PRACTICE QUESTIONS

for SSC-JE : CBT-2

Heat Transfer

Mechanical Engineering

07 Heat Transfer

Q.1 A very long 25 mm diameter rod (k = 2250 W/mK) extends horizontally from a plane heated wall. The temperature of surrounding is 25°C and heat transfer coefficient is 9 W/m^{3}K. Then the length of the rod, to be considered as infinite, will be:
(a) 1 m (b) 2.5 m
(c) 3.3 m (d) 5 m

Q.2 When is transient heat transfer problem considered as a lump capacity problem?
(a) The surface convection resistance of the object is negative.
(b) The internal convection resistance of the object is zero.
(c) The surface conduction resistance of the object is infinite.
(d) The internal conduction resistance of the object is negligible.

Q.3 In forced convection, heat transfer coefficient of air at 300°C flowing over a cylinder of diameter 84 mm and length 5 m is 50 W/m^{3}K. Then the convective resistance will be (ambient temperature = 27°C).
(a) 0.355°C/W (b) 0.21°C/W
(c) 0.151°C/W (d) 0.0151°C/W

Q.4 Consider the following statements:
1. Absorptivity depends on wavelength of incident radiation waves.
2. Emissivity is independent of wavelength of incident radiation waves.

Which of the above statements is/are correct?
(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

Q.5 An electric cable of aluminium (k = 240 W/mK) is to be insulated with rubber (k = 0.15 W/mK) and outside heat transfer coefficient of 6 W/m^{2}K, the critical radius of insulation will be:
(a) 40 mm (b) 25 mm
(c) 80 mm (d) 160 mm

Q.6 Consider the following statements about the free convection:
1. The critical Grashoff number for the flow of air over a flat plate has been observed to be 4×10^8 approximately.
2. Role of Grashoff number is same in free convection as that of Nusselt number is forced convection.
3. Grashoff number incorporates coefficient of thermal expansion in its expansion.

Which of the above statements are correct?
(a) 2 only (b) 2 and 3
(c) 1 and 3 (d) 1, 2 and 3

Q.7 A spherical ball having surface temperature 120°C placed inside room with air circulation (T_{air} = 30°). After 10 min ball surface temperature changes to 105°C then the temperature of core will nearly be
(a) 120°C (b) 109°C
(c) 105°C (d) data insufficient

Given:
Ball : Radius = 30 cm
Thermal conductivity = 50 W/mk
Density = 7800 kg/m3
Air : ρ_{air} = 1.2 kg/m^3 ; h_{air} = 10 W/m^2–K

Q.8 A spherical shaped vessel of 1.4 m outer diameter is 90 mm thick. What is the rate of the heat leakage, if the temperature difference

between the inner and outer surface is 220°C? (K_{sphere} = 0.083 W/m-K)
(a) 0.2 kW (b) 0.5 kW
(c) 1 kW (d) 1.6 kW

Q.9 In a long cylinder rod of radius R and a surface heat flux of q_g, the uniform internal heat generation rate is
(a) $\frac{2q_g}{R}$ (b) $\frac{2q_g}{R^2}$
(c) $\frac{q_g}{R}$ (d) $2q_g$

Q.10 What is the equivalent emissivity for radiant heat exchange between a small body (emissivity ϵ_1) in a very large enclosure (emissivity ϵ_2)?
(a) ϵ_2 (b) ϵ_1
(c) $\epsilon_2 - \epsilon_1$ (d) $\epsilon_1 \cdot \epsilon_2$

Q.11 When a liquid flows through a tube with subcooled or saturated boiling the process is
(a) Pool boiling
(b) Convection boiling
(c) Force convection boiling
(d) Bulk boiling

Q.12 Temperature variation given as $T(r) = 50 - 2r^2$ °C where r(in m) from centerline. If mean velocity of flowing fluid is 5 m/s and radius of pipe is 2 m, then bulk mean temperature (T_b) will be ($u \neq f(r)$)
(a) 50°C (b) 46°C
(c) 42°C (d) 25°C

Q.13 The inner surface of a plane brick wall is at 105°C and outer surface is at 45°C. If the wall thickness is 250 mm and the thermal conductivity of the brick is 0.7 W/m°C, then the rate of heat transfer per m^2 of surface area of the wall is
(a) 120 W/m^2 (b) 142 W/m^2
(c) 168 W/m^2 (d) 187 W/m^2

Q.14 Consider the following points regarding heat conduction through a hollow cylinder:
1. The temperature distribution is logarithmic.
2. Temperature at any point in the cylinder can be expressed as a function of radius only.
3. The temperature profile is nearly linear for large values of (r_{outer}/r_{inner}).
4. Thermal resistance of a hollow cylinder is given by $\frac{\ln\left(\frac{r_2}{r_1}\right)}{2\pi kL}$.

Which of the above statements are correct?
(a) 1 and 3 (b) 1, 2 and 4
(c) 2, 3 and 4 (d) 1, 2, 3 and 4

Q.15 Logarithmic mean area of the hollow sphere is given by:
(a) $A_m = \frac{A_o A_i}{A_o - A_i}$ (b) $A_m = \frac{A_o - A_i}{A_o A_i}$
(c) $A_m = \frac{A_o - A_i}{\ln\left(\frac{A_o}{A_i}\right)}$ (d) $A_m = \sqrt{A_i A_o}$

Q.16 What will be the critical radius of insulation of asbestos (K = 0.168 W/mk), surrounding a hollow sphere which is exposed to room air at 300 K with h = 2.8 W/m^{2}k?
(a) 6 cm (b) 9 cm
(c) 12 cm (d) 15 cm

Q.17 The ratio of heat transfer coefficient to the flow of heat per unit temperature rise due to the velocity of the fluid is known as
(a) Prandtl number (b) Nusselt number
(c) Stanton number (d) Peclet number

Q.18 Two very large parallel walls (gray bodies) facing each other have emissivities of 0.5 and 0.7. The view factor between these walls is
(a) 0.36 (b) 0.41
(c) 0.48 (d) 0.56

Q.19 Consider the following statements regarding heat transfer through fins:
1. Fins are equally effective irrespective of whether they are on the hot side or cold side of the fluids.
2. The temperature along the fin is variable and hence the rate of heat transfer varies along the fin.

3. Fins are made of materials that have a higher thermal conductivity than the material of the wall.
4. Fins must be arranged at right angles to the direction of fluid flow.

Which of the above statements are correct?
(a) 1 and 2 (b) 2 and 4
(c) 1 and 3 (d) 2 and 3

Q.20 A large concrete slab 1 m thick has one dimensional temperature distribution:
$T = 14 - 115x + 30x^2 - 10x^3$
where T is temperature and x is distance from one face towards other face of wall. If the slab material has thermal diffusivity of 2.03×10^{-3} m^2/hr, what is rate of change of temperature at the other face of the wall at $x = 1$ m?
(a) 0.1°C/h (b) 0°C/h
(c) 0.15°C/h (d) 1°C/h

Q.21 The conduction heat diffuses in a material when the material has:
1. High thermal conductivity.
2. High density.
3. High specific heat.
4. High viscosity.

Which of the above are correct?
(a) 1 and 3 (b) 2 and 3
(c) 1 only (d) 1, 2 and 4

Q.22 For combined forced and natural convection, the relative magnitude of the following dimensionless parameter governs the relative importance of natural convection in relation to force convection.
(a) Gr/Re^2 (b) Gr/Re
(c) Gr Pr/Re (d) Gr/RePr

Q.23 A 16 m high vertical pipe at 200°C wall temperature is in a room with still air at 50°C. The pipe supplies heat to room air at a rate of 16 kW by natural convection.
Assuming laminar flow and other conditions remaining the same, the height of pipe required to supply 2 kW will be
(a) 3 m (b) 2 m
(c) 4 m (d) 1 m

Q.24 For laminar flows in circular pipes, the hydrodynamic entry length L_H is correlated by
(a) $0.0575\, D\, Re_D$ (b) $0.023\, D\, Re_D$
(c) $0.04305\, D\, Re_D\, Pr$ (d) $0.037 D\, Re_D\, Pr$

Q.25 For extended surface the relation between efficiency and effectiveness is
(a) $\frac{\epsilon}{\eta} = \frac{A_{cs}}{A_{fin}}$ (b) $\frac{\epsilon}{\eta} = A_{fin} \cdot A_{cs}$
(c) $\frac{\epsilon}{\eta} = \frac{A_{fin}}{A_{cs}}$ (d) $\frac{\epsilon}{\eta} = 1 + \frac{A_{fin}}{A_{cs}}$

Q.26 Two finned surfaces with long fins are identical. The convection heat transfer coefficient for the first finned surface is twice that of second one. The correct statement for the effectiveness and efficiency for the first finned surface relative to second one is
(a) Higher effectiveness but lower efficiency
(b) Higher effectiveness and higher efficiency
(c) Lower effectiveness and higher efficiency
(d) Lower effectiveness and lower efficiency

Q.27 For lumped heat analysis the relation between temperature and time is
(a) $\frac{T - T_\infty}{T_i - T_\infty} = e^{-\frac{B_i}{F_o}}$ (b) $\frac{T - T_\infty}{T_i - T_\infty} = e^{(B_i F_o)}$
(c) $\frac{T - T_\infty}{T_i - T_\infty} = e^{\frac{-F_o}{B_i}}$ (d) $\frac{T - T_\infty}{T_i - T_\infty} = e^{-(B_i F_o)}$

Where, B_i = Biot number, F_o = Fourier number

Q.28 A gray body is the one whose absorptivity
(a) varies with the wavelength of incident ray
(b) varies with temperature of incident ray
(c) does not vary with temperature and wavelength of incident ray
(d) varies with the wavelength and temperature of incident ray

Q.29 A parallel flow shell and tube heat exchanger is used to heat water with hot gases. The water(c = 4200 J/kgK) flows at a rate of 2 kg/s and the exhaust gases (c = 1000 J/kgK) flow at a rate of 5 kg/s. If heat transfer surface area is 50 m^2 and the overall heat transfer coefficient is 200 W/m^2K. The NTU of the heat exchanger is
(a) 2.5 (b) 1.5
(c) 2 (d) 3

Q.30 For a counter flow heat exchanger with equal capacity rates the temperature profiles of the two fluids along the length of the heat exchanger is
(a) parallel (b) parabolic
(c) linear (d) linear and parallel

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Answer Keys

1.	(c)	2.	(d)	3.	(d)	4.	(a)	5.	(b)	6.	(c)	7.	(c)
8.	(c)	9.	(a)	10.	(b)	11.	(c)	12.	(b)	13.	(c)	14.	(b)
15.	(d)	16.	(c)	17.	(c)	18.	(b)	19.	(b)	20.	(b)	21.	(c)
22.	(a)	23.	(d)	24.	(a)	25.	(c)	26.	(d)	27.	(d)	28.	(b)
29.	(c)	30.	(d)										

Detailed Solutions

1. (c)

As, $m = \sqrt{\frac{hP}{kA}} = \sqrt{\frac{h\times\pi d}{k\times\frac{\pi}{4}d^2}} = \sqrt{\frac{4\times h}{kd}}$

$$= \sqrt{\frac{4\times 9}{2250\times 0.025}} = \frac{2\times 3}{15\times 0.5} = 0.8$$

As $Q = kA_{cs}m\,(t_o - t_a)$...... (for infinitely long pin)

$Q = kA_{cs}m\,(t_o - t_a)$...... (for fin with insulated tip)

We know $ml \geq 2.646$ (Standard result to remember)

So, Length, $l = \frac{2.646}{m} = \frac{2.646}{0.8} = 3.3075$ m

2. (d)

For transient heat transfer the internal conduction resistance should be zero so that the internal temperature gradient in the body becomes negligible. It helps the body to maintain uniform temperature throughout the mass.

3. (d)

$$\text{Convective resistance} = \frac{\Delta t}{q} = \frac{1}{hA}$$

$$\Rightarrow R_{conv} = \frac{1}{h\times\pi DL} = \frac{1}{50\times\frac{22}{7}\times 84\times 5\times 10^{-3}}$$

$$= \frac{1}{50\times 22\times 12\times 5\times 10^{-3}} = \frac{1}{60} \simeq 0.0151°C/W$$

4. (a)

Both emissivity and absorptivity depend on the wavelength of incident radiation. The emissivity for real surface at a certain wavelength is called spectral emissivity.

5. (b)

For a cylindrical pipe, the critical radius of insulation is given by

$$r_c = \frac{k_{insulation}}{h_o} = \frac{0.15}{6} = 0.025 \text{ m} = 25 \text{ mm}$$

6. (c)

The role of Grashoff number in free convection is same as that of Reynolds number in forced convection.

7. (c)

$$\text{Bi} = \frac{h\,L_C}{K} = \frac{10\times0.3}{50\times3} = 0.02 < 0.1$$

∴ We can consider the ball as lumped system

Hence temperature across the body at given time will be same (temperature gradient negligible), so the core temperature will be 105°C (equal to the surface temperature).

8. (c)

$$Q = \frac{\Delta T}{R}$$

$$R_{sphere} = \frac{r_2 - r_1}{4\pi\,K\,r_1\,r_2}$$

Where $r_2 - r_1 = 90$ mm, $r_2 = 0.7$ m,

$r_1 = 0.7 - 0.09 = 0.61$ m

$\Delta T = 220°C$, K = 0.083 W/m–K.

$$\Rightarrow Q = \frac{220}{\left(\frac{(0.09)}{4\times\pi\times0.083\times0.7\times0.61}\right)} = 1088 \text{ W}$$

9. (a)

Energy balance $Q = q_g \times (2\pi RL) = q \times (\pi R^2 L)$

$$\Rightarrow q = \frac{2q_g}{R}$$

Where, q_g = surface heat flux

q = Uniform internal heat generation

10. (b)

When body 1 is completely enclosed by body 2 and body 1 is small, then equivalent emissivity is $\in_1$.

$$Q_{1-2} = \sigma\left(T_1^4 - T_2^4\right)\in_1 A_1 \qquad (\text{for } A_2 >>> A_1)$$

11. (c)

If heating surface of evaporator is submerged beneath a free surface of liquid, this is known as "pool boiling".

When the liquid flow through a tube with subcooled or saturated boiling, this bounded convection process is called forced-convection boiling, even through circulation may occur either by density difference or by a pump in a fluid circuit.

12. (b)

Bulk mean temperature (T_b)

$$T_b = \frac{2}{R^2\bar{u}}\int_0^R r.u(r)T(r)dr$$

$$= \frac{2}{R^2\,\bar{u}}\int_0^R r.\bar{u}.\left(50-2r^2\right)dr$$

$$= \frac{2}{R^2}\left[\frac{50r^2}{2} - \frac{2r^4}{4}\right]_0^R = \frac{2}{R^2}\left(25R^2 - \frac{R^4}{2}\right)$$

$$= 2\left(25 - \frac{R^2}{2}\right)$$

$T_b = 2 \times (25 - 2) = 46°C (R = 2 \text{ m})$

13. (c)

Rate of heat transfer,

$$q'' = \frac{k(T_i - T_0)}{t} = \frac{0.7(105-45)}{0.250} = 168 \text{ W/m}^2$$

14. (b)

The temperature distribution is given by,

$$\frac{t - t_1}{t_2 - t_1} = \frac{ln\left(\frac{r}{r_1}\right)}{ln\left(\frac{r_2}{r_1}\right)}$$

Temperature profile is nearly linear for values of $\left(\frac{r_2}{r_1}\right)$ near to 1, but non-linear for larger values.

15. (d)

Logarithmic mean area for hollow cylinder,

$$A_m = \frac{A_o - A_i}{ln\left(\frac{A_o}{A_i}\right)}$$

For hollow sphere, $A_m = \sqrt{A_o A_i}$

16. (c)

Critical radius of hollow sphere,

$$r_c = \frac{2K}{h_o}$$

$$r_c = \frac{2 \times 0.168}{2.8} = 0.12 \text{ m} = 12 \text{ cm}$$

17. (c)

Stanton number can be used in correlating forced convection data. This becomes obvious when we observe the velocity V contained in the expression of Stanton number. It is the ratio of heat transfer coefficient to the flow of heat per unit temperature rise due to the velocity.

18. (b)

$$\frac{1}{F_{12}} = \frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1 = \frac{1}{0.5} + \frac{1}{0.7} - 1 = 2.4286$$

$$\therefore \quad F_{12} = 0.412$$

19. (b)

Fin become more effective when they are installed to the side having lower heat transfer coefficient.

20. (b)

$T = 14 - 115x + 30x^2 - 10x^3$

$$\frac{\partial T}{\partial x} = -115 + 60x - 30x^2$$

$$\frac{\partial^2 T}{\partial x^2} = +60 - 60x = 60(1 - x)$$

at $x = 1$ m

$$\frac{\partial^2 T}{\partial x^2} = 0$$

For plane slab, 1–D heat conduction,

$$\frac{\partial^2 T}{\partial x^2} = \frac{1}{\alpha}\frac{\partial T}{\partial \tau} \qquad [q_{gen} = 0]$$

$$\therefore \quad \frac{\partial T}{\partial \tau} = 0$$

21. (c)

22. (a)

23. (d)

$$\overline{\text{Nu}} = C(\text{Gr}\cdot\text{Pr})^{1/4}$$

$$\frac{\bar{h}L}{k} = C\left(\frac{g\beta\Delta TL^3}{\nu^2}\text{Pr}\right)^{1/4}$$

$$\Rightarrow \quad \frac{\bar{h}_2}{\bar{h}_1} = \left(\frac{L_1}{L_2}\right)^{1/4}$$

As we know,

$$Q = \bar{h}A(\Delta T)$$

So,

$$Q = \bar{h}A(\Delta T)$$

$$Q = \bar{h}(\pi DL)\Delta T$$

$$Q = \bar{h}L$$

$$\frac{Q_2}{Q_1} = \frac{\bar{h}_2}{\bar{h}_1} \times \frac{L_2}{L_1} = \left(\frac{L_2}{L_1}\right)^{1/4} \times \left(\frac{L_2}{L_1}\right)$$

$$\frac{Q_2}{Q_1} = \left(\frac{L_2}{L_1}\right)^{3/4}$$

$$\frac{L_2}{L_1} = \left(\frac{2}{16}\right)^{4/3}$$

$$L_2 = \frac{16}{16} = 1 \text{ m}$$

25. (c)

$$\in = \frac{q_{\text{fin}}}{q_{\text{without fin}}}$$

$$\eta = \frac{q_{\text{fin}}}{q_{\text{max}}}$$

$\Rightarrow q_{fin} = \eta(q_{max})$

$$\in = \frac{\eta(q_{fin})}{q_{\text{without fin}}} = \frac{\eta \times hA_{fin}(\Delta T)}{hA_{cs}(\Delta T)}$$

$$\in = \frac{\eta(A_{fin})}{(A_{cs})}$$

$$\frac{\in}{\eta} = \frac{A_{fin}}{A_{cs}}$$

Where A_{fin} = Total surface area of fin

A_{cs} = Cross-sectional area of fin base

26. (d)

$$\text{Effectiveness} \propto \frac{1}{\sqrt{h}}$$

$$\text{Efficiency} \propto \frac{1}{\sqrt{h}}$$

27. (d)

We know

$$\frac{T - T_\infty}{T_i - T_\infty} = e^{-\left(\frac{hA}{\rho Vc}\right)\tau}$$

$$B_iF_o = \frac{hL}{k} \times \frac{\alpha\tau}{L^2} = \frac{kL}{k} \times \frac{k}{\rho C} \times \frac{\tau}{L^2} = \frac{h\tau}{\rho CL}$$

$$= \frac{hA}{\rho cV}\tau \text{ where } L = \frac{V}{A}$$

28. (b)

Absorptivity is independent of wavelength.

29. (c)

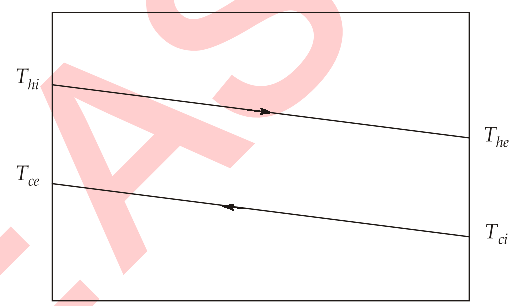
$C_{hot} = 5 \times 1000 = 5000$ W/K

$C_{cold} = 2 \times 4200 = 8200$ W/K

$\therefore \quad C_{min} = C_{hot}$

$$\text{NTU} = \frac{UA}{C_{min}} = \frac{200 \times 50}{5000} = 2$$

30. (d)



$$\dot{m}_c c_{pc} = \dot{m}_h c_{ph}$$

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