AP Physics
Electricity and Magnetism

Ben Feuer

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Contents

Chapter 1

Electric Fields and Forces

Note:-

This is a compilation of notes for Electricity and Magnetism for my AP Physics class.
Much of the content is taken from the textbook *College Physics: A Strategic Approach* by Knight, Jones, and Field, specifically chapters 20 to 24 or from my physics class that is taught by Thomas J. Erickson mailto:terickson@mxschool.edu

1.1 Equations for Electric Fields and Forces

- $m_{electron} = 9.11 * 10^{-31}$
- $m_{proton} = 1.67 * 10^{-27}$
- $q_{electron} = -1.6 * 10^{-19} C$
- $q_{proton} = +1.6 * 10^{-19} C$
- $F_{1on2} = F_{2on1} = \frac{k*q_1*q_2}{r^2}$
- $E = \frac{F_{onq}}{q}$
- $E = \frac{kQ}{r^2}$
- $E_{capacitor} = \frac{Q}{\epsilon_0 A}$
- $k = 9.0 * 10^9 \frac{N \cdot m^2}{C^2}$
- $\epsilon_0 = 8.85 * 10^{-12} \frac{C^2}{N \cdot m^2}$

1.2 Charges and Forces

- Frictional forces, such as rubbing, add something called charge to an object or remove it from the object. The process itself is called charging. More vigorous rubbing produces a larger quantity of charge.
- There are two kinds of charges: positive and negative
- Two objects with the same charge repel each other while two objects with differing charges attract each other. The forces of repulsion and attraction here are called *electric forces*.
- The forces of two charged objects are long-range forces. The magnitude increases as charge increases and decreases as the distance between charges increases.
- Neutral objects have an *equal mixture* of positive and negative charges.

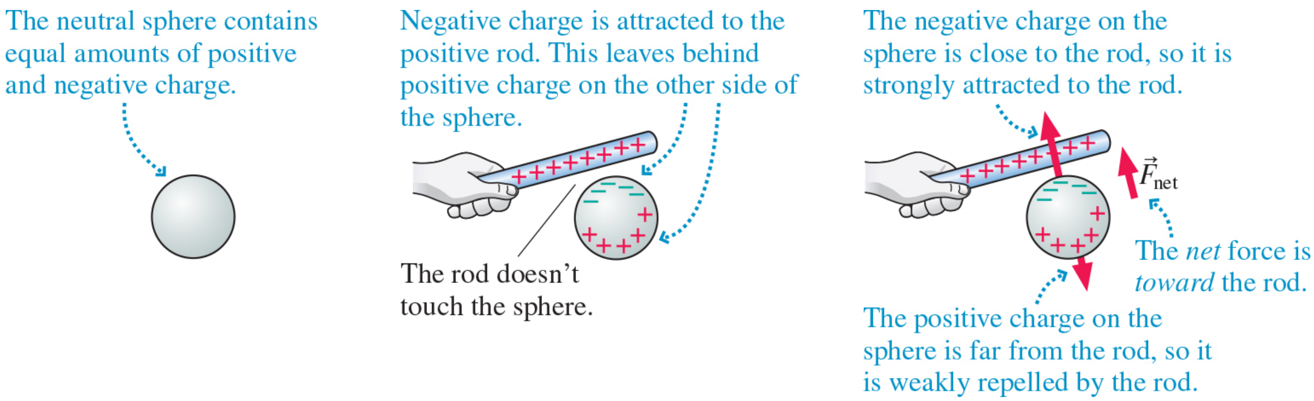


Figure 1.1: Polarization Diagram

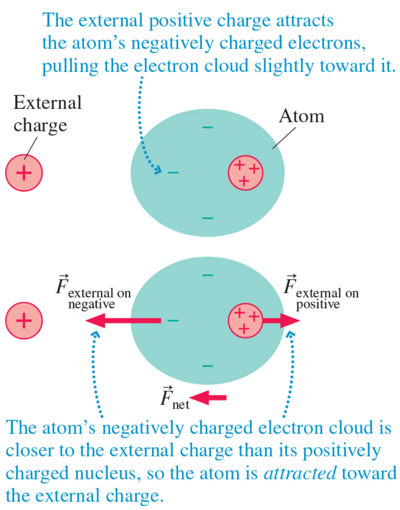


Figure 1.2: Figure of an electric dipole

- Rubbing processes charges objects by transferring charges from one to another. The objects aquire opposite charges.
- charge is conserved: It can't be destroyed nor created.
- There are two types of material: insulators and conductors. Insulators do not allow for the exchange of charge whilst conductors do allow for the exchange of charge.

Definition 1.2.1: Polorization

Polorization is the slight seperation of the positive and negative charge in a neutral object when a charged object is brought near. Seen here in Figure 1.1

1.3 Charges, Atoms, and molecules

Definition 1.3.1: Electric Dipoles

Two equal but opposite charges with a seperation between them are called an electric dipole. In the figure below(Figure 1.2) where an external charge has caused polarization, the atom has become an induced electric dipole.

1.4 Coulomb's Law

$$F = K\frac{|q_1||q_2|}{r^2} \tag{1.1}$$

The equation above gives the magnitude of force of Electric Forces; however, Electric forces are additionally vectors in which direction is based on attraction and repulsion.

1.5 Electric Fields

1. A group of charges, which we call the source charges, alter the space around them by creating an electric field $\vec{E}$
2. If another charge is then placed in this electric field, it experiences a force $/vecF$ exerted by the field.
3. The electric field due to multiple charges is the vector sum of the electric field due to each of the charges.

Definition 1.5.1: Parallel-plate capacitors

Parallel-plate capacitors are when you have two plates one uniformly positively charged and the other negatively in which the only electric fields are between the plates as charges within the plates are cancelled out. This gives uniform electric fields from plate to plate in which the equation for the electric field is

$$\vec{E}_{capacitor} = \frac{Q}{\epsilon_0 A} \tag{1.2}$$

1.6 Electric field lines

1. Electric field lines are imaginary lines drawn through a region of space.
2. The tangent to any field line at any point is in the direction of the electric field at that point.
3. The field lines are closer together where the electric field strenth is greater.
4. Electric field lines cannot cross!
5. The electric field is created by charges. Field lines start on positive charges and end on negative charges.
6. Dipoles when interacting with an electric field will rotate do to the torque caused when the positive side goes toward the direction of the field lines whilst the negative side goes away from the direction of the field lines.

Chapter 2

Electric Potential

2.1 Equations for Electric potential and electric potential energy

- $V = \frac{U_{elec}}{q}$
- $K_f + U_f = K_i + U_i$
- $\Delta K = -q\Delta V$
- $\mathrm{U}_{elec} = \frac{kq_1q_2}{r}$
- $V = k\frac{q}{r}$
- $V = \sum_i \frac{kq_i}{r_i}$
- $V = \frac{x}{d}\Delta V_c$

2.2 Electric potential Energy

Definition 2.2.1: Electric Potential Energy

Electric potential energy is $\Delta \mathrm{U}_{elec}$
$\mathrm{U}_{elec} = qV$

2.3 Electric potential

Definition 2.3.1: Electric Potential

Ratio of electric potential energy to charge.

Definition 2.3.2: Voltage

Voltage is a measure of electric potential.

- symbol Voltage $= V$
- unit Volt $= \mathrm{V} = \frac{\mathrm{J}}{\mathrm{C}}$

2.4 Conservation of Energy for a charged particle moving in an electric Potential V

$$\Delta K = -q\Delta V$$
$$K_f + qV_f = K_i + qV_i$$
$$\frac{1}{2}mv_f^2 = \frac{1}{2}mv_i^2 + (qV_i - qV_f)$$
$$v_f^2 = v_i^2 + \frac{2}{m}(qV_i - qV_f) = v_i^2 = \frac{2q}{m}(V_i - V_f)$$

2.5 Electric potential in a parallel-plate capacitor

Parallel Plate Capactitor giving you:

- Charges Q plus/minus
- $E = \frac{Q}{\epsilon_0 A}$
- Plate seperation - d
- Displacement - x

Equations:

- $W = \text{forcexdisplacement} = F_{hand}x = qEx$
- $U_{elec} = W = qEx$

2.6 Equipotential lines

Definition 2.6.1: Equipotential lines

Equipotential lines are lines that show equal voltage constantly.
Electric field lines point in the direction of decreasing potential.
Electric field strength in terms of the potential difference between two ΔV Between two equipotential surfaces a distance d apart.

$$E = \Delta\frac{V}{d}$$

2.7 Capacitance and capacitors

Definition 2.7.1: Capacitor

Two conductors with equal but opposite charge. The two conductors are called its electrodes, or plates.
The potential difference between the electrodes is directly proportional to their charge.
The charge of a capacitor is directly proportional to the potential difference between its electrodes.

$$Q = C\Delta V_C$$

Charge on a capacitor with a potential difference ΔV_C

Definition 2.7.2: Capacitance

The constant of proportionality C between Q and ΔV_C is called the capacitance of the capacitor.
The SI unit for capacitance is called the farad 1 farad $= 1F = 1\frac{C}{V}$

Chapter 3

Current and Resistance

Equations:

- Current - $I = \frac{\Delta q}{\Delta t}$ - 1 ampere = 1 A = 1 coulomb per second
- Restistivity - $R = \frac{pL}{A}$
- $\Delta V_{bat} = \epsilon$ - where epsilon is emf
- $U = q\Delta V_{bat}$
- $\Delta V_{wire} = \Delta V_{bat}$
- Power in circuits - $P_{emf} = I\epsilon$

  $P = \frac{W}{t} = \frac{\Delta u}{t} = \frac{q\Delta V}{t} = I\Delta V$
- $\Delta V = IR$
- $P = \frac{V^2}{R}$
- $P = V \times I$

3.1 Current

Definition 3.1.1: Current

Current is the rate of flow of positive charge.
The SI unit for current is the ampere.
The symbol for current is I.
The equation for current is $I = \frac{\Delta q}{\Delta t}$

3.2 Conservation of Current at a junction

Definition 3.2.1: Junction

A point where a wire branches is called a junction.

Definition 3.2.2: Kirchoff's junction law

The total current entering a junction is equal to the total current leaving the junction.
The equation for Kirchoff's junction law is $I_{in} = I_{out}$

3.3 Resistance

Definition 3.3.1: Resistance

The measure of how hard it is to push charges through a wire.
We use the symbol R for resistance.
The equation for resistance is $R = \frac{\Delta V}{I} \longrightarrow 1\Omega = 1\frac{V}{A}$

Definition 3.3.2: Ohm's Law

The equation for Ohm's Law is $\Delta V = IR$

3.4 Resistivity

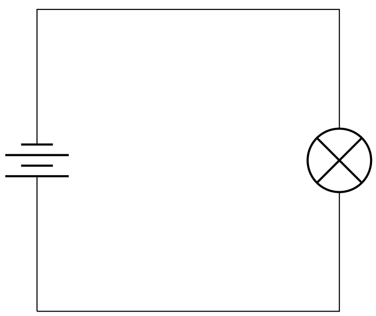
Definition 3.4.1: Resistivity

A property of a material that determines how much resistance it has.
We use the symbol ρ for resistivity.
The equation for resistivity is $R = \frac{\rho L}{A}$ where p is the resistivity of the material, L is the length of the wire, and A is the cross-sectional area of the wire.

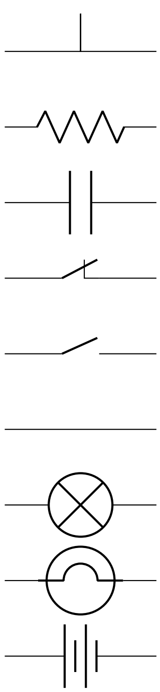
Chapter 4

Circuits

4.1 A basic circuit



4.2 Symbols for basic circuit components



4.3 Kirchoff's Laws

Definition 4.3.1: Kirchoff's Junction Law

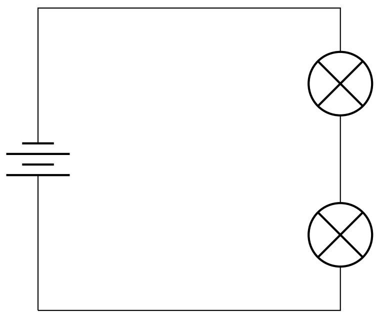
The total current entering a junction is equal to the total current leaving the junction.
The equation for Kirchoff's junction law is $\sum I_{in} = \sum I_{out}$

Definition 4.3.2: Kirchoff's Loop Law

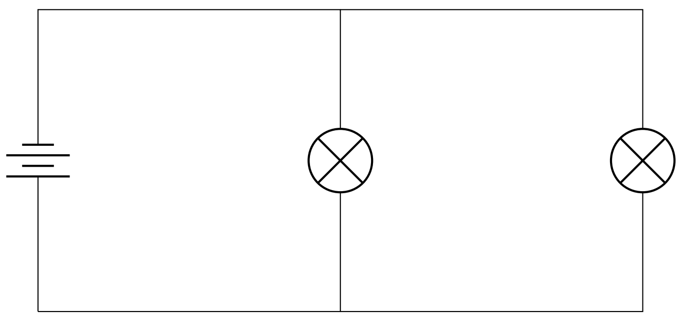
The sum of the potential differences around a loop is equal to zero.
The equation for Kirchoff's loop law is $\sum \Delta V = 0$
$\Delta V = V_{downstream} - V_{upstream} = 0$ - downstream is the direction of the battery from negative to positive.

4.4 Series and Parallel Circuits

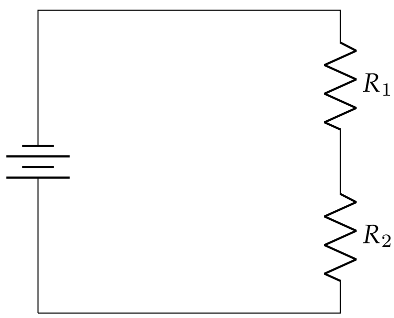
4.4.1 Series Circuits



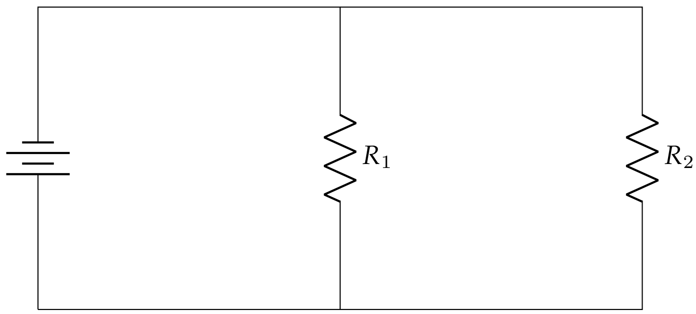
4.4.2 Parallel Circuits



4.4.3 Resistors in Series



4.4.4 Resistors in Parallel



4.5 Equivalent Resistance

Definition 4.5.1: Equivalent Resistance

The equivalent resistance of a circuit is the resistance of a single resistor that has the same current as the circuit.
The equation for the equivalent resistance of a series circuit is $R_{eq} = R_1 + R_2 + ... + R_n$
The equation for the equivalent resistance of a parallel circuit is $R_{eq} = (\frac{1}{R_1} + \frac{1}{R_2} + \ldots \frac{1}{R_n})^{-1}$

4.6 Measuring Voltage and Current

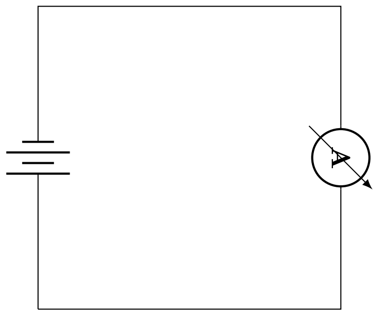
Definition 4.6.1: Ammeter

A device that measures current is called an ammeter. Because charge flows through circuit elements, an ammeter must be placed in series with the circuit element whose current is to be measured.

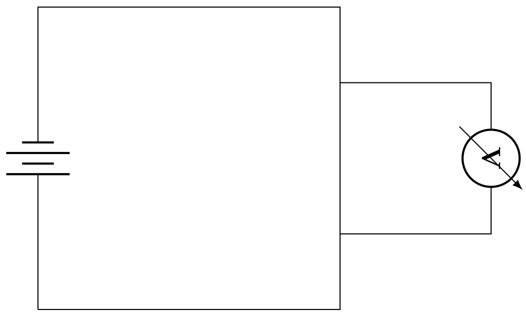
Definition 4.6.2: Voltmeter

A device that measures voltage is called a voltmeter. Because voltage is the difference in electric potential between two points, a voltmeter must be placed in parallel with the circuit element whose voltage is to be measured.

4.6.1 Ammeters in a Circuit



4.6.2 Voltmeters in a Circuit



Chapter 5

Magnetism

5.1 Magnetic Fields

Definition 5.1.1: Magnetic Field

A magnetic field is a region of space where a magnetic force can be detected.
The symbol for magnetic field is B.
The SI unit for magnetic field is the tesla (T) where $1T = 1\frac{Nm}{A}$.

Long straight wire:

$$B = \frac{\mu_0 I}{2\pi r}$$

Current Loop:

$$B = \frac{\mu_0 I}{2r}$$

Solenoid:

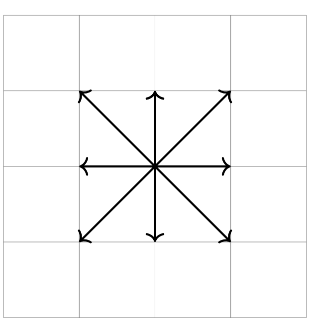
$$B = \mu_0 I \frac{N}{L}$$

Value of μ_0:

$$\mu_0 = 4\pi \times 10^{-7} \frac{N}{A^2}$$

Definition 5.1.2: Magnetic Field Lines

Magnetic field lines are lines that show the direction of the magnetic field.
The direction of the magnetic field is the direction that a north pole would move if placed in the field.
Thus, magnetic fields point to the south pole.
The closer the lines are together, the stronger the magnetic field is.
Magnetic field lines are always closed loops.



Note:-

convention: a dot is going towards you(out of the page), a cross is going away from you(into the page).

5.2 Magnetic Force

Definition 5.2.1: Magnetic Force

The magnetic force is the force that a magnetic field exerts on a moving charge.
The equation for the magnetic force is $\vec{F} = q\vec{v} \times \vec{B} \sin\alpha$
The direction of the magnetic force is perpendicular to both the velocity and the magnetic field.

Theorem 5.2.1 Force of a field on a wire

The force of a magnetic field on a wire is $\vec{F} = BIl$
The direction of the force is perpendicular to both the wire and the magnetic field.

Definition 5.2.2: Cyclotronic Equation

$$F_c = F_{mag} = \frac{mv^2}{r} = qvB$$
$$\frac{mv^2}{r} = qvB$$
$$r = \frac{mv}{qB}$$

Question 1: Find the magnitude of the magnetic field of a proton ...

...that takes 1.00 μs to complete a circlular path. Given that the mass of a proton and the charge of a proton are:

$$m_p = 1.67 \times 10^{-27} kg$$
$$q_p = 1.6 \times 10^{-19} C$$

Solution:

Theorem 5.2.2 Electro-motive force

$$\epsilon = vlB$$