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ESE- 2018 (Prelims) - Offline Test Series Test - 13

MECHANICAL ENGINEERING

SUBJECT: FLUID MECHANICS + TURBO MACHINERY + THERMODYNAMICS AND HEAT TRANSRFER – SOLUTIONS

01. Ans: (d)

Sol:

- Heat transfer coefficient is minimum when flow is separated.
- Local heat transfer coefficient is independent in laminar forced convection.

Nu = 4.36 (For constant heat flux condition)

Nu = 3.66 (For constant wall temperature condition)

In general, N_u = constant = c

$$\frac{h_x.D}{k} = c$$

h = c [∵ Diameter of tube (D) is constant throughout of the length]

Average heat transfer coefficient ($\bar{h}$)

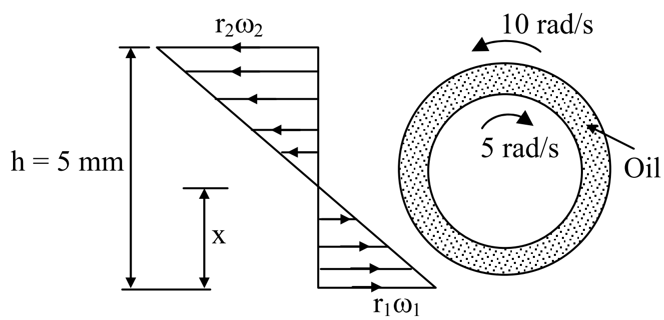
$$= \frac{1}{L}\int_0^L h_x.dx$$

$$= \frac{1}{L}.h.L$$

$$\bar{h} = h$$

02. Ans: (a)

Sol:



From similarity of triangles

$$\frac{x}{h-x} = \frac{r_1\omega_1}{r_2\omega_2}$$

$$\Rightarrow \frac{x}{h} = \frac{r_1\omega_1}{r_1\omega_1 + r_2\omega_2}$$

$$\Rightarrow x = 5\times\left(\frac{20\times5}{20\times5+20.5\times10}\right)$$

$$\Rightarrow x = 1.64 \text{ mm}$$

03. Ans: (d)

Sol:

- The entropy of a system can increase, decrease or remains constant. But the entropy of universe always increases.
- If a system loses heat then entropy of a system decreases.

04. Ans: (c)

Sol: Thermal conductivity of gas generally decreases with increasing molecular weight.

And thermal conductivity (k) ∝ $V_{r.m.s.}$(Kinetic theory of gas)

$\therefore \quad k \propto \sqrt{T}$

05. Ans: (d)

Sol: Air bubble in water has only one surface, hence it is analogous to the liquid drop.

$$p_i - p_o = \frac{4\sigma}{D}$$

$$p_i = p_o + \frac{4\sigma}{D}$$

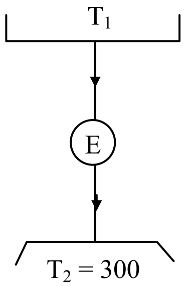
$$= \rho g h + \frac{4\sigma}{D}$$

$$= 1000\times10\times1 + \frac{4\times0.07}{10^{-3}}$$

= 12.8 kPa

06. Ans: (a)

Sol:



$$\eta_{carnot} = \frac{T_1 - T_2}{T_1} = \frac{T_1 - 300}{T_1}$$

η_E = 0.36 or 36%

$$\eta_{2nd law} = \frac{\eta_E}{\eta_{carnot}}$$

$$0.6 = \frac{0.36}{\frac{T_1 - 300}{T_1}}$$

$$\frac{0.6(T_1 - 300)}{T_1} = 0.36$$

$$T_1 = 750\,K$$

07. Ans: (c)

Sol:

- Thermal diffusivity $(\alpha) = \dfrac{k}{\rho c_p}$

  If $\rho c_p \downarrow \Rightarrow \alpha \uparrow$

ρc_p = volumetric heat capacity

If volumetric heat capacity is less, propagation of thermal energy will be more, that means quick response of the material with its surrounding.

- Thermal diffusivity of air $(\alpha)_{air} = \dfrac{k_{air}}{\rho_{air} c_{p_{air}}}$

$$= \frac{0.012}{1.2 \times 1.005 \times 10^3} = 2.155 \times 10^{-5} m^2/s$$

Thermal diffusivity of water

$$(\alpha)_{water} = \frac{k_{water}}{\rho_{water} c_{p_{water}}}$$

$$= \frac{0.61}{1000 \times 4.18 \times 10^3} = 1.45 \times 10^{-7} m^2/s$$

$\therefore \ (\alpha)_{air} > (\alpha)_{water}$

Heat storing capacity of water is much more than that of air

- We know that, Prandtl number

$$(Pr) = \frac{\text{momentum diffusivity}}{\text{thermal diffusivity}} = \frac{\nu}{\alpha}$$

If $\alpha > \nu \Rightarrow Pr < 1$

$$\frac{\delta}{\delta t} = (Pr)^{1/3} \Rightarrow Pr < 1 \Rightarrow \delta < \delta_t$$

08. Ans: (d)

Sol: $k = \dfrac{-dP}{(dv/V)}$ at constant temperature

Now, $\rho V = m = \text{constant}$

$$\rho dV + V d\rho = 0$$

or $\dfrac{d\rho}{\rho} = -\dfrac{dV}{V}$

$$k = \frac{dP}{\left(\frac{d\rho}{\rho}\right)} \text{ at constant temperature}$$

i.e., $k = \rho\left(\dfrac{\partial P}{\partial \rho}\right)_T$

09. Ans: (b)

Sol: For adiabatic process, $\delta Q = 0$

For reversible process, $dS = 0$

10. Ans: (a)

Sol: We know that the temperature distribution with time

$$\frac{T - T_\infty}{T_0 - T_\infty} = e^{\left(-\frac{hA}{\rho vc}\times\tau\right)}$$

∴ The temperature profile will be exponential with time.

11. Ans: (d)

Sol: Assume that the ball is in equilibrium at some intermediate depth 'x'.

For equilibrium

Buoyancy force = weight

$$\rho Vg = \rho_s Vg$$

i.e., $1000\,(1+x^2) = 5000$

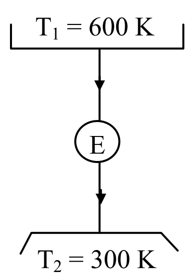
∴ $x = 2$ m

but $x > 1.5$ m (i.e., depth of tank)

Hence the ball will reach the floor of the tank where difference between weight and buoyancy force is balanced by the normal reaction at the surface.

12. Ans: (b)

Sol: $\eta = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1}$ (Carnot)



$$\eta = \frac{W}{Q_1} = \frac{T_1 - T_2}{T_1}$$

$$\Rightarrow \frac{600}{Q_1} = \frac{327 - 27}{(600)}$$

$\Rightarrow Q_1 = 1200$ kJ

$$dS = \frac{Q_2}{T_2} = \frac{600}{300} = 2\,\text{kJ/K}$$

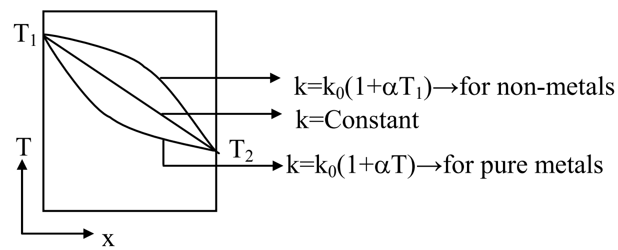
13. Ans: (a)

Sol: Generally, thermal conductivity of pure metal decreases with increasing temperature and vice-versa in case of non-metals.

$k = k_0(1 + \alpha T)$

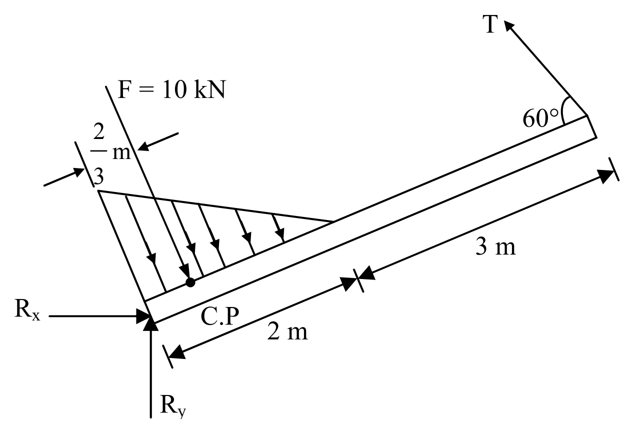
$\alpha > 0 \rightarrow$ non-metals

$\alpha < 0 \rightarrow$ pure metals



14. Ans: (c)

Sol: Consider the free body diagram of the plate.



The hydrostatic force is given by

$$F = P_{c.G}\,A = \left(\rho g\frac{h}{2}\right)\times\left(\frac{h}{\sin 30}\times 1\right)$$

$$= 1000 \times 10 \times \frac{1}{2} \times 2 \times 1$$

$$= 10\text{ kN}$$

Taking the moment about hinge

$$T\sin 60\times 5 - F\times\frac{2}{3} = 0$$

$$T\times\frac{\sqrt{3}}{2}\times 5 - 10\times\frac{2}{3} = 0$$

i.e., $T = 10\times\frac{2}{3}\times\frac{2}{\sqrt{3}}\times\frac{1}{5} = \frac{8}{3\sqrt{3}}\,\text{kN}$

15. Ans: (c)

Sol: $\oint\frac{\delta Q}{T} = \frac{Q_1}{T_1}+\frac{Q_2}{T_2}-\frac{Q_3}{T_3}$

$$= \frac{100}{1000}+\frac{50}{500}-\frac{120}{300} = -0.2 < 0$$

$\therefore$ Thus, irreversible heat engine

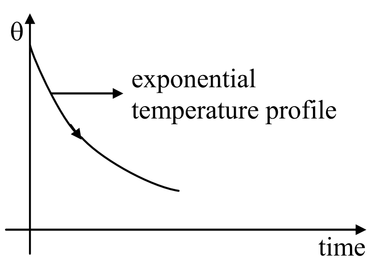
16. Ans: (c)

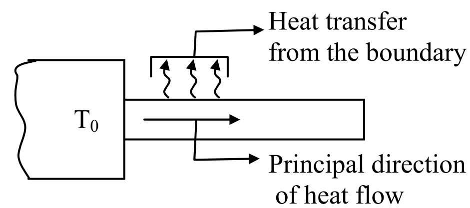
Sol: Effectiveness of the fin $(\in) = \sqrt{\frac{PK}{hA}}$

If $h\downarrow \Rightarrow \in\uparrow$

As, the heat transfer coefficient of gas is lesser than that of liquid in free convection, the effectiveness of the fin will be more in gas side rather than liquid side.

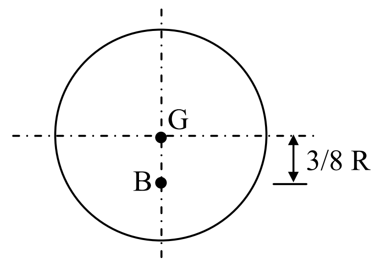
- The temperature profile inside the fin is exponential. $\frac{T-T_\infty}{T_0-T_\infty} = e^{-mx}$





17. Ans: (c)

Sol: Since the density of sphere is half of that of water 50 % of the sphere will be below free surface of the water.



As the sphere is symmetric, the shape of the displaced volume and hence the position centre of buoyancy is same even though the sphere is tilted about any axis. As the position of centre of buoyancy is not changing the corrective couple is not generated. Hence the sphere will remain as it is in its new position. Thus the type of equilibrium must be neutral.

The same can be concluded from the formula of metacentric height

$$GM = \frac{I_{min}}{\forall} - BG$$

$$= \frac{\frac{\pi}{4}R^4}{\frac{2}{3}\pi R^3} - \frac{3}{8}R = 0$$

18. Ans: (c)

Sol: For same thermal efficiency of temperature of intermediate cycle can be given as

$$T = \sqrt{T_1 \times T_2}$$

$$= \sqrt{1800 \times 300} = 735\ K$$

19. Ans: (b)

Sol:

- Thermal time constant $(\tau^*) = \frac{\rho vc}{hA}$

$$\tau^* = \left(\frac{1}{hA}\right) \times \rho vc$$

$\frac{1}{hA}$ = convective resistance

ρvc = lumped thermal capacitance

As, $\frac{1}{hA} \uparrow \Rightarrow \tau^* \uparrow$

- If Biot number increases, internal conductive resistance will increase thus temperature difference will increase.
- If temperature inside the solid body is uniform every time that means the thermal conductivity approaches infinite and Biot number tends to zero. Thus lumped capacity analysis can be applied.

20. Ans: (b)

Sol: $(Re_{cr})_{air} = (Re_{cr})_{water}$

i.e., $\left(\frac{U x}{\nu}\right)_{air} = \left(\frac{U x}{\nu}\right)_{water}$

i.e., $x_w = x_a \times \frac{\nu_w}{\nu_a} \times \frac{U_a}{U_w}$

$$= 0.5 \times \frac{1}{10} \times \frac{10}{5} = 0.1\ m$$

21. Ans: (a)

Sol:

- $P_1V_1 = P_2V_2$ so temperature is constant
- Internal energy is function of temperature only.

22. Ans: (c)

Sol: Heat transfer rate

$$Q = -kA\frac{\partial T}{\partial x} = \frac{kA(T_1 - T_2)}{L}$$

$$Q \propto \frac{k}{L}$$

$$\frac{Q_A}{Q_B} = \frac{\left(\frac{k_A}{k_B}\right)}{\left(\frac{L_A}{L_B}\right)} = \frac{4}{2} = 2$$

$$\frac{Q_A}{Q_B} = 2$$

23. Ans: (a)

Sol:

- Golf ball has dimples to make boundary layer turbulent. The turbulent boundary layer separates late hence it has lower pressure drag. This helps to travel golf ball longer distance.

- Aerofoil lift is produced due to unsymmetric flow over top and bottom surface. The unsymmetric flow causes unsymmetric pressure distribution which produces lift force.
- Stokes law is used to calculate drag force on a sphere in creeping flow (Re < 1)
- In pipe flow skin friction is present at the surface of pipe.

24. Ans: (b)

Sol: From first law of thermodynamics ,

$$Q - W = \Delta U$$

$\because$ $W = -\Delta U \Rightarrow$ Process is adiabatic,

Since internal energy is decreasing so temperature must decrease.

25. Ans: (d)

Sol: Effectiveness of the fin $(\in) = \eta \times \frac{PL}{A_c}$

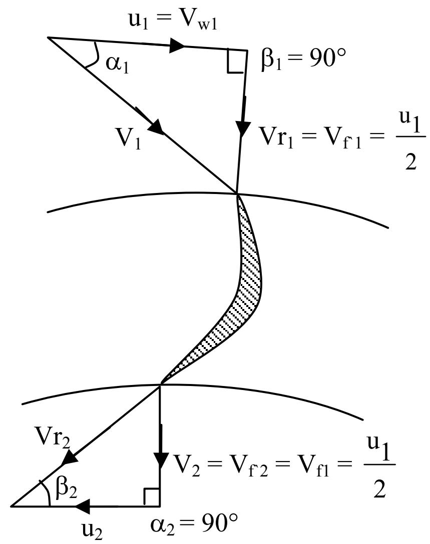
[p= perimeter, L = length, A_c = cross-sectional area, η = efficiency of fin]

$$\in = 0.65 \times \frac{2\times(0.002+0.002)\times 0.03}{0.002\times 0.002}$$

$$\in = 39$$

26. Ans: (a)

Sol:



The degree of reaction of the Francis turbine is given by

$$R = \frac{\left(\frac{P_1 - P_2}{\rho g}\right)_{rotor}}{H_e}$$

$$= \frac{\left(\frac{V_{r2}{}^2 - V_{r1}{}^2}{2g} + \frac{u_1^2 - u_2^2}{2g}\right)}{H_e}$$

$$= \frac{H_e - \frac{V_1^2 - V_2^2}{2g}}{H_e}$$

$$\left[\because H_e = \frac{V_1^2 - V_2^2}{2g} + \frac{u_1^2 - u_2^2}{2g} + \frac{V_{r2}^2 - V_{r1}^2}{2g}\right]$$

$$= 1 - \frac{V_1^2 - V_2^2}{2gH_e}$$

$$= 1 - \frac{V_1^2 - V_2^2}{2u_1V_{w1}} \quad \left[\because H_e = \frac{u_1 V_{w1}}{g}\right]$$

$$= 1 - \frac{(u_1^2 + V_{f1}^2) - (V_{f2})^2}{2u_1 V_{w1}}$$

$$= 1 - \frac{u_1^2 + (u_1/2)^2 - (u_1/2)^2}{2u_1^2}$$

$$= 1 - \frac{1}{2} = 0.5$$

27. Ans: (c)

Sol: Process is isothermal. Therefore, T = constant, Volume is increasing, therefore, pressure will decrease $\left(p \propto \frac{1}{V}\right)$

In a chamber A :

$$\Delta p = (p_A)_i - (p_A)_f = \frac{n_A RT}{V} - \frac{n_A RT}{2V}$$

$$= \frac{n_A RT}{2V} \text{ ----------(1)}$$

In chamber B :

$$1.5\Delta p = (p_B)_i - (p_B)_f = \frac{n_B RT}{V} - \frac{n_B RT}{2V}$$

$$= \frac{n_B RT}{2V} \text{ ---------(2)}$$

From equation (1) and (2)

$$\frac{n_A}{n_B} = \frac{1}{1.5} = \frac{2}{3}$$

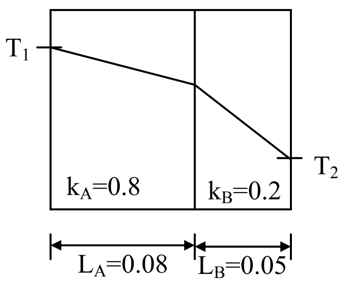
$$\frac{m_A/M}{m_B/M} = \frac{2}{3}$$

$$\frac{m_A}{m_B} = \frac{2}{3}$$

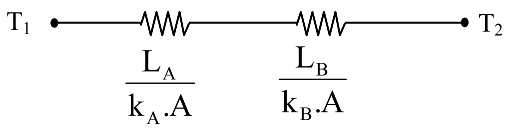
$3m_A = 2m_B$

28. Ans: (a)

Sol:



Thermal circuit:



$$\text{Heat flux}(q) = \frac{T_1 - T_2}{\Sigma R_{Th}} = \frac{18}{\frac{0.08}{0.8} + \frac{0.05}{0.2}}$$

$$(q) = \frac{18}{\frac{1}{10} + \frac{1}{4}} = \frac{360}{7}\,\text{W/m}^2$$

$$(q) = \frac{360}{7} \times 60\left(\frac{\text{J}}{\text{min} - \text{m}^2}\right)$$

(q) = 3085.7 J/min-m^2

29. Ans: (b)

Sol: $F = \rho a\,(V - u)^2$

$= 1000 \times 10 \times 10^{-4}\,(7 - 4)^2$

$= 9$ N

$W = F \times u$

$= 9 \times 4 = 36$ W

30. Ans: (a)

Sol: $\eta = 1 - \frac{T_2}{T_1} = \frac{1}{6} \Rightarrow \frac{T_2}{T_1} = 1 - \frac{1}{6} = \frac{5}{6}$

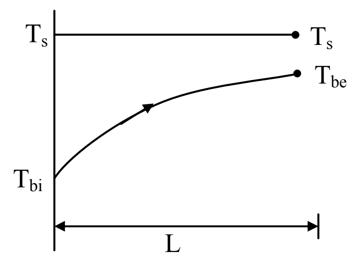
$$\frac{1}{3} = 1 - \frac{(T_2 - 62)}{T_1} \Rightarrow \frac{T_2 - 62}{T_1} = \frac{2}{3}$$

$$\Rightarrow \frac{5(T_2 - 62)}{6T_2} = \frac{2}{3}$$

$$\Rightarrow T_2 = 310 \quad \text{and} \quad T_1 = \frac{6 \times 310}{6T_2} = 372\ \text{K}$$

31. Ans: (c)

Sol: *Temperature Profile :*



Heat transfer rate (Q) = hA $(\Delta T)_m$

where, h = heat transfer coefficient

A = πdL → surface area of the tube

ΔT_m = logarithmic mean temperature difference

32. Ans: (b)

Sol: $P_u = \frac{P}{H^{3/2}}$

$P = P_u \times H^{3/2} = 2 \times (225)^{3/2}$

$= 2 \times 15^3$

$= 6750$ kW

33. Ans: (d)

Sol: For process A to B be from first law of thermodynamics.

$Q - W = \Delta U$

$nC_p 200 - W = n\,C_v\,200$

$W = n(C_p - C_v) \times 200$

$W = n \times R \times 200$

$= 400\,R$

34. Ans: (b)

Sol: Energy of the fluid = $\dot{m}c_p T_m = \int_{\dot{m}} c_p T(r)\delta\dot{m}$

$$\dot{m} = \rho A_c . u(r)$$

$$\delta\dot{m} = \rho u(r) dA_c$$

$$\dot{m}c_p T_m = \int_{A_c} c_p T(r)\rho u(r) dA_c$$

$$T_m = \frac{1}{\dot{m}}\int_{A_c} \rho T(r) u(r) dA_c$$

35. Ans: (b)

Sol: For the fluid coupling there is no third mechanical component between driving pump and driven turbine. Both are connected by the fluid only.

By Newton's third law torque transmitted must be same. i.e., $T_1 = T_2$

In order to have continuous flow the centrifugal head developed by the pump must be more than the centrifugal head in turbine. i.e,. $N_1 > N_2$

Alternatively,

$P_1 > P_2$ [$\because$ some power is lost in friction]

i.e., $N_1T_1 > N_2T_2$

$\Rightarrow$ $N_1 > N_2$ [$\because T_1 = T_2$]

36. Ans: (d)

Sol:

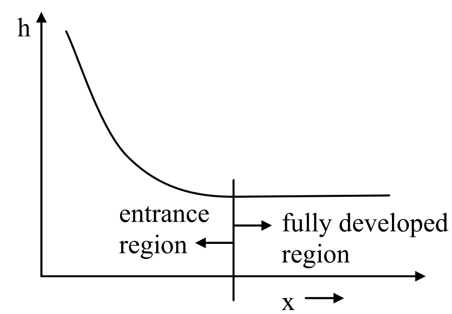
- In turbulent flow →

  Thermal entrance length ≅ hydrodynamic entrance length ≅ 10 D

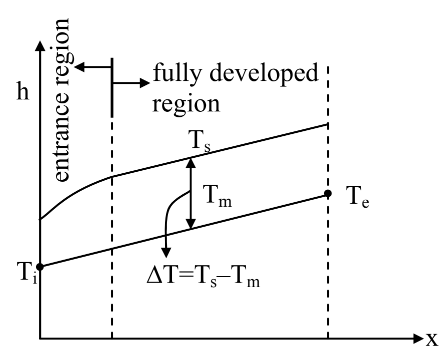
  $L_{t,\,turbulent} \cong L_{h,\,turbulent} \cong 10D$

  D = Diameter of tube

- Variation of heat transfer coefficient along the tube



- Variation of tube surface and the mean fluid temperature along the tube for the constant heat flux



37. Ans: (a)

Sol: For cyclic process $\Sigma Q = \Sigma W$

$5 = W_{AB}+W_{BC}+W_{CA}$

$5 = 10 \times (2-1) + 0 + W_{CA}$

$W_{CA} = -5$

38. Ans: (d)

Sol: The positive displacement pump pushes 'trapped' volume of fluid at higher pressure through mechanical action of devices such as piston, vane screw etc. None of the above device works on this principle.

Centrifugal pump : Flow is driven by centrifugal forces.

Jet pump: Pressure rise is obtained due to mixing of flow with high velocity jet.

Hydraulic ram : Works on the principle of water hammer.

39. Ans: (a)

Sol: $(\dot{m}c_p)_{water} = 0.5 \times 4.2 = 2.1 \text{kW/K}$

$(\dot{m}.c_p)_{air} = 1.8 \times 1 = 1.8 \text{kW/K}$

$(\dot{m}.c_p)_{air} < (\dot{m}c_p)_{water}$

$c_{min} = (\dot{m}c_p)_{air}$ and $c_{max} = (\dot{m}c_p)_{water}$

Maximum possible heat transfer

$(Q_{max}) = C_{min} \times (\Delta T)_{max}$

$= (\dot{m}c_p)_{air} \times (T_{hi} - T_{ci})$

$= 1.8 \times (50 - 15) = 63$ kW

40. Ans: (b)

Sol: $\beta_2 = 180 - 120 = 60°$

$$\eta_w = \frac{2u(v-u)(1+k\cos\beta_2)}{v^2}$$

$$= 2\left(\frac{u}{v}\right)\left(1-\frac{u}{v}\right)(1+k\cos\beta_2)$$

$= 2 \times 0.5 \times (1 - 0.5)(1 + 1\times \cos60)$

$= 2 \times 0.5 \times 0.5 \times (1 + 0.5)$

$= 0.75$

41. Ans: (d)

Sol:

- Baffles are commonly placed in the shell to force the shell-side fluid to flow across the shell to enhance heat transfer and to maintain uniform spacing between the tubes. Despite their widespread use, shell-and-tube heat exchangers are not suitable for use in automotive and air-craft applications because of their relatively large size and weight. [Note that the tubes in a shell-and-tube heat exchanger open to some large flow areas called headers at both ends of the shell, where the tube-side fluid accumulates before entering the tubes and after leaving them].
- The fouling factor depends on the temperature and the velocity of the fluids, as well as length of service. Fouling

increases with increasing temperature and decreasing velocity.

- ε - NTU method is used to design the size of the heat exchanger.

  The procedure to be followed by the selection process is:

  1. Select the type of heat exchanger suitable for the application.
  2. Determine any unknown inlet or outlet temperature and the heat transfer rate using an energy balance.
  3. Calculate the log mean temperature difference ΔT_{lm} and the correction factor F, if necessary.
  4. Obtain (select or calculate) the value of the overall heat transfer coefficient U.
  5. Calculate the heat transfer surface area A_s.

42. Ans: (c)

Sol: $\eta_m = \dfrac{gH_m}{u_2 v_{w2}}$

$$H_m = \eta_m \frac{u_2 v_{w2}}{g}$$

$$H_m = \frac{P_d - P_s}{\rho g} + \frac{V_d^2 - V_s^2}{2g} + z_d - z_s$$

$$P_d - P_s = \rho g H_m = \rho g \eta_m \frac{u_2 v_{w2}}{g}$$

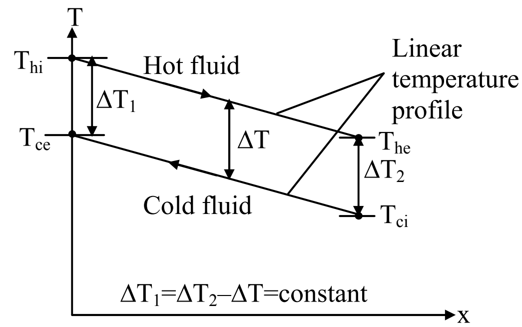
$$= \rho\, \eta_m\, u_2\, v_{w2}$$

$$= 1000 \times 0.8 \times 300 = 240 \text{ kPa}$$

43. Ans: (b)

Sol: If $\dot{m}_c c_{p_c} = \dot{m}_n c_{p_n}$

$$C = \frac{C_{min}}{C_{max}} = \frac{\dot{m}_c c_{p_c}}{\dot{m}_n c_{p_n}} = 1$$



44. Ans: (b)

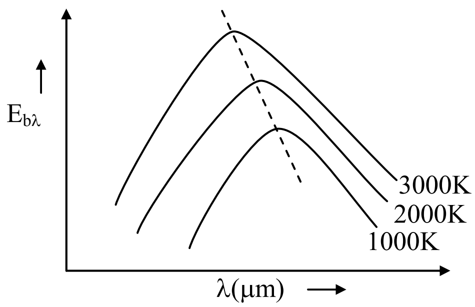
Sol:

- Kaplan turbine has good part load efficiency due to adjustable rotor vanes.
- For Francis turbine guide vanes are adjustable but rotor vanes are fixed.
- Pelton turbine is not suitable for high discharge because it has less flow area. (nozzle area)

45. Ans: (b)

Sol:

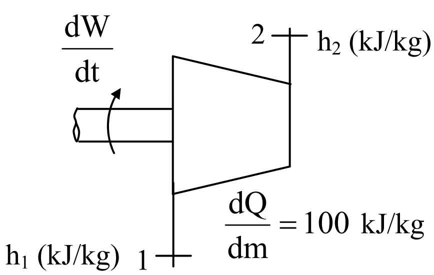
- The term 'diffuse' means "independent of direction."
- At any wavelength, the amount of emitted radiation increases with increasing temperature.



(The variation of black body emissive power with wavelength for several temperatures)

46. Ans: (b)

Sol:



$$\dot{m}h_1 + \dot{m}\frac{dQ}{dm} = \dot{m}h_2 + \frac{dW}{dt}$$

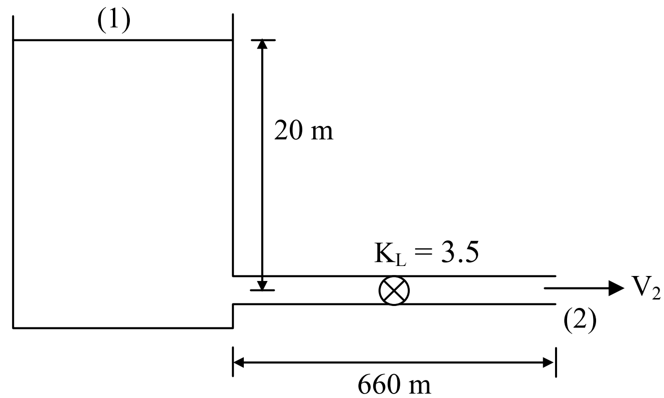
$$\frac{dW}{dt} = \dot{m}(h_1 - h_2) + \dot{m}\left(\frac{dQ}{dm}\right)$$

$= 1(200 – 400) + 1(–100)$

$= –300$ kW

47. Ans: (c)

Sol:



Applying Bernoulli's equation between free surface of reservoir and pipe exit we get,

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + z_2 + h_L$$

i.e., $z_1 - z_2 = \frac{V_2^2}{2g} + h_{L,\text{entrace}} + h_f + h_{L,\text{valve}}$

$$= \frac{V_2^2}{2g} + 0.5\frac{V_2^2}{2g} + \frac{f L V_2^2}{2gD} + 3.5\frac{V_2^2}{2g}$$

$$= \frac{V_2^2}{2g}\left(1 + 0.5 + 3.5 + \frac{0.03 \times 660}{0.09}\right)$$

i.e., $20 = \frac{V_2^2}{2g} \times 225$

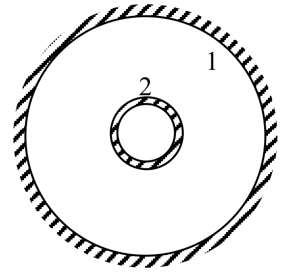
$$V_2 = \sqrt{\frac{20 \times 2 \times 10}{225}} = \frac{20}{15} = 1.33\,\text{m/s}$$

48. Ans: (b)

Sol:

$d_1 = 20$ cm

$d_2 = 15$ cm



$F_{2-1} = 1$ (from the geometry)

Using reciprocity theorem

$A_1F_{1-2} = A_2F_{2-1}$

$$4\pi r_1^2 \times F_{1-2} = 4\pi r_2^2 \times 1$$

$$F_{1-2} = \left(\frac{r_2}{r_1}\right)^2 = \left(\frac{d_2}{d_1}\right)^2 = \left(\frac{15}{20}\right)^2 = \frac{9}{16} = 0.56$$

49. Ans: (b)

Sol:

- The shear stress and velocity gradient relationship is not linear hence fluid is not Newtonian.
- Yield stress (i.e shear stress at zero velocity is gradient) is zero hence fluid is not Bingham plastic.

The apparent viscosity increases with shear strain rate as shown in the table below, hence fluid is dilatant.

$\mu_a = \frac{\tau}{\frac{du}{dy}}$	0.01	0.016	0.02

50. Ans: (c)

Sol: Heat transfer coefficient in film condensation on a vertical plate

$$(h) = \left[\frac{g\rho_\ell(\rho_\ell - \rho_v)h_{fg}K_\ell^3}{4\mu_\ell(T_{sat} - T_s)x}\right]^{1/4}$$

$$h \propto \frac{1}{(T_{sat} - T_s)^{1/4}}$$

Heat transfer rate (Q) = $hA\Delta T$

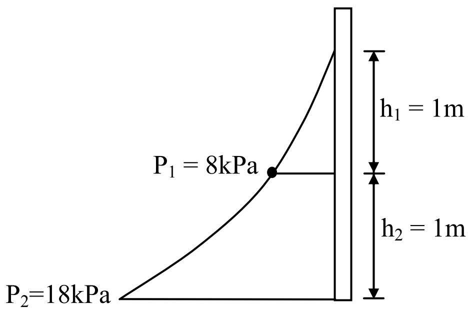
$$Q \propto h\Delta T$$

$$Q \propto \frac{1}{(T_{sat} - T_s)^{1/4}}(T_{sat} - T_s)$$

$$Q \propto (T_{sat} - T_s)^{3/4}$$

51. Ans: (b)

Sol: The pressure distribution on the wall is as shown in the figure below:



$P_1 = \rho_{oil}\, g\, h_1$

$= 800\times10\times1 = 8$ kPa

$P_2 = \rho_{oil}gh_1 + \rho_w gh_2$

$= 800\times10\times1+1000\times10\times1$

$= 18$ kPa

F_H = Area of pressure diagram

$$= \frac{1}{2}P_1\times h_1\times1+\frac{1}{2}(P_1+P_2)\times h_2\times1$$

$$= \frac{1}{2}\times8\times1+\frac{1}{2}(8+18)\times1 = 17\text{kN}$$

52. Ans: (d)

Sol: In steel, thermal conductivity is higher than that of charcoal. So, if both are picked up by bare hands, then heat transfer from the body (steel or charcoal) to our hands will be larger in case of steel. Hence, steel will be hotter than the charcoal.

On the other hand, emissivity of charcoal is higher as compared to steel. So, if the two are picked up from the lawn and kept in a cold chamber, charcoal will lose heat at a faster rate than steel.

53. Ans: (a)

Sol: $u = -\frac{\partial\Psi}{\partial y} = 2y$

$v = \frac{\partial\Psi}{\partial x} = 2x$

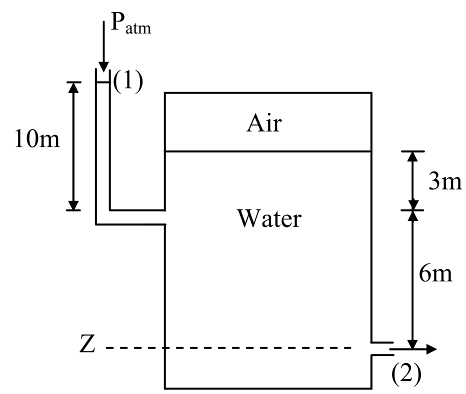
$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y} = 0+0 = 0$

Flow field is incompressible

$$\omega_z = \frac{1}{2}\left(\frac{\partial v}{\partial x}-\frac{\partial u}{\partial y}\right) = \frac{1}{2}(2-2) = 0$$

54. Ans: (d)

Sol:



The Bernoulli's equation when applied between free surface and orifice gives.

$$\frac{P_{atm}}{\rho g}+\frac{V_1^2}{2g}+Z_1 = \frac{P_2}{\rho g}+\frac{V_2^2}{2g}+z_2$$

$$10+6 = \frac{V_2^2}{2g}+0$$

$$V_2 = \sqrt{2g\times16} = \sqrt{320}\ \text{m/s}$$

55. Ans: (c)

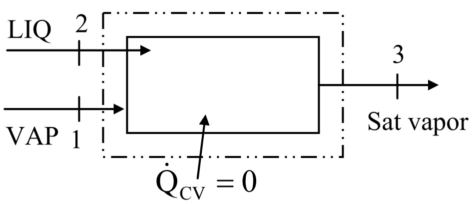
56. Ans: (a)

Sol: $V = \frac{2}{3}u_{max} = \frac{2}{3} \times 1.5 = 1 m/s$

$$\Delta P = \frac{12\mu VL}{B^2} = \frac{12 \times 0.01 \times 1 \times 1}{0.01^2} = 1.2 kPa/m$$

57. Ans: (a)

Sol:



Continuity equation: $\dot{m}_1 + \dot{m}_2 = \dot{m}_3$

$$\dot{m}_1 h_1 + \dot{m}_2 h_2 = \dot{m}_3 h_3$$

$$0.5 \times 3200 + \dot{m}_2 \times 170 = (0.5 + \dot{m}_2)2800$$

$$\Rightarrow \dot{m}_2 = 0.076 kg/s$$

58. Ans: (c)

Sol:

- Flow separation is possible only when pressure gradient is adverse i.e positive
- Turbulent boundary layer can withstand positive pressure gradient for longer distance due to its high momentum flux.

59. Ans: (c)

Sol: For laminar flow friction factor is given by $f = \frac{64}{Re}$, hence statement II wrong. If diameter, discharge and fluid is same then Reynolds number is same. For laminar flow, the friction factor depends only on Reynolds number. Therefore, friction factor is also constant under given condition. Hence statement I is true.

60. Ans: (d)

Sol: Effectiveness of the fin $(\in) = \sqrt{\frac{Pk}{hA}}$

As $h \downarrow \rightarrow \in \uparrow$

$\therefore$ Fins should be used where heat transfer coefficient is small

$\because \quad h_{air} < h_{water}$

$\therefore \quad (\in_{fin})_{air} > (\in_{fin})_{water}$

61. Ans: (d)

Sol: Losses in nozzle meter are less as compared to orifice meter. Higher the losses lower is the value of coefficient of discharge.

$\therefore C_{d,\ orifice} < C_{d,nozzle} < C_{d,venturi}$

62. Ans: (d)

Sol: Heat transfer rate always reduces due to the addition of insulation inside the surface of pipe.

63. Ans: (b)

Sol: The loss due to friction is called major loss because its magnitude is high as compared to other losses in pipe flows such as sudden expansion, entrance, exit etc.

64. Ans: (c)

Sol: In free vortex angular velocity of fluid element about its own mass centre is zero. Hence it is called irrotational vortex. The streamlines in free vortex are circular, hence statement (II) is wrong.

65. Ans: (b)

Sol: In adiabatic process, there is no heat transfer. If adiabatic process is reversible then it is called as isentropic process.

66. Ans: (c)

Sol: Apparent viscosity of dilatant fluids is given

by $$\mu_a = \frac{\tau}{\left(\frac{du}{dy}\right)}$$

i.e., $$\mu_a = \frac{A\left(\frac{du}{dy}\right)^n}{\left(\frac{du}{dy}\right)} = A\left(\frac{du}{dy}\right)^{n-1}$$

For dilatant fluids, $n > 1$

Hence apparent viscosity of dilatant fluids increases with respect to the deformation rate. At higher deformation rate more stress is required to deform the dilatant fluid.

Therefore, statement (I) is true but statement (II) is false.

67. Ans: (c)

Sol: As boundary layer grows in the downstream direction, the velocity varies from zero to maximum velocity in comparatively larger distance. Boundary layer thickness increases in the downstream direction.

68. Ans: (a)

Sol: $Tds = dh - vdp$

$P = C$

$dp = 0$

$$\left(\frac{dh}{ds}\right)_{P=C} = T$$

69. Ans: (a)

Sol: Prandtl number of liquid metal <<< 1

$Pr < 1$

$\therefore \quad \delta < \delta t$

Hydrodynamic boundary layer thickness < Thermal boundary layer thickness

70. Ans: (a)

Sol: Ideally efficiencies of model and prototype are expected to be same under homologous operating conditions. However the bigger turbines have smaller relative clearances hence their volumetric efficiency is comparatively high. Relative frictional losses are also slightly less in bigger turbines due to low relative roughness. Due to these effects the efficiency of larger turbine is slightly better as compared to geometrically similar smaller turbine. Moody's step up formula is used to predict the efficiency of bigger turbine by knowing efficiency of smaller turbine.

$$\left(\frac{1-\eta_2}{1-\eta_1}\right)=\left(\frac{D_1}{D_2}\right)^{\frac{1}{5}} \rightarrow \text{Moody's step up formula}$$

71. Ans: (a)

Sol: Entropy is point function and it depends only on end states.

72. Ans: (b)

Sol: Specific heat ratio (C) = $\frac{C_{min}}{C_{max}}$

If C = 0 (during phase change)

$(\in)_{parallel} = (\in)_{counter} \Rightarrow$ Maximum value

If C = 1,

$(\in)_{counter} > (\in)_{parallel} \Rightarrow$ minimum value

$\therefore \quad 0 \le C \le 1$

73. Ans: (a)

Sol: The function of diffuser is to convert kinetic energy into pressure. If diffuser area increases, velocity decreases and pressure increases.

74. Ans: (b)

Sol: Dropwise condensation is much desirable because of its higher heat transfer rates. However, it hardly occurs on a cooling surface. When the surface is coated with some promoter like teflon, grease, mercaptan, oleic acid and so on, drop condensation can occur for some time. But the effectiveness of the promoter gradually decays due to fouling, oxidation or its slow removal by the flow of the condensate. Condensers are usually designed on the basis that film condensation are usually designed on the basis that film condensation would prevail.

75. Ans: (b)

Sol:

- Heat engine cannot have a thermal efficiency of 100% this is because some amount of heat has to be rejected to low temperature sink.
- Second law efficiency = $\frac{W_{act}}{W_{rev}}$ = 100%

  (for reversible process)

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