Chapter 3 Steady Electric Current

3.1 Steady-State Condition

3.2 Resistance and the Ohm's Law

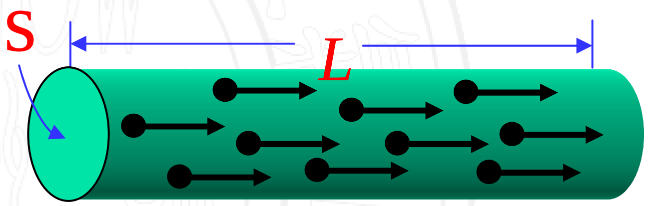
3.3 Electromotive Force and Kirchhoff's law

3.1 Steady–state Condition

◈ Current and Current Density

Current Intensity

- Consider a region in which there is a flow of charges:
  - E.g. cylindrical conductor



  - We define a current:

The charge/unit time flowing through a certain surface

$$I = \frac{dq}{dt}$$

  - unit: 1C/s=1A(Ampere)

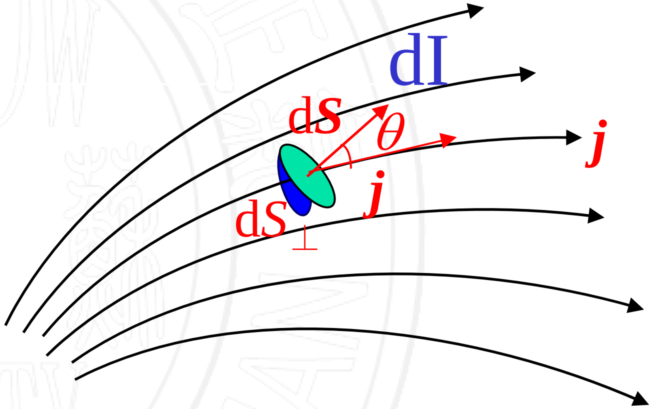
3.1 Steady–state Condition

Current and Current Density

Current Density J

- Consider a region in electric current field
- We define a current density:

the current/unit perpendicular area flowing through a point



$$j = \frac{\mathrm{d}I}{\mathrm{d}S_{\perp}}$$

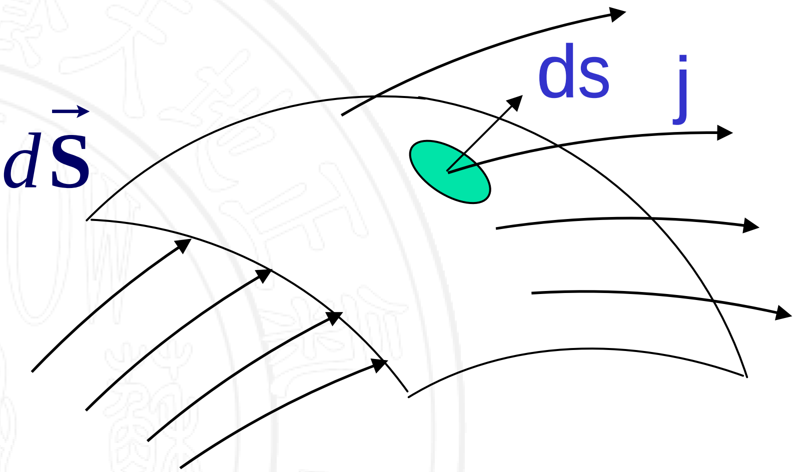
j: vector
- magnitude: current per unit area
- direction: the same as positive charge moving

- unit: A/m^2

3.1 Steady–state Condition

◈ Current and Current Density

- Current & Current density J



$$\mathrm{d}I = j\mathrm{d}S_{\perp} = j\mathrm{d}S\cos\theta = \vec{\mathbf{j}}\cdot d\vec{\mathbf{S}}$$

$$I = \iint_S \vec{\boldsymbol{j}}\cdot \mathrm{d}\vec{\boldsymbol{S}}$$

- The Continuity Equation for Current

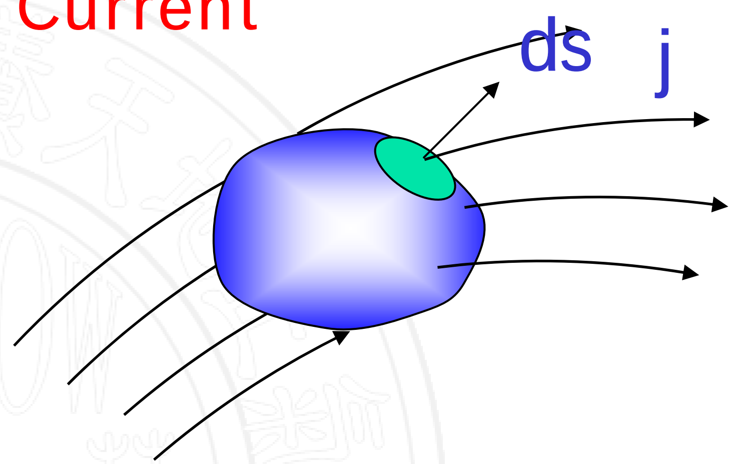
$$I = \iint_S \vec{\boldsymbol{j}}\cdot \mathrm{d}\vec{\boldsymbol{S}}$$

Charges/unit time passing through a surface

3.1 Steady–state Condition

◈ The Continuity Equation for Current

$$\oiint_{(S)} \vec{j}\cdot \mathrm{d}\vec{S} = ?$$



Net charge/unit time passing through a closed surface

- Conservation law for charge

$$\oiint_{(S)} \vec{j}\cdot \mathrm{d}\vec{S}$$ =Decreased charges in unit time inside the closed surface

3.1 Steady–state Condition

The Continuity Equation for Current

$$\oiint_{(S)} \vec{j} \cdot d\vec{S} = -\frac{dq}{dt}$$

- Steady-state condition of current

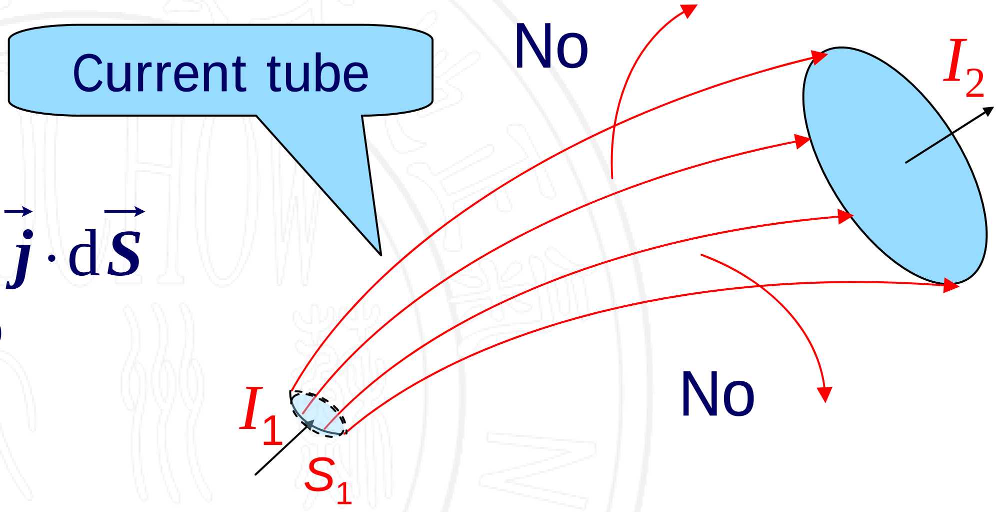
There is an electric field ***E*** in circuit. If the field doesn't change with time, or is independent of time, the field is called steady-state field.

If the field doesn't change with time, neither the distribution of charges in the circuit, i.e. dq=0

3.1 Steady–state Condition

◈ Steady-state condition of current

$$\oiint_{(S)} \vec{j} \cdot \mathrm{d}\vec{S} = 0$$



$$\oiint_{(S)} \vec{j} \cdot \mathrm{d}\vec{S} = \iint_{(S_1)} \vec{j} \cdot \mathrm{d}\vec{S} + \iint_{(S_2)} \vec{j} \cdot \mathrm{d}\vec{S}$$

$$= -I_1 + I_2 = 0$$

$$I_1 = I_2$$

The currents flowing resistors in parallel are the same.