# Homework #1

MEMS 0071 - Introduction to Fluid Mechanics

Assigned: August 30$^{\text{th}}$, 2019
Due: September 6$^{\text{th}}$, 2019

## Problem #1

You are scuba diving in great lakes, which are freshwater lakes ($\rho$=998 [kg/m$^3$]). Determine the pressure at the following depths:
It is noted that each lake is assumed to exists at sea level, i.e. $P_{atm}$=101.325 [kPa]. In actuality, this is not true, however, the contribution of atmospheric pressure to the total hydrostatic pressure is so minimal that it does not matter. Also, recall a Pascal, [Pa], is a [kg/m-s$^2$].

a) At the maximum depth of Lake Erie, 64 [m]

$$P_{btm} = P_{atm} + \rho g h = (101.325\,[\text{kPa}]) + \left(998\left[\frac{\text{kg}}{\text{m}^3}\right]\right)\left(9.81\left[\frac{\text{m}}{\text{s}^2}\right]\right)(64\,[\text{m}])\left(\frac{1\,[\text{kPa}]}{1,000\,[\text{kg/m-s}^2]}\right)$$
$$= 727.9\,[\text{kPa}]$$

b) At the maximum depth of Lake Huron, 229 [m]

$$P_{btm} = P_{atm} + \rho g h = (101.325\,[\text{kPa}]) + \left(998\left[\frac{\text{kg}}{\text{m}^3}\right]\right)\left(9.81\left[\frac{\text{m}}{\text{s}^2}\right]\right)(229\,[\text{m}])\left(\frac{1\,[\text{kPa}]}{1,000\,[\text{kg/m-s}^2]}\right)$$
$$= 2,342.3\,[\text{kPa}]$$

c) At the maximum depth of Lake Ontario, 244 [m]

$$P_{btm} = P_{atm} + \rho g h = (101.325\,[\text{kPa}]) + \left(998\left[\frac{\text{kg}}{\text{m}^3}\right]\right)\left(9.81\left[\frac{\text{m}}{\text{s}^2}\right]\right)(244\,[\text{m}])\left(\frac{1\,[\text{kPa}]}{1,000\,[\text{kg/m-s}^2]}\right)$$
$$= 2,490.2\,[\text{kPa}]$$

d) At the maximum depth of Lake Michigan, 302 [m]

$$P_{btm} = P_{atm} + \rho g h = (101.325\,[\text{kPa}]) + \left(998\left[\frac{\text{kg}}{\text{m}^3}\right]\right)\left(9.81\left[\frac{\text{m}}{\text{s}^2}\right]\right)(302\,[\text{m}])\left(\frac{1\,[\text{kPa}]}{1,000\,[\text{kg/m-s}^2]}\right)$$
$$= 3,058.0\,[\text{kPa}]$$

e) At the maximum depth of Lake Superior, 406 [m]

$$P_{btm} = P_{atm} + \rho g h = (101.325\,[\text{kPa}]) + \left(998\left[\frac{\text{kg}}{\text{m}^3}\right]\right)\left(9.81\left[\frac{\text{m}}{\text{s}^2}\right]\right)(406\,[\text{m}])\left(\frac{1\,[\text{kPa}]}{1,000\,[\text{kg/m-s}^2]}\right)$$
$$= 4,076.2\,[\text{kPa}]$$

## Problem #2

You are flying a single-engine, non-pressurized cabin Cessna 172. Determine the atmospheric pressures, in [kPa], at the following elevations above sea level (ASL), assuming the temperature of air does not change with changing elevation

a) 5,000 [ft] ASL

$$P_{btm} = P_{atm} - \rho g h = (101.325\,[\text{kPa}]) - \left(1.225\left[\frac{\text{kg}}{\text{m}^3}\right]\right)\left(9.81\left[\frac{\text{m}}{\text{s}^2}\right]\right)(1,524\,[\text{m}])\left(\frac{1\,[\text{kPa}]}{1,000\,[\text{kg/m-s}^2]}\right)$$
$$= 83.0\,[\text{kPa}]$$

b) 10,000 [ft] ASL

$$P_{btm} = P_{atm} - \rho g h = (101.325\,[\text{kPa}]) - \left(1.225\left[\frac{\text{kg}}{\text{m}^3}\right]\right)\left(9.81\left[\frac{\text{m}}{\text{s}^2}\right]\right)(3,048\,[\text{m}])\left(\frac{1\,[\text{kPa}]}{1,000\,[\text{kg/m-s}^2]}\right)$$
$$= 64.7\,[\text{kPa}]$$

c) 12,000 [ft] ASL

$$P_{btm} = P_{atm} - \rho g h = (101.325\,[\text{kPa}]) - \left(1.225\left[\frac{\text{kg}}{\text{m}^3}\right]\right)\left(9.81\left[\frac{\text{m}}{\text{s}^2}\right]\right)(3,657.6\,[\text{m}])\left(\frac{1\,[\text{kPa}]}{1,000\,[\text{kg/m-s}^2]}\right)$$
$$= 57.4\,[\text{kPa}]$$

## Problem #3

Imagine you are in a submarine exploring the Mariana Trench, which is 10,994 [m] below sea level.

a) What is the pressure outside the submarine?
Assuming the water is sea water, $\rho$=1,027 [kg/m$^3$],

$$P_{btm} = P_{atm} + \rho g h = (101.325\,[\text{kPa}]) + \left(1,027\left[\frac{\text{kg}}{\text{m}^3}\right]\right)\left(9.81\left[\frac{\text{m}}{\text{s}^2}\right]\right)(10,944\,[\text{m}])\left(\frac{1\,[\text{kPa}]}{1,000\,[\text{kg/m-s}^2]}\right)$$
$$= 110,864.4\,[\text{kPa}] \approx 16,080\,[\text{psi}]$$

b) What is the pressure inside the submarine?
The pressure inside the submarine is *not* the pressure outside the submarine unless 1.) the submarine's structure has failed and it has collapsed in upon itself or 2.) the submarine's structure has failed and it has flooded. The pressure inside the submarine is that of atmosphere at sea level, assuming the pressure inside the submarine was atmospheric at the beginning of the descent and that the volume of the submarine did not change during the descent.

## Problem #4

Determine the following material properties:

a) The specific gravity, SG, or mercury ($\rho$=13,600 [kg/m$^3$])

$$\text{SG}_{\text{Hg}} = \frac{\rho_{\text{Hg}}}{\rho_{\text{H}_2\text{O}|_{4^\circ\text{C}}}} = \frac{13,600\,[\text{kg/m}^3]}{1,000\,[\text{kg/m}^3]} = 13.6$$

b) The specific gravity of air at STP

$$\text{SG}_{\text{air}} = \frac{\rho_{\text{air}}}{\rho_{\text{H}_2\text{O}|_{4^\circ\text{C}}}} = \frac{1.225\,[\text{kg/m}^3]}{1,000\,[\text{kg/m}^3]} = 0.001225$$

c) The specific gravity of castor oil ($\rho$=956.1 [kg/m$^3$])

$$\text{SG}_{\text{oil}} = \frac{\rho_{\text{oil}}}{\rho_{\text{H}_2\text{O}|_{4^\circ\text{C}}}} = \frac{956.1\,[\text{kg/m}^3]}{1,000\,[\text{kg/m}^3]} = 0.9561$$

d) The specific weight of water at STP

$$\gamma_{\text{H}_2\text{O}} = \rho_{\text{H}_2\text{O}}g = \left(998\left[\frac{\text{kg}}{\text{m}^3}\right]\right)\left(9.81\left[\frac{\text{m}}{\text{s}^2}\right]\right) = 9,790.4\left[\frac{\text{kg}}{\text{m}^2\text{s}^2}\right] = 9.79\,[\text{kN/m}^3]$$

e) The specific weight of sea water ($\rho$=1,025 [kg/m$^3$])

$$\gamma_{\text{H}_2\text{O}} = \rho_{\text{H}_2\text{O}}g = \left(1,027\left[\frac{\text{kg}}{\text{m}^3}\right]\right)\left(9.81\left[\frac{\text{m}}{\text{s}^2}\right]\right) = 10,074.9\left[\frac{\text{kg}}{\text{m}^2\text{s}^2}\right] = 10.07\,[\text{kN/m}^3]$$

f) The specific weight of beer (SG=1.01)

$$\rho_{\text{beer}} = \text{SG}_{\text{beer}}\rho_{\text{H}_2\text{O}|_{4^\circ\text{C}}} = (1.01)(1,000\,[\text{kg/m}^3]) = 1,010\,[\text{kg/m}^3]$$

$$\gamma_{\text{beer}} = \rho_{\text{beer}}g = \left(1,010\left[\frac{\text{kg}}{\text{m}^3}\right]\right)\left(9.81\left[\frac{\text{m}}{\text{s}^2}\right]\right) = 9,908.1\left[\frac{\text{kg}}{\text{m}^2\text{s}^2}\right] = 9.91\,[\text{kN/m}^3]$$

g) The specific weight of propane (SG=0.495)

$$\rho_{\text{propane}} = \text{SG}_{\text{propane}}\rho_{\text{H}_2\text{O}|_{4^\circ\text{C}}} = (0.495)(1,000\,[\text{kg/m}^3]) = 495\,[\text{kg/m}^3]$$

$$\gamma_{\text{propane}} = \rho_{\text{propane}}g = \left(495\left[\frac{\text{kg}}{\text{m}^3}\right]\right)\left(9.81\left[\frac{\text{m}}{\text{s}^2}\right]\right) = 4,855.95\left[\frac{\text{kg}}{\text{m}^2\text{s}^2}\right] = 4.86\,[\text{kN/m}^3]$$

h) The specific weight of glycerin (SG=1.263)

$$\rho_{\text{glycerin}} = \text{SG}_{\text{glycerin}}\rho_{\text{H}_2\text{O}|_{4^\circ\text{C}}} = (1.263)(1,000\,[\text{kg/m}^3]) = 1,263\,[\text{kg/m}^3]$$

$$\gamma_{\text{glycerin}} = \rho_{\text{glycerin}}g = \left(1,263\left[\frac{\text{kg}}{\text{m}^3}\right]\right)\left(9.81\left[\frac{\text{m}}{\text{s}^2}\right]\right) = 12,390.03\left[\frac{\text{kg}}{\text{m}^2\text{s}^2}\right] = 12.39\,[\text{kN/m}^3]$$

i) The density of glycerin (SG=1.263)

$$\rho_{\text{glycerin}} = \text{SG}_{\text{glycerin}}\rho_{\text{H}_2\text{O}|_{4^\circ\text{C}}} = (1.263)(1,000\,[\text{kg/m}^3]) = 1,263\,[\text{kg/m}^3]$$

## Problem #5

Determine the following material properties:

a) The absolute pressure of a system if the gauge pressure is 200 [kPa]

$$P_{abs} = P_{atm} + P_{gauge} = (101.325\,[\text{kPa}]) + (200\,[\text{kPa}]) = 301.325\,[\text{kPa}]$$

b) The gauge pressure of a system with an absolute pressure of 350 [kPa]

$$P_{gauge} = P_{abs} - P_{atm} = (350\,[\text{kPa}]) - (101.325\,[\text{kPa}]) = 248.675\,[\text{kPa}]$$

c) The force generated on a 0.5 [m] by 0.75 [m] surface that is exposed to atmospheric pressure on one side and a perfect vacuum on the other

$$F = PA = (101.325\,[\text{kPa}])(0.5\,[\text{m}])(0.75\,[\text{m}]) = 37,997\,[\text{kg-m/s}^2] = 38\,[\text{kN}]$$