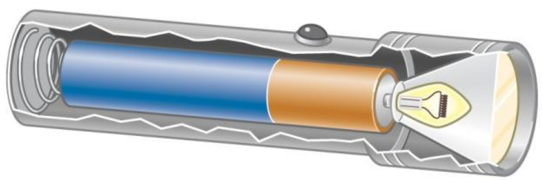
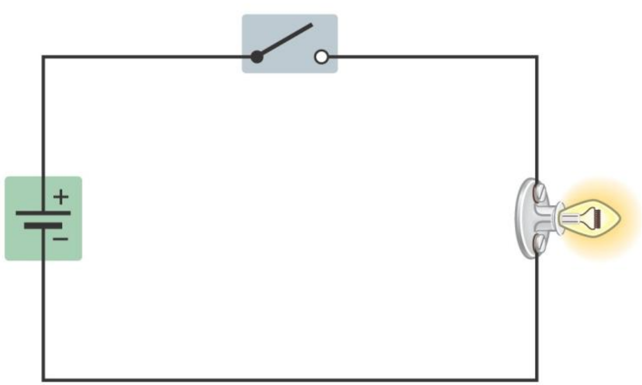
- Electric Current
- Resistance and Ohm's Law
- Energy and Power in Electric Circuits
- Resistors in Series and Parallel
- Kirchhoff's Rules
- Circuits Containing Capacitors
- RC Circuits
- Ammeters and Voltmeters

Electric Current

A battery uses chemical reactions to produce a potential difference between its terminals. It causes current to flow through the flashlight bulb similar to the way the person lifting the water causes the water to flow through the paddle wheel.



(a)



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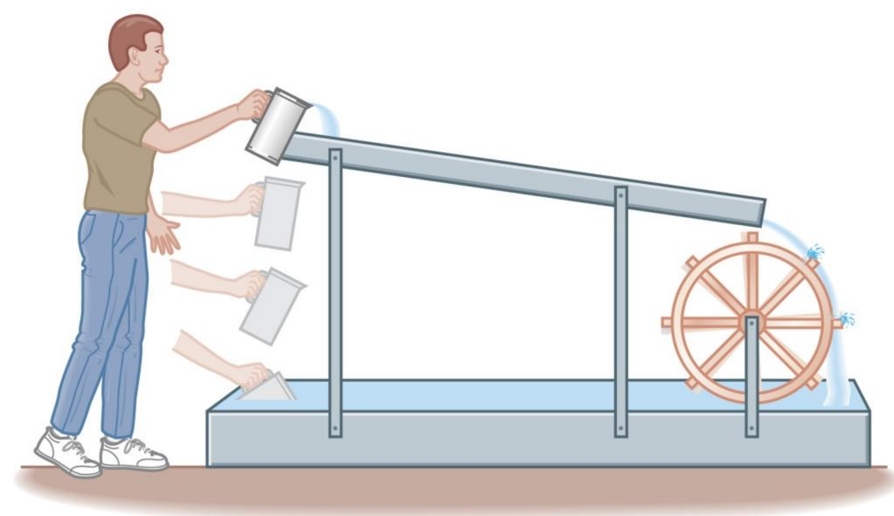


2 Resistance and Ohm's Law

The difference between insulators, semiconductors, and conductors can be clearly seen in their resistivities:

TABLE 21–1 Resistivities

Substance	Resistivity, $\rho\,(\Omega \cdot \mathrm{m})$
Insulators	
Quartz (fused)	7.5×10^{17}
Rubber	$1 \text{ to } 100 \times 10^{13}$
Glass	$1 \text{ to } 10{,}000 \times 10^{9}$
Semiconductors	
Silicon*	0.10 to 60
Germanium*	0.001 to 0.5
Conductors	
Lead	22×10^{-8}
Iron	9.71×10^{-8}
Tungsten	5.6×10^{-8}
Aluminum	2.65×10^{-8}
Gold	2.20×10^{-8}
Copper	1.68×10^{-8}
Silver	1.59×10^{-8}

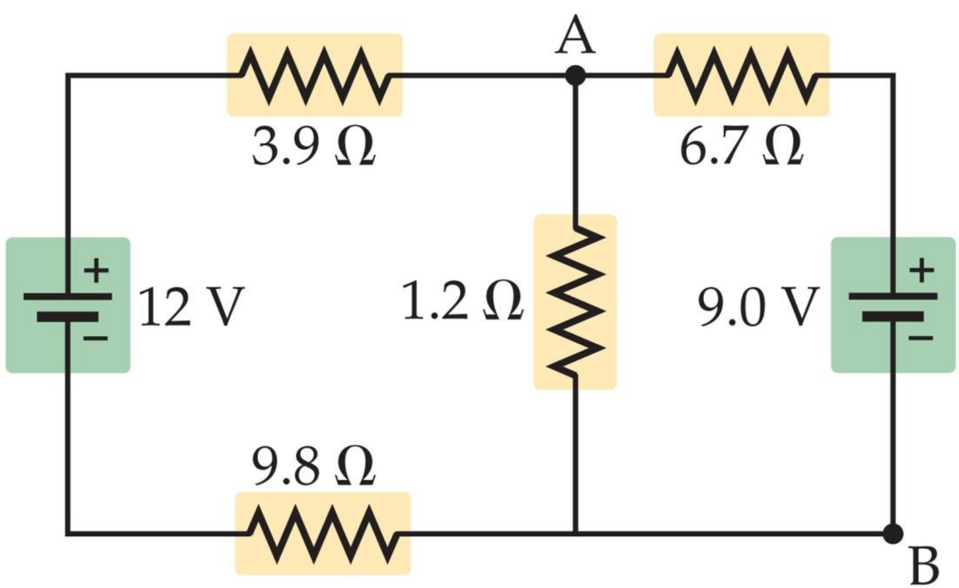
*The resistivity of a semiconductor varies greatly with the type and amount of impurities it contains. This property makes them particularly useful in electronic applications.

5 Kirchhoff's Rules

More complex circuits cannot be broken down into series and parallel pieces.

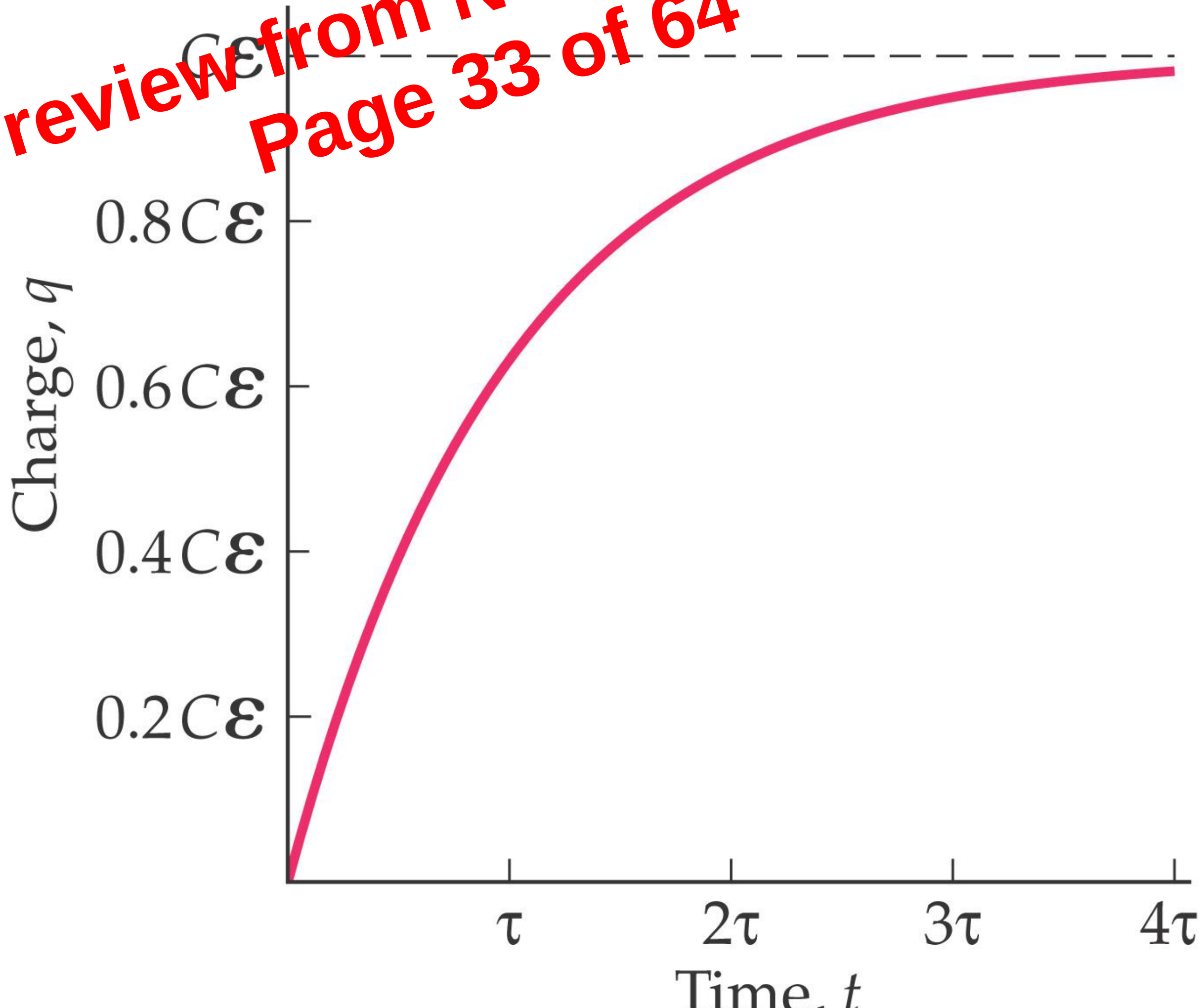
For these circuits, Kirchhoff's rules are useful.

The junction rule is a consequence of charge conservation; the loop rule is a consequence of energy conservation.



7 *RC* Circuits

Here is the charge vs. time for an *RC* circuit:



Transients Analysis

Solution to First Order Differential Equation

Consider the general Equation

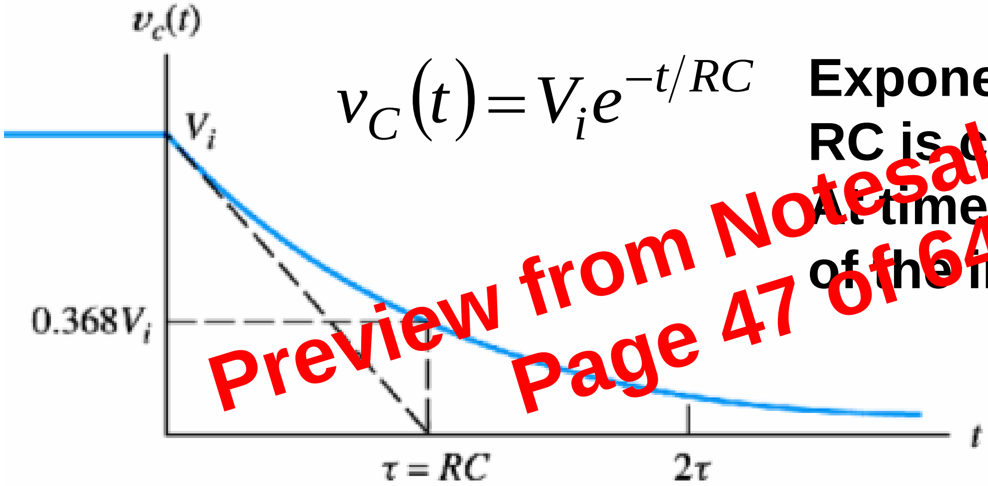
$$\tau \frac{dx(t)}{dt} + x(t) = K_s f(t)$$

Let the initial condition be *x*(*t* = 0) = *x*(0), then we solve the differential equation:

$$\tau \frac{dx(t)}{dt} + x(t) = K_s f(t)$$

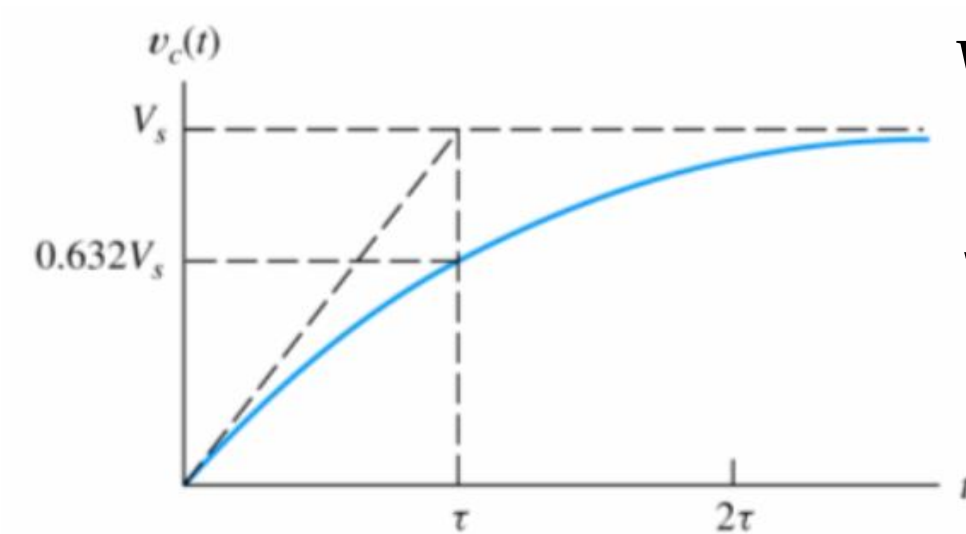
The complete solution consists of two parts:

- **the homogeneous solution (natural solution)**
- **the particular solution (forced solution)**



$$v_C(t) = V_i e^{-t/RC}$$

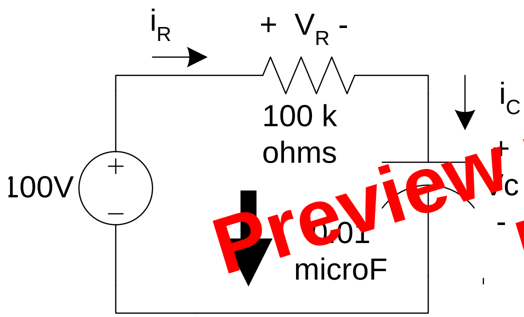
Exponential decay waveform
RC is called the time constant.
At time constant, the voltage is 36.8% of the initial voltage.



$$v_C(t) = V_i(1 - e^{-t/RC})$$

Exponential rising waveform
RC is called the time constant.
At time constant, the voltage is 63.2% of the initial voltage.

Example



Initial condition *Vc*(0) = 0V

$$i_R = i_C$$

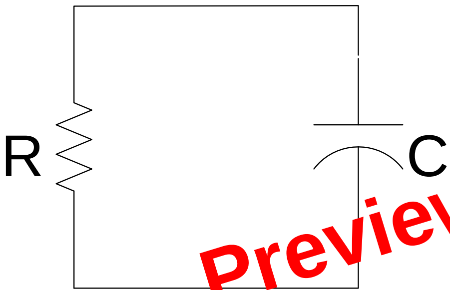
$$i_R = \frac{v_s - v_C}{R}, i_C = C\frac{dv_C}{dt}$$

$$RC\frac{dv_C}{dt} + v_C = v_s$$

$$10^5 \times 0.01 \times 10^{-6}\frac{dv_C}{dt} + v_C = 100$$

$$10^{-3}\frac{dv_C}{dt} + v_C = 100$$

RC CIRCUIT



Power dissipation in the resistor is:

$$p_R = v^2/R = (V_o^{\,2}/R)\, e^{-2t/RC}$$

Total energy turned into heat in the resistor

$$W_R = \int_0^{\infty} p_R\,dt = \frac{V_o^2 \int_0^{\infty} e^{-2t/RC}\,dt}{R}$$

$$= V_o^2 R\left(-\frac{1}{2RC}\right) e^{-2t/RC}\Big|_0^{\infty}$$

$$= \frac{1}{2} C V_o^2$$