Ch 9

Concept Questions 1, 8, 10, 14

Problems 1, 4, 5, 7, 11, 15, 16, 18, 19, 27, 28, 38, 40, 45, 53, 56a

States of Matter

- solids
  - definite shape and volume
  - hard to compress
- liquids
  - definite volume but no fixed shape
  - intermolecular forces not strong enough to keep molecules in fixed positions
  - hard to compress
- gas

  has neither definite volume or shape

  relatively easy to compress

  molecules exert weak forces on each other, most of time move without restraint

Types of solids

- crystalline solid

  the atoms have an ordered structure

amorphous solid

  Atoms are arranged almost randomly

Deformation of solids

Solids have definite shape and volume.

When small forces are applied, the object tends to return to its original shape and size.

If a big enough force is applied, the object will deform or break.

This is called elastic behavior.

Kind of makes you want to think about the object s a spring.

3 ways to deform a solid

- Elasticity in length

- Elasticity in shape

- Elasticity in volume

- Definitions

  Stress is the force per unit area causing a deformation. (Stress acts like pressure)

  Strain is a measure of the amount of the deformation.

  The stress will be proportional to the strain.

  stress = elastic modulus X strain

Similar to Hooke's Law for springs $F = -k\Delta x$

Young's Modulus

- Elasticity in length
- Take a long rod. Internal forces keep the rod together. Pull on the rod a bit. Internal forces resist the force of the pull. So even if the rod is stretched a tiny bit, the bar is in equilibrium. The internal forces balance out the external force.
- The rod is stressed.
- This is an example of tensile stress.

Pressure

- Pressure is force per area.
- SI unit for pressure is the Pascal.
- 1 Pa = 1N/m^2

Tensile Strain

- tensile strain = ratio of the change in length (ΔL) to the original length (L_0).

stress = modulus x strain

$$\frac{F}{A} = Y\,\frac{\Delta L}{L_0}$$

Y = Young's Modulus

$F = k\Delta L$
$k = AY/L_0$

Y describes how easy it is for a solid to be stretched.

Big Y = Hard to stretch   Steel: $Y = 20 \times 10^{10}$ PA

Small Y = Easier to stretch   Rubber: $Y = 0.1 \times 10^{7}$ Pa

Table on page 271

Shear Modulus

- Elasticity in shape. See picture on page 271 of a book being deformed.

- shear strain = $\Delta x/h$, where Δx is the horizontal distance the shear force moves, and h is the height of the object.
- shear stress = $\frac{F}{A} = S\frac{\Delta x}{h}$

S = shear modulus

Again we can make the analogy to Hooke's Law.

$F = (A\ S/h)\Delta x \quad = k\ \Delta x$

$k = (A\ S/h)$

Big S = difficult to bend

Small S = easy to bend

Bulk Modulus

- volume elasticity

- relates to the response of an object to uniform squeezing.
- The volume stress ΔP is defined as the ratio of the magnitude of the change in the applied Force ΔF to the surface area A.
- volume strain = $\Delta V/V$
- $\Delta P = - B \Delta V/V$

- $\Delta P = - B \Delta V/V$
- Notice the minus sign. If ΔV is negative ΔP is positive. If you squeeze an object, the pressure increases.
- B = bulk modulus. Tells how easy it is to compress an object.

- The reciprocal of B is defined as the compressibility (κ).
- $B = 1/\kappa$
  - Small B – easy to compress
  - Big κ – easy to compress

- Side note

  Many materials such as bone and building materials are stronger under compression than they are under tension.

  The ability of bricks and stone to resist compression better than tension, led to the development of the arch.

  The weight that the arch supports forces the stones to squeeze against each other. This results in the horizontally outward forces at the base of the arch.

  The arch is kept stable by using heavy walls.

Density

Density ρ

Defined as the mass of an object divided by the object's volume.

$\rho = M/V$

SI units kg/m^3

Specific gravity: Ratio of the density of a material to the density of water. (Unitless)

Density of silver is $10.5x10^3$ kg/m^3

Density of water is $1x10^3$ kg/m^3

Specific gravity of silver is 10.5

Pressure

- Pressure = Force per area
- P = F/A
- SI units pascal (Pa)

- By increasing the area, the pressure produced by a large force is reduced.
  - snowshoes
  - bed of nails

Pressure and Depth

When a liquid is at rest, all portions must be in equilibrium. So all points at the same depth must be at the same pressure.

As depth increases, the pressure rises.

$P = P_0 + \rho g h$

P_0 = atmospheric pressure (1.013×10^5 Pa)

ρ = density

h = depth

see pg. 279

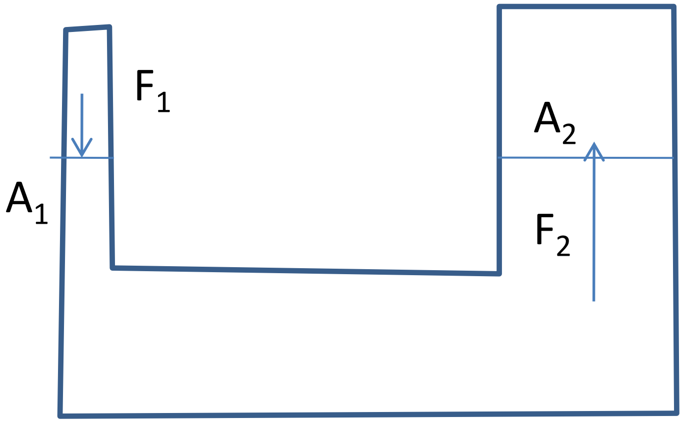
Pascal's Pricniple

Any increase in pressure at the surface must be transmitted to every point on the liquid.

An application of this is hydraulics.

The pressures at the two lines must be equal. $F_1/A_1 = F_2/A_2$

By varying the different areas, different forces can be exerted.



Archimedes Principle

- Considers buoyant forces
- Any object completely or partially submerged in a fluid is buoyed up by a force with magnitude equal to the weight of the fluid displaced by the object.
- $B = \rho_f V_f g$
- If B – W is positive, object rises
- If B – W is negative, object sinks

Floating object

- consider a floating object

The buoyant force is $B = \rho_f V_f g$

weight is $w = mg = \rho_o V_o g$

Floating means $B = w$

So: $\rho_f V_f g = \rho_o V_o g$

$(\rho_o/\rho_f) = (V_f/V_o)$

Fluid Motion

We will work with ‘ideal fluids’.

Characteristics of an ideal fluid

- **Nonviscous**, there is no internal friction force between adjacent layers in the liquid.
- **Incompressible**, the density is constant.
- **Motion is steady**, the velocity, density, and pressure at each point don’t change with time.
- **No turbulence**, zero angular velocity about its center. A small wheel won’t spin if placed in the liquid.

Continuity

Mass is conserved since the flow is steady.

The mass per time through each segment of a pipe is the same.

Units of mass/time = kg/s

$\rho A v = (kg/m^3)(m^2)(m/s) = kg/s$

$$\rho_1 A_1 v_1 = \rho_2 A_2 v_2$$

Since incompressible $\rho_1 = \rho_2$

So, $A_1 v_1 = A_2 v_2$

If the cross sectional area decreases, the velocity increases.

Bernoulli's Equation

- As a fluid moves through a pipe of varying cross section and elevation, the pressure will change.
- This is a consequence of conservation of energy.

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

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

This equation states that the sum of the pressure, the kinetic energy per unit volume and the potential energy per unit volume is a constant.

Each term in the equation has units similar to that of pressure.

Hole in a dam problem.

Suppose the is a hole in a dam located 2 meters below the surface of the lake the dam is holding back.

You can find using Bernoulli's eqn. how fast the water is pouring out of the hole.

$$P_L + \frac{1}{2} \rho v_L^2 + \rho g y_L = P_H + \frac{1}{2} \rho v_H^2 + \rho g y_H$$

$$P_L + \frac{1}{2}\rho v_L^2 + \rho g y_L = P_H + \frac{1}{2}\rho v_H^2 + \rho g y_H$$

Assuming the lake is large, the velocity of the water level dropping is 0.

Also, since the water is free to flow out of the hole, the pressures at the two relevant points are equal.

The equation becomes:

$\rho g y_L = \frac{1}{2}\rho v_H^2 + \rho g y_H$

Solve for v_H: $v_H = \sqrt{2g(y_L - y_H)}$

Bernoulli's Eqn. and airplanes

- Bernoulli's equation show why airplanes can leave the ground.
  - When air reaches the wing, it splits into 2 paths. One path goes above the wing, while the other goes under.
  - At the back side of the wing, the two air masses rejoin. This means that the two air masses take the same amount of time to go around the wing.
  - The wing is designed so that the air going over the wing moves faster than the air below the wing.

$$P_A + \frac{1}{2}\rho v_A^2 + \rho g y_A = P_B + \frac{1}{2}\rho v_B^2 + \rho g y_B$$

Since the wing is 'thin'. The two potential energy/volume terms cancel out.

$$P_A + \frac{1}{2}\rho v_A^2 = P_B + \frac{1}{2}\rho v_B^2$$

Since the velocity v_A is greater than v_B, for the equation to hold true, P_B must be greater than P_A.

If the pressure below the wing is greater than the pressure above the wing, a net force is acting upwards and provides 'lift'.

The plane rises.

Viscous flow – refers to the internal friction of a liquid.

Easier to pour water than to pour honey.

The honey is more viscous.

η = viscosity, r = radius, L = length

P1 – P2 = change in pressure across the pipe

$$\text{Rate of flow} = \frac{\pi R^4 (P_1 - P_2)}{8\eta L}$$

Motion in a viscous fluid

When an object moves through a viscous fluid, there is resistance.

Air resistance, water resistance…

The resistance force is determined by the geometry of the object (size and shape).

For a small sphere. $F_r = 6\pi\eta rv$

As velocity increases, so does F_r

For a falling object; when the resistive force F_r becomes equal to the weight, terminal velocity is reached.