Chapter 25: Electric Currents and Resistance

Electric Current:

$\bar{I} = \dfrac{\Delta Q}{\Delta t}$, instantaneous current: $I = \dfrac{dQ}{dt}$. In SI units, $1\,A = 1\,C/s$.

Example 25.1

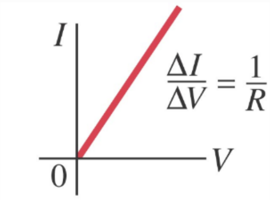
$I = 2.5A$

$\Delta t = 4.0\,min$

a) $\Delta Q = I\Delta t = (2.5A)(240s) \Rightarrow Q = 600C$

b) $600C/(1.6\times10^{-19}C) = 3.8\times10^{21}$ electrons

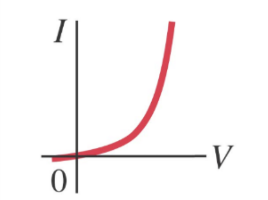
Ohm's Law:



rate of voltage to current is resistance: $I = \dfrac{V}{R}$, $V = IR$.

$\rightarrow$ an ohmic material

In SI, the unit of R: $1\,\Omega = 1\,V/A$.



$\rightarrow$ non-ohmic material

Example 25.4

a) $I = 300mA = 0.3A$, $V = 1.5V \Rightarrow R = V/I = (1.5/0.3)\,\Omega = 5.0\,\Omega$

b) $V = 1.2V$, $R = 5.0\,\Omega \Rightarrow I = V/R = (1.2/5.0)\,A = 0.24\,A$

Resistivity:

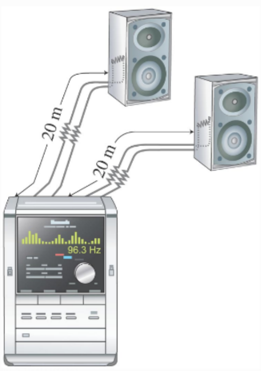
$R = \rho \dfrac{l}{A}$

$l \rightarrow$ length of the wire

$A \rightarrow$ cross-sectional area

$\rho \rightarrow$ resistivity

Example 25.5



a) $A = \rho \dfrac{l}{R}$

$A = (1.68\times10^{-8})\dfrac{20m}{0.10\Omega} = 3.4\times10^{-6}\,m^2$

$\pi r^2 = A \Rightarrow r = 1.04\times10^{-3}\,m$

$d = 2r = 2.08\times10^{-3}\,m$

b) $V = IR$

$V = (4.0A)(0.10\,\Omega) = 0.40\,V$

Temperature dependence of Resistivity:

$$\rho_T = \rho_0[1 + \alpha(T - T_0)]$$

ρ_0 → resistivity at T_0

ρ_T → resistivity at T

$\alpha \rightarrow$ Temperature coefficient $(1/C^\circ)$

Example 25.7

$T_0 = 20.0 C^\circ$

$R_0 = 164.2\,\Omega$

$R = 187.4\,\Omega$

$T = ?$

$$R = R_0[1 + \alpha(T - T_0)] \quad , \quad \alpha = 3.927 \times 10^{-3}\,(C^{\circ -1})$$

$$T = T_0 + \frac{R - R_0}{\alpha R_0} = 20^\circ C + \frac{187.4\,\Omega - 164.2\,\Omega}{(3.927 \times 10^{-3}\,C^{\circ -1})(164.2\,\Omega)} = 56.0\,C^\circ$$

Electric Power

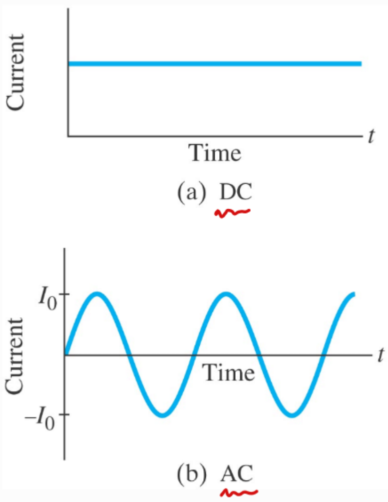
$$P = \frac{dU}{dt} \, , \quad U = qV \Rightarrow P = \frac{d(qV)}{dt} \Rightarrow P = \frac{dq}{dt}V = IV$$

Recalling Ohm's law: $P = IV = I^2R = V^2/R$

Example 25.8

$$P = V^2/R \Rightarrow R = V^2/P \Rightarrow R = (12V)^2/40W = 3.6\,\Omega$$

Alternating Current:



(a) DC

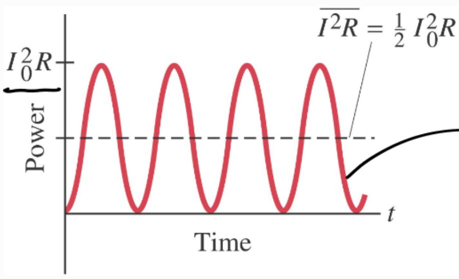
(b) AC

Voltage varies sinusoidally in time:

$$V = V_0 \sin(2\pi f t) \, , \quad 2\pi f = \omega \Rightarrow V = V_0 \sin\omega t$$

$$I = V/R = \underbrace{(V_0/R)}_{I_0} \sin\omega t = I_0 \sin\omega t$$

Power is given by $P = I^2R = I_0^2 R \sin^2\omega t$



$\sin^2\omega t$

Average Power: $\bar{P} = I_0^2 R \overline{\sin^2 \omega t} \Rightarrow \bar{P} = \frac{1}{2} I_0^2 R = \frac{1}{2} \frac{V_0^2}{R}$

* The current and voltage have vanishing averages, thus we define RMS values:

$$I_{rms} = \sqrt{\overline{I^2}} = \frac{I_0}{\sqrt{2}} = 0.707\, I_0 \quad , \quad V_{rms} = \sqrt{\overline{V^2}} = \frac{V_0}{\sqrt{2}} = 0.707\, V_0$$

Example 25.13

$\bar{P} = 1000\,W$

$V_{rms} = 120\,V$

a) $I_0 = ?$ $\Rightarrow$ $I_0 = \sqrt{2}\, I_{rms} = \sqrt{2}(8.33A) = 11.8\,A$

$\bar{P} = I_{rms} V_{rms} \Rightarrow I_{rms} = \bar{P} / V_{rms} = 1000/120\,A = 8.33A$

$R = V_{rms} / I_{rms} \Rightarrow R = 120V / 8.33A = 14.4\,\Omega$