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Phys 145 (General Physics)

Chapter 5:The Mechanics of Nonviscous Fluids

Week n° 07

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Chapter 5: The Mechanics of Nonviscous Fluids

- **We will learn in this chapter 5:**

- Equation of Continuity; Streamline Flow
- Bernoulli's Equation
- Static Consequences of Bernoulli's Equation
- Dynamic Consequences of Bernoulli's Equation

Equation of Continuity; Streamline Flow

4 common states of matter:

♦ **Solid: Maintains shape & size (approx.), even under large forces.**
♦ **Liquid: No fixed shape. Takes shape of container.**
♦ **Gas: Neither fixed shape, nor fixed volume. Expands to fill container**

♦ **Plasma: Neither fixed shape, nor fixed volume. Expands to fill container**

Liquid, Gas and Plasma are called Fluids.

Fluid Flow

1. **The fluid is nonviscous. In a nonviscous fluid, internal friction is neglected. An object moving through the fluid experiences no viscous force.**
2. **The flow is steady. In steady (laminar) flow, the velocity of the fluid at each point remains constant.**
3. **The fluid is incompressible. The density of an incompressible fluid is constant.**
4. **The flow is irrotational. In irrotational flow, the fluid has no angular momentum about any point.**
5. **If a small paddle wheel placed anywhere in the fluid does not rotate about the wheel's center of mass, then the flow is irrotational.**
6. **The path taken by a fluid particle under steady flow is called a streamline.**

Density and Pressure

- **Density**

  In fluids, we are interested in properties that can vary from point to point. Thus, it is more useful to speak of density and pressure than of mass and force.

  ρ=m/v (uniform density)

  Density is a scalar, the SI unit of density is kg/m^3.

- **Pressure** $p = \frac{F}{A}$
- **(*p* is the pressure of uniform force on flat area)**
- ***F* is the magnitude of the normal force on area *A*.**
- **The SI unit of pressure is N/m^2, called the Pascal (Pa).**

  (The tire pressure of cars are in kilopascals: kPa).

- **1 atm = 1.013x10^5 Pa = 76 cm Hg = 760mm Hg**

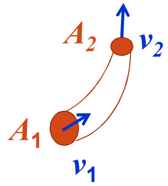
Equation of Continuity; Streamline Flow

- **A fluid moving with steady flow through a pipe of varying cross-sectional area. The volume of fluid flowing through area A1 in a time interval t must equal the volume flowing through area A2 in the same time interval.**
- **Therefore,**

Area$_1$ x velocity$_1$ = Area$_2$ x velocity$_2$

$$Q = A_1 \times v_1 = A_2 \times v_2$$

$$r_1^2 \times v_1 = r_2^2 \times v_2$$



- **This expression is called the equation of continuity for fluids.**
- **It states that the product of the area and the fluid speed at all points along a pipe is constant for an incompressible fluid.**

Example 5.1

- A water pipe leading up to a hose has a radius of 1 cm. water leaves the hose at a rate of 3 litres per minute.

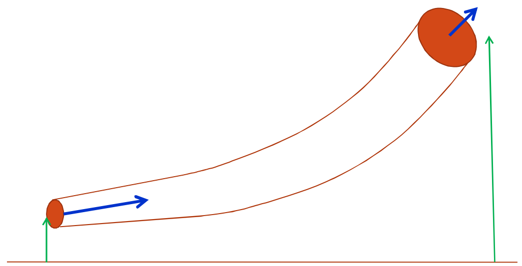
  a/ Find the velocity of the water in the pipe.

  $$Q = 3\ \ell/\text{mn} = \frac{3\times10^{-3}}{60} = 5\times10^{-5}\ \text{m}^3/\text{s} \Rightarrow v = \frac{Q}{A} = \frac{5\times10^{-5}}{\pi(10^{-2})^2} = 0.16\ \text{m/s}$$

- b/ The hose has a radius of 0.5 cm. What is the velocity of the water in the hose?

  $$Av = A'v' \Rightarrow v' = \left(\frac{A}{A'}\right)v = \left(\frac{r}{r'}\right)^2 v = 4v = 0.64\ \text{m/s}$$

Bernoulli's Equation



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

Video 01 of week 07: Bernoulli's principle

Summary of week 07

Flow rate is: $Q = A \times v$

The equation of continuity is: $Q = A_1 \times v_1 = A_2 \times v_2$

The Bernoulli's equation is: $P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$

Quiz for week 07