Phys102 Lecture 9
Electric Currents and Resistance

Key Points

- Ohm's Law
- Resistivity
- Electric Power
- Alternating Current

References

18-1,2,3,4,5,6,7

Electric Current

Electric current is the rate of flow of charge through a conductor:

$$\overline{I} = \frac{\Delta Q}{\Delta t}.$$

The instantaneous current is given by:

$$I = \frac{dQ}{dt}.$$

Unit of electric current: the ampere, A:

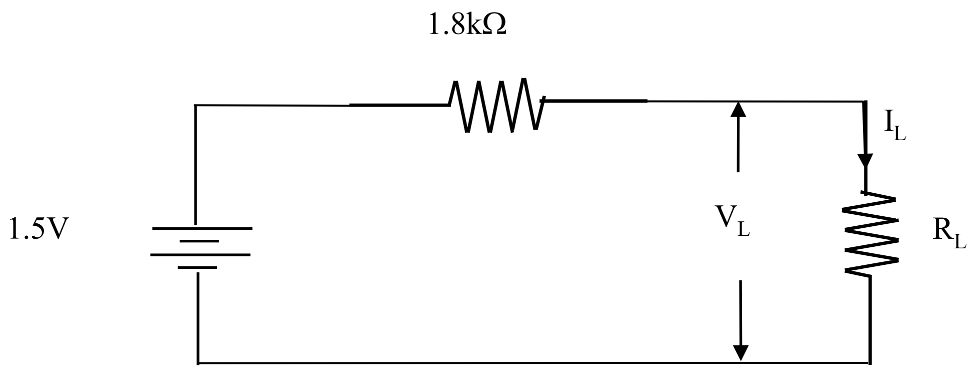
1 A = 1 C/s.

Ohm's Law

The ratio of voltage to current is called the resistance:

$$I = \frac{V}{R}.$$

$$V = IR.$$

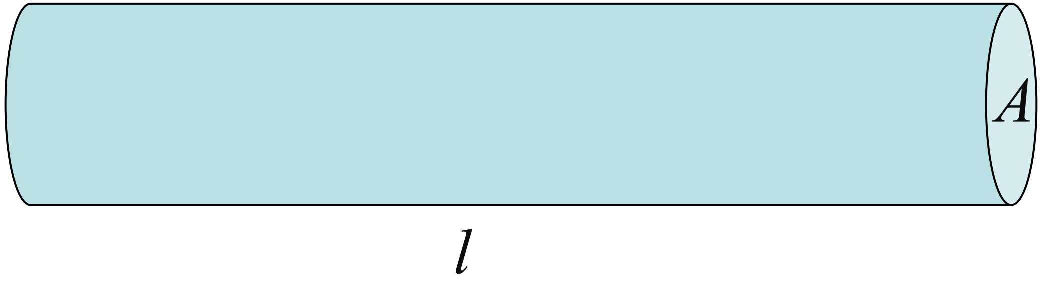


Resistivity

The resistance of a wire is directly proportional to its length and inversely proportional to its cross-sectional area:

$$R = \rho \frac{\ell}{A}.$$

The constant *ρ*, the resistivity, is characteristic of the material.



Resistivity

This table gives the resistivity and temperature coefficients of typical conductors, semiconductors, and insulators.

TABLE 18-1 Resistivity and Temperature Coefficients (at 20°C)

Material	Resistivity, ρ ($\Omega \cdot m$)	Temperature Coefficient, α $(C^\circ)^{-1}$
Conductors		
Silver	1.59×10^{-8}	0.0061
Copper	1.68×10^{-8}	0.0068
Gold	2.44×10^{-8}	0.0034
Aluminum	2.65×10^{-8}	0.00429
Tungsten	5.60×10^{-8}	0.0045
Iron	9.71×10^{-8}	0.00651
Platinum	10.60×10^{-8}	0.003927
Mercury	98.00×10^{-8}	0.0009
Nichrome (Ni, Fe, Cr alloy)	100.00×10^{-8}	0.0004
Semiconductors†		
Carbon (graphite)	$(3-60) \times 10^{-5}$	−0.0005
Germanium	$(1-500) \times 10^{-3}$	−0.05
Silicon	0.1 – 60	−0.07
Insulators		
Glass	$10^{9} - 10^{12}$	
Hard rubber	$10^{13} - 10^{15}$	

† Values depend strongly on the presence of even slight amounts of impurities.

Electric Power

Power, as in kinematics, is the energy transformed by a device per unit time:

$$P = \frac{dU}{dt} = \frac{dq}{dt}V$$

or

$$P = IV.$$

Electric Power

The unit of power is the watt, W.

For ohmic devices, we can make the substitutions:

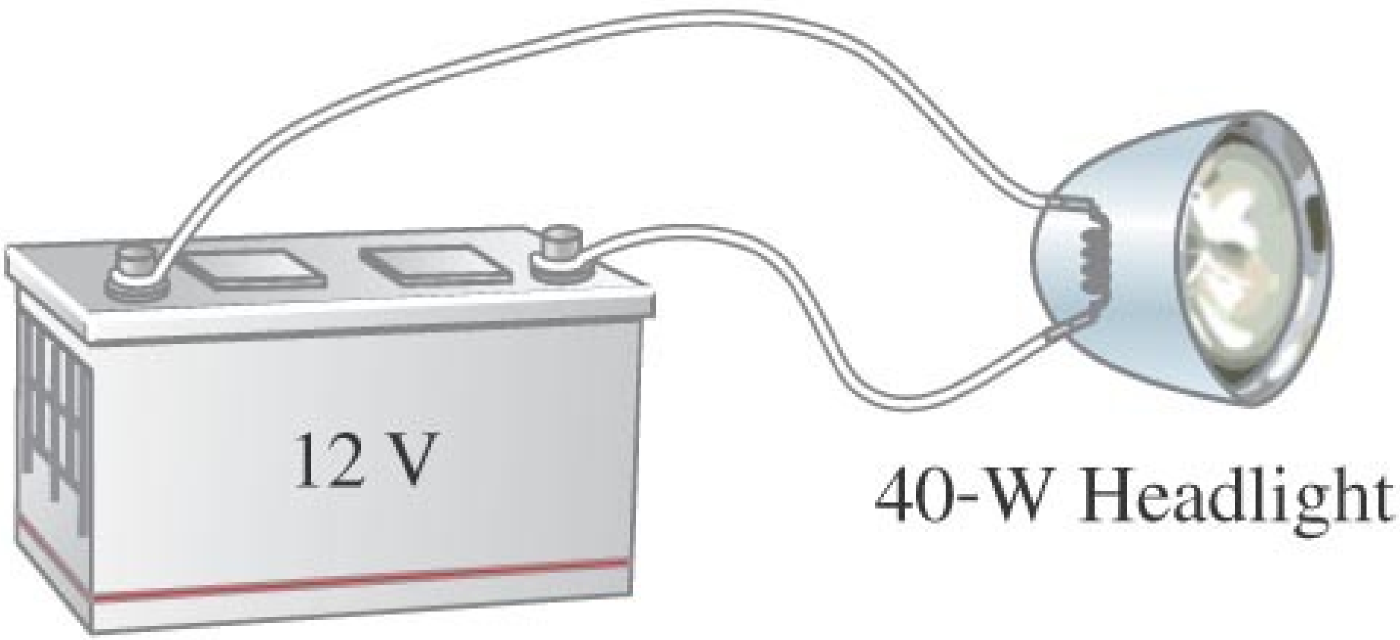
$$P = IV = I(IR) = I^2R$$

$$P = IV = \left(\frac{V}{R}\right)V = \frac{V^2}{R}.$$

Electric Power

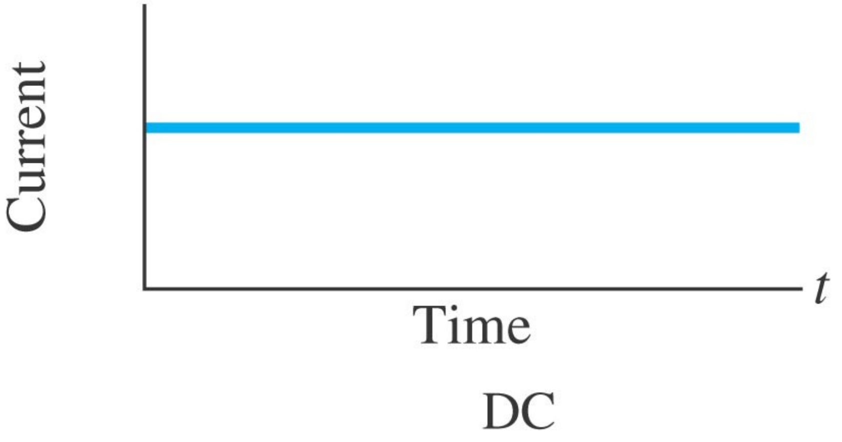
Example: Headlights.

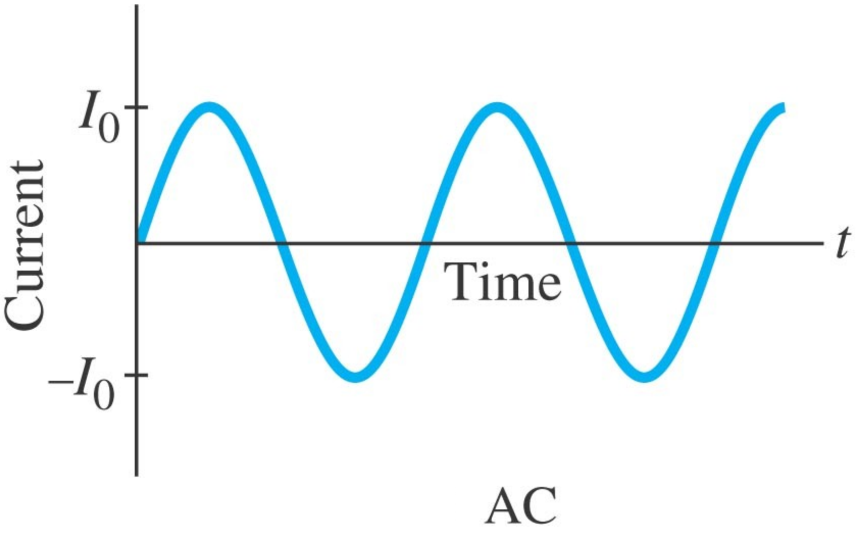
Calculate the resistance of a 40-W automobile headlight designed for 12 V.



Alternating Current

Current from a battery flows steadily in one direction (direct current, DC). Current from a power plant varies sinusoidally (alternating current, AC).





Alternating Current

The voltage varies sinusoidally with time:

$$V = V_0 \sin 2\pi f t = V_0 \sin \omega t,$$

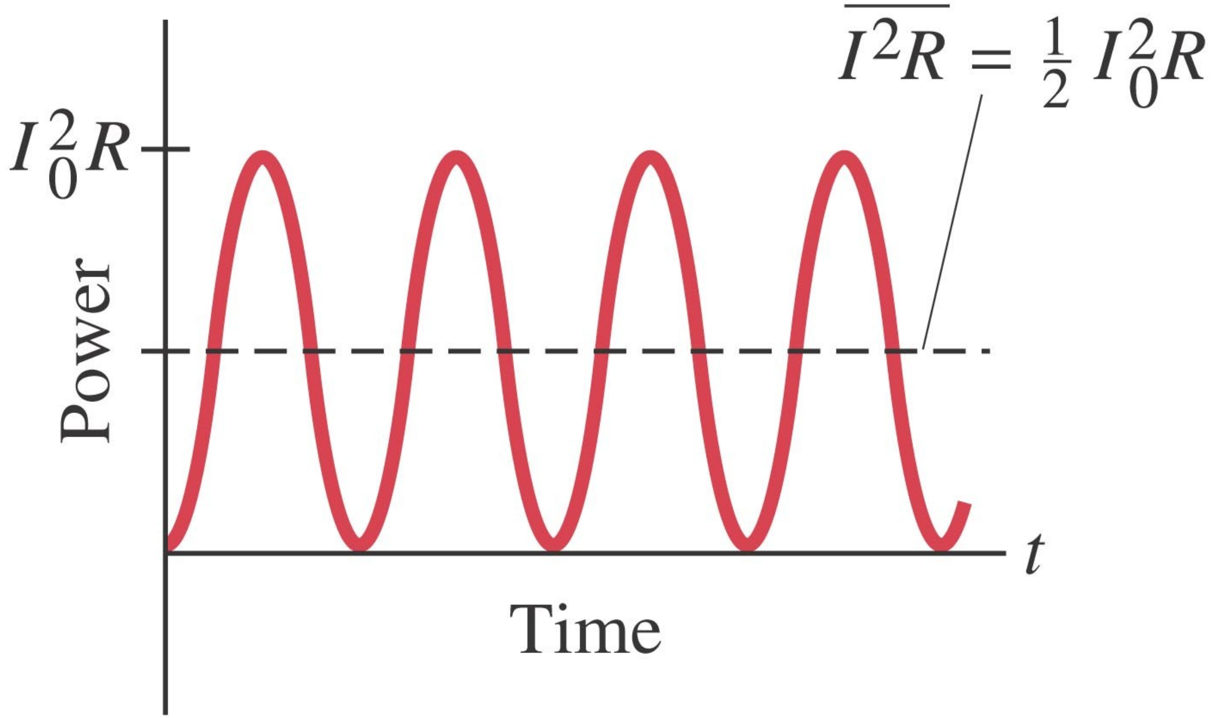
as does the current:

$$I = \frac{V}{R} = \frac{V_0}{R} \sin \omega t = I_0 \sin \omega t.$$

Alternating Current

Multiplying the current and the voltage gives the power:

$$P = I^2R = I_0^2 R\sin^2\omega t.$$



Alternating Current

Usually we are interested in the average power:

$$\overline{P} = \tfrac{1}{2} I_0^2 R$$

$$\overline{P} = \tfrac{1}{2} \frac{V_0^2}{R}.$$

Alternating Current

The current and voltage both have average values of zero, so we square them, take the average, then take the square root, yielding the root-mean-square (rms) value:

$$I_{\mathrm{rms}} = \sqrt{\overline{I^2}} = \frac{I_0}{\sqrt{2}} = 0.707\, I_0 ,$$

$$V_{\mathrm{rms}} = \sqrt{\overline{V^2}} = \frac{V_0}{\sqrt{2}} = 0.707\, V_0 .$$

Alternating Current

Example: Hair dryer.

(a) Calculate the resistance and the peak current in a 1000-W hair dryer connected to a 120-V line. (b) What happens if it is connected to a 240-V line in Britain?