

## Chapter 27

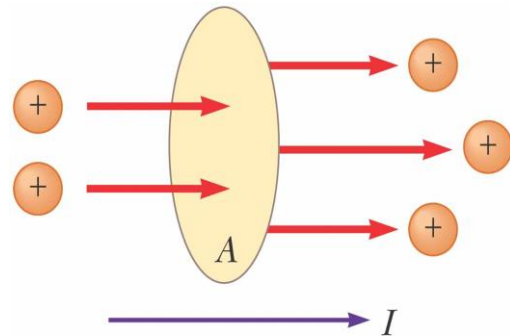
### Current and Resistance

#### 27-1 Electric Current

Consider a system of electric charges in motion. A current is said to exist whenever there is a net flow of charge through some region.

The current is the rate at which charge flows through this surface:

$$I = \frac{\Delta q}{\Delta t} \quad (1-27)$$



- The unit of current is Ampere [A].

$$\frac{\text{Coulomb}}{\text{second}} = \text{Ampere} [C/s = A]$$

- That is, 1 A of current is equivalent to 1 C of charge passing through the surface area in 1 s.
- The direction of the current is defined as the direction of the flow of positive charge, which is opposite the direction of the flow of electrons.
- It is common to refer to a moving charge (positive or negative) as a mobile charge carrier. For example, the mobile charge carriers in a metal are electrons.

See the simulation: [Flow of electric current | electron direction #short #shorts #animation #physics - YouTube](#)

## Microscopic View of Electric Current

The net motion of charge carriers is responsible for electric current. In an isolated conductor, we know there is no net motion of electric charge.

However, individual electrons move quite a bit due to their thermal

energy. There is no net charge transfer because the thermal motion is random, and as many electrons move to the left, they move to the right.

One can apply an electric field (or a potential) to cause a net charge transfer. For example, a battery supplies the electric field (or potential difference) necessary for charges to move in an electric circuit.

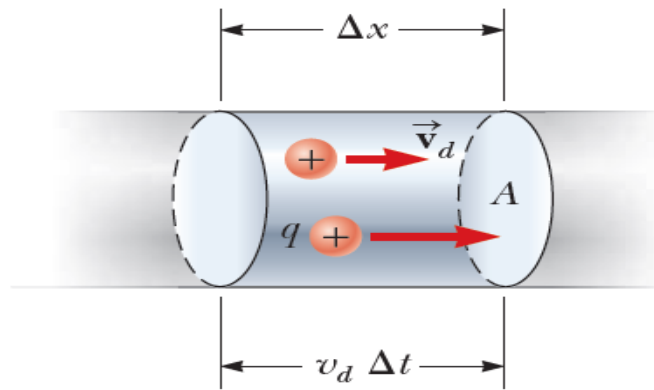
It is interesting to figure out how fast the electrons that are responsible for current move in a conductor.

If  $n$  = **number of charge carriers per volume** ( $n = \frac{N}{V}$ ); then the total number of charge,  $q$ , of the carriers in a length of wire  $l$  long with cross-sectional area  $A$  is:

$$N = nV = n.(A.\Delta x) = n.(A.\Delta x) \cdot \frac{\Delta t}{\Delta t} = n.A.\left(\frac{\Delta x}{\Delta t}\right).\Delta t = n.A.v_d.\Delta t \quad (2-27)$$

Then, the total charge can be written as:

$$\Delta q = N.e \quad (3-27)$$



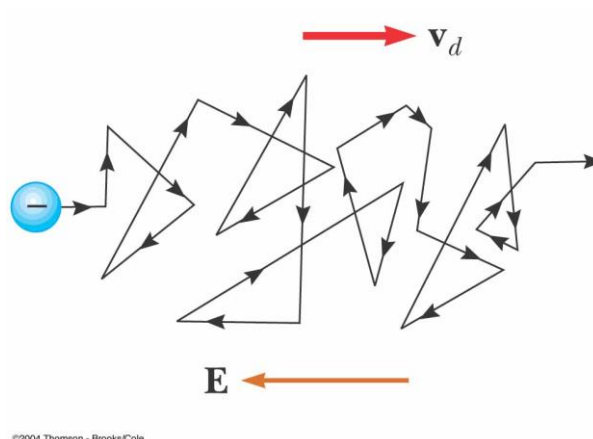
**Figure 26.2** A segment of a uniform conductor of cross-sectional area  $A$ .

Finally, we can give an expression of the electric current:

$$I = \frac{\Delta q}{\Delta t} = n v_d e A$$

Where  $v_d$  is called the drift velocity, it represents the average speed of the charge carriers.

(Carriers move in a zigzag fashion due to collision with atoms.)



### Example 27-1

The 12-gauge copper wire in a typical residential building has a cross-sectional area of  $3.31 \times 10^{-6} \text{ m}^2$ . It carries a constant current of 10.0 A. What is the drift speed of the electrons in the wire? Assume each copper atom contributes one free electron to the current. The density of copper is  $8.92 \text{ g/cm}^3$ .

### Example 27-2

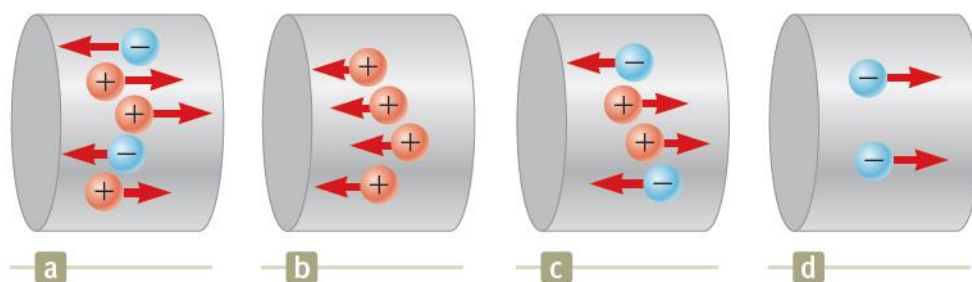
The measured beam current is  $30.0 \mu\text{A}$  in a particular cathode ray tube. How many electrons strike the tube screen every 40.0 s?

### Example 27-3

An aluminum wire having a cross-sectional area of  $4.00 \times 10^{-6} \text{ m}^2$  carries a current of 5.00 A. Find the drift speed of the electrons in the wire. The density of aluminum is  $2.70 \text{ g/cm}^3$ . Assume that each atom supplies one conduction electron. (The aluminum (Al) molar mass is 27 g/mol).

### Example- 27-4

Consider positive and negative charges of equal magnitude moving horizontally through the four regions shown in the following Figure. Rank the current in these four regions from highest to lowest.



### COMMENTS:

**Drift velocity** ( $v_d$ ) is the slow, average velocity at which free electrons move through a conductor due to an applied electric field. While individual electrons experience rapid random motion, their overall net movement in a specific direction—caused by the field—constitutes drift velocity.

### !!! Drift Velocity and the Speed of Electricity Transfer !!!

- Drift velocity is very slow (typically around 0.1 mm/s in household wiring).
- However, electricity (energy transfer) happens almost instantly when a switch is turned on.
- This is because the electric field propagates close to the speed of light in the wire (~50–99% of  $c$ , depending on the material).
- The electric field pushes electrons all along the wire simultaneously, like a chain reaction in a pipe full of water—when you push electrons at one end, others respond immediately at the other end.

## Notes:

i- The number of moles ( $n$ ) is given by:

$$n = \frac{\text{mass of substance (in grams)}}{\text{molar mass } \left(\frac{\text{g}}{\text{mol}}\right)}$$

Where:

- Mass of substance = Given mass in grams.
- Molar mass = Mass of one mole of the element (found in the periodic table).

ii- The Total Number of Atoms

Use Avogadro's number ( $N_A = 6.022 \times 10^{23}$  atoms/mol) to find the number of atoms:

$$\text{Number of atoms} = n \times N_A$$

Where:

- $n$  = Number of moles (from I).
- $N_A$  = Avogadro's number.

iii- The Number of Electrons per Atom

Each element has a specific atomic number ( $Z$ ), which tells you the number of electrons in a neutral atom.

$$\text{i.e., Total number of electrons} = \text{Number of atoms} \times Z$$

where:

- $Z$  = Atomic number (from the periodic table).

In previous problems 1 and 3, for simplicity, we assume that each atom contributes one electron.