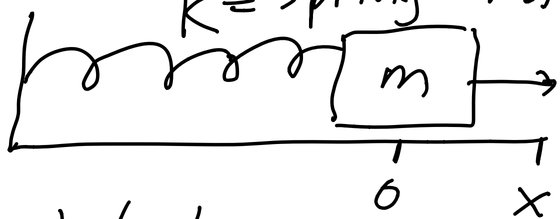
Plasma Oscillations modeled as a mass on a spring

$k \equiv$ spring constant → property of the material



Hooke's Law

$$\boxed{\underline{F} = -kx}$$ → displacement from equilibrium

$$\underbrace{\text{Restoring Force} \propto \text{displacement}}$$

that system exhibit Simple Harmonic Motion

$$x(t) = A\cos(2\pi f t)$$

Very useful model:

1) Amplitude is independent of freq of oscillation
2) Freq is related only to spring constant k, and the inertia of the system, m

1) $\Rightarrow$ Hooke's Law

2) $K \Rightarrow$ springiness

$m \Rightarrow$ how much it resists

$$f = \frac{1}{2\pi}\sqrt{\frac{K}{m}}$$

Model plasma as a mass on a spring

$\Rightarrow$ Restoring Force $\sim$ displacement

$\Rightarrow$ Spring constant

$\Rightarrow$ Mass

$\Rightarrow$ Displacement

Plasma is collection of charged ions and electrons that exhibit collective behavior

Consider

$$F = qE$$

$$E = \frac{q}{4\pi\varepsilon_0 r^2}$$

$$F \sim \frac{q^2}{r^2}$$

$$F \Rightarrow \frac{q^2}{(r+x)^2}$$

Rather than just a system of particles

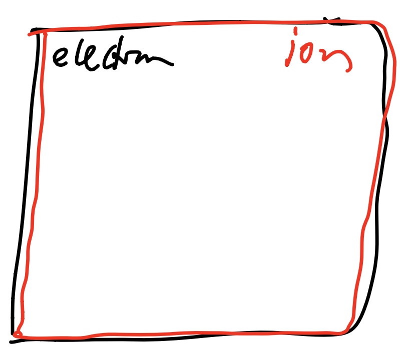
$\Rightarrow$ Consider a plasma as a charged fluid

$\Rightarrow$ bulk properties

density, temperature

flow / velocity

2 Fluids $\Rightarrow$ electron fluid, ion fluid



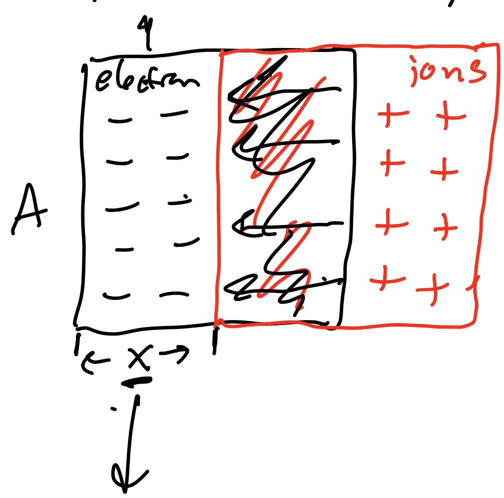
$\frac{\#\ \text{particle}}{\text{vol}}$ n # density

$\frac{\text{mass}}{\text{vol}}$ mass density

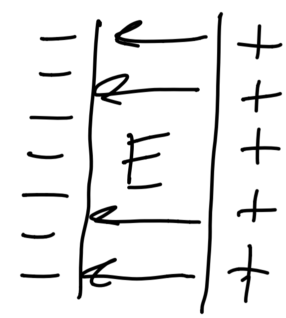
$\frac{\text{charge}}{\text{vol}}$ charge density

Assumptions

1) Particles stay charged
2) Particles don't move $(T=0)$
3) Slabs are infinite
4) Motion is only 1D $\Rightarrow x$



$\Rightarrow$



$E \Rightarrow$ uniform and constant

Force $F = qE$

$$E = \frac{Q_{TOT}}{\varepsilon_0 A}$$

$$F = q\,\frac{Q_{TOT}}{\varepsilon_0 A} \Rightarrow$$

$$Q_{TOT} = (\text{charge density})V$$
$$enAx$$

$$F = \frac{e^2 n \cancel{A}}{\varepsilon_0 \cancel{A}}\,x$$

$$\boxed{F = \frac{e^2 n}{\varepsilon_0} x}$$

Restoring Force ~ displacement

$$F = kx \qquad k = \frac{e^2 n}{\varepsilon_0}$$

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} = \frac{1}{2\pi}\sqrt{\frac{e^2 n}{\varepsilon_0 m_e}}$$

Plasma oscillation frequency