3.8. For material media, Maxwell's equations of electromagnetism are generally written, in Gaussian units, as

$$\nabla \cdot \mathbf{D} = 4\pi\sigma \tag{3.1}$$

$$\nabla \cdot \mathbf{B} = 0 \tag{3.2}$$

$$\nabla \times \mathbf{E} = -\frac{1}{c} \cdot \frac{\partial \mathbf{B}}{\partial t} \tag{3.3}$$

$$\nabla \times \mathbf{H} = \frac{1}{c}\left(4\pi\mathbf{j} + \frac{\partial \mathbf{D}}{\partial t}\right), \tag{3.4}$$

where **E** is the electric field strength (or electric intensity), **D** is the electric flux density (or electric induction or displacement), **H** is the magnetic field strength (or magnetic intensity), **B** is the magnetic flux density (or magnetic induction), σ is the electric charge density, and **j** is the current density; t is the time and c the velocity of light.

3.9. In this form of the Maxwell equations, σ represents the free charge density and **j** is the free current density, as distinguished from the bound

* Although the terms "confinement" and "containment" are used somewhat interchangeably in connection with plasmas, the former term will be employed here for the restraint placed upon the charged particles, e.g., by a magnetic field, whereas the latter will refer to the vessel or container in which the plasma is held or enclosed. For example, it may be stated that "a plasma contained in a toroidal tube is confined by a magnetic field."

charges and currents. The latter currents are then supposed to give rise to a magnetization **M**, such that

$$\mathbf{B} = \mathbf{H} + 4\pi\mathbf{M}.$$

In plasma physics, however, it is more convenient to treat all current densities explicitly, that is, to include in **j** both the "free" current and that which may produce diamagnetism. It is correct, therefore, to use **B** rather than **H**, and the term $\nabla \times \mathbf{B}$ should then be substituted for $\nabla \times \mathbf{H}$ in equation (3.4).

3.10. The specification of σ as the free charge implies the existence in general material media of bound charges. In dielectrics, such charges are indeed present, and the difference between **D** and **E** is proportional to the density of dipole moments, or polarization **P**, produced by the distorting effect of the imposed field **E** on the charge configuration; thus,

$$\mathbf{D} = \mathbf{E} + 4\pi\mathbf{P}.$$

In a fully ionized and stripped plasma, there are no bound charges and hence no polarization under a steady applied field. The dielectric constant K, defined by $\mathbf{D} = K\mathbf{E}$, is then unity, and **D** in equations (3.1) and (3.4) may be replaced by **E**.

3.11. In applying Maxwell's equations to a plasma, therefore, they will be written in the form

$$\nabla \cdot \mathbf{E} = 4\pi\sigma \tag{3.5}$$

$$\nabla \cdot \mathbf{B} = 0 \tag{3.6}$$

$$\nabla \times \mathbf{E} = -\frac{1}{c} \cdot \frac{\partial \mathbf{B}}{\partial t} \tag{3.7}$$

$$\nabla \times \mathbf{B} = \frac{1}{c}\left(4\pi\mathbf{j} + \frac{\partial \mathbf{E}}{\partial t}\right), \tag{3.8}$$

where **B** is generally referred to as the magnetic field strength and is expressed in gauss. Basically, these equations imply that, in their application to a plasma, **E**, **D**, **B**, and **H** are the microscopic vacuum field values, so that **E** and **D** are equal and so also are **B** and **H**, and all charges and currents are treated explicitly.