Answer ALL questions in Module I and II
Answer ONE out of two questions in Modules III, IV and V
All Questions Carry Equal Marks
All parts of the question must be answered in one place only

## MODULE - I

1. (a) Derive the expression for general three dimensional heat conduction equation in cartesian coordinate system.
[BL: Understand| CO: 1|Marks: 7]
(b) A furnace wall is composed of 220 mm of fire brick, 150 mm of common brick, 50 mm of $85 \%$ magnesia and 3 mm of steel plate of the outside. If the inside surface temperature is $1500^{\circ} \mathrm{C}$ and outside surface temperature is $90^{\circ} \mathrm{C}$, estimate the temperatures between layers and calculate the heat loss in $W / m^{2}$ Assume, k (for fire bricks) $=4 W / m K, \mathrm{k}($ for common brick $)=2.8 W / m K, \mathrm{k}($ for $85 \%$ magnesia) $=0.24 \mathrm{~W} / \mathrm{mK}$, and $k($ steel $)=240 \mathrm{~W} / \mathrm{mK}$
[BL: Apply| CO: 1|Marks: 7]

## MODULE - II

2. (a) Explain the following terms with neat sketches
i) Thermal boundary layer
ii) Hydrodynamic boundary layer
[BL: Understand| CO: 2|Marks: 7]
(b) Air is flowing over a flat plate 5 m long and 2.5 m wide with a velocity of $4 \mathrm{~m} / \mathrm{s}$ at $15^{\circ} \mathrm{C}$. if density $=1.208 \mathrm{~kg} / \mathrm{m}^{3}$ and viscosity $=1.47 \times 10^{-5} \mathrm{~m}^{2} / \mathrm{s}$, calculate
i) Length of plate over which the boundary layer is laminar and thickness of the boundary layer (laminar)
ii) Shear stress at the location where boundary layer ceases to be laminar
iii) Total drag force on the both sides on that portion of plate where boundary layer is laminar [BL: Apply| CO: 2|Marks: 7]

## MODULE - III

3. (a) With neat schematic elaborate boiling regimes. Highlight the engineering applications of boiling and the factors affecting nucleate boiling.
[BL: Understand| CO: 3|Marks: 7]
(b) A vertical tube of 60 mm outside diameter and 1.2 m long is exposed to steam at atmospheric pressure. The outer surface of the tube is maintained at a temperature of $50^{\circ} \mathrm{C}$ by circulating cold water through the tube. Calculate the following.
i) The rate of heat transfer to the coolant
ii) The rate of condensation of steam
[BL: Apply| CO: 3|Marks: 7]
4. (a) Determine an expression for LMTD for counter flow heat exchanger. Also, state the assumptions made.
[BL: Understand| CO: $4 \mid$ Marks: 7]
(b) A counter flow double pipe heat exchanger using superheated steam to heat water at the rate of $10500 \mathrm{~kg} / \mathrm{h}$. The steam enters the heat exchanger at $180^{\circ} \mathrm{C}$ and leave at $130^{\circ} \mathrm{C}$. The inlet and exit temperatures of water are $30^{\circ} \mathrm{C}$ and $80^{\circ} \mathrm{C}$ respectively. If overall heat transfer coefficient from steam to water is $814 W / m^{2 \circ} C$, calculate the heat transfer area, What would be the increase in area if the fluid flows were parallel?
[BL: Apply| CO: 4|Marks: 7]

## MODULE - IV

5. (a) Summarize the following terms
i) Stefan-Boltzman law
ii) Black body and grey body
iii) Kirchhoff's law
[BL: Understand| CO: 5|Marks: 7]
(b) Calculate the net radiant heat exchange per $m^{2}$ area for two large parallel plates at temperatures of $427^{\circ} \mathrm{C}$ and $27^{\circ} \mathrm{C}$ respectively. $\epsilon$ (hot plate) $=0.9$ and $\epsilon$ (cold plate) $=0.6$. if a polished aluminum shield is placed between them, find the percentage reduction in the heat transfer; $\epsilon($ shield $)=0.4$.
[BL: Apply| CO: 5|Marks: 7]
6. (a) Discuss the following terms
i) Wein's displacement law
ii) Lambert's cosine law
iii) Planck's law
[BL: Understand| CO: 5|Marks: 7]
(b) Two large parallel plates with $\epsilon=0.5$ each, are maintained at different temperatures and are exchanging heat only by radiation. Two equally large radiation shields with surface emissivity 0.05 are introduced in parallel to the plates. Find the percentage reduction in net radiative heat transfer.
[BL: Apply| CO: 5|Marks: 7]

## MODULE - V

7. (a) State Fix's law of diffusion. With suitable example, explain modes of mass transfer.
[BL: Understand| CO: 6|Marks: 7]
(b) Hydrogen gas at $25^{\circ} \mathrm{C}$ and 2.5 atmosphere, flows through a rubber tubing of 12 mm inside radius and 24 mm outside radius. The binary diffusion coefficient of hydrogen is $2.1 \times 10^{-8} \mathrm{~m}^{2} / \mathrm{s}$ and the solubility of hydrogen is $0.055 m^{3}$ of hydrogen per $m^{3}$ of rubber at 1 atmosphere. If the gas constant for hydrogen is $4160 \mathrm{~J} / \mathrm{kgK}$ and the concentration of hydrogen at the outer surface of tubing is negligible, calculate the diffusion flux of hydrogen per meter length of rubber tubing.
[BL: Apply| CO: 6|Marks: 7]
8. (a) Derive expression for general mass diffusion equation in stationary media
[BL: Understand| CO: 6|Marks: 7]
(b) An open tank 5.5 m in diameter contains 1 mm deep layer of benzene (molecular weight=78) at its bottom. The vapour pressure of benzene in the tank is 0.13 bar. The diffusion of benzene takes place through a stagnant air film 2.8 mm thick. The system is operating at 1 atm and 20 ${ }^{\circ} \mathrm{C}$ and under these conditions the diffusivity of benzene is $8.3 \times 10^{-6} \mathrm{~m}^{2} / \mathrm{s}$. Assuming the density of benzene as $880 \mathrm{~kg} / \mathrm{m}^{3}$, calculate the time taken for the entire benzene to evaporate.
[BL: Apply| CO: 6|Marks: 7]

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