Total No. of Questions : 12]

SEAT No. :

P2256

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T.E. (Mechanical) (Common to Mech S/W, Automobile)

HEAT TRANSFER

(2008 Course) (302042)

Time : 3 Hours] *[Max. Marks : 100*

Instructions to the candidates:

1) *Answer 3 questions from Section I and 3 questions from Section II.*
2) *Answer to the Two Sections should be written in separate answer books.*
3) *Draw Neat diagrams wherever necessary.*
4) *Assume suitable data wherever necessary.*
5) *Figures to the right indicate full marks.*

SECTION - I

Q1) a) Explain the following: **[6]**

i) Fourier's Law of heat conduction,

ii) Newton's Law of cooling

iii) Stefan Boltzmann's Law of radiation

b) Differentiate between **[8]**

i) Conduction and Convection

ii) Isotropic and anisotropic materials

c) A 5 cm diameter steel pipe maintained at a temperature of 60 °C is kept in a large room where the air and wall temperatures are 25 °C. If the surface emissivity of steel is 0.85, calculate the total heat loss per unit length, if the convective heat transfer coefficient is 6.5 $W/m^2 °C$, **[4]**

OR

Q2) a) A furnace wall lining is made up of a material with k = 2.5 W/mK. The temperatures of the inner and outer surfaces of this plane wall lining are 810 °C and 330 °C respectively. the outer surface is exposed to ambient air at 30 °C with convective heat transfer coefficient = 10 W/m^2K. **[9]**

Calculate:

i) The rate of heat flow per unit area

ii) Thickness of lining in given situation.

iii) The thickness of lining required if the heat flow rate is to be reduced by 50%.

b) Explain Electrical analogy of heat transfer. **[5]**

c) Write a note on variation of thermal conductivity for metals. **[4]**

Q3) a) Derive the expression for critical radius of insulation for a cylinder with usual notations. **[8]**

b) A steel tube with 5 cm ID and 7cm OD(k = 28 W/mK) is covered with an insulation covering of thickness 15mm (k = 0.2 W/m °C). A hot gas at a temperature of 400 °C with convective heat transfer coefficient of 300 W/m^2K flows inside the tube. The outer surface of insulation is exposed to cold air at –5°C with h = 20 W/m^2K. Calculate the heat flow rate from the pipe and the interface temperature between steel and insulation. **[8]**

OR

Q4) a) Write a note on Thermal contact resistance. **[4]**

b) Nichrome having a resistivity of 100 $\mu\Omega$ cm is to be used as a heating element in a 10 kW heater. The nichrome surface temperature should not exceed 1220 °C. Other design features include, surrounding air temperature as 20 °C, Outside surface coefficient = 1150 W/m^2K, thermal conductivity of nichrome as 17 W/mK. Find out the diameter of nichrome wire necessary for a 1 m long heater. Also find the rate of current flow. **[8]**

c) Explain why the concept of critical radius in not applicable for plane wall? **[4]**

Q5) a) Starting from the boundary conditions, derive the expressions for temperature distribution along the length and heat flow rate for a very long fin using standard notations. **[8]**

b) A centrifugal pump which circulates a hot liquid metal at 500 °C is driven by a 3600 rpm electric motor. The motor is coupled to the pump impeller by a horizontal steel shaft 25mm in diameter. If the temperature of the motor is limited to a maximum value of 60 °C with the ambient air at 25 °C, what length of the shaft should be specified between the motor and the pump. Assume k = 35 W/mK for shaft material and h = 15.7 W/m^2K. Consider insulated tip condition for fin analysis. **[8]**

OR

Q6) a) Derive the expression for Lumped heat capacity with usual notations. **[8]**

b) A solid brass sphere 20 cm diameter initially at a temperature of 200 °C is suddenly exposed to air stream at –10 °C with a convection heat transfer coefficient of 50 W/m^2K. Find the time required by the sphere to attain the temperature of 0 °C. If the brass sphere is replaced by copper sphere, what percent increase or decrease in time will occur to attain the same temperature of 0 °C. Properties are **[8]**

i) Copper : ρ = 7670 kg/m^3, C = 372 J/kg °C, k = 370 W/mK

ii) Brass : ρ = 8552 kg/m^3, C = 385 J/kg °C, k = 100 W/mK

SECTION - II

Q7) a) Explain in brief following terms: **[8]**

i) Black surface,

ii) Radiation shape factor,

iii) Intensity of radiation,

iv) Reflectivity of surface.

b) Two large parallel plates are maintained at temperatures of 600 °C and 300 °C having their emissivities of 0.9 and 0.4 respectively. A radiation shield having emissivity of 0.02 is inserted in between them.

Calculate **[8]**

i) Heat transfer rate without shield,

ii) Heat transfer rate with shield and

iii) Temperature of shield.

OR

Q8) a) Write note on Radiation shield. **[8]**

b) Consider a black body at a temperature of 2000 K. Calculate its total hemispherical emissive power. Also calculate the wavelength at which the maximum emissive power is available from this body.

State and explain the laws of radiation which you have used to calculate the above mentioned quantities. **[8]**

Q9) a) Explain Velocity and Thermal boundary layer. **[8]**

b) Water at 3000 kg/hr is heated from 30 ºC to 70 ºC by pumping it through a heated pipe. Diameter of tube is 25mm and its surface temperature is 110 ºC. Estimate the length of the tube and the rate of heat transfer from tube to water.

Use $Nu = 0.023\ (Re)^{0.8}\ (Pr)^{0.4}$

Thermophysical properties of water at 50 ºC are

$\rho = 972\ kg/m^3$, $\mu = 355 \times 10^{-6}\ Ns/m^2$, $k = 0.667\ W/mK$,

$Cp = 4187\ J/kgK$. **[8]**

OR

Q10) a) Identify the characteristic dimension for following cases in Natural convection. **[4]**

i) Vertical cylinder,

ii) Horizontal cylinder,

iii) Horizontal plate,

iv) Sphere.

b) Define and explain the significance of Prandtl number and Grashof number. **[4]**

c) A horizontal cylinder rod of 4 cm diameter and 60 cm length is initially at a temperature of 124 ºC. Calculate the rate of heat loss from it, if it is exposed to still water at 30 ºC. **[8]**

Use, $Nu = 0.53\ Ra^{1/4}$ for $10^4 < Ra < 10^9$

$Nu = 0.13\ Ra^{1/3}$ for $10^9 < Ra < 10^{12}$.

Properties of water are $\rho = 937.7\ kg/m^3$, $\mu = 3.72 \times 10^{-4}\ Ns/m^2$, $k = 0.668\ W/mK$, $Cp = 4191\ J/kgK$, $\beta = 6.286 \times 10^{-4}$ per K

Q11) a) A counter flow concentric tube heat exchanger is used to cool engine oil (C = 2130 J/kgK) from 160 ºC to 60 ºC with water (C = 4186 J/kgK) available at 25 ºC as the cooling medium. The flow rate of cooling water through the inner tube of 0.5m in diameter is 2 kg/s while the flow rate of oil through the outer annulus O.D. = 0.7 m is also 2 kg/s. If the value of the overall heat transfer coefficient is 250 W/m^{2}K, how long must be the heat exchanger to meet its cooling requirement. **[8]**

b) Derive the expression of LMTD for counter flow heat exchanger with usual notations. **[8]**

c) Explain significance of NTU. **[2]**

OR

Q12) a) Write a note on Regimes of Pool boiling. What is the significance of critical heat flux? **[10]**

b) A chemical having specific heat of 3.3 kJ/kg K flowing at the rate of 20,000 kg/hr enters a parallel flow heat exchanger at 120 ºC. The flow rate of cooling water is 50,000 kg/hr with an inlet temperature of 20 ºC. The heat transfer area is 10 m^2 and overall heat transfer coefficient is 1200 W/m^2 ºC. **[8]**

Taking specific heat of water as 4.186 kJ/kgK, find

i) Effectiveness of heat exchanger

ii) Outlet temperature of water and chemical.

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