CHAPTER 1: PROPERTIES OF FLUIDS

SPECIFIC WEIGHT

Specific weight= $\frac{weight}{volume}$

$$ϒ=\frac{W}{V}$$

Specific weight of water at 20°C

ϒ=9.79 kN/m^3

Specific weight of water at 20
ϒ=9.79 kN/

Specific weight of water at 4°C

ϒ=9.81kN/m^3

Specific weight of water at 4
ϒ=9.81kN/

Mass density= $\frac{mass}{volume}$

$\rho = \frac{M}{V}$

$\rho = \frac{m}{V}$ (kg/m^3 or slugs/ft^3)

For water:

ρ= 1000 kg/m^3 at 4°C

ρ= 988 kg/m^3 at 20°C

$m = \frac{W}{g}$

$m = \frac{lbs}{32.2}$

Specific volume= $\frac{1}{mass\ density}$

Specific volume= $\frac{1}{\rho}$

Specific volume=

Specific volume= m^3/kg or ft^3/slugs

Specific volume= /kg or /slugs

Problem: 1

If 5.6 m^3 of oil weighs 46,800 N, calculate the following:

1) Unit weight
2) Density
3) Specific gravity

Solution:

1) Unit weight:

$\gamma_w = \frac{46800}{5.6}$

γ_w = 8357.14 N/m^3

2) Density:

Density = $\frac{8357.14}{9.81}$

Density = 852 kg/m^3

3) Specific gravity:

Sp. Gravity = $\frac{852}{1000}$

Sp. Gravity = 0.85

Problem: 2

The volume of a tetrachloride having a mass of 1200 kg is 0.952 m^3. Compute the following:

1) Mass density
2) Specific weight
3) Specific gravity

Solution:

Weight= 1200 (9.81)
Weight= 11772 N
Weight= 11.77 kN

1) Mass density:

ρ= $\frac{m}{v}$

ρ= $\frac{1200}{0.952}$

ρ= 1,260.5 kg/
ρ= 1,260.5 kg/m^3

2) Specific weight:

ϒ= $\frac{11.77}{0.952}$

ϒ= 12.36 kN/m^3

3) Specific gravity= $\frac{unit\ wt.\ of\ glycerine}{unit\ wt.\ of\ H_2 0}$

Specific gravity= $\frac{12.36}{9.81}$

Specific gravity= 1.26

3) Specific gravity=

Specific gravity=

Specific gravity= 1.26

Problem 3:

Carbon letrachloride with a mass of 500 kg is placed in container with 0.325 m^3 volume.

1) Calculate its density

2) Calculate its specific weight

3) Determine also its weight

Solution:

1) Density:

Density= $\frac{500}{0.325}$

Density= 15.38 kg/m^3

2) Specific weight:

Specific weight= 15.38 (9.81)

Specific weight= 15088 N/m^3

Specific weight= 15.1 kN/m^3

3) weight= 15.1 (0.325)

Weight= 4.9 kN

Problem 4:

A certain liquid has a unit weight of **56 kN/**m^3.

1) Compute the mass density

2) Compute its specific volume

3) Compute its specific gravity

Solution:

1) Mass density:

ρ= $\frac{56000}{9.81}$

ρ= 5,708 kg/m^3

2) Specific volume= $\frac{1}{ρ}$

Specific volume= $\frac{1}{5708}$

Specific volume= 0.000175m^3/kg

Specific volume= 0.000175/kg

3) Specific gravity:

Sp. gravity= $\frac{58}{9.81}$

Sp. gravity= 5.71

Problem 5:

An object has a specific weight of 2.23 kN/m^3.
Compute the following:

1) Mass density

2) Mass if the volume is 0.001 m^3

3) Specific volume

Solution:

1) Mass density:

ρ= mass density

$$\rho = \frac{2230}{9.810}$$

ρ= 227.32 kg/m^3

2) M= ρ Vol.

M= 227.32 (0.001)

M= 0.23 kg

3) Specific volume= $\frac{1}{\rho}$

Specific volume= $\frac{1}{227.32}$

Specific volume= 0.0044 m^3/kg

Problem 6:

A quart of water weights 4.08 lb. Compute the following:

1) Mass in slugs

2) Mass in kg

3) Volume in cu.ft

Solution:

1) Mass in slugs:

W= mg

4.08= m(32.2)

m= 0.1267 slugs

2) Mass in kg:

m= $\frac{0.1267\ (32.2)}{2.2}$

m= 1.85 kg

3) Volume in cu.ft:

W= ϒ Vol.

4.08= 62.4 Vol

Vol= 0.065 ft^3

Problem 7:

The unit weight of water at 50°F is $62.4\ pcf$. If the volume of the vessel that contains water is $3.50\ ft^3$.

1) What will be the change in this volume when it is heated to 160°F (unit weight of water is 61 pcf at 160°F).

2) Compute the percentage change of volume.

3) What weight of water must be removed to maintain the original volume.

Solution:

1) **Weight of water** = ϒV

ϒ so V50 = $\Upsilon_{160}\ V_{160}$

62.4 (3.5) = 61 V_{160}

V_{160} = 3.5803 ft^3

= 3.5803

2) Change in volume = $\frac{(3.5803 - 3.50)}{3.50}$

Change in volume= 0.023

Change in volume= 2.3% (increase)

3) wt. of water that must be removed

= (3.5803 – 3.5) (61)
= 4.90 lb.

Problem 8:

A 10 m. diam. Cylindrical tank has a height of 5 m. and a full of water at 20°C (unit weight of water = 9.789 kN/m^3) if the water is heated to a temperature of 50°C (unit weight of water = 9.689 kN/m^3).

1) Compute the weight of water.

2) What is the final volume when heated to a temp. of 50°C.

3) Determine the volume of water that will spill over the edge of the tank.

Solution:

1) Weight of water:

$V_1 = \frac{\pi}{4}(10^2)(5)$

$V_1 = 392.70\ m^3$

$w_1 = v_1\ D_1$

$w_1 = 392.70\ (9.789)$

$w_1 = 3844.14$

2) Final volume when heated a temp of 50C

$w_2 = V_2 D_2$

$3844.14 = V_2\ (9.689)$

$V_2 = 396.75\ m^3$

3) Volume of water

$\Delta V = 396.75 - 392.70$

$\Delta V = 4.05\ m^3$

BULK MODULUS

BULK MODULUS OF WATER

$$E=\frac{\Delta P}{\frac{\Delta V}{V}}$$

E= bulk modulus
ΔP= change in pressure
ΔV= change in volume

E = bulk modulus
= change in pressure
= change in volume

COEFFICIENT OF COMPRESSIBILITY

$$\beta = \frac{1}{Bulk\ Modulus}$$

$$\beta = \frac{1}{E}$$

Coeff. Of compressibility

β = Coeff. Of compressibility

Problem 9:

A liquid which is compressed in a cycle if it has a volume of 1000 cu. cm (1 liter) at 2MPa and a volume of 990 cu. cm at 2.5 Mpa.

1) Compute the bulk modulus of elasticity.
2) Compute the percentage of volume decreased.
3) Compute the coefficient of compressibility.

Solution:

1) **Bulk modulus of elasticity**

$E_V = \frac{\Delta P}{\frac{\Delta V}{V}}$

$E_V = \frac{2.5-2}{\frac{10}{1000}}$

= 100(0.5)
= 50MPa

$E_v = 100(0.5)$

$E_V = 50\text{MPa}$

2) Percentage of volume decreased

$\% = \frac{10}{1000} \times 100$

$\% = 1\%$

3) **Coefficient of compressibility**

$\beta = \frac{1}{E}$

$\beta = \frac{1}{50}$

0.02

$\beta = 0.02$

Problem 10:

A volume of one cu. Meter of water is subjected to a pressure increase of 14 MPa.

1) Compute the change in its volume if it has a bulk modulus of elasticity of 2200 MPa.

2) Compute the percentage of volume decreased.

3) Compute the coefficient of compressibility.

Solution:

1) **Change in its volume if it has a bulk modulus of elasticity of 2200 Mpa.**

$E = \frac{-\Delta P}{\frac{\Delta V}{V}}$

$2200 = \frac{-(14-0)}{\frac{\Delta V}{1}}$

$\Delta V =$ -0.0064 m^3

2) Percentage of volume decreased:

$\% = 0.0064 \times 100$

$\% =$ 0.64 %

3) **Coefficient** of compressibility:

$\beta = \frac{1}{2200}$

$\beta =$ 4.54x 10^{-4}

Problem 10A :

A rigid container is partly filled with a liquid at 1520 kPa. The volume of the liquid is 1.232 liters. At a pressure of 3039 kPa, the volume of the liquid is 1.231 liters.

1) Compute the average bulk modulus of elasticity of the liquid.

2) Compute the coefficient of compressibility

3) If the liquid has a density of 1593 kg/m^3, what is the speed of sound in the medium.

Solution:

1) **Bulk modulus of elasticity:**

$$K = -\frac{(P_2 - P_1)}{\frac{V_2 - V_1}{V_1}}$$

$$K = -\frac{(3039 - 1520)}{\frac{1.231 - 1.232}{1.232}}$$

$K = 1.87 \times 10^6$ kPa

K= 1.87GPa

2) **coeff. Of compressibility:**

$$\beta = \frac{1}{K}$$

$$\beta = \frac{1}{1.87}$$

$\beta = 0.5347$ GPa

3) **Velocity of sound:**

$$V = \sqrt{\frac{K}{\rho}}$$

$$V = \sqrt{\frac{1.87 \times 10^9}{1593}}$$

V= 1083 m/s

Problem 10-B :

At a depth of 7 km in the ocean, the pressure is 71.6 Mpa. Assume a specific weight at the surface of 10.05 N/m^3 and an average bulk modulus of elasticity of 2.34 Gpa for that pressure range.

1) Compute the change in specific volume between the surface and 7 – m.

2) Compute the specific volume at 7 –m.

3) Compute the specific weight at 7-m.

Solution :

① Change in specific volume between the surface and 7 km. depth:

$$V_{s_1} = \frac{1}{\rho}$$

$$\rho = \frac{10050}{9.81}$$

$$\rho = 1024.46 \ kg/m^3$$

$$V_{s_1} = \frac{1}{\rho}$$

$$V_{s_1} = \frac{1}{1024.46}$$

$$V_{s_1} = 0.0009761 \ m^3/kg$$

$$K = -\frac{\Delta P}{\frac{\Delta V_s}{V_{s_1}}}$$

$$2.34 \times 10^9 = \frac{-71.6 \times 10^6 - 0}{\frac{\Delta V_s}{0.0009761}}$$

$$\Delta V_s = -0.0000299 \ m^3/kg$$

Problem 11

A liquid is compressed in a cylinder having a volume of 1 liter at one MN/m^2 and a volume of 995 cm^3 at 2 MN/m^2.

1) Compute the change in volume.

2) Compute the change in pressure.

3) Compute the bulk modulus of elasticity.

Solution

1) Change in volume

$$\Delta V = 995 - 1000$$

$$\Delta V = 5\ liters$$

2) Change in pressure

$$\Delta P = 2 - 1$$

$$\Delta P = 1\ MPa$$

3) Bulk modulus of elasticity

E= $\frac{-\Delta P}{\frac{\Delta V}{V}}$

E= $\frac{-2(1)}{\frac{(995-1000)}{1000}}$

E= 200 MPa

E= 200 MPa

SPECIFIC WEIGHT OF AIR AND GASSES

Specific weight of air and gases

Sp. Weight Y= $\frac{P}{RT}$

P= absolute pressure

T= absolute temperature in kelvin or rankine

R= $°C + 273\ in\ kelvin$

T= $°F + 460\ in$ rankine

R= gas constant

P= absolute pressure

T= absolute temperature in kelvin or rankine

R=

T= 460 in rankine

R= gas constant

Problem 12

A gas having a volume of 1 liters has a pressure of 0.24 MPa at 20°C. If the gas constant R is equal to 212 N/kg.k compute

1) Density of the gas

2) Mass of the gas

3) Weight of gas

Solution

p= $\frac{P}{RT}$

T= 273° + ℃

T= 273 + 24

T= 297° K

1) p= $\frac{0.24\ (10)^{\wedge}3}{212(297)}$

p= 3.81 kg/m^3

2) m= pV

m= 3.81(0.04)

m= 0.152 kg

3) W= Mg

W= 0.152(9.81)

W= 1.49 N

Problem 13

A gas is under pressure of 21.868 bar abs at 40.

1) Compute the pressure in kPa

2) Compute the gage pressure.

3) Compute the gas constant R if it has a unit weight of 362 N/m^3

Solution

1) Pressure in kPa

P= 21.868 (100)

P= 2186.8 kPa abs

2) Gage pressure

$P_{abs=} P_{gage} + P_{atm}$

2186.8 = P_{gage} + 101.3

P_{gage} = 2085.5 kPa

3) Gage constant R

$\Upsilon = g\frac{P}{RT}$

P= 21.868 x 10^5 kPa

Note

1 bar = 10^5 kPa = 100 kPa

$362 = \frac{21.868 \ x \ 10^5}{R(40+273)}(9.81)$

R= 189.3 m^3/ft

Problem 14

1) What is the difference in pressure between the inside and outside of a bubble having a diameter of 0.003 in if it is equivalent to an airwater interface having a surface tension of 0.005 lb/ft.

2) Compute the pressure in kPa

3) Compute the force due to surface tension.

Solution

1) Difference in pressure

P$\frac{\pi d^2}{4} = \pi d \sigma$

$\sigma = \frac{P(0.003)}{4(12)}$

P= 80 psf

2) Pressure in kPa

P= 80 $\frac{lb}{ft}$ $(\frac{4.448\ N)}{lb})(\frac{3.28\ ft}{m^2})$

P= 3.83 kPa

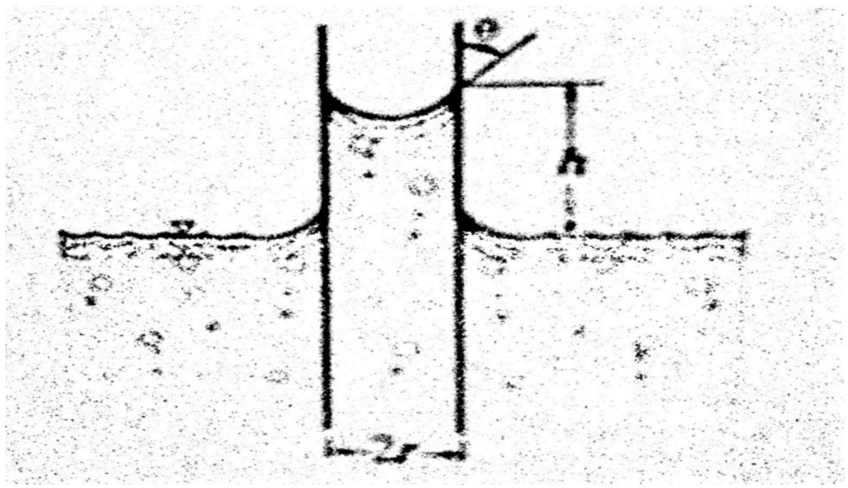
3) Force due to surface tension

F= $\pi(\frac{0.003}{12})$0.005

F= 3.93 x 10^3

Problem 15

The radius of the tube as shown in the figure is 1 mm. the surface tension of water at 20°c is equal to 0.0728 N/m. For a water glass interface $\theta = 0°$



1) Compute the capillary rise in the tube in mm
1) Compute the capillary rise in the tube in mm

2) Compute the total force due to surface tension
2) Compute the total force due to surface tension

3) Compute the weight of water above the surface due to surface tension
3) Compute the weight of water above the surface due to surface tension

Solution

1) Capillary rise in the tube mm

h= $\frac{2\sigma Cos\,\theta}{\rho g r}$

h= $\frac{2(\,0.0728)\cos 0°}{1000(9.81)(0.01)}$

h= 14.8 mm

2) Total force due to surface tension

F= $\sigma\pi d cos\theta$

F= 0.0728$(2\pi)(0.001)cos\theta$

F= 4.57 x 10^{-4} N

3) Weight of water

W= γVol= 9810 π $(0.001)^2$(0.0148)

W= 4.56 x 10^{-4} N

Problem 16

1) Find the depression *h* of the mercury in the glass capillary tube having diameter of 2 mm if the surface tension is 0.514 N/m for $\theta = 40°$.
2) Compute the force caused by surface tension.
2) Compute the force caused by surface tension.
3) Determine the density of mercury.
3) Determine the density of mercury.

Solution

h= $\frac{2\sigma Cos\ \theta}{pgr}$

p= $\frac{13.6(9810)}{9.81}$

p= 13600 kg/m^3

1) Depression h

h= 5.9 mm

2) Force caused by surface tension

F= $\sigma\pi d\cos\theta$

F= $0.154 \times \pi\,(0.002)\cos 40°$

F= 2.47 x 10^{-3}N

3) Density of mercury

P= 13600 kg/m^3

Problem 17

1) Determine the surface tension in a tube with 0.2 m radius and wetting angle and capillary rise of 5 mm.

2) Determine the surface tension in lb/ft

3) If wetting angle θ=80°, determine the surface tension.

3) If wetting angle =80, determine the surface tension.

Solution

1) Surface tension in a tube

h= $\frac{2\sigma Cos\ \theta}{\Upsilon w r}$

0.005 = $\frac{2\sigma Cos 0°}{9810\ (0.2)}$

$\sigma = \ \ 4.91\ N/m$ (surface tension)

2) Surface tension in lb/ft

$\sigma = 4.91\ \frac{N}{m}(\frac{m}{3.28\ ft})(\frac{lb}{4.448\ N})$

σ= 0.34 lb/ft

3) Surface tension

0.005 = $\frac{2\sigma Cos\ 80°}{98100(.2)}$

σ= 28.25 N/m