Heat Transfer, Refrigeration and Air Conditioning Test 4

Number of Questions 35 **Time:60 min.**

Directions for questions 1 to 35: Select the correct alternative from the given choices.

1. Convective heat transfer coefficient '*h*' varies significantly with
(A) the type of fluid
(B) the temperature
(C) the thermal conductivity
(D) All of the above

2. In case of one dimensional heat conduction in a medium with constant properties, *T* is the temperature at position *x*, at time *t*. Then $\frac{\partial T}{\partial t}$ is proportional to
(A) $\frac{T}{X}$ (B) $\frac{\partial T}{\partial X}$
(C) $\frac{\partial^2 T}{\partial X \partial T}$ (D) $\frac{\partial^2 T}{\partial X^2}$

3. Biot number is the ratio of
(A) internal resistance to the surface resistance
(B) surface resistance to the internal resistance
(C) conductivity to the heat transfer co-efficient
(D) convective heat transfer to conductive heat transfer

4. Which one of the following configurations has the highest fin effectiveness?
(A) Thin, closely spaced fins
(B) Thin, widely spaced fins
(C) Thick, widely spaced find
(D) Thick, closely spaced fins

5. Fouling factor in heat exchanger is estimated as
(A) $U_{\text{foul}} = R_f + U_{\text{clean}}$ (B) $U_{\text{foul}} + R_f = U_{\text{clean}}$
(C) $\frac{1}{U_{foul}} = R_f + \frac{1}{U_{clean}}$ (D) $\frac{1}{U_{foul}} + R_f = \frac{1}{U_{clean}}$

6. Thermal conductivity is lower for
(A) wood (B) air
(C) water at 100°C (D) steam at 1 bar

7. In pool boiling, the highest heat transfer coefficient occurs in
(A) sub-cooled boiling zone
(B) nucleate boiling zone
(C) partial film boiling zone
(D) film boiling zone

8. Which of the following is closed to black body nature?
(A) glass (B) water at 100°C
(C) ice (D) coal

9. The number of transfer units in heat exchanges is equal to
Where *A* = Area
U = over all heat transfer co-efficient.
C_{min} = minimum heat capacity.
(A) $\frac{AU}{C_{\min}}$ (B) $\frac{C_{\min}}{AU}$
(C) $\frac{AU}{C_{\max}}$ (D) $\frac{C_{\max}}{AU}$

10. In counter flow heat exchanger, if $\theta_1 = \theta_2$ then the LMTD for the heat exchanger will be
(A) zero (B) $\frac{\theta_1 - \theta_2}{\ln(\theta_1/\theta_2)}$
(C) θ_1 (or) θ_2 (D) undefined

11. The refrigerant used for absorption refrigerators, working heat from solar collectors is mixture of water and
(A) carbon dioxide (B) sulphur dioxide
(C) lithium bromide (D) freon 12

12. During the adiabatic cooling of moist air
(A) DBT remains constant
(B) Specific humidity remains constant
(C) Relative humidity remains constant
(D) WBT remains constant

13. For an air conditioning plant above 300 ton, which one of the following system would normally be preferred?
(A) Ammonia reciprocating compressor
(B) Centrifugal chiller
(C) Absorption refrigeration system
(D) Hermetic compressor

14. The maximum COP for the absorption cycle is given by (T_G = generator temperature, T_C = environment temperature, T_E = refrigerated space temperature)
(A) $\frac{T_E(T_G - T_C)}{T_G(T_C - T_E)}$ (B) $\frac{T_G(T_C - T_E)}{T_E(T_G - T_C)}$
(C) $\frac{T_C(T_G - T_E)}{T_G(T_C - T_E)}$ (D) $\frac{T_G(T_C - T_E)}{T_C(T_G - T_E)}$

15. One ton refrigeration is equivalent to
(A) 3.5 kW (B) 50 kJ/s
(C) 1000 J/min (D) 1000 kJ/min

16. Consider the development of laminar boundary layer for a moving non-reacting fluid in contact with a flat plate of length 'l' along the flow direction. The average value of heat transfer co-efficient can be obtained by multiplying the local heat transfer co-efficient at the trailing edge by the factor
(A) 0.75 (B) 1.0
(C) 1.5 (D) 2.0

17. A spherical aluminum shell of inside diameter 2.5 m is evacuated and used as radiation test chamber. If the inner surface is coated with carbon black and maintained at 600 K, the irradiation on a small test surface placed inside the chamber (Stefan-Boltzman constant $\sigma = 5.67 \times 10^{-8}$ W/m^2 K^4) in W/m^2 is

(A) 500.54 (B) 7348.32
(C) 8500 (D) 10000

18. Match List-I with List-II and select the correct answer using the codes given below.

	List - I		List - II
P	Fin	1	AU/C_{min}
Q	Heat exchanger	2	$X/2\sqrt{\alpha\tau}$
R	Transient conduction	3	$\sqrt{hp/kA}$
S	Heisler chart	4	hL/k

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

19. A 1m thick plane wall has its two surfaces kept at 400°C and 300°C. Thermal conductivity of the wall varies linearly with temperature and its values at 400°C and 300°C are 40 W/mK and 30 W/mK, respectively. The steady heat flux through the wall in kW/m^2 is

(A) 5 (B) 4
(C) 3.5 (D) 3

20. The average Nusselt number in laminar natural convection from a vertical wall at 180°C with still air at 20°C is found to be 48. If the wall temperature becomes 30°C, all other parameters remaining same, the average Nusselt number will be

(A) 8 (B) 16
(C) 24 (D) 32

21. Match List I with List II and select the correct answer using the code given below the lists.

	List - I (Application)		List - II (Type of heat exchanger)
P.	Gasto liquid	1.	Compact
Q.	Space vehicle	2.	Shell and tube
R.	Condenser	3.	Finned tube
S.	Air pre-heater	4.	Regenerative

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

22. In a mass transfer process of diffusion of hot smoke in cold air in a power plant, the temperature profile and the concentration profile will become identical when

(A) Prandtl No. = 1 (B) Nusselt No. = 1
(C) Lewis No. = 1 (D) Schmit No. = 1

23. Heat is lost from a 100 mm diameter steam pipe placed horizontally in ambient at 30°C. If the Nusselt number is 25 and thermal conductivity of air is 0.03 W/mK, then the heat transfer co-efficient in W/m^{2}K will be

(A) 10 (B) 7.5
(C) 5 (D) 2.5

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

	List - I		List - II
P.	Grashof number	1.	Mass diffusion
Q.	Schmid number	2.	Free convection
R.	Weber number	3.	Surface tension
S.	Fourier number	4.	Transient-heat conduction

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

25. The time constant of thermo couple is

(A) The time taken to attain 100% initial temperature difference.
(B) Time taken to attain 63.2% of initial temperature difference.
(C) Time taken to attain 50% of initial temperature difference.
(D) The minimum time taken to record a temperature reading.

26. A large concrete slab of 1 m thick has one dimensional temperature distribution:
$T = 4 - 10\,x + 20\,x^2 + 10\,x^3$,
Where T is temperature and x is distance from one face towards other face of wall. If slab material has thermal diffusivity of 2×10^{-3} m^2/h.
The rate of change of temperature at the other face of the wall in °C/h is

(A) 0.4 (B) 0.3
(C) 0.2 (D) 0.1

27. A hollow pipe of 1 cm outer diameter is to be insulated by thick cylindrical insulation having thermal conductivity 1 W/mK. The surface heat transfer co-efficient on the insulation surface is 5 W/m^2 K. The minimum effective thickness of insulation for causing the reduction in heat leakage the insulated pipe is

(A) 10 cm (B) 0.5 cm
(C) 19.5 cm (D) 20 cm

28. The geometric radius of heat transfer for a hollow sphere of inner and outer radii r_1 and r_2 is

(A) $\sqrt{r_1 r_2}$ (B) $r_2\, r_1$
(C) $\frac{r_1 + r_2}{2}$ (D) r_2/r_1

29. A vapour compression refrigerator has a COP of 4 and extracts 10 kJ of heat from the cold reservoir. If this machine is worked as a heat pump, how much heat will it deliver to the environment?

(A) 5 kJ (B) 10 kJ
(C) 12.5 kJ (D) 15 kJ

30. During the sensible cooling process, specific humidity
(A) remains constant (B) increases
(C) decreases (D) undpredicable

31. The wet bulb depression is zero, when relative humidity is equal to
(A) 100% (B) 60%
(C) 40% (D) zero

Common Data Questions 32 and 33:
In a 5 kW cooling capacity refrigeration system operating on simple VCRS. The refrigerant enters the evaporator with a enthalpy of 75 kJ/kg and leaves with enthalpy of 185 kJ/kg. The enthalpy of the refrigerant after compression is 210 kJ/kg.

32. The C.O.P will be
(A) 3.4 (B) 4.4
(C) 5 (D) 5.2

33. Power input in kW is
(A) 0.98 (B) 1.02
(C) 1.05 (D) 1.13

Statement for linked answer Questions 34 and 35:
In a certain counter flow heat exchanger, hot fluid enters at 450 °C and has mass flow rate of 1 kg/s. Cold fluid enters at 25 °C and has mass flow rate of 4 kg/s. Effectiveness of heat exchanger is 75%. Specific heat of hot fluid is 4 kJ/kg K and that of cold fluid is 1 kJ/kg K.

34. Exit temperature of cold fluid in °C is
(A) 343 (B) 243
(C) 143 (D) 43

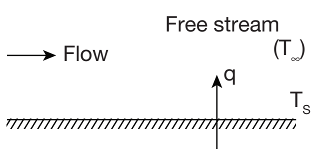
35. The heat transfer rate in kW is
(A) 1175 (B) 1275
(C) 2275 (D) 3175

Answer Keys

1. D	**2.** D	**3.** A	**4.** A	**5.** C	**6.** B	**7.** C	**8.** C	**9.** A	**10.** C
11. D	**12.** B	**13.** A	**14.** C	**15.** A	**16.** D	**17.** B	**18.** A	**19.** C	**20.** C
21. B	**22.** A	**23.** B	**24.** A	**25.** B	**26.** C	**27.** C	**28.** A	**29.** C	**30.** A
31. A	**32.** B	**33.** D	**34.** A	**35.** B					

Hints and Explanations

1.



Velocity of fluid layer at the wall is zero (no slip condition) so the heat must be transferred only by conduction at the wall

$$\therefore \quad h(\Delta T) = -K \left.\frac{\partial T}{\partial y}\right|_{y=0}$$

$$\therefore \quad h = -\frac{K}{T_s - T_\infty} \left.\frac{\partial T}{\partial y}\right|_{y=0}$$

Hence convective heat transfer co-efficient depends on thermal conductivity and temperature gradient at the wall.

And also heat transfer co-efficient h varies with the type of fluid and temperature. Choice (D)

2. One dimensional heat conduction equation is

$$\frac{\partial^2 T}{\partial X^2} + \frac{q_y}{k} = \frac{1}{\alpha}\frac{\partial T}{\partial t}$$

$$\therefore \frac{\partial T}{\partial t} \propto \frac{\partial^2 T}{\partial X^2}$$ Choice (D)

3. Biot number $(Bi) = \frac{h L_c}{k} = \frac{\left(\frac{L_c}{k}\right)}{1/k} = \frac{\text{internal resistance}}{\text{surface resistance}}$

Choice (A)

4. Choice (A)

5. Fouling factor $R_f = \frac{1}{U_{foul}} - \frac{1}{U_{clean}}$ Choice (C)

6. Choice (B)

7. Choice (C)

8. For ice absorptivity $\alpha \approx 0.98$

$\therefore$ emissivity = 0.98

Hence ice is approximately closed to black body.

Choice (C)

9. NTU = $\frac{AU}{C_{min}}$ Choice (A)

10. Choice (C)

11. Choice (D)

12. Choice (B)

13. Choice (A)

14. Choice (C)

15. Choice (A)

16. Choice (D)

17. Irradiation $q = \sigma T_1^4$
$= 5.67 \times 10^{-8} \times 600^4$
$= 7348.32$ W/m^2 Choice (B)

18. Choice (A)

19. Thickness of plane wall $L = 1$ m
$t_1 = 400°C$ $k_1 = 40$ W/mK
$t_2 = 300°C$ $k_2 = 30$ W/mK

Heat flow rate $d = \dfrac{km\,A(t_1 - t_2)}{L}$

Where $k_m = \dfrac{k_1 + k_2}{2} = \dfrac{40+30}{2} = \dfrac{70}{2}$

= 35 W/mK

$$Q = \frac{35 \times (400-300)}{1} = 3500 \text{ W/m}^2$$

= 3.5 kW/m^2 Choice (C)

20. In laminar flow $Nu = (Gr.Pr)^{1/4}$

$$Gr = \frac{g\beta L^2 (\Delta T)}{\vartheta^2}$$

Nu µ $(\Delta T)^{1/4}$

$$\frac{Nu_1}{Nu_2} = \frac{(\Delta T_1)^{1/4}}{(\Delta T_2)^{1/4}} = \frac{(180-20)^{1/4}}{(30-20)^{1/4}} = 2$$

$Nu_2 = \dfrac{48}{2} = 24$ Choice (C)

21. Choice (B)

22. $\dfrac{\delta_h}{\delta_t} = (P_r)^{1/3}$

δ_h = thickness of hydrodynamic boundary layer
δ_t = thickness of thermal boundary layer.
If $P_r = 1$, $\delta_h = \delta_t$ Choice (A)

23. $Nu = 25$

$$Nu = \frac{hD}{k}$$

$$h = \frac{Nu.k}{D} = \frac{25 \times 0.03}{100 \times 10^{-3}}$$

= 7.5 W/m^2 K Choice (B)

24. Choice (A)

25. Choice (B)

26. Given $T = 4 - 10\,x + 20\,x^2 + 10\,x^3$
$\alpha = 2 \times 10^{-3}$ m^2/hr

$$\frac{\partial^2 T}{\partial x^2} = \frac{1}{\alpha}.\left(\frac{\partial T}{\partial \iota}\right)$$

$$\left(\frac{\partial T}{\partial \iota}\right)_{x=1} = \alpha.\left(\frac{\partial^2 T}{\partial x^2}\right)_{x=1}$$

$$\frac{\partial T}{\partial x} = -10 + 40\,x + 30\,x^2$$

$$\frac{\partial^2 T}{\partial x^2} = 40 + 60x$$

$\therefore \left(\dfrac{\partial T}{\partial \iota}\right)_{x=1} = 2 \times 10^{-3}(40 + 60 \times 1) = 0.2°C/\text{hr}$ Choice (C)

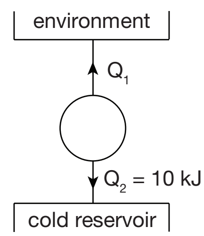
27. $d_o = 1$ cm, $r_o = 0.5$ cm
$k = 1$ W/mK
$h_o = 5$ W/m^2 K

$$r_c = \frac{k}{h_o} = \frac{1}{5} = 0.2 \text{ m} = 20 \text{ cm}$$

The minimum effective thickness $= r_c - r_o$
$= 20 - 0.5 = 19.5$ cm Choice (C)

28. Choice (A)

29.



$(C.O.P)_R = 4$
$(C.O.P)_{HP} = 1 + (C.O.P)_R$
$= 1 + 4 = 5$

$$(C.O.P)_{HP} = \frac{Q_1}{Q_1 - Q_2}$$

$$5 = \frac{Q_1}{Q_1 - 10}$$

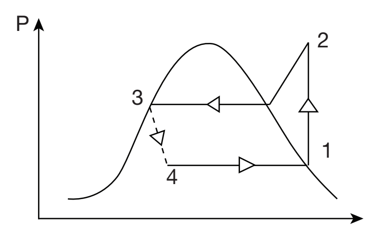
$5Q_1 - 50 = Q_1$
$4Q_1 = 50$

$Q_1 = \dfrac{50}{4} = 12.5$ kJ Choice (C)

30. Choice (A)

31. Wet bulb depression $= DBT - WBT$
For saturated air ($\phi = 100\%$) $DBT = WBT$ Choice (A)

32.



$h_1 = 185$ kJ/kg
$h_2 = 210$ kJ/kg
$h_4 = 75$ kJ/kg
Refrigeration capacity = 5 kW
i.e., $m(h_1 - h_4) = 5$ kW

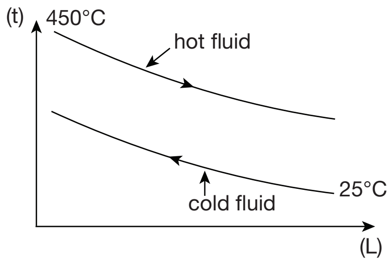
$$m = \frac{5}{(185-75)} = 0.04545 \text{ kg/s}$$

$$\text{C.O.P} = \frac{h_1 - h_4}{h_2 - h_1} = \frac{185-75}{210-185}$$

= 4.4 Choice (B)

33. Power require = $m(h_2 - h_1)$
= 0.04545(210 – 185)
= 1.13 kW Choice (D)

34.



m_h = 1 kg/s
c_{ph} = 4 kJ/kg.K
m_c = 4 kg/s
c_{pc} = 1 kJ/kg.K
t_{h1} = 450°C
t_{c1} = 25°C

$$\text{effectiveness } (E) = \frac{Q_{act}}{Q_{max}}$$

$$= \frac{m_c\, c_{pc}\left(t_{c_2} - t_{c_1}\right)}{C_{\min}\left(t_{h_1} - t_{c_1}\right)}$$

$$0.75 = \frac{t_{c_2} - 25}{450 - 25}$$

$$t_{c_2} = 343.75^{\circ}\text{C}$$ Choice (A)

35. Heat Flow rate $Q = m_c\, c_{pc}\left(t_{c_2} - t_{c_1}\right)$
= (4) × 1 (343.75 – 25)
= 1275 kW Choice (B)