Read and discussed New York Times article “For Earth Day, 7 New Rules to Live By.”

Handed back Ps8.

Briefly discussed the relative permittivity of liquid water.

\[ \varepsilon_r = \varepsilon_{\infty} + \frac{\varepsilon_r - \varepsilon_{\infty}}{1 + j\omega\tau_r} \]

\[ f = \text{frequency, Hz} \]

\[ \tau_w = \text{relaxation period, s} \]

\[ \varepsilon_r \approx 5 \text{ high-frequency limit} \]

\[ \varepsilon_r \approx 80 \text{ but it's a function of temperature} = \text{low-frequency limit} \]

Water is a polar molecule:

It has a permanent dipole moment \( \mathbf{P} \).

When an electric field is applied to liquid water, the random orientation of water molecules is destroyed and the molecules "line up" with the field.

For a general dielectric

\[ P = \text{polarization density of bulk liquid water} \]

\[ P = \varepsilon_0 \chi_e E \]

\( \chi_e = \text{electric susceptibility} \)

\( \chi_e = 1 + \chi_e \)

so \( \chi_e \) is a measure of how much different the dielectric is from free space (\( \varepsilon_r \)).
When the electric field is taken away, the polarization density slowly goes away,

\[ P(t) = P(0) e^{-\frac{t}{T_w}} \]

This decay is characterized by \( T_w \).

Physically what is happening is that once the electric field is gone, thermal motion destroys the uniform orientation and eventually the polarization density is zero. But this does not happen instantaneously.

This phenomenon is what causes the relative permittivity \( \varepsilon \) of liquid water to change as it does with frequency; it is the rotation of the water molecules in the direction of the electric field.

See Figures.

Then discussed #4 \& Ps8: variation of \( T_b \) with angle for different situations.
**Note** that $T_w$ decreases as temperature increases, bulk liquid water returns to random orientation state in a shorter amount of time when temperature is higher (more thermal motion of molecules).

$T_w$ determines where the peak of $\varepsilon_r'' = \text{Im}(\varepsilon_{r_w})$ is, so peak will move as a function of temperature.