POSTAL Book Package 2023

GATE • PSUs

PRODUCTION AND INDUSTRIAL ENGINEERING

Objective Practice Sets

General Engineering : Volume VII

Heat Transfer

MADE EASY Publications

Heat Transfer

Q.1 Thermal conductivity is lower for
(a) wood (b) air
(c) water at 100°C (d) steam at 1 bar

Q.2 For a current carrying wire of 20 mm diameter exposed to air (h = 20 W/m^{2}K), maximum heat dissipation occurs when thickness of insulation (k = 0.5 W/mK) is
(a) 30 mm (b) 25 mm
(c) 20 mm (d) 15 mm

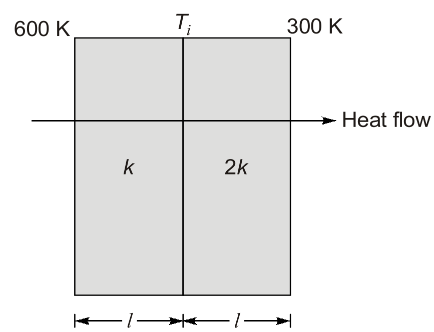
Q.3 For a given heat flow and for the same thickness, the temperature drop across the material will be maximum for
(a) Copper (b) Steel
(c) Glass wool (d) Refractory brick

Q.4 A stainless steel tube (k_s = 19 W/mK) of 2 cm ID and 5 cm OD is insulated with 3 cm thick asbestos (k_a = 0.2 W/mK). If the temperature difference between the inner most and outermost surfaces is 600°C, the heat transfer rate per unit length is
(a) 0.94 W/m (b) 9.44 W/m
(c) 944.72 W/m (d) 9447.21 W/m

Q.5 A long glass cylinder of inner diameter = 0.03 m and outer diameter = 0.05 m carries hot fluid inside. If the thermal conductivity of glass is 1.05 W/mK, then the thermal resistance (K/W) per unit length of the cylinder is
(a) 0.031 (b) 0.077
(c) 0.17 (d) 0.34

Q.6 A coolant fluid at 30°C flows over a heated flat plate maintained at a constant temperature of 100°C. The boundary layer temperature distribution at a given location on the plate may be approximated as $T = 30 + 70\,\text{expt}(-y)$ where y (in m) is the distance normal to the plate and T is in °C. If thermal conductivity of the fluid is 1.0 W/mK, the local convective heat transfer coefficient (in W/m^{2}K) at that location will be
(a) 0.2 (b) 1
(c) 5 (d) 10

Q.7 Heat transfer through a composite wall is shown in figure. Both the sections of the wall have equal thickness (l). The conductivity of one section is k and that of the other is $2k$. The left face of the wall is at 600 K and the right face is at 300 K.



The interface temperature T_i (in K) of the composite wall is _____.

Q.8 Heat transfer coefficients for free convection in gases, forced convection in gases and vapours, and for boiling water lie, respectively, in the range of
(a) 5–15, 20–200 and 3000–50000 W/m^{2}K
(b) 20–50, 200–500 and 50000–100000 W/m^{2}K
(c) 50–100, 500–1000 and 100000–100000 W/m^{2}K
(d) 20–100, 200–1000 and a constant 1000000 Wm^2

Q.9 For the three-dimensional object shown in the figure below, five faces are insulated. The sixth face (PQRS), which is not insulated, interacts thermally with the ambient, with a convective heat transfer coefficient of 10 W/m^{2}K. The ambient temperature is 30°C. Heat is uniformly generated inside the object at the rate of 100 W/m^3. Assuming the face PQRS to be at uniform temperature, its steady state temperature is

Answers Heat Transfer

1. (b)	2. (d)	3. (c)	4. (c)	5. (b)	6. (b)	7. (400°C)	8. (a)
9. (d)	10. (d)	11. (a)	12. (b)	13. (d)	14. (c)	15. (24936)	16. (c)
17. (c)	18. (a)	19. (b)	20. (a)	21. (a)	22. (a)	23. (d)	24. (d)
25. (c)	26. (a)	27. (b)	28. (a)	29. (d)	30. (c)	31. (d)	32. (d)
33. (c)	34. (c)	35. (a)	36. (d)	37. (c)	38. (a)	39. (c)	40. (b)
41. (c)	42. (c)	43. (b)	44. (a)	45. (a)	46. (a)	47. (a)	48. (d)
49. (b)	50. (c)	51. (d)	52. (b)	53. (b)	54. (a)	55. (a)	56. (d)
57. (c)	58. (b)	59. (c)	60. (c)	61. (c)	62. (c)	63. (b)	64. (c)
65. (b)	66. (b)	67. (63.96)	68. (a)	69. (0.94)	70. (c)	71. (a)	72. (c)
73. (d)	74. (0.424)	75. (–16.84)	76. (b)	77. (c)	78. (539.67)	79. (533.33)	80. (4.87)
81. (45.45)	82. (a)	83. (a)	84. (36.23)				

Explanations Heat Transfer

1. (b)

Material	Thermal conductivity : *k* (W/mK)
Wood (wood fire)	0.11
Air (20°C)	0.025
Water (100°C)	0.6804
Steam (1 bar & 200°C)	0.03349

2. (d)

Given data:

$$d = 20 \text{ mm}$$

$$\therefore \quad r = \frac{d}{2} = \frac{20}{2} = 10 \text{ mm}$$

$$h_o = 20 \text{ W/m}^2\text{K}$$

$$k = 0.5 \text{ W/mK}$$

For maximum heat dissipation,

Critical radius,

$$r_c = \frac{k}{h} \quad \text{for cylinder or wire}$$

$$= \frac{0.5}{20} = 0.025 \text{ m} = 25 \text{ mm}$$

Thickness of insulation,

$$= r_c - r = 25 - 10 = 15 \text{ mm}$$

3. (c)

Fourier's law,

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

At constant Q, A and dx,

$$dT \propto \frac{1}{k}$$

Temperature drop (dT) is inversely proportional to the thermal conductivity.

Material	Thermal conductivity : *k* (W/mK)
Copper	385
Steel	45
Glass wool	0.0372
Refractory brick	1.50

Hence, lower the thermal conductivity, higher temperature drop. So, glass wool has minimum thermal conductivity and maximum temperature drop.

4. (c)

Given data:

$$k_s = 19 \text{ W/mK}$$

$$d_1 = 2 \text{ cm} = 0.02 \text{ m}$$

$$\therefore \quad r_1 = \frac{d_1}{2} = \frac{0.02}{2} = 0.01 \text{ m}$$

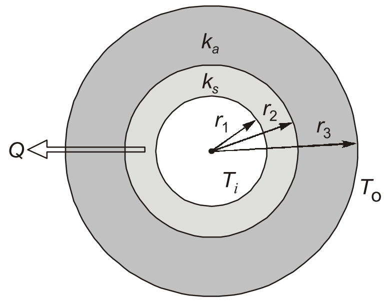
$$d_2 = 5 \text{ cm} = 0.05 \text{ m}$$

$$\therefore \quad r_2 = \frac{d_2}{2} = \frac{0.05}{2} = 0.025 \text{ m}$$

$$t = 3 \text{ cm} = 0.03 \text{ m}$$

$$\therefore \quad r_3 = r_2 + t = 0.025 + 0.03$$

$$= 0.055 \text{ m}$$
$$k_a = 0.2 \text{ W/mK}$$
$$T_i - T_o = 600°\text{C}$$



Heat transfer,

$$Q = \frac{T_i - T_o}{\frac{1}{2\pi k_s l}\log_e\frac{r_2}{r_1} + \frac{1}{2\pi k_a l}\log_e\frac{r_3}{r_2}}$$

$$\frac{Q}{l} = \frac{T_i - T_o}{\frac{1}{2\pi k_s}\log_e\frac{r_2}{r_1} + \frac{1}{2\pi k_a}\log_e\frac{r_3}{r_2}}$$

$$q = \frac{600}{\frac{1}{2\times 3.14\times 19}\log_e\frac{0.025}{0.01} + \frac{1}{2\times 3.14\times 0.2}\log_e\frac{0.055}{0.025}}$$

$$= \frac{600}{0.007679 + 0.627752}$$

$$= 944.72 \text{ W/m}$$

5. (b)

Given data:

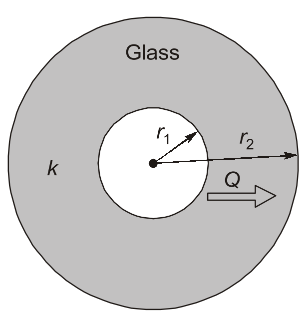
$$d_1 = 0.03 \text{ m}$$

$$\therefore \quad r_1 = \frac{d_1}{2} = \frac{0.03}{2} = 0.015 \text{ m}$$

$$d_2 = 0.05 \text{ m}$$

$$\therefore \quad r_2 = \frac{d_2}{2} = \frac{0.05}{2} = 0.025 \text{ m}$$

$$k = 1.05 \text{ W/mK}$$



Long glass cylinder

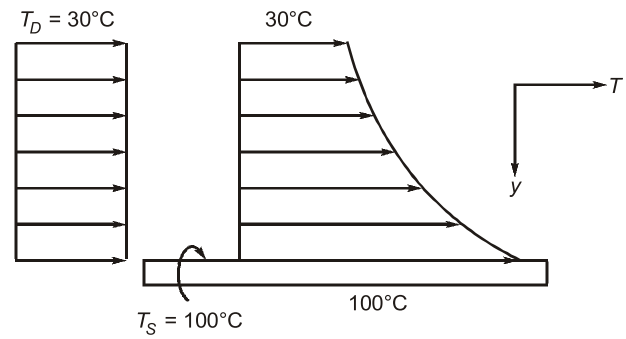
Thermal resistance,

$$R_t = \frac{1}{2\pi k l}\log_e\frac{r_2}{r_1}$$

$$= \frac{1}{2\times 3.14\times 1.05\times 1}\log_e\frac{0.025}{0.015}$$

$$= 0.077 \text{ W/m}$$

6. (b)



At $y = 0$; $q_{cond} = q_{conv}$

$$-k_f \left.\frac{\partial T}{\partial y}\right|_{y=0} = h\Delta T = h(T_s - T_\infty)$$

$$-(1)\left.\frac{\partial}{\partial y}\left[30 + 70\, e^{-y}\right]\right|_{y=0} = h(100 - 30)$$

$$-\left[0 + 70(-1)\, e^{-y}\right]\Big|_{y=0} = h(70)$$

$$70\, e^{-0} = h(70)$$

or $\quad h = 1 \text{ W/m}^2\text{K}$

Alternatively:

Given data:

$$T_\infty = 30°\text{C}$$
$$T_s = 100°\text{C}$$
$$k_f = 1 \text{ W/mK}$$
$$T = 30 + 70\exp(-y)$$

Differentiating w.r.t y, we get

$$\frac{dT}{dy} = -70\, e^{-y}$$

At $\quad y = 0$

$$\left(\frac{dT}{dy}\right)_{y=0} = -70$$

We know that local convective heat transfer coefficient:

$$h_x = \frac{-k_f\left(\frac{dT}{dy}\right)_{y=0}}{T_s - T_\infty} = \frac{-1\times(-70)}{100 - 30} = 1 \text{ W/m}^2\text{K}$$

7. (400°C)

Given data:

$$T_1 = 600 \text{ K}$$
$$T_2 = 300 \text{ K}$$