Summary Chapter 3.

The starting relation in electromagnetics is Coulomb's law which gives the force between two point charges. It may be written in different forms but **Eq. (3.11)** is representative

$$\mathbf{F}_{12} = \hat{\mathbf{R}}_{12}\frac{Q_1Q_2}{4\pi\varepsilon_0 R_{12}^2}, \qquad \mathbf{F}_{21} = \hat{\mathbf{R}}_{21}\frac{Q_1Q_2}{4\pi\varepsilon_0 R_{21}^2} \qquad [\text{N}] \quad (3.11)$$

Where ε_0 is the permittivity (in this case that of free space). From Coulomb's law we defined the electric field intensity **in Eq. (3.17)** as force per unit charge. The forms in **Eq. (3.18)** are more useful:

$$\mathbf{E} = \frac{Q\mathbf{R}}{4\pi\varepsilon_0 |\mathbf{R}|^3} \quad \text{or} \quad \mathbf{E} = \hat{\mathbf{R}}\frac{Q}{4\pi\varepsilon_0 |\mathbf{R}|^2} \qquad \left[\frac{\text{N}}{\text{C}}\right] \qquad (3.18)$$

The relations for point charges were extended to distributed charge densities by defining elemental, differential charges based on line, surface and volume charge distributions. Viewing the elemental charges as point charges, Coulomb's law provides a general way of calculating the electric field intensity due to distributed charges as:

$$d\mathbf{E} = \frac{(\mathbf{r}-\mathbf{r}')\rho_{\Omega'}}{4\pi\varepsilon_0|\mathbf{r}-\mathbf{r}'|^3}d_{\Omega'}, \qquad \mathbf{E} = \int_{\Omega'}\frac{(\mathbf{r}-\mathbf{r}')\rho_{\Omega}}{4\pi\varepsilon_0|\mathbf{r}-\mathbf{r}'|^3}d_{\Omega'}$$

r' is the position vector of the elemental point charge (source point), **r** the position vector of the field point at which the field is calculated (see **Figure 3.13**) and Ω' stands for *l*', *s*' or *v*' (see **Eqs. (3.44), (3.47)** and **(3.50)**).

Finally, the electric flux density **D** is introduced, for now simply as a means of eliminating the dependence of the electric field intensity on permittivity from calculation:

$$\mathbf{D} = \varepsilon\mathbf{E} \qquad [\text{C/m}^2] \qquad (3.55)$$

In effect, all of this chapter deals with the electric field of point charges and the forces between them – either physical point charges such as isolated electrons, protons and ions or differential point charges defined on line, surface and volume distributions:

Important reminders

1. Note the distinction between field points and source points (denoted with a ('))
2. Pay attention to symmetries – they can help in understanding and in solving problems
3. Superposition of fields and forces can be used to calculate fields of complex distributions
4. The electric field intensity and the force are vectors. When summing up various contribution to either of these, separation into components simplifies the task
5. An appropriate choice of coordinates can often simplify calculations

Useful quantities:

Permittivity of free space: $\varepsilon_0 = 8.854187\times10^{-12}$ [F/m]

Charge of an electron: $e = -1.602129\times10^{-19}$ [C]