

CONVECTION

1. Air at 20°C and at a pressure of 1 bar is flowing over a flat plate at a velocity of 3 m/s. If the plate is 280 mm wide and at 56°C, thickness of the thermal boundary layer in mm at $x = 280$ mm is _____.

Properties of air are:

$$\rho = 1.1374 \text{ kg/m}^3; K = 0.02732 \text{ W/m}^0\text{C}; c_p = 1.005 \text{ kJ/kgK}; \nu = 16.786 \times 10^{-6} \text{ m}^2/\text{s}; Pr = 0.7.$$

2. In the above question average heat transfer coefficient in $\text{W/m}^2\text{K}$ is _____

3. Air at atmospheric pressure and 200°C flows over a plate with a velocity of 5 m/s. The plate is 15 mm wide and is maintained at a temperature of 120°C. The local heat transfer coefficient at a distance of 0.5 m from the leading edge in $\text{W/m}^2\text{K}$ is _____.

Assume that flow is on one side of the plate.

$$\rho = 0.815 \text{ kg/m}^3; \mu = 24.5 \times 10^{-6} \text{ Ns/m}^2; Pr = 0.7, K = 0.0364 \text{ W/m K}.$$

4. Air at atmospheric pressure and 40°C flows with a velocity of $U = 5$ m/s over a 2 m long flat plate whose surface is kept at a uniform temperature of 120°C. The rate of heat transfer between the plate and the air per 1 m width of the plate is _____ W.

Take

$$\nu = 2.107 \times 10^{-5} \text{ m}^2/\text{s}, K = 0.03025 \text{ W/mK}, Pr = 0.69651$$

5. Air at 20°C is flowing over a flat plate which is 200 mm wide and 500 mm long. The plate is maintained at 100°C. The ratio of heat loss rate

from the plate if the air is flowing parallel to 500 mm side with 2m/s velocity to the case if the flow is parallel to 200 mm side with the same 2m/s is _____

The properties of air are $\nu = 18.97 \times 10^{-6} \text{ m}^2/\text{s}$, $K = 0.025 \text{ W/m}^0\text{C}$ and $Pr = 0.7$.

6. A flat plate, 1m wide and 1.5 m long is to be maintained at 90°C in air with a free stream temperature of 10°C. The velocity with which air must flow over flat plate along 1.5m side so that the rate of energy dissipation from the plate is 3.75 kW is _____ m/s. Take the following properties of air as:

$$\rho = 1.09 \text{ kg/m}^3, k = 0.028 \text{ W/m}^0\text{C}, c_p = 1.007 \text{ kJ/kg}^0\text{C}, \mu = 2.03 \times 10^{-5} \text{ kg/m-s}, Pr = 0.7.$$

7. Air at 30°C flows with a velocity of 2.8 m/s over a plate 1000 mm (length) x 600 mm (width) x 25 mm (thickness). The top surface of the plate is maintained at 90°C. If the thermal conductivity of the plate material is 25W/m°C, Bottom temperature of the plate for the steady state condition in °C is _____

The thermo-physical properties of air

$$\rho = 1.06 \text{ kg/m}^3, c_p = 1.005 \text{ kJ/kgK}, K = 0.02894 \text{ W/m}^0\text{C}, \nu = 18.97 \times 10^{-6} \text{ m}^2/\text{s}, Pr = 0.696.$$

8. Air at 30°C and at atmospheric pressure flows at a velocity of 2.2 m/s over a plate maintained at 90°C. The length and the width of the plate are 900 mm and 450 mm respectively. Using

exact solution, the heat transfer rate from the second half of the plate is _____ W.

The properties of air is

$$\rho = 1.06 \text{ kg/m}^3, \mu = 7.211 \text{ kg/hm}, \nu = 18.97 \times 10^{-6} \text{ m}^2/\text{s}, \text{Pr} = 0.696, K = 0.02894 \text{ W/m}^0\text{C}.$$

- 9.** For laminar flow in a circular tube of 120 mm radius, the velocity and temperature distribution are given by the relations:

$$u = (2.7r - 3.2r^2); T = 85(1 - 2.2r) ^0\text{C}$$

where the distance r is measured from the tube surface. The mean bulk temperature of the fluid is _____ ^0C

- 10.** In the above question the heat transfer coefficient based on the bulk mean temperature is _____ $\text{W/m}^2\text{K}$ if the tube surface is maintained at a constant uniform temperature of 90^0C & there occurs a heat loss of 1000 kJ/h per meter length of the tube.

- 11.** Lubricating oil at a temperature of 60^0C enters 1 cm diameter tube with a velocity of 3 m/s. The tube surface is maintained at 40^0C , Assuming that the oil has the following average properties The tube length in meter required to cool the oil to 45^0C is _____ m.

$$\rho = 865 \text{ kg/m}^3; K=0.14 \text{ W/mK}; c_p=1.78 \text{ kJ/kg}^0\text{C}.$$

Assume flow to be laminar & fully developed

$$\overline{Nu} = 3.657$$

- 12.** Air flows over a heated plate at a velocity of 50 m/s. The local skin friction co-efficient at a point on a plate is 0.004. The local heat transfer coefficient at this point is _____ $\text{W/m}^2\text{K}$.

The following property data for air are given:

$$\text{Density} = 0.88 \text{ kg/m}^3;$$

$$\text{Viscosity} = 2.286 \times 10^{-5} \text{ kg m/s};$$

$$\text{Specific heat, } c_p = 1.001 \text{ kJ/kg K};$$

$$\text{Conductivity} = 0.035 \text{ W/m K}.$$

- 13.** The crankcase of an I.C. engine measuring 80 cm \times 20cm may be idealized as a flat plate. The engine runs at 90 km/h and the crankcase is cooled by the air flowing past it at the same speed. The heat loss rate from the crank surface maintained at 85^0C , to the ambient air at 15^0C is _____ W.

Due to road induced vibration, the boundary layer becomes turbulent from the leading edge itself.

$$K = 0.02824 \text{ W/m}^0\text{C}, \nu = 17.95 \times 10^{-6} \text{ m}^2/\text{s}, \text{Pr} = 0.698.$$

- 14.** A square plate maintained at 95^0C experience a force of 10.5 N when forced air at 25^0C flows over it at a velocity of 30 m/s. Assuming the flow to be turbulent and using Colburn analogy the heat transfer coefficient is _____ $\text{W/m}^2\text{K}$.

Properties of air are:

$$\rho = 1.06 \text{ kg/m}^3, c_p = 1.005 \text{ kJ/kgK}, \nu = 18.97 \times 10^{-6} \text{ m}^2/\text{s}, \text{Pr} = 0.696.$$

- 15.** A tube 5m long is maintained at 100^0C by steam jacketing. A fluid flows through the tube at the rate of 2940 kg/h at 30^0C . The diameter of the tube is 2 cm. The average heat transfer coefficient is _____ $\text{W/m}^2\text{K}$.

Take the following properties of the fluid:

$$\rho = 850 \text{ kg/m}^3, c_p = 2000 \text{ J/kg}^0\text{C}, \nu = 5.1 \times 10^{-6} \text{ m}^2/\text{s} \text{ and } K = 0.12 \text{ W/m}^0\text{C}.$$

16. In a straight tube of 60 mm diameter, water is flowing at a velocity of 12 m/s. The tube surface temperature is maintained at 70°C and the flowing water is heated from the inlet temperature 15°C to an outlet temperature of 45°C. The length of the tube is _____ m.

$$\rho = 995.7 \text{ kg/m}^3, c_p = 4.174 \text{ kJ/kgK}, \nu = 0.805 \times 10^{-6} \text{ m}^2/\text{s}, K = 0.61718 \text{ W/m}^0\text{C}, Pr = 5.42$$

17. Air entering at 2 bar pressure and bulk temperature of 200°C is heated as it flows through a tube with a diameter of 25.4 mm at a velocity of 10 m/s. 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. The bulk temperature increase over 3 metres length of the tube is _____ °C. Take the properties of air as:

$$\rho = 1.493 \text{ kg/m}^3, \mu = 2.57 \times 10^{-5} \text{ Ns/m}^2, k = 0.0386 \text{ W/m}^0\text{C}, c_p = 1025 \text{ J/kg}^0\text{C}$$

Use the relation:

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

18. Assuming that there is no change in the temperature of the liquid and the tube wall and the flow through the tube is turbulent in

character. If the diameter of the tube & the flow velocity is maintained constant by a change in the rate of liquid flow then the ratio of new heat transfer coefficient to the old heat transfer coefficient is _____

19. Assuming that there is no change in the temperature of the liquid and the tube wall and the flow through the tube is turbulent in character. The flow velocity is doubled, by varying mass flow rate then the ratio of new heat transfer coefficient to the old heat transfer coefficient is _____

20. Water is heated while flowing through a 1.5 cm × 3.5cm rectangular tube at a velocity of 1.2 m/s. The entering water temperature is 40°C and tube wall is maintained at 85°C. The length of the tube required to raise the temperature of water by 35°C is _____ m.

Use the following properties of water:

$$\rho = 985.5 \text{ kg/m}^3; k = 0.653 \text{ W/m K}; \nu = 0.517 \times 10^{-6} \text{ m}^2/\text{s}; c_p = 4.19 \text{ kJ/kg K}.$$

∴ ANSWERS ∴

1. 7.05 mm

2. $\bar{h} = 12.86 \text{ W/m}^2\text{°C}$

3. $h_x = 6.189 \text{ W / m}^2\text{K}$

4. $Q = 981.28 \text{ W}$

5. 0.632

6. $U = 100 \text{ m/s}$

7. $T_b = 90.39^\circ\text{C}$

8. 43.54 W

9. 68.29°C

10. $h = 16.97 \text{ W/m}^2\text{°C}$

11. $L = 312.7 \text{ m}$

12. $h_x = 116.9 \text{ W/m}^2 \text{ K}$

13. $Q = 868.56 \text{ W}$

14. $\bar{h} = 70.32 \text{ W/ m}^2\text{°C}$

15. $\bar{h} = 1052.8 \text{ W/m}^2\text{°C}$

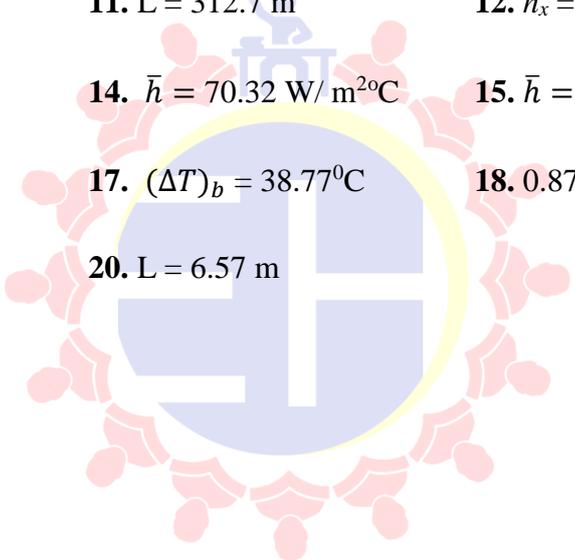
16. $L = 23.4 \text{ m}$

17. $(\Delta T)_b = 38.77^\circ\text{C}$

18. 0.87

19. 1.74

20. $L = 6.57 \text{ m}$



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