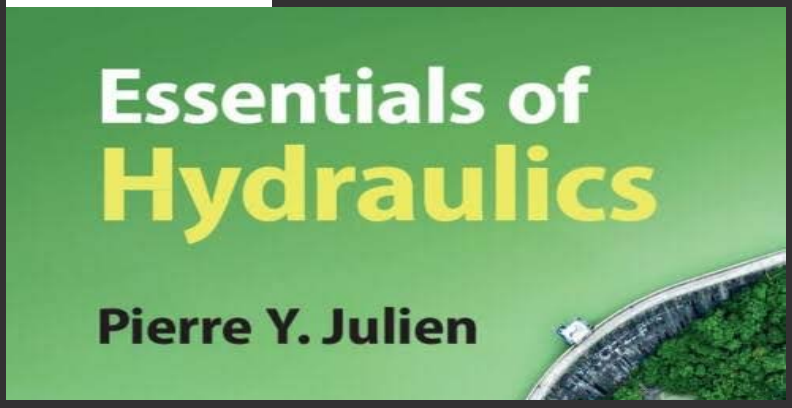
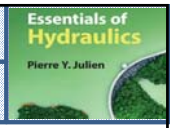
연세대학교
YONSEI UNIVERSITY

1. Hydrostatics



1.1.1 Dimensions and Units



- Dimensions and units
- Fundamental dimensions: M, L, T
- In SI units, they are kg, m, s
- The unit of force is N = kg m/s^2
- The unit of g is m/s^2
- The unit of weight is the same as the force.
- The pressure is the force per unit area. 1 N/m^2 = 1 Pa

☞ What is the Newton's 2–nd law?

☞ Engineers must be able to use two systems of units.

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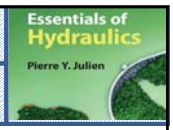

Table 1.1

- Geometric (L)

  length, area, volume

- Kinematic (L, T)

  velocity, acceleration, discharge

- Dynamic (M, L, T)

  mass, force, pressure, work

- Dimensionless

  slope, Reynolds number, Froude number

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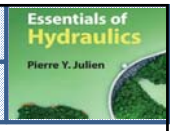

• Density of water

- ρ =1,000 kg/m^3 = 1.94 slugs/ft^3 (at 4°C)
- The density of water decreases with increasing temperature.

• Specific weight of water

- The weight for unit volume of water
- γ = ρg = 9,800 N/m^3 = 62.4 lb/ft^3

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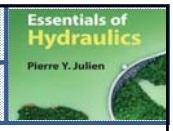

1.1.2 Properties of Water

• Dynamic viscosity μ

- The viscosity is a measure of fluid's resistance to angular deformation. The lower the viscosity, the thinner a fluid is.
- μ = [M/LT]

☞ What is the Newton's law of viscosity?

• Kinematic viscosity ν

- $$\nu = \frac{\mu}{\rho}$$
- ν = [L^2/T]
- ν = 1.0x10^{-6} m^2/s = 0.01 cm^2/s (at 20°C)

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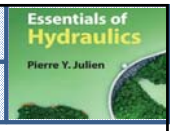

1.1.3 Fluid Density

• Specific gravity G

- the ratio of the density of fluid to the density of water
- $$G = \frac{\rho_{fluid}}{\rho_{water}}$$
- Materials whose G < 1 such as woods and ice float in water.

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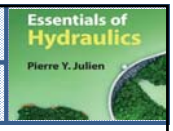

1.2.1 Atmospheric Pressure

- Pressure
  - Dimension: force per unit area
  - In a fluid, the pressure is the same in all directions.

- Atmospheric pressure
  - P_{atm} = 101.3 kPa = 14.7 psi
  - The atmospheric pressure decreases with altitude.
  - The atmospheric pressure is about 10 m high water column.

☞ How do you know that the atmospheric pressure is not zero?

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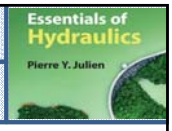
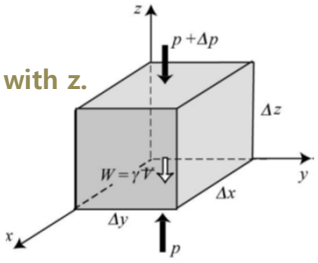


1.2.2 Hydrostatic Pressure

- Hydrostatic pressure
  - Hydrostatics refers to fluids at rest.
  - Application of Newton's 2–nd law results in

$$\frac{dp}{dz} = -\gamma$$

  - which states that pressure decreases with z.



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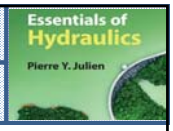
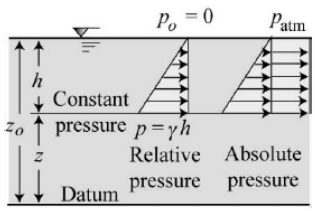


- Relative and absolute pressure
  - Integration leads to

$$p = p_0 + \gamma h$$



  - where h = z_0 – z.
  - Relative pressure is obtained by assuming that the atmospheric pressure is zero. That is,

$$p_{abs} = p_{atm} + p_{rel}$$

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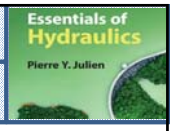
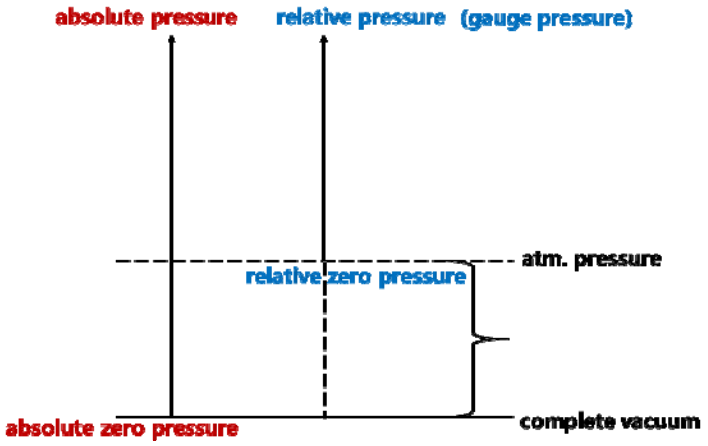


- Relative and absolute pressure



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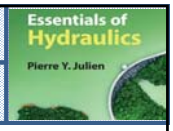
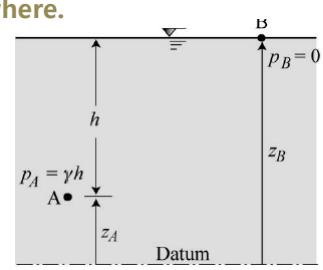


• Piezometric head

- pressure head = p/γ
- piezometric head $= z + \frac{p}{\gamma}$
- In a fluid at rest, the piezometric head is constant everywhere.



Piezometric head

$$\frac{p_A}{\gamma} + z_A = h + z_A = \underbrace{\frac{p_B}{\gamma}}_{0} + z_B$$

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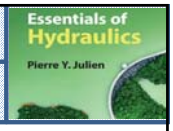
1. Hydrostatics | 1.2 Hydrostatic Pressure
1.2.4 Hydraulic Grade Line



• Hydraulic Grade Line (HGL)

- Hydraulic Grade Line (HGL) is the line connecting the piezometric head.
- In hydrostatics, HGL is the free surface.

• Energy Line (EL)

- Energy Line (EL) is the line connecting the piezometric head plus velocity head.

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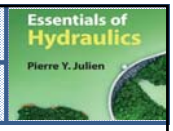
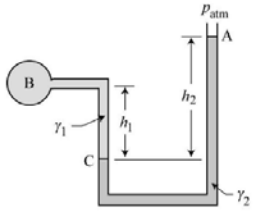


- Ex. 1.4: Piezometer
  - Find the absolute and relative pressure at B.



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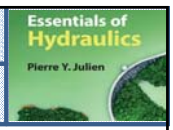
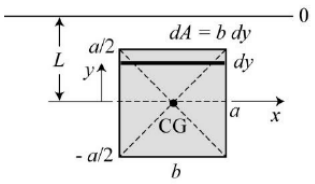


- Area moment of inertia
  - Moment of inertia is defined by

$$\bar{I} = \int y^2 dA$$

  - For a rectangle, $\bar{I} = ba^3/12$
  - Parallel axis theorem

$$I_0 = \bar{I} + AL^2$$



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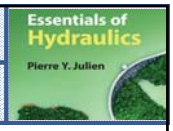


1.3.2 Force Magnitude on a Plate

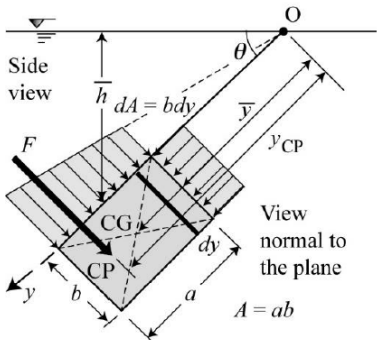
- Force on a plate

$$p = \gamma h = \gamma y \sin\theta$$

$$dF = pdA = \gamma y \sin\theta dA$$

$$F = \int_A dF = \gamma \sin\theta \int_A y dA = \gamma A \bar{y} \sin\theta$$

$$\boxed{F = \gamma A \bar{h}}$$



- Here $\bar{h}$ is the vertical distance to centroid.
- The hydrostatic force is the surface area times the pressure at the centroid.

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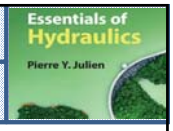

1.3.3 Center of Pressure

- Center of pressure force
- The moment about O

$$M_0 = Fy_{cp}$$

- or

$$M_0 = \int_A dM_0 = \int_A y(\gamma y \sin\theta) dA = \gamma \sin\theta \int_A y^2 dA = \gamma \sin\theta I_0$$

- Here $I_0 = \bar{I} + A\bar{y}^2$

$$\boxed{y_{cp} = \bar{y} + \frac{\bar{I}}{A\bar{y}}}$$

- The center of the pressure force is always below the centroid.

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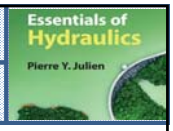
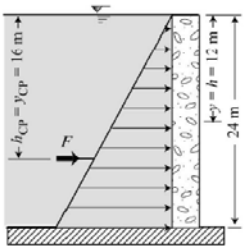


- Ex. 1.9: Force on a vertical plate
  - Find F (per unit width) and the center of force on a vertical plate.



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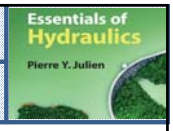
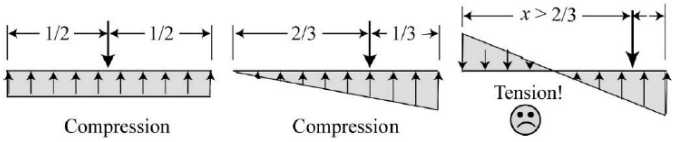


- Center of pressure force
  - The stability of the gravity dam is related with the hydrostatic force and the weight of concrete.
  - The stability is obtained if not (1) overturning of the dam; and (2) tension cracks at the base of the concrete dams.
  - For (1), the resultant force must pass to through the base of the dam. For (2), the resultant force must pass through the central third of the base.



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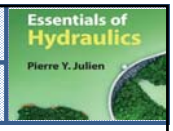
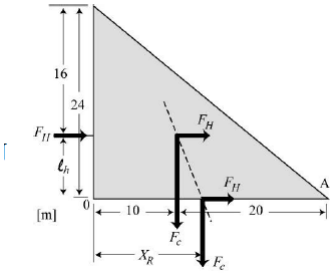


1.4.1 Dam Stability Concept

- Ex. 1.10: Dam stability
  - Will tension develop at the base of the dam?



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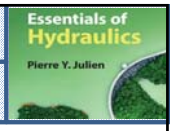

- Homework Assignment (Due: one week from today)
  - 4, 5, 6, 7, 8, 9, 10, 12, 13, 16

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