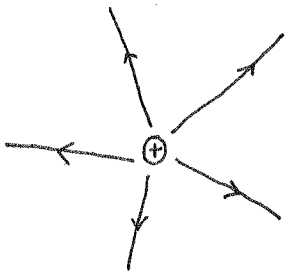
The Sources of Electric and Magnetic Fields

Electrostatics

(stationary charges)

$$\vec{E}(\vec{r}_o) = \frac{1}{4\pi\epsilon_o} \sum_{\substack{\text{source} \\ \text{charges } i}} \frac{q_i}{r_{oi}^2} \hat{r}_{oi}$$

(Coulomb's law)



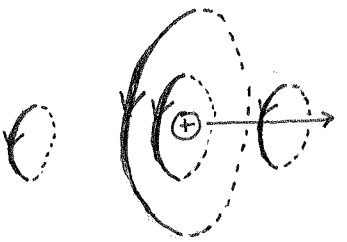
Electric field lines from a single source

Magnetostatics

(steady currents, stationary charge distributions)

$$\vec{B}(\vec{r}_o) = \frac{\mu_o}{4\pi} \sum_{\substack{\text{source} \\ \text{charges } i}} \frac{q_i}{r_{oi}^2} \vec{v}_i \times \hat{r}_{oi}$$

(Biot-Savart law)



Magnetic field lines from a single source

$$\oint_{\text{closed surface}} \vec{E} \cdot \hat{n}\, dA = \frac{Q_{\text{inside}}}{\epsilon_o}$$

(Gauss's law)

$$\oint_{\text{closed loop}} \vec{E} \cdot d\vec{\ell} = 0$$

(Existence of electrical potential)

Electric field lines begin and end on charges (or at infinity); they never loop.

$$\oint_{\text{closed surface}} \vec{B} \cdot \hat{n}\, dA = 0$$

(Gauss's law of magnetism)

$$\oint_{\text{closed loop}} \vec{B} \cdot d\vec{\ell} = \mu_o I_{\text{linked}}$$

(Ampere's law)

Magnetic field lines neither begin nor end (except at infinity); instead they form loops.