

Section 3 Chapters 9-11

Chapter 9 Solid and Fluids

States of matter. Solid, Liquid, Gas, Plasma, Dark Matter, Dark Energy

Deformation of Solids

There are three moduli

1. Young's Y for tensile stress
2. Shear S for Shear stress
3. Bulk B for compression

All modulus are defined as modulus = Stress/Strain

Stress is always Force/Area

Strain is defined different of each type of strain

Tensile is $\Delta L/L$

Shear is $\Delta x/h$

Bulk is $-\Delta V/V$

See page 275 on Arches

Liquids

In liquids we do not measure mass and force. We use density and pressure

Pressure P is defined as F/A and the units are Newton's/sq meter or Pascal

Atmospheric pressure, the weight of the air above us is 1.013×10^5 P also sometime stated as 29.92 in, 1013 bar, 760 torr

Density ρ is defined as mass/volume.

Problem my brother in FL has a canoe that he fills with water when there is a hurricane. Approximate size is a box 5 m by 1 meter by .5 meters. How much will it weigh?

Answer: Its volume is $5 \times 1 \times .5 = 2.5$ cubic meters. The density of water is 10^3 kg/cubic m

The mass of the water is 2.5×10^3 kg. Weight $= mg = 24 \times 10^3$ n

5.4×10^3 lb \Rightarrow 2.7 ton!

Fluid and the three Laws of Fluid Statics

1. Variation of pressure with depth $P = P_0 + \rho gh$

See Building of the Pyramids p 282

How a Barometer works. $P_0 = \rho gh \Rightarrow h = P_0 / \rho g = 1.013 \times 10^5 / 9.8 \times 10^3 = 760 \text{ mm}, 29.92 \text{ in.}$

Problem: How tall a column would be needed for a water barometer?

Solution: $h = P_0 / \rho g = 1.013 \times 10^5 / 9.8 \times 10^3 = 10.3 \text{ m}, 34 \text{ ft.}$

This is the length of the longest straw!

2. Law of Hydraulics or Pascal's Law

Pressure is transmitted equally throughout a fluid.

P is equal every in a fluid under pressure. $P_1 = P_2 \Rightarrow F_1 / A_1 = F_2 / A_2$

See Example 9.7 p 281

See problem 28 page 316

Solution: Use $F_1 / A_1 = F_2 / A_2$ Where $A = \pi r^2 \Rightarrow 500 / \pi (.75)^2 = F_1 / \pi (.125)^2$

The force at point 1 $F_1 = 13.9 \text{ lb}$

Now use rotational equilibrium and sum of the torques = 0

$Fd = Fd, 13.9 \times 2 = F \times 12 \Rightarrow F = 2.3 \text{ lb}$

See Figure P9.27 how brake work.

3. Archimedes Principle An object in liquid displaces its weight of liquid creating a buoyancy force $B = \rho g V$, $B = W = mg = \rho V g$

Example 9.8 page 287

See Exercise 9.9 on 289

Solution: Fraction under water is defined by Volume Below water / Total Volume. Consider the special case of an ice cube of sides "a" floating in water. Total Volume is $a(a)(a)$, Volume below water is $a(a)(h)$ where h is the length of the side under the water. The fraction under water is then $aah / aaa = h/a$

Use Archimedes Principle $B = W$

Weight of ice $W=mg = \rho_{ice} Vg = \rho_{ice} aahg$

Buoyancy force is only on the ice that is under the water so

$B= \rho_{water} Vg= \rho_{water} aahg$ setting $W=B$, $\rho_{ice} aahg = \rho_{water} aahg$

$h=\rho_{ice} / \rho_{water} =917/1025=98.5\%$

Fluid Dynamics two Laws

Review assumptions of ideal fluid

1. Law of continuity of flow $v_1 A_1 = v_2 A_2$

As the area narrows the velocity of the flow increases. Note the unit of flow are cubic meters per second.

Problem: My brother fills his 2.5 cubic meter canoe with water. He stands 1 meter from the canoe and hold a hose with a 1.5 cm radius at his side 1 meter above the ground. How long will it take to fill the canoe?

Answer: Use Flow rate is vA . First find velocity of the water. This is old stuff. The water drops 1 m so $t=.45$ sec is the time for a drop of water to fall to the ground. The water travels 1 meter in the x direction in .45 sec so $v =d/t=1/.45=2.2$ m/sec

Area of the opening in the hose is $A=\pi r^2 =\pi(.015)^2 =.00071$ sq m

Flow rate $=2.2 \times .00071 = .0015$ cubic m/sec

Time $= 2.5/.0015 = 1667$ sec, 27.8 min

2. Bernoulli's Equation (Conservation of Energy for fluids)

$P + 1/2 \rho v^2 = \rho gh = \text{constant}$.

At constant height as velocity increases the pressure decreases.

Examples

- Blood in veins
- Blowing on pages to separate them
- Perfume atomizer
- Air foil
- Kitchen plumbing

See Torricelli's Law Example 9.13 page297

Chapter 10 Thermal Physics

Zeroth Law of Thermodynamics. Heat flow from hot to cold objects until they have the same temperature.

Ways to measure temperature

1. Volume of a gas at constant pressure
2. Pressure of a gas at constant volume
3. Length of a solid
4. Volume of a liquid
5. Color
6. Electrical resistance
7. Thermocouple, two dissimilar metal connected EGT

Temperature scales Fahrenheit 180 degrees between boiling a freezing water.

Celsius/Centigrade and Kelvin 100 degrees between boiling a freezing water.

Taking account of 32F is freezing and 0 C and 273K

$180C=100F \Rightarrow 1.8C = F$ except the zero are not the same so the scales are offset by 32 degrees. $1.8C+32 = F$. For weather type temperatures Double C and add 30 to get F

Linear expansion

$$\Delta L = L\alpha\Delta T$$

Problem: A steel I-beam is 30 m long at 30 degrees C. How much does it expand when the temperature is raised to 90 C?

Answer: $\Delta L = 30 \times 60 \times 11 \times 10^{-6} = 2cm$

Why does glass break when it goes from hot to cold?

Why does Pyrex glass not break?

Coefficient of linear expansion!

Bimetallic strips and thermostats

Does a hole in a plate of metal get larger or smaller when the plate is heated? Larger.

Coefficient of area expansion.

$$A_0 = L_0 L_0$$

$$A = LL = (L_0 + \Delta L)(L_0 + \Delta L)$$

$$A = L_0 L_0 + 2L_0 \Delta L + \Delta L \Delta L$$

$$A = A_0 + 2L_0 \alpha L_0 \Delta T$$

$$\Delta A = A - A_0 = 2\alpha A_0 \Delta T$$

$$\Delta A = 2\alpha A_0 \Delta T = \beta A_0 \Delta T$$

Where

$$\beta = 2\alpha$$

$$\gamma = 3\alpha$$

Strange Behavior of Water and lake freezing from the top not bottom

Ideal Gas Laws

- 1. Gas is made up of tiny elastic balls (energy and momentum are conserved)**
- 2. The move at random**
- 3. They are point and have no volume.**

THE STATE EQUATION OF AN IDEAL GAS

$$**PV=nRT**$$

P is pressure

V is volume

T is temperature **in Kelvin**

R is the universal gas constant =8.31 J/mol K

n is the number of moles

Moles

1 mole of any substance contains Avogadro's number of the particles 6.02×10^{23}

The atomic number of carbon is 12 and 12 grams of carbon is one mole

e.g The atom weight of water is 18 and 18 grams of water is one mole.

See Example 10.6 on page 336

Note this trick

$$P_1V_1 = n_1RT_1$$

$$\frac{P_1V_1}{P_2V_2} = \frac{n_1RT_1}{n_2RT_2}$$

$$\frac{P_1V_1}{P_2V_2} = \frac{n_1T_1}{n_2T_2}$$

Problem: Your tire has a pressure of 30 PSI at 31 C. What is the pressure at 1 C

Answer: If your answer is .97 PSI you forgot T is in Kelvins!

$$31C=304K$$

$$1C =274K$$

n and V do not change so we have

$$\frac{P_1}{P_2} = \frac{T_1}{T_2}$$

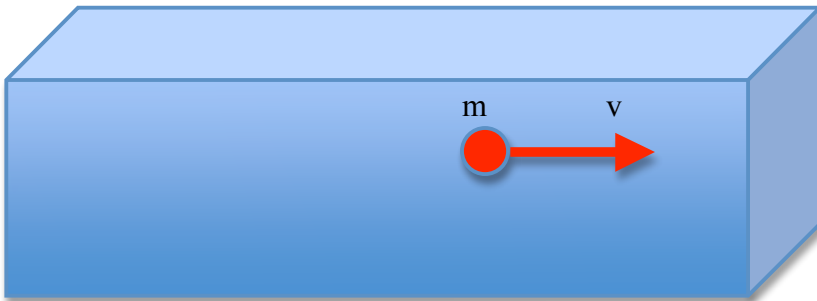
$$\frac{30}{P_2} = \frac{304}{274}$$

$$P_2 = 27PSI$$

See Example 10.8 Page 338

Kinetic Theory of Gas Connects the microscopic the macroscopic.

L



Ideal gas molecule of mass m moving at velocity v in the x direction and bouncing off ends of a box L m long.

There is a double transfer of momentum because of the elastic collision off of the wall

$$F\Delta t = \Delta mv = 2mv$$

Δt is time between collisions with the right hand wall. The molecule travels 2L at velocity v, so

$$\Delta t = 2L/v$$

$$F = \frac{2mv}{2L/v} = \frac{mv^2}{L}$$

Divide by A the area of the end piece

$$\frac{F}{A} = P = \frac{mv^2}{V} \text{ where } AL = V$$

Now account for N molecules hitting the wall

$$P = \frac{Nmv^2}{V}$$

$$PV = N2(1/2mv^2)$$

But the molecule must hit six wall not just to so we must divide by 3

$$PV = N \frac{2}{3} (1/2mv^2) = nRT$$

$$N(1/2mv^2) = \frac{3}{2} nRT$$

$$N(1/2mv^2) = \text{Kinetic Energy of all the molecule in the gas}$$

This astounding result state that the temperature of a gas is related only to the motion if the molecules and is equal to the total energy of the molecules. This is so important that it is given a special name U internal energy and is the property of a gas just like P, T, n, and V

$$U=3/2nRT$$

The opposite is also true. The temperate determines the distribution of velocities in a gas. See Figure 10.15 page 343.

Chapter 11 Energy in Thermal Process

Scientist studying heat measure heat energy in calories. Note weight loss Calories Cal = 1,000 cal calories. Let it was discovered that heat was a form of energy (kinetic energy) and could be measured in joules.

$$1 \text{ cal} = 4.186 \text{ joules}$$

Example a 60 kg woman walks from ground to the MS lab 6 meter does $W=Fd=60 \times 9.8 \times 6=3,528$ J or she used $3,528/4.186 = 843 \text{ cal}$ or $.843 \text{ C}$. A low calorie slice of bread has 70 C how many time must the woman walk up to the lab to burn off 70C? Answer $70/.843= 83$ times.

Calorimetry

The Zeroth Law of Thermodynamics states heat flow from hot object to cold object. Calorimetry is used to find out how much heat.

Q is heat flow $Q=mc\Delta T$ c is the specific heat of a substance.

$$Q_{\text{Cold}} = -Q_{\text{Hot}}$$

See Example 11.3 page 357

Latent Heat and Phase Change

During a phase change Liquid to Solid, Solid to Liquid, Liquid to Gas, Gas to Liquid there is **NO TEMPERATURE CHANGE**

Q heat flow $Q=Lm$ where L is the latent heat.

FL planter spray water before a freeze and farmer keep a tub of water in there fruit cellars.

See Page 361

Problem I have 40 gr. of hot tea at 80 C and want to ice tea at 2C how much ice must I add?

$$Q_{\text{Cold}} = -Q_{\text{Hot}}$$

$$Q_{\text{Hot}} = mc\Delta T = 40(1)(2-80) = -3,160 \text{ cal}$$

$$Q_{\text{Cold}} = Lm + mc\Delta T = 80(m) + m(1)(2-0) = 82m$$

$$82m = -(-3,160) \quad m=38.5 \text{ gr.}$$

Methods of Energy Transfer

1. Conduction
2. Convection

3. Radiation

Conduction Hot and cold source must be in contact

$$P = kA \frac{\Delta T}{L}$$

Where k is thermal conductivity

See Quick Quiz 11.4

$$P = kA \frac{\Delta T}{L} = A \frac{\Delta T}{L/K} = A \frac{\Delta T}{R} = A \frac{\Delta T}{\sum R}$$

$R = R - \text{Value}$

See Example 11.10 page 369

Why do code require more insulation in the attic than in the walls?

Convection actual matter moves from hot to cold areas (Wind)

My childhood coal furnace. Lake cooling. Baseboard heating

Why does a space craft get cold (Apollo 13)

No conduction nothing in contact, No convection no molecules is space.

Radiation

Every object radiates energy based on it temperature

$$P = \sigma A e (T^4 - T_0^4)$$

σ is Stefan - Boltzman constan 5.669×10^{-8}

e is the reflective %. 0 100% reflection 1 no reflection (black body)

T_0 is the surrounding temperature

Some information from Alton Brown Cookbook *I'm Just Here For the Food*