Debye Relaxation Model

MSE/EE 590 Discussion 1

Pressure Broadening and Debye’s Relaxation Equation

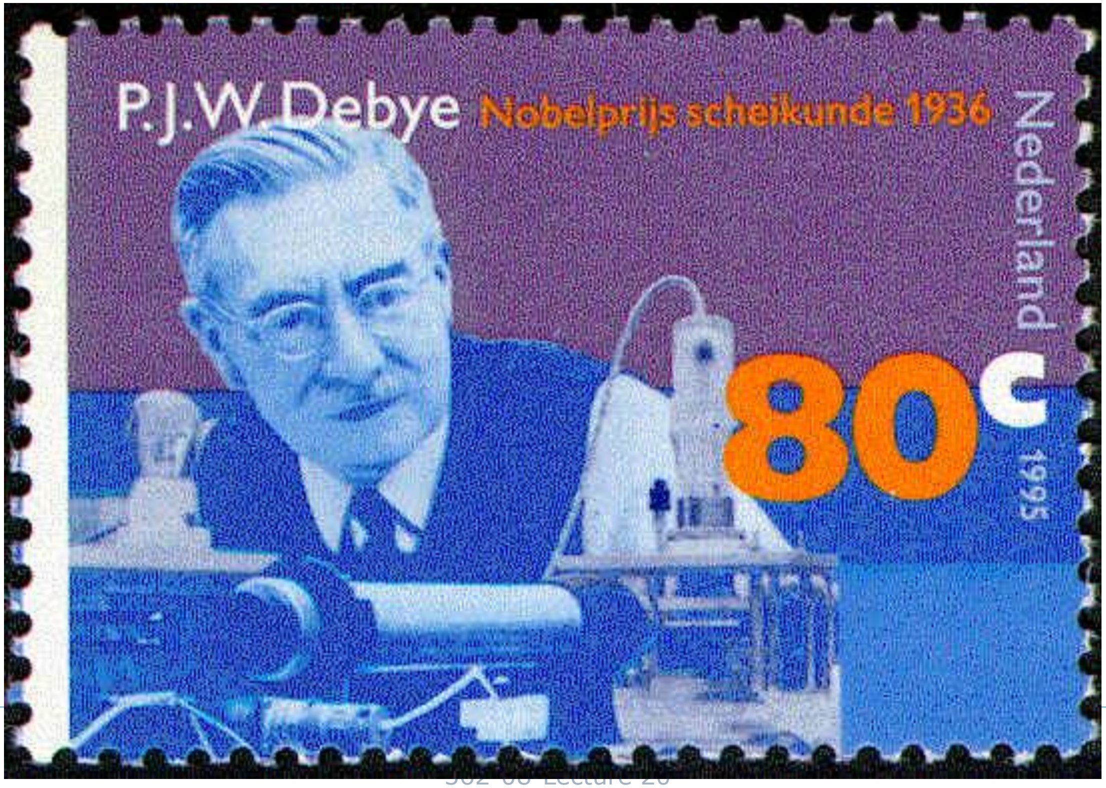
P. Debye, Polar Molecules, The Chemical Catalog Company, Inc., New York, 1929. Section 18, pp. 89-95.

Polar Liquids under the Influence of High Frequencies

A. R. von Hippel, Dielectrics and Waves, Chapman & Hall, Ltd., New York, 1954. Section 22, pp. 174-178.

Debye

- Dutch-American physicist, 1884-1966
- Nobel prize in chemistry, 1936



Electric dipole moment

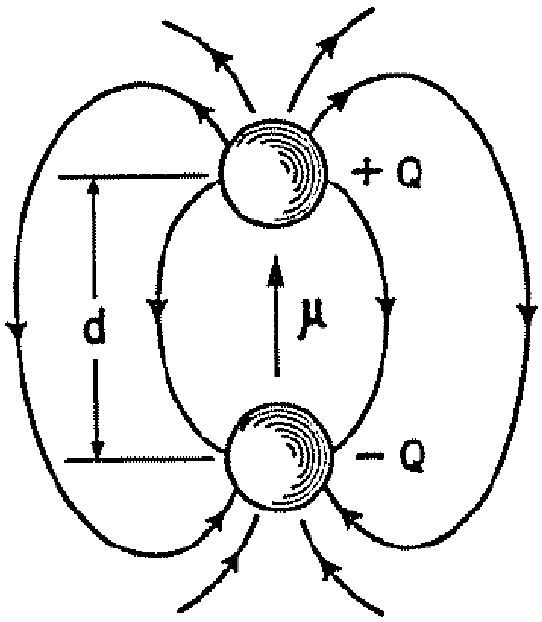
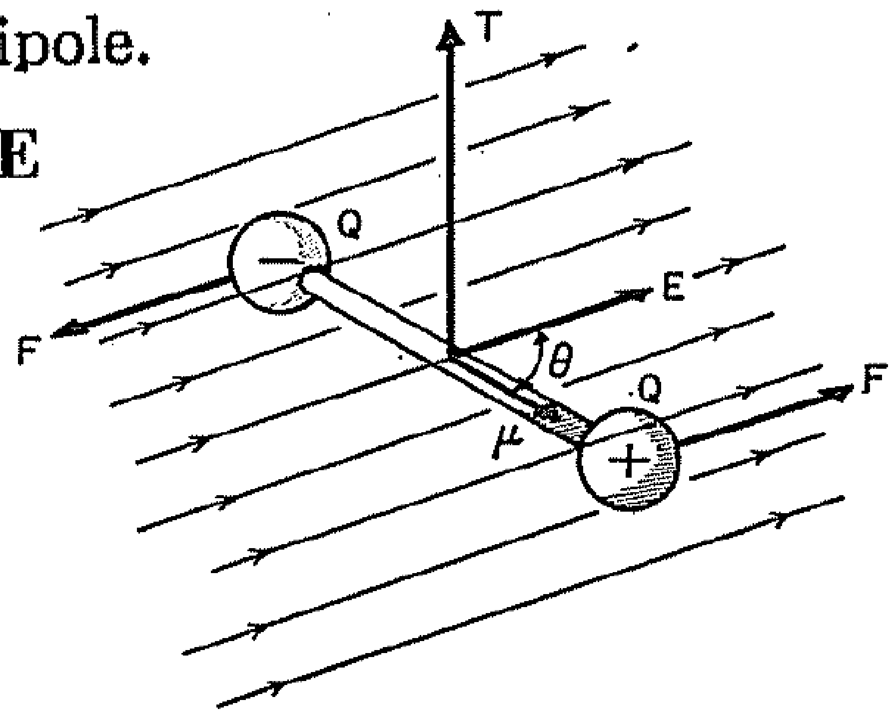


Fig. 2.3. Electric dipole of the moment $\mu = Qd$.

Torque and potential energy

Torque acting on electric dipole.

$$\mathbf{T} = |\boldsymbol{\mu}|\ |\mathbf{E}| \sin\theta = \boldsymbol{\mu} \times \mathbf{E}$$



Potential energy: $U = -\,\mu \cdot E = -\,|\mu||E|\cos\theta$

Polarization mechanisms

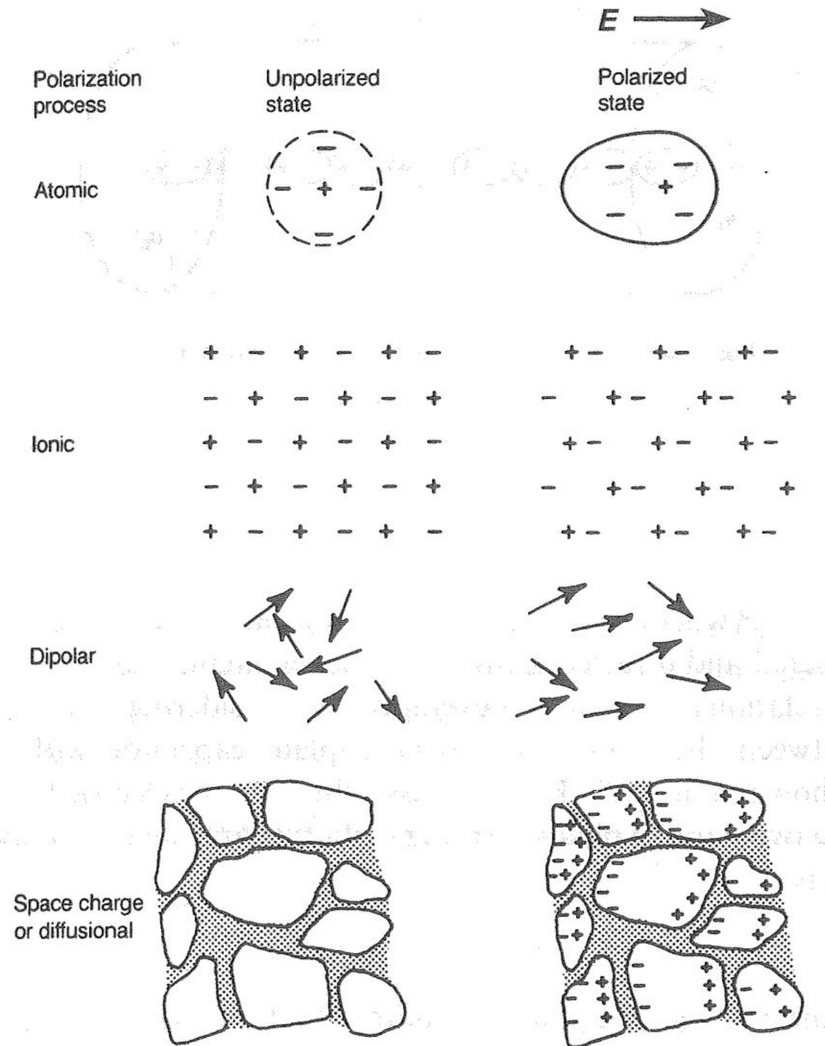
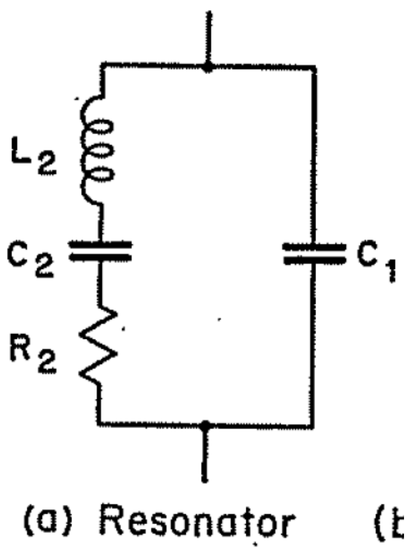


Fig. 2.25 Various polarization processes.

Relaxation time

- τ – relaxation time
  - *The time required for the dipole moments of the molecules to revert to a random distribution after removal of the applied field* **E**.
  - Measures the time required to reduce the order to 1/e of its original value, due to the randomizing agitation of Brownian movement.

Equivalent circuit - resonator



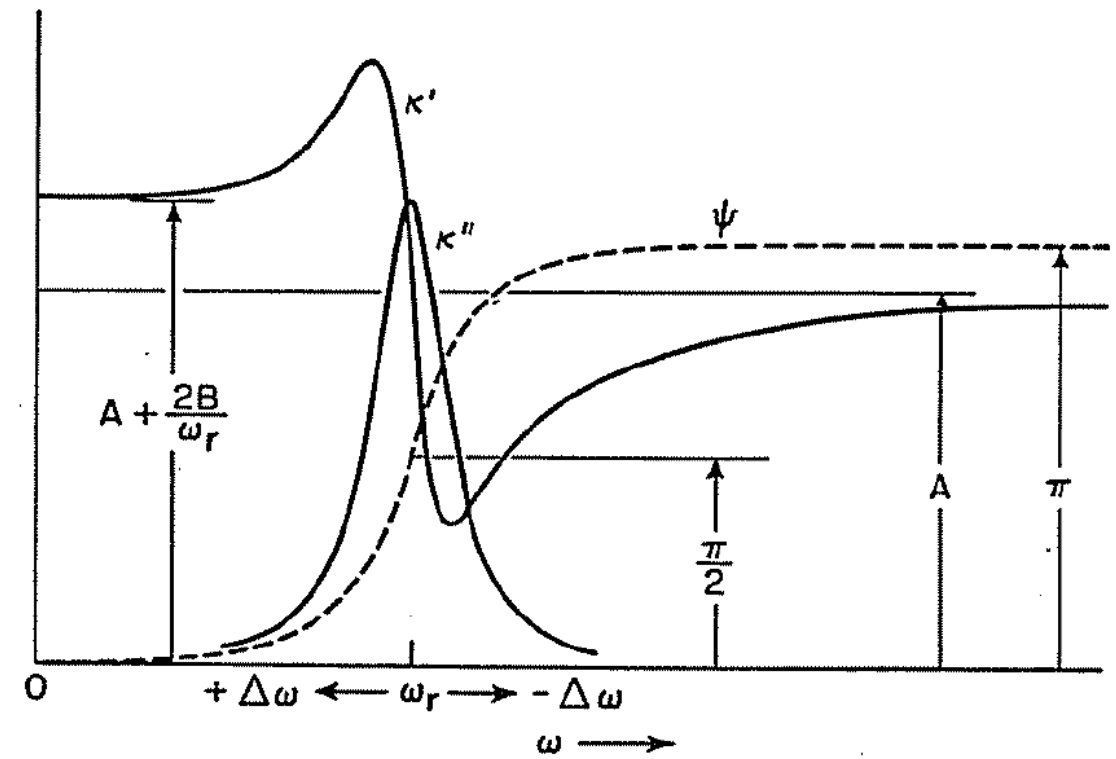
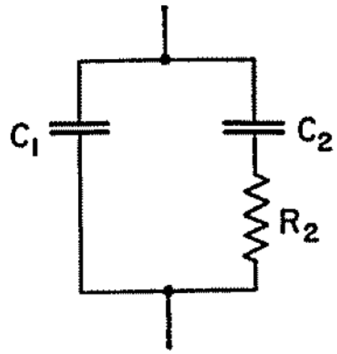


Fig. 4.2. Anomalous dispersion and resonance absorption

Equivalent circuit - relaxor



Network representing the simplest type of relaxation spectrum of a polar material.

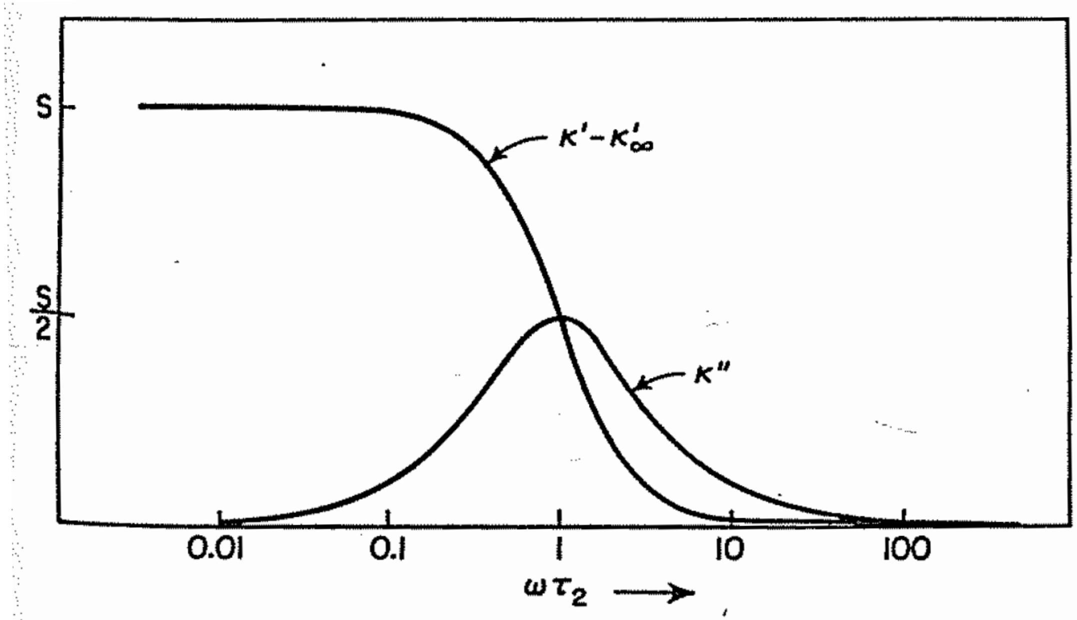


Fig. 26.6. Frequency response of equivalent circuit of Fig. 26.5

Summary: Debye relaxation

- Assumes polar molecules rotate in a medium of dominating friction (over-damped)
- Applied **E** is replaced by Lorentz **E**′ that accounts for the presence of polar neighbors
  - Necessary for condensed matter
  - Replacing **E** by **E**′ has the effect of lengthening τ

Does this make sense to you?