K. D.K. College of Engineering, Nagpur

Department of Mechanical Engineering

Subject: - Heat Transfer

Fifth Semester

Assignment No. 1

1) Explain modes of heat transfer and Law of heat conduction.
2) Explain concept of Contact Resistant.
3) Critical thickness of insulation.
4) Derive three dimensional steady state heat conduction equation in Cartesian coordinate
5) Thermal contact Resistance.
6) Explain the different mode of heat transfer with their governing laws.
7) Derive the general heat conduction equation in cylindrical coordinates
8) Draw a neat sketch showing thermal resistances series and parallel. Write expression for heat transfer for both
9) Derive the general heat conduction equation with internal heat generation
10) Explain in brief with example the three modes of Heat Transfer
11) A certain building wall consists of 0.15 m of concrete [K=0.15W/mo C],0.15 m of fiber glass insulation and 10 mm of gypsum board [K=0.15 W/m]. The inside and outside convection coefficients are 10 and 40W/m2o C, respectively. The outside air temperature is -6oC and the inside temperature is 22oC.Calculaye the overall heat transfer coefficient for the wall the R value, and the heat loss per area.
12) A plane wall 80 mm thick (K=0.15 W/mo C) is insulated on one side while the other is exposed to environment at 90oC.The rate of heat generation within the wall is 12X104 W/m3. If the convective heat transfer coefficient between the wall and the environment is 560 W/m2o C, determine the maximum temperature to which the wall will be subjected.
13) A Furnace wall consists of an inside layer of silica brick 15 cm thick. (K=1.744 W/mK) followed by a 30 cm thick later of magnesite brick. (K=5.8 W/mK) on the outside. The inside surface of silica wall is maintained at 780oC while the outside surface magnesite is at 60oC. The contact thermal resistance between tow walls at the interface is 2.57 X 10-3oC/W per unit wall area. What is the rate of heat loss through the composite structure per unit area of the wall? Also find the temperature drop at the interface. Draw a thermal circuit and find total resistance to heat flow.
14) An exterior wall of a house may be approximated by a 0.1 m layer of common brick (k =0.7 W/mo C) followed by a 0.04 m layer of gypsum plaster (k = 0.40 W/mo C). What thickness of loosely packed rock wool insulation (k = 0.065 W/mo C) should be added to reduce the heat loss through the wall by 80%?
15) A wall is constructed of several layers. The first consists of brick (K = 0.66) W/mo K) 25 mm thick, the second layer consists of 2.5 cm thick mortar (K = 0.7 mo K), the third later of 10 cm thick Lime Stone (K = 0.66W/moK) and the outer layer consists of 1.25 cm thick plaster (K = 0.7W/moK). The heat transfer coefficient on the interior and exterior of the wall fluid layer are 5.8W/m2K and 11.6W/m2oK respectively.

Find:-

(a)Overall heat transfer coefficient from the air on the interior to the air at the exterior on the wall.
(b) Overall thermal resistance per m2
(c) The rate of heat transfer per m2 if the interior of the room is 26oC while the outside air is at a temperature of -7oC.
(d) Temperature at the junction between the motor and lime stone.

1) A 2 kW resistance heat wire whose thermal conductivity (K = 15 W/mo C) has a diameter (d= 4 mm) and length of (L = 0.5 m) and is used to boil water. If the outer surface temperature of the resistance heat wire is 105o C, determine centre temperature of wire

2) A carbon steel (K=54 W/mK) rod with a cross section of an equilateral triangle (each side of 5 mm) is cm long. It is attached to plane wall which is maintained at a temperature of 400oC. The surrounding environment is at 50oC and convective heat transfer coefficient is 90 W/m2K. calculate the heat dissipated by the rod

3) A wire of 6.5 mm diameter at a temperature of 60oC is to be insulated by a material having k = 0.174 W/mo C Convection heat transfer coefficient (ho) = 8.722 W/m2oC. The ambient temperature is 20oC. Foe maximum heat loss, what is the minimum thickness of insulation and heat loss per meter length? Also find percentage increase in heat dissipation

4) determine the rate of heat flow through a spherical boiler wall which is 2 m in diameter and 2 m thick steel (k = 58 W/m K). The outside surface of boiler wall is covered with asbestos (k = 0.116 W/m K) 5 mm thick. The temperature of outer surface and that of fluid inside are 50oC and 300oC respectively. Take inner film resistance as 0.0023 K/W

5) Calculate the temperature distribution at the middle and rate of heat floe at the root of a turbine blade 80 mm long, 600 mm2 in C.S. and 159 mm in perimeter. The blade is made of stainless steel (k = 23.3 W/m k) and is exposed to steam at 1000oC. While its root is maintained at 600oC. The heat transfer coefficient between the blade surface steam is 5000 W/m2K.

6) A hot cylinder ingot 50 mm diameter and 200 mm long is taken out from the furnace at 800oC and dipped in water till its temperature fall to 500oc. Then it is directly exposed to air till its temperature falls to 100oC. Find the total time required for the ingot reach the temperature from 800 to 100oC. Take the following:

K = 60 W/mo C, C = 200J/kg o C, p = 800kg/m3

Heat transfer coefficient in water = 200 W/kg m2o C

Heat transfer coefficient in air = 20 W/kg m2o C, Temperature of air = 30o C.

7. What is meant by a lumped capacity? What are the physical assumptions necessary for a lumped-capacity unsteady-state analysis to apply?

8. What is meant by a semi-infinite solid?

9. What initial conditions are imposed on the transient solutions presented in graphical form in this chapter?

10. What boundary conditions are applied to problems in this chapter?

11. Define the error function.

12. Define the Biot and Fourier numbers.

K. D.K. College of Engineering, Nagpur

Department of Mechanical Engineering

<u>Assignment No. 3</u>

1) Water at the rate of 3kg/s is heated from 5 to 15o C by passing it through a 50 mm ID copper tube. The tube wall temperature is maintained at 90oC. What is the length of the tube?

2) Air at 30oC is flowing over 2 cm long plate maintained at 70oC at m/s. Determine heat transfer from the plate.

3) A highly viscous fluid flows through a 5 cm I.D. pipe at rate 50 kg/hr. Fluid passes through 1 m long heated section where a constant flux of 1000 Wm2 is supplied. Calculate the final temperature of liquid if initial temperature is 40oC. Obtain the maximum wall temperature. Assume properties of liquid as,

P = 1500 kg/m3,
Cp = 1.675 kJ/kg K,
ks = 0.865 W/mK.

4) Water at 20oC is to be heated by passing it through the tube. Surface of tube is maintained at 90oC. The diameter of tube is 4 cm while its length is 9 m. Find the mass flow rate so that exit temperature of water will be 60oC. The properties of water are

p = 995 kg/m3
Cp = 4.175 kJ/ kg K,
K = 0.64 W/mK. , V = 0.62 x 10-6 m2/s,
B = 4.25 x 10-3K-1
Use the correlation Nu = 0.023* (Re)0.8. (Pr)0.3

5) In a certain process, castor oil at 30oC flows past a flat plate. The velocity of oil is 0.08 m/sec. The length of the plate is 5 m. The plant is heated uniformly and maintained at 90oC. Calculate the following:

(i) Hydrodynamic and thermal boundary layer thickness at the trailing edge of plate.
(ii) Total drag force per unit width on one side of the plate.

Use the following correlation:
Nu = 0.332 (Rel)1/2 . (Pr)1/3
Take properties as,
P = 956.8 kg/m3 , k = 0.213 W/ mo K,
a = 7.2 x 10-8 m2 /s
v = 0.65 x 10-4 m2 /s

6) Explain boundary layer concept and define Hydrodynamic and thermal boundary layer with reference to flow over flow heated plate.

7) What do you mean by Lumped heat capacity analysis State the significance of Heisler chart.

8) In a certain process, castor oil at 30oC flows past a flat plate. The velocity of oil is 0.08 m/sec. The length of the plate is 5 m. The plate is heated uniformly and maintained at 90oC.

Calculate the following

(a) Hydrodynamic and Thermal Boundary layer thickness at the trailing edge of plate.
(b) Total drag force per unit width on one side of the plate Use following correlation:-

Nu = 0.332 (Rel)1/2 (Pr)1/3
Take properties as,
p = 956.8kg/m3, k = 0.2132 W/mo K, a = 7.2 X 10-8m2/s, v = 0.65 X 10-4m2/s

9) Air at 16oC pressure of 1 bar is flowing over a plate at a velocity of 3 m/s. If the plate is 30 cm wide and at 60oC, using exact method at x=30 cm at the distance corresponding to the transition point, Find the following:

(1) Boundary layer thickness
(2) Average friction coefficient
(3) Shearing stress due to friction
(4) Average convection heat transfer coefficient
(5) Total drag force on the plate

Take properties at Bulk mean temperature as,
P = 1.1374 kg/m3 k = 2.732 X 10-2 W/mo C
Cp = 1.005 kJ/ kg o K v = 16.x 10-6 m2/sec

Use correlation as, $pr = 0.7$

$Nu = 0.332 (Re_x)^{1/2}. (Pr)^{1/3}$

10) Explain the following Dimensionless number and their physical significance:

(i) Reynolds number

(ii) Prandtl number

(iii) Nusselt number

11) In a particular solar collector of cylindrical type, energy is collector by placing a tube at the focal line of parabolic collector and passing fluid through the tube. The arrangement resulting is a uniform heat flux of 2000 W/m^2 along the axis of the tube of diameter 60 mm. Determine:

(i) Length of the tube required to the heat water from 20^oC to 80^oC which flows at the rate of 0.01 kg/s.

(ii) Surface temperature at the outlet

Properties of water are:

$u = 352 \times 10^{-6}$ Ns/ m^2 , Cp = 4187 J/kg K

k = 0.67 W/m K.

12) Air at a velocity of 3 m/s and at 29^oC flows over a flat plate along its length. The length, width and thickness of the plate are 100 cm and 50 cm respectively. The top surface of the plate is maintained at 100^oC. Calculate the heat loss by the plate and steady state conditions. The thermal conductivity of the plate may taken as 23 W/mK.

(b) Write short notes on (any two):

(i) Biot number and Fourier and their significance.

(ii) Hydrodynamic and Thermal boundary layer

(iii) Lumped heat capacity and Heisler charts.

13) Air at a velocity of 3 m/sec and 20^oC flows over a flat plate along its length. The length, width and thickness of the plate are 100 cm, 50 cm and 2 cm respectively. The top surface of the plate is maintained at 100^oC. Calculate the heat loss by the plate and bottom temperature of the plate for the steady state condition. Conductivity of the plate may be taken at 23 W/m^o K.

K. D.K. College of Engineering, Nagpur

Department of Mechanical Engineering

Assignment No. 4

1) Sketch temperature and velocity profiles in free convection on a vertical wall:-

i) When the plate is being cooled.

ii) When the plate is heated

2)Calculate the heat transfer from a 60 W incandescent bulb at 115oC to ambient air 25oC. Assume the bulb as a sphere of 50 mm diameter. Also find the percentage of power lost by free convection.

3) Explain briefly the various regions in boiling heat transfer.

4) A vertical tube of 60 mm outside diameter and 2.2 m long is exposed to steam at atmospheric pressure. The outer surface of the tube is maintained at a temperature of 50oC by circulating cold water through the tube. Calculate-i) Rate of heat transfer to the coolant.ii) Rate of condensation of steam.

Take properties as:-

P = 975kg/m3 , u l = 375 X 10-6 , N-S/m2

K = 0.67 W/mo C , p v = 0.59kg/m3.

h fg = 2257 kJ /kg.

5) A2 – stroke cycle petrol engine cylinder consists of 16 fins. If the surface temp. is 475oC and atmospheric air temperature is 25oC, calculate the heat transfer rate from the fins for the following cases :

(a) When the motor cycle is stationary.

(b) When the motor cycle is running at a speed of 60 km/h.

The fin may be idealized as single horizontal flat plate of the same area.

Properties of air at 250oC

K = 4.266 X 10-2 W/mo C , v = 40.61 X 10-6 m2/s Pr = 0.677

Use correlations :

Nu = 0.54 [Gr . Pr]0.25 for laminar flow

Nu = 0.036 [re]0.8 [Pr]0.33 for turbulent flow.

6)A steam condenser consisting of a square array of 625 horizontal tubes, each 6 mm in diameter, is installed at the exhaust of a steam turbine. The tubes are exposed to saturated of a pressure of 15 kPa. If the tube surface temperature is maintained at 25oC, calculate :

i) The heat transfer coefficient and

ii) the rate at which steam is condensed per unit length of the tubes.

Assume film condensation on the tubes and absence of non-condensable gases.

Properties of saturated water at film temperature are

P = 992 kg/m3 , u = 663 X 10-6 Ns/m2 , k = 0.0631 W/mo C.

7) What is the significance of Grashof’s Number and Rayleigh Number.

8) Explain with neat sketch the pool boiling carve and Regime of pool boiling.

9) A hot plate of 40 cm in height and 70 cm wide at 150oC is exposed to the air at 30oC. Calculate the following:-

(i) Maximum velocity at 30 cm from the leading edge of the plant.

(ii) Mean velocity at 30 cm from the leading edge.

(iii) Boundary layer transfer thickness at 30 cm from the leading edge.

(iv) Local heat transfer coefficient at 30 cm from the leading edge.

(v) Average heat transfer coefficient.

(vi) Total mass flow through the boundary.

(vii) Total heat loss from the side of the plant.

(viii) Rise in temperature of the air passing the boundary.

(ix) Total drag force on the plant.

10) State the effect of non-condensable gases on condensation.

11) Explain with neat sketch development of velocity boundary layer on hot and cold vertical plate subjected to Natural Convection.

12) A horizontal fluorescent tube which is 3.8 cm in diameter and 120 cm long stands in still air at 1 atm. and 20oC. If the surface temperature of the tube is 40oC and radiation is neglected, what percentage of power is being dissipated by convection? Take properties of air as v = 16.19 X 10-6 m2/sec., K air = 0.02652 W/mk, Pr = 0.706, p = 1.02 kg/m3 , Cp = 1.004 kJ/kg K

Use relation N uD = 0.53 [R aD]1/4

13)Air flow through a long rectangular (30 cm height X 65 cm width) air conditioning the outer duct surface temperature at 15oC. If the duct is insulated and exposed to air at 25oC, calculate the heat gained by the duct per meter length assuming it to be horizontal. Use the following co-relation:

Vertical surface = NuL = 0.59 (RaL)1/4

Upper surface heated lower surface

Cooled – NuL = 0.54 (RaL)1/4

Lower surface heated or upper surface

Cooled – NuL = (RaL) ¼

Taking the following properties of air:

p = 1.205kg/m3 ; Cp = 1005 J/kgo K

u = 15 X 10-6m2/sec ; K = 0.02593 w/mk

14) Saturated F-12 vapour at 12.3/bar condenses on the outside of a bank of horizontal tubes 1 cm OD arranged in 5X5 square array. Calculate the rate of condensation per meter length of the array if the tube surface is maintained at 40oC.

F-12 has following properties:-

Liquid density = 1218kg/m3 ,Latent heat = 128.12kJ/kg,Liquid K = 0.0686 W/mo K,Liquid u = 2.84 X 10-6kg/m-s.

Saturation temperature at 12.3/bar = 48.9o C

15)A vertical plate is heated from one side and is maintained at 96oC. On the other side is air at 30oC. Calculate:-

(i) Local value of convective Heat Transfer coefficients at distance of 20 cm from the lower edge.

(ii) Average value of convective Heat transfer coefficient over the whole 20 cm length of plate.

16) A steel plate 20 cm2 and 0.5 cm thick heated uniformly to 430oC and is kept vertically in still air at a temperature of 20oC. Neglecting radiation or making suitable assumption. Calculate time required for the plate to cool at 330oC.

17) Explain in brief Heat Pipe.

K. D.K. College of Engineering, Nagpur

Department of Mechanical Engineering

Assignment No. 5

1) A double walled flask may be idealized be idealized to be equivalent to two infinite parallel plates. The emissivities of wall are 0.3 and 0.7 respectively. The space between them is evacuated A shied of polished Aluminium of € = 0.05 is inserted between tem. Find the reduction in hest transfer rate due to insertion of radiation shield.

2) Explain the following:

(i) Kirchhoff's law of radiation,

(ii) Wien's displacement law,

iii)Shape factor

3)Explain shape factor and calculate the shape factor for a cylindrical cavity of diameter D and height L with respect to itself.

4)An industrial furnace in the from of a black body emits radiation at 3000oK calculate:-

i) Monochromatic emissive power at 1 um wavelength.

ii) Wavelength at which the emission is maximum.

iii) Maximum emissive power

5)The net radiation from the surface of two parallel plates maintained at T1 and T2 is to be reduced by 99%. Calculate the number of screens to be placed between the two surface to achieve this reduction in heat exchanger assuming the emissivities of the screens as 0.05 and that of surface as 0.8

6) Two parallel square plates, each 4m2 area are large, compared to a gap of 5 mm separating them. One plate has a temperature of 800oK and surface emissivities of 0.6, while the other has a temperature of 300oK and surface emissivities of 0.9 find the net energy exchange by radiation between the plates. If a thin polished metal sheet of surface emissivities 0.1 on both sides is now located centrally between the two plates, what will be its steady state temperature? How the heat transfer would be altered? Neglect the convection and edge effects, if any. Comment upon the significance of this exercise

7) An enclosure measures 1.5 X 1.7m with a height of 2 m. The walls and ceiling are maintained at 250oC and the floor at 130oC. The walls and ceiling have an emissivity of 0.82 and the floor 0.7. Determine the net radiation to the floor.

8) Two very large parallel planes with emissivities 0.3 and 0.8 exchanger radiative energy. Determine the percentage reduction in radiative energy transfer when a polished aluminum radiation shield (€ = 0.04) is placed between them.

9)Determine the net radiation heat exchanger between two surfaces:-

A1 = (€1 = 0.8, T1 = 1000 K)

A2 = (€2 = 1.0, T2 = 500 K)

Neglect radiation from the surrounding. Take Shape factor F12 = 0.22

10)Liquid oxygen at atmospheric pressure (normal boiling point -180oC) is to be stored in a cylinder container which can be considered as a sphere of 0.3 m outer diameter. The system is insulated by enclosing the container inside another concentric sphere of 0.45 m diameter with intermediate space evacuated. Both the sphere surfaces are made of Aluminium (€ = 0.3). The outer sphere has a temperature of 40oC. Estimate the rate of heat transfer flow by radiation to oxygen. What will be the reduction in heat gained if polished Aluminium with emmissivity of 0.03 is used?

K. D.K. College of Engineering, Nagpur

Department of Mechanical Engineering

<u>Assignment No. 6</u>

1) A parallel flow of heat transfer uses 1500 kg/hr of cold water entering at 25oC to cool 600 kg/hr of Hot water at 70oC. The exit temperature on hot side is required to be 59oC. Neglecting the effects of fouling factor, calculate the area of Heat exchanger. If may be assumed that the individual Heat Transfer coefficient on both sides are 1600 W/m2K Use mean temperature difference and NTU approach separately. Also calculate the exit temperature of hot and cold steam if the flow of hot water is doubled, i.e. 1200 kg/hr. It has been stated that individual Heat Transfer coefficient are proportional to 0.8th power of the flow rate. Take Cp = 4180J/kgK.

2) In an oil cooler, oil enters at 160oC. If water entering at 35oC flows parallel to oil, the exit temperature of oil and water are 90oC and 70oC respectively. Determine the exit temperature of oil and water if the two fluids flow in opposite directions. Assume that the flow rates of the two fluids and Uo remain unaltered. What would be the minimum temperature to which oil could be cooled in parallel flow and counter-flow operations?

3) A tubular heat exchanger consists of 1200 tube each 20 mm OD and 5m length. Hot fluid flows inside the tube and cold over it but in opposite direction to hot fluid. The overall heat transfer coefficient based on OD is 320 W/m2 K. Determine the outlet temperatures of both fluids and total heat transfer. Given, Thi = 120oC , Tci = 20oC ,mh = 20 kg/s , mc = 5 kg/s, Cpc = 4000 J/kg K, Cph = 2000 J/kg K.

4) A shell and tube type steam condenser, employed in a large steam power plant, effects a heat exchange rate of 2200 MW. The condenser of a single pass shell and 32000 tubes, each exceeding two passes. The water at the rate of 3.2 X 104 kg/sec passes through the tubes which are of thin wall and of diameter 30 m. the steam condenser on the outer surface on the tubes. The heat transfer coefficient on the steam side may be taken as 11500 W/m2oK. Steam condenses at 50oC while water enters the condenser at 20oC. Using LMTD correction factor method and NTU method, calculate the following:-(i) Outlet temperature of cooling water.(ii) Length of tube per pass, Take following properties of water: Cp = 4.18 kJ/ kgo K ,,u = 855 X 10-6 N-sec/m2,K = 0.613 W/mo K, Pr = 5.83.

5) A counter flow heat exchanger is employed to cool 0.55 kg/s (Cp = 2.45 kJ/kgo C) of oil from 155oC to 40oC by the use of water. The inlet and outlet temperature of cooling water are 15oC and 75o C respectively. The overall heat transfer coefficient is expected to be 1450 W/m2o C. Using NTU method calculate the following :i) The mass flow rate of water

ii) The effectiveness of heat exchanger, iii) The surface area required.

6) An oil cooler of the from tubular heat exchanger cools oil from a temperature of 85oC to 35oC by a large pool of stagnant water assumed at constant temperature of 25oC. The tube carrying oil is 35 m long and 25 mm inside diameter. The specific heat and specific gravity of oil are 2.51 kJ/kg oK and 0.8 respectively. The average velocity of the oil is 60 cm/sec. Estimate the overall heat transfer coefficient obtained from the system

7) Cold water at 1495 kg/h enters at 25oC through a parallel flow heat exchanger to cool 605 kg/h of hot water entering at 70oC and leaving at 50oC. Find the area of heat exchanger. The individual heat transfer coefficients on both sides are 1590 W/m2K. Use LMTD and NTU method. Find also the exit temperature of cold and hot fluid streams, if the flow of hot water is doubled. Assume that the individual heat transfer coefficients are proportional to 0.8th power of the flow rate.

For water Cp = 4180 J/kg K.

8) In an industry, 0.6 hg/sec of oil, (Cp = 2.5kJ/kgoK) is to be cooled in a counter flow heat exchanger from 110oC to 35oC by the use of water entering at 20oC. The overall heat transfer coefficient is expected to be 1500 W/m2oK. Presume that the exit temperature of water is not to exceed 80oC.Using NTU Method, calculate,

(1) Water flow rate, (2) Surface area required,

(3) Effectiveness of exchanger

9) The flow rates of hot and cold water streams running through a parallel flow heat exchanger are 0.2 kg/sec and 0.5 kg/sec respectively. The inlet temperatures on the hot and cold side are 75oC and 20oC respectively. The exit temperature of hot water is 45oC. If the individual heat transfer coefficients on both sides are 650 W/m2oC, calculate area of heat exchanger.

10)) In a food processing plant a brine solution is heated from 6oC to 12oC in a double pipe that exchanger by water entering at 50oC and leaving at 40oC at the rate of 0.166 kg/s. if the overall hate transfer coefficient is 850 W/m2, what heat exchanger area is required for

i) Parallel flow

ii) Counter flow.

11. Define the overall heat-transfer coefficient.

12. What is a fouling factor?

13. Why does a “mixed” or “unmixed” fluid arrangement influence heat-exchanger performance?

14. When is the LMTD method most applicable to heat-exchanger calculations?

15. Define effectiveness.

16. What advantage does the effectiveness-NTU method have over the LMTD method?

17. What is meant by the “minimum” fluid?

18. Why is a counterflow exchanger more effective than a parallel-flow exchanger?