Physics II: 1702
Gravity, Electricity, & Magnetism

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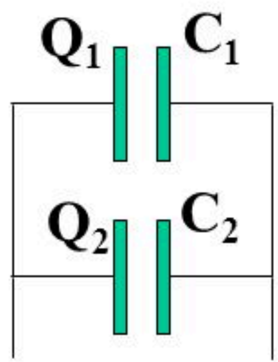
Van Allen 70 [Clicker Channel #18]
MWF 11:30-12:30 Lecture, Th 12:30-1:30 Discussion

Capacitance vs. Resistance

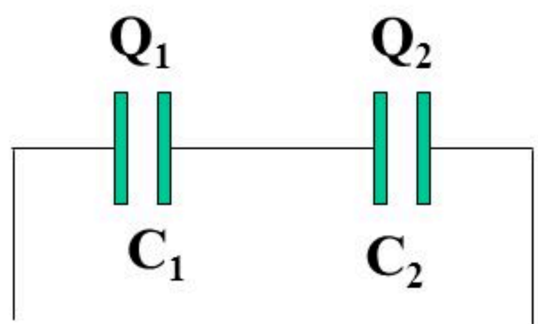
- Both material & geometrical properties
  - C proportional to A, inversely proportional to d
  - R proportional to L, inversely proportional to A
- V = IR across resistor
- V = Q/C across capacitor

Series and Parallel Capacitors

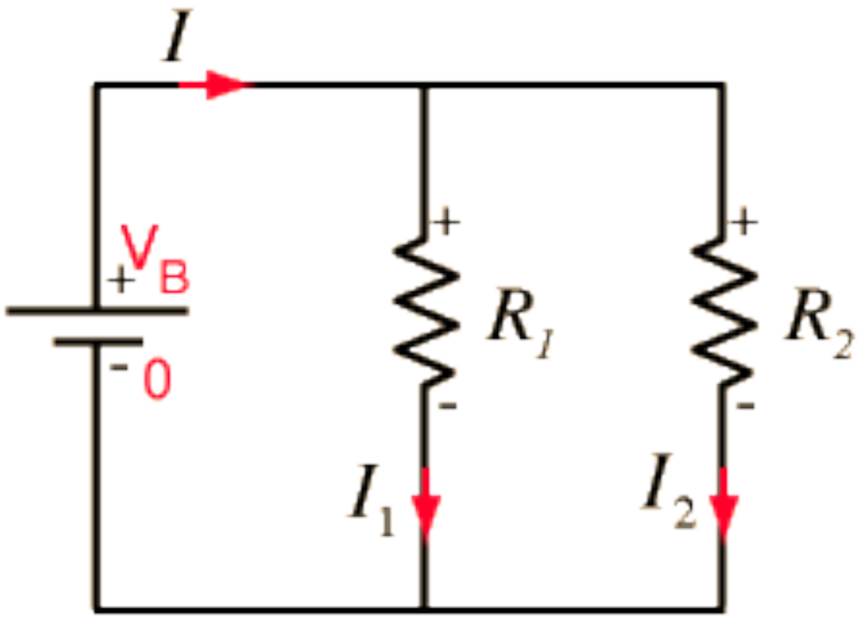
- **In parallel :**
  - $C_{eq} = C_1 + C_2$
  - $V_{eq}=V_1=V_2$
  - $Q_{eq}=Q_1+Q_2$



- **In series :**
  - $1/C_{eq} = 1/C_1 + 1/C_2$
  - $V_{eq}=V_1+V_2$
  - $Q_{eq}=Q_1=Q_2$

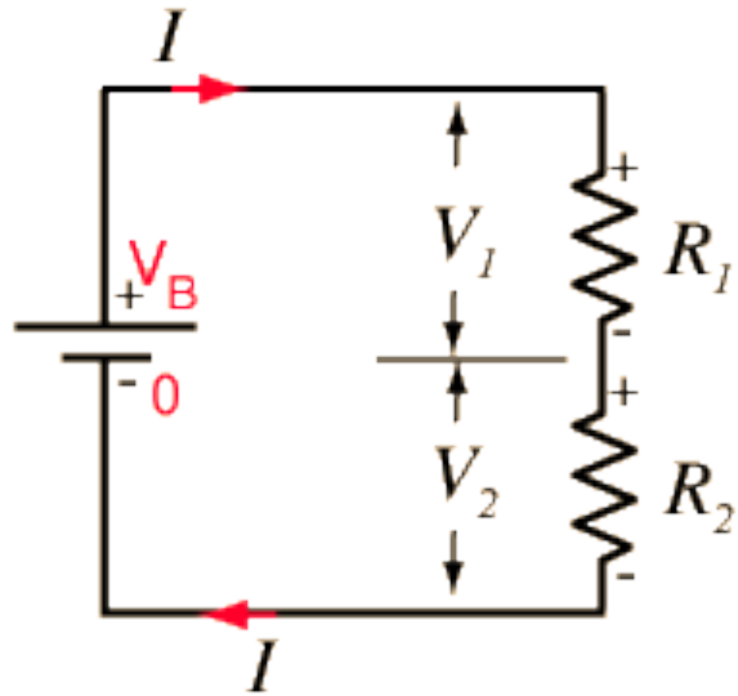


Series and Parallel Resistors



Parallel resistors

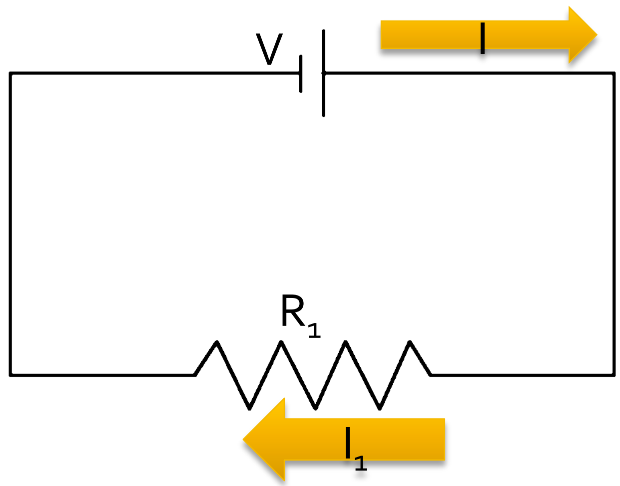
$$\frac{1}{R_{equivalent}} = \frac{1}{R_1} + \frac{1}{R_2}$$

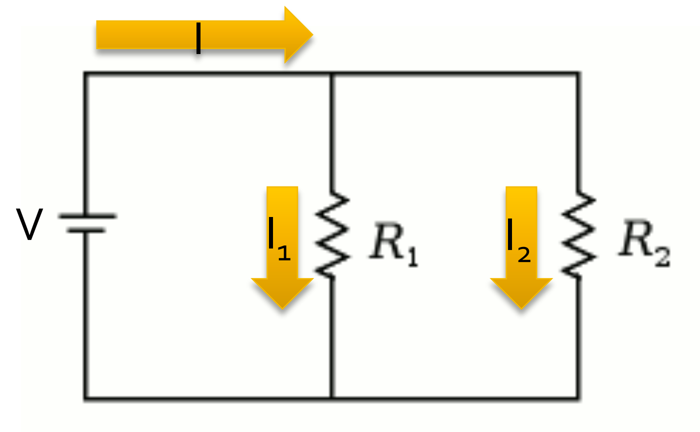


Series resistors

$$R_{equivalent} = R_1 + R_2$$

Concept Check





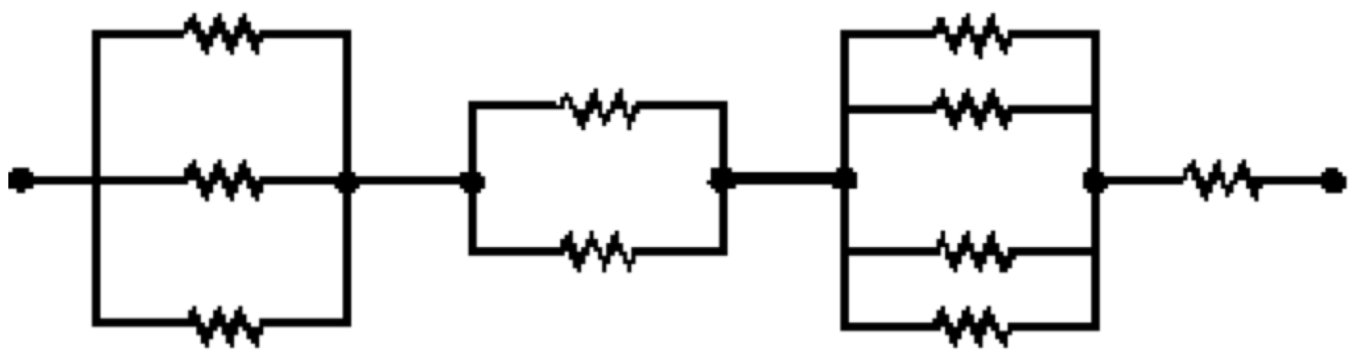
- If I keep the same voltage across my circuit, but add a second identical resistor in parallel with the first resistor ($R_1 = R_2$), what happens to the current I_1 through R_1?

1. It stays the same
2. It doubles
3. It drops by a factor of two
4. It goes to zero

Concept Check

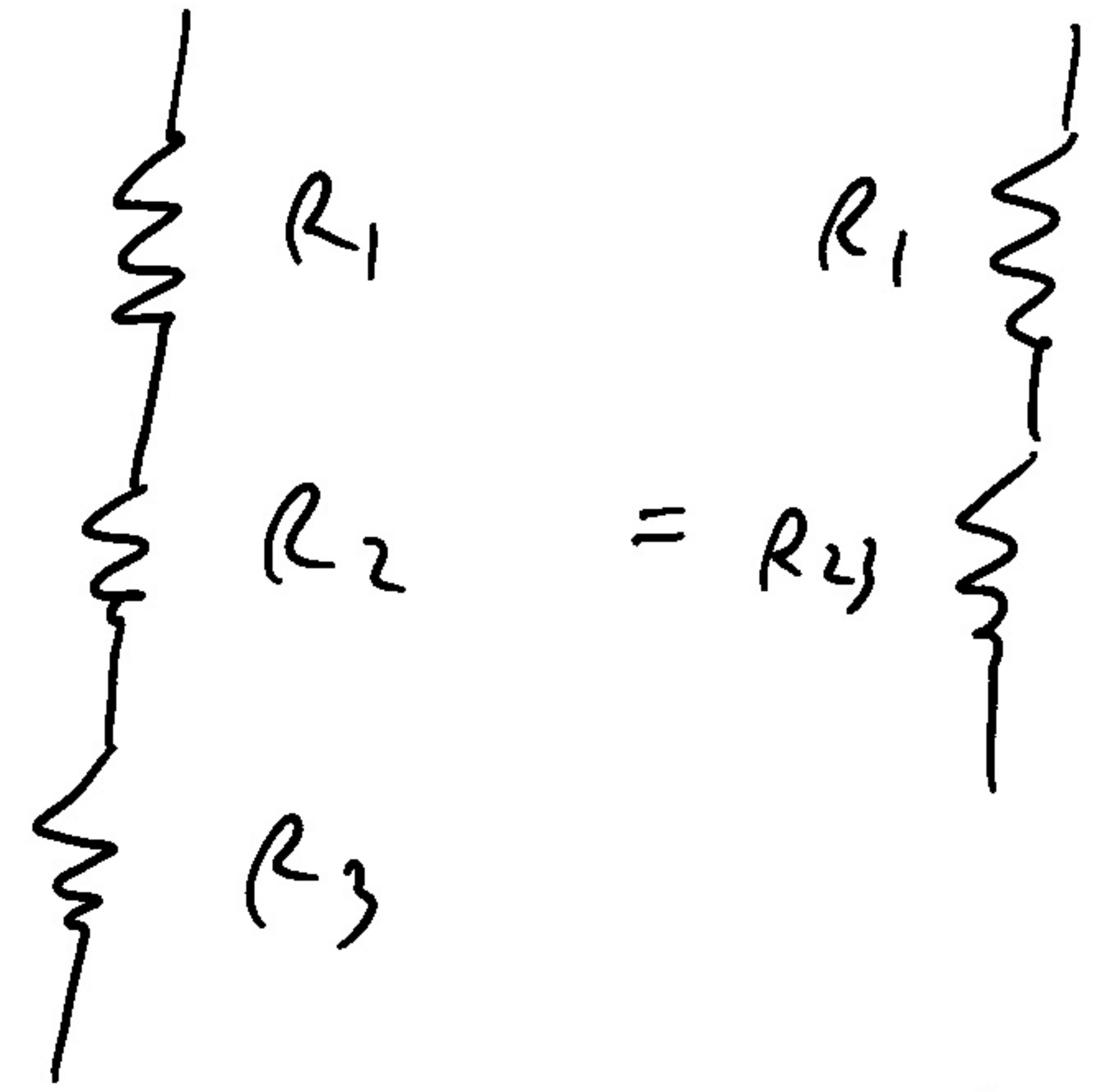
Q14) Each of the resistors in the diagram below has a resistance of 12 Ω. The resistance of the entire circuit is:

1) 6 Ω
2) 12 Ω
3) 18 Ω
4) 25 Ω
5) 48 Ω



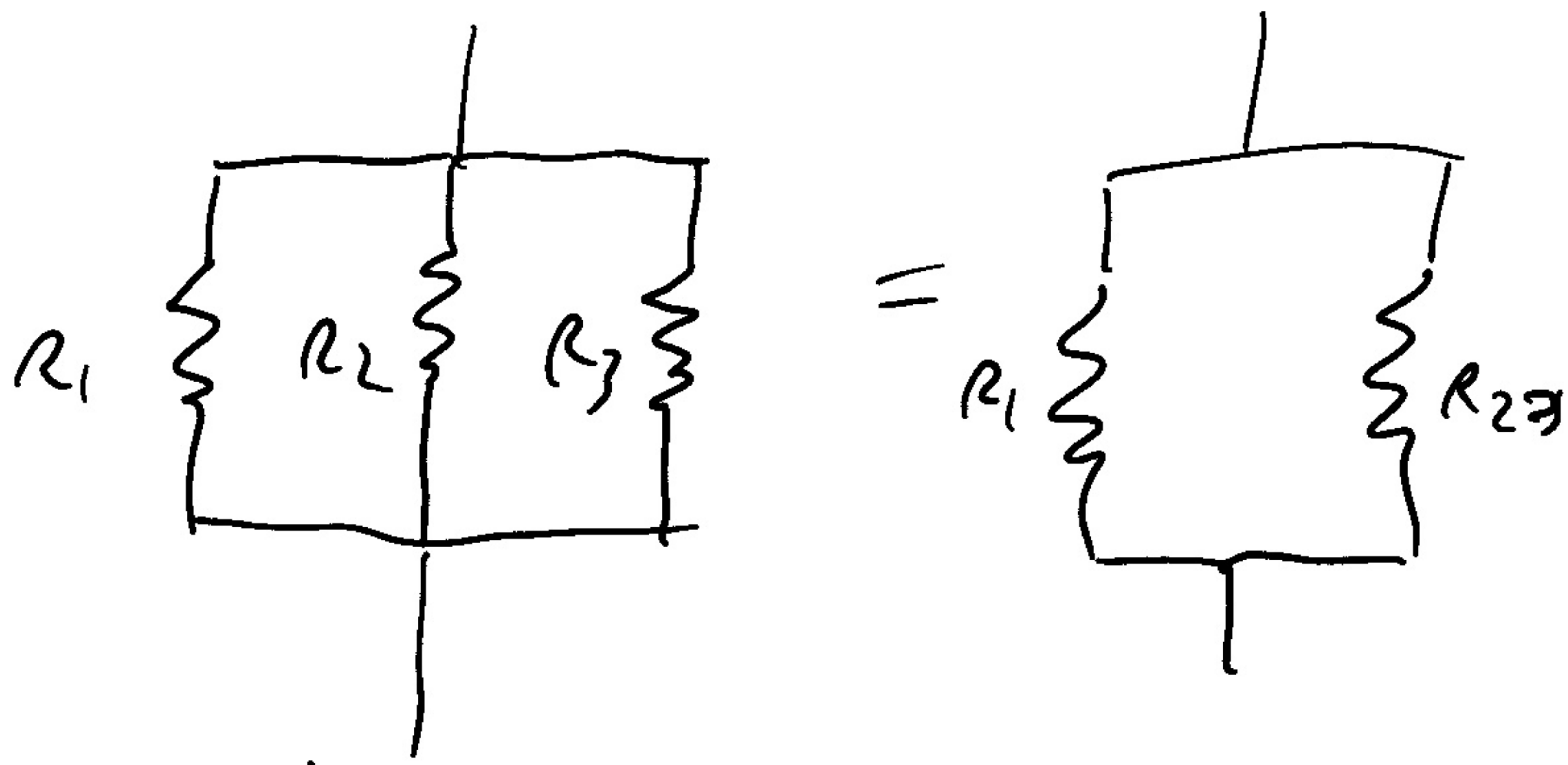
Multiple resistors:

Series



$$R_{eq} = R_1 + (R_2 + R_3)$$
$$= R_1 + R_2 + R_3$$
$$= \Sigma R$$

parallel



$$R_{eq} = 1/(1/R_1 + 1/R_{23})$$
$$= 1/(1/R_1 + 1/R_2 + 1/R_3)$$
$$= 1/\Sigma 1/R_n$$

power dissipation:

- Moving charge through a circuit takes energy

$$dU = V\,dq$$

= potential energy to push dq across potential V

$$dq = I\,dt$$

$$\Rightarrow dU = IV\,dt$$

or $dU/dt = P$ = power

$$= \boxed{IV}$$

For a resistor:

$$P = I^2 R = V^2/R$$

Series: More resistors
$\Rightarrow$ less current

Parallel: More resistors
$\Rightarrow$ more paths
$\Rightarrow$ more current

What about power?

$P = V^2/R$

$P_{series} = V^2/R_{tot} = V^2/R_1+R_2$

- Adding resistance in series decreases power dissipation

$P_{parallel} = V^2/R_{tot}$

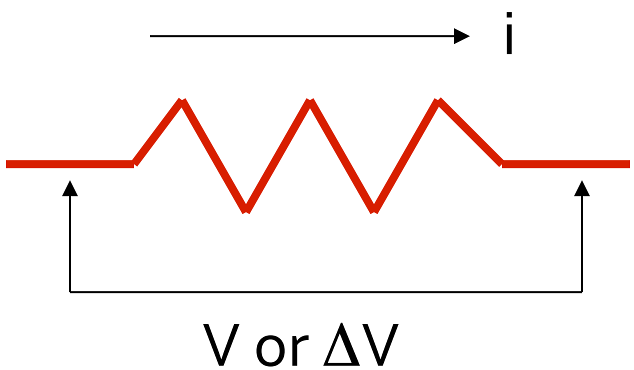
$= V^2 \cdot (1/R_1 + 1/R_2)$

- Adding resistance in parallel increases power dissipation

Power

Power

$$P = iV$$

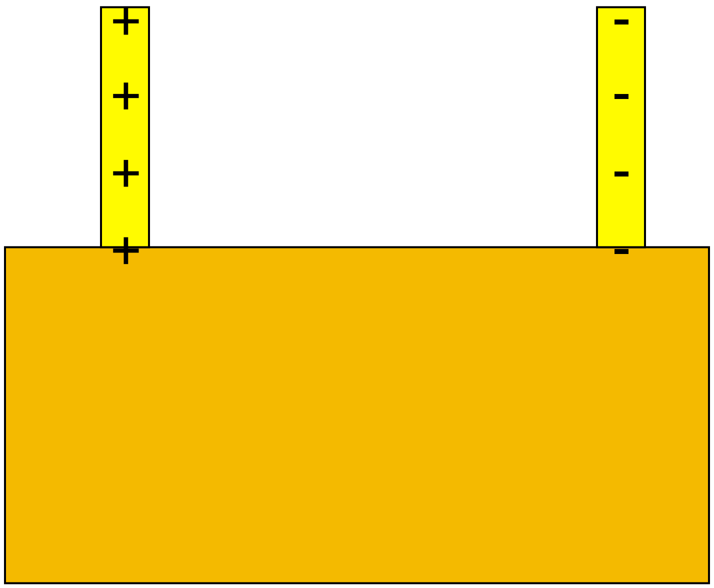


If the resistor is Ohmic, then V=iR and thus

$$P = iV = i^2 R = \frac{V^2}{R}$$

Batteries

Battery – device that generates and maintains an electrical potential difference.



How do we get charges to move opposite to the direction that the Coulomb force wants them to move in?

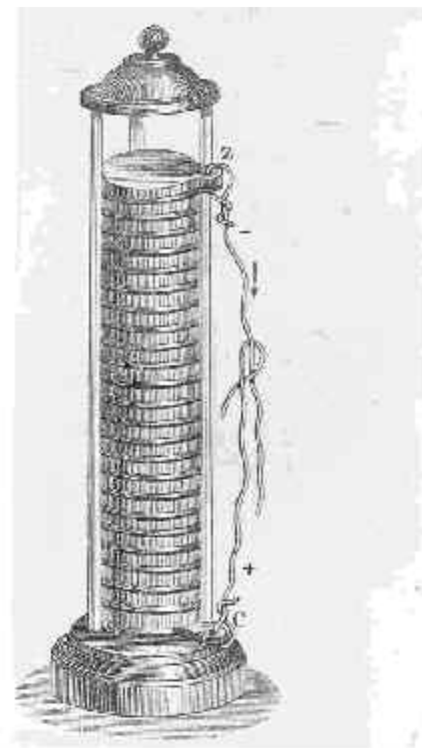
Batteries

People knew how to make a brief spark, but not how to keep charges moving.

Volta invented the battery in 1800's.

Two metal plates are called electrodes.

Liquid or Paste inside battery called electrolyte (often a strong acid)



Batteries

By using two different metals for the electrodes, we can have two different chemical reactions.

The reactions build up charges creating the electrical potential difference between the metal electrodes.

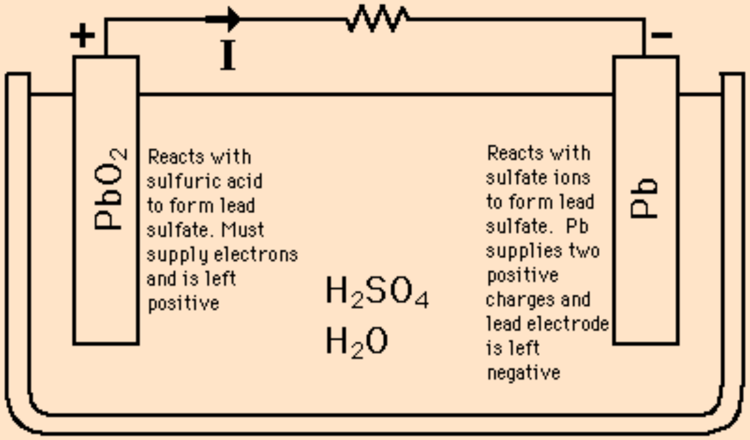
One unit is called a cell.
Many cells put together is called a battery.

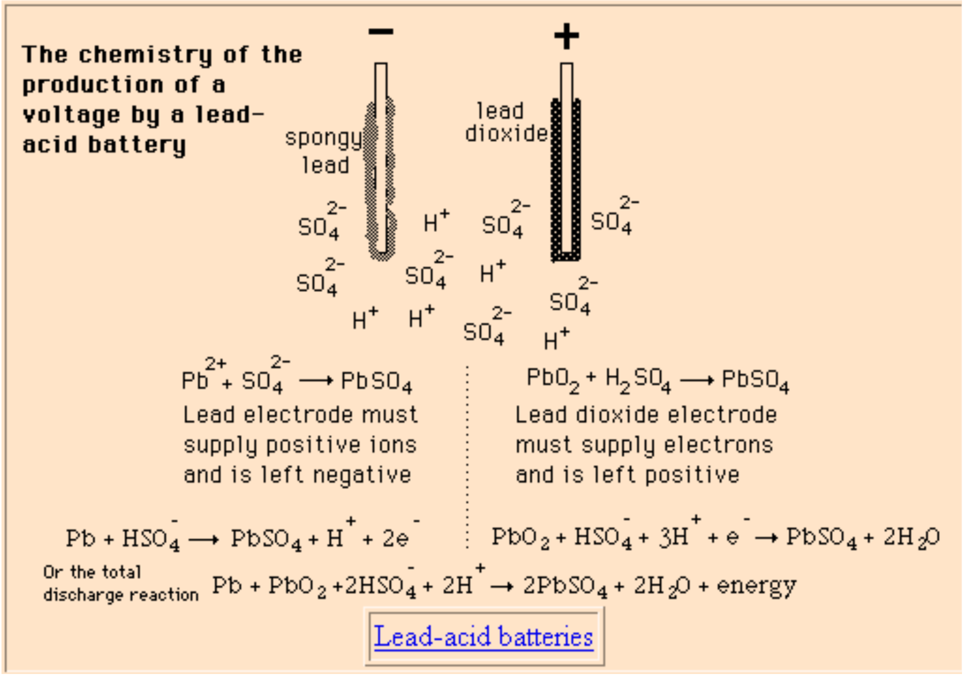
Example: Car battery is six 2 V cells = 12 V battery

Batteries

Lead-Acid Battery

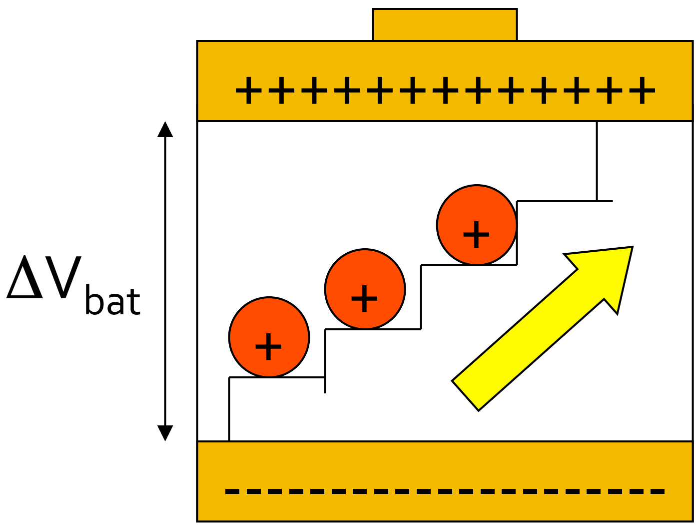
The reaction of lead and lead oxide with the sulfuric acid electrolyte produces a voltage. The supplying of energy to and external resistance discharges the battery.

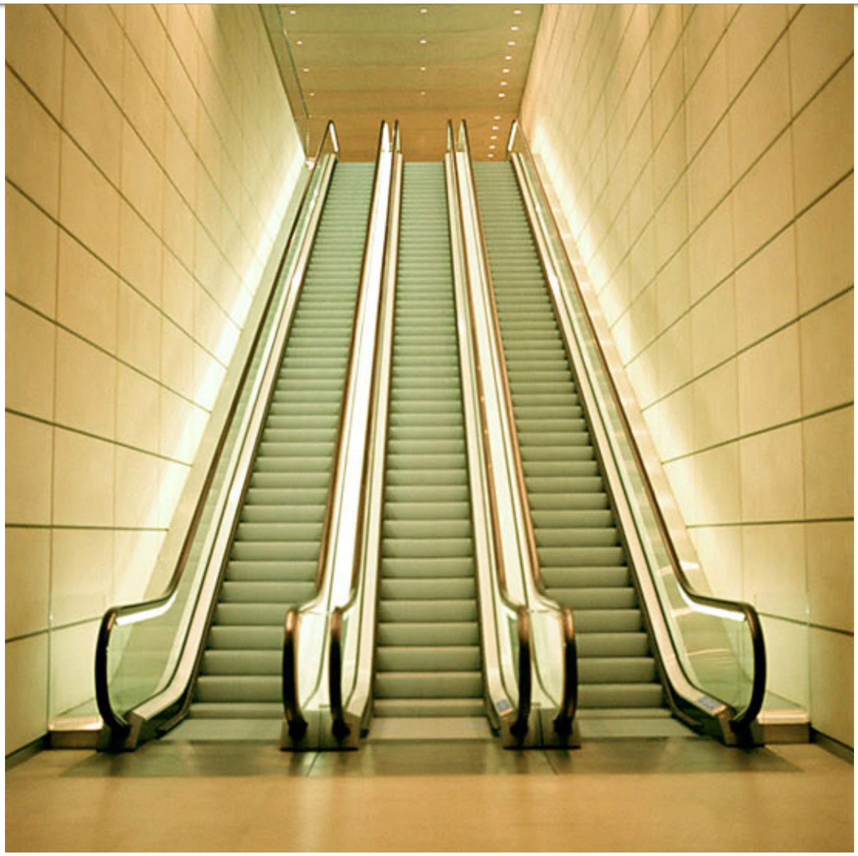




Batteries

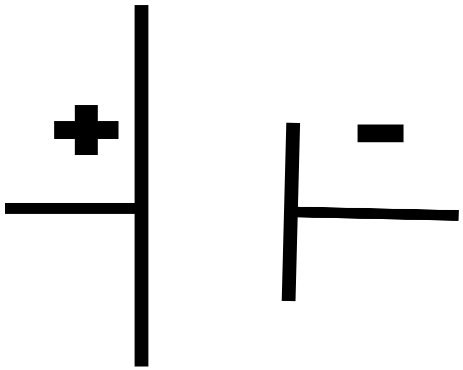
Analog between a battery and an escalator.





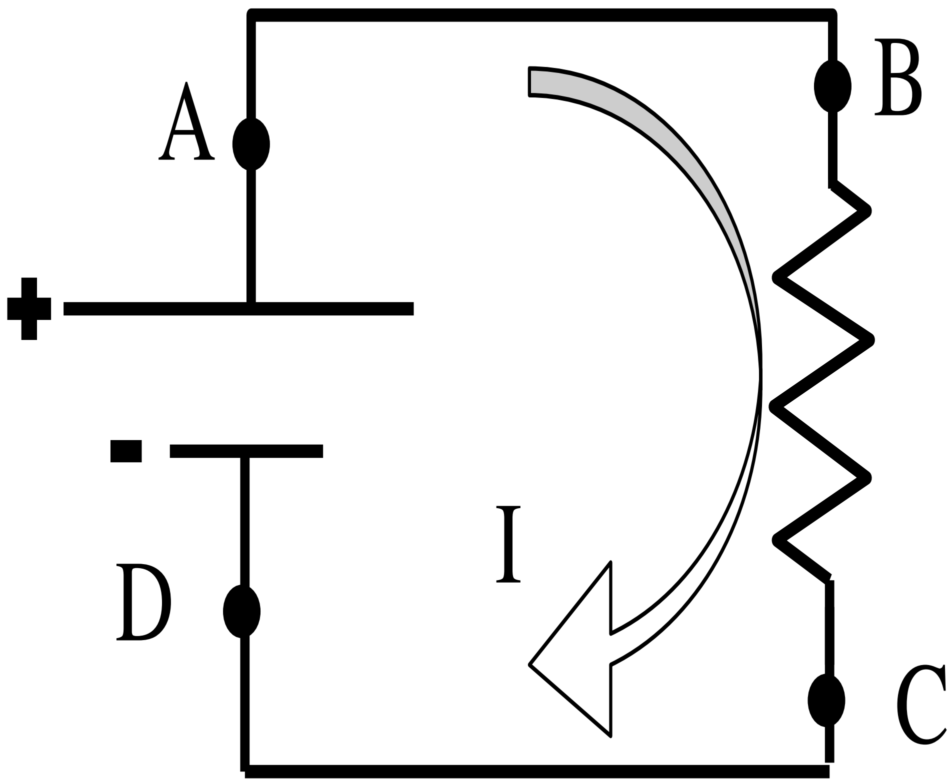
Generalized EMF

- EMF = Electro-Motive Force
  - Not actually a force!



- Anything that does work on a charge can be considered as applying EMF
- EMF = dW/dq with units of Volts
- W = qΔV, so EMF is really just ΔV

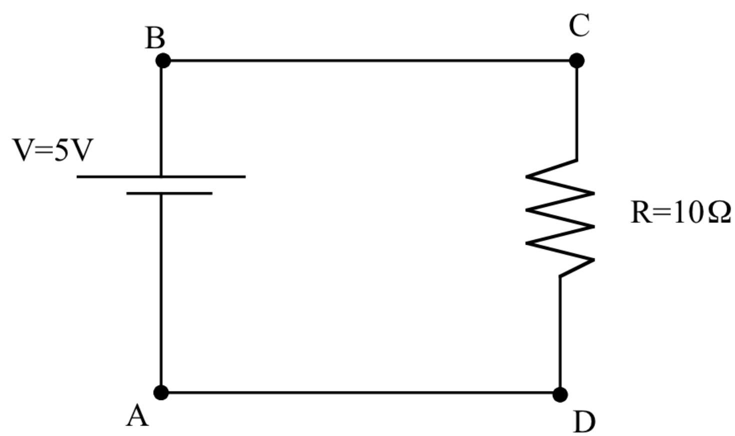
Simple Circuit



Concept Check

Q29) A battery with emf or voltage V is attached to a resistor of resistance R. The circuit diagram is shown below. The point A is at zero volts. The correct voltages at the points B, C, and D are:

1) $V_B = 0V$, $V_C = 5V$, $V_D = 0V$.
2) $V_B = 5V$, $V_C < 5V$, $V_D > 0V$.
3) $V_B = 5V$, $V_C < 5V$, $V_D = 0V$.
4) $V_B = 5V$, $V_C = 5V$, $V_D = 0V$.
5) None of these.



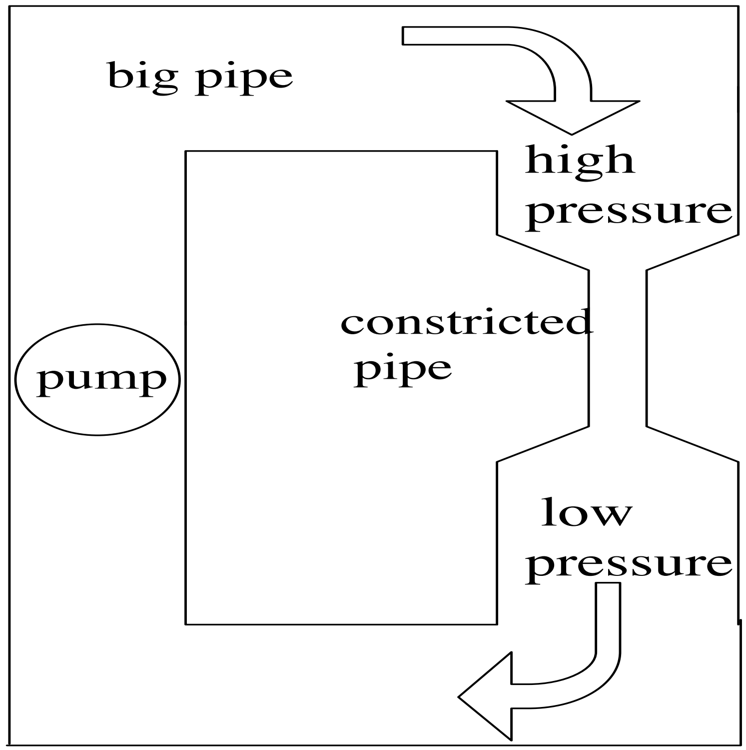
Loop Rule (aka Kirchoff's Law)

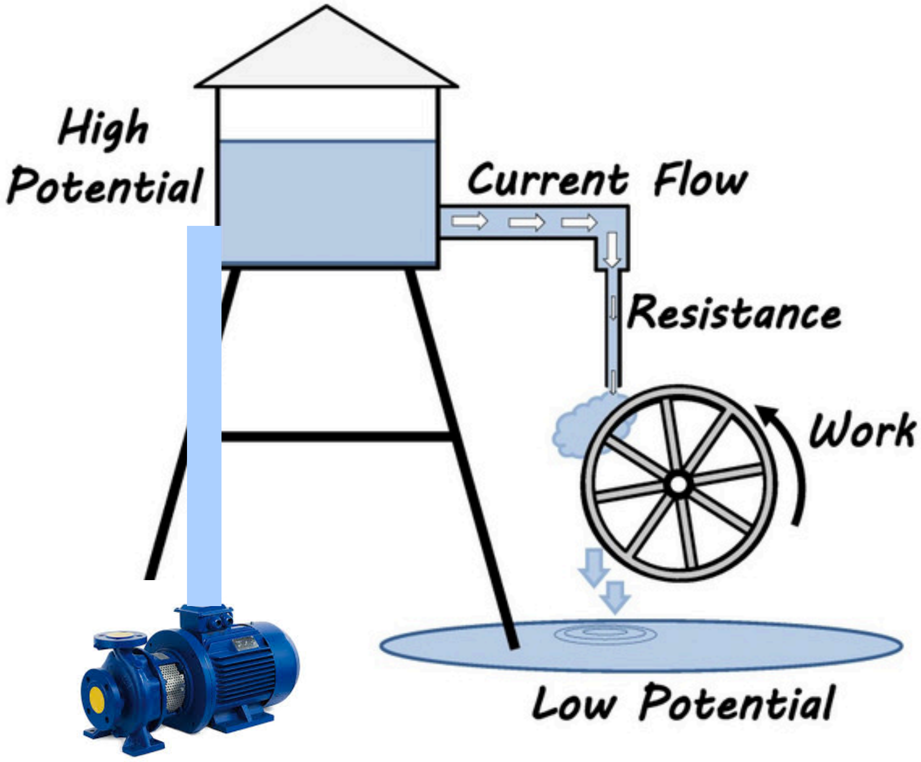
- LOOP RULE: The algebraic sum of the changes in potential encountered in a complete traversal of any loop of a circuit must be zero.
  - These changes in potential include those across an EMF device, and those across any electrical components [resistors, capacitors, etc]

$$\sum_{loop} \Delta V_{rises} = \sum_{loop} \Delta V_{drops}$$

"Conservation of Energy (per Charge)"

Circuit with EMF: Water Analogies





Circuit with EMF: Ski-Lift Analogy