

Physics 303K Handout 13

Before now, we have dealt almost exclusively with point masses and some with mass distributed in space (for example, moment of inertia and the gravitational force). In all cases of mass distributions, the spatial relationship between particles has been fixed. (This means the object is rigid.) Now we will deal with distributions of mass where the individual constituents can change relative positions (i.e. the material can flow.) These materials are called fluids and include both liquids and gases. We will talk about the properties and behaviors of fluids.

1 Chapter 15: Fluid Statics

1. A fluid is unable to support shear forces (forces parallel to the surface); this is why a fluid flows. The pressure p is the normal force per unit area. Pressure is a scalar.
2. The density ρ is mass per unit volume. Bulk modulus B is

$$B = -\frac{\Delta p}{\Delta V/V}. \quad (1)$$

With B positive, an increase in pressure will cause a decrease in volume V . The pressure change Δp in a homogeneous increases with depth Δy as $\Delta p = \rho g \Delta y$. For a gas in a gravitational field, if we assume that the temperature is constant and if we assume that density ρ is proportional to pressure p , then p decreases exponentially with height: $p = p_0 e^{-h/a}$.

3. Pascal's Principle: Pressure applied to an enclosed fluid is transmitted undiminished to every portion of the fluid and to the walls of the containing vessel.
4. Archimedes' Principle: A body wholly or partially immersed in a fluid is buoyed up by a force equal in magnitude to the weight of the fluid displaced by the body.
5. Surface tension γ is the amount of energy necessary to create more surface area of a fluid, $\gamma = \frac{\Delta U}{\Delta A}$.

2 Chapter 16: Fluid Dynamics

1. Fluid flow can be steady (time-independent) or unsteady (time-dependent).
2. Fluid flow can be compressible or incompressible.
3. Fluid flow can be viscous or nonviscous (usually called inviscid).
4. Fluid flow can be rotational or irrotational.
5. The conservation of mass for a fluid can be written as $\rho A v = \text{constant}$. If there are sources S and sinks D , then mass conservation for one point in space looks like:

$$\vec{\nabla} \cdot \vec{v} + \frac{\partial \rho}{\partial t} = S + D. \quad (2)$$

6. For an inviscid, incompressible, steady flow, Bernoulli's equation holds

$$p + \frac{1}{2} \rho v^2 + \rho g y = \text{constant} \quad (3)$$

along a streamline. If we assume the flow is irrotational, then the constant is the same throughout the entire fluid.

7. There are two kinds of pressure we will distinguish: Static pressure $P_{static} = p + \rho g y$ ($v=0$) and Dynamic pressure $P_{dyna} = \frac{1}{2} \rho v^2$ (change in y is zero).
8. Viscosity is the friction in a moving fluid. Applying a shear force F to a surface area A of a fluid creates a velocity gradient dv/dy proportional to the force:

$$F = \eta A \frac{dv}{dy}. \quad (4)$$

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adapted from Resnick, Halliday, and Krane.