

**IV B.Tech II Semester Examinations, APRIL 2011****HEAT TRANSFER****Aeronautical Engineering****Time: 3 hours****Max Marks: 80****Answer any FIVE Questions****All Questions carry equal marks**

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1. Engine oil at  $40^{\circ}\text{C}$  flows at a velocity of 1 m/s over a 2m long flat plate whose surface is maintained at a uniform temperature of  $80^{\circ}\text{C}$ . Determine the average heat transfer coefficient over 2m length of plate. [16]
2. Explain the finite difference method in unsteady state heat conduction. [16]
3. (a) What do you mean by a radiation shield? Where is it used?  
(b) By using one radiation shield between two surfaces and if all the three surfaces have the same emissivity, show that the net radiant heat transfer is reduced by 50%. [6+10]
4. An electrically heated copper spherical element of diameter 10 cm is immersed in water at atmospheric pressure and saturation temperature. The surface of the element is maintained at a uniform temperature of  $115^{\circ}\text{C}$ . Calculate
  - (a) The surface heat flux
  - (b) The rate of evaporation
  - (c) Peak heat flux. [16]
5. (a) Derive expression for temperature distribution and heat dissipation in a straight fin for the case of fin insulated at the tip.  
(b) Find out the amount of heat transferred through an iron fin of length 50mm, width 100mm and thickness 5mm. Assume  $K = 210 \text{ KJ/mh}^{\circ}\text{C}$  and  $h = 42 \text{ KJ/m}^2\text{h}^{\circ}\text{C}$  for the material of the fin and the temperature at the base of the fin as  $80^{\circ}\text{C}$ . Also determine the temperature at tip of the fin, if the atmosphere temperature is  $20^{\circ}\text{C}$ . [6+10]
6. (a) Write an expression for overall heat transfer coefficient (U) for double pipe heat exchanger. Explain the significance of various terms in this expression.  
(b) A horizontal steel pipe of 5.25 cm ID and 6.03 cm OD is exposed to atmospheric air at  $20^{\circ}\text{C}$ . Hot water at  $98^{\circ}\text{C}$  flows through this pipe with a velocity of 15 meters per minute. Taking the following data calculate the overall heat transfer coefficient based on the outer area of the pipe. Take  $K$  for steel =  $54 \text{ W/mK}$ ,  $h_i = 1961 \text{ W/m}^2\text{K}$ ,  $h_o = 7.91 \text{ W/m}^2\text{K}$ . [6+10]
7. (a) How does the temperature in a cylinder vary?

- (b) A thin plate 500 mm is subjected to 400 W of heating on one surface and dissipates the heat by combined convection and radiation from the other surface into the ambient air at 290K. If the surface of the plate has an emissivity of 0.9 and the heat coefficient between the surface and the ambient air is 15 W/m<sup>2</sup> K, calculate the temperature of the plate. [4+12]
8. A power amplifier is mounted vertically in air at 25°C. The case is made of anodized aluminium with a surface area of about 3800 mm<sup>2</sup> and a height of 40 mm. Determine
- (a) The heat transfer coefficient for natural convection cooling with a case temperature of 125°C.
  - (b) The rate of total heat dissipation
  - (c) What is the percentage of total heat that is lost by natural convection? Properties of air at 75°C are  $\nu = 2.06 \times 10^{-5} \text{ m}^2/\text{s}$ ,  $\text{Pr} = 0.697$  and  $K = 0.0299 \text{ W/mK}$ . [16]

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1. (a) The boundary layer thickness for a free convection process is more than in the case of forced convection process. Why?  
 (b) A plate of size 20 cm × 30 cm is used as a water heater in a process plant. The temperature of water is 20°C while the heater plate is maintained at a temperature of 120°C. Determine the heat transfer rate by free convection when 20 cm side of the heater is kept vertical. [4+12]
2. (a) Explain the significance of following dimensions nos:  
 i) Reynolds number(Re) ii) Prandlt number(Pr) iii) Stanton number(St)  
 (b) Water at 30 °C with a flow rate of 0.01 kg/s enters a 3cm diameter tube which is maintained at 100 °C. Assuming hydro-dynamically developed flow determine the tube length required to heat the water to 60 °C. [8+8]
3. (a) What are radiation shape factors? Why are they used?  
 (b) Show that the direct heat exchange area between a disc of radius 'r' and a sphere of radius 'R', whose center is on the normal through the center of the disc separated by a center to center distance 'H' is  

$$2 \pi R^2 \left[ 1 - \left\{ H / \sqrt{H^2 + r^2} \right\} \right].$$
 [4+12]
4. Calculate the heat transfer coefficient during stable film boiling of water from 9mm diameter horizontal carbon tube. The water is saturated at 100°C and the tube surface is at 1000°C. Assume the emissivity of carbon surface to be 0.8. Properties of steam are  $\rho_v = 0.266 \text{ kg/m}^3$ ,  $\mu_v = 28.7 \times 10^{-6} \text{ kg/ms}$  and  $k_v = 0.0616 \text{ W/mk}$ . [16]
5. (a) Discuss the concept of transient heat conduction in semi infinite solids.  
 (b) A steel ingot (large in size) heated uniformly to 745°C is hardened by quenching it in an oil bath maintained at 20°C. Find the time required for the temperature to reach 595°C at a depth of 12mm. The ingot may be approximated as a flat plate. For steel ingot take (thermal diffusivity) =  $1.2 \times 10^{-5} \text{ m}^2/\text{s}$ . [6+10]
6. Hot exhaust gases, which enter a finned tube, cross flow heat exchanger at 300°C and leave at 100°C, are used to heat pressurized water at a flow rate of 1 kg/s from 35°C to 125°C. The exhaust gas specific heat is approximately 1000 J/kg K, and the overall heat transfer coefficient based on the gas side surface area is  $U_h = 100 \text{ W/m}^2\text{K}$ . Determine the required gas side surface area by the NTU method. [16]
7. (a) Derive an expression for 1- Dimensional, steady state heat conduction with internal heat generation for plane wall.

- (b) Nichrome, having a resistivity of  $100\mu\Omega\text{-cm}$  is to be used as a heating element in a 10kW heater. The Nichrome surface temperature should not exceed  $1220^{\circ}\text{C}$ . Other design features include surrounding air temperature is  $20^{\circ}\text{C}$ , Outside surface coefficient is  $1.15\text{ W/m}^2\text{-k}$ , Thermal conductivity of Nichrome =-  $17\text{ W/mk}$ . Find out which diameter Nichrome wire is necessary for a 1 meter long heater. Also find the rate of current flow. [8+8]
8. (a) How do the temperature distributions in a solid vary its thermal conductivity various linearly with temperature?
- (b) A thin metallic plate is insulated at the back surface and is exposed to the sun at the front surface. The front surface absorbs solar radiation at  $900\text{ W/m}^2$  and dissipates it mainly by convection to the ambient air at  $30^{\circ}\text{C}$ . If the heat transfer coefficient between the plate and the air is  $15\text{ W/m}^2\text{ K}$ , what is the temperature of the plate? [6+10]

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1. (a) What is meant by sub-cooled and saturated boiling?  
(b) A heated polished copper plate is immersed in a pool of water boiling at atmospheric pressure. If the surface temperature of the copper plate is maintained at a temperature of  $113^{\circ}\text{C}$ , determine the surface heat flux and the evaporation rate per unit area of the plate. [6+10]
2. (a) Distinguish between free and forced convection heat transfer processes.  
(b) A vertical plate 10 cm high and 5 cm wide is cooled by natural convection. The rate of heat transfer is 5.55W and the air temperature  $38^{\circ}\text{C}$ . Estimate the maximum temperature of the plate. Assume uniform heat flux. [4+12]
3. (a) How are exit fluid temperatures determined with the help of  $\varepsilon$ -NTU method?  
(b) When one of the two fluids undergoes phase change, show that the effectiveness values for both parallel flow and counter flow heat exchangers are equal and given by  
 $\varepsilon = 1 - \exp(-NTU)$ . [4+12]
4. (a) Derive expression for temperature distribution under steady state in one dimensional heat conduction for a plane wall.  
(b) Calculate the critical radius of insulation for asbestos, ( $K = 0.17 \text{ W/m}^{\circ}\text{C}$ ) surrounding a pipe and exposed to room air at  $20^{\circ}\text{C}$  with  $h = 3.0 \text{ W/m}^2\text{C}$ . Calculate the heat loss from a  $200^{\circ}\text{C}$ , 50 mm diameter pipe when covered with the critical radius of insulation and without insulation. [6+10]
5. (a) A 25mm OD solid steel (20% Cr) ball bearing at a temperature of  $600^{\circ}\text{C}$  is quenched in oil at  $40^{\circ}\text{C}$ . The convection heat transfer coefficient between the bearing surface and the oil is  $1500 \text{ W/m}^2\text{k}$ . Determine the centre temperature and the temperature at 1.25 mm from the surface after the bearing has been in the oil for 30 seconds. Also determine the heat lost by the spherical ball during the first half minute  
(b) Determine the heat transfer from a 40 W incandescent bulb at  $125^{\circ}\text{C}$  which is exposed to an air stream at  $29^{\circ}\text{C}$  moving with 0.3 m/sec. The bulb may be treated as a sphere of 50 mm diameter. Determine the heat transfer rate and the percentage of power lost due to convection. The properties of air at the film temperature of  $77^{\circ}\text{C}$  are  $K = 0.03 \text{ W/mk}$ ,  $Pr = 0.697$ ,  $\gamma = 2.08 \times 10^{-5} \text{ m}^2/\text{sec}$ . [8+8]

6. A long cylinder having a diameter of 2 cm is maintained at  $600^{\circ}\text{C}$  and has an emissivity of 0.4. Surrounding the cylinder is another long, thin walled concentric cylinder having a diameter of 6 cm and an emissivity of 0.2 on both the inside and outside surfaces. The assembly is located in a large room having a temperature of  $27^{\circ}\text{C}$ . Calculate the net radiant energy lost by the 2 cm diameter cylinder per meter length. Also calculate the temperature of the 6 cm diameter cylinder. [16]
7. (a) Explain the scope of the study of heat transfer.
- (b) A cubical tank of water of volume  $1\text{ m}^3$  is kept at a steady temperature of  $65^{\circ}\text{C}$  by a 1 kW heater. The heater is switched off. How long does the tank take to cool to  $50^{\circ}\text{C}$  if the room temperature is  $15^{\circ}\text{C}$ . [6+10]
8. (a) Air at  $20^{\circ}\text{C}$  flows over a flat plate with a velocity of 2 m/sec. The size of the plate is  $60\text{cm} \times 30\text{ cm}$ . The plate is maintained at  $100^{\circ}\text{C}$ . Calculate the heat transfer rate from the plate if the air is flowing parallel to 60 cm side. What will be the effect on heat transfer if the flow of air is parallel to 30 cm side?
- (b) Prove that the momentum equation for the boundary layer over a flat plate is given by [8+8]
- $$u \frac{du}{dx} + v \frac{du}{dy} = \gamma \frac{d^2u}{dy^2}$$

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1. Write short notes on following basic laws
  - (a) First law of thermodynamics
  - (b) Second law of thermodynamics
  - (c) Law of conservation of mass
  - (d) Newton's laws of motion. [4+4+4+4]
2. Deduce an expression for temperature distribution and heat transfer under one dimensional steady state conduction with internal heat generation for cylinder. [16]
3.
  - (a) Give a comparison of parallel flow and counter flow heat exchangers. Why are counter flow exchangers are mostly used?
  - (b) Sketch the temperature distribution of hot and cold fluids along the length of heat exchanger for counter flow arrangement and derive the expression for LMTD. [6+10]
4.
  - (a) Plot  $E_{b\lambda} / T^5$  versus  $\lambda T$ . What does the curve signify?
  - (b) Explain the electrical analogy for radiative heat transfer in a black enclosure. Draw the equivalent electrical net work for radiative flux between four walls of a black enclosure. [6+10]
5. Using dimensional analysis establish a relation between Nusselt, prandtl and Grashoff numbers. [16]
6. A vertical tube 12.5 mm diameter and 1.7m long is used for condensing steam at 0.4 bar. The tube surface temperature is maintained at  $54^\circ\text{C}$ . Determine the average heat transfer coefficient in condensation. What would be the value of the heat transfer coefficient if the tube were held in a horizontal position? [16]
7.
  - (a) A large block of steel is initially at  $35^\circ\text{C}$ . The surface temperature is suddenly raised and maintained at  $250^\circ\text{C}$ . Calculate the temperature at a depth of 2.5cm after a time of 30s. The thermal diffusivity and thermal conductivity of steel are  $1.4 \times 10^{-5} \text{m}^2/\text{s}$  and  $45 \text{W/mk}$  respectively.
  - (b) A solid steel, 160mm long cylinder with a 80mm diameter initially at  $800^\circ\text{C}$ , is cooled in a medium which is at a constant temperature of  $30^\circ\text{C}$ . The surface heat transfer coefficient is  $120 \text{W/m}^2\text{k}$ . Determine the centre line temperature at the midpoint of length 30 minuets after cooling is initiated. Take  $\alpha = 0.022 \text{m}^2/\text{hr}$ ,  $k=23.5 \text{W/mk}$ . [8+8]

8. (a) Explain the terms 'hydrodynamic boundary layer' and 'thermal boundary layer', how are these thickness related to Prandtl number.
- (b) Compute the coefficient of heat transfer from a vertical plate of height 2 m to the surrounding still air at  $20^{\circ}\text{C}$  when the plate is maintained at  $100^{\circ}\text{C}$ . Use the following relation
- $$\text{Nu}_L = 0.15(\text{Gr}_L \text{Pr}_L)^n (\text{Pr}/\text{Pr}_s)^{0.25}.$$
- Where all fluid properties except  $\text{Pr}_s$  (Pratsurface) are taken at the ambient temperature. [6+10]

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