Fluid Mechanics and Machinery + Heat Transfer

Q.126 The Navier-Stoke's equation for an incompressible fluid with constant viscosity is

(a) $-\vec{\nabla}P + \rho\vec{g} + \mu\vec{\nabla}^2\vec{V} = 0$

(b) $\rho\frac{D\vec{V}}{Dt} = \vec{\nabla}P + \mu\vec{\nabla}^2\vec{V}$

(c) $\rho\frac{D\vec{V}}{Dt} = -\vec{\nabla}P + \rho\vec{g} + \mu\vec{\nabla}^2\vec{V}$

(d) $\rho\frac{D\vec{V}}{Dt} = -\vec{\nabla}P + \rho\vec{g} + \mu\vec{\nabla}^2\vec{V} + \vec{\nabla}\cdot\vec{V} = 0$

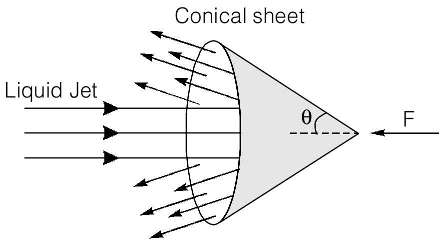
Q.127 The impeller of a centrifugal pump has an outer diameter of 30 cm and inner diameter of 15 cm. The pump runs at 1200 rpm. The impeller vanes are set at a blade angle of 30° at the outlet. If the velocity of flow is constant at 2.0 m/s. The head developed is
(Assume manometric efficiency = 0.85 and g = 9.81 m/s^2)

(a) 25.13 m
(b) 23.6 m
(c) 28.4 m
(d) 29.8 m

Q.128 A double overhung 1.5 m diameter impulse turbine installation is to develop 3000 kW at 400 rpm under a net head of 300 m. If the overall efficiency is 0.90, then the diameter of the jet is _________ cm. (Take C_v = 0.95, unit weight of water = 9.79 kN/m^3) [Correct upto 1 decimal place]

Q.129 A double jet Pelton wheel has a specific speed of 15 (SI units) and is required to deliver a power of 1500 kW. The turbine is supplied through a pipeline from a reservoir whose level is 500 m above the nozzles. Allowing 5% for friction loss in the pipe, the rotational speed is ________ rpm. (Correct upto two decimal places)

Q.130 A liquid jet of velocity V_j and diameter D_j strikes a fixed cone and deflects back as a conical sheet with the same velocity as shown in figure below. The expression for restraining force may be given as $F = \frac{3}{2}\left(\rho A_j V_j^2\right)$. The cone angle (θ) is



(a) 30°
(b) 43°
(c) 45°
(d) 60°

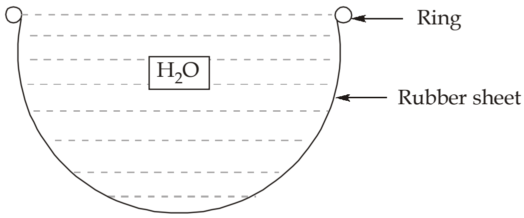
Q.131 A fluid flow field is given by

$$V = x^2y\hat{i} + y^2z\hat{j} - \left(2xyz + yz^2\right)\hat{k}$$

The x-component of acceleration at point (3, 2, 1) is __________ units.

Q.132 An oil of viscosity 0.02 Ns/m^2 is flowing between two stationary parallel plates 1 m wide maintained 15 mm apart. The velocity midway between the plates is 3 m/s. The pressure gradient along the flow is_______ N/m^2/m. [Correct upto 1 decimal place]

Q.133 A sheet of rubber in stretched out over a ring of radius 0.25 m. After pouring liquid water on it, the rubber forms a half sphere as shown in figure. Neglecting the rubber mass, the surface tension near the ring is equal to



(a) 153.3 N/m
(b) 51.1 N/m
(c) 204.4 N/m
(d) 102.2 N/m

Q.134 The velocity distribution within a laminar boundary layer is described by the following parabolic function:

$$\frac{u}{U} = 2\left(\frac{y}{\delta}\right) - \left(\frac{y}{\delta}\right)^2$$

Then the ratio of displacement thickness (δ^*) to boundary layer thickness (δ) is

(a) $\frac{2}{3}$
(b) $\frac{1}{4}$
(c) $\frac{1}{3}$
(d) $\frac{2}{5}$

Q.135 Two reservoirs are connected by a pipeline. The diameter of the pipe is 0.5 m and the difference in levels of the two reservoirs is 12.5 m. The total length of the pipe is 1000 m. The velocity of flow in the pipe taking into account both major and minor losses will be
[Take, friction factor $f = 0.04$ and $g = 10$ m/sec^2]

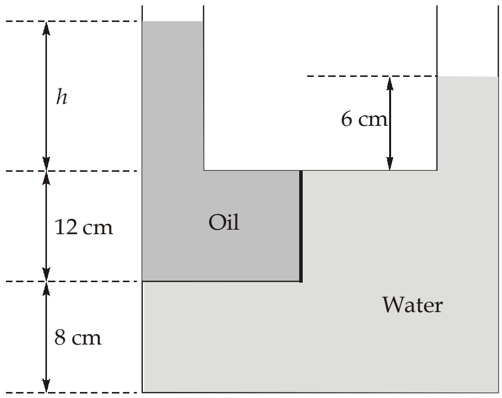
(a) 1.75 m/s
(b) 3.2 m/s
(c) 4.5 m/s
(d) 0.5 m/s

Q.136 The air velocity in the duct of a heating system is to be measured by a Pitot-static probe inserted into the duct parallel to the flow. If the differential height between the water columns connected to the two outlets of the probe is 2.4 cm, then the flow velocity (in m/s) at the tip of the probe is _________. The air temperature and pressure in the duct are 45°C and 98 kPa, respectively. Take the density of water to be ρ = 1000 kg/m^3 and the gas constant of air is R = 0.287 kPa m^3/kgK. (Correct up to one decimal place)

Q.137 A 0.9 m diameter vertical cylindrical tank open to the atmosphere contains water upto a height of 0.3 m. The tank is now rotated about the centerline, and the water level drops at the center while it rises at the edges. Then the angular velocity at which the bottom of the tank will first be exposed is _________ rad/s. (Correct up to three decimal places).

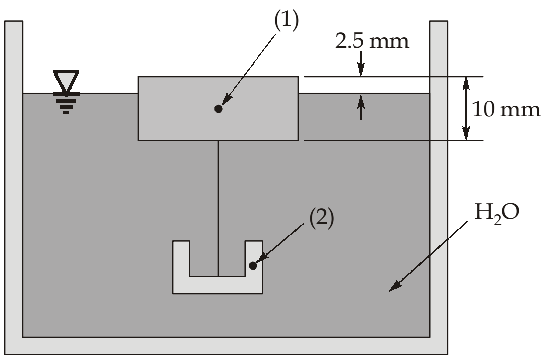
Q.138 Which one of the following is correct with respect to dimensional analysis?
(a) A dimension is a measure of a physical quantity (without numerical values)
(b) A unit is a way to assign a number to the dimension
(c) Both (a) and (b)
(d) None of these

Q.139 As the tank shown below contains water and immiscible oil at 20 °C. Then the height h of the column is
[Assume the density of oil is 898 kg/m^3]



(a) 0.010 m
(b) 0.017 m
(c) 1.01 m
(d) 0.080 m

Q.140 A metal part (object 2) is hanging by a thin cord from a floating wood block (object 1). The wood block has a specific gravity S_1 = 0.3 and dimensions of 50 × 50 × 10 mm^3. The metal part has a volume of 6600 mm^3 (g = 9.8 m/s^2). The mass m_2 of the metal part is



(a) 0.01282
(b) 0.01540
(c) 0.01372
(d) 0.01785

Q.141 Consider conditions for which a fluid with a free stream velocity V flows over a surface with characteristic length L, providing an average convection heat transfer coefficient $\bar{h}$. The experimental measurements showed following results: When V_1 = 25 m/s, $\bar{h}_1$ = 60 W/m^{2}K and when V_2 = 15 m/s, $\bar{h}_2$ = 30 W/m^{2}K. Assume that Nusselt number is of the form $\overline{Nu}$ = CRe^{m}Pr^n, where C, m and n are constants. The value of convective heat transfer (W/m^{2}K) when V = 40 m/s is ________. (Correct upto two decimal places)

Q.142 In a steam condenser, the steam condenses at a temperature of 60°C. The cooling water enters at 25°C and leaves at 45°C. The surface area of condenser tubes is 30 m^2 and the overall heat transfer coefficient for the heat exchanger is 2000 W/m^2°C. The heat of vaporization of water at 60°C is h_{fg} = 2358 kJ/kg. The rate of condensation of steam (in kg/s) in the condenser is

(a) 0.2
(b) 0.4
(c) 0.6
(d) 0.8

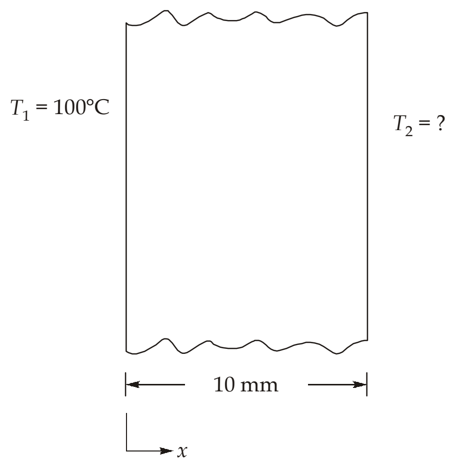
Q.143 In a counter flow, concentric tube heat exchanger, water flows through the inner tube having diameter 30 mm at 30°C. The hot oil enters the annulus having diameter 50 mm at 100°C and leaves at 60°C. The mass flow rate of the water and the oil are 0.5 kg/s and 0.7 kg/s, respectively. The specific heat of water and oil are 4200 J/kgK and 2400 J/kgK, respectively. If the overall heat transfer coefficient of the heat exchanger is 300 W/m^2°C, the length of the tube required to achieve the desired heat transfer is ___________ m. (Correct upto two decimal places)

Q.144 A drying oven is shaped like a long equilateral-triangular duct. The width of each side is 1.5 m and heat is supplied from the base surface (ε = 0.9) at a rate of 1000 W/m while the side surfaces (ε = 0.4) are maintained at 400 K. Neglecting any end effects, the temperature of the base surface is _________ K. (Correct upto one decimal place)

Q.145 An infinitely long copper (k = 400 W/mK) rod of length L and diameter D is attached at one end to a heated wall and transfers heat $\dot{q}_1$ by convection to a cold fluid. If an aluminium (k = 250 W/mK) rod of length L and diameter 0.4D is used in place of copper rod, the heat transfer is $\dot{q}_2$. The ratio $\frac{\dot{q}_1}{\dot{q}_2}$ is ________.

Q.146 The time required for a lumped system (time constant, τ = 10 s) to reach the average temperature, $T_{avg} = (T_i + T_\infty)/2$, where T_i is the initial temperature and T_∞ is the temperature of the environment, is _______________ s. (Correct upto two decimal places)

Q.147 A wall is made from an inhomogeneous material for which the thermal conductivity varies through the thickness according to $k = ax + b$ where, $a = 7 \times 10^4$ W/m^2K and b = 200 W/mK. Assume that the heat flux is constant and is equal to 3.723×10^6 W/m^2, the temperature at x = 10 mm, is



(a) 80°C
(b) 94.4°C
(c) 20°C
(d) 64°C

Multiple Select Questions (MSQ)

Q.148 Which of the following statements is/are correct for turbulent flow through pipe?
(a) Frictional head loss varies directly as the average velocity.
(b) Frictional head loss varies directly as the square of average velocity.
(c) Shear stress is due to fluctuation of the velocity in the direction of flow as well as transverse to it.
(d) The laminar sublayer is a region next to wall where the inertia force is predominate while the rest of the flow is turbulent.

Q.149 Which of the following statements is/are correct in respect of Kaplan turbine?
(a) It is a reaction turbine.
(b) It is mixed flow turbine
(c) Low frictional losses
(d) Part load efficiency is considerably high

Q.150 In respect of free convection over a vertical flat plate the Nusselt number varies with Grashof number 'Gr' as
(a) $Gr^{1/7}$ for turbulent flow
(b) $Gr^{1/3}$ for laminar flow
(c) $Gr^{1/4}$ for laminar flow
(d) $Gr^{1/3}$ for turbulent flow

■■■■

Detailed Explanation

126. (c)

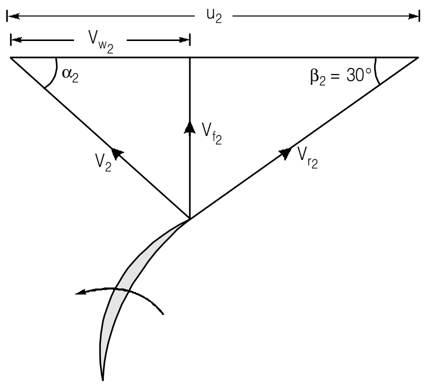
For an incompressible fluid, Navier-Stoke's equation, $\rho \frac{D\vec{V}}{Dt} = -\vec{\nabla}P + \rho\vec{g} + \mu\vec{\nabla}^2\vec{V}$

127. (a)

At the outlet, $u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.30 \times 1200}{60} = 18.85 \text{ m/s}$

$V_{f2} = 2.0 \text{ m/s and } \beta_2 = 30°$

From the outlet velocity triangle,



$$\tan \beta_2 = \frac{V_{f2}}{u_2 - V_{w_2}}$$

$$\tan 30° = \frac{2.0}{18.85 - V_{w_2}}$$

$$18.85 - V_{w_2} = 3.464; \text{ and hence } V_{w_2} = 15.386 \text{ m/s}$$

Manometric efficiency

$$\eta_m = \frac{gH}{u_2 V_{w_2}}$$

Head developed, $H = \eta_m \frac{u_2 V_{w_2}}{g} = \frac{0.85 \times 18.85 \times 15.386}{9.81} = 25.13 \text{ m}$

128. (9.95) (9.8 to 10.0)

$$\text{Power per wheel} = \frac{3000}{2} = 1500 \text{kW}$$

$$\text{Power} = \eta_o \gamma Q H$$

$\Rightarrow$ $1500 = 0.90 \times 9.79 \times Q \times 300$

$\Rightarrow$ $Q = 0.5674 \text{ m}^3/\text{s}$

Velocity of the jet, $V_1 = C_V\sqrt{2gH}$

$$= 0.95\sqrt{2 \times 9.81 \times 300} = 72.88 \text{m/s}$$

$$\text{For the nozzle: } Q = \frac{\pi}{4} d^2 V_1$$

$$\Rightarrow \quad 0.5674 = \frac{\pi}{4} \times d^2 \times 72.88$$

$$\Rightarrow \quad d = 9.95 \text{ cm}$$

129. (1214.58)(1214.50 to 1214.65)

$$\text{Net available head, } H = 500\ (1 - 0.05) = 475 \text{ m}$$

$$\text{Power per jet} = \frac{1500}{2} = 750 \text{ kW}$$

$$\text{Specific speed } (N_s) = \frac{N\sqrt{P}}{H^{5/4}}$$

$$\Rightarrow \quad 15 = \frac{N\sqrt{750}}{(475)^{5/4}}$$

$$\Rightarrow \quad N = 1214.58 \text{ rpm}$$

130. (d)

$$\sum F_x = -F = \dot{m}_{out} u_{out} - \dot{m}_{in} u_{in}$$

$$= \dot{m}(-V_j \cos\theta) - \dot{m} V_j = -\rho A_j V_j^2 (1 + \cos\theta)$$

$$F = \rho A_j V_j^2 (1 + \cos\theta)$$

$$\Rightarrow \quad \frac{3}{2} \rho A_j V_j^2 = \rho A_j V_j^2 (1 + \cos\theta)$$

$$\cos\theta = \frac{1}{2} \quad \Rightarrow \theta = 60^\circ$$

131. (252)

x-component of acceleration,

$$a_x = u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z}$$

$$a_x = x^2 y(2xy) + y^2 z(x^2) - (2xyz + yz^2)(0)$$

$$= 2x^3y^2 + x^2y^2z$$

$$= 2(3)^3(2)^2 + (3)^2(2)^2(1)$$

$$= 2 \times 27 \times 4 + 9 \times 4 \times 1$$

$$= 54 \times 4 + 36$$

$$= 216 + 36$$

$$= 252 \text{ units}$$

132. (–2133.33) (–2134.0 to –2132.0)

The velocity midway between the plates is the maximum velocity.

Pressure gradient $\left(\frac{\partial p}{\partial x}\right)$,

$$\therefore \quad U_{max} = \frac{-1}{8\mu}\left(\frac{\partial p}{\partial x}\right) \times t^2$$

$$\Rightarrow \quad 3 = \frac{-1}{8 \times 0.02}\left(\frac{\partial p}{\partial x}\right) \times (0.015)^2$$

$$\Rightarrow \quad \left(\frac{\partial p}{\partial x}\right) = \frac{-3 \times 8 \times 0.02}{(0.015)^2} = -2133.33 \text{ N/m}^2/\text{m}$$

133. (d)

The length in the perimeter, $2\pi r$ and there are two surfaces of rubber sheet (inside and outside) by force balance,

$$\sigma \times 2\pi r \times 2 = mg$$

$$mg = \frac{1}{2} \times \frac{4}{3}\pi r^3 \rho g = \frac{1}{2} \times \frac{4}{3} \times \pi \times 0.25^3 \times 1000 \times 9.81 = 321.02 \text{ N}$$

$$\sigma = \frac{321.03}{2 \times 2\pi \times 0.25} \Rightarrow 102.187 \text{ N/m}$$

$$\sigma \approx 102.2 \text{ N/m}$$

134. (c)

As per given data:

$$u^* = \frac{u}{U} \text{ and } y^* = \frac{y}{\delta}$$

$$dy^* = \delta^{-1}\, dy$$

The given parabolic velocity distribution and the expression for the displacement thickness can then be expressed as

$$u^* = 2y^* - y^{*2}, \text{ and } \delta^* = \delta\int_0^1 (1 - u^*)\, dy^*$$

Combining these equations gives,

$$\delta^* = \delta\int_0^1 \left(1 - 2y^* + y^{*2}\right) dy^*$$

$$\delta^* = \delta\left[y^* - y^{*2} + \frac{1}{3}y^{*3}\right]_0^1$$

$$\delta^* = \frac{1}{3}\delta$$

$$\frac{\delta^*}{\delta} = \frac{1}{3}$$

135. (a)

Applying Bernoulli's equation between the two reservoirs, we get

$$12.5 = 0.5\frac{V^2}{2g} + \frac{fLV^2}{2gD} + \frac{V^2}{2g}$$

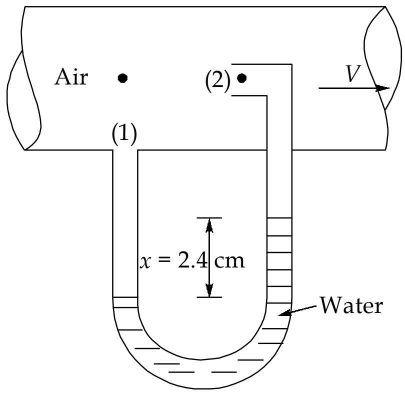
$$\Rightarrow \quad 12.5 = \frac{V^2}{2g}\left[1.5 + \frac{fL}{D}\right]$$

$$\Rightarrow \quad 12.5 = \frac{V^2}{2\times 10}\left[1.5 + \frac{0.04\times 1000}{0.5}\right]$$

$$\Rightarrow \quad 12.5 = \frac{V^2}{20}\times 81.5$$

$$\Rightarrow \quad V = 1.75 \text{ m/s}$$

136. (20.9)(20.8 to 21.0)



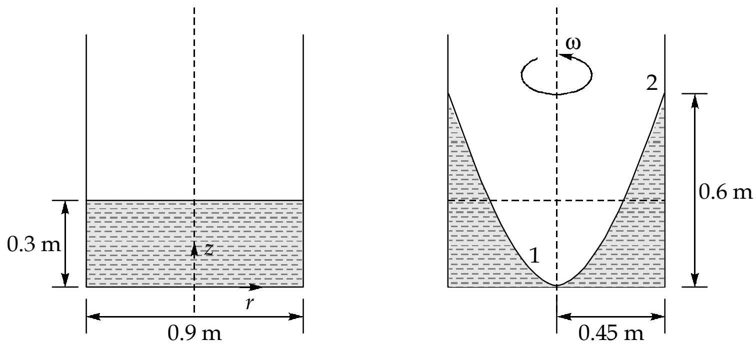
$$\rho_{air} = \frac{P}{RT} = \frac{98}{0.287(27+45)} = 1.0737 \text{ kg/m}^3$$

$$h = x\left(\frac{S_m}{s} - 1\right) = 0.024\left(\frac{1000}{1.0737} - 1\right) = 22.326 \text{ m}$$

So, $$V_1 = \sqrt{2gh} = \sqrt{2(9.81)(22.326)}$$

$$V_1 = 20.9 \text{ m/s}$$

137. (7.624) (7.520 to 7.820)



Initial conditions

Final condition when bottom starts exposing

Apply forced vortex motion equation at points (1) and (2)

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

At point 1, $P_1 = P_{atm} \Rightarrow P_{gauge} = 0$

$V_1 = \omega R_1 = 0$

$z_1 = 0$

At point, $P_2 = P_{atm} \Rightarrow P_{gauge} = 0$

$z_2 = 0.6$

Therefore, $0 - 0 + 0 = 0 - \frac{(\omega R_2)^2}{2g} + 0.6$

$$\Rightarrow \quad \frac{\omega^2 (0.45)^2}{2 \times (9.81)} = 0.6$$

$$\Rightarrow \quad \omega = 7.624 \text{ rad/s}$$

138. (c)

A dimension is a measure of a physical quantity (without numerical values), while a unit is a way to assign a number to that dimension.

139. (d)

$\rho_{water} = 1000 \text{ kg/m}^3$.

Apply the hydrostatic relation from the oil surface to the water surface, skipping the 8 cm part:

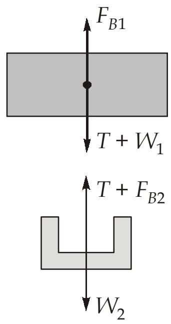
$p_{atm} + (898)(9.81)(h + 0.12) - (1000)(9.81)(0.06 + 0.12) = p_{atm}$

On solving, $h = 0.08$ m

140. (d)

Free body diagram

From ΣF_y



$T = F_{B1} - W_1$

$F_{B1} = \rho g(V)_{submerged}$

$= (9.8 \times 1000)(50 \times 50 \times 7.5)(10^{-9})$

$F_{B1} = 0.18375$ N

$W_1 = \gamma$(Specific gravity of block) × Volume of block

$= (9.8 \times 1000)(0.3)(50 \times 50 \times 10)(10^{-9}) = 0.0735$ N

$T = (0.18375 - 0.0735) = 0.11025$ N

Force equilibrium (vertical direction) applied to metal part:

$F_{B2} = \gamma V_2 = (9800)(6600)(10^{-9})$

$= 0.06468$ N

$W_2 = T + F_{B2} = (0.1102 \text{ N}) + (0.06468 \text{ N})$

Mass of metal part, $m_2 = \frac{W_2}{g} = 0.01785 \text{ kg}$

141. (113.53)(113.50 to 113.59)

$$\overline{Nu} = C\,\text{Re}^m\,\text{Pr}^n$$

$$\bar{h}L \propto (VL)^m$$

$$\frac{h_1 L_1}{h_2 L_2} = \left(\frac{V_1 L_1}{V_2 L_2}\right)^m$$

$$L_1 = L_2 = L$$

$$\therefore \quad \frac{60}{30} = \left(\frac{25}{15}\right)^m$$

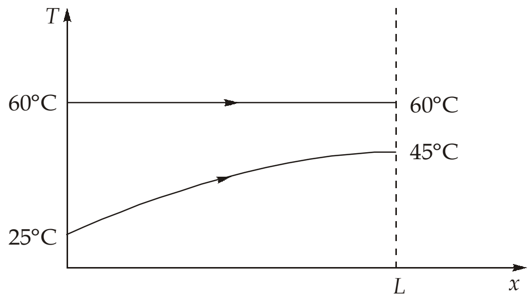
$$\therefore \quad m = 1.3569$$

When $V = 40$ m/s

$$\frac{\bar{h}}{60} = \left(\frac{40}{25}\right)^{1.3569}$$

$$\Rightarrow \quad h = 113.53 \text{ W/m}^2\text{K}$$

142. (c)



$$\Delta T_i = 60 - 25 = 35°\text{C}$$

$$\Delta T_e = 60 - 45 = 15°\text{C}$$

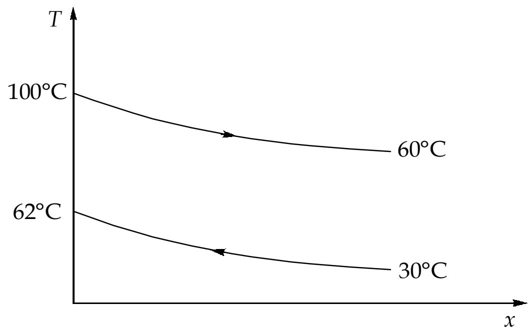
$$\text{LMTD} = \frac{\Delta T_i - \Delta T_e}{\ln\left(\frac{\Delta T_i}{\Delta T_e}\right)} = \frac{35 - 15}{\ln\left(\frac{35}{15}\right)} = 23.60°\text{C}$$

$$q = \text{UA(LMTD)} = \dot{m}_s h_{fg}$$

$$2000 \times 30 \times 23.60 = \dot{m}_s \times 2358 \times 10^3$$

$$\dot{m}_s = 0.6 \text{ kg/s}$$

143. (70.23)(70.12 to 70.32)



$$q = \dot{m}_h c_{ph}\left(T_{h,i} - T_{h,o}\right) = 0.7 \times 2400 \times (100 - 60) = 67200 \text{ W}$$

$$67200 = \dot{m}_c c_{pc}\left(T_{c,o} - T_{c,i}\right)$$

$$= 0.5 \times 4200(T_{c,o} - 30)$$

$$T_{c,o} = 62°\text{C}$$

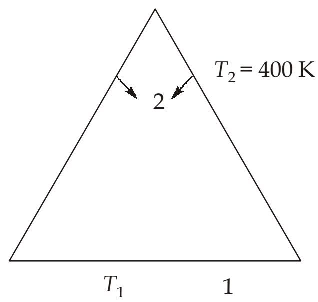
$$\text{LMTD} = \frac{\Delta T_1 - \Delta T_2}{\ln\frac{\Delta T_1}{\Delta T_2}} = \frac{38-30}{\ln\frac{38}{30}} = 33.84°\text{C}$$

$$q = UA(\text{LMTD})$$

$$67200 = 300 \times 33.84 \times \pi(0.03)L$$

$$L = 70.228 \text{ m} \simeq 70.23 \text{ m}$$

144. (466.8)(465 to 467)



$$\dot{q}_{12} = \frac{\sigma\left(T_1^4 - T_2^4\right)}{\frac{1-\epsilon_1}{\epsilon_1 A_1} + \frac{1}{F_{12}A_1} + \frac{1-\epsilon_1}{\epsilon_2 A_2}}$$

$$F_{12} = 1$$

$$A_1 = 1.5 \times 1 = 1.5 \text{ m}^2$$

$$A_2 = 2 \times 1.5 \times 1 = 3 \text{ m}^2$$

$$1000 = \frac{5.67\times10^{-8}\left(T_1^4 - 400^4\right)}{\frac{1-0.9}{1.5\times0.9} + \frac{1}{1.5} + \frac{1-0.4}{3\times0.4}}$$

Solving, $T_1 = 466.8$ K

145. (5)(4.99 to 5.01)

For infinitely long fin,

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

For circular fin, $P = \pi D$

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

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

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

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

146. (6.93)(6.92 to 6.94)

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

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

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

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

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

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

147. (c)

Wall thickness, δ = 10 mm = 0.01 m

As given in question,

Thermal conductivity, $k = ax + b$

Heat flux, $$q'' = -k\frac{dT}{dx}$$

$$q'' = -(ax+b)\frac{dT}{dx}$$

$$\frac{q''}{ax+b}dx = -dT$$

On integrating,

$$q''\int_0^\delta \frac{dx}{ax+b} = -\int_{T_1}^{T_2} dT$$

$$\Rightarrow \quad \frac{q''}{a}[\ln|ax+b|]_0^{\delta} = -(T_2 - T_1)$$

$$\Rightarrow \quad \frac{q''}{a}\ln\left|\frac{a\delta+b}{a\times 0+b}\right| = (T_1 - T_2)$$

$$\Rightarrow \quad \frac{q''}{a}\ln\left|\frac{a\delta+b}{b}\right| = (T_1 - T_2)$$

$$\frac{3.723\times 10^6}{7\times 10^4}\ln\left|\frac{7\times 10^4\times 0.01+200}{200}\right| = (100 - T_2)$$

$$T_2 = 20.0046°\text{C}$$

$$T_2 \simeq 20°\text{C}$$

148. **(b, c)**

The laminar sublayer is a region, next to the wall where viscous force is predominate while the rest of the flow is turbulent.

149. **(a, c, d)**

150. **(c, d)**

In free convection,

$$\text{Nu} = C(Gr\cdot Pr)^{1/4}\text{, for laminar flow}$$

$$\text{Nu} = C(Gr\cdot Pr)^{1/3}\text{, for turbulent flow}$$

■■■■