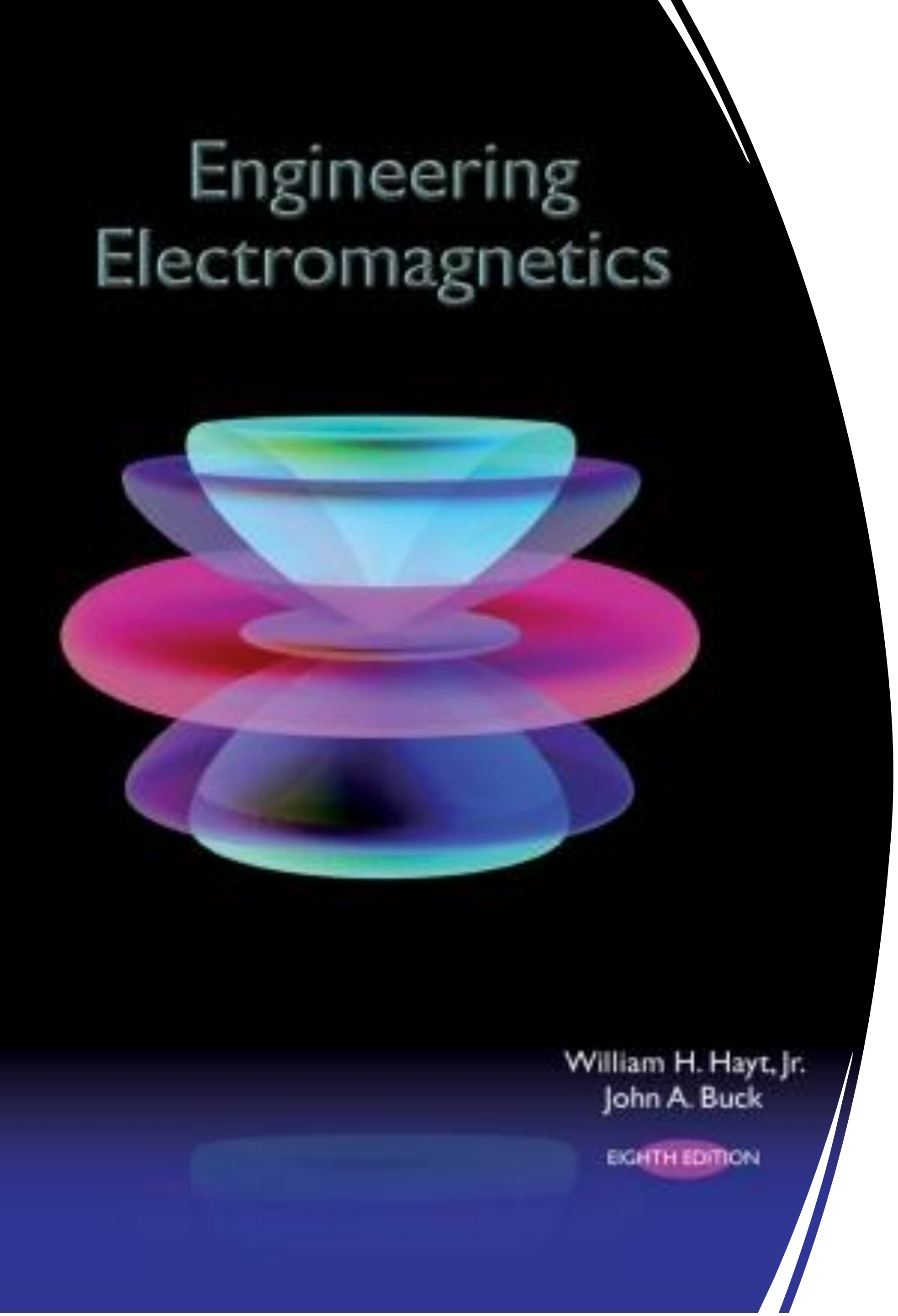


6. Magnetic Forces, Materials, and inductance

6.1 Force on a Moving Charge

6.2 Force on a Differential Current Element

6.3 Force and Torque on a Closed Circuit

6.4 The Nature of Magnetic Materials

6.5 Magnetization and Permeability

6.1 Force on a Moving Charge

- In an electric field, the definition of the electric field intensity shows us that the force on a charged particle is

$$\mathbf{F} = Q\mathbf{E}$$

- A charged particle in motion in a magnetic field of flux density **B** is

$$\mathbf{F} = Q\mathbf{v} \times \mathbf{B}$$

- The force on a moving particle arising from combined electric and magnetic fields is obtained easily by superposition

$$\mathrm{F} = \mathrm{Q}(\mathrm{E} + \mathrm{v} \times \mathrm{B})$$

- This equation is known as the Lorentz force equation

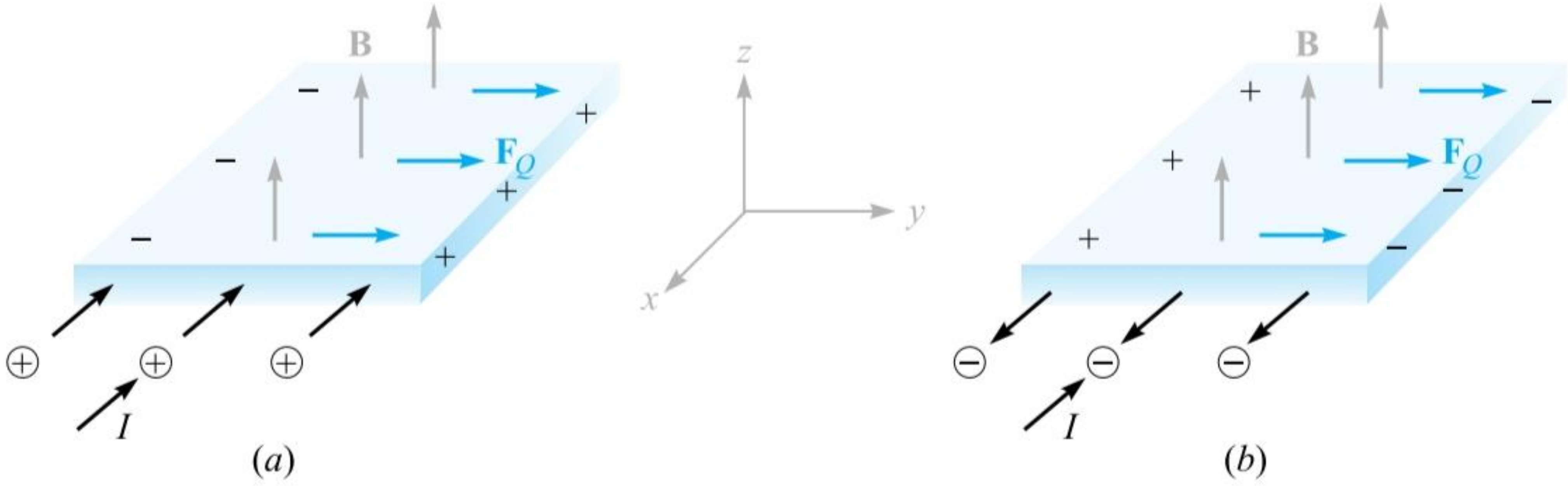
6.1 Force on a Moving Charge

The point charge $Q = 18\text{nC}$ has a velocity of 5×10^6 m/s in the direction $\mathbf{a}_v = 0.60\mathbf{a}_x + 0.75\mathbf{a}_y + 0.30\mathbf{a}_z$. Calculate the magnitude of the force exerted on the charge by the field: $(a)\mathbf{B} = -3\mathbf{a}_x + 4\mathbf{a}_y + 6\mathbf{a}_z\text{mT}$;
(b) $\mathbf{E} = -3\mathbf{a}_x + 4\mathbf{a}_y + 6\mathbf{a}_z\text{kV/m}$; (c)B and E acting together.

Ans. $660\mu\text{N}; 140\mu\text{N}; 670\mu\text{N}$

6.2 Force on a Differential Current Element

- Equal currents directed into the material are provided by positive charges moving inward in (a) and negative charges moving outward in (b). The two cases can be distinguished by oppositely directed Hall voltages, as shown.



6.3 Force and Torque on a Closed Circuit

- Now assume that two forces, $\mathbf{F}_1$ at P_1 and $\mathbf{F}_2$ at P_2, having lever arms $\mathbf{R}_1$ and $\mathbf{R}_2$ extending from a common origin O, as shown in Figure 8.5b, are applied to an object of fixed shape and that the object does not undergo any translation. Then the torque about the origin is

$$\mathbf{T} = \mathbf{R}_1 \times \mathbf{F}_1 + \mathbf{R}_2 \times \mathbf{F}_2$$

where $\mathbf{F}_1 + \mathbf{F}_2 = 0$

- and therefore

$$\mathbf{T} = (\mathbf{R}_1 - \mathbf{R}_2) \times \mathbf{F}_1 = \mathbf{R}_{21} \times \mathbf{F}_1$$

6.4 The Nature of Magnetic Materials

- Characteristics of magnetic materials

Classification	Magnetic Moments	B Values	Comments
Diamagnetic	$\mathbf{m}_{\text{orb}} + \mathbf{m}_{\text{spin}} = 0$	$B_{\text{int}} < B_{\text{appl}}$	$B_{\text{int}} \doteq B_{\text{appl}}$
Paramagnetic	$\mathbf{m}_{\text{orb}} + \mathbf{m}_{\text{spin}} = \text{small}$	$B_{\text{int}} > B_{\text{appl}}$	$B_{\text{int}} \doteq B_{\text{appl}}$
Ferromagnetic	$\lvert\mathbf{m}_{\text{spin}}\rvert \gg \lvert\mathbf{m}_{\text{orb}}\rvert$	$B_{\text{int}} \gg B_{\text{appl}}$	Domains
Antiferromagnetic	$\lvert\mathbf{m}_{\text{spin}}\rvert \gg \lvert\mathbf{m}_{\text{orb}}\rvert$	$B_{\text{int}} \doteq B_{\text{appl}}$	Adjacent moments oppose
Ferrimagnetic	$\lvert\mathbf{m}_{\text{spin}}\rvert \gg \lvert\mathbf{m}_{\text{orb}}\rvert$	$B_{\text{int}} > B_{\text{appl}}$	Unequal adjacent moments oppose; low σ
Superparamagnetic	$\lvert\mathbf{m}_{\text{spin}}\rvert \gg \lvert\mathbf{m}_{\text{orb}}\rvert$	$B_{\text{int}} > B_{\text{appl}}$	Nonmagnetic matrix; recording tapes

6.5 Magnetization and Permeability

- A section d L of a closed path along which magnetic dipoles have been partially aligned by some external magnetic field. The alignment has caused the bound current crossing the surface defined by the closed path to increase by $nl_b dS \cdot d$ LA.