Heat Transfer Test 2

Number of Questions: 25 **Time:60 min.**

Directions for questions 1 to 25: Select the correct alternative from the given choices.

1. Match List-I and List-II and select the CORRECT answer using the code given below the lists:

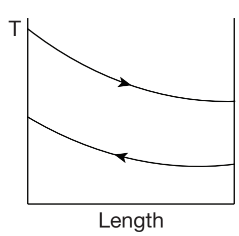
List – I		List – II	
P.	Heat Exchangers	1.	Reynolds number
Q.	Turbulent flow	2.	Effectiveness
R.	Forced convection	3.	Grashoff number
S.	Natural convection	4.	Eddy diffusivity

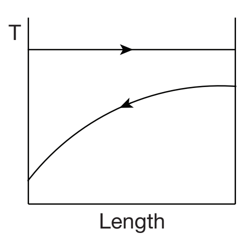
	P	*Q*	*R*	*S*
(A)	2	1	4	3
(B)	2	4	1	3
(C)	3	1	4	2
(D)	3	4	1	2

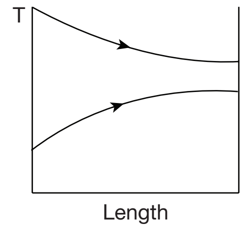
2. Heat is lost from a steam pipe placed horizontally in ambient air at 30°C. If the Nusselt number is 30, thermal conductivity of air is 0.03 W/m-K and the heat transfer coefficient is 10 W/m^2-K then the diameter of pipe will be.
(A) 100 mm (B) 80 mm
(C) 90 mm (D) 110 mm

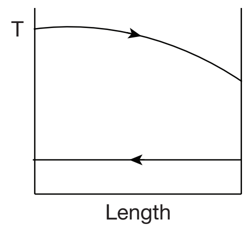
3. When 'α' is the absorbtivity, 'ρ' is the reflectivity and 'τ' is the transmitivity then for a diathermous body, which one of the following relation is correct?
(A) $\alpha = 1, \rho = 0, \tau = 0$
(B) $\alpha = 0, \rho = 0, \tau = 0$
(C) $\alpha = 0, \rho = 0, \tau = 1$
(D) $\alpha + \rho = 1, \tau = 0$

4. In Rankine cycle, heat is removed from the steam in a specific device. Which one of the following diagrams correctly shows the temperature distribution for the above given device.

(A)


(B)


(C)


(D)


5. Heat transfer by radiation between two gray bodies of emissivity $\in$ is proportional to
(A) $\frac{E_b - J}{(1 + \in)}$ (B) $\frac{E_b - J}{(1 - \in)^2}$
(C) $\frac{E_b - J}{\frac{(1 - \in)}{\in}}$ (D) $\frac{E_b - J}{(1 + \in^2)}$

6. For a turbulent flow over a flat plate, the heat transfer coefficient (h) varies with the length of the plate (x) in what relation?
(A) $h \mu x^{-1/2}$ (B) $h \mu x^{-1/5}$
(C) $h \mu x^{-1/3}$ (D) $h \mu x^{-1/4}$

7. For a natural convection from the vertical plates, if Rayleigh number is given as 1×10^{10} then the Nusselt number will be
(A) 215.4 (B) 312.3
(C) 267.3 (D) 298.4

8. If the LMTD of parallel flow condenser is θ_1 then the LMTD of counter flow condenser (θ_2) will be
(A) $\theta_2 > \theta_1$ (B) $\theta_2 < \theta_1$
(C) $\theta_2 = \theta_1$ (D) Insufficient data

9. A body is at a temperature of 927°C. The irradiation from the body will be (in kW/m^2)
(A) 41.87 (B) 86.3
(C) 117.6 (D) 103.2

10. A cross-flow type device has an area of 100 m^2 and overall heat transfer coefficient is 200 W/m^2-K. If the heat capacity of both the hot and cold stream is same and the value of NTU is 10 then the value of heat capacity (in kJ/K) will be
(A) 1500 (B) 500
(C) 1000 (D) 2000

11. A furnace is of cylindrical shape having diameter 20 cm and 40 cm height is opened at one end to surrounding which is at a temperature of 27°C. The side and bottom of furnace can be treated as black bodies and are maintained at a temperature of 1600°C and 1800°C respectively. If the shape factor from the bottom surface to surroundings is 0.06 then the power required to maintain the surface of the furnace at this condition will be

(A) 16.21 (B) 6.32
(C) 12.6 (D) 10.3

12. Two parallel oxidized iron plates are placed at a distance of 50 mm having size of 5 m × 5 m. The surface temperature of two plates are 150°C and 50°C respectively. If the emissivity of the surfaces is 0.6 then the net radiant heat interchanged (in kW) will be

(A) 12.84 (B) 14.23
(C) 10.61 (D) 7.53

13. A commercial aeroplane is modeled as a flat plate which is 2 m wide and 10 m long in size. It is maintained at 27°C. The properties of air at average temperature of 13.5°C are; thermal conductivity = 2.5×10^{-2} W/m-K; dynamic viscosity = 1.363×10^{-5} N-s/m^2; Prandtl number = 0.705. If the aeroplane is flying at a speed of 800 km/hr in air at 0°C and 60 cm of Hg pressure and the flow is parallel to the width of the wing, then the heat loss from the wing (in kW) will be

(A) 393.55 (B) 413.62
(C) 363.35 (D) 401.23

14. A solid sphere of diameter 20 cm is heated to 1200°C and suspended in a room whose walls are at 30°C. Assuming emissivity for the sphere as 0.1, density = 8680 kg/m^3, specific heat = 0.098 J/kg-K, the time taken by the sphere to cool to 600°C will be

(A) 2.5 seconds (B) 0.8 seconds
(C) 1.5 seconds (D) 2 seconds

15. Air at 20°C is flowing along a heated plate at 200°C at a velocity of 4 m/s. The plate is 2 m long and 2 m wide. The properties of air at 110°C are: density = 1 kg/m^3, kinematic viscosity = 21×10^{-6} m^2/s, thermal conductivity = 0.03 W/m-K, Prandtl number (Pr) = 0.7, C_p of air = 1.009 kJ/kg°C. If the Nusselt number (Nu) is given by $Nu = 0.332\, Re^{1/2}\, Pr^{1/3}$ then the heat transferred from the first 0.5 m of the plate (in watts) will be

(A) 3931.6 (B) 4021.2
(C) 3123.6 (D) 1965.6

16. Two plates of circular cross-section of 40 cm diameter are 3 m apart and are maintained at 927°C and 527°C respectively. If their corresponding emissivities are 0.25 and 0.4 and the radiant heat energy exchange is 20 watts then the fouling factor will be

(A) 0.0142 (B) 0.00623
(C) 0.01687 (D) 0.0234

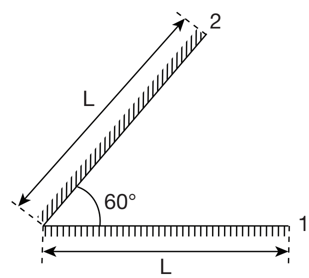
17. A thermo couple of emissivity 0.8 is implemented to measure the temperature of fuel flowing through a pipe. The surrounding temperature is 27°C. If the thermocouple measures a temperature of 90°C, then the error between the thermocouple temperature and fuel temperature will be (Take h = 20 W/m^2-K)

(A) 20°C (B) 21°C
(C) 33°C (D) 19°C

18. Air at a pressure of 8 kN/m^2 and a temperature of 250°C flows over a flat plate 0.3 m wide, 1 m long and a velocity of 10 m/sec. If the plate is to be maintained at a temperature of 78°C, Reynolds number = 2×10^4, local drag coefficient is 4.6×10^{-3}, Prandtl number is 0.9 and thermal conductivity of 36.4×10^{-3} W/m-K then the rate of heat to be removed continuously from the plate (in watts) will be

(A) 76.4 (B) 70.3
(C) 81.2 (D) 72.3

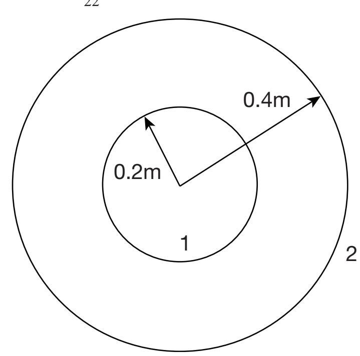
19.



The shape factor F_{12} will be

(A) $1-\sqrt{2}$ (B) 0.5
(C) $\sqrt{2}$ (D) $\frac{1}{\sqrt{2}}$

20. Two spheres are such that one is placed one inside the other as shown in the figure.
The view factor F_{22} will be



(A) 0.25 (B) 0.5
(C) 0.75 (D) zero

21. A tube of inner radius 1.2 cm and outer radius 1.8 cm having thermal conductivity of 100 W/m-K is fouled with scaling of fouling factor of 0.0004 m^2-K/W on both the side. If the heat transfer coefficients at the inside and outside of the tube are h_i = 5500 W/m^2-K and h_o = 3800 W/m^2-K then the overall heat transfer coefficient (in W/m^2-K) will be

(A) 321.4 (B) 432.3
(C) 732.4 (D) 621.5

22. Saturated steam at 200°C is condensing on the outer tube surface of a single pass heat exchanger. If the heat exchanger is capable of heating 600 kg/hr of water from 27°C to 97°C and it is given that the latent heat for condensation is 2200 kJ/kg then the rate of condensation of steam will be

(A) 0.0222 kg/min (B) 79.93 kg/hr
(C) 1.332 kg/hr (D) 0.0222 kg/hr

23. A cooling device is cooling 100 kg/hr of hot fluid of specific heat 4000 J/kg-K at 100°C 600 kg/hr of cold fluid is required for cooling purposes at a temperature of 12°C (specific heat is 4500 J/kg-K). If the surface area of heat exchanger is 0.25 m^2 and overall heat transfer coefficient is 800 W/m^2-K then the actual heat transfer rate (in kW) will be

(A) 9.34 (B) 6.28
(C) 8.12 (D) 7.44

24. Match List-I and List-II and select the correct answer using the codes given below the lists:

List – I		List – II	
P.	Heat transfer in boiling	1.	Conduction, Convection and Radiation heat transfer.
Q.	Heat transfer from one body to another separate in space.	2.	Newton law of cooling.
R.	Heat transfer in boiling furnace.	3.	Only radiation heat transfer.
S.	Heat transfer in fins	4.	Conduction and convection heat transfer.

	P	Q	R	S
(A)	2	3	4	1
(B)	2	3	1	4
(C)	3	2	4	1
(D)	3	2	1	4

25. In a heat exchanger, the temperature difference of hot fluid is 40°C. If the capacity ratio of the heat exchanger is 0.4 and the inlet temperature of cold fluid is 30°C then the outlet temperature of the cold fluid will be

(A) 225°C (B) 150°C
(C) 130°C (D) 200°C

Answer Keys

1. B	**2.** C	**3.** D	**4.** B	**5.** C	**6.** B	**7.** A	**8.** C	**9.** C	**10.** D
11. D	**12.** A	**13.** A	**14.** D	**15.** A	**16.** C	**17.** B	**18.** A	**19.** B	**20.** C
21. D	**22.** B	**23.** D	**24.** B	**25.** C					

Hints and Explanations

1. Choice (B)

2. $Nu = \dfrac{hd}{k}$

$\Rightarrow\ 30 = \dfrac{10 \times d}{0.03} \Rightarrow d = 0.09$ m

or $d = 90$ mm Choice (C)

3. Choice (D)

4. The device is condenser (counter flows) Choice (B)

5. $q_{\text{surface}} = A(J - G)$

For opaque gray bodies, $\tau = 0$, $\rho + \alpha = 1$

$\rho = (1 - \alpha)$

Now $J = E + \rho G$

$\Rightarrow\ J = E + (1 - \alpha)G$

$\Rightarrow\ J = E + (1 - \alpha)G$

$\Rightarrow\ J = E_b + (1 - \alpha)G$

or $G = \dfrac{J - \in E_b}{1 - \in}$ [By Kirchhoff's Law, $\alpha = \in$ and $\in = \dfrac{E}{E_b}$]

$\therefore\ q_{\text{surface}} = A\left[J - \dfrac{J - \in E_b}{1 - \in}\right]$

$\Rightarrow\ q_{surface} = A\left[\dfrac{J - \in J - J + \in E_b}{1 - \in}\right]$

$\Rightarrow\ q_{surface} = \in A\left[\dfrac{E_b - J}{1 - \in}\right]$

$\Rightarrow\ q_{surface} = \dfrac{(E_b - J)}{\dfrac{(1 - \in)}{\in}}$ Choice (C)

6. Choice (B)

7. $Nu = 0.10 \times Ra^{1/3}$

[For $10^9 < Ra < 10^{12}$]

or $Nu = 0.10 \times (1 \times 10^{10})^{1/3} = 215.44$ Choice (A)

8. Choice (C)

9. $G = \sigma T^4 = 5.67 \times 10^{-8} \times 1200^4$

$\Rightarrow\ G = 117.57$ kW/m^2 Choice (C)

10. $NTU = \dfrac{UA}{C_{min}}$

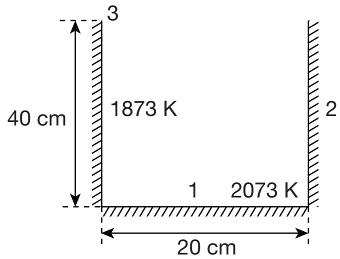
or $C_{min} = \dfrac{200\times100}{10} = 2000$ kJ/K Choice (D)

11. $F_{13} = 0.06$; $F_{11} = 0$

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

$\therefore\quad 0 + F_{12} + 0.06 = 1$

$\Rightarrow\quad F_{12} = 0.94$ and $F_{21} + F_{22} + F_{23} = 1$



$\therefore\quad F_{21} = F_{23}$ [Form symmetry]

Also $F_{12}\,A_1 = F_{21}\,A_2$

$$F_{21} = F_{12} \times \frac{A_1}{A_2} = F_{21} = \frac{0.94\times\frac{\pi}{4}\times0.2^2}{\pi\times0.2\times0.4}$$

$\Rightarrow\quad F_{21} = 0.1175 = F_{23}$

Power required to drive furnace

$$Q = A_2 F_{21}\times\sigma_b\times\left[T_2^4 - T_1^4\right] + A_2 F_{23}\,\sigma_b\left[T_2^4 - T_3^4\right]$$

$\Rightarrow\quad Q = A_2 F_{21}\,\sigma_b\left[2T_2^4 - T_1^4 - T_3^4\right]$

$\Rightarrow\quad Q = \pi \times 0.2 \times 0.4 \times 0.1175 \times 5.67 \times 10^{-8} \times [(2 \times 1873^4) - 2073^4 - 300^4]$

$\Rightarrow\quad Q = 10.278$ kW ~ 10.3 kW Choice (D)

12. $$Q = \frac{A\sigma\left(T_1^4 - T_2^4\right)}{\frac{1}{\epsilon_1}+\frac{1}{\epsilon_2}-1}$$

$$\Rightarrow\quad Q = \frac{5\times5\times5.67\times10^{-8}\times\left[423^4 - 323^4\right]}{\frac{1}{0.6}+\frac{1}{0.6}-1}$$

$\Rightarrow\quad Q = 12837.11$ watts or 12.84 kW Choice (A)

13. $P = \rho gh = 13600 \times 9.81 \times 0.6$

$\Rightarrow\quad P = 80.05$ kPa and $T_{avg} = \dfrac{27+0}{2} = 13.5°C$

$= 286.5$ K

Density of air, $\rho_{air} = \dfrac{P}{RT_{avg}} = \dfrac{80.05}{0.287\times286.5}$

$\Rightarrow\quad \rho_{air} = 0.97354$ kg/m^3

Now, Reynolds number $= \dfrac{\rho VL}{\mu}$

$$\Rightarrow\quad R_e = \frac{222.23\times10\times0.97354}{1.363\times10^{-5}} = 158.73\times10^6$$

$Re > 5 \times 10^5$, Hence it is turbulent flow

$\Rightarrow\quad Nu = 0.036\,Re^{0.8}\,Pr^{0.33}$

$\dfrac{hL}{k} = 0.036 \times (158.73 \times 10^6)^{0.8} \times (0.705)^{0.33}$

$$\Rightarrow h = \frac{116609.0138\times2.5\times10^{-2}}{8} = 364.4\ \text{W/m}^2\text{-K}$$

Heat loss from the plane, $Q = hA\Delta T$

$\Rightarrow\quad Q = 364.4 \times (2 \times 2 \times 10) \times (27 - 0)$

$\Rightarrow\quad Q = 393.55$ kW Choice (A)

14. Energy Balance equation:

$$-mC\frac{dT}{dt} = \sigma\quad A[T^4 - 303^4]$$

$$-\frac{\rho VC}{\sigma\in A}\int_{1473}^{873}\frac{dT}{\left(T^4 - 303^4\right)} = \int_o^t dt$$

$$t = \frac{8680\times\frac{4}{3}\times\pi\times0.1^3\times0.098}{5.67\times10^{-8}\times0.1\times4\pi\times0.1^2}\times 4\times10^{-10}$$

$\Rightarrow\quad$ t = 2 seconds Choice (D)

15. $Re_x = \dfrac{U_\infty\times x}{v} = \dfrac{4\times0.5}{21\times10^{-6}} = 9.5238 \times 10^4$

$$\Rightarrow\quad \frac{h_x\times x}{k} = 0.332\times\left(9.5238\times10^4\right)^{\frac{1}{2}}\times(0.7)^{1/3}$$

$\Rightarrow\quad h_x = 5.46$ W/m^2-K

The average value of the heat transfer is twice of this value.

$\bar{h}_x = 2 \times 5.46 = 10.92$ W/m^2–K

Heat flow, $Q = \bar{h}_x A(T_s - T_\infty)$

$= 10.92 \times 0.5 \times 2 \times (200 - 20) = 1965.6$ W

Heat flow from the both side of the plate $= 2 \times 1965.6$

$= 3931.6$ watts

Choice (A)

16. Equivalent emissivity, $\bar{\in} = \varepsilon_1 \times \varepsilon_2 = 0.25 \times 0.4 = 0.1$

We know, $Q = \bar{\in} AF\,\sigma\left(T_1^4 - T_2^4\right)$

$\Rightarrow\quad 20 = 0.1 \times \dfrac{\pi}{4} \times 0.4^2 \times F \times 5.67 \times 10^{-8} \times [1200^4 - 800^4]$

$\Rightarrow\quad F = 0.01687$ Choice (C)

17. $h\,A_C(T_\infty - T_c) = \sigma A_c\,\varepsilon_c\left[T_C^4 - T^4\right]$

$\Rightarrow\quad 20[T_\infty - 363] = 5.67 \times 10^{-8} \times 0.8 \times [363^4 - 300^4]$

$T_\infty = 384$ K

Error is $(384 - 363) = 21°C$

Choice (B)

18. Given:

$C_{fx} = 4.6 \times 10^{-3}$

$Pr = 0.69$

$$\text{St. } Pr^{2/3} = \frac{C_{fx}}{2} \Rightarrow St = \frac{4.6\times10^{-3}}{2\times0.69^{2/3}}$$

$\Rightarrow \quad St = 2.9455 \times 10^{-3}$

$$\text{Now, } St = \frac{Nu}{\text{Re.Pr}}$$

$\Rightarrow \quad Nu = 2.9455 \times 10^{-3} \times 2 \times 10^{4} \times 0.69$

$$\Rightarrow \quad Nu = \frac{h.x}{k} = 40.6479$$

$\Rightarrow \quad h = 1.48 \text{ W/m}^2 - K$

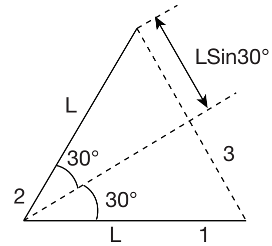
Now $q = h \times (0.3 \times 1) \times (250 - 78)$

$= 1.48 \times 0.3 \times 172 = 76.368$ W Choice (A)

19. $F_{11} + F_{12} + F_{13} = 1$ or $F_{12} + F_{13} = 1$

$$F_{12} = \frac{L + L - 2L\sin 30^{o}}{2L} = 1 - \text{Sin } 30^{o}$$

$\Rightarrow \quad F_{12} = 0.5$



Choice (B)

20. $F_{11} + F_{12} = 1$ or $F_{12} = 1$ $[\Rightarrow F_{11} = 0]$

$$A_1 F_{12} = A_2 F_{21} \Rightarrow F_{21} = \frac{A_1}{A_2} = \frac{4\pi(0.2)^2}{4\pi(0.4)^2}$$

$\Rightarrow \quad F_{21} = 0.25$

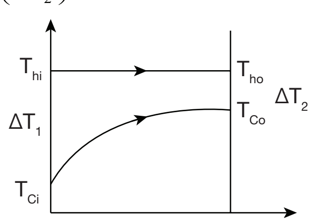
Now $F_{21} + F_{22} = 1 \Rightarrow F_{22} = 0.75$ Choice (C)

21.
$$U_o = \frac{1}{\frac{1}{h_o} + R_{fo} + \frac{r_o}{k}\ln\left(\frac{r_o}{r_i}\right) + \left(\frac{r_o}{r_i}\right)R_{fi} + \left(\frac{r_o}{r_i}\right)\frac{1}{h_i}}$$

$$\Rightarrow \quad U_o = \frac{1}{\frac{1}{3800} + 0.0004 + \frac{0.018}{100}\ln\left(\frac{0.018}{0.012}\right) + \left(\frac{0.018}{0.012}\right)\times 0.0004 + \left(\frac{0.018}{0.012}\right)\times\frac{1}{5500}}$$

$\Rightarrow \quad U_o = 621.55 \text{ W/m}^2\text{-K}$ Choice (D)

22.
$$\text{LMTD} = \frac{\Delta T_1 - \Delta T_2}{\ln\left(\frac{\Delta T_1}{\Delta T_2}\right)}$$



$$\Rightarrow \quad LMTD = \frac{(200-27)-(200-97)}{\ln\left[\frac{(200-27)}{(200-97)}\right]} = 135°\text{C}$$

Rate of heat transfer, $Q = m_c\, c_c\, (\Delta T)$

$$= \frac{600}{3600}\times 4.187\times(97-27)$$

$\Rightarrow \quad Q = 48.85$ kW

Now $Q = \dot{m}_s \times h_{fg}$

$$\Rightarrow \quad \dot{m}_s = \frac{Q}{h_{fg}}$$

$$\Rightarrow \quad \dot{m}_s = \frac{48.85}{2200} = 0.0222 \text{ kg/s}$$

or $\dot{m}_s = 79.933$ kg/hr Choice (B)

23. **Cold Fluid:** $C_C = \dot{m}_c\, C_c = \frac{600}{3600} \times 4500 = 750$ W/K

Hot Fluid: $C_h = \dot{m}_h\, C_h = \frac{100}{3600} \times 4000 = 111.12$ W/K

$\therefore \quad C_{min} = C_h = 111.12$ W/K

$$NTU = \frac{UA}{C_{min}} = \frac{800\times0.25}{111.12} = 1.8$$

$$\text{Effectiveness,} \quad = \frac{1-\exp\left[-NTU\left\{1+\left(\frac{C_{min}}{C_{max}}\right)\right\}\right]}{\left[1+\frac{C_{min}}{C_{max}}\right]}$$

$$\Rightarrow \quad \in = \frac{1-\exp\left[-1.8\left\{1+\frac{111.12}{750}\right\}\right]}{\left[1+\frac{111.12}{750}\right]}$$

$\Rightarrow \quad = 0.7607$

Actual heat transfer rate, $Q_a = \quad Q_{max}$

$\Rightarrow \quad Q_a = 0.7607 \times C_{min}\left[T_{h_i} - T_{c_i}\right]$

$= 0.7607 \times 111.12 \times [100 - 12]$
$= 7438.467\ W$ or 7.44 kW

Choice (D)

24. Choice (B)

25. $\frac{C_c}{C_h} = 0.4$

Now $\dot{m}_h \times C_{ph}\left(t_{h_1} - t_{h_2}\right) = \dot{m}_c \times \mathrm{C_{pc}} \times \left(t_{c_2} - t_{c_1}\right)$

$40 = 0.4\left[t_{c_2} - 30\right]$

$\Rightarrow \quad t_{c_2} = 130°C$ Choice (C)