EEE105 - Summary Sheet – Lectures 1-6

Key points :

1. Electric Field determines the force acting on a charged particle. It is a vector quantity. $\boxed{\underline{F} = \underline{E}.q}$ (where q is the charge on the particle that has been placed in the field)

2. Potential Difference is the difference in the potential field between two points. It determines how much energy can be extracted (or is required) to move a charged particle between the two points. It is a scalar quantity: $\boxed{Energy = V.q}$

3. Poisson's Equation: $\boxed{\frac{d^2V}{dx^2} = -\frac{dE}{dx} = -\frac{\rho}{\varepsilon}}$
   This equation tells us two things.
   First the rate of change of the E-field with distance, x, in a region of charge density, ρ, is equal to the charge density divided by the permittivity. Note from this that this means that if the charge density is constant the E field will vary linearly with x.
   Second the rate of change in the potential difference, or voltage, with distance x is equal to the negative of the E-field strength in that region. Note again that the voltage will change linearly with distance if the E-field is constant.

4. Electrons are accelerated in an Electric field due to the force applied on them.

5. In an insulator charges are not free move through a solid, but they can redistribute to create a surface charge at the ends of the material. This surface charge sets up a field to oppose the E-field between capacitor plates. This means for a particular voltage applied across a capacitor we need more charge on the plates – increasing the capacitance as $\boxed{C = Q/V}$ (also $\boxed{C = \varepsilon_o \varepsilon_r A/d}$)

6. At room temperature electrons that are free to conduct are rapidly moving round the material due to their thermal energy. However there is no NET motion of electrons from one part of the material to another. Thus there is no Current flow.

7. In a solid free electrons 'see' a periodic array of atoms and must adjust to this environment. They can do this by changing their apparent mass inside the material, which we call ***the effective mass***.

8. If an electric field is applied free electrons will ***drift*** in the direction opposite to the field direction. The current density produced is given by $\boxed{J_{drift} = \sigma E}$ where $\boxed{\sigma = nq\mu}$
   a) The above assumes that the electrons have a drift velocity proportional to the field. The drift velocity is the average velocity of electrons in the material.
   b) To obtain the drift velocity we must consider the electron population as a whole and calculate the change in momentum of the drifting electrons due to the field and also due to the electrons being scattered off defects in the solid material structure.

9. If there is a non-uniform distribution of free electrons in the material there will be a net ***diffusion*** of the electrons from the higher concentration regions to the lower concentration regions. This leads to ***diffusion current.*** The diffusion current depends on the concentration gradient of the electrons:
   $\boxed{J_{diff} = -D\,dn/dx}$ where the diffusion coefficient, $\boxed{D = \frac{kT}{q}\mu}$ (this is the so-called Einstein relation).

10. There is a special case we will find useful later where the ***drift*** and ***diffusion*** currents cancel each other out.