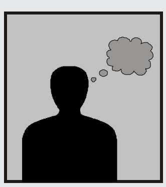
GATE PSUs

State Engg. Exams

MADE EASY WORKBOOK 2024



Detailed Explanations of Try Yourself *Questions*

Chemical Engineering

Fluid Mechanics

MADE EASY PUBLICATIONS

1 Fluid Properties

Detailed Explanation of Try Yourself Questions

T1 : Solution

(74 N/m)

$$P_i - P_o = \frac{2\sigma}{0.25 \times 10^{-3}}$$

$$\sigma = 74 \text{ N/m} = 74 \text{ N/m}$$

T2 : Solution

(5×10^{-3} Ns/m^2)

$$\tau = \mu \frac{du}{dy}$$

$$\frac{0.5}{1} = \mu \times \frac{1}{0.01}$$

$$\mu = 5 \times 10^{-3} \text{ N-s/m}^2$$

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2 Fluid Statics

Detailed Explanation of Try Yourself Questions

T1 : Solution

(283.33) (283 to 284)

$$\rho_o = 760 \text{ mm of Hg}$$

$$= \frac{760}{1000} \times 13.6 \times 1000 \times 9.81 = 101.396 \text{ kN/m}^2$$

Pressure at mountain, P = 735 mm of Hg

$$= \frac{735}{1000} \times 13.6 \times 1000 \times 9.81 = 98.060 \text{ kN/m}^2$$

Let h = Height of the mountain from sea level

$$P = p_o - \rho \times g \times h$$

$$h = \frac{P_o - P}{\rho g} = \frac{101396 - 98060}{1.2 \times 9.81} = 283.33 \text{ m}$$

T2 : Solution

(c)

Absolute = Local + Guage

= 91.52 + 22.48 = 114 kPa

T3 : Solution

(d)

$$H_A + h_A S_A - (h_A - h_B) S_1 + (h_A - h_B) S_3 - h_B S_B = H_B$$

$$H_B - H_A = h_A S_A - (h_A - h_B)(S_1 - S_3) - h_B S_B$$

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3 Fluid Kinematics

Detailed Explanation of Try Yourself Questions

T1 : Solution

(0.4)

$$u = \frac{\theta}{Ax} = \frac{\theta}{(0.5 - 0.2x)}$$

$$\frac{\partial u}{\partial t} = \frac{1}{(0.5-0.2x)} \times \frac{\partial \theta}{\partial t}$$

at (x = 0), $$\frac{\partial u}{\partial t} = \frac{0.2}{0.5} = 0.4 \text{ m/s}^2$$

T2 : Solution

($\phi = 3x^2y - y^3$)

$$\frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} = 0 \text{ [Irrotational]}$$

$$u = -\frac{\partial \psi}{\partial y} \Rightarrow u = 6xy$$

$$\frac{\partial \phi}{\partial x} = 6xy \Rightarrow \phi = 3x^2y \quad \text{...(1)}$$

$$v = \frac{\partial \psi}{\partial y} = 3x^2 - 3y^2 = \frac{\partial \phi}{\partial y}$$

$$\phi = 3x^2y - y^3$$

Hence, [$\phi = 3x^2y - y^3 + c$]

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4 Fluid Dynamics and Flow Measurement

Detailed Explanation of Try Yourself Questions

T1 : Solution

(b)

$$H = U\sin\theta \times t - \frac{1}{2}gt^2$$

$$\frac{dH}{dt} = U\sin\theta - gt \text{ or } t = \frac{U\sin\theta}{g}$$

$$H_{max} = U\sin\theta = \left(\frac{U\sin\theta}{g}\right) - \frac{1}{2}g\left(\frac{U\sin\theta}{g}\right)^2 = 12.4 \text{ m}$$

T2 : Solution

(5.407)

$$L = 2 \text{ m}, V_1 = 5 \text{ m/s}, \frac{P_1}{\rho g} = 2.5 \text{ m of liquid}$$

$$v_2 = 2 \text{ m/s}$$

$$h_L = 0.35\frac{(5-2)^2}{2g} = 0.16 \text{ m}$$

Apply Bernoulli equation,

$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + z_2 + h_L$$

$$2.5 + 1.27 + 2 = \frac{P_2}{\rho g} + 0.203 + 0.16$$

$$\left[\frac{P_2}{\rho g} = 5.407 \text{m of fluid}\right]$$

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5 Flow Through Pipes

Detailed Explanation of Try Yourself Questions

T1 : Solution

(950)

$$\theta_c = \theta_w + \theta_0$$
$$= 0.15 + 0.05 = 0.2 \text{ m}^3/\text{s}$$

$$A_c = \text{Area of pipe } c = \frac{\pi}{4}(0.564)^2$$

Average velocity through, $c = \dfrac{0.2}{\frac{\pi}{4}(0.564)^2} = 0.8$ m/s

Mass flow rate at 'c'

$$\dot{m}_c = \rho_w \theta_w + P_0 \theta_0$$
$$= 1000 \times 0.15 + 0.05 \times 800 = 190 \text{ kg/s}$$
$$\rho_c = \frac{190}{0.2} = 950 \text{ kg/m}^3$$

T2 : Solution

(6.86)

$$\Delta P = \frac{2fL\rho u^2}{D}$$

$$1 \times 10^6 = \frac{2 \times 0.049 \left[\frac{0.6 \times v \times 900}{0.025}\right]^{-0.25} 1000 \times 900 \times v^2}{0.6}$$

$$v = 2.541 \text{ m/s}$$

$$Q = \frac{\pi}{4} D^2 v = \frac{\pi}{4}(0.6)^2 \times 2.541$$

$$= 0.71845 \text{ m}^3/\text{s}$$

Since flow rate is same.

$$\frac{\pi}{4}(0.4)^2 v = 0.71845$$

$\Rightarrow$ $$v = 5.717 \text{ m/s}$$

Again, $$\Delta P = \frac{2(0.079)\text{Re}^{-0.25} L\rho v^2}{D}$$

$$\Delta P = 6.86 \times 10^6 \text{ N/m}^2 = 6.86 \text{ MPa}$$

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6 Laminar and Turbulent Flow

Detailed Explanation of Try Yourself Questions

T1 : Solution

(i) 0.75, (ii) 70.7 mm

$$\frac{u_{max}}{u} = 2, \quad \frac{1.5}{4} = 2$$

$$\bar{u} = 0.75 \text{ m/s}$$

Radius at which $\bar{u}$ occurs

$$u = -\frac{1}{4\mu}\frac{\partial P}{\partial u}\left(R^2 - r^2\right) = \rightarrow$$

$$u = u_{max}\left(1 - \left(\frac{r}{R}\right)^2\right)$$

Solving $\quad r = 0.0707 \text{ m} = 70.7 \text{ mm}$

T2 : Solution

(32.588)

$$h_f = \frac{32\mu\bar{u}L}{\rho g D^2}$$

$$\text{Power required} = W \times h_f$$

$$w = \text{Weight of oil flowing per sec}$$

$$= \text{Density} \times g \times Q$$

$$\text{Power required} = \rho g \times Q \times \frac{32\mu\bar{v}l}{\rho g D^2}$$

$$\therefore \quad \bar{u} = \frac{Q}{\text{Area}} = \frac{0.01\times 4}{\pi(0.1)^2} = 1.273$$

$$\text{Power} = \frac{0.01\times 32\times 0.8\times 1.273\times 1000}{0.1^2} = 32.588 \text{ kW}$$

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7 Dimensional Analysis and Boundary Layer Theory

Detailed Explanation of Try Yourself Questions

T1 : Solution

(20000)

$$\text{Ratio} = \frac{\rho_m}{\rho_p} \times \frac{L_m^2}{L_p^2} \times \frac{V_m^2}{V^2}$$

$$\frac{F_M}{F_p} = 1 \times \left(\frac{1}{10}\right)^2 \left(\frac{5}{10}\right)^2$$

$$\frac{50}{F_P} = \frac{1}{100 \times 4}$$

$$F_P = 50 \times 400 = 20000 \text{ N}$$

T2 : Solution

(0.5)

As $\delta \propto \frac{1}{\text{Re}_x^{1/2}}$ for laminar, flow

and $$\text{Re}_x = \frac{Vx}{\nu} = \frac{v \cdot x}{\nu}$$

$\text{Re}_x \propto$ velocity

$$\frac{\delta_1}{\delta_2} = \sqrt{\frac{\text{Re}_2}{\text{Re}_1}}$$

$$\Rightarrow \quad \frac{1 \times 10^{-3}}{\delta_2} = \sqrt{\frac{4000}{1000}}$$

$$\delta_2 = \frac{1 \times 10^{-3}}{2} = 0.5 \times 10^{-3} \text{ m} = 0.5 \text{ mm}$$

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8 Forces on Sub-Merged Bodies

Detailed Explanation of Try Yourself Questions

T1 : Solution

(0.081) mm

As in stokes law regime

$$v_t = \frac{dp^2(\rho_p - \rho_f)g}{18\mu_f} \quad ...(i)$$

$$Re = 1 = \frac{\rho v d}{\mu}, \; v = \frac{\mu}{\rho d} \quad ...(ii)$$

Putting (ii) in (i)

$$\frac{\mu_{air}}{\rho_{air} d} = \frac{dp(\rho_w - \rho_{air})g}{18\mu_{air}}$$

$$\mu_a = 1.5 \times 10^{-8} \times 1.3$$

$$d_p^3 = \frac{18\mu_{air}^2}{\mu_{air}(\rho_w - \rho_a)g}$$

$$d_p^3 = \frac{18 \times (1.5 \times 1.3 \times 10^{-5})^2}{1.3(1000 - 1.3)9.81}$$

$\Rightarrow$ $$d_p = 0.0813 \text{ mm}$$

T2 : Solution

(865) (864 to 866)

Let total volume of body is v,

Balancing forces, we get

$$700(0.45\,v)g + 1000(0.55\,v)g = \rho_b \times v \times g$$

$$\rho_b = 865 \text{ kg/m}^3$$

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9 Pump and Compressors

Detailed Explanation of Try Yourself Questions

T1 : Solution

(b)

Given,

$$l = 4 \text{ km} = 4000 \text{ m}$$
$$d = 0.2 \text{ m}$$
$$f = 0.01$$
$$V = 2 \text{ m/s}$$
$$h = 5 \text{ m}$$

$$h_f = \frac{flV^2}{2gd} = \frac{0.01 \times 4000 \times (2)^2}{2 \times 9.81 \times 0.2} = 40.77 \text{ m}$$

Head produced by the pump,

$$H = h + h_f$$
$$= 5 + 40.77 = 45.77 \text{ m of water}$$

Absolute discharge pressure at the pump exit

$$p_{abs} = \rho g H + p_{atm}$$
$$= 1000 \times 9.81 \times 45.77 + 101325$$
$$= 5.503 \times 105 \text{ Pa} = 5.503 \text{ bar}$$

T2 : Solution

(40)

$$Q = 4 \times 10^{-3} \text{ m}^3\text{/s}$$

(Power = $\rho_g \times h_p \times Q$)

$$1.6 \times 10^3 = 1000 \times 10 \times h_p \times 4 \times 10^{-3}$$
$$h_p = 40 \text{ m}$$

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