Homework 17

Dielectric constant

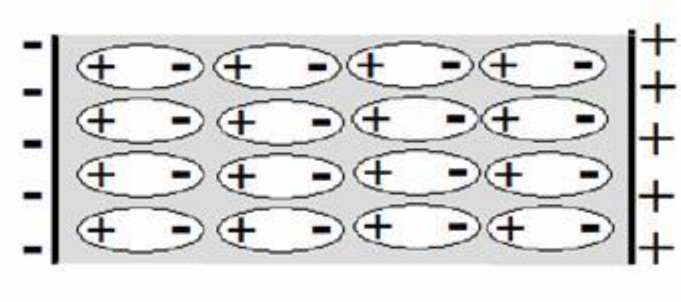
Last class we discussed an important parameter in the expression for the capacitance C of the plane capacitor. This parameter, ε, is a dimensionless number which characterizes the material between the plates. This parameter is called *dielectric constant* or *dielectric permittivity* of the material. By definition, the dielectric constant ε=1 for vacuum. Just to remind, the expression for the capacitance is:

$$C = \frac{\varepsilon_0 \varepsilon S}{d} \qquad (2),$$

where S is the area of the plate, d is the distance between the plates and $\varepsilon_0 = 8.85 \cdot 10^{-12} \frac{C}{V \cdot m}$ is electric constant. Dielectric constants of some materials are given in the table below:

Material or media	Dielectric constant
Vacuum	1
Air	1.0005
Water	88
Paper	3.5
Concrete	4,5
Glass	4,7
Rubber	7

As we can see from the table, the dielectric constant of a material is higher than this of vacuum. It means that if we fill the space between the plates of a plane capacitor with something, the capacitance will increase. This, in turn, means that we have to put more charge to the capacitor's plate to reach same voltage. Looks like the material somehow weakens or screens the charge we put on the capacitor's plates. We can try to explain this effect. Let us remember that all the materials around us contain charged particles – electrons and protons. In a dielectric, these particles cannot transfer electric current. You may think that in a solid dielectric such as glass, rubber or concrete these particles are tied together. In spite that they cannot move, they can be slightly displaced with respect to each other. For example, if you place the material between the charged plates of a capacitor, the positively charged plate will attract the electrons of the dielectric and displace them with respect to the positively charged nuclei (see Figure below):



So, on the side of the dielectric material, which is close to the positively charged plate a negative charge will be induced. This effect is called *polarization*. The polarization charge partially compensates the charge of the plate, so we need to put more charge to the capacitor's plate to reach the same voltage. There are several mechanisms of polarization. The polarization which we discussed above is called electronic polarization.

1. Calculate capacitance of a plane capacitor with the plates of 100 cm^2 each, separated by a 1mm thick glass plate.

2. Three identical parallel metal plates, separated by equal distances, are connected to a voltage source of 10V (see Figure below). The area of each plate is 100cm^2, the distance between the plates is 1mm.
   a) Calculate the charge on plates A and C.
   b) How does this charge change if we will fill the space between the plates A and B with pure water?
   c) How we should change the distance between plates B and C to return the charge back to the original value?