Table 1-3: The three branches of electromagnetics.

Branch	Condition	Field Quantities (Units)
Electrostatics	Stationary charges ($\partial q/\partial t = 0$)	Electric field intensity **E** (V/m) Electric flux density **D** (C/m^2) $\mathbf{D} = \varepsilon\mathbf{E}$
Magnetostatics	Steady currents ($\partial I/\partial t = 0$)	Magnetic flux density **B** (T) Magnetic field intensity **H** (A/m) $\mathbf{B} = \mu\mathbf{H}$
Dynamics (Time-varying fields)	Time-varying currents ($\partial I/\partial t \neq 0$)	**E**, **D**, **B**, and **H** (**E**, **D**) coupled to (**B**, **H**)

In view of these terms, let us now examine the relationship between the electric field **E** and the magnetic flux density **B**. Because **E** is governed by the charge q and **B** is governed by $I = dq/dt$, one might expect that **E** and **B** must be somehow related to each other. They may or may not be interrelated, depending on whether I is static or dynamic.

Let us start by examining the dc case in which I remains constant with time. Consider a small section of a beam of charged particles, all moving at a constant velocity. The moving charges constitute a dc current. The electric field due to that section of the beam is determined by the total charge q contained in it. The magnetic field does not depend on q, but rather on the rate of charge (current) flowing through that section. Few charges moving very fast can constitute the same current as many charges moving slowly. In these two cases the induced magnetic field will be the same because the current I is the same, but the induced electric field will be quite different because the numbers of charges are not the same.

Electrostatics and ***magnetostatics*** refer to the study of EM under the specific, respective conditions of stationary charges and dc currents. They represent two *independent* branches, so characterized because the induced electric and magnetic fields do not couple to each other. ***Dynamics***, the third and more general branch of electromagnetics, involves ***time-varying fields*** induced by time-varying sources, that is, currents and associated charge densities. If the current associated with the beam of moving charged particles varies with time, then the amount of charge present in a given section of the beam also varies with time, and vice versa. As we will see in Chapter 6, the electric and magnetic fields become coupled to each other in that case. In fact, ***a time-varying electric field will generate a time-varying magnetic field, and vice versa.*** Table 1-3 provides a summary of the three branches of electromagnetics.

The electric and magnetic properties of materials are characterized by the parameters ε and μ, respectively. A third fundamental parameter is also needed, the ***conductivity*** of a material σ, which is measured in siemens per meter (S/m). The conductivity characterizes the ease with which charges (electrons) can move freely in a material. If $\sigma = 0$, the charges do not move more than atomic distances and the material is said to be a ***perfect dielectric***. Conversely, if $\sigma = \infty$, the charges can move very freely throughout the material, which is then called a ***perfect conductor***. The parameters ε, μ, and σ are often referred to as the ***constitutive parameters*** of a material (Table 1-4). A medium is said to be ***homogeneous*** if its constitutive parameters are constant throughout the medium.

Review Question 1-1: What are the four fundamental forces of nature and what are their relative strengths?

Review Question 1-2: What is Coulomb's law? State its properties.

Review Question 1-3: What are the two important properties of electric charge?

Review Question 1-4: What do the electrical permittivity and magnetic permeability of a material account for?

Review Question 1-5: What are the three branches and associated conditions of electromagnetics?