General Physics - E&M (PHY 1308) Lecture Notes

Lecture 012: Using Resistors

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no tags

Electrical Safety

The interface of biology and physics in this subject is electrical safety: when is electric current safe or unsafe, or when are working conditions in which electric current is employed becoming unsafe?

There are some popular sayings that we can think about having developed tools to analyze them:

- *Beware of high voltage.* Is that always true?
- *It isn't the voltage that kills you - it's the current.* Is that more accurate?

Remember your Ohm's Law: voltage drives current, but the amount of current depends on the resistance. High voltage is safe if the current it drives is comparatively small. Let's look at some situations:

- The primary lethality of electricity are electrical signals that pace your heartbeat, which itself is the result of a buildup and release of charge (contraction and relaxation of muscles). The lethal zone is a current across the heart of $100 - 200\mathrm{mA}$. At this point, the heart enters *fibrillation* - uncontrolled spasms of cardiac muscle.
  - If the current is applied internally, close to the heart (less length of resistor between the potential and the heart), less current is needed to do damage. Heart surgeons performing catheterization near the heart worry about micro-amperes, not milli-amperes.
- Above 200mA, cardiac arrest can occur, breathing can stop, and burns can result.
  - high currents can be useful to undo the damage. Emergency defibrillators use enough current to temporarily stop it, allowing

for a "reboot" - a resuming of normal heart activity.
- under dry conditions, the typical human resistance is $10^5\Omega$.

Series and Parallel Resistors

- Introduce the symbol for the resistor and use this to discuss a basic circuit diagram
  - Lines represent very, very good conductors (assumed to be perfect)
  - jagged squiggles describes resistors - conductors whose resistivity and geometry inhibit the flow of electrons
  - for a bit longer, we'll denote the source of electric potential difference as a gap with a "V" inside the gap.

We considered series and parallel capacitors. Series and parallel are the two simplest way to connect ANY two electronic components. Two components are in series if the current has nowhere to go but through both components. They are in parallel if the current can flow *either* through one *or* the other component.

Let's consider series and parallel resistors.

Series Resistors

When in series, and if the circuit is in a *steady state* - that is, there is no charge buildup anywhere in the circuit - then the current has no choice but to go through one resistor, R_1, and then the other, R_2.

The current through series resistors is the same in both resistors

We can write Ohm's Law for each resistor:

$$V_1 = I_1 R_1$$

$$V_2 = I_2 R_2$$

We know that $I_1 = I_2 = I_{total}$. We also know that the total electric potential in the circuit is V_{total}, and that the sum of the individual potential differences must add up to that:

$$V_{total} = V_1 + V_2$$

Finally, we know that whatever the TOTAL resistance of the circuit, there is also an Ohm's Law for that:

$$V_{total} = I_{total} R_{total}$$

We can then solve for the total resistance:

$$V_{total} = V_1 + V_2 = I_{total}(R_1 + R_2) = I_{total} R_{total}$$

Thus we can make the identification that:

$$R_{total} = R_1 + R_2.$$

The total resistance of series resistors is the sum of the individual resistances.

We can then reverse this and use Ohm's Law to solve for the voltage across each resistor:

$$V_1 = \frac{R_1}{R_1 + R_2} V_{total}$$

$$V_2 = \frac{R_2}{R_1 + R_2} V_{total}$$

Add these up and you will recover the total voltage, V_{total}.

Parallel Resistors

What about resistors in parallel? Now, the current across the two resistors is not the same, but the potential difference IS the same. Thus:

$$I_{total} = I_1 + I_2$$

$$V_{total} = V_1 = V_2$$

We can then solve for the total resistance of parallel resistors:

$$I_{total} = V_{total}/R_{total} = I_1 + I_2 = V_1/R_1 + V_2/R_2 = V_{total}\left(1/R_1 + 1/R_2\right)$$

Thus:

$$1/R_{total} = 1/R_2 + 1/R_2$$

And the total resistance is given by:

$$R_{total} = \frac{R_1 R_2}{R_1 + R_2}$$

Lightbulb Info

- Resistance of a 40W lightbulb using 120V:
  - $P = V^2/R \rightarrow R = V^2/P = 360\Omega$
- Resistance of a 100W lightbulb using 120V:
  - 144Ω
- Actual voltage in room
  - 125.1V
- Expected current through single 40W lightbulb:
  - $I = V/R = 0.35A$
- Expected current through single 100W lightbulb:
  - $I = 0.87A$