# MODULE-3

# HEAT TRANSFER

Q1: Give similarities and differences between Newton's law of viscosity and Fourier's law of conduction.
A1: Newton's law of viscosity and Fourier's law of heat conduction both are empirical laws, based on the observations. Newton's law of viscosity describes that momentum flux in any fluid is proportional to the velocity gradients while Fourier's law describes that heat flux due to conduction is proportional to temperature gradients where velocity and temperature gradients are the driving force, respectively.

Q2: Write the order of tensor of thermal conductivity, temperature and heat flux.
A2: Thermal conductivity and temperature are the zero order tensor while heat flux is first order tensor.

Q3: What is the effect of temperarature on thermal conductivity of solid, liquid and gases?
A3: Thermal conductivity of metals increases with temperature. For gases, it increases with temperature at low densities while decreases with temperature for most of the liquids.

Q4: What is the range of Prandtl number of liquids and gases?
A4: For metals (liquids), Prandtl number is very low below 0.1. For non-metal (liquids), it is more than 1 and varies largely. Examples: 13.4 for seawater and 40,000 for engine oil. For gases, it is less than one (0.1 to 0.9).

Q5: Define the system and surrounding for I.C engine.
A5: In I.C engine, combustion chamber and piston are the system while outside of combustion chamber is surrounding.

Q6: Write the possible heat source for any systems.
A6: The possible heat sources for any system may be nuclear fusion, heat produced by reaction, heat produced by electric dissipation or heat produced by viscous dissipation.

Q7: Define conduction, convection and radiation on molecular level.
A7: Conduction is defined as transport of energy by transfer of kinetic energy from one molecule to another while convection is transport of energy by bulk motion of

molecules, which takes energy associated with them. Radiation is defined as transport of energy by emission or absorption of electromagnetic waves.

Q8: Why the heat flux is not constant in hollow composite cylinder unlike in the problem of composite wall?
A8: Heat flux is dependent on cross sectional area of cylinder. The cross sectional area for heat transfer is changing with radius in hollow composite cylinder problem.

Q9: What is unit of heat transfer coefficient?
A9: Heat transfer coefficient

$h = \frac{Q}{A.\Delta T}$ Where, Q is heat flow (J/s = W), A = heat transfer surface area ($m^2$.) $\Delta$T is difference in temperature between the solid surface and surrounding fluid area (K). Thus, the unit of heat transfer coefficient is W/($m^2$K)

Q10: Is Fourier's first law is applicable for unsteady state system?
A10: No, for unsteady state system, energy balance is required.

$$\frac{dH}{dt} = -\frac{dq}{dz}$$

Where, H is energy content, t is time and q is heat flow across distance dz. It is also called as Fourier's second law of heat conduction.

Q11: Give the condition when critical radius of insulation is negligible or significant?
A11: If heat transfer coefficient of surrounding is larger than thermal conductivity of insulation (h>>k), the value of critical radius is negligible and if thermal conductivity of insulation is larger than heat transfer coefficient of surrounding (k>>h), the critical radius of insulation is significant.

Q12: Define kinetic, potential and internal energy of system.
A12: The kinetic energy is due to the motion of the system's particles (translations, rotations, vibrations), and the potential energy is associated with the static constituents of matter. The summation of all energy associated with the system is called as internal energy.

Q13: Can mechanical energy of system be converged?
A13: No, only total energy of the system is converged.

Q14: Write the condition when equation of thermal energy can be

solved without equation of motion.
A14: As convection is not significant, equation of thermal energy can be solved without solving equation of motion.

Q15: Write the condition when equation of motion can be solved without solving equation of energy for non-isothermal system.
A15: For potential flow, where viscous momentum transport is negligible or if viscosity is not the function of temperature for given temperature range, the equation of motion can be solved without solving equation of energy for non-isothermal energy.

Q16: What is the significance of $-(\tau : \nabla v)$ term present in equation of thermal energy? And why it is always positive?
A16: The term $-(\tau : \nabla v)$ represents irreversible degradation of mechanical energy into thermal energy. It is always positive.

Q17: Where we use equation of mechanical energy and equation of thermal energy?
A17: Equation of mechanical energy used when energy of the system is changed due to change in potential energy or internal energy. Equation of thermal energy is used when energy of system is changed due to change in temperature of the system.

Q18: What is critical radius of insulation for sphere?
A18: $R_c = \frac{2k}{h}$ where, k is the thermal conductivity and h is the heat transfer coefficient.

Q19: In which case specific heat at constant volume is equal to specific heat at constant pressure?
A19: For incompressible fluids.

Q20: Give some example where transpiration cooling or heating is used.
A20: Cooling of electronic equipment, processors of computers and cooling stagnation points of high speed aerospace vehicle

Q21: Give the condition when efficiency of transpiration cooling is very low.

A21: If velocity or heat capacity of cooling fluid is very low or heat conductivity of solid is very high then efficiency of transpiration cooling is very low.

Q22: Give the example of fin in daily use technology.
A22: Radiators in cars and heat exchangers.

Q23: Is the efficiency of a circular fin is greater than a rectangular fin?
A23: No, surface area of circular fin is lesser than a rectangular fin.