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P.E.S. College of Engineering, Mandya - 571 401

(An Autonomous Institution affiliated to VTU, Belgaum)

Fifth Semester, B.E. - Automobile Engineering

Semester End Examination; Dec - 2016/Jan - 2017

Heat Transfer

Time: 3 hrs *Max. Marks: 100*

***Note**: i) Answer **FIVE** full questions, selecting **ONE** full question from each unit.*

ii) Assume suitable missing data, if any.

iii) Use of Heat transfer hand book is permitted.

UNIT - I

1 a. State and explain the modes of heat transfer with governing laws and equations. 12

b. A 10 cm diameter copper ball is to be heated from 100ºC to an average temperature of 150ºC in 30 minutes. Taking the average density and specific heat of copper, in the temperature range to be ρ = 8950 kg/m^3, and C_p = 0.395 kJ/kgºC respectively. Determine; 8

i) The total amount of heat transfer to the copper ball

ii) The average rate of heat transfer to the ball

iii) The average heat flux.

2 a. Derive a one-dimensional, time dependent heat conduction equation in rectangular coordinates. Also get the expression for constant thermal conductivity and steady state. 12

b. With sketches, write down the mathematical representation of boundary condition 2nd and 3rd kind for one-dimensional heat conduction in rectangular coordinates. 8

UNIT - II

3 a. Derive an expression for the critical radius appropriate for the insulation of a cylinder. 8

b. A steel tube with 50 mm inside diameter, 76 mm outside diameter and thermal conductivity 15 W/m.K is covered with an insulative covering of thickness 20 mm and thermal conductivity 0.2 W/m.K. A hot gas at temperature of 330ºC and heat transfer coefficient of 400 W/m^2.K flows inside the tube. The outer surface of the insulation is exposed to cooler air at 30ºC and heat transfer coefficient of 60 W/m^2.K. 12

i) Calculate the heat loss from the tube to the air for 10 m length of the tube

ii) Calculate the temperature drop resulting from the thermal resistances of the hot gas flow, the steel tube, insulation layer and the outside air.

4 a. Starting from the general 1-D fin equation, derive an expression for heat transfer rate through a circular fin of uniform cross-section assuming it to be a long fin. 8

Contd…2

b. Fins, 12 in number with tips insulated, having thermal conductivity 75 W/m.K and 0.75 mm thickness protrude 25 mm from a cylindrical surface of 50 mm diameter and 1m length placed in an atmosphere of 40º. If the cylindrical surface is maintained at 150ºC and the heat transfer coefficient is 23 $W/m^2.K$. Calculate;

i) The rate of heat transfer by the fins 12

ii) The percentage increases in heat transfer due to fins

iii) The temperature at the centre of fins

iv) The fin efficiency

v) The fin effectiveness.

UNIT - III

5 a. What is lumped system analysis? When it is applicable? What is the physical significance of Biot Number? 6

b. A solid iron rod [k = 60 W/m.K, ρ = 7280 kg/m^3, C_p = 410 J/kg.K and $\alpha = 2x10^{-5}$ m^2/s] of 6 cm diameter initially at temperature 800ºC, is suddenly dropped into an oil bath at 50ºC. The heat transfer coefficient between the fluid and the surface is 400 $W/m^2.K$. Using the transient temperature charts, determine; 14

i) The centerline temperature 10 min after immersion in the fluid

ii) The temperature at a depth of 2 cm from the surface 10 min after immersion in the fluid

iii) The energy removed from the rod during this period.

6 a. Define the following dimensionless numbers. Also give their physical significance, 9

i) Reynolds number ii) Prandtl number iii) Nusselt number.

b. A horizontal pipe 0.3 m in diameter is maintained at a temperature of 245ºC in a room where the ambient air is at 15ºC. Calculate the free convection heat loss per meter length of the pipe. Take the properties of air at the bulk mean temperature of 130ºC as, 11

[k = $34.14x10^{-3}$ W/m.K, v = $26.63x10^{-6}$ m^2/s and P_r = 0.685].

UNIT - IV

7 a. Distinguish between hydrodynamic and thermal boundary layers. 8

b. Air at 20ºC and at atmospheric pressure flows over a flat plate at a velocity of 3 m/s. The plate is 0.3 m long and at 60°C. The properties of air at the bulk mean temperature of 40º are [k = 0.02756 W/m.K, C_p = 1005 J/kg.K, ρ = 1.128 kg/m^3, v = $19.96x10^{-6}$ m^2/s and P_r = 0.699]. Calculate ;

i) Velocity and thermal boundary layer thickness at 0.2 from the leading edge 12

ii) Local and average friction coefficient

iii) Average heat transfer coefficient

iv) Rate of heat transfer by convection

v) Total drag force on the plate per unit width

Contd…3

8 a. Briefly explain the classification of heat exchanges by flow arrangement. 8

b. A two-shell pass, four tube pass heat exchanger has water on the shell and brine on the tube side Water is cooled from 18ºC and 6ºC with brine entering at -1ºC and leaving at 3ºC. The overall heat transfer coefficient at 600 $W/m^2.K$. Calculate the heat transfer area required for a design heat load of 24 kW. 12

UNIT - V

9 a. State: 10

i) Kirchhoff's law ii) Planck's law iii) Steffan-Botzmann law.

b. Two large parallel are at 700º C and 500º C. Determine the rate of heat exchange per unit area when, 10

i) The surfaces are black

ii) The hot surface has an emissivity of 0.9 and the cold surface has an emissivity of 0.6

iii) A large plate of emissivity 0.1 is inserted between them. Also find the percentage of reduction in heat transfer because of introduction of the large plate.

10 a. Derive an expression for the radiant heat exchange between two infinite parallel grey surfaces. 10

b. Define intensity of radiation and solid angle 4

c. Show that the emissive power of a black body is π - times the intensity of emitted radiation. 6

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