As an introduction to this chapter you should view the following movie. If you cannot click on the link, then copy it and paste it into your web browser.

http://www.ionaphysics.org/movies/VIR.mp4
Electric circuits always have
• a source of energy
• a load (which uses energy)
• a complete closed circuit (or path).

A battery or a generator is the energy source.

You may speak of positive or negative charge flowing. In solids it is electrons which move.
The man does work lifting up the water and then the water does work turning the wheel.

In the electrical circuit the battery or generator does work moving the charge to a higher potential and then the charge does work turning the motor, or lighting the bulb, etc.
Electric Current - when charge flows from one place to another. Current is measured in Amperes (or Amps)

\[ I = \frac{q}{t} \] Therefore an Amp = Coulomb/sec
Current = charge/time

I = q/t

1 amp = 1 coulomb/second (C/s)

Example:
A normal household circuit can carry a maximum of 15 amps. How many coulombs pass through the circuit each minute?
Current will flow from higher potential to lower potential.

(a) Equal potential energy → no flow

(b) Water flows from high potential energy to low.
Potential Difference is measured in Volts

\[ V = \frac{w}{q} \]

Therefore a Volt = Joule/Coulomb

1. How much work will it take to move 1 electron through a potential difference of 10 volts? – Hint: remember the charge on an electron?
2. How much charge can be moved through a potential difference of 9.0 volts by 30 Joules of work.

3. It takes 20 Joules of work to move 1.3 coulombs from point A to point B. What is the potential difference between the points?
Current = \text{charge/time} \\
Amp = \text{coul/s}

4. How many coulombs go through a circuit in 2.0 minutes if there is a current of 15 Amperes in the circuit?

5. If a current of 20 mA flows through a 5.0 volt circuit for 10 seconds, what is the total amount of charge which has moved through the circuit?
A Schematic Diagram is an electrical "blueprint". It uses standard symbols and is always drawn very neatly.

http://www.kpsec.freeuk.com/symbol.htm

<table>
<thead>
<tr>
<th>Circuit Element</th>
<th>Symbol</th>
<th>Physical Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistor</td>
<td>📁💊💊</td>
<td>Resists the flow of electric current. Converts electric energy into thermal energy.</td>
</tr>
<tr>
<td>Ideal wire</td>
<td>⬤</td>
<td>An ideal wire has zero resistance. It is used to connect various elements in a circuit.</td>
</tr>
<tr>
<td>Battery</td>
<td>🍻</td>
<td>A device that produces a constant difference in electrical potential between its two terminals.</td>
</tr>
<tr>
<td>Switches (open and closed)</td>
<td>🔔</td>
<td>Devices used to control whether electric current is allowed to flow through a circuit or a portion of a circuit.</td>
</tr>
<tr>
<td>Diode</td>
<td>⚪</td>
<td>A device that allows electric current to flow in one direction only.</td>
</tr>
<tr>
<td>Incandescent lightbulb</td>
<td>💡</td>
<td>A device containing a resistor that gets hot enough to give off visible light.</td>
</tr>
</tbody>
</table>
(a) A simple flashlight

(b) Circuit diagram for flashlight

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Physical Diagram

Schematic Diagram
Batteries produce Direct Current (DC). DC always flows in the same direction. Household outlets supply Alternating Current (AC). AC reverses direction (in the US the frequency is 60 Hz).

Difference in potential (Voltage) causes current to flow.

(a) Equal potential energy → no flow

(b) Water flows from high potential energy to low.
Resistance: Opposition to current flow measured in Ohms Ω

Higher Voltage = more current
Higher Resistance = less current

\[ V = I \times R \]

\( V = \text{Voltage} \quad \text{- in Volts} \)
\( I = \text{Current} \quad \text{- in Amps} \)
\( R = \text{Resistance} \quad \text{- in Ohms} \)

Problem: A potential difference of 24V is applied to a 150 Ohm resistor. How much current will flow?
Problem:
You have an air conditioner which operates at 120 V and draws 7.5 A. Find the equivalent resistance.
Conductors: permit current flow (low resistance)
Insulators: prevent current flow (high resistance)
Semi-conductors: may act as conductors or as insulators, depending upon the circumstances.

Example of a semi-conductor:
A Diode permits current to flow in one direction, but not in the opposite direction.

(a) Forward-biased diode
(b) Reverse-biased diode
Semiconductor example 2: Transistor

(a) Image of a transistor component with labels: Collector, Base, Emitter.

(b) Diagram showing the transistor symbol with labels: Collector, Emitter, Base.

No base current

Valve is closed, and no current flows between collector and emitter.

Small base current

Valve is open, and a large current flows between collector and emitter.
There are two kinds of circuits, series and parallel. Watch this movie for a good introduction:

http://www.ionaphysics.org/moviesSeriesParallel.mp4
Electric Circuits:
Series Circuit: Only one path for current

VT = V1 + V2 + V3
IT = I1 = I2 = I3
RT = R1 + R2 + R3

(a) Three resistors in series

(b) Equivalent resistance has the same current.
Electric Circuits:
Series Circuit: Only one path for current

\[ V_{T} = V_{1} + V_{2} + V_{3} \]
\[ I_{T} = I_{1} = I_{2} = I_{3} \]
\[ R_{T} = R_{1} + R_{2} + R_{3} \]

You have 2 resistors in series. One is 100 ohms and the other is 300 ohms. Find the total resistance of the circuit.
Electric Circuits:
Series Circuit: Only one path for current

\[ VT = V_1 + V_2 + V_3 \]
\[ IT = I_1 = I_2 = I_3 \]
\[ RT = R_1 + R_2 + R_3 \]

You have 2 resistors in series. One is 100 ohms and the other is 300 ohms. Find the total resistance of the circuit. If 8 V is supplied by the battery, what is the current in the circuit?
Electric Circuits:  
Series Circuit: Only one path for current

\[ VT = V_1 + V_2 + V_3 \]
\[ IT = I_1 = I_2 = I_3 \]
\[ RT = R_1 + R_2 + R_3 \]

You have 2 resistors in series. One is 100 ohms and the other is 300 ohms. Find the total resistance of the circuit. If 8 V is supplied by the battery, what is the current in the circuit? How many volts are across the 100 ohm resistor?
Parallel Circuit:
More than one path for current

\[ VT = V1 = V2 = V3 \]
\[ IT = I1 + I2 + I3 \]
\[ \frac{1}{RT} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3} \]

(a) Three resistors in parallel

(b) Equivalent resistance has the same current.
You have three resistors, $R_1 = 200$ Ohms, $R_2 = 200$ Ohms, and $R_3 = 100$ Ohms. They are wired in parallel and connected to a 10 Volt battery. Calculate $I_1$, $I_2$, $I_3$, $I$, and $R_t$
Power = Voltage * Current \[ P = V \times I \]
Watt = Volt * Amp

A 100 watt light bulb operates at 120 volts. How much current flows through the bulb? How much electrical energy is consumed each hour the bulb is left operating?
Power = work (or energy)/Time
Therefore Energy = power * time

P=VI
W = VIt
Work or energy is usually measured in Joules. However, that is a small unit. Electrical energy rates are usually stated as so many cents per kilowatt hour.

Problem: You go on vacation and leave a 100 Watt bulb burning for 14 days. How many kWhr does the bulb use?
Electric rates in the continental US vary a lot. See this chart:


Calculate the cost of running the bulb for the 14 days you were away. (Use information from previous page.)
Here is a challenge:
Three light bulbs are wired according to the diagram. Assuming current will tend to flow along the path of least resistance, state what will happen when the switch (currently shown in the open position) is closed.