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Roll No. of candidate | | | | | | | | | | |

2023

B.Tech. 6th Semester End-Term Examination

HEAT TRANSFER II

(New Regulation (w.e.f. 2017-18) & New Syllabus (w.e.f. 2018-19))

Full Marks – 70 Time – Three hours

The figures in the margin indicate full marks for the questions.

Answer question No. 1 and any *four* from the rest.

1. Choose the correct answer: (10 × 1 = 10)

(i) Free convection heat flow depends on all of the followings, except

(a) Density (b) Coefficient of viscosity

(c) Gravitational force (d) Velocity

(ii) Which of the following number represents the ratio of kinematic viscosity to thermal diffusivity?

(a) Grashof number (b) Prandtl number

(c) Reynold number (d) Nusselt number

(iii) The convective heat transfer coefficient in laminar flow over a flat plate

(a) Increases with distance

(b) Increases if a higher viscosity fluid is used

(c) Increases if a denser fluid is used

(d) Decreases with increase in free stream velocity

(iv) For laminar condition, the thickness of thermal boundary layer increases with its distance from the leading edge in proportion to

(a) x (b) $x^{1/2}$

(c) $x^{1/3}$ (d) $x^{1/4}$

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(v) For a fluid having Prandtl number equal to unity, the hydrodynamic boundary layer thickness δ and thermal boundary layer thickness δ_{th} are related as

(a) $\delta = \delta_{th}$ (b) $\delta > \delta_{th}$

(c) $\delta < \delta_{th}$ (d) $\delta = 2\delta_{th}$

(vi) The steam condenser in a thermal power plant is a heat exchanger of the type

(a) Direct contact (b) Regenerator

(c) Recuperator (d) None of these

(vii) Consider the following statements:

In a shell and tube heat exchanger, baffles are provided on the shell side to

(1) Prevent the stagnation of shell side fluid

(2) Improve heat transfer

(3) Provide support for tubes

(4) Prevent fouling for tubes

Which of these statements are correct?

(a) (1) and (2) (b) (2) and (3)

(c) (1), (2) and (3) (d) (1), (2) (3) and (4)

(viii) ε-NTU method is particularly useful in thermal design of heat exchanger when

(a) The outlet temperatures of the fluid streams are not known as a priori

(b) The outlet temperatures of the fluid streams are known as a priori

(c) The outlet temperature of the hot fluid is stream is known but that of cold fluid stream is not known as priori

(d) The inlet temperature of the fluid streams are not known as a priori

(ix) Dropwise condensation usually occurs on

(a) Glazed surface (b) Smooth surface

(c) Oily surface (d) Coated surface

(x) In nucleate pool boiling the heat flux depends on

(a) Material of the surface only

(b) Material and roughness of the surface

(c) Liquid properties and material of the surface

(d) Liquid properties, material and condition of the surface

2. (a) Explain the mechanism of heat transfer by natural convection. (3)

(b) Write the physical significance of Nusselt number and Prandtl number in convection heat transfer. (2+2=4)

(c) Show by dimensional analysis that data for forced convection may be correlated by an equation of the form: $Nu = \phi$ (Re, Pr) Where Nu= Nusselt number, Re = Reynold number, Pr = Prandtl number. (8)

3. (a) Write the concept of thermal boundary layer. (2)

(b) Show that $\delta_{th} > \delta$ for $Pr < 1$ where δ_{th} and δ are the thermal and hydrodynamic boundary layer thickness at a certain location x from the leading edge. (3)

(c) Air at 30°C and at atmospheric pressure flows at a velocity of 4 m/s past a flat plate with a sharp leading edge. The entire plate surface is maintained at a temperature of 50°C. Assuming that the transition occurs at a critical Reynolds number of 5×10^5, find the distance from the leading edge at which the flow in the boundary layer changes from laminar to turbulent. At the location calculate the following:

(i) Thickness of hydrodynamic boundary layer

(ii) Thickness of thermal boundary layer

(iii) Local and average convective heat transfer coefficients

(iv) Heat transfer rate from both sides for unit width of the plate

(v) Mass entrainment in the boundary layer

The thermo-physical properties of air at mean film temperature 40°C are: $\rho = 1.128$ kg/m^3; $\upsilon = 16.96 \times 10^{-6}$m^2/s; Pr = 0.699; k = 0.2755 W/mK. (10)

4. (a) A vertical plate 0.5 m high and 1 m wide is maintained at a uniform temperature of 124°C. It is exposed to ambient air at 30°C. Calculate the heat transfer rate from the plate. The properties of air at 77°C are: $\upsilon = 2.076 \times 10^{-5}$ m^2/s, Pr = 0.697, k = 0.03 W/mK. (7)

(b) Air at 2 bar pressure and 200°C temperature gets heated as it flows through 2.5 cm diameter tube with a velocity of 10 m/s. A constant heat flux condition is maintained at the wall and wall temperature is 20°C above the air temperature all along the length of the tube. Calculate the heat transfer per unit length of the tube. Also determine the increase in bulk temperature over a 3 metre length of the tube. The appropriate correlation for the convection coefficient is

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

Where the different thermo-physical properties of air are:

$\mu = 2.57 \times 10^{-5}$ Ns/m; k = 0.0385 W/m°C; Cp = 1025 J/kgK. (8)

5. (a) What do you mean by fouling factor? How does it affect the performance of a heat exchanger? (2+3=5)

(b) A chemical having specific heat 3.3 kJ/kgK flowing at the rate of 20000 kg/h enters a parallel flow heat exchanger at 120°C. The mass flow rate of cooling water is 50000kg/h with an inlet temperature of 20°C. The heat transfer area is 10 m^2 and the overall heat transfer coefficient is 1050 W/m^2K. Find

(i) The effectiveness of the heat exchanger

(ii) The outlet temperature of water and chemical

Take for water, specific heat = 4.186 kJ/kgK (5+5=10)

6. (a) Derive an expression for Logarithmic Mean Temperature Difference (LMTD) in case of parallel flow heat exchanger. (7)

(b) Air at 35°C and 1 atm flows at a velocity of 60 m/s over (4+4=8)

(i) a flat plate 0.5 m long

(ii) a sphere 5 cm in diameter

Calculate the mass transfer coefficient of water vapour in air. Neglect the concentration of vapour in air. Take the diffusion coefficient of water vapour in air is 0.256×10^{-4} m^2/s and the properties of air at 35°C are: Cp = 1.006 kJ/kgK; $\mu = 2 \times 10^{-5}$ kg/ms; Pr = 0.706; $\rho = 1.146$ kg/m^3. Use the following correlation:

For flat plate: $Sh = 0.0296\ Re^{0.8}\ Sc^{1/3}$

For sphere: $Sh = 2[1 + 0.27\ Re^{1/2}\ Sc^{1/3}]$

7. (a) Explain the various regimes of boiling with neat sketch. (5)

(b) A vertical plate in the form of fin is 500 mm height and is exposed to steam at atmospheric pressure. If the surface of the plate is maintained at 60°C, calculate the following:

(i) The film thickness at the trailing edge of the film

(ii) The overall heat transfer coefficient

(iii) The heat transfer rate

(iv) The condensate mass flow rate.

Assume laminar flow condition and unit width of the plate. The properties of vapour at atmospheric pressure are:

$t_{sat} = 100^\circ C;\ h_{fg} = 2257\ kJ/kg;\ \rho_v = 0.596\ kg/m^3$. The properties of saturated vapour at the mean film temperature $\frac{100+60}{2} = 80^\circ C$ are : $\rho_1 = 971.8\ kg/m^3$;

$\mu = 353.3 \times 10^{-6}\ Ns/m^2;\ k = 67.413 \times 10^{-2}\ W/m^\circ C$. (10)