FLUID MECHANICS

DENSITY

MASS DENSITY $\frac{[M]}{[L]^3} \equiv$ DENSITY $\equiv \rho = \frac{\text{MASS}}{\text{VOLUME}} = \frac{m}{V}$

- IN GENERAL, MASS DENSITY IS A FUNCTION OF TEMPERATURE AND PRESSURE...

$$\rho(T, P)$$

... BUT IT IS ROUGHLY CONSTANT OVER A LIMITED RANGE OF TEMPS AND PRESSURES

PRESSURE

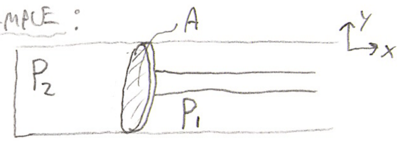
- MACROSCOPIC VIEW:

PRESSURE $\frac{[M]}{[L][T]^2} \equiv P = \frac{\text{FORCE}}{\text{AREA}} = \frac{F_\perp}{A}$

* SI UNIT = PASCAL (Pa)

- PRESSURE GRADIENTS RESULT IN NET FORCES

EXAMPLE:



IF $P_2 > P_1$ THEN $\Sigma \vec{F} \longrightarrow$

$$\Sigma F_x = A \Delta P = A(P_2 - P_1)$$

- ATMOSPHERIC PRESSURE — IS THE AVERAGE PRESSURE OF THE ATMOSPHERE AT SEA LEVEL HEIGHT AND AT A STANDARD TEMPERATURE OF 288.15 K.

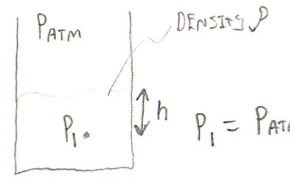
$$P_{atm} \approx 101300 \text{ Pa} \equiv 1 \text{atm}$$

- GAUGE PRESSURE — THE EXTRA PRESSURE ABOVE/BELOW ATMOSPHERIC PRESSURE
- ABSOLUTE PRESSURE — THE TOTAL PRESSURE

$$P_{ABS} = P_{atm} + P_{GAUGE}$$

HYDROSTATICS

- WHEN NEAR MASSIVE OBJECTS, PRESSURE OF A FLUID IS A FUNCTION OF DEPTH. (i.e. PRESSURE AT A DEPTH IS CAUSED BY GRAVITY)



$$P_1 = P_{ATM} + \rho g h$$

- PASCAL'S PRINCIPLE — FOR AN INCOMPRESSIBLE AND ENCLOSED FLUID, A CHANGE IN PRESSURE AT ONE LOCATION RESULTS IN THE SAME CHANGE IN PRESSURE, WITHOUT A DIMINISH IN MAGNITUDE, AT ALL LOCATIONS WITHIN THE ENCLOSED FLUID AND WALLS.

  * WITH PASCAL'S PRINCIPLE, WE CAN CONSTRUCT HYDRAULIC SYSTEMS WHICH PROVIDE MECHANICAL ADVANTAGE.

BUOYANCY

- WHEN A FLUID IS NEAR A MASSIVE OBJECT, THE RESULTING PRESSURE GRADIENT WITHIN THE FLUID CAUSES THE BUOYANT FORCE AN OBJECT WITHIN THE FLUID EXPERIENCES.
- ARCHIMEDES' PRINCIPLE — THE BUOYANT FORCE AN OBJECT SUMERGED WITHIN A FLUID EXPERIENCES IS EQUAL TO THE WEIGHT OF THE DISPLACED FLUID.

$$|\vec{F}^B| = \rho_F V_d g$$

(ρ_F = DENSITY OF FLUID; V_d = VOLUME OF DISPLACED FLUID; $\rho_F V_d$ = MASS OF DISPLACED FLUID)

IF $\bar{\rho}_o > \rho_F$ ... SINKS
IF $\bar{\rho}_o < \rho_F$ ... FLOAT
IF $\bar{\rho}_o = \rho_F$ ... NEUTRAL BUOYANCY

($\bar{\rho}_o$ IS THE AVERAGE DENSITY OF THE OBJECT)

FLUID DYNAMICS

- SIMPLIFIED MODEL (ASSUMPTIONS):
  - FLUID IS INCOMPRESSIBLE (i.e. CONSTANT DENSITY)
  - LAMINAR FLOW (SMOOTH AND STEADY, NON TURBULENT)
  - NO VISCOUS FORCES (i.e. NO INTERNAL OR EXTERNAL FRICTION)
- CONTINUITY (CONSERVATION OF MASS FLOW RATE)

  "WHAT GOES IN MUST COME OUT AT THE SAME RATE"

MASS FLOW RATE $\frac{[M]}{[T]} \equiv \dot{m} = \rho A v$ (A = CROSS SECTIONAL AREA; v = SPEED)

$$\Sigma \dot{m}_{IN} = \Sigma \dot{m}_{OUT}$$

* IF SAME FLUID — ρ = CONSTANT, USE VOLUME FLOW RATE (Q)

VOLUME FLOW RATE $\frac{[L]^3}{[T]} \equiv Q = \frac{\dot{m}}{\rho} = vA$

$$\Sigma Q_{IN} = \Sigma Q_{OUT}$$

- BERNOULLI'S PRINCIPLE

  * ENERGY DENSITY CONSERVATION EQUATION

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2 = \text{CONSTANT}$$

P = PRESSURE
v = SPEED
y = HEIGHT