1.1 Kinematics

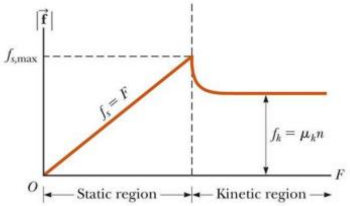
$v = \frac{\Delta x}{\Delta t}$ $a = \frac{\Delta v}{\Delta t}$

Newtonian mechanics

1st + 2nd: $\vec{F} = m \times \vec{a}$

3rd: $\overrightarrow{F1} = -\overrightarrow{F2}$

Friction force



Circular motion

$$F = m\,\frac{v^2}{r} = m\,\omega^2 r$$

Gravitation

$F = G\,\frac{m1\,m2}{r^2}$ (G = 6.673* 10^{-11})

Energy

KE = $\frac{1}{2}mv^2$

PE = mgh

1.2 Forces & Motion in Liquids

Pressure

$P = \frac{F}{A}$ (pa)

$P = \rho g h$ (In liquid of depth h)

Pascal Principle: A change in pressure applied to an enclosed fluid is transmitted undiminished to every point of the fluid and to the walls of the container.

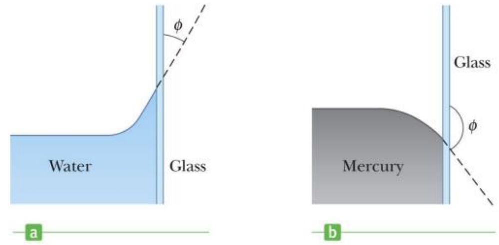
One atmosphere (1 atm) = 76.0 cm of mercury

= 1.013 × 10^5 Pa

Buoyant force

$F = \rho g V = weight\ displaced$

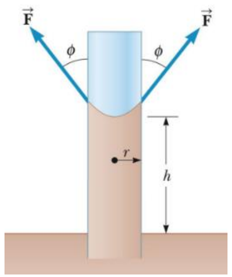
Surface Tension



Φ is called the contact angle

- In a, ϕ < 90° and adhesive forces are greater than cohesive forces
- In b, ϕ > 90° and cohesive forces are greater than adhesive forces
- A lifting or pressing force directed along the contact angle

Capillary action



F = γ(2πr)

γ is a constant decided by liquid & solid

$$h = \frac{2\gamma}{\rho g r}\cos\varphi$$

The weight of the lifted liquid

w = Mg = ρVg ≈ ρg($\pi r^2 h$)

Flow of liquid

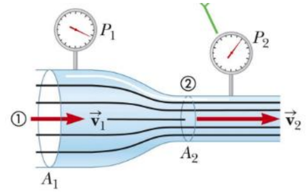
Poiseuille's Law: the volume flow rate of a fluid in a tube is proportional to the pressure difference

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

A1v1 = A2v2 = constant

Bernoulli's Equation

$$P + \frac{1}{2}\rho v^2 + \rho g y = \text{constant}$$



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

Liquid viscosity

A fluid between two solid surfaces (the bottom surface is fixed and the top moveable) A force moves upper surface by a constant speed v so that the force equals to friction

$$F = \eta \frac{Av}{d}$$

A is contact area between the upper surface and liquid

η is the coefficient of viscosity (N s/m^2)

Sedimentation rate & centrifuge

Frictional coefficient for a small, spherical object (good approximation for cells & biomolecules)

$K_r = 6\pi\eta r$

The speed at which materials fall through a fluid to reach the bottom of a container is called the **sedimentation rate,** which is often determined by the terminal speed of the materials in the fluid

$$v_t = \frac{mg}{k_r}\left(1 - \frac{\rho_f}{\rho}\right)$$

m - mass of the object

$\rho(\rho_f)$ – density of the object (fluid)

For an object in centrifuge, g is replaced by $\omega^2 r$

(ω - angular speed of the rotation, here combines into centripetal acceleration)

Reynolds number

Consider an object (e.g., a cubic fluid parcel) of size L moving at speed U in liquid

$$\mathrm{Re} = \frac{\rho U^2 / L}{\eta U / L^2} = \rho L U / \eta = \frac{\text{kinetic energy}}{\text{dissipated energy}}$$

Diffusion

Diffusion rate is proportional to concentration difference

$$\text{Diffusion rate} = \frac{\text{Mass}}{\text{time}} = DA\left(\frac{C_2 - C_1}{L}\right)$$

$(C_2 - C_1)/L$ is concentration change per unit of distance along the flow direction

D is the diffusion coefficient

A is cross-sectional area of the tube

1.3 Electric-magnetic force & motion

Coulomb's Law K_e= 8.9875 x $10^9\ N\ \frac{m^2}{C^2}$

$$F = k_e \frac{|q_1||q_2|}{r^2}$$

Like charges repeal, unlike charges attract

$$e = 1.6 \times 10^{-19} C$$

Electric Field (N / C)

Field at the position of the test charge is defined as the electric force on it divided by its charge

$$\vec{E} = \frac{\vec{F}}{q_0} \qquad E = |\vec{E}| = \frac{k_e q}{r^2}$$

Direction of the field is that of the force on the positive test charge

Electric Flux (N m² / C)

Electric flux is a measure of how much the electric field vectors penetrate through a given surface.

Φ_E = E A cos θ, when the perpendicular to the area A is at an angle θ to the field

Gauss' Law

The electric flux passing through any closed surface from inside to outside is equal to the net charge Q inside the surface divided by εo (permittivity of free space and equals 8.85 x $10^{-12}\ C^2/\text{Nm}^2$)

$$\Phi_E = \frac{Q_{inside}}{\varepsilon_o}$$

Coulomb constant $k_e = \frac{1}{4\pi\varepsilon_0}$

Electric Potential Energy

The change of electric potential energy of a charge q making a displacement Δx in the direction of a constant field E is defined as

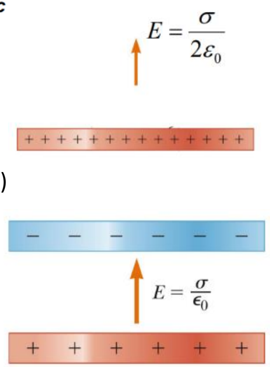
$$\Delta PE = -q\ E\ \Delta x \qquad PE = k\ \frac{Q}{r}\ (point\ charge)$$

$$C = \kappa C_o = \kappa\varepsilon_o(A/d)$$

Capacitor

κ is called the ***dielectric constant.***

σ=charge density



The constant of proportionality is called **capacitance**, C, of a capacitor (F)

Q = CΔV; C = Q / ΔV

Energy = ½ Q ΔV

Conductor

1: The electric field is zero everywhere inside the conductor

2: Any excess charge on an isolated conductor resides entirely on its surface

3: The electric field just outside a charged conductor is perpendicular to the conductor's surface

4: On an irregularly shaped conductor, the charge accumulates at sharp points

Current

n is the number of charge carriers per unit volume; q is the charge per carrier

$$\Delta Q = (n\ A\ \Delta x)q$$

Current-drift speed relation $I = \frac{\Delta Q}{\Delta t} = nqvdA$

Ohms law

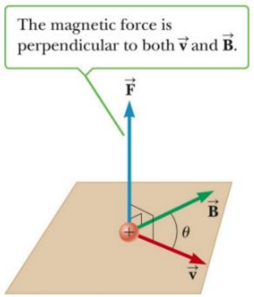
$$\mathbf{R} = \frac{\Delta V}{I} \qquad R = \rho\frac{\ell}{A}$$

$$Power = I^2 R$$

1.3.2 Magnetic force, field & motion

$$F = B\ q\ v\ sin\ \theta$$

Right Hand Rule (positive charge) =>



Magnetic Field (Tesla)

$$B \equiv \frac{F}{qv\sin\theta} \qquad T = \frac{N}{C\cdot(m/s)} = \frac{N}{A\cdot m}$$

Force on a Charged Particle in a Magnetic Field

Causes uniform circular motion

$$F = qvB = \frac{mv^2}{r} \qquad r = \frac{mv}{qB}$$

Mass Spectrometer

The perpendicular component still follows the circular path

The parallel component remains a constant, why?

$$v_{para} = cons\tan t$$

Combined the two motional components, the particle follows a spiral

Two particles of small mass difference can have large radius difference by shooting them into a magnetic field with a high speed

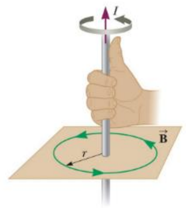
Magnitude of the Field of a Long Straight Wire

The magnitude of the field at a distance r from a wire carrying a current of I is

μo = 4 $\pi \times 10^{-7}$ T m / A

$$B = \frac{\mu_o I}{2\pi r}$$

μo is called the permeability of free space



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(Done by DDX-510)