Fluid Statics

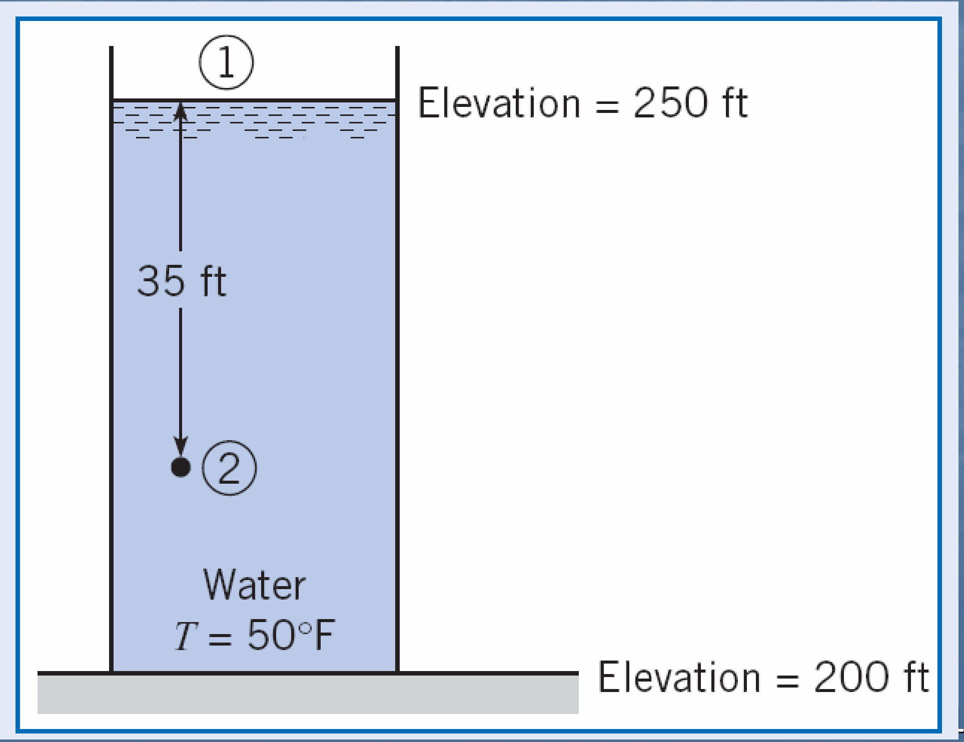
The pressure difference between two points with a given fluid can be given as

$$p_2 - p_1 = \gamma(z_1 - z_2) \quad OR \quad \Delta p = -\gamma \Delta z$$

For illustration consider Figure below

Find Gauge Pressure at (2)

$$p_2 - p_1 = -\gamma(z_2 - z_1)$$
$$p_2 = -\rho g(-35)$$
$$p_2 = 62.4 \times 35 = 2180\ psfg = 15.2\ psi$$



Fluid Statics

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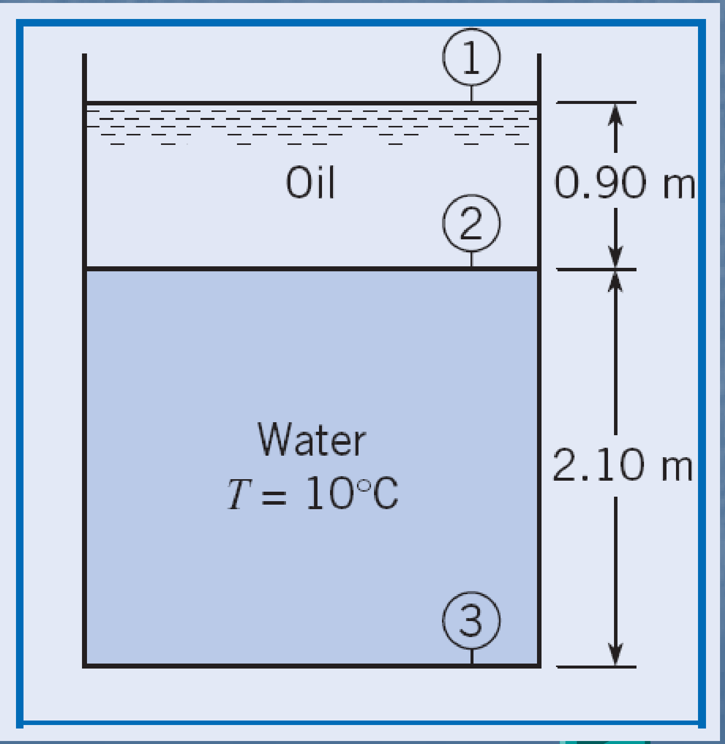
For illustration consider Figure below

$$S_{oil} = 0.8$$

Calculate P(gauge) at bottom

Of tank?



PRESSURE VARIATION WITH COMPRESSIBLE FLUID

FROM IDEAL GAS EQUATION

$$p = \rho RT \quad OR \quad \rho = \frac{p}{RT}$$

$$\rho g = \frac{pg}{RT} = \gamma = -\frac{dp}{dz}$$

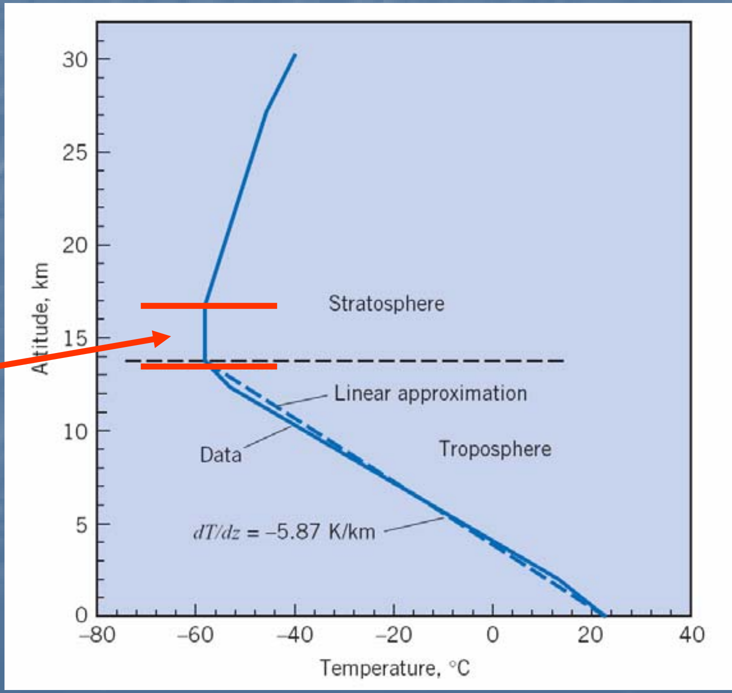
From Eqn. above, it can be deduced that for the same gas, pressure varies with temperature as well as elevation.

a. Troposphere region (0-13.7 km)

b. Stratosphere region (>13.7 km)

(T is nearly constant (13.7 – 16.8 km)

(45000 ft-55000 ft)



Temperature variation with altitude for the U.S.A standard atmosphere in July

Fluid Statics

Pressure variation in the *Troposphere region*

$$T = T_0 - \alpha(z - z_0)$$

Where T_0 **is a reference temperature**

α **is the lapse rate = -5.87 K/Km**

$$\frac{dp}{dz} = \frac{pg}{R[T_0 - \alpha(z - z_0)]}$$

$$\int \frac{dp}{p} = \int \frac{g}{R[T_0 - \alpha(z - z_0)]} dz$$

$$\frac{p}{p_0} = \left[\frac{T_0 - \alpha(z - z_0)}{T_0}\right]^{g/\alpha R}$$

Example (3.5) is an illustration

Example (3.5)

If at sea level the absolute pressure and temperature are 101.3 kPa and 23°C, what is pressure at an elevation of 2000 m, assuming that standard atmospheric conditions prev

Solution Use the equation for atmospheric pressure variation:

$$p = p_0\left[\frac{T_0 - \alpha(z - z_0)}{T_0}\right]^{g/\alpha R}$$

where $p_0 = 101{,}300\ \text{N/m}^2$, $T_0 = 273 + 23 = 296\ \text{K}$, $\alpha = 5.87 \times 10^{-3}\ \text{K/m}$, $z - z_0 =$ 2000 m, and $g/\alpha R = 5.823$. Then

$$p = 101.3\left(\frac{296 - 5.87 \times 10^{-3} \times 2000}{296}\right)^{5.823} = 80.0\ \text{kPa}$$

Fluid Statics

Pressure variation in the Stratosphere region

The temperature (T) can be assumed constant.

$$\frac{pg}{RT} = -\frac{dp}{dz}$$

$$\int \frac{dp}{p} = -\int \frac{g}{RT} dz$$

$$In\ p = -\frac{gz}{RT} + C$$

$$\frac{p}{p_0} = e^{-(z-z_0)g/RT}$$

Example (3.6) is an illustration

Example (3.6)

If the pressure and temperature are 2.31 psia (p = 15.9 kPa absolute) and –71.5°F (–57.5°C) at an elevation of 45,000 ft (13.72 km), what is the pressure at 55,000 ft (16.77 km), assuming isothermal conditions over this range of elevation?

Solution For isothermal conditions,

$$T = -71.5 + 460 = 388.5\text{°R}$$

$$p = p_0 e^{-(z-z_0)g/RT} = 2.31e^{-(10{,}000)(32.2)/(1716 \times 388.5)} = 2.31e^{-0.483}$$

Therefore the pressure at 55,000 ft is

$$p = 1.43 \text{ psia} \quad \triangleleft$$

SI units $p = 9.82$ kPa absolute ◁

END OF LECTURE (3)