CLASS TEST S.No.: 02DLSK_ABCDEFGH_130926

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HEAT TRANSFER

MECHANICAL ENGINEERING

Date of Test : 13/09/2026

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (d)

$$\eta = \frac{Q_{\text{actual}}}{Q_{\text{ideal}}} = \frac{\sqrt{hPkA}\,(T_b - T_\infty)}{hA_{\text{fin}}(T_b - T_\infty)} = \frac{\sqrt{hPkA}}{hPL} = \frac{1}{L}\sqrt{\frac{kA}{hP}}$$

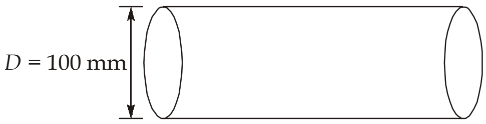
For circular fin

$$A = \frac{\pi}{4}d^2$$

$$P = \pi d$$

$$\eta = \frac{1}{L}\sqrt{\frac{kd}{4h}} = \frac{1}{2L}\sqrt{\frac{kd}{h}}$$

2. (d)



Diameter of steel pipe, D = 100 mm

Nusselt number, Nu = 20

Thermal conductivity, k = 0.06 W/mK

For horizontal pipe, $$\text{Nu} = \frac{hD}{k}$$

$$\Rightarrow \quad 20 = \frac{h \times 0.1}{0.06}$$

Heat transfer coefficient, h= 12 W/m^{2}K

3. (a)

$$\nu < \alpha$$

$$\text{Pr} = \frac{\nu}{\alpha}, \text{ so Pr} < 1$$

For Pr < 1, $$\frac{\delta_t}{\delta_v} > 1$$

$$\delta_t > \delta_v \text{ or } \delta_v < \delta_t$$

4. (d)

5. (d)

Critical radius of insulation, $r_c = \dfrac{k}{h_o}$

$$= \frac{0.5}{10} = 0.05 \text{ m} = 50 \text{ mm}$$

Maximum value of heat dissipation rate,

$$q_{\max} = \frac{\Delta T}{\frac{\ln\left(\frac{r_o}{r_i}\right)}{2\pi kL} + \frac{1}{hA_o}} = \frac{100-25}{\frac{\ln(50/0.5)}{2\pi\times0.5\times1} + \frac{1}{2\pi\times\frac{50}{1000}\times1\times10}} = 42.036 \text{ W/m}$$

6. (a)

Heat transfer rate through composite structural wall, $q_1 = -k_1 A\frac{\Delta T}{\delta_1} = -0.2A\frac{\Delta T}{0.09}$

Heat transfer rate through masonry wall,

$$q_2 = -k_2 A\frac{\Delta T}{\delta_2} = -0.7A\times\frac{\Delta T}{\delta_2}$$

As per given condition,

$$q_2 = 0.6q_1$$

$$\Rightarrow \quad -0.7A\times\frac{\Delta T}{\delta_2} = 0.6\times\left(-0.2A\times\frac{\Delta T}{0.09}\right)$$

$$\delta_2 = 0.525 \text{ m} = 525 \text{ mm}$$

7. (b)

For parallel flow heat exchanger,

$$\varepsilon = \frac{1-\exp(-NTU(1+C))}{1+C}$$

Put $C = 0$,

$$\varepsilon = \frac{1-\exp(-NTU)}{1}$$

$$\varepsilon = 1 - \exp(-\text{NTU})$$

For counter flow heat exchanger,

$$\varepsilon = \frac{1-\exp\{-NTU(1-C)\}}{1-C\exp\{-NTU(1-C)\}}$$

Put $C = 0$,

$$\varepsilon = \frac{1-\exp\{-NTU(1-0)\}}{1-0\times\exp\{-NTU(1-0)\}}$$

$$\varepsilon = 1 - \exp(-\text{NTU})$$

So, expression:

$$\varepsilon = 1 - \exp(-\text{NTU})$$

is valid for all the heat exchangers having zero capacity ratio.

8. (d)

The relative magnitude of the dimensionless parameter $\frac{Gr}{\text{Re}^2}$ governs the relative importance of natural convection in relation to forced convection where,

$$\frac{Gr}{\text{Re}^2} = \frac{g\beta(T_w - T_\infty)L}{U_0^2}$$

which represents the ratio of the buoyancy forces to inertia forces.

9. (c)

$$\text{Reflectivity, } \rho = 0.4$$

For opaque body,

$$\alpha + \rho = 1$$

$$\alpha + 0.4 = 1$$

$$\text{Absorptivity, } \alpha = 0.6 = \frac{G_{abs}}{G} = \frac{G_{abs}}{600}$$

Part of radiation absorbed,

$$G_{\text{abs}} = 0.6 \times 600 = 360 \text{ W/m}^2$$

10. (d)

For infinitely long fin,

$$\dot{q} = \sqrt{hPkA}\,(T_b - T_\infty)$$

$$\text{For circular fin, } P = \pi D$$

$$A = \frac{\pi}{4}D^2$$

So,

$$\dot{q} = \sqrt{h \times \pi D \times k \times \frac{\pi}{4}D^2}\,(T_b - T_\infty)$$

$$\dot{q} \propto \sqrt{k}D^{3/2}$$

$$\frac{\dot{q}_1}{\dot{q}_2} = \frac{\sqrt{k_1}}{\sqrt{k_2}}\frac{D_1^{3/2}}{D_2^{3/2}} = \left(\frac{400}{250}\right)^{1/2}\left(\frac{D}{0.4D}\right)^{3/2} = 5$$

11. (b)

$$\frac{T(t) - T_\infty}{T_i - T_\infty} = e^{-bt}$$

$$\Rightarrow \quad \frac{\frac{T_i + T_\infty}{2} - T_\infty}{T_i - T_\infty} = e^{-bt}$$

$$\Rightarrow \quad \frac{1}{2} = e^{-bt}$$

Where

$$b = \frac{1}{\tau}$$

$$\text{Time required, } t = \frac{\ln 2}{b}$$

$$= \tau \ln 2 = 10 \times 0.693 = 6.93 \text{ s}$$

12. (c)

Mass flow rate of air, $\dot{m}_h = 1$ kg/s

Specific heat at constant pressure of air, $c_{ph} = 1.005$ kJ/kgK

$$\dot{m}_h c_{ph} = 1 \times 1.005 = 1.005 \text{ kW/K}$$

Mass flow-rate of water, $\dot{m}_c = 2$ kg/s

$$c_{pc} = 4.18 \text{ kJ/kgK}$$

$$\dot{m}_c c_{pc} = 2 \times 4.18 = 8.36 \text{ kW/K}$$

Since, $$\dot{m}_h c_{ph} < \dot{m}_c c_{pc}$$

$$C_{min} = \dot{m}_h c_{ph} = 1.005 \text{ kW/K}$$

Maximum heat transfer rate,

$$q_{max} = C_{min}(T_{hi} - T_{ci})$$
$$= 1.005 \times (80 - 15) = 65.325 \text{ kW}$$

13. **(a)**

Given : c_p = 4.18 kJ/kgK; D = 5 cm = 0.05 m; L = 20 m; $\dot{m} = 0.1$ kg/s; T_{bi} = 20°C; T_{be} = 80°C; h = 1500 W/m^{2}K

For constant wall heat flux (q),

$$q = \dot{m}c_p\left(T_{be} - T_{bi}\right) = hA_s\left(T_{w_e} - T_{b_e}\right)$$

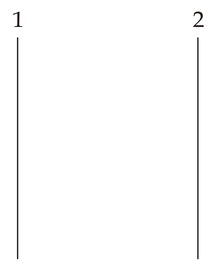
$$\Rightarrow \quad 0.1 \times (4.18 \times 10^3) \times (80 - 20) = 1500 \times (\pi \times 0.05 \times 20)\left(T_{w_e} - 80\right)$$

$$\Rightarrow \quad T_{we} = 80 + \frac{(0.1)\times\left(4.18\times10^3\right)(80-20)}{1500\times(\pi\times0.05\times20)}$$
$$= 80 + 5.322$$
$$= 85.322° \simeq 85.3°\text{C}$$

14. **(b)**

Without shield

Radiation heat transfer rate,

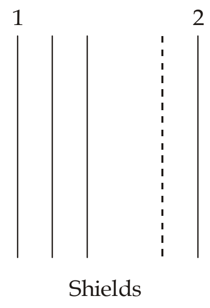


$$q = \frac{\sigma\left(T_1^4 - T_2^4\right)}{\dfrac{1}{\varepsilon_1} + \dfrac{1}{\varepsilon_2} - 1}$$

Let number of shields be N.

With shield

Radiation heat transfer rate,



$$q' = \frac{\sigma\left(T_1^4 - T_2^4\right)}{\left(\dfrac{1}{\varepsilon_1} + \dfrac{1}{\varepsilon_2} - 1\right) + N\left(\dfrac{2}{\varepsilon} - 1\right)}$$

As per the conditions,

$$q' = (1 - 0.9)q$$

$$\frac{q}{q'} = \frac{1}{0.1} = 10$$

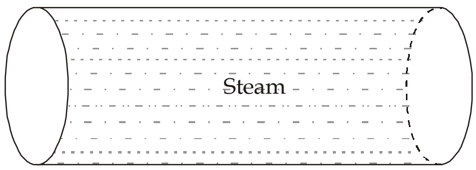
$$\frac{\left(\dfrac{1}{\varepsilon_1} + \dfrac{1}{\varepsilon_2} - 1\right) + N\left(\dfrac{2}{\varepsilon} - 1\right)}{\left(\dfrac{1}{\varepsilon_1} + \dfrac{1}{\varepsilon_2} - 1\right)} = 10$$

$$\frac{\left(\frac{1}{0.8}+\frac{1}{0.6}-1\right)+N\left(\frac{2}{0.29}-1\right)}{\left(\frac{1}{0.8}+\frac{1}{0.6}-1\right)} = 10$$

$$\text{Number of shields, } N = 2.925$$

$$N \simeq 3$$

15. (a)



Heat transfer rate due to radiation,

$$q = \varepsilon\sigma(T_1^4 - T_2^4)$$

$$= 0.8 \times 5.67 \times 10^{-8} \times [(200 + 273)^4 - (25 + 273)^4] = 1912.7638 \text{ W/m}^2$$

$$= h_r(T_1 - T_2)$$

where, h_r = Radiation heat transfer coefficient

$$\Rightarrow \quad 1912.7638 = h_r \times (200 - 25)$$

$$h_r = 10.93 \text{ W/m}^2\text{K}$$

Convection heat transfer coefficient

$$h_c = 6 \text{ W/m}^2\text{-K}$$

So, combined heat transfer coefficient

$$= h_r + h_c = 10.93 + 6 = 16.93 \text{ W/m}^2\text{-K}$$

16. (a)

$$\text{Reynold's number, Re} = \frac{\rho \times U_\infty \times D}{\mu} = \frac{1.5\times10\times0.02}{2.6\times10^{-5}}$$

$$= 11538.46 > 2300$$

So, the flow through the tube is turbulent flow.

$$\therefore \quad \text{Nu} = \frac{\bar{h}\cdot D}{k}$$

$$\Rightarrow \quad 35.44 = \frac{\bar{h}\times0.02}{0.04}$$

$$\Rightarrow \quad \bar{h} = 70.88 \text{ W/m}^2\text{K}$$

17. (a)

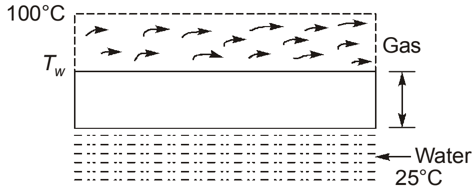
The heat transfer per unit length of tube is given by,

$$\frac{Q}{L} = h \times (\pi D) \times (T_w - T_b)$$

$$\Rightarrow \quad \frac{Q}{L} = 70.88 \times \pi \times 0.02 \times 20$$

$$= 89.07 \text{ W/m}$$

18. (a)



$$\text{Rate of heat transfer} = \frac{T_g - T_w}{\Sigma R}$$

$$\Sigma R = \frac{1}{h_g} + \frac{L}{k} + \frac{1}{h_w} = \frac{1}{14500} + \frac{4\times10^{-3}}{95.5} + \frac{1}{2250}$$

$$\Sigma R = 5.553 \times 10^{-4}\ \text{m}^2\text{K/W}$$

$$Q = \frac{100-25}{5.553\times10^{-4}} = 135063.4\ \text{W/m}^2$$

$$Q = (T_g - T_p)h_g$$

$$135063.4 = [100 - T_p]14500$$

$$T_p = 90.7°\text{C}$$

19. (c)

Minimum heat capacity rate,

$$C_{\min} = \dot{m}_c c_{pc} = 3 \times 4.2 = 12.6\ \text{kW/K}$$

Overall heat transfer coefficient, $U = 1600\ \text{W/m}^2\text{°C}$

Heat transfer area, $A = 12\ \text{m}^2$

$$\text{NTU} = \frac{UA}{C_{\min}} = \frac{1600\times12}{12.6\times1000} = 1.5238$$

$$\text{Effectiveness, } \varepsilon = 1 - e^{-\text{NTU}} = 1 - e^{-(1.5238)} = 0.782$$

20. (b)

For steady state, $\dfrac{\partial T}{\partial t} = 0$

$$\therefore \quad 0 = \frac{1}{r}\frac{\partial}{\partial r}\left(r \cdot \frac{\partial T}{\partial r}\right) + q$$

$$\frac{\partial}{\partial r}\left(r \cdot \frac{\partial T}{\partial r}\right) = -q \cdot r$$

On integration,

$$r \cdot \left(\frac{\partial T}{\partial r}\right) = \frac{-qr^2}{2} + A$$

$$\frac{\partial T}{\partial r} = \frac{-qr}{2} + \frac{A}{r}$$

$$T(r) = \frac{-qr^2}{4} + A\ln r + B$$

21. (c)

δ_H = 1.2 mm; $\mu = 20 \times 10^{-6}$ Pa-s; c_p = 3 kJ/kgK and k = 0.05 W/mK

$$Pr = \frac{\mu c_p}{k} = \frac{20\times10^{-6}\times3\times10^3}{0.05} = 1.2$$

$$\frac{\delta_H}{\delta_t} = 1.026 \times Pr^{1/3}$$

$$\Rightarrow \quad \delta_t = \frac{\delta_H}{1.026\times Pr^{1/3}}$$

$$= \frac{1.2}{1.026\times(1.2)^{1/3}} = 1.1 \text{ mm}$$

Note : It can be easily observed for the expression, the Pr > 1, so $\delta_t < \delta_H$ (1.2 mm).
So, option (c) will be correct.

22. (d)

Given : A = 30 m^2; U = 300 W/m^{2}K; $(c_p)_o$ = 3.5 kJ/kgK; $\dot{m}_0 = 2$ kg/s; $(c_p)_w$ = 4.18 kJ/kgK; $\dot{m}_w = 1$ kg/s

$$\text{Heat capacity rate; } c_{oil} = \dot{m}_o \times (c_p)_o = 2\times(3.5\times10^3) = 7\times10^3 \text{ W/K}$$

$$c_{water} = \dot{m}_w \times (c_p)_w = 1\times(4.18\times10^3) = 4.18\times10^3 \text{ W/K}$$

$$\text{Number of transfer units, NTU} = \frac{U.A.}{C_{min}}$$

$$= \frac{300\times30}{(4.18\times10^3)} = 2.15311 \simeq 2.15$$

23. (a)

$$\text{Initially, } T_H = 1850 + 273 = 2123 \text{ K}$$

$$Q = 25 \text{ W}, \; T_L = 500 + 273 = 773 \text{ K}$$

$$25 = \sigma\cdot A\left(T_H^4 - T_L^4\right)$$

$$25 = \sigma\cdot A\left(2123^4 - 773^4\right)$$

$$\sigma\cdot A = \frac{25}{(2123^4 - 773^4)}$$

$$\text{After some time, } T_H = 1500 + 273 = 1773 \text{ K}$$

$$T_L = 750 + 273 = 1023 \text{ K}$$

$$Q = \sigma_1 A\left(T_H^4 - T_L^4\right)$$

$$Q = \frac{25\left(1773^4 - 1023^4\right)}{(2123^4 - 773^4)} = 11 \text{ Watt}$$

24. (a)

We know that,

$$\text{Gr} = \frac{g\beta\Delta T L_c^3}{\nu^2}$$

$$\beta = \frac{1}{T_{avg}} = \frac{1}{161+273} = 2.304\times10^{-3}\,\text{K}^{-1} \quad \left(T_{avg} = \frac{25+297}{2} = 161°\text{C}\right)$$

For horizontal plate:

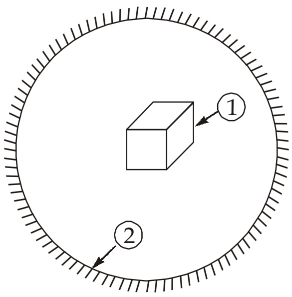
$$L_C = \frac{A_s}{p} = \frac{50\times50}{4\times50} = 12.5 \text{ cm or } 0.125 \text{ m}$$

So,

$$\text{Gr} = \frac{9.81\times(2.304\times10^{-3})\times272\times(0.125)^3}{(30\times10^{-6})^2}$$

$$= 133.184 \times 10^5$$

25. (c)



Given : a = 10 mm; d = 60 mm

$$A_1 = 6a^2 = 6 \times 10^2 = 600 \text{ mm}^2$$

$$A_2 = 4\pi\left(\frac{d}{2}\right)^2 = 4\pi\left(\frac{60}{2}\right)^2 = 3600\pi \text{ mm}^2$$

$$F_{11} = 0$$

Using summation rule;

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

$\Rightarrow$

$$F_{12} = 1$$

Using reciprocity relation;

$$A_1F_{12} = A_2F_{21}$$

$\Rightarrow$

$$F_{21} = \frac{A_1}{A_2}\times F_{12} = \frac{600}{3600\pi}\times1 = \frac{1}{6\pi}$$

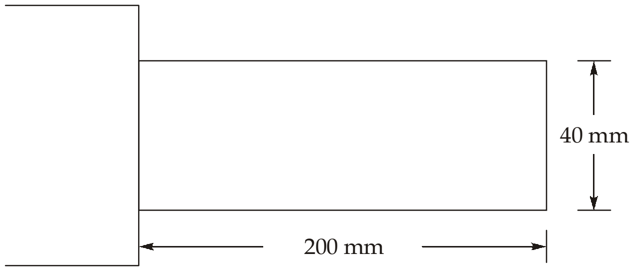
Using summation rule;

$$F_{21} + F_{22} = 1$$

$\Rightarrow$

$$F_{22} = 1 - F_{21} = 1 - \frac{1}{6\pi}$$

26. (d)



$$\text{Efficiency of fin, } \eta_{fin} = 40\%$$

$$\text{Diameter of fin, } d = 40 \text{ mm}$$

$$\text{Cross-sectional area of fin, } A_b = \frac{\pi}{4}d^2$$

$$= \frac{\pi}{4}\times 0.04^2 = 1.2566 \times 10^{-3} \text{ m}^2$$

$$\text{Surface area of fin, } A_{fin} = \pi dl$$

$$= \pi \times 0.04 \times 0.2 = 0.02513 \text{ m}^2$$

As we know,

$$\text{Effectiveness of fin, } \in_{fin} = \eta_{fin}\frac{A_{fin}}{A_b}$$

$$= 0.4\times\frac{0.02513}{1.2566\times 10^{-3}} = 7.99$$

27. (c)

Given : D = 12 mm; k_{wire} = 200 W/mK; $k_{insulation}$ = 0.16 W/mK; h = 20 W/m^{2}K; t = 1 mm

$$R = \frac{D}{2} = \frac{12}{2} = 6 \text{ mm}$$

$$\text{Critical radius of insulation, } r_c = \frac{K_{insulation}}{h} = \frac{0.16}{20}$$

$$= 0.008 \text{ m} = 8 \text{ mm}$$

$$\text{Radius of insulation, } R_o = R + t$$

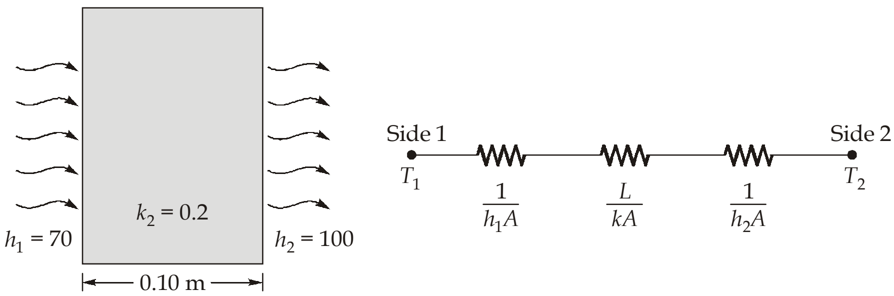
$$= 6 + 1 = 7 \text{ mm}$$

As $R_o < r_c$, so on addition of further insulation of the same material, the heat loss will increase to maximum and then decreases continuously.

28. (c)

$$Q = \frac{\Delta T}{R} = \frac{T_1 - T_2}{R}$$

$$R = \frac{1}{h_1 A} + \frac{1}{kA} + \frac{1}{h_2 A} = \frac{1}{70} + \frac{0.1}{0.2} + \frac{1}{100} = 0.5242°\text{C/W}$$

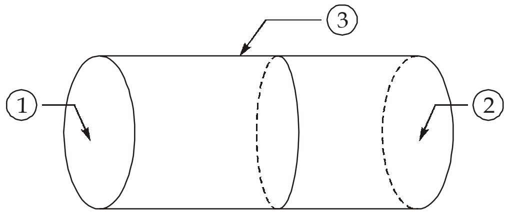


$$\begin{aligned} T_1 - T_2 &= Q \times R = 100 \times 0.5242 \\ &= 52.42°\text{C} \approx 52.4°\text{C} \end{aligned}$$

29. (d)

$$\begin{aligned} Q_1 &= A_1[F_{12}(J_1 - J_2) + F_{1-3}(J_1 - J_3)] \\ J_1 &= \sigma\, 550^4 = 5188.4 \text{ W/m}^2\text{K} \\ J_2 &= 7500 \text{ W/m}^2 \\ J_3 &= 3200 \text{ W/m}^2 \\ Q &= 9(0.2 \times (5188.4 - 7500) + 0.8 \times (5188.4 - 3200)) = 10.15 \text{ kW} \end{aligned}$$

30. (c)



$$\begin{aligned} F_{12} &= F_{21} = 0.2 \\ R &= 5 \text{ cm and } L = 10 \text{ cm} \end{aligned}$$

By summation rule:

$$F_{1\text{-}1} + F_{1\text{-}2} + F_{1\text{-}3} = 1 \text{ and} \qquad \text{...(i)}$$

$$F_{3\text{-}3} + F_{3\text{-}2} + F_{3\text{-}1} = 1 \qquad \text{...(ii)}$$

But, $F_{3\text{-}1} = F_{3\text{-}2}$ ...(iii)

Also, $F_{1\text{-}1} = F_{2\text{-}2} = 0$ ...(iv)

From equation (i), we get

$$\begin{aligned} F_{1\text{-}3} &= 1 - F_{1\text{-}1} - F_{1\text{-}2} \\ &= 1 - 0 - 0.2 = 0.8 \end{aligned}$$

By reciprocity rule: $F_{1\text{-}3} \times A_1 = F_{3\text{-}1} \times A_3$

So, $F_{3\text{-}1} = \dfrac{A_1}{A_3} \times F_{1-3}$

$$F_{3\text{-}1} = \frac{\pi R^2}{2\pi RL} \times F_{1-3} = \frac{0.8 \times 5}{2 \times 10}$$

$$F_{3\text{-}1} = 0.2$$

From equation (ii), we get

$$\begin{aligned} F_{33} &= 1 - F_{3\text{-}1} - F_{3\text{-}2} \\ &= 1 - 2 \times F_{3\text{-}1} \qquad \text{[From equation (iii)]} \\ &= 1 - 2 \times 0.2 = 0.6 \end{aligned}$$

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