Physics 152

Lecture 27

Monday, April 2, 2007

• Capacitor Circuits
• Capacitors & Energy
• Dielectrics
• Ohm's Law
• Resistance & Resistivity

Announcements

• Help sessions
  • W 9 - 10 pm in NSC 119
• MasteringPhysics
  • WU #17 due Wed., April 4
  • WU #18 due Mon., April 9
  • Hwk #4 due Mon., April 9
  • WU #19 due Fri., April 13
• Exam - Thurs., April 12

Worksheet Problem #1

Ch. 30: Potential and Field

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What is the effective capacitance of this circuit?

1) 0.28 μF  
2) 0.61 μF  
3) 0.93 μF  
4) 1.00 μF  
5) 1.50 μF  
6) 3.00 μF  
7) 6.00 μF  
8) None of the above

Worksheet Problem #2

Ch. 30: Potential and Field

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An electron is accelerated across a potential difference of 1 V.

It gains kinetic energy as it moves across the potential, losing potential energy.

This amount of energy is known as...
The amount of energy 1 electron gains when accelerated through a potential difference of 1 Volt:

\[ 1 \text{ eV} = (1.6 \times 10^{-19} \text{ C})(1 \text{ V}) = 1.6 \times 10^{-19} \text{ J} \]

Capacitors store charge. It takes work to put charges on capacitors. That work increases the potential energy of the capacitor. So capacitors store energy. We take advantage of this all the time!

How much work does it take to charge a capacitor?

\[ W = q \Delta V \]

Start with uncharged plates. \( \Delta V' = 0 \)

So no work is required to bring up the first bits of charge, \( dq \).

When our capacitor has a charge \( Q \), what is the potential difference across its plates?

\[ \Delta V = \frac{Q}{C} \]

As we bring up more and more charge, \( \Delta V \) increases with \( Q \) at the rate \( 1/C \), so we can plot \( \Delta V \) as a function of \( Q \):

The total amount of work that must be done by an external source to put charge \( Q \) onto an initially uncharged capacitor is simply the area under the curve:

\[ \Delta V = \frac{Q}{C} \]

\[ W = \frac{1}{2} QV = \frac{Q^2}{2C} = \frac{1}{2} CV^2 \]

Of course, you can derive the same answer using calculus, adding up the work done to bring up each little bit of charge \( dq \):

\[ dW = dq \Delta V \]

\[ \Delta V = q/C \]

\[ dW = \frac{dW}{dV} q \Delta V \]

\[ W = \frac{Q^2}{2C} \]

BINGO! The same answer!
Capacitors store the energy used by many of our cordless, rechargeable devices. When it's gone, we have to plug the devices into the wall socket to recharge the capacitors!

\[ W = U = \frac{1}{2} QV = \frac{Q^2}{2C} = \frac{1}{2} CV^2 \]

\( U \) = INTERNAL ENERGY of the capacitor.

Dielectrics

Insulating materials placed between capacitor plates, generally with the intention being to increase the capacitance of the capacitor.

In the circuits we have dealt with thus far, that material is air. It could be other insulators (glass, rubber, etc.).

Dielectrics

Dielectrics, therefore, increase the charge a capacitor can hold at a given voltage, since...

\[ Q = \kappa C_o V = \kappa C_o V \]

\( \kappa C_o \)

\( C = \kappa C_o \)

\( C_o \) is the capacitance in vacuum or air.
Knight's Learning Objectives (2004)

- To develop and use a conceptual model of simple DC circuits.
- To understand series and parallel resistances.
- To apply Kirchhoff's laws to the analysis of circuits.
- To understand energy transfer and power dissipation in circuits.
- To understand how and why circuits are grounded.
- To understand RC circuits.

**Resistance**

Describes the degree to which a current through a conductor is impeded.

In particular, if a voltage \( V \) is applied across a conductor, a current \( I \) will flow. The resistance \( R \) is defined to be:

\[
R = \frac{V}{I}
\]

**Resistance**

\( [R] = \frac{[V]}{[I]} \)

\( [R] = \text{Volt} / \text{Amp} \)

\( = \text{Ohm (Ω)} \)

Georg Ohm (early 19th century) systematically examined the electrical properties of a large number of materials. He found that the resistance of a large number of objects is NOT dependent upon the applied voltage. That is...

**Ohm's Law**

\( V = I R \)

We now plot voltage across versus current through a given resistor...

The objects for which Ohm's Law holds are known as OHMIC.

Objects for which resistance IS a function of the applied voltage (i.e., Ohm's Law is invalid) are known as NON-OHMIC.
On what does the Resistance ($R$) of an object depend? (OHMIC CONDUCTORS)

- Length
- Cross-sectional area

Certainly, if two wires have the same cross-sectional area, the longer of the two will have the greater resistance.

$R \sim L$

For two wires of the same length, the one with the larger cross-sectional area will have the smaller resistance. Think of water flowing in a pipe.

$R \sim \frac{1}{A}$

So if we plotted the resistance ($R$) versus the ratio of the length ($L$) to the cross-sectional area ($A$)

$R = \frac{\rho L}{A}$

The proportionality constant, $\rho$, is the resistivity.

Every material has its own characteristic resistivity to the conduction of electric charge.

I have two pieces of wire, both made of the same material. Piece A is twice as wide and twice as long as Piece B. How does the resistance of A compare to the resistance of B?

1) They have the same resistance
2) $R_A = 4 R_B$
3) $R_A = 2 R_B$
4) $R_A = R_B / 2$
5) $R_A = R_B / 4$
6) None of the above.