POSTAL Book Package 2023

Mechanical Engineering

Objective Practice Sets

Heat Transfer

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3 CHAPTER Steady State Conduction with Heat Generation

MCQ and NAT Questions

Q.1 Heat conduction equation in spherical coordinate system will be when temperature varies in *r*-direction only.

(a) $\frac{\partial^2 T}{\partial r^2} + \frac{1}{r}\left(\frac{\partial T}{\partial r}\right) + \frac{q}{K} = \frac{1}{\alpha} \cdot \frac{\partial T}{\partial t}$

(b) $\frac{\partial^2 T}{\partial r^2} + \frac{1}{2r}\frac{\partial T}{\partial r} + \left(\frac{q}{K}\right) = \frac{1}{2\alpha} \cdot \left(\frac{\partial T}{\partial t}\right)$

(c) $\frac{\partial^2 T}{\partial r^2} + \frac{2}{r}\left(\frac{\partial T}{\partial r}\right) + \left(\frac{q}{K}\right) = \frac{1}{\alpha} \cdot \left(\frac{\partial T}{\partial t}\right)$

(d) $\frac{\partial^2 T}{\partial r^2} + \frac{2}{r}\left(\frac{\partial T}{\partial r}\right) + \left(\frac{q}{2K}\right) = \frac{1}{\alpha} \cdot \left(\frac{\partial T}{\partial t}\right)$

Q.2 The temperature drop in a plane wall with uniformly distributed heat generation can be decreased by reducing

(a) wall thickness
(b) heat generation rate
(c) thermal conductivity of wall material
(d) convection coefficient at the surface

Q.3 The temperature profile for heat conduction through a wall of constant thermal conductivity in the presence of heat source is

(a) a straight line (b) parabolic
(c) logarithmic (d) hyperbolic

Q.4 For a cylindrical rod with uniformly distributed heat sources, the thermal gradient dt/dr at half the radius location will be

(a) one-fourth of that at the surface
(b) one-half of that at the surface
(c) twice of that at the surface
(d) four times of that at the surface

Q.5 A plane wall 10 cm thick generating heat at the rate of 4×10^4 W/m^3 when an electric current is passed through it. The convective heat transfer coefficient between each face of wall and the ambient air is 50 W/m^2-K. The ambient air temperature 20°C and K = 15 W/m-k. The maximum temperature in the wall is

(a) 43.33°C (b) 53.33°C
(c) 63.33°C (d) 73.33°C

Q.6 A copper wire of 25 mm, carries 200 A and has a resistance of 0.4×10^{-4} ohms/cm length. The heat loss is

(a) 100 W/m (b) 160 W/m
(c) 1000 W/m (d) 1600 W/m

Q.7 A 20 mm wire generates 3000 kW/m^3 heat. If surface temperature is 200°C, the maximum temperature in the wire will be equal to (assume K = 14 W/m-k)

(a) 205.4°C (b) 215.9°C
(c) 219.2°C (d) 225.2°C

Q.8 If ambient air temp is 10°C, the heat transfer coefficient between the wire surface and ambient air will be (in W/m^2-k) in above problem.

(a) 59 (b) 69
(c) 79 (d) 89

Q.9 For a long cylinder of radius R with uniformly distributed heat sources, the temperature distribution in the dimensionless form is

(a) $\frac{t - t_w}{t_{max} - t_w} = 1 - \frac{r}{R}$

(b) $\frac{t - t_w}{t_{max} - t_w} = 1 - \left(\frac{r}{R}\right)^2$

(c) $\frac{t - t_w}{t_{max} - t_w} = 1 - \left(\frac{r}{R}\right)^3$

(d) $\frac{t - t_w}{t_{max} - t_w} = 1 - \left(\frac{r}{R}\right)^4$

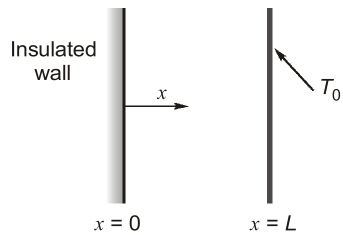
where t_w is the temperature at the outer surfaces of the cylinder and t_{max} is the temperature along the cylinder axis.

Q.10 Heat transfer by conduction through hollow cylinder is given by

(a) $Q = \frac{2\pi l(T_1 - T_2)}{k(r_2 - r_1)}$ (b) $Q = \frac{2\pi kl(T_1 - T_2)}{(r_2 - r_1)}$

(c) $Q = \frac{2\pi kl(T_1 - T_2)}{\ln(r_2 / r_1)}$ (d) $Q = \frac{2\pi kl(T_1 - T_2)}{(r_1 + r_2)}$

Q.22 A slab of thickness L with one side ($x = 0$) insulated and other side ($x = L$) maintained at a constant temperature T_0 is shown below:



A uniformly distributed internal heat source produces heat in the slab at the rate of W/m^3. Assume the heat conduction to be steady state and 1-D along the x-direction, the maximum temperature in the slab occurs at x equal to ______.

Multiple Select Questions (MSQ)

Q.23 A solid sphere of radius 0.5 m has an internal heat generation rate of 2×10^6 W/m^3. If the thermal conductivity of the material is 40 W/mK and the convective heat transfer coefficient at the surface of the sphere is 10 kW/m^{2}K. Which of the following is(are) correct, if the ambient temperature is 30°C?

(a) The temperature at the outer surface is 63.33°C.
(b) The temperature at the outer surface is 163.32°C.
(c) The temperature at the centre is 2146.66°C.
(d) The temperature at the centre is 2246.66°C.

Q.24 Which of the following statements is/are correct with respect to conduction heat transfer with heat generation in a slab under steady state, 1-D heat conduction with uniform heat generation and constant thermal conductivity of material?

(a) If one side of the slab is perfectly insulated, then maximum temperature will be at the another end of the slab (i.e. uninsulated side)
(b) Temperature distribution is parabolic in nature in the slab.
(c) Value of maximum temperature in the slab depends upon convection heat transfer coefficient of the liquid on the sides of the slab also.
(d) If one side of the slab is an adiabatic wall, then maximum temperature will be at this side or at this surface.

Q.25 Consider steady 1-D heat flow in a plate of 50 mm thickness with a uniform heat generation of 200 MW/m^3. The left and right faces are kept at constant temperatures of 200°C and 150°C respectively. The plate has a constant thermal conductivity of 200 W/mK.
Which of the following statements is/are correct?

(a) The location of maximum temperature within the plate from its left face is 26 mm.
(b) The location of maximum temperature within the plate from its left face is 24 mm.
(c) The maximum temperature within the plate is 488°C.
(d) The maximum temperature within the plate is 390°C.

■■■■

Answers — Steady State Conduction with Heat Generation

1. (c)	2. (a)	3. (b)	4. (b)	5. (c)	6. (b)	7. (a)
8. (c)	9. (b)	10. (c)	11. (c)	12. (a)	13. (a)	14. (a)
15. (d)	16. (200)	17. (0.0854)	18. (700)	19. (95.72)	20. (365.34)	21. (32)
22. (0)	23. (a, c)	24. (b, c, d)	25. (b, c)			

Explanations — Steady State Conduction with Heat Generation

1. (c)

Conduction equation in spherical form:

$$\frac{\partial^2 T}{\partial r^2} + \frac{2}{r}\left(\frac{\partial T}{\partial r}\right) + \frac{1}{r^2 \sin\psi}\frac{\partial}{\partial \psi}\left[\sin\psi \frac{\partial T}{\partial \psi}\right] + \frac{1}{r^2 \sin^2\psi}\frac{\partial^2 T}{\partial \psi^2} + \frac{\dot{q}}{k} = \frac{1}{\alpha}\frac{\partial T}{\partial \tau}$$

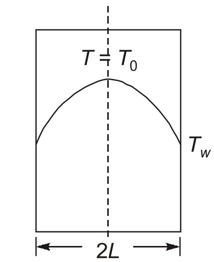
In one dimensional form it is

$$\frac{\partial^2 T}{\partial r^2} + \frac{2}{r}\left(\frac{\partial T}{\partial r}\right) + \frac{\dot{q}}{k} = \frac{1}{\alpha}\left(\frac{\partial T}{\partial \tau}\right)$$

2. (a)

Temperature drop in a plane with heat generation is

$$\Delta T = T_0 - T_w = \frac{\dot{q}L^2}{2k}$$



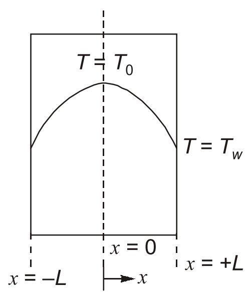
ΔT can be reduced by reducing wall thickness.

3. (b)

Temperature profile is,

$$T_0 - T = \frac{\dot{q}}{k}\frac{x^2}{2}$$

$\therefore$ Parabolic curve



4. (b)

The temperature distribution through a cylindrical rod with uniformly distributed heat sources is parabolic and prescribed as

$$t = t_w + \frac{q_g}{4K}(R^2 - r^2)$$

$$\frac{dt}{dr} = \frac{q_g}{4K}(-2r)$$

$$\left(\frac{dt}{dr}\right)_{r=R} = \frac{q_g}{4K}\times(-2\times R)$$

$$\left(\frac{dt}{dr}\right)_{r=R/2} = \frac{q_g}{4K}\times\left(-2\times\frac{R}{2}\right)$$

Apparently, $\left(\frac{dt}{dr}\right)_{r=R/2} = \frac{1}{2}\left(\frac{dt}{dr}\right)_{r=R}$

5. (c)

$$T_{max} = T_\infty + \frac{qL}{2h} + \frac{qL^2}{8K}$$

$$= \left(60 + \frac{4\times10^4\times(0.1)}{2\times50} + \frac{4\times10^4\times(0.1)^2}{8\times15}\right)$$

$$= 63.33°\text{C}$$

6. (b)

$$Q = I^2R = (200)^2\times(0.4\times10^{-4})$$

$$= 1.6 \text{ W/cm} = 160 \text{ W/m}$$

7. (a)

$$T_c = T_o + \frac{q}{4K}\cdot r_0^2$$

$$= 200 + \frac{3000}{4\times14}\times(10\times10^{-3})^{-2}\times10^3$$

$$= 205.4°\text{C}$$

8. (c)

$$\because \quad T_o = T_\infty + \frac{\dot{q}\,r_o}{2h}$$

$$\therefore \quad h = \frac{\dot{q}\,r_o}{2(T_o - T_\infty)}$$

$$= \frac{300\times10^3\times10\times10^{-3}}{2(200-10)}$$

$$= 78.95 \simeq 79 \text{ W/m}^2\text{k}$$

9. (b)

The temperature distribution inside a cylinder with heat generation is a parabola i.e., a second degree equation. Hence, the correct answer is (b).

10. (c)

From Fourier law of heat conduction

$$Q = -kA\frac{dT}{dr}$$

For hollow cylinder

$$Q = -k(2\pi rl)\frac{dT}{dr}$$

$$\int_{r_1}^{r_2} Q\left(\frac{dr}{r}\right) = \int_{T_1}^{T_2}(-2\pi kl)\,dT$$

$$Q = \frac{2\pi kl}{\ln\left(\frac{r_2}{r_1}\right)}(T_1 - T_2)$$

11. (c)