Applied Fluid Mechanics 6th Edition Solutions

Solution: (a) Convert 2 miles = 3219 m and use a linear-pressure-variation estimate:

Then $p = p_a + \gamma h = 101{,}350\ \text{Pa} + (12\ \text{N/m}^3)(3219\ \text{m}) = 140{,}000\ \text{Pa} = \mathbf{140\ kPa}$ *Ans.* (a)

Alternately, the troposphere formula, Eq. (2.27), predicts a slightly higher pressure:

$$p = p_a(1 - Bz/T_o)^{5.26} = (101.3\ \text{kPa})[1 - (0.0065\ \text{K/m})(-3219\ \text{m})/288.16\ \text{K}]^{5.26}$$
$$= \mathbf{147\ kPa} \quad \textit{Ans. (a)}$$

(b) The gage pressure at this depth is approximately 40,000/133,100 = 0.3 m Hg or 300 mm Hg ±1 mm Hg or ±0.3% error. Thus the error in the actual depth is 0.3% of 3220 m or about **±10 m** if all other parameters are accurate. *Ans.* (b)

2.9 Integrate the hydrostatic relation by assuming that the isentropic bulk modulus, $B = \rho(\partial p/\partial \rho)_s$, is constant. Apply your result to the Mariana Trench, Prob. 2.7.

Solution: Begin with Eq. (2.18) written in terms of B:

$$dp = -\rho g\,dz = \frac{B}{\rho}d\rho, \quad \text{or:} \quad \int_{\rho_o}^{\rho}\frac{d\rho}{\rho^2} = -\frac{g}{B}\int_0^z dz = -\frac{1}{\rho} + \frac{1}{\rho_o} = -\frac{gz}{B}, \text{ also integrate:}$$

$$\int_{p_o}^{p} dp = B\int_{\rho_o}^{\rho}\frac{d\rho}{\rho} \quad \text{to obtain } p - p_o = B\ln(\rho/\rho_o)$$

Eliminate ρ between these two formulas to obtain the desired pressure-depth relation:

$$\mathbf{p = p_o - B\ln\left(1 + \frac{g\rho_o z}{B}\right)} \quad \textit{Ans. (a)} \quad \text{With } B_{seawater} = 2.33E9\ \text{Pa from Table A.3,}$$

$$p_{Trench} = 101350 - (2.33E9)\ln\left[1 + \frac{(9.81)(1025)(-11034)}{2.33E9}\right]$$
$$= 1.138E8\ \text{Pa} = \mathbf{1123\ atm} \quad \textit{Ans. (b)}$$

2.10 A closed tank contains 1.5 m of SAE 30 oil, 1 m of water, 20 cm of mercury, and an air space on top, all at 20°C. If p_{bottom} = 60 kPa, what is the pressure in the air space?

Solution: Apply the hydrostatic formula down through the three layers of fluid:

$$p_{bottom} = p_{air} + \gamma_{oil}h_{oil} + \gamma_{water}h_{water} + \gamma_{mercury}h_{mercury}$$

$$\text{or:} \quad 60000\ \text{Pa} = p_{air} + (8720\ \text{N/m}^3)(1.5\ \text{m}) + (9790)(1.0\ \text{m}) + (133100)(0.2\ \text{m})$$

Solve for the pressure in the air space: $p_{air} = \mathbf{10500\ Pa}$ *Ans.*

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