FM 题解（部分）

Chapter 1

P1. 1

1.1 A gas at 20°C may be *rarefied* if it contains less than 10^{12} molecules per mm^3. If Avogadro's number is 6.023E23 molecules per mole, what air pressure does this represent?

Solution: The mass of one molecule of air may be computed as

$$m = \frac{\text{Molecular weight}}{\text{Avogadro's number}} = \frac{28.97\ \text{mol}^{-1}}{6.023\text{E}23\ \text{molecules/g}\cdot\text{mol}} = 4.81\text{E–}23\ \text{g}$$

Then the density of air containing 10^{12} molecules per mm^3 is, in SI units,

$$\rho = \left(10^{12}\ \frac{\text{molecules}}{\text{mm}^3}\right)\left(4.81\text{E–}23\ \frac{\text{g}}{\text{molecule}}\right)$$
$$= 4.81\text{E–}11\ \frac{\text{g}}{\text{mm}^3} = 4.81\text{E–}5\ \frac{\text{kg}}{\text{m}^3}$$

Finally, from the perfect gas law, Eq. (1.13), at 20°C = 293 K, we obtain the pressure:

$$p = \rho RT = \left(4.81\text{E–}5\ \frac{\text{kg}}{\text{m}^3}\right)\left(287\ \frac{\text{m}^2}{\text{s}^2\cdot\text{K}}\right)(293\ \text{K}) = \mathbf{4.0\ Pa} \quad \textit{Ans.}$$

P1.12

1.12 For low-speed (laminar) flow in a tube of radius r_o, the velocity u takes the form

$$u = B\frac{\Delta p}{\mu}\left(r_o^2 - r^2\right)$$

where μ is viscosity and Δp the pressure drop. What are the dimensions of B?

Solution: Using Table 1-2, write this equation in dimensional form:

$$\{u\} = \{B\}\frac{\{\Delta p\}}{\{\mu\}}\{r^2\}, \quad \text{or:} \quad \left\{\frac{L}{T}\right\} = \{B?\}\frac{\{M/LT^2\}}{\{M/LT\}}\{L^2\} = \{B?\}\left\{\frac{L^2}{T}\right\},$$

$$\text{or:} \quad \mathbf{\{B\} = \{L^{-1}\}} \quad \textit{Ans.}$$

P1.55

P1.55 A block of weight W is being pulled over a table by another weight W_o, as shown in Fig. P1.55. Find an algebraic formula for the steady velocity U of the block if it slides on an oil film of thickness h and viscosity μ. The block bottom area A is in contact with the oil. Neglect the cord weight and the pulley friction.

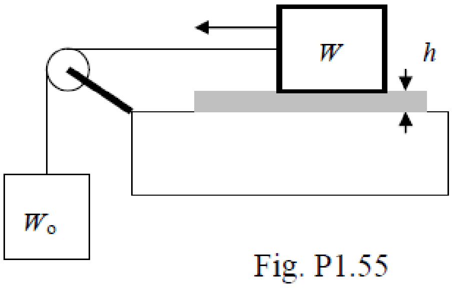


Fig. P1.55

Solution: This problem is a lot easier to *solve* than to set up and sketch. For steady motion,

$$\sum F_{x,block} = 0 = \tau A - W_o = (\mu \frac{U}{h})A - W_o$$

$$\text{Solve for} \quad U = \frac{W_o h}{\mu A} \qquad \textit{Ans.}$$

there is no acceleration, and the falling weight balances the viscous resistance of the oil film: The block weight W has no effect on steady horizontal motion except to smush the oil film.

P1.82

1.82 A velocity field is given by u = V cosθ, v = V sinθ, and w = 0, where V and θ are constants. Find an expression for the streamlines of this flow.

Solution: Equation (1.44) may be used to find the streamlines:

$$\frac{dx}{u} = \frac{dy}{v} = \frac{dx}{V\cos\theta} = \frac{dy}{V\sin\theta}, \quad \text{or:} \quad \frac{dy}{dx} = \tan\theta$$

$$\text{Solution:} \quad y = (\tan\theta)\,x + constant \quad \textit{Ans.}$$

The streamlines are straight parallel lines which make an angle θ with the x axis. In other words, this velocity field represents a *uniform stream V moving upward at angle θ.*

FE1.1 (b)

FE1.4 (b)

FE1.7(a)

Chapter 2

FE2.1 (d)

FE2.2 (b)

FE2.3 (c)

FE2.4 (d)

FE2.5 (d)

FE2.6 (e)

FE2.7(d)

FE2.8(d)

FE2.9(c)

FE2.10(e)

P2.6

2.6 Express standard atmospheric pressure as a head, $h = p/\rho g$, in (a) feet of glycerin; (b) inches of mercury; (c) meters of water; and (d) mm of ethanol.

Solution: Take the specific weights, $\gamma = \rho g$, from Table A.3, divide p_{atm} by γ:

(a) Glycerin: $h = (2116\ \text{lbf/ft}^2)/(78.7\ \text{lbf/ft}^3) \approx$ **26.9 ft** *Ans.* (a)

(b) Mercury: $h = (2116\ \text{lbf/ft}^2)/(846\ \text{lbf/ft}^3) = 2.50\ \text{ft} \approx$ **30.0 inches** *Ans.* (b)

(c) Water: $h = (101350\ \text{N/m}^2)/(9790\ \text{N/m}^3) \approx$ **10.35 m** *Ans.* (c)

(d) Ethanol: $h = (101350\ \text{N/m}^2)/(7740\ \text{N/m}^3) = 13.1\ \text{m} \approx$ **13100 mm** *Ans.* (d)

P2.12

2.12 In Fig. P2.12 the tank contains water and immiscible oil at 20°C. What is h in centimeters if the density of the oil is 898 kg/m^3?

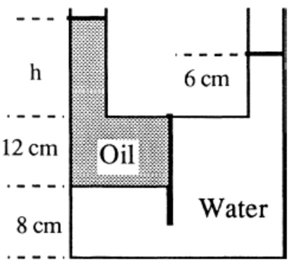


Fig. P2.12

Solution: For water take the density = 998 kg/m^3. Apply the hydrostatic relation from the oil surface to the water surface, skipping the 8-cm part:

$$p_{atm} + (898)(g)(h + 0.12) - (998)(g)(0.06 + 0.12) = p_{atm},$$

Solve for $h \approx 0.08\ \text{m} \approx$ **8.0 cm** *Ans.*

P2.16

P2.16 If the absolute pressure at the interface between water and mercury in Fig. P2.16 is 93 kPa, what, in lbf/ft^2, is (*a*) the pressure at the surface, and (*b*) the pressure at the bottom of the container?

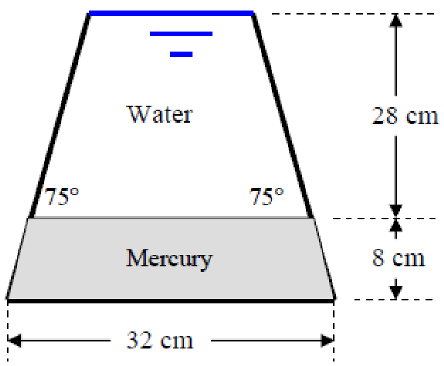


Fig. P2.16

Solution: Do the whole problem in SI units and then convert to BG at the end. The bottom width and the slanted 75-degree walls are irrelevant red herrings. Just go up and down:

$$p_{surface} = p_{interface} - \gamma_{water}\,\Delta h = 93000\,Pa - (9790\,N/m^3)(0.28m) =$$

$$= 90260\,Pa \div 47.88 = \mathbf{1885}\ lbf/ft^2 \quad Ans.(a)$$

$$p_{bottom} = p_{interface} + \gamma_{mercury}\,\Delta h = 93000\,Pa + (133100\,N/m^3)(0.08m) =$$

$$= 103650\,Pa \div 47.88 = \mathbf{2165}\ lbf/ft^2 \quad Ans.(b)$$

P2.17

2.17 All fluids in Fig. P2.17 are at 20°C. If p = 1900 psf at point A, determine the pressures at B, C, and D in psf.

Solution: Using a specific weight of 62.4 lbf/ft^3 for water, we first compute p_B and p_D:

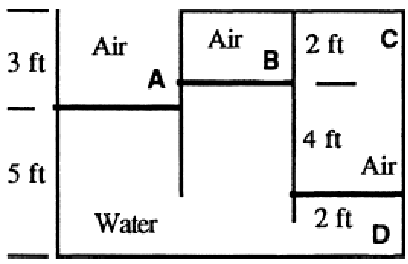


Fig. P2.17

$$p_B = p_A - \gamma_{water}(z_B - z_A) = 1900 - 62.4(1.0\text{ ft}) = \mathbf{1838\ lbf/ft^2} \quad Ans.\text{ (pt. B)}$$

$$p_D = p_A + \gamma_{water}(z_A - z_D) = 1900 + 62.4(5.0\text{ ft}) = \mathbf{2212\ lbf/ft^2} \quad Ans.\text{ (pt. D)}$$

Finally, moving up from D to C, we can neglect the air specific weight to good accuracy:

$$p_C = p_D - \gamma_{water}(z_C - z_D) = 2212 - 62.4(2.0\text{ ft}) = \mathbf{2087\ lbf/ft^2} \quad Ans.\text{ (pt. C)}$$

The air near C has $\gamma \approx 0.074$ lbf/ft^3 times 6 ft yields less than 0.5 psf correction at C.

P2.20

2.20 The hydraulic jack in Fig. P2.20 is filled with oil at 56 lbf/ft^3. Neglecting piston weights, what force F on the handle is required to support the 2000-lbf weight shown?

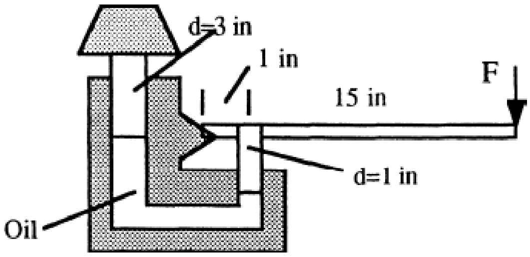


Fig. P2.20

Solution: First sum moments clockwise about the hinge A of the handle:

$$\Sigma M_A = 0 = F(15+1) - P(1),$$

or: F = P/16, where P is the force in the small (1 in) piston.

Meanwhile figure the pressure in the oil from the weight on the large piston:

$$p_{oil} = \frac{W}{A_{3\text{-in}}} = \frac{2000 \text{ lbf}}{(\pi/4)(3/12 \text{ ft})^2} = 40744 \text{ psf},$$

$$\text{Hence} \quad P = p_{oil}A_{small} = (40744)\frac{\pi}{4}\left(\frac{1}{12}\right)^2 = 222 \text{ lbf}$$

Therefore the handle force required is $F = P/16 = 222/16 \approx \mathbf{14\ lbf}$ *Ans.*

P2.21

2.21 In Fig. P2.21 all fluids are at 20°C. Gage A reads 350 kPa absolute. Determine (a) the height h in cm; and (b) the reading of gage B in kPa absolute.

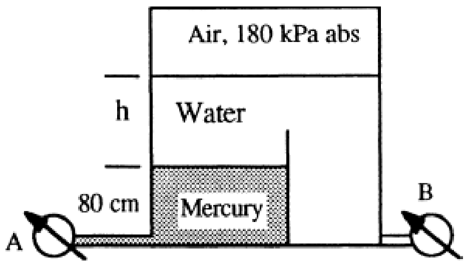


Fig. P2.21

Solution: Apply the hydrostatic formula from the air to gage A:

$$p_A = p_{air} + \Sigma\gamma h$$

$$= 180000 + (9790)h + 133100(0.8) = 350000 \text{ Pa},$$

Solve for $h \approx \mathbf{6.49\ m}$ *Ans.* (a)

Then, with *h* known, we can evaluate the pressure at gage B:

$$p_B = 180000 + 9790(6.49 + 0.80) = 251000 \text{ Pa} \approx \mathbf{251\ kPa} \quad \textit{Ans. (b)}$$

P2.31

2.31 In Fig. P2.31 determine Δp between points A and B. All fluids are at 20°C.

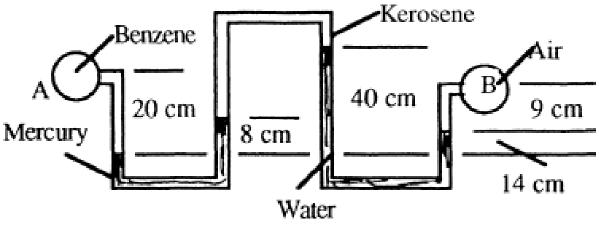


Fig. P2.31

Solution: Take the specific weights to be

Benzene: 8640 N/m^3 Mercury: 133100 N/m^3

Kerosene: 7885 N/m^3 Water: 9790 N/m^3

and γ_{air} will be small, probably around 12 N/m^3. Work your way around from A to B:

$$p_A + (8640)(0.20\text{ m}) - (133100)(0.08) - (7885)(0.32) + (9790)(0.26) - (12)(0.09)$$
$$= p_B, \quad \text{or, after cleaning up,} \quad p_A - p_B \approx \mathbf{8900\ Pa} \quad \textit{Ans.}$$

P2.44

2.44 Water flows downward in a pipe at 45°, as shown in Fig. P2.44. The mercury manometer reads a 6-in height. The pressure drop p2 − p1 is partly due to friction and partly due to gravity. Determine the total pressure drop and also the part due to friction only. Which part does the manometer read? Why?

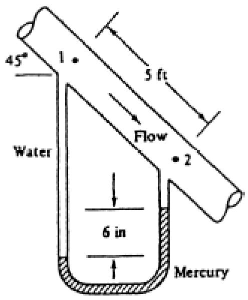


Fig. P2.44

Solution: Let "h" be the distance down from point 2 to the mercury-water interface in the right leg. Write the hydrostatic formula from 1 to 2:

$$p_1 + 62.4\left(5\sin 45° + h + \frac{6}{12}\right) - 846\left(\frac{6}{12}\right) - 62.4h = p_2,$$

$$p_1 - p_2 = \underbrace{(846 - 62.4)(6/12)}_{\text{friction loss}} - \underbrace{62.4(5\sin 45°)}_{\text{gravity head}} = 392 - 221$$

$$= \mathbf{171\,\frac{lbf}{ft^2}} \quad \textit{Ans.}$$

The manometer reads only the <u>*friction loss*</u> of 392 lbf/ft^2, not the gravity head of 221 psf.

P2.48

P2.48 The system in Fig. P2.49 is open to 1 atm on the right side.

(*a*) If $L = 120$ cm, what is the air pressure in container A?

(*b*) Conversely, if $p_A = 135$ kPa, what is the length L?

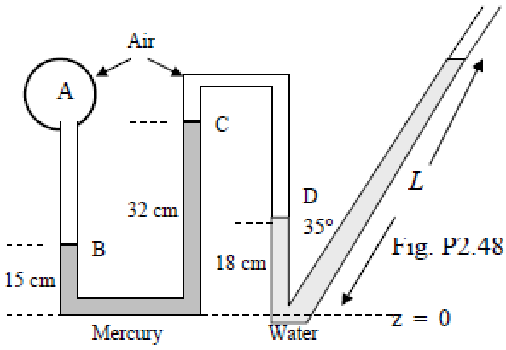


Fig. P2.48

Solution: (*a*) The vertical elevation of the water surface in the slanted tube is (1.2m)(sin55°) = 0.983 m. Then the pressure at the 18-cm level of the water, point D, is

$$p_D = p_{atm} + \gamma_{water}\,\Delta z = 101350\,Pa + (9790\frac{N}{m^3})(0.983 - 0.18m) = 109200\,Pa$$

Going up from D to C in air is negligible, less than 2 Pa. Thus $p_C \approx p_D = 109200$ Pa. Going down from point C to the level of point B increases the pressure in mercury:

$$p_B = p_C + \gamma_{mercury}\,\Delta z_{C-B} = 109200 + (133100\frac{N}{m^3})(0.32 - 0.15m) = \mathbf{131800\,Pa}\quad Ans.(a)$$

This is the answer, since again it is negligible to go up to point A in low-density air.
(*b*) Given $p_A = 135$ kPa, go down from point A to point B with negligible air-pressure change, then jump across the mercury U-tube and go up to point C with a decrease:

$$p_C = p_B - \gamma_{mercury}\Delta z_{B-C} = 135000 - (133100)(0.32 - 0.15) = 112400\,Pa$$

Once again, $p_C \approx p_D \approx 112400$ Pa, jump across the water and then go up to the surface:

$$p_{atm} = p_D - \gamma_{water}\,\Delta z = 112400 - 9790(z_{surface} - 0.18m) = 101350Pa$$

Solve for $z_{surface} \approx 1.306m$

Then the slanted distance $L = 1.306m/\sin 55^\circ = \mathbf{1.594\,m}$ *Ans.(b)*

P2.63

2.63 The tank in Fig. P2.63 has a 4-cm-diameter plug which will pop out if the hydrostatic force on it reaches 25 N. For 20°C fluids, what will be the reading h on the manometer when this happens?

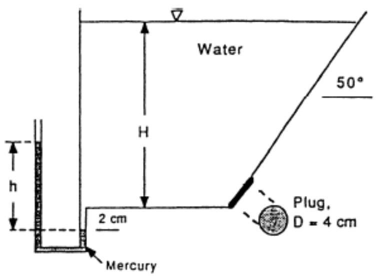


Fig. P2.63

Solution: The water depth when the plug pops out is

$$F = 25\text{ N} = \gamma h_{CG} A = (9790)h_{CG}\frac{\pi(0.04)^2}{4}$$

or $h_{CG} = 2.032$ m

It makes little numerical difference, but the mercury-water interface is a little deeper than this, by the amount (0.02 sin 50°) of plug-depth, plus 2 cm of tube length. Thus

$$p_{atm} + (9790)(2.032 + 0.02\sin 50° + 0.02) - (133100)h = p_{atm},$$

$$\text{or:}\quad h \approx \mathbf{0.152\ m}\quad Ans.$$

P2.68

2.68 Isosceles triangle gate AB in Fig. P2.68 is hinged at A and weighs 1500 N. What horizontal force P is required at point B for equilibrium?

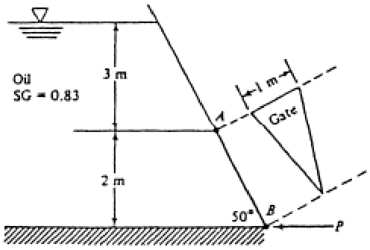
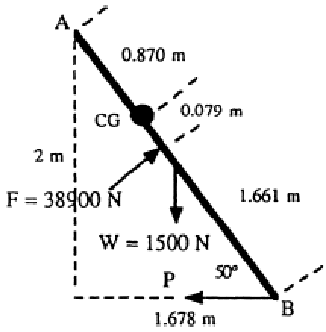


Fig. P2.68

Solution: The gate is 2.0/sin 50° = 2.611 m long from A to B and its area is 1.3054 m^2. Its centroid is 1/3 of the way down from A, so the centroidal depth is 3.0 + 0.667 m. The force on the gate is

$$F = \gamma h_{CG} A = (0.83)(9790)(3.667)(1.3054)$$
$$= 38894 \text{ N}$$

The position of this force is below the centroid:



$$y_{CP} = -\frac{I_{xx}\sin\theta}{h_{CG}A}$$

$$= -\frac{(1/36)(1.0)(2.611)^3 \sin 50^\circ}{(3.667)(1.3054)} = -0.0791 \text{ m}$$

The force and its position are shown in the freebody at upper right. The gate weight of 1500 N is assumed at the centroid of the plate, with moment arm 0.559 meters about point A. Summing moments about point A gives the required force P:

$$\Sigma M_A = 0 = P(2.0) + 1500(0.559) - 38894(0.870 + 0.0791),$$

Solve for $P = \mathbf{18040\ N}$ *Ans.*