POSTAL Study Package 2021

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

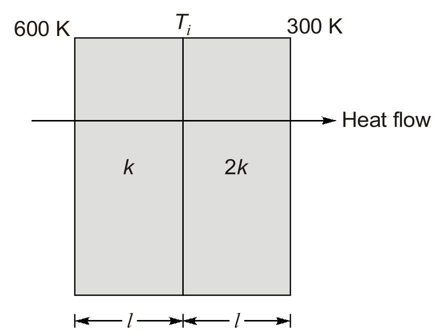
Q.3 For a given heat flow and for the same thickness, the temperature drop across the material will be maximum for
(a) Copper (b) Steel
(c) Glass wool (d) Refractory brick

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 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

Q.19 Consider the following statements:

1. Under certain conditions, an increase in thickness of insulation may increase the heat loss from a heated pipe.
2. The heat loss from an insulated pipe reaches a maximum when the outside radius of insulation is equal to the ratio of thermal conductivity to the surface heat transfer coefficient.
3. Small diameter tubes are invariably insulated.
4. Economic insulation is based on minimum heat loss from pipe.

Which of these statements are correct?

(a) 1 and 3 (b) 1 and 2
(c) 2 and 4 (d) 3 and 4

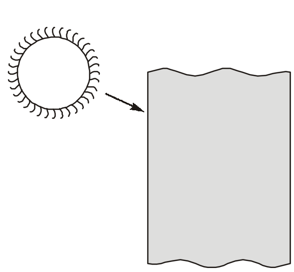
Q.20 A cube at high temperature is immersed in a constant temperature bath. It loses heat from its top, bottom and side surfaces with heat transfer coefficient of h_1, h_2 and h_3 respectively. The average heat transfer coefficient for the cube is

(a) $h_1 + h_2 + h_3$ (b) $(h_1 h_2 h_3)^{1/3}$
(c) $\frac{1}{h_1} + \frac{1}{h_2} + \frac{1}{h_3}$ (d) None of these

Q.21 A steam pipe is covered with two layers of insulating materials, with the better insulating material forming the outer part. If the two layers are interchanged, the heat conducted

(a) will decrease
(b) will increase
(c) will remain unaffected
(d) may increase or decrease depending upon the thickness of each layer

Q.22 Solar energy is absorbed by the wall of a building as shown in the figure below. Assuming that the ambient temperature inside and outside are equal and considering steady-state, the equivalent circuit will be as shown in

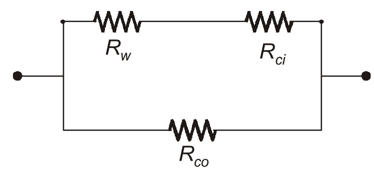


Symbols:

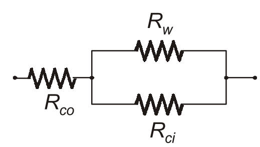
$R_{co} = R_{\text{convection outside}}$

$R_{ci} = R_{\text{convection inside}}$, $R_w = R_{\text{wall}}$

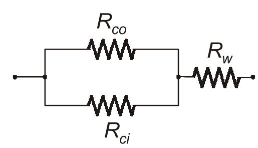
(a)



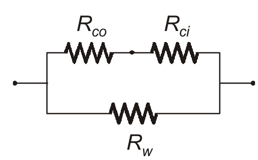
(b)



(c)



(d)



Q.23 Consider the following statements:
The Fourier heat conduction equation

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

1. steady-state conditions.
2. constant value of thermal conductivity.
3. uniform temperatures at the wall surfaces.
4. one-dimensional heat flow.

Which of these statements are correct?

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

Q.24 A composite plane wall is made up of two different materials of the same thickness and having thermal conductivities of k_1 and k_2 respectively. The equivalent thermal conductivity of the slab is

(a) $k_1 + k_2$ (b) $k_1 k_2$
(c) $\frac{k_1 + k_2}{k_1 k_2}$ (d) $\frac{2k_1 k_2}{k_1 + k_2}$

Q.25 A 0.5 m thick plane wall has its two surfaces kept at 300°C and 200°C. Thermal conductivity of the wall varies linearly with temperature and its values at 300°C and 200°C are 25 W/mK and 15 W/mK, respectively. Then the steady heat flux through the wall 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:

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

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

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

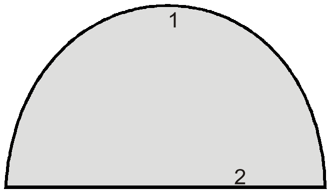
$$d_2 = 5 \text{ cm} = 0.05 \text{ m}$$

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

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

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

15. (24936 kW)



Given data: $r = 1$ m; $\varepsilon_1 = 1$

$T_1 = 800$ K; $\varepsilon_2 = 0.5$; $F_{21} = 1$

$$Q = \frac{\sigma(T_1^4 - T_2^4)}{\frac{1}{A_1}\left(\frac{1-\varepsilon_1}{\varepsilon_1}\right) + \frac{1}{F_{21}A_2} + \frac{1-\varepsilon_2}{\varepsilon_2 A_2}}$$

$$= \frac{5.67 \times 10^{-8}(800^4 - 600^4)}{\frac{1}{2\pi \times 1^2}\left(\frac{1-1}{1}\right) + \frac{1}{1 \times \pi \times 1^2} + \frac{1-0.5}{0.5 \times \pi \times 1^2}}$$

$= 24937.96$ W **= 24936 kW**

16. (c)

E(emmisive power) $\propto T^4$ $(\because \in = \text{Constant})$

$$\frac{E_1}{E_2} = \left(\frac{T_1}{T_2}\right)^4$$

or $$\frac{T_1}{T_2} = \left(\frac{500}{1200}\right)^{1/4} = 0.803$$

17. (c)

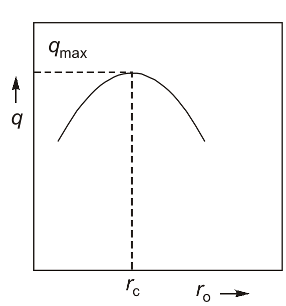
Heat transfer takes place according to second law of thermodynamics.

Second law of thermodynamics states that "heat will flow naturally from one reservoir to another at a lower temperature, but not in opposite direction without assistance".

18. (a)

In usual analysis R_{ins} and R_{air} are larger magnitude than R_{pipe} and R_{steam}.

19. (b)



If $r_o < r_c$

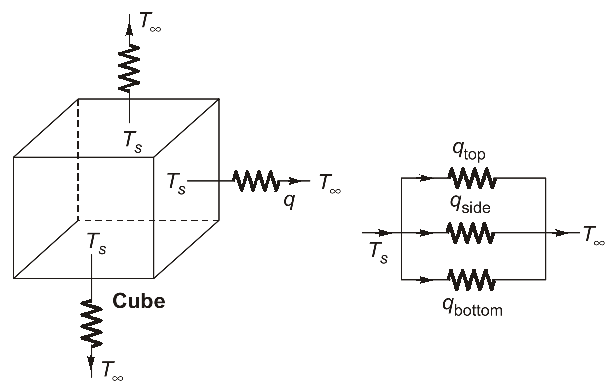
An increase in thickness of insulation increases the heat loss.

If $r_o = r_c$

The heat loss from an insulated pipe reaches a maximum value when the outside radius of insulation is equal to the ratio of thermal conductivity to the surface heat transfer coefficient.

For cylinder, $r_c = k/h$.

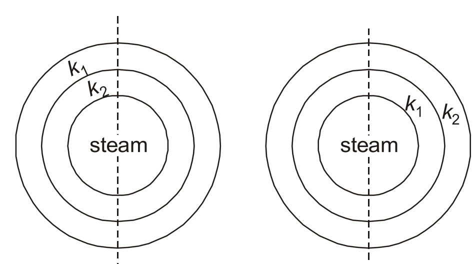
20. (a)



Parallel connections,

$$\bar{h} = h_1 + h_2 + h_3$$

21. (a)



$k_1 < k_2$ [k_1 better insulator]

$$Q \propto \frac{k.A.\Delta T}{\ln\left(\frac{r_2}{r_1}\right)}$$

$\therefore$ $Q \propto k$

This means that the material having better insulating material should be inside to minimize the heat flux. If higher 'k' material then 'Q' is more since total thermal resistance is lesser.