ANSWER KEY

1.	(C)	13.	(A)	25.	(5918)	37.	(868.56)	49.	(A)	61.	(D)
2.	(387.75)	14.	(B)	26.	(0)	38.	(934)	50.	(A)	62.	(A)
3.	(C)	15.	(A)	27.	(178.2)	39.	(17.33)	51.	(B)	63.	(B)
4.	(D)	16.	(A)	28.	(61)	40.	(1.11)	52.	(C)	64.	(D)
5.	(B)	17.	(B)	29.	(A)	41.	(92.5)	53.	(191 W)	65.	(B)
6.	(D)	18.	(A)	30.	(10^5 W/m^3)	42.	(3.09)	54.	(1/3)		
7.	(D)	19.	(B)	31.	(B)	43.	(14.5)	55.	(36900)		
8.	(B)	20.	(B)	32.	(B)	44.	(A)	56.	(B)		
9.	(A)	21.	(D)	33.	(A)	45.	(61.7)	57.	(B)		
10.	(D)	22.	(C)	34.	(1122)	46.	(50)	58.	(D)		
11.	(D)	23.	(A)	35.	(A)	47.	(0.64)	59.	(B)		
12.	(A)	24.	(0.363)	36.	(A)	48.	(170)	60.	(D)		

SOLUTIONS

1. (C)

$Wt = \rho A.L$

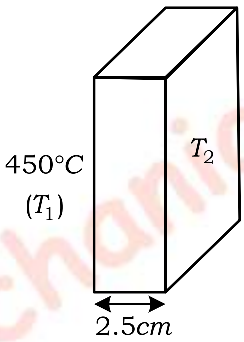
$(R_{th})_{cond.} = \frac{L}{kA}$

$= \rho.A.(R_{th})_{cond.}.k.A$

$= (\rho.k)A^2.(R_{th})_{cond.}$

2. (387.75)

$$q_{cond.} = -kA\frac{dT}{dx} = kA\frac{T_1 - T_2}{L}$$



$$5\times10^3 = 0.2\times20\times\frac{415 - T_2}{2.5\times10^{-2}}$$

$\Rightarrow 31.25 = 415 - T_2$

$\Rightarrow T_2 = 415 - 31.25 = 383.75^0 C$

3. (C) **4. (D)**

5. (B) **6. (D)** **7. (D)**

8. (B)

$$T(x) = \frac{\dot{q}L^2}{2k}\left(1 - \frac{x^2}{L^2}\right) + \left(\frac{T_{S2} - T_{S1}}{L}\right)\frac{x}{L} + \frac{T_{S1} + T_{S2}}{2}$$

9. (A)

Gas has lower convection co-efficient, which will increase the fin effectiveness

$$\in_f = \left(\frac{kP}{hA_C}\right)^{1/2}$$

10. (D)

For infinite long fin,

$q = (kPhA_C)^{1/2}\,\theta_b$

$$= \left[k(\pi D)h\left(\frac{\pi}{4}D^2\right)\right]^{\frac{1}{2}}\theta_b = \frac{\pi}{2}(hk)^{\frac{1}{2}}D^{\frac{3}{2}}\theta_b \quad \frac{q(3D)}{q(D)} = 3^{\frac{3}{2}}$$

$= 5.2$

$\therefore$ 420% increase

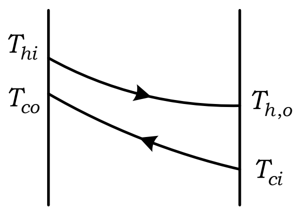
11. (D) **12. (A)**

13. (A) **14. (B)**

15. (A) **16. (A)**

17. (B) **18. (A)** **19. (B)**

20. (B)



[It is possible only in counter flow heat exchanger]

21. (D) **22. (C)** **23. (A)**

24. (0.363)

$$F_{2-1} = \frac{A_1F_{12}}{A_2} = \frac{2RL}{\pi RL}\times1.0 = \frac{2}{\pi} = 0.637$$

$$F_{22} = 1 - F_{2-1} = 1 - 0.637 = 0.363$$

25. (5918)

$$\lambda_{\max}T = 2900\mu m - k$$
$$\lambda_{\max}T = 2898\mu m - k \text{ or } 2900\mu m - k$$
$$\Rightarrow T = \frac{2900}{0.49} = 5918k$$

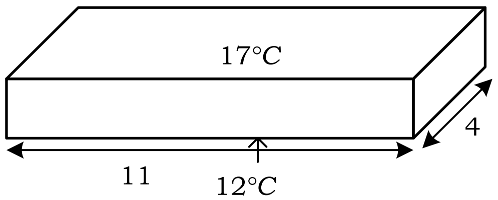
26. (0)

Heat equation

$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} = \frac{1}{\alpha}\frac{\partial T}{\partial t}$$
$$T = x^2 - 2y^2 + z^2 - xy + 2yz$$
$$\Rightarrow \frac{\partial}{\partial x}(2x - y) + \frac{\partial}{\partial y}(-4y - x + 2z) + \frac{\partial}{\partial z}(2z + 2y)$$
$$= \frac{1}{\alpha}\frac{\partial T}{\partial t}$$
$$\Rightarrow 2 - 4 + 2 = \frac{1}{\alpha}\frac{\partial T}{\partial t} \Rightarrow \frac{\partial T}{\partial t} = 0$$

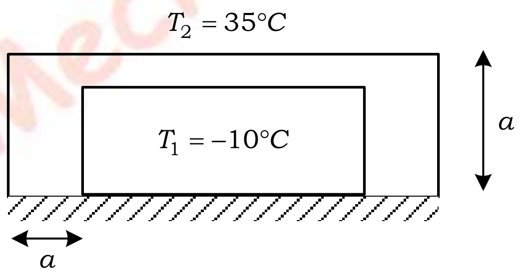
So temperature is every where independent of time at that instant

27. (178.2)



$$q = -kA\frac{dT}{dx} = (1.5)(44)\frac{(17-12)}{0.2} = 1650W$$
$$\text{cost} = \frac{1650 \times (\text{Rs.}1/\text{MJ})}{0.8 \times 10^6 J/MJ} \times (24 \times 3600)$$
$$= 178.2/day$$

28. (61)



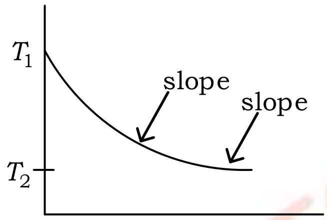
$$q = kA\frac{dT}{dx}$$
$$A_{total} = 5 \times a^2, \Rightarrow 1000 = 0.03 \times (5 \times 3^2)\frac{(35-(-10))}{t}$$
$$\Rightarrow t = \frac{0.03 \times (5 \times 3^2) \times 45}{1000} = 0.061m \approx 61mm$$

29. (A)

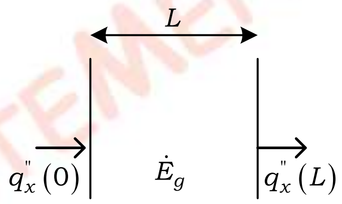
$$q_x = -kA_x\frac{dT}{dx}$$
$$q_x = \text{constant}$$
=Heat rate within object is constant.

k = constant property

$\therefore A_x\frac{dT}{dx} = const, \Rightarrow$ As area increased $\left(\frac{dT}{dx}\right)$, *slope of the curve T − x, will decrease.*



30. ($10^5\ W/m^3$)



Heat equation is,

$$\frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right) + \frac{\partial}{\partial y}\left(k\frac{\partial T}{\partial y}\right) + \frac{\partial}{\partial z}\left(k\frac{\partial T}{\partial z}\right) + \dot{q} = \rho C_P\frac{\partial T}{\partial t}$$

Condition

- one dimensional
- steady state
- constant thermal conductivity

Heat equation reduces to

$$k\frac{\partial^2 T}{\partial x^2} + \dot{q} = 0$$
$$\dot{q} = -k\frac{\partial^2 T}{\partial x^2} = -50\frac{\partial^2}{\partial x^2}(a + bx^2)$$
$$= -50.2b = -50 \times 2 \times \left(-1000\frac{{}^0C}{m^2}\right)$$
$$\dot{q} = 10^5 W/m^3$$

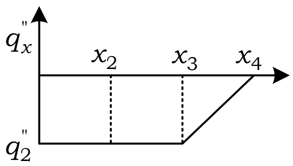
31. (B)

32. (B)

Parabolic temperature distribution in “C” implies existence of heat generation.

Hence $\frac{dT}{dx}$ increases with decreasing in (x) so heat flux in **(C)** increases with decreasing (x) $q_3'' > q_4''$. Linear temperature distribution in “A” & “B” shows no heat penetration $\therefore q_2'' = q_3''$.

33. (A)



34. (1122)

$$\frac{\theta}{\theta_i}=\frac{T-T_\infty}{T_i-T_\infty}=\exp(-B_i\times F_0)$$

$$\Rightarrow \ell n\frac{T-T_\infty}{T_i-T_\infty}=-B_i\times\frac{\alpha t}{L_C^2}$$

$$\Rightarrow t=(-)\frac{L_C^2}{B_i\times\alpha}\ell n\left(\frac{T-T_\infty}{T_i-T_\infty}\right)$$

$$=(-)\frac{\left(\frac{6\times10^{-3}}{3}\right)^2}{.001\times8.57\times10^{-6}}\ell n\left[\frac{400-325}{1150-325}\right]$$

$$=1122.2\sec\approx1122\sec$$

35. (A)

$$m=\int_0^\delta\rho u dy=\int_0^\delta\rho\left[U\left\{\frac{3}{2}\left(\frac{y}{\delta}\right)-\frac{1}{2}\left(\frac{y}{\delta}\right)^3\right\}\right]dy,$$

$$\boxed{m=\frac{5}{8}\rho U\delta}$$

36. (A)

Parallel to 500mm

$$\bar{h}=.664(R_{eL})^{1/2}(\Pr)^{1/3}\left(\frac{k}{L}\right)\Bigg|\quad R_L=\frac{2\times0.5}{18.9\times10^{-6}}$$

$$=5.27\times10^4$$

$$Q=\bar{h}A_s(t_s-t_\infty),\frac{Q_{500}}{Q_{200}}$$

$$=\frac{\bar{h}_{500}}{\bar{h}_{200}}\cdot\frac{A_s(t_s-t_\infty)}{A_s(T_s-t_\infty)}=\frac{\bar{h}_{500}}{\bar{h}_{200}}$$

$$\frac{\bar{h}_{500}}{\bar{h}_{200}}=\frac{.664(R_L)_{500}^{1/2}(\Pr)^{1/3}\frac{k}{L_{500}}}{.664(R_L)_{200}^{1/2}(\Pr)^{1/3}\frac{k}{L_{200}}}$$

$$\Rightarrow\frac{\bar{h}_{500}}{\bar{h}_{200}}=\left(\frac{L_{500}}{L_{200}}\right)^{1/2}\times\frac{L_{200}}{L_{500}}$$

$$=\left(\frac{.5}{.2}\right)^{1/2}\left(\frac{.2}{.5}\right)=\sqrt{\frac{.2}{.5}}=0.63$$

37. (868.56)

$$\mathrm{Re}_L=\frac{UL}{\upsilon}=\frac{25\times0.8}{17.95\times10^{-6}}=1.114\times10^6$$

$\mathrm{Re}_L>5\times10^5$, Flow is turbulent, $\bar{N}u=\frac{\bar{h}L}{k}$

$$=.036(\mathrm{Re}_L)^{0.8}(\Pr)^{0.333}$$

$$\Rightarrow\bar{h}=\frac{k}{L}\times.036\times(\mathrm{Re}_L)^{0.8}(\Pr)^{0.333}$$

$$=\frac{.02824}{0.8}\times.036\times\left(1.114\times10^6\right)^{0.8}(0.698)^{.333}$$

$$=77.55W/m^2-{}^0C$$

$$Q=\bar{h}A(T_S-T_\infty)=77.55\times(.8\times.2)(85-15)$$

$$=868.56W$$

38. (934)

$$U=\frac{30\times1000}{60\times60}=8.33m/s$$

$$\mathrm{Re}=\frac{UD}{\nu}=\frac{8.33\times.350}{15\times10^{-6}}=1.94\times10^5$$

$$Nu=\frac{\bar{h}D}{k}=.027\,\mathrm{Re}^{.805}\,\Pr^{.33}$$

$$\Rightarrow\bar{h}=.027\times\frac{2.59\times10^{-2}}{35}\times\left(1.94\times10^5\right)^{.805}(.707)^{.33}$$

$$=32.18W/m^2-{}^0C$$

Heat lost by man, $Q=\bar{h}A_s(t_s-t_\infty)$

$$=32.18\times(\pi\times.35\times1.65)(28-12)$$

$$\boxed{Q=934W}$$

39. (17.33)

$$\mathrm{Re}=\frac{UD}{\nu}=\frac{0.4\times.065}{2.08\times10^{-5}}=1250$$

$$\bar{N}u=\frac{\bar{h}D}{k}=0.37(Re)^{0.6}$$

$$\bar{h}=\frac{0.37(1250)^{0.6}\times.03}{.065}$$

$$=1232W/m^2-{}^0C$$

$$Q=\bar{h}A_s(t_s-t_\infty)$$

$$=12.32\times\left[4\pi\times\left(\frac{.065}{2}\right)^2\right](130-24)$$

$$=17.33W$$

$$\%Power=\frac{17.33}{100}\times100=17.33\%$$

40. (1.11)

$$\bar{h}_x=\frac{1}{x}\int_0^x h_x(x)dx=\frac{1}{x}\int_0^x ax^{-0.1}dx=\frac{a}{x}\left(\frac{x^{.9}}{.9}\right)$$

$$=1.11ax^{-0.1}$$

$$\Rightarrow\bar{h}_x=1.11ax^{-.1}$$

$$\Rightarrow\bar{h}_x=1.11h_x(x)$$

$$\Rightarrow\boxed{\frac{\bar{h}_x}{h_x(x)}=1.11}$$

41. (92.5)

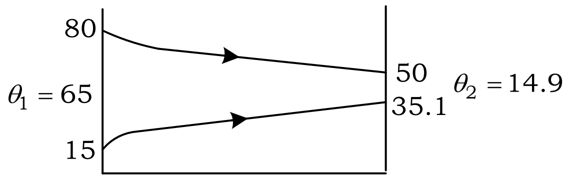
Electric power = Total convection loss

$= h.A.(t_s - t_w)$

$= 3275 \times \left(\pi \times 1.5 \times 10^{-3} \times 200 \times 10^{-3}\right)(130-100)$

$= 92.5W$

42. (3.09)



$$LMTD = \frac{\theta_2 - \theta_1}{\ell n\left(\frac{\theta_2}{\theta_1}\right)} = \frac{14.9-65}{\ell n\left(\frac{14.9}{65}\right)} = \frac{-50.1}{-1.47} = 34.01^0 C$$

$Q = UA\theta_{\ell m}$

$\Rightarrow m_h c_{p.h}\left(T_{h,i} - T_{h,o}\right) = UA\theta_{\ell m}$

$$\Rightarrow A = \frac{m_h c_{p.h}\left(T_{hi} - T_{h.o}\right)}{U\theta_{\ell m}}$$

$$= \frac{2 \times 3500 \times (80-50)}{2000 \times 34.01} = 3.09m^2$$

43. (14.5)

$A_{counter} = 2.64m^2$

$A_{parallel} = 3.09m^2$

$$\% \text{ Reduction} = \frac{3.09 - 2.64}{3.09} = 14.5\%$$

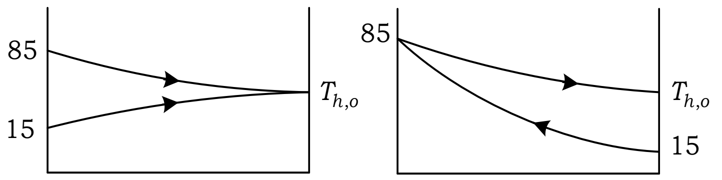
44. (A)

	Hot	Cold
C_{hot}	$= \rho_h.Flow\ Rate.(C_P)_h$	
	$= 997 \times \frac{14}{3600} \times 4179$	$= 1247 \times \frac{16}{3600} \times 2564$
	$= 16202.9$	$= 14210.3$

Maximum possible heat transfer rate = $C_{mn} \times temp.diff$

C_{min} = cold fluid

45. (61.7)



Parallel flow Counter flow

For very long exchanger, parallel flow, $T_{h,o}$ and $T_{c,o}$ will be same

$\dot{m}_h = 2\dot{m}_c$

$(c_P)_h = (c_p)_c$

$\Rightarrow C_h = 2.C_c$

$T_{h,o} = T_{c,o}$

Heat gain by cold water = Heat lost by hot water

$\Rightarrow C_C\left[T_{c,o} - T_{c,i}\right] = C_h\left[T_{h,i} - T_{h,o}\right]$

$\Rightarrow C_C\left[T_{h,o} - T_{c,i}\right] = 2.C_C\left[T_{h,i} - T_{h,o}\right]$

$\Rightarrow 3T_{h,o} = 2T_{h,i} + T_{c,i}$

$$\Rightarrow T_{h,o} = \frac{2T_{h,i} + T_{c,i}}{3} = \frac{(2 \times 85) + 15}{3}$$

$= 61.7^0 C$

46. (50)

For very long heat exchanger, $T_{h,i} = T_{c,o}$

$C_C\left[T_{c,o} - T_{c,i}\right] = C_h\left[T_{h,i} - T_{h,o}\right]$

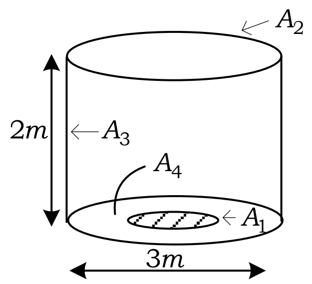
$\Rightarrow C_C\left[T_{h,i} - T_{c,i}\right] = 2.C_C\left[T_{h,i} - T_{h,o}\right]$

$\Rightarrow 85 - 15 = 2\left[85 - T_{h,o}\right]$

$\Rightarrow 35 = 85 - T_{h,o}$

$\Rightarrow T_{h,o} = 85 - 35 = 50$

47. (0.64)



$F_{11} + F_{12} + F_{13} + F_{14} = 1$

$F_{11} = 0 | F_{14} = 0 |$

$$\Rightarrow F_{12} = \frac{D^2}{D^2 + 4L^2}$$

(when a circular disk of diameter D is located parallel to small area)

$$= \frac{3^2}{3^2 + 4(2)^2} = 0.36$$

$F_{13} = 1 - F_{12}$

$= 1 - 0.36$

$= 0.64$

48. (170)

$q_{1-3} = A_1 F_{13} \sigma\left(T_1^4 - T_3^4\right)$

$= .05 \times 0.64 \times \left(5.67 \times 10^{-8}\right)\left(1000^4 - 500^4\right)$

$= 1701$

49. (A)

$$G_{upper} = \begin{bmatrix}\text{Flux emitted by} \\ \text{surface (2)}\end{bmatrix} + \begin{bmatrix}\text{Reflection by surface (2)} \\ \text{of flux emitted by (1)}\end{bmatrix}$$

$$= \epsilon_2 E_{b2} + \rho_2 E_{b1}$$

$$= \epsilon_2 \sigma T_2^4 + (1-\epsilon_2)\sigma T_1^4$$

$$= \left[0.8 \times 5.67 \times 10^{-8} \times (500)^4\right] + \left[(1-0.8) \times 5.67 \times 10^{-8} \times 1000^4\right]$$

$$= 2835 + 11340 = 14175\ W/m^2$$

50. (A)

2- opening

1- inner surface

Cone:

$$F_{21} + F_{22} = F_{21} + 0 = 1 \Rightarrow \boxed{F_{21} = 1}$$

$$F_{12} = \frac{A_2F_{21}}{A_1} = \frac{\left(\frac{\pi}{4}d^2\right)}{\frac{\pi d}{2}\left[L^2 + \left(\frac{d}{2}\right)^2\right]^{\frac{1}{2}}} = \frac{1}{2}\left[\left(\frac{L}{d}\right)^2 + \frac{1}{4}\right]^{\frac{-1}{2}}$$

51. (B)

Cylinder:

$$F_{21} = 1$$

$$F_{12} = \frac{A_2F_{21}}{A_1} = \frac{\frac{\pi}{4}d^2}{\pi dL + \frac{\pi}{4}d^2} = \left[1 + \frac{4L}{d}\right]^{-1}$$

52. (C)

Sphere:

$$F_{21} = 1$$

$$F_{12} = \frac{A_2F_{21}}{A_1} = \frac{\frac{\pi}{4}d^2}{\pi D^2 - \frac{\pi}{4}d^2} = \left[4D^2/d^2 - 1\right]^{-1}$$

53. (191W)

$$q_{12} = \frac{\sigma A_1\left[T_1^4 - T_2^4\right]}{\frac{1}{\epsilon_1} + \frac{1-\epsilon_2}{\epsilon_2}\left(\frac{r_1}{r_2}\right)^2}$$

$$= \frac{\left(5.67 \times 10^{-8}\right)\left(\pi \times 0.8^2\right)\left(400^4 - 300^4\right)}{\frac{1}{0.5} + \frac{1-0.05}{.05}\left(\frac{0.4}{0.6}\right)^2}$$

$$= 191W$$

54. (1/3)

$$\frac{(Q)_{n-shield}}{(Q)_{without\ shield}} = \frac{1}{n+1} = \frac{1}{3}$$

55. (36900)

$$q_{21} = A_2F_{21}\sigma\left(T_2^4 - T_1^4\right)$$

$$= (490.87)\left(5.67 \times 10^{-8}\right)\left(288^4 - 273^4\right)$$

$$= 3.69 \times 10^4 W$$

$$A_2F_{21} = A_1F_{12} = \left(\frac{\pi}{4}D_1\right)^2 .1 = \frac{\pi}{4} \times 25^2 = 490.87$$

56. (B)	**57. (B)**
58. (D)	**59. (B)**
60. (D)	**61. (D)**
62. (A)	**63. (B)**
64. (D)	**65. (B)**

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