Skeleton Notes
For PHY1322

ELECTRICITY: PART I

E1 ELECTRIC CHARGES, FORCE, FIELD and POTENTIAL
E2 ELECTRIC CURRENT, RESISTANCE, CURRENT
E3 CAPACITANCE AND CAPACITORS
E4 ELECTRIC CIRCUITS

PHY1322 WINTER 2017
Dr.Czajkowski

LECTURE 1
(E1) ELECTRIC CHARGES FORCES AND FIELDS

PLAN:

Short and Sweet but Superficial Overview:

Electric Charge
Electric Force
Concept of Electric Field
Field Lines
Electric Potential
Equipotential Lines
Conductors Insulators and Semi-conductors

READING: TO BE ACCOMPLISHED BEFORE THIS LECTURE
Serway Jewett **Physics for Scientists and Engineers,** 9th Edition
Chapter 20

SUGGESTED FOLLOW UP HOMEWORK:

Redo all of the examples worked out in the textbook in these two chapters

Electric Charge and Electric Force

There are two types of charges: _________ and _________

Like charges _________ Unlike charges__________

SI unit of charge is called coulomb – [1C]

Charge is quantized entity.
The fundamental charge (the smallest observed in nature = $1e=1.6\times10^{-19}C$)

Two point charges interact via Coulomb force (electrostatic force) over a distance

$$F = k_e \frac{q_2 q_1}{r^2}$$

ke is electrostatic constant $k_e = 8.987\times10^{9} Nm^2/C^2$ also $k_e = \frac{1}{4\pi\varepsilon_0}$

ε_0 is called vacuum permittivity $\varepsilon_0 = 8{,}854\times10^{-12}\ C^2/Nm^2$

Direction of the force vector is along the line joining the two forces.

Electric Field

Electric Force can be conveniently presented as a product of a charge and a Electric Vector Field.

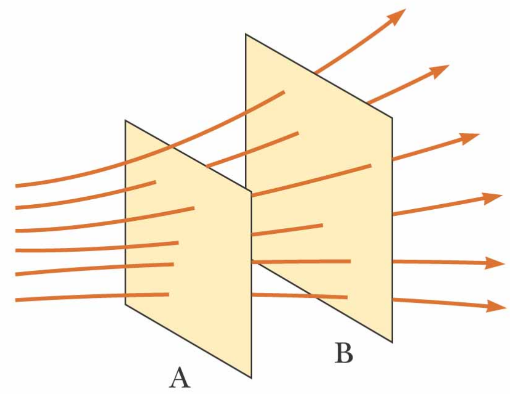
$$\overleftarrow{F} = q\overleftarrow{E}$$

E- Electric Field; q electric charge

What is a Vector Field?

Electric Field Lines: Visual representation of Electric Field

- Field lines give us a means of representing the electric field pictorially
- The electric field vector **E** is tangent to the electric field line at each point
  - The line has a direction that is the same as that of the electric field vector
- The number of lines per unit area through a surface perpendicular to the lines is proportional to the magnitude of the electric field in that region
- If the density of lines through surface A is greater than through surface B => the magnitude of the electric field is greater on surface A than B
- Of the lines at different locations point in different direction, it indicates the field is non-uniform



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- The field lines radiate outward in all directions
  - In three dimensions, the distribution is spherical
- The lines are directed away from the source charge
  - A positive test charge would be repelled away from the positive source charge

CONVENTION FOR DRAWING OF THE FIELD LINES:

- **The lines must begin on a positive charge and terminate on a negative charge**
  - **In the case of an excess of one type of charge, some lines will begin or end infinitely far away**

- **The number of lines drawn leaving a positive charge or approaching a negative charge is proportional to the magnitude of the charge**

- **No two field lines can cross**

Electric Potential : Scalar Function such that Electric Field at any point in space is defined as

$$\overleftarrow{E} == -grad\, V(x,y,z) = -(\frac{\partial V}{\partial x}, \frac{\partial V}{\partial x}, \frac{\partial V}{\partial x})$$

Equipotential Surfaces Surfaces joining the points of equal (same) potential

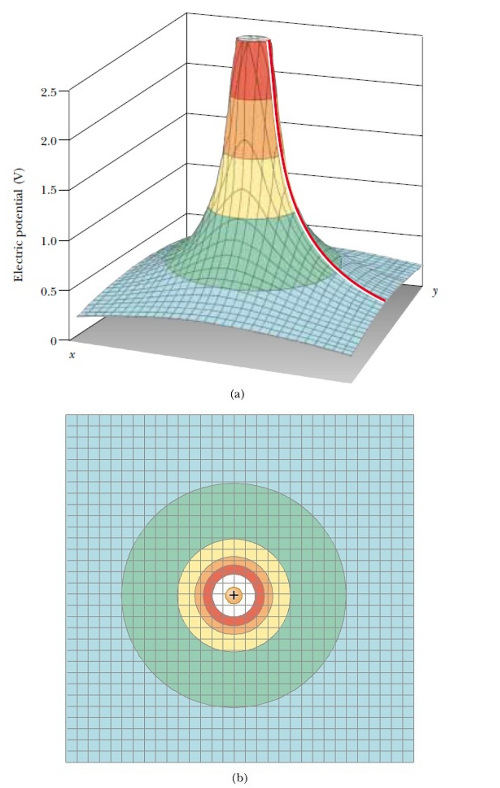


Figure 25.7 (a) The electric potential in the plane around a single positive charge is plotted on the vertical axis. (The electric potential function for a negative charge would look like a hole instead of a hill.) The red line shows the $1/r$ nature of the electric potential, as given by Equation 25.11. (b) View looking straight down the vertical axis of the graph in part (a), showing concentric circles where the electric potential is constant. These circles are cross sections of equipotential spheres having the charge at the center.

From the point of view of their conducting properties all materials may be divided into three categories:

Conductors

- Electrical conductors are materials in which some of the electrons are free electrons
  - Free electrons are not bound to the atoms
  - These electrons can move relatively freely through the material
  - Examples of good conductors include copper, aluminum and silver
  - When a good conductor is charged in a small region, the charge readily distributes itself over the entire surface of the material

Insulators

- Electrical insulators are materials in which all of the electrons are bound to atoms
  - These electrons can not move relatively freely through the material
  - Examples of good insulators include glass, rubber and wood
  - When a good insulator is charged in a small region, the charge is unable to move to other regions of the material

Semiconductors

- The electrical properties of semiconductors are somewhere between those of insulators and conductors and depend on external conditions (temp, field, intensity of light etc)
- First discovered semiconductor materials were silicon and germanium

LECTURE 2
(E2) ELECTRIC CURRENT, RESISTANCE, AND POTENTIAL DIFFERENCE

Date:

PLAN:

Electric Current
Resistance
Ohm's Law
Structural Model of Conductor
Electric Energy and Power Dissipated on the Resistor
EMF Sources

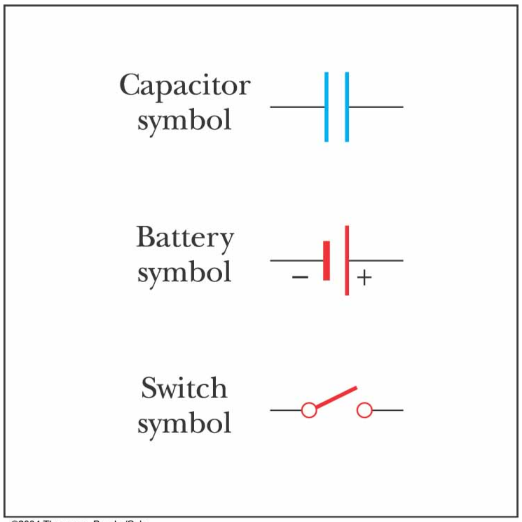
READING: TO BE ACCOMPLISHED BEFORE THIS LECTURE
Serway Jewett **Physics for Scientists and Engineers,** 9th Edition

CH27. Current and Resistance.

SUGGESTED FOLLOW UP HOMEWORK:
Redo all of the examples worked out in the textbook in these two chapters

CIRCUIT DIAGRAMS

- A circuit diagram is a simplified representation of an actual circuit
- Circuit symbols are used to represent the various elements
- Lines are used to represent wires
- The battery's positive terminal is indicated by the longer line



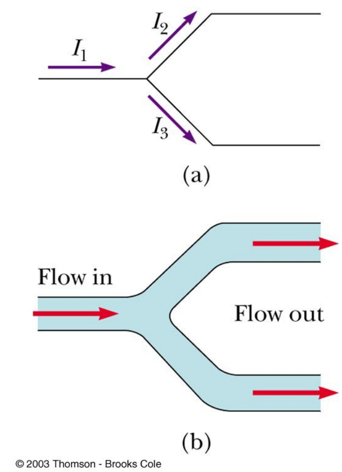
LECTURE 3
(E2) ELECTRIC CIRCUITS

Resistors in Series and Parallel
Kirchhoff's Rules

Ch 28

Kirchhoff's Rules

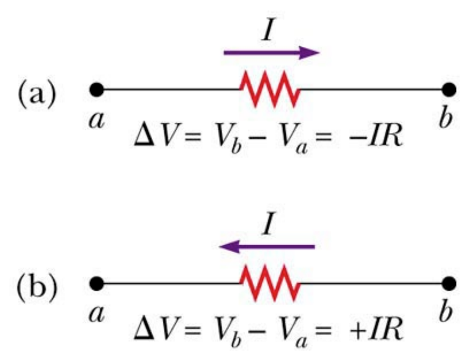
- There are ways in which resistors can be connected so that the circuits formed cannot be reduced to a single equivalent resistor
- Two rules, called Kirchhoff's Rules, can be used instead
- Junction Rule
  - At any junction, the sum of the currents must equal zero
    - A statement of Conservation of Charge
- Loop Rule
  - The sum of the potential differences across all the elements around any closed circuit loop must be zero
    - A statement of Conservation of Energy



- Junction Rule:
  SIin = SIout

- Loop Rule:

$$\sum_{\substack{closed\\loop}} \Delta V = 0$$



- Traveling around the loop from a to b
- In a, the resistor is transversed in the direction of the current, the potential across the resistor is –IR
- In b, the resistor is transversed in the direction opposite of the current, the potential across the resistor is is +IR

- Draw the circuit diagram and assign labels and symbols to all known and unknown quantities. Assign directions to the currents.
  - The direction is arbitrary, but you must adhere to the assigned directions when applying Kirchhoff's rules
- Apply the junction rule to any junction in the circuit that provides new relationships among the various currents
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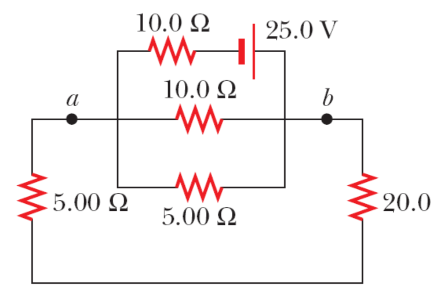
  - The direction is arbitrary, but you must adhere to the assigned directions when applying Kirchhoff's rules
- Apply the junction rule to any junction in the circuit that provides new relationships among the various currents

E4 Suggested Problems.

1 A copper wire of length 1m and diameter of 1mm is stretched so that its resistance is doubled. Find the new diameter and length of the wire

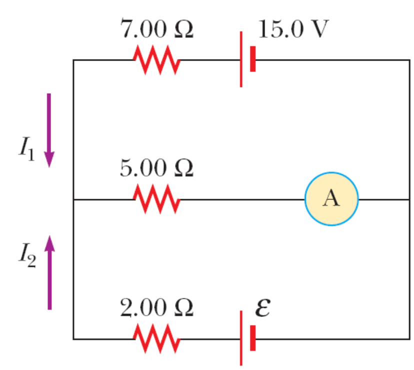
2. Two 1.50-V batteries—with their positive terminals in the same direction—are inserted in series into the barrel of a flashlight. One battery has an internal resistance of 0.255 Ω and the other an internal resistance of 0.153 Ω. When the switch is closed, a current of 600 mA occurs in the lamp. (a) What is the lamp's resistance? (b) What fraction of the chemical energy transformed appears as internal energy in the batteries?

3. Consider the circuit shown in Figure P21.29. Find (a) the current in the 20.0-Ω resistor and (b) the potential difference between points *a* and *b*.



4. Assume that global lightning on the Earth constitutes a constant current of 1.00 kA between the ground and an atmospheric layer at potential 300 kV. (a) Find the power of terrestrial lightning. (b) For comparison, find the power of sunlight falling on the Earth. Sunlight has an intensity of 1 370 W/m^2 above the atmosphere. Sunlight falls perpendicularly on the circular projected area that the Earth presents to the Sun.

5 The ammeter shown in Figure P21.34 reads 2.00 A. Find $I1$, $I2$, and ε. *Note:* The currents are not necessarily in the direction shown for some circuits.



LECTURE 4

(E4) CAPACITORS AND CAPACITANCE

Date:

OUTLINE:

Concept of Capacitance
Combination of Capacitors
Energy Stored in a Charged Capacitor
Capacitors with Dielectrics

READING: TO BE ACCOMPLISHED BEFORE THIS LECTURE
Serway Jewett **Physics for Scientists and Engineers,** 8th Edition

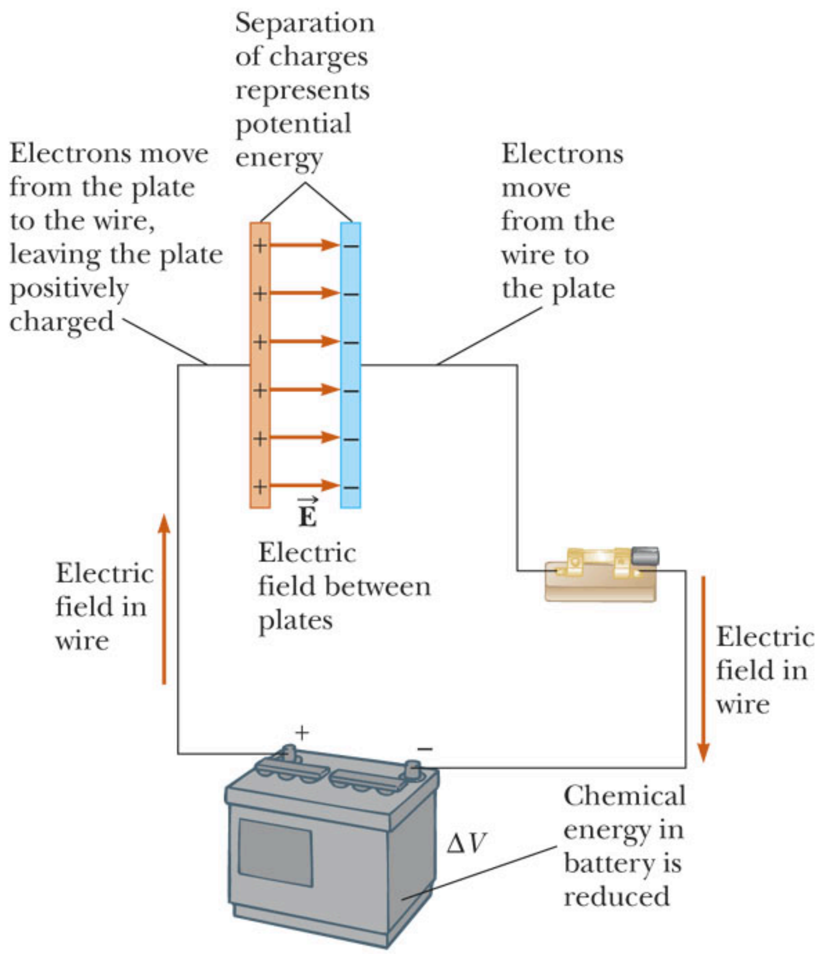
CH26. Capacitance and Dielectrics.

SUGGESTED FOLLOW UP HOMEWORK:

Redo all of the examples worked out in the textbook in this chapter

Energy in a Capacitor – Overview

- Consider the circuit to be a system
- Before the switch is closed, the energy is stored as chemical energy in the battery
- When the switch is closed, the energy is transformed from chemical to electric potential energy
- The electric potential energy is related to the separation of the positive and negative charges on the plates
- A capacitor can be described as a device that stores energy as well as charge



Capacitors with Dielectrics

- A *dielectric* is an insulating material that, when placed between the plates of a capacitor, increases the capacitance
  - Dielectrics include rubber, plastic, or waxed paper
- With a dielectric, $C = \kappa C_o$
  - The capacitance is multiplied by the factor κ when the dielectric completely fills the region between the plates
  - For a parallel plate capacitor, this becomes $C = = \kappa\varepsilon_o(A/d)$
- In theory, d could be made very small to create a very large capacitance
- In practice, there is a limit to d
  - d is limited by the electric discharge that could occur though the dielectric medium separating the plates
- For a given d, the maximum voltage that can be applied to a capacitor without causing a discharge depends on the *dielectric strength* of the material

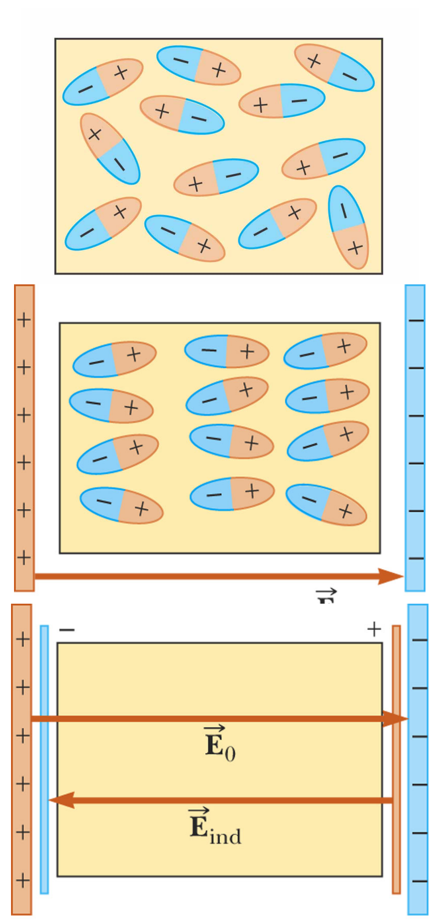
- Dielectrics provide the following advantages
  - Increase in capacitance
  - Increase the maximum operating voltage
  - Possible mechanical support between the plates
    - This allows the plates to be close together without touching
    - This decreases d and increases C

Dielectrics – An Atomic View

- The molecules that make up the dielectric are modeled as dipoles
- The molecules are randomly oriented in the absence of an electric field

- When an external electric field is applied it produces a torque on the molecules and the molecules partially align with the electric field

- An external field can polarize the dielectric whether the molecules are polar or nonpolar



(c)

- The charged edges of the dielectric act as a second pair of plates producing an induced electric field in the direction opposite the original electric field

TABLE 20.1 Approximate Dielectric Constants and Dielectric Strengths of Various Materials at Room Temperature

Material	Dielectric Constant κ	Dielectric Strength[a] (10^6 V/m)
Air (dry)	1.000 59	3
Bakelite	4.9	24
Fused quartz	3.78	8
Mylar	3.2	7
Neoprene rubber	6.7	12
Nylon	3.4	14
Paper	3.7	16
Paraffin-impregnated paper	3.5	11
Polystyrene	2.56	24
Polyvinyl chloride	3.4	40
Porcelain	6	12
Pyrex glass	5.6	14
Silicone oil	2.5	15
Strontium titanate	233	8
Teflon	2.1	60
Vacuum	1.000 00	—
Water	80	—

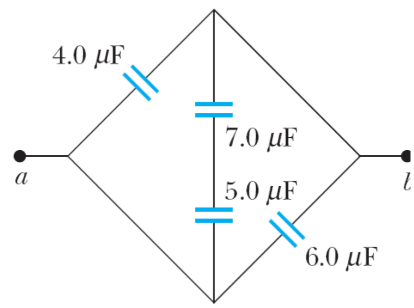
[a]The dielectric strength equals the maximum electric field that can exist in a dielectric without electrical breakdown. Note that these values depend strongly on the presence of impurities and flaws in the materials.

Suggested Problems:

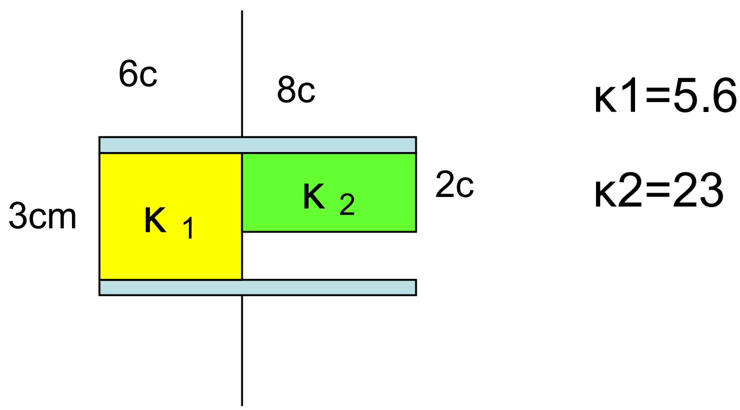
1 A 50.0-m length of coaxial cable has an inner conductor that has a diameter of 2.58 mm and carries a charge of 8.10 μC. The surrounding conductor has an inner diameter of 7.27 mm and a charge of −8.10 μC. (a) What is the capacitance of this cable? (b) What is the potential difference between the two conductors? Assume that the region between the conductors is air.

2 Two capacitors, $C1$ = 5.00 μF and $C2$ = 12.0 μF, are connected in parallel, and the resulting combination is connected to a 9.00-V battery. (a) What is the equivalent capacitance of the combination? What are (b) the potential difference across each capacitor and (c) the charge stored on each capacitor?

3 Find the equivalent capacitance between points *a* and *b* in the combination of capacitors shown below



4 Find the equivalent capacitance of the square parallel plate capacitor below



5 Find the charge on the capacitor *C* if all of the batteries are 10 V and all of the capacitors are 6μF