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2.2.4. Fluid Dynamics

Density

1. density of a substance is a weight per unit volume.
2. The unit volume selected for use in in the imperial system of measurment is 1 cubic foot (ft^3).
3. In the metric system, it is 1 cubic centimeter (cm^3).
4. density is expressed in (lb/ft^3) or (g/cm^3)

To find density weight and volume must be known

$$\text{density} = \frac{\text{Weight}}{\text{volume}}$$

Example:- weight 1497.6 lb container 4 ft long, 3 wide, 2 ft deep.

$W = 1497.6\ lb$

$V = 4 \times 3 \times 2 = 24\ ft$

$d = \frac{W}{V} = \frac{1497.6}{24}$

$24 \overline{)1497.6}$ = $\boxed{62.4}$

$\boxed{= 62.4\ lb/ft^3}$

6. The term "specific weight" or "specific density" are sometimes used to express this ratio. is not expresed in unit

→ change in temperature will not change the weight, but will change the volume. by expansion or contraction, thus changing its weight / unit volume.

Formula to find specific gravity of liquid and ~~gas~~ solid:

$$\text{Specific gravity} = \frac{\text{Weight of the substance}}{\text{Weight of equal volume of water.}}$$

or

$$\text{Specific gravity} = \frac{\text{Density of substance}}{\text{Density of water}}$$

→ For this ~~pur~~ purpose, a standard is needed

The same formula used to find density of gases by substituting air or hydrogen for water.

Example: hydraulic fluid has specific gravity 0.8 ft^3, of liquid weight 0.8 times much 1 ft^3 of water, 62.4 time 0.8, or 49.92 lb

liquid

$\text{specific gravity} = \frac{0.8}{0.8} = 1\ ft^3$

water : $62.4 \times 0.8 = \boxed{49.92\ lb}$

$624 \times 8 = 4992$

specific gravity and density are independent of the size of the sample.

Specific Gravity

1. It is often necessary to compare the density of one substance with that of another. For this purpose, a standard is needed
2. Water is the standard that physicists have chosen to use when comparing the densities of all liquids and solids.
3. For gases, air is most commonly used.
4. hydrogen is sometimes used as a standard for gases.
5. the word "specific" implies a ratio.
6. Specific gravity is calculated by comparing weight of volume of given substance with weight of an equal volume of water.

hydrometer

1. is used for measuring specific gravity of liquid.
2. this device consist of tublar glass float contained in a large glass tube

Example :- tublar, glass SG ↑ when immersed in a liquid of greater density, the float rises, indicating a ↑ specific gravity

-> for liquid of lesser density ↓ The float sink, indicating lower specific gravity ↓ ∴ ∂↓ SG ↓ will sink

another example of use of hydrometer electrolyte (battery liquid) in aircraft battery

visconsity :-

1. one of the most important properties of fluid is viscosity
2. is internal resistance to flow.
3. A liquid such as gasoline that has low viscosity flow easily.
4. A liquid such as tar that has high viscosity flow slowly.

~~ ~~ high viscosity index indicates the fluid experiences small change in viscosity as temperature varies

The saybolt viscometer measures the time required, in second, for 60 ml of the tested fluid at 100°F to pass through a standard orifice.

instrument used to measure the viscosity of a liquid are known viscometers or viscosimeters

The time measured is used to express the fluid's viscosity in saybolt universal seconds or saybolt furol seconds.

Fluid resistance :-

1. Fluid is any substance that it is able to flow if it's not in some way confined or restricted.
2. liquids and gases are both classified as fluids and often act in very similar way.
3. One significant difference come into when a force applied,

5. All fluids have viscosity
6. while easier to see in a liquid, gases, such as air also have viscosity
6. In aerodynamics, as air flow over the surface of the aircraft, the viscosity of the air affect the nature of the flow.
7. viscosity ↑ as temperature ↓ inverse relationship.

Maintaining a functional viscosity throughout the operating temperature range is also an issue in lubricating system.

viscosity index is a number that indicates the effect of temperature changes on the viscosity lubricating oil.

low viscosity index signifies a relatively large change of viscosity during temperature ~~operation~~ variations

liquids tend to be incompressible
gases tend to be highly compressible

4. theory of lift on a wing and the force generated by hydraulic system can be explained and quantified by using the law of fluid mechanics.

Pascal's Law

1. he discovered that pressure set up in a fluid act equally in all direction.
2. This pressure acts at right angles to containing surfaces
3. when the pressure in the fluid is caused solely by the fluid's weight, the pressure against the wall of the container is = at any given level but it is not ≠ if the pressure at the bottom is compared to the pressure half way down.

1. concept of the pressure
1. set up in a fluid
2. how it relates to the force acting on fluid
3. surface area through which it acts

is pascal's Law

relationship between F_{out} and F_{in} is Mechanical advantage.

$$MA = \frac{F_{out}}{F_{in}} , \quad MA = \frac{D_{in}}{D_{out}}$$

two piston hydraulic system
relationship between piston area and distance

Formula :-

input piston Area (Distance moved) = output piston Area (Distance moved)

$$A_{in} \cdot D = A_{out} \cdot D$$

$$volume_{in} = volume_{out}$$

Example: A two piston hydraulic system, has input piston an Area $\frac{1}{4}$ in², output piston Area 15 in², input force 50 lb, input piston moves 30 in. What is the pressure in system, how much force is generated by output piston

Formula :-

Force = pressure x Area (lb)
pressure = $\frac{Force}{Area}$ (psi)
Area = $\frac{Force}{pressure}$ (in²)

Example :-

$F_{in} = 5$ lb

piston Area = $\frac{1}{2}$ in²

pressure = $\frac{Force}{Area} = \frac{F}{A}$

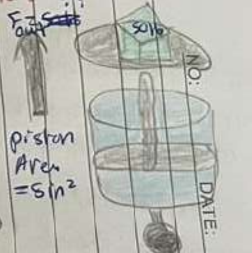
what is pressure
F = 5 lb
A = $\frac{1}{2}$ in²

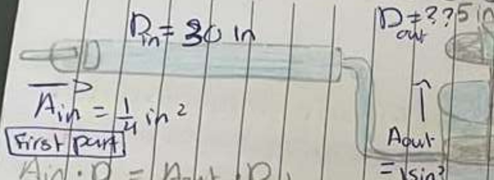
$$= \frac{5}{\frac{1}{2}}$$

$$5 \times \frac{2}{1} = \boxed{10 psi}$$

Example ??

what is Force
P = 10 psi
A = 5 in²
F = 10 x 5
$\boxed{= 50 lb}$





$D_{in} = 30$ in

$D_{out} = ??5$ in

$A_{in} = \frac{1}{4}$ in^2

$A_{out} = 15$ in^2

$\boxed{\text{First part}}$

$A_{in} \cdot D = A_{out} \cdot D$

$\frac{1}{4} \cdot \frac{30}{1} = 15 \cdot D$

$\frac{30}{4} = 15D$

$\frac{7.5}{15} = \frac{15D}{15}$

$\boxed{5 \text{ in} = D}$

$\boxed{\text{Second part}}$

$P = \frac{\text{Force in}}{\text{Area in}}$

$= \frac{50 \text{ in}}{\frac{1}{4}} = 50 \times \frac{4}{1}$

$\boxed{= 200 \text{ psi}}$

$\boxed{\text{Third part Fout}}$

$F = \text{pressure} \times \text{Area}_{out}$

$= 200 \times 15$

$\boxed{= 3000 \text{ lb}}$

$\boxed{\text{Fourth part}}$

$MA = \frac{F_{out}}{F_{in}}$

$= \frac{300\cancel{0}}{5\cancel{0}}$

$\boxed{= 60}$

~~last part~~

1. gases are compressible, liquid are incompressible

3. In normal temperature and pressure condition volume or density of gas doesn't change. However they can easily have small change in temperature or pressure

2. The main difference between compressible and incompressible when a force applied to a compressible changes density while when force applied to an incompressible doesn't change it meaningful degree.

At molcular level :-

when pressure is applied on a gas, it affects gas on all direction, causing molecules to collide with greater frequency.

This collisions
1. give more time for the gas molecules to interact
2. more attraction force occur between molecules

These attraction force reduce motion of gas molecules

Streamlining :-

When a fluid encounters a particular obstacle ...s flow around, even the wing of the aircraft ...r curve in hydraulic system line

1. curved surface enable the possibility of smooth flow with is freed from turbulence
2. Fluid particle able to speed up to negotiate the obstacle smoothly without tumbling.
3. This smooth flow is essential for low pressure development on the upper surface of a wing

known as Streamlining, gradual shaping of areas where fluids must flow reduces the compression of gases and temperature of liquids in areas where turbulent flow may otherwise result

Compessibility:

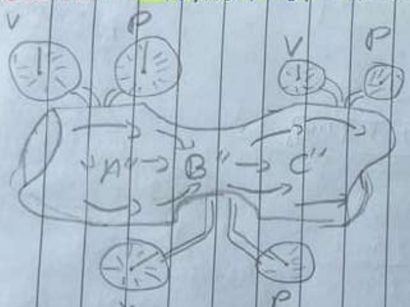
↳ is a measure of how much volume of fluid change as a response of pressure change.

Bernoulli's principle:

1. explain the action of a liquid following through the varying cross sectional areas of tubes.

2. A tube is shown the cross sectional area gradually decrease to a minimum diameter in its center-section

3. A tube constructed in this manner is called "venturi" or venturi tube".

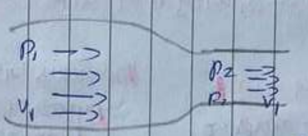


[1] cross sectional area ↓ the passageway referred to as converging duct.

[2] As passageway starts to spread out is reffered to as diverging duct

dynamic pressure is associated with KE in the airflow.

Total pressure = Static pressure + Dynamic pressure.



$$P_t = P_1 + \frac{1}{2}\rho_1 V_1^2 = P_2 + \frac{1}{2}\rho_2 V_2^2$$

total pressure

$$P_2 < P_1$$

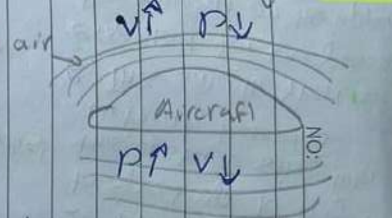
The venturi is used to illustrate Bernoulli's principle which state:-

The static pressure of fluid (liquid or gas) ↓ P at point where

The velocity of fluid ↑ V provided no energy is added nor taken away from fluid

The velocity of the air is KE and static pressure of air is PE.

Velocity of fluid ↑
pressure static ↓
→ inverse relationship



the total pressure of air flow remain the same

→ static pressure ↓

→ dynamic pressure ↑

Formulas :-

Center of gravity (CG)

$$\Sigma M_i = W_1 d_1 + W_2 d_2 + W_3 d_3 + W_4 d_4$$

ΣM → moments

$$\Sigma W_i = W_1 + W_2 + W_3 + W_4$$

ΣW → weight

$$CG = \frac{\Sigma M}{\Sigma W} = \frac{\text{total moment}}{\text{total weight}}$$

$$CG = \frac{W_1 \cdot d_1 + W_2 d_2 + W_3 d_3 + W_4 d_4}{W_1 + W_2 + W_3 + W_4}$$

moment:

$W \cdot A$ → Arm

W → weight

$M = W \cdot A$ or $M = W \cdot d$

unit of moment => In-lb

Buoyancy :-

$B = V \cdot \rho$

ρ → density

$B > W$ will float

$B < W$ will sink

Speed and velocity :-

$S = \frac{d}{t}$

S → it can be m/h or ft/s

$V = \frac{d}{t}$ with direction

convert m/h to f/s multiply x 1.467

Acceleration:

$$A = \frac{V_f - V_i}{t}$$

acceleration due to gravity

32.2 fps/s (9.8 mps/s)

Newton second law:

$$F = \frac{W(V_f - V_i)}{gt} \quad / \quad F = ma$$

$m = \frac{W}{g}$, $a = \frac{V_f - V_i}{t}$

Centripital Force :-

$$F_c = \frac{mv^2}{r}$$

v → fps

r → ft

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

periodic motion "pendulum"

$$T = 2\pi\sqrt{\frac{L}{g}}$$

L → ft or m

T → s

g → 32.2 ft/s² or 9.8 m/s²

Vibration

Frequency :/ period :

$f = \frac{1}{T}$ → Hz

$T = \frac{1}{f}$ → s

$$T = 2\pi\sqrt{\frac{m}{k}}$$

T → s

m → lb or kg

k → lb/ft or N/m

velocity ratio:-

velocity ratio = $\frac{\text{distance moved by effort}}{\text{distance moved by load}}$

Mechanical Advantage

$MA = F_{out} \cdot D_{out} = F_{in} \cdot D_{in}$

lb or N . it depends

$= \frac{F_{out}}{F_{in}} = \frac{D_{in}}{D_{out}}$

gear ratio

$\frac{\text{Teeth (of first object)}}{\text{teeth (of second object)}} = \frac{\text{Speed (of second object)}}{\text{Speed (of first object)}}$

rpm

rpm

gears:

$\frac{\text{effort arm}}{\text{resistance arm}} = \frac{F_{out}}{F_{in}}$

Efficiency

mechanical Advantage

Efficiency = $\frac{MA}{\text{speed ratio}} \times 100$

measured in %

Another Way

Efficiency = $\frac{\text{Measured performance}}{\text{ideal performance}}$

density

density = $\frac{\text{weight}}{\text{Volume}}$ → lb/ft^3 or g/cm^3

imperial system

~~[illegible]~~ ft^3

metric system ~~[illegible]~~

cm^3

two piston hydraulic system

input piston Area (Distance moved) =

output piston Area (Distance moved)

$A_{in} \cdot D = A_{out} \cdot D$

this shows

$\text{Volume}_{in} = \text{Volume}_{out}$

Pascal's Law

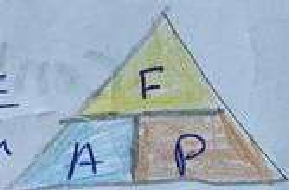
Force = Pressure X Area

unit lb psi in^2

$F = P \cdot A$

Pressure = $\frac{\text{Force}}{\text{Area}}$

psi

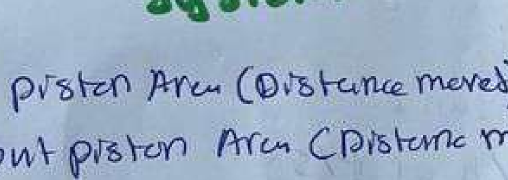


Area = $\frac{\text{Force}}{\text{Pressure}}$

in^2

Bernoulli's principle

Total pressure = Static pressure + Dynamic pressure



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