

# L6 More on Dielectrics

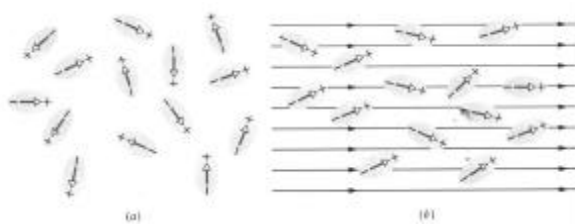
Lecture outline:

- Effect of temperature.
- Effect of frequency.
- Piezoelectricity.
- Ferroelectrics.

## L6.1 More on Dielectrics

Some molecules have an intrinsic dipole moment called polar molecules an example is the water molecule, as we have seen.

Effect of temperature: the orientations of the molecules may be random due to their thermal motion, so there is no net polarization. An applied electric field will tend to line up the dipoles:

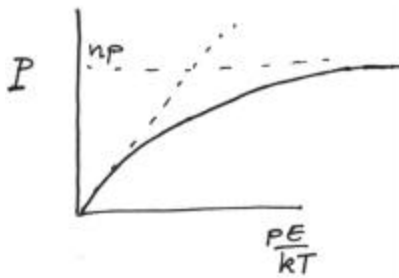


## L6.2 More on Dielectrics

The resulting polarization is given by the Langevin equation:

$$P = np \left[ \coth \left( \frac{pE}{kT} \right) - \frac{1}{\left( \frac{pE}{kT} \right)} \right]$$

(k = Boltzmann's constant)



For big T,  $P \approx np \cdot pE/3kT$ ,  
small alignment, so small P.

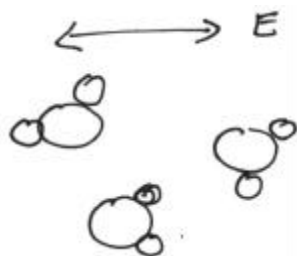
For small T,  $P \approx np$ , strong  
alignment, so large P.

## L6.3 More on Dielectrics

Polarization depends on the frequency of E.

High frequency means only electrons respond.

Example of water: for DC,  $K=80$ , but for light  
wavelength (500nm, 600THz),  $K=1.77$ .



E oscillates too fast for molecules  
to rotate, so small polarization.

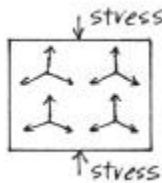
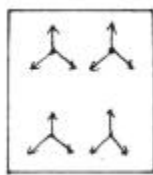
Refractive index n:  $K=n^2$ ,  
so for water at visible wavelength,  
 $n=1.33$ .

## L6.4 More on Dielectrics

### Piezoelectricity:

Mechanical stress  $\longleftrightarrow$  polarization  $\longleftrightarrow$  electric field

Under stress, charges in the crystal are symmetrically arranged, so get dipole moment:



$$D = K\epsilon_0 E + eS$$

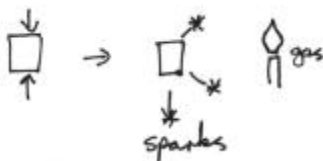
$$T = cS - eE$$

where  $e$ =piezoelectric constant,  $S$ =strain,  $T$ =stress,  
 $c$ =elastic constant (Young's modulus).

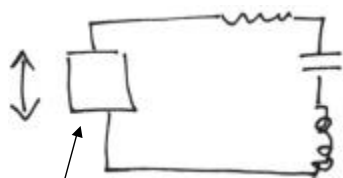
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### Applications:

Gas lighter



Quartz crystal (watch, computers)



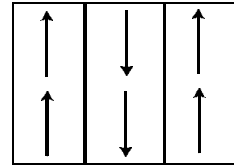
Mechanical oscillations  
 (definite frequency) give voltage  
 in circuit. Feedback and a battery  
 keeps it ringing.

Electromechanical transducers: microphone, speakers,  
 record player pickup, scanning tunnelling microscope.

## L6.6 More on Dielectrics

Ferroelectrics: have a permanent electric dipole moment, eg barium titanate. They are much less common than ferromagnets.

Anti-ferroelectrics: neighbouring domains in the crystal have opposite polarization:



Electrets have a permanent polarization retained when a liquid solidifies, eg wax with long chain molecules.