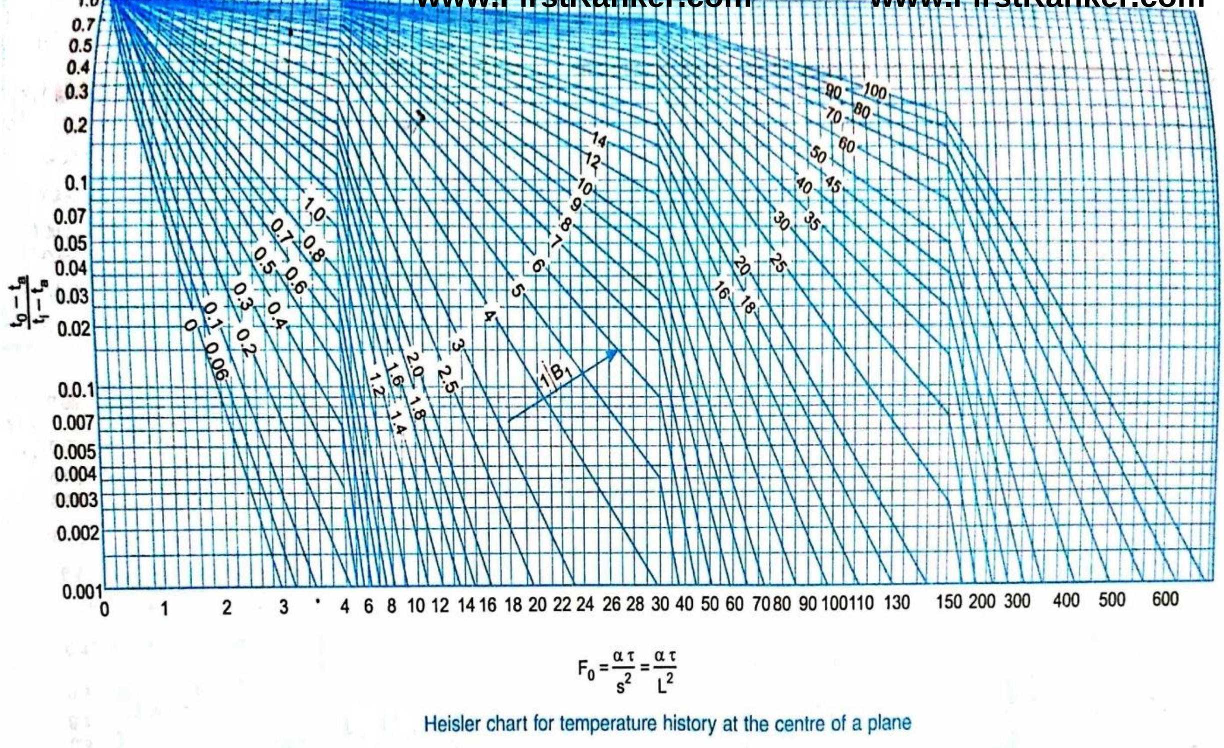
$\frac{t - t_a}{t_0 - t_a}$
1.0
0.7
0.5
0.4
0.3
0.2
0.1
0.07
0.05
0.04
0.03
0.02
0.01
0.007
0.005
0.004
0.003
0.002
0.001
0 1 2 3 4 6 8 10 12 14 16 18 20 22 24 26 28 30 40 50 60 70 80 90 100 110 130 150 200 300 400 500 600
1/B_i
$F_0 = \frac{\alpha \tau}{s^2} = \frac{\alpha \tau}{L^2}$
Heisler chart for temperature history at the centre of a plane

Fig. 3

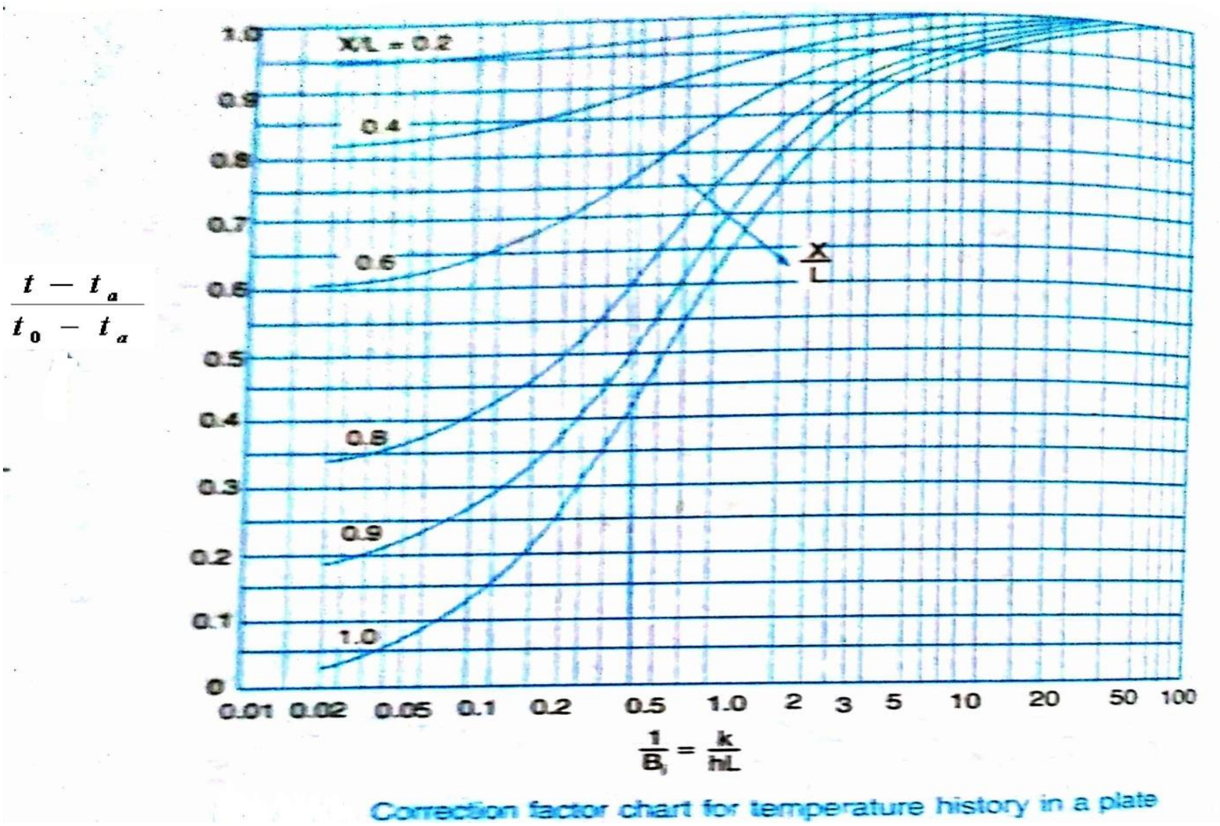
X/L = 0.2
0.4
0.6
0.8
0.9
1.0
X/L
$\frac{t - t_a}{t_0 - t_a}$
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.01 0.02 0.05 0.1 0.2 0.5 1.0 2 3 5 10 20 50 100
$\frac{1}{B_i} = \frac{k}{hL}$
Correction factor chart for temperature history in a plate

Fig. 4

www.FirstRanker.com

Fig. 5

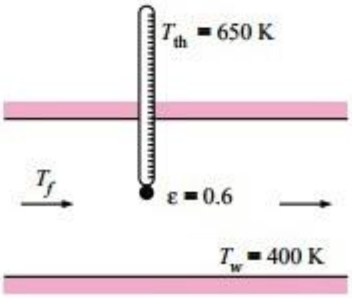

Fig. 6

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