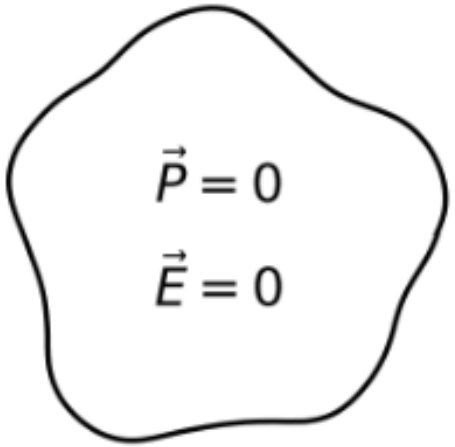
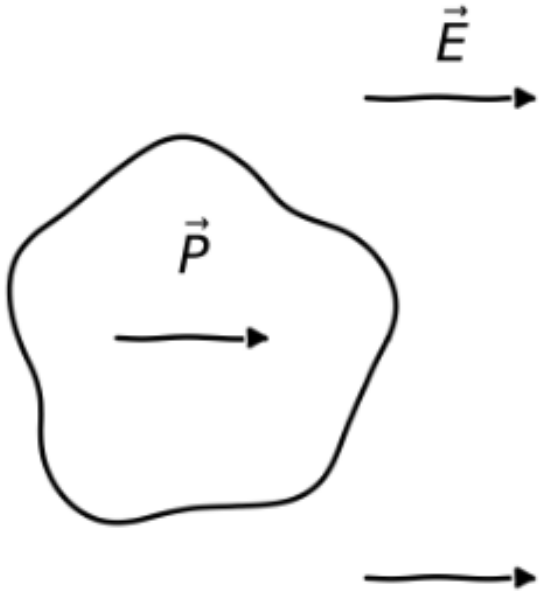
Lecture 24 Slides
Phys 313 Fall 2026

Electric Field vs. Displacement Field

$\vec{E}$	$\vec{D} = \varepsilon_0 \vec{E} + \vec{P}$
$\nabla \cdot \vec{E} = \rho/\varepsilon_0$	$\nabla \cdot \vec{D} = \rho_{free}$
$\oint_S \vec{E} \cdot d\vec{a} = \frac{Q_{enc}}{\varepsilon_0}$	$\oint_S \vec{D} \cdot d\vec{a} = Q_{enc,free}$
$\vec{E}(\vec{r}) = \frac{1}{4\pi\varepsilon_0} \int_V \rho(\vec{r}\,') \frac{\hat{\boldsymbol{z}}}{\boldsymbol{z}^2} \, d\tau'$	$\vec{D}(\vec{r}) \neq \frac{1}{4\pi} \int \rho_{free}(\vec{r}\,') \frac{\hat{\boldsymbol{z}}}{\boldsymbol{z}^2} \, d\tau'$
$\nabla \times \vec{E} = 0$ in electrostatics	$\nabla \times \vec{D} = -\varepsilon_0 \nabla \times \vec{E} + \nabla \times \vec{P}$ $\neq 0$ in general!

Linear Isotropic Homogeneous (LIH) Dielectrics





$$\vec{P} = \varepsilon_0 \chi_e \vec{E}$$

Charge neutral ($Q = 0$) polarizable material

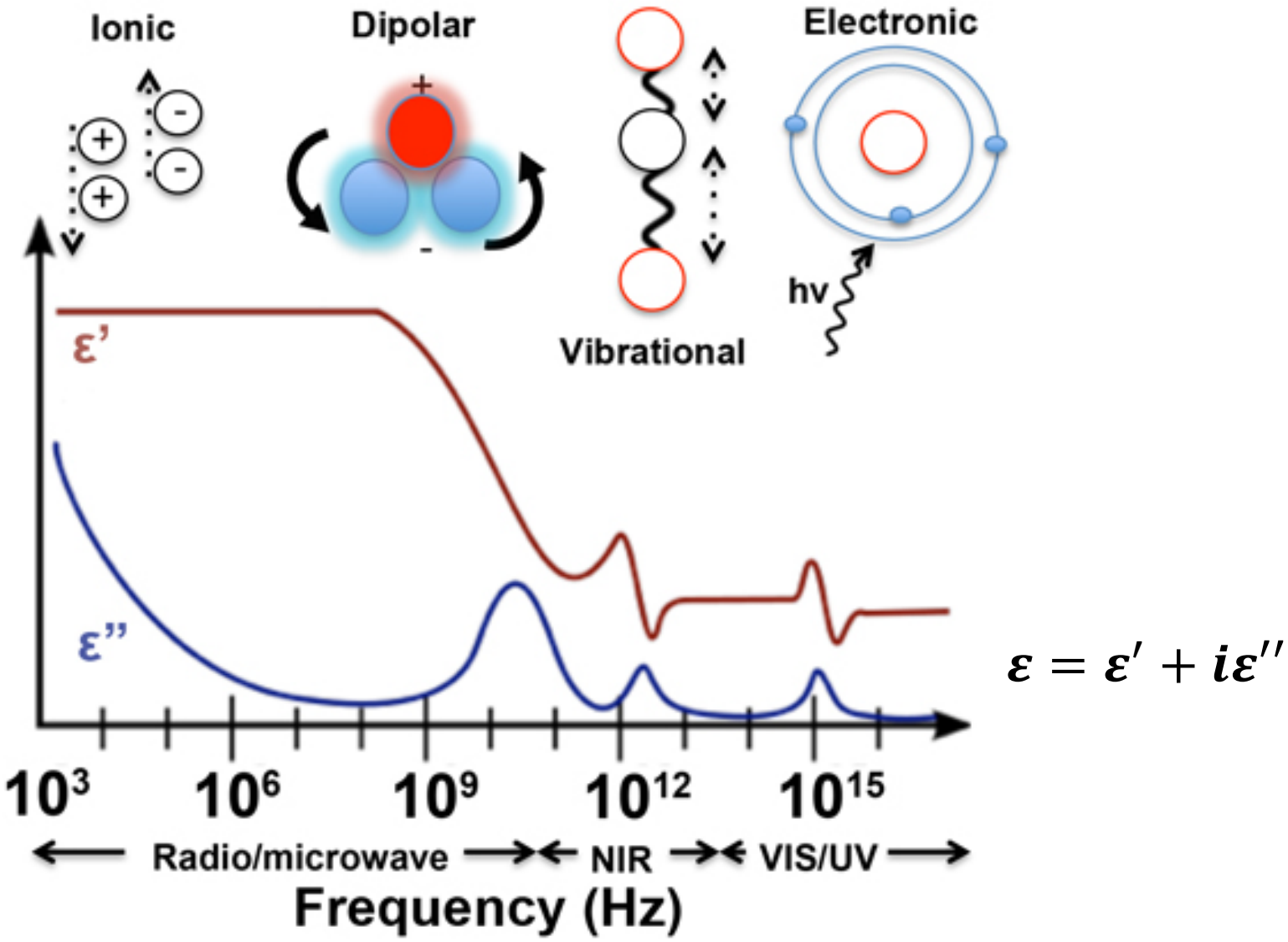
$\varepsilon \equiv \varepsilon_0(1+\chi_e)$ is called the permittivity, or dielectric constant, of the material

$$\varepsilon_r \equiv \frac{\varepsilon}{\varepsilon_0} = 1 + \chi_e$$

Material	Dielectric constant	Material	Dielectric constant
Vacuum	1	Benzene	2.28
Helium	1.000065	Diamond	5.7–5.9
Neon	1.00013	Sodium chloride	5.9
Hydrogen (H_2)	1.000254	Silicon	11.7
Argon	1.000517	Methanol	33.0
Air (dry)	1.000536	Water	80.1
Nitrogen (N_2)	1.000548	Ice (−30°C)	104
Water vapor (100°C)	1.00589	$KTaNbO_3$ (0°C)	34,000

Dielectric ‘Constant’ vs. Frequency of Alternating Electric Field

$$\varepsilon_r \equiv \frac{\varepsilon}{\varepsilon_0} = 1 + \chi_e$$



$$\varepsilon = \varepsilon' + i\varepsilon''$$

https://stanslegacy.com/documents/the-dielectric-constant-of-water