ME8593-HEAT AND MASS TRANSFER

UNIVERSITY TWO MARKS Q&A

UNIT: I -

CONDUCTION

1. State Fourier's Law of conduction. (April/May 2011, Nov/Dec 14, Nov/Dec 16)

The rate of heat conduction is proportional to the area measured – normal to the direction of heat flow and to the temperature gradient in that direction.

$$Q \propto -A\frac{dt}{dx}$$

$$Q = -KA\frac{dt}{dx}$$

Where, A are in m²

$\frac{dt}{dx}$ is temperature gradient in K/m

K is Thermal Conductivity W/mk

2. State Newton's law of cooling or convection law. (May/June 2009)

Heat transfer by convection is given by Newton's law of cooling

$$Q = hA\,(Ts - T_\infty)$$

Where A – Area exposed to heat transfer in m^2 , h - heat transfer coefficient in W/m^2K

T_s – Temperature of the surface in K, T_∞ - Temperature of the fluid in K.

3. Define overall heat transfer co-efficient. (May/June 2007)

The overall heat transfer by combined modes is usually expressed in terms of an overall conductance or overall heat transfer co-efficient 'U'.

Heat transfer Q = UA ΔT.

4. Write down the equation for heat transfer through composite pipes or cylinder. (April/ May 2008)

$$\text{Heat transfer } Q = \frac{\Delta T overall}{R} \text{ where } \Delta T = Ta - Tb$$

$$R = \frac{1}{2\pi L}\cdot\frac{1}{h_a r_1} + \frac{ln\left[\frac{r_2}{r_1}\right]}{K_1} + \frac{ln\left[\frac{r_1}{r_2}\right]}{K_1} L_2 + \frac{1}{h_a r_{13}}$$

5. What is critical radius of insulation (or) critical thickness? (May/June 2014) (Nov/Dec 2008)

Critical radius = r_c Critical thickness = $r_c – r_1$ Addition of insulating material on a surface does not reduce the amount of heat transfer rate always. In fact under certain circumstances it actually increases the heat loss up to certain thickness of insulation. The radius of insulation for which the heat transfer is maximum is called critical radius of insulation, and the corresponding thickness is called critical thickness .

6. Define Fin efficiency and Fin effectiveness. (Nov/Dec 2015& Nov/Dec 2010)

The efficiency of a fin is defined as the ratio of actual heat transfer by the fin to the maximum possible heat transferred by the fin.

Fin effectiveness is the ratio of heat transfer with fin to that without fin.

7. Define critical thickness of insulation with its significance. [MAY-JUN 14]

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For cylinder, Critical radius = r_c = k/h, Where k- Thermal conductivity of insulating material, h- heat transfer coefficient of surrounding fluid. Significance: electric wire insulation may be smaller than critical radius. Therefore the plastic insulation may actually enhance the heat transfer from wires and thus keep their steady operating temperature at safer levels.

8. What is lumped system analysis? When is it applicable? [Nov/Dec 14 & April/May 2010]

In heat transfer analysis, some bodies are observed to behave like a "lump" whose entire body temperature remains essentially uniform at all times during a heat transfer process. The temperature of such bodies can be taken to be a function of time only. Heat transfer analysis which utilizes this idealization is known as the lumped system analysis. It is applicable when the Biot number (the ratio of conduction resistance within the body to convection resistance at the surface of the body) is less than or equal to 0.1.

9. Define fins (or) extended surfaces.

It is possible to increase the heat transfer rate by increasing the surface of heat transfer. The surfaces used for increasing heat transfer are called extended surfaces or sometimes known as fins.

10. State the applications of fins.

The main applications of fins are

1. Cooling of electronic components
2. Cooling of motor cycle engines.
3. Cooling of transformers
4. Cooling of small capacity compressors

UNIT: II

CONVECTION

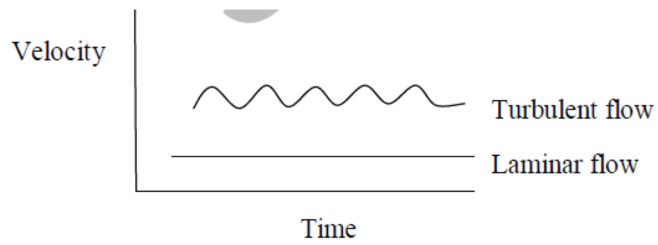
1. Define critical Reynolds number. What is its typical value for flow over a flat plate and flow through a pipe? (May 2013, Nov/Dec 16)

The critical Reynolds number refers to the transition from laminar to turbulent flow. The critical Reynolds number for flow over a flat plate is $5*10^5$; the critical Reynolds number for flow through a pipe is 4000.

2. How does or Distinguish laminar flow differ from turbulent flow? (May 2013 & May 2015)

Laminar flow: Laminar flow is sometimes called stream line flow. In this type of flow, the fluid moves in layers and each fluid particle follows a smooth continuous path. The fluid particles in each layer remain in an orderly sequence without mixing with each other.

Turbulent flow: In addition to the laminar type of flow, a distinct irregular flow is frequently observed in nature. This type of flow is called turbulent flow. The path of any individual particle is zig-zag and irregular.



3. Define grashoff number and prandtl number. Write its significance. (May 2014 & Nov 2014 & Nov 2015-Reg 2008)(Nov 2015) (APR/MAY 2017)

Grashoff number is defined as the ratio of product of inertia force and buoyancy force to the square of viscous force.

$$Gr = \frac{\text{Inertia Force} * \text{Buoyancy Force}}{(\text{Viscous Force})^2}$$ [HMT Data Book, P.No 112]

Significance: Grashoff number has a role in free convection similar to that played by Reynolds number in forced convection.

Prandtl number is the ratio of the momentum diffusivity of the thermal diffusivity.

$$Pr = \frac{\text{Momentum Diffusivity}}{\text{Thermal Diffusivity}}$$ [HMT Data Book, P.No. 112]

Significance: Prandtl number provides a measure of the relative effectiveness of the momentum and energy transport by diffusion.

4. Define convection.(May 2014 & Nov 2014 & Nov 2015-Reg 2008)

Convection is a process of heat transfer that will occur between a solid surface and a fluid medium when they are at different temperatures.

5. Define Nusselt number (Nu).

It is defined as the ratio of the heat flow by convection process under an unit temperature gradient to the heat flow rate by conduction under an unit temperature gradient through a stationary thickness (L) of metre.

6. What is meant by free or natural convection & forced convection?

If the fluid motion is produced due to change in density resulting from temperature gradients, the mode of heat transfer is said to be free or natural convection.

If the fluid motion is artificially created by means of an external force like a blower or fan, that type of heat transfer is known as forced convection.

7. Define boundary layer thickness.

The thickness of the boundary layer has been defined as the distance from the surface at which the local velocity or temperature reaches 99% of the external velocity or temperature

8.Differentiate hydrodynamic and thermal boundary layer. (May 2016)

The hydrodynamic boundary layer is a region of a fluid flow, near a solid surface, where the flow patterns (velocity) are directly influenced by viscous drag from the surface wall. The velocity of the fluid is less than 99% of free stream velocity. The thermal boundary layer is a region of a fluid flow, near a solid surface, where the fluid temperatures are directly influenced by heating or cooling from the surface wall. The temperature of the fluid is less than 99% of free stream temperature.

9. Mention the significance of boundary layer. (Nov 2015)

Boundary layer is the layer of fluid in the immediate vicinity of a bounding surface where the effects of viscosity are significant.

10. What is the form of equation used to calculate heat transfer for flow through cylindrical pipes?

$Nu = 0.023 (Re)0.8 (Pr)^n$ [HMT Data Book, P.No.126]

n = 0.4 for heating of fluids

n = 0.3 for cooling of fluids

UNIT: III

PHASE CHANGE HEAT TRANSFER AND HEAT EXCHANGERS

1. What is meant by Boiling and condensation?

The change of phase from liquid to vapour state is known as boiling.

The change of phase from vapour to liquid state is known as condensation.

2. Give the applications of boiling and condensation.

Boiling and condensation process finds wide applications as mentioned below.

1. Thermal and nuclear power plant.
2. Refrigerating systems
3. Process of heating and cooling
4. Air conditioning systems

3. What is meant by pool boiling?(Nov/Dec 2014)

If heat is added to a liquid from a submerged solid surface, the boiling process referred to as pool boiling. In this case the liquid above the hot surface is essentially stagnant and its motion near the surface is due to free convection and mixing induced by bubble growth and detachment.

Example: Boiling of water in a pan on top of a stove.

4. What is meant by Film wise and Drop wise condensation?

The liquid condensate wets the solid surface, spreads out and forms a continuous film over the entire surface is known as film wise condensation.

In drop wise condensation the vapour condenses into small liquid droplets of various sizes which fall down the surface in a random fashion.

5. Define NTU (May/June 2013 & May/June 2016)

NTU (No. of Transfer Units) It is used to calculate the rate of heat transfer in heat exchangers, when there is insufficient information to calculate the Log-Mean Temperature Difference (LMTD). In heat exchanger analysis, if the fluid inlet and outlet temperatures are specified or can be determined, the LMTD method can be used; but when these temperatures are not available The NTU or The Effectiveness method is used.

6. Define LMTD of a heat exchanger .

The temperature difference between the hot and cold fluids in the heat exchanger varies from point in addition various modes of heat transfer are involved. Therefore based on concept of appropriate mean temperature difference, also called logarithmic mean temperature difference, the total heat transfer rate in the heat exchanger is expressed as

$$Q = U A (\Delta T)_m$$

Where U – Overall heat transfer coefficient W/m^2K A – Area m_2 $(\Delta T)_m$ – Logarithmic mean temperature difference.

7. What is heat exchanger?

A heat exchanger is defined as an equipment which transfers the heat from a hot fluid to a cold fluid.

8. What are the types of heat exchangers?(May/June 2015)

The types of heat exchangers are as follows

1. Direct contact heat exchangers
2. Indirect contact heat exchangers
3. Surface heat exchangers
4. Parallel flow heat exchangers
5. Counter flow heat exchangers
6. Cross flow heat exchangers
7. Shell and tube heat exchangers
8. Compact heat exchangers.

9. What are the limitations of LMTD method? Discuss the advantage of NTU over the LMTD method. (May/June 2015 & Nov/Dec 2012 & Nov/Dec 2013)

The LMTD method cannot be used for the determination of heat transfer rate and outlet temperature of the hot and cold fluids for prescribed fluid mass flow rates and inlet temperatures when the type and size of heat exchanger are specified. Effectiveness NTU is superior for the above case because LMTD requires tedious iterations for the same.

10. What do you understand by fouling factor? (Nov/Dec 2014 & Nov/Dec 2015)

The surfaces of heat exchangers do not remain clean after it has been in use for some time. The surfaces become fouled with scaling or deposits. The effect of these deposits affecting the value of overall heat transfer coefficient. This effect is taken care of by introducing an additional thermal resistance called the fouling resistance or fouling factor.

11. Define effectiveness. (May/June 2016)

The heat exchanger effectiveness is defined as the ratio of actual heat transfer to the maximum possible heat transfer.

Effectiveness ε = Actual heat transfer /Maximum possible heat transfer

12. What is meant by parallel flow and counter flow heat exchanger?

In this type of heat exchanger, hot and cold fluids move in the same direction.

In this type of heat exchanger hot and cold fluids move in parallel but opposite directions.

UNIT: IV

RADIATION

1. State Planck's distribution law. (Nov/Dec 2013)

The relationship between the monochromatic emissive power of a black body and wave length of a radiation at a particular temperature is given by the following expression, by Planck.

$$E_{b\lambda} = \frac{C_1 \lambda^{-5}}{e^{\left(\frac{C_2}{\lambda T}\right)} - 1}$$

Where

$c_1 = 0.374 \times 10^{-15}$ W m^2

$c_2 = 14.4 \times 10^{-3}$ mK

2. State Wien's displacement law & Stefan – Boltzmann law. (Nov/Dec 2010)

The Wien's law gives the relationship between temperature and wave length corresponding to the maximum spectral emissive power of the black body at that temperature.

$$\lambda_{max} T = 2.9 \times 10^{-3}\ mK$$

The emissive power of a black body is proportional to the fourth power of absolute temperature.

$E_b = \sigma T^4$

Where σ = Stefan – Boltzmann constant

$= 5.67 \times 10^{-8}$ W/m^{2}K^4

$\Rightarrow E_b = (5.67 \times 10^{-8})(2773)^4$

$E_b = 3.35 \times 10^6$ W/m^2

3. State Kirchoff's law of radiation. (April/May 2015)

This law states that the ratio of total emissive power to the absorptivity is constant for all surfaces which are in thermal equilibrium with the surroundings. This can be written as

$$\frac{E_1}{\alpha_1} = \frac{E_2}{\alpha_2} = \frac{E_3}{\alpha_3} \ldots\ldots\ldots\ldots$$

It also states that the emissivity of the body is always equal to its absorptivity when the body remains in thermal equilibrium with its surroundings. $\alpha_1 = E_1$; $\alpha_2 = E_2$ and soon

4. What is the purpose of radiation shield? (Nov/Dec 2014)

Radiation shields constructed from low emissivity (high reflective) materials. It is used to reduce the net radiation transfer between two surfaces.

5. What are the factors involved in radiation by a body. (Nov /Dec 2014)

- Wave length or frequency of radiation
- The temperature of surface
- The nature of the surface

6. Define emissive power [E] and monochromatic emissive power. [Eb]

The emissive power is defined as the total amount of radiation emitted by a body per unit time and unit area. It is expressed in W/m^2.

The energy emitted by the surface at a given length per unit time per unit area in all directions is known as monochromatic emissive power.

7. **What is meant by shape factor?**

The shape factor is defined as the fraction of the radiative energy that is diffused from on surface element and strikes the other surface directly with no intervening reflections. It is represented by Fig. Other names for radiation shape factor are view factor, angle factor and configuration factor.

8. What is black body and gray body?

Black body is an ideal surface having the following properties. A black body absorbs all incident radiation, regardless of wave length and direction. For a prescribed temperature and wave length, no surface can emit more energy than black body.

If a body absorbs a definite percentage of incident radiation irrespective of their wave length, the body is known as gray body. The emissive power of a gray body is always less than that of the black body.

9. Define Emissivity.

It is defined as the ability of the surface of a body to radiate heat. It is also defined as the ratio of emissive power of any body to the emissive power of a black body of equal temperature.

$$\text{Emissivity } \varepsilon = \frac{E}{E_b}$$

10. What is meant by absorptivity, reflectivity and transmissivity?

Absorptivity is defined as the ratio between radiation absorbed and incident radiation.

Reflectivity is defined as the ratio of radiation reflected to the incident radiation.

Transmissivity is defined as the ratio of radiation transmitted to the incident radiation.

UNIT: V
MASS TRANSFER

1. What is mass transfer?

The process of transfer of mass as a result of the species concentration difference in a mixture is known as mass transfer.

2. Give the examples of mass transfer.

Some examples of mass transfer. 1. Humidification of air in cooling tower 2. Evaporation of petrol in the carburettor of an IC engine. 3. The transfer of water vapour into dry air.

3. What are the modes of mass transfer? (Nov/Dec 2010)(Nov/Dec 2104)

There are basically two modes of mass transfer, 1. Diffusion mass transfer 2. Convective mass transfer

4. What is molecular diffusion?

The transport of water on a microscopic level as a result of diffusion from a region of higher concentration to a region of lower concentration in a mixture of liquids or gases is known as molecular diffusion.

5. What is Eddy diffusion?

When one of the diffusion fluids is in turbulent motion, eddy diffusion takes place.

6. What is convective mass transfer? (May/June 2006)

Convective mass transfer is a process of mass transfer that will occur between surface and a fluid medium when they are at different concentration.

7. State Fick's law of diffusion. **(April/May 2012) (NOV-DEC 14)(Nov/Dec 16)**

The diffusion rate is given by the Fick's law, which states that molar flux of an element per unit area is directly proportional to concentration gradient.

$$\frac{ma}{A} = -Dab\frac{dCa}{dx}$$

$\frac{ma}{A}$ – Molar flux, $\frac{kg - mole}{s - m^2}$

Dab- Diffusion coefficient of species a and b, m^2/s

$\frac{dCa}{dx}$ – Concentration gradient, kg/m^3

8. Define schmidt number and state its physical significance.) (Nov/Dec 16)

Schmidt number (Sc) is a dimensionless number defined as the ratio of momentum diffusivity (viscosity) and mass diffusivity, and is used to characterize fluid flows in which there are simultaneous momentum and mass diffusion convection processes.

Significance: Analogous of Prandtl number in Heat Transfer. Used in fluid flows in which there is simultaneous momentum & mass diffusion. It is also ratio of fluid boundary layer to mass transfer boundary layer thickness.

9. Distinguish between mass concentration and molar concentration (April/May 2017)

Mass Concentration Mass of a component per unit volume of the mixture. It is expressed in kg/m^3

$$\text{Mass concentration} = \frac{\text{Mass of a component}}{\text{Unit volume of mixture}}$$

Molar concentration Number of molecules of a component per unit volume of the mixture. It is expressed in Kg – mole /m^3

$$\text{Molar concentration} = \frac{\text{Number of moles of component}}{\text{Unit volume of mixture}}$$

10. Define Sherwood Number. (April/May 2012)

It is defined as the ratio of concentration gradients at the boundary.

$$Sc = \frac{hmX}{D_{ab}}$$

hm- Mass transfer coefficient, m/s

D_{ab}-Diffusion coefficient, m^2/s

X- length, m