Online class # 16

Date: aa/09/2021

Topics: Plasmons, Polaritons, and Polarons

Time: 0950 – 1050

Video: https://youtu.be/gAbwcKvBbEU

Reference

Introduction To Solid State Physics

– Charles Kittel

Topics: Plasmons, Polaritons, and Polarons

Plasmons, Polaritons, and Polarons

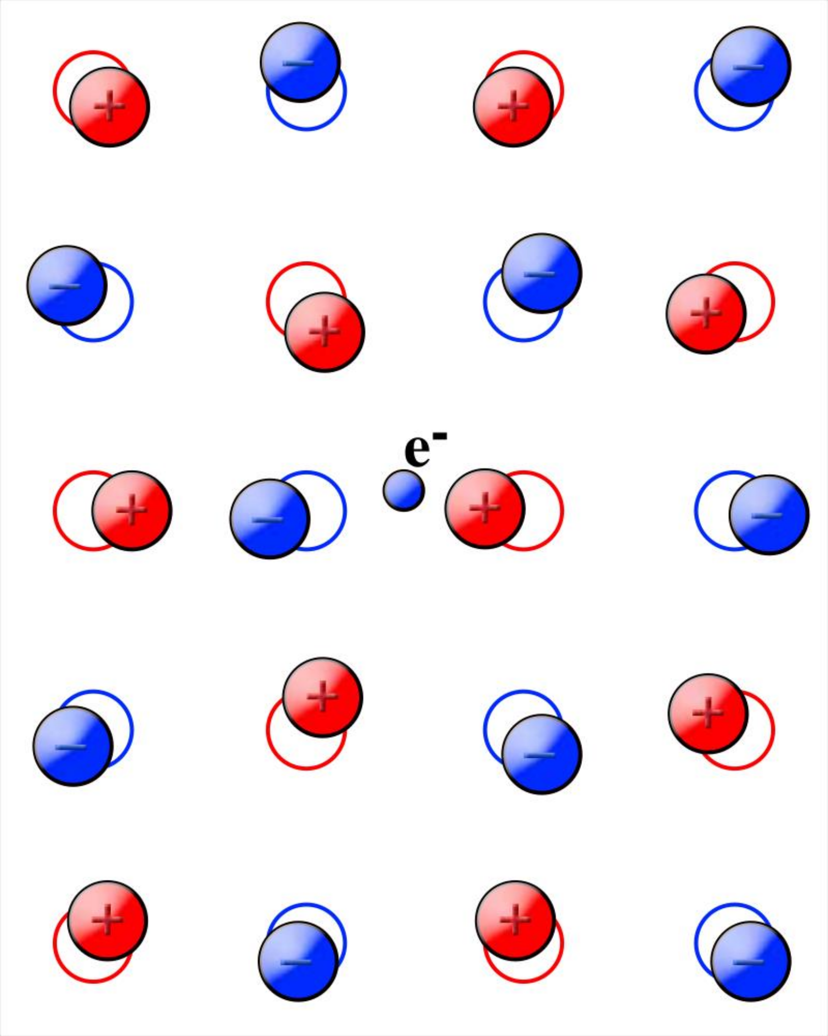
Plasmon: A quantum or quasiparticle associated with a local collective oscillation of charge density.

A polariton is a quasi-particle formed when photons couple strongly with excitons. Polaritons are quasiparticles in a medium that form as a result of interaction and mixing of light with dipole active transitions of the medium.

Plasmons, Polaritons, and Polarons

A polaron is a quasiparticle used in condensed matter physics to understand the interactions between electrons and atoms in a solid material.

An electron accompanied by this kind of electrical displacement of neighbouring charges constitutes a polaron.



What is dielectric?

Dielectric Constant

$\parallel$

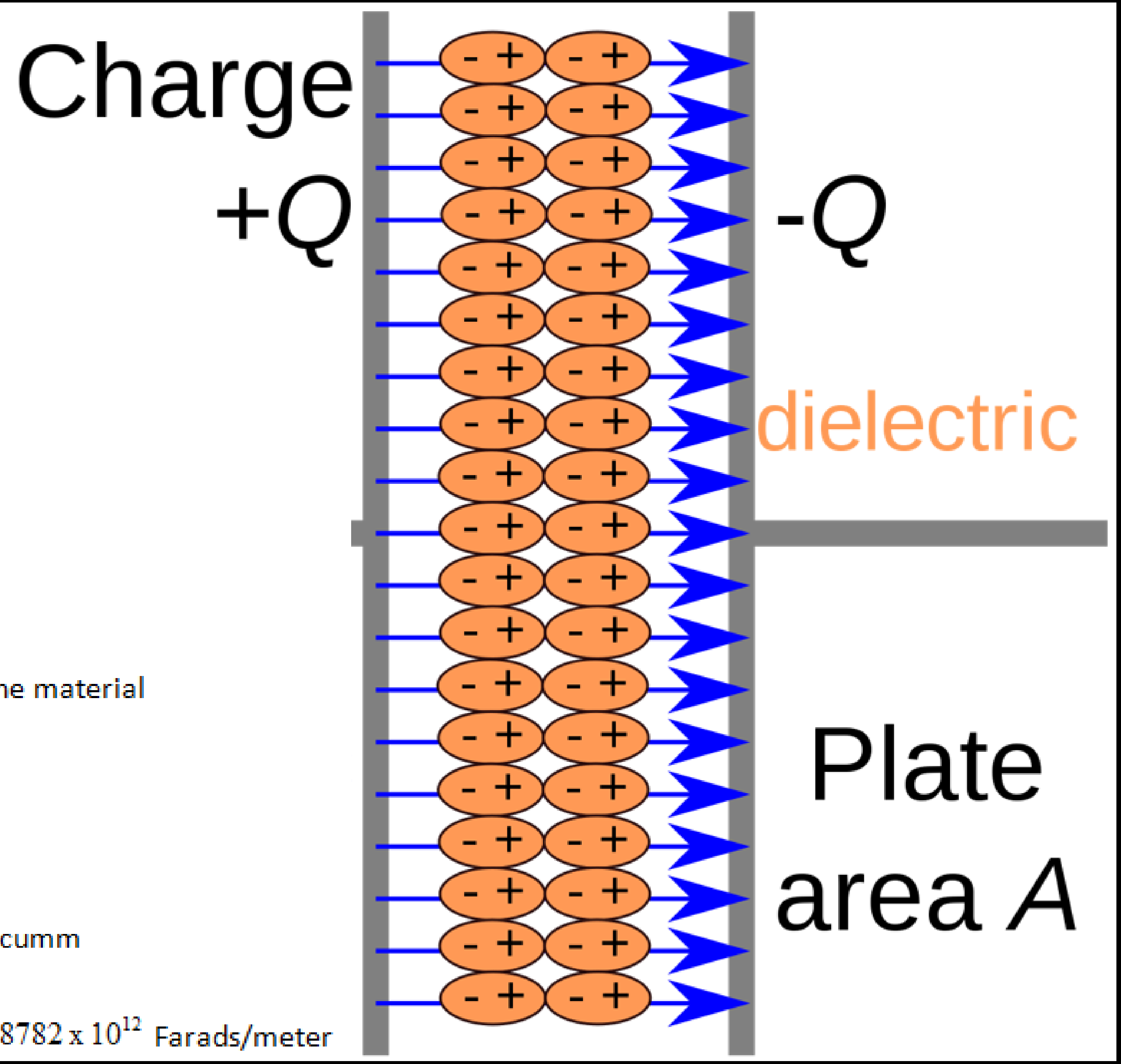
Relative Permittivity

Permittivity of the material

$$\kappa = \varepsilon_r = \frac{\varepsilon_m}{\varepsilon_0}$$

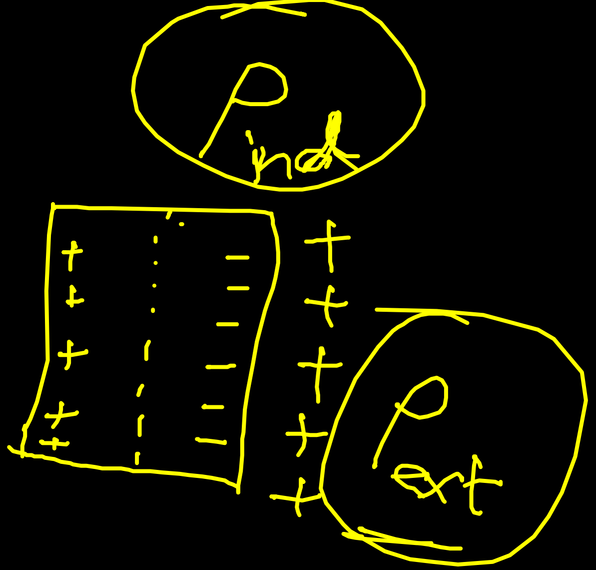
Permittivity of Vacumm

$8.85418782 \times 10^{12}$ Farads/meter



Dielectric function: ϵ ε

$$\bar{D} = \bar{E} + 4\pi \bar{P} = \epsilon \bar{E}$$



$$\boxed{\mathrm{div}\, D} = 4\pi \rho_{ext}$$

$$\boxed{\mathrm{div}\, E} = 4\pi \rho = 4\pi(\rho_{ind} + \rho_{ext})$$

$$\rho = \rho_{ext} + \rho_{ind}$$

$$\rho_{ext} = \rho - \rho_{ind}$$

$$D(k) = \epsilon(k)\, \underline{E(k)} \qquad E$$

$$\operatorname{div}\bar{E} = \operatorname{div}\sum \bar{E}(k)\, e^{i\bar{k}\cdot\bar{r}}$$

$$= 4\pi \sum \rho(k)\, e^{i\bar{k}\cdot\bar{r}}$$

$$\operatorname{div}\bar{D} = 4\pi \sum \rho_{ext}(k)\, e^{i\bar{k}\cdot\bar{r}}$$

$$\boxed{\epsilon} = \frac{\rho_{ext}}{\rho} = 1 - \frac{\rho_{ind}}{\rho}$$

$$\bar{D} = -\bar{\nabla}\phi_{ext} \rightarrow \bar{\nabla}\cdot\bar{D} = -\bar{\nabla}^2\phi_{ext}$$

$$\bar{E} = -\bar{\nabla}\phi \rightarrow \bar{\nabla}\cdot\bar{E} = -\bar{\nabla}^2\phi$$

$$-\nabla^2\phi_{ext} = 4\pi\rho_{ext}$$

$$\epsilon(q) = \frac{\rho_{ext}}{\rho} = \frac{\phi_{ext}}{\phi}$$

$$-\nabla^2\phi = 4\pi\rho$$

$F = ma$

$ma = F$?

Equation of motion

$$\boxed{m\frac{d^2x}{dt^2} = -eE}$$

$e^{-i\omega t}$

E, x

$\frac{d^2x}{dt^2} =$

$E = E_0 e^{-i\omega t}$

$x = x_0 e^{-i\omega t}$

$-e$

x

E

ex

x_0

$+e \quad -e$

$$x = x_0 e^{-i\omega t}$$

$$(-i)^2 = (-i)(-i) = i^2 = -1$$

$$\frac{dx}{dt} = x_0(-i\omega)e^{-i\omega t}$$

$$\frac{d^2x}{dt^2} = \frac{d}{dt}\left(\frac{dx}{dt}\right) = x_0(-i\omega)^2 e^{-i\omega t}$$

$$= -\omega^2 x$$

$$\boxed{-m\omega^2 x = -eE}$$

$$x = \frac{eE}{m\omega^2}$$

$$\omega^2 = \frac{eE}{mx}$$

$\rho = ne$

$-ex = -e^2 E / m\omega^2$

$-exn$

$P = -nex = -\frac{ne^2}{m\omega^2} E$

$n \rightarrow$ number of electrons per unit volume

$\epsilon = \frac{D}{E} = \frac{E + 4\pi P}{E} = 1 + 4\pi \frac{P}{E}$

$$\boxed{\epsilon(\omega) = 1 - \frac{4\pi n e^2}{m\omega^2}}$$

$$\epsilon(\omega) = 1 - \frac{4\pi n e^2}{m\omega^2}$$

$\omega \rightarrow$ frequency

Plasma frequency

$$\omega_p^2 = \frac{4\pi n e^2}{m}$$

$$\boxed{\epsilon(\omega) = 1 - \frac{\omega_p^2}{\omega^2}}$$

CGS

$\epsilon(\infty)$

$$\epsilon(\omega) = \epsilon(\infty) - \frac{4\pi n e^2}{m\omega^2} = \epsilon(\infty) - \frac{\omega_p^2}{\omega^2}$$

$$\omega_p^2 = \epsilon(\infty)\,\bar{\omega}_p^2$$

$$\omega = \bar{\omega}_p$$

$$= \epsilon(\infty)\left[1 - \frac{\bar{\omega}_p^2}{\omega^2}\right]$$

$$\boxed{\epsilon(\omega) = 0}$$

$$\bar{\omega}_p^2 = \frac{4\pi n e^2}{\epsilon(\infty)\, m}$$

$$E = h\nu = \frac{hc}{\lambda}$$

$$\frac{E\,(cm^{-1})}{\nu\,(cm^{-1})}$$

$$= \frac{h\omega}{2\pi} = \hbar\omega$$