Week 3

Physics 1409/1430 – Physics 2

Hello and Welcome to the weekly resources for PHY 1409/1430 – Physics 2!

This week is Week 3 of classes, and typically in this week of the semester, your professors are covering these topics below. If you do not see the topics your particular section of class is learning this week, please take a look at other weekly resources listed on our website for additional topics throughout the semester.

We also invite you to take a look at the group tutoring chart on out website to see if this course has a group tutoring session offered this semester.

If you have any questions about these study guides, group tutoring sessions, private 30-minute tutoring appointments, the Baylor Tutoring YouTube channel or any tutoring services we offer, please visit our website www.baylor.edu/tutoring or call our drop in center during open business hours, M-Th 9am-8pm on class days, at 254-710-4135.

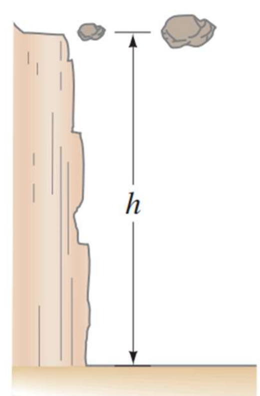
Keywords: Electric Potential, Potential Difference, Capacitance

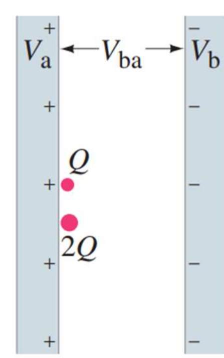
Important Notes
Important Conventions

Topic of the Week:

Electric Potential Energy and Potential Difference

Much like you saw in physics 1, the concept of energy is applicable throughout in physics 2 as well. The idea of electric potential was formed on the same basic principle. When looking at a charge in a uniform electric field, we can better visualize the principles of energy.





As you have learned over the past week, like charges repel one another and unlike charges attract. Their distance from one another dictates the magnitude of the force on them. The magnitude of the force follows the inverse square law. Now compare the position of the charge in the electric field to a person holding a rock over a cliff. In the cliff scenario, the rock has gravitational potential energy. So, much like the rock, the charge in the electric field also has electric potential energy. As it moves from the positive side to the negative side, the potential energy decreases. This electric field uses the potential energy to do work on the charge and push it to the negative plate.

Hence, this change in potential energy can be related to work to derive.

All images are from Physics: Principles with Applications (7th Edition) by Douglas C. Giancoli

$$PE_b - PE_a = -qEd$$

From this, we derive electric potential. Electric potential is the electric potential energy per unit charge. But in a simpler sense, electric potential is the ability of the charge to move in an electric field. The difference in the potential at on position versus another is called the potential difference. This distinction is highly important, especially as you move forward this semester. The unit for electric potential and potential difference is Volts (v). Potential difference is also referred to as voltage, much like what you have heard on packaging for electric devices. You will gain a better understanding for how it applies to appliances later in the semester. We can relate electric potential energy and to potential.

$$\Delta PE = PE_b - PE_a = q(V_b - V_a) = qV_{ba}$$

This relationship is important because it allows us to also relate electric potential to the electric field. This relationship is very important and will be very useful during this section.

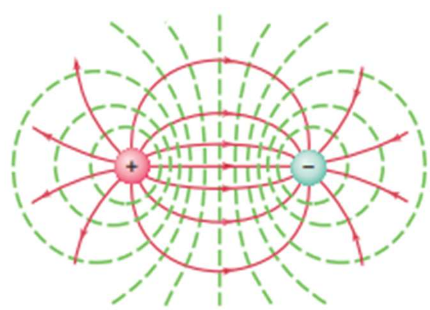
$$V_{ba} = -Ed$$

Remember that when there is a single letter in the subscript, that represents electric potential at that point and if there are two letters, that is the potential difference between those points.

One thing to keep in mind when looking at electric field and potential difference is the charge you are looking at. And electric field shows the behavior of a POSITIVE charge in the field. It maps how positive charges would behave. Similarly, the potential also decreases as it moves with the electric field if it is a positive charge. But if it is a NEGATIVE charge, it does the OPPOSITE of the positive charge. It moves in the opposite direction of the electric field. Hence, if the negative charge is moved with the electric field, its potential will INCREASE. Please keep these rules in mind because it is the part of the most important information for the semester. Physics 2 is heavy in concepts and it is important to keep everything straight to be successful.

Highlight 1: Equipotential Lines and Surfaces

Much like how we use electric field lines to visualize electric fields, we can use equipotential lines to visualize potential around charges. But the difference is that they do not describe the movement of charges, they show a boundary line where the potential is equal. If a charge moves from one location on the boundary to another location on the same boundary, there is no change in potential. They are shown as dashed lines. If the charge moves from one line to another, there is a change in potential.



Electric Potential Due to Point Charges:

As we saw above, we had a formula for potential between two charged plates. Electric potential is also present around point charges. After using calculus, the formula derived for potential is as follows.

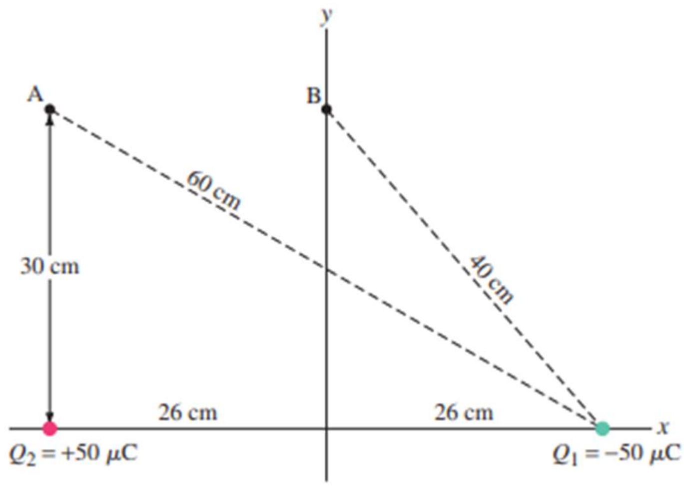
k = Coulomb Constant

$$V = k\frac{Q}{r} \qquad\qquad V = \frac{1}{4\pi\epsilon_0}\int\frac{dq}{r}$$

This potential is also referred to as the coulomb potential. This formula can be easily be confused with the formula for the electric field so be careful when working with problems. The formula on the left is used when considering a charge distribution besides a point charge(for PHY 1430).

Example:

Calculate the electric potential (a) at point A due to the two charges shown and (b) at point B.



Solution:

(a)

$V_a = V_{a2} + V_{a1}$

$= (kQ_2) / r_2 + (kQ_1) / r_1$

$= [(9 \times 10^9)(5 \times 10^{-5})/0.3] + [(9 \times 10^9)(-5 \times 10^{-5})/0.6]$

$= 7.5 \times 10^5$ V

(b)

$V_b = V_{b2} + V_{b1}$

$= [(9 \times 10^9)(5 \times 10^{-5})/0.4] + [(9 \times 10^9)(-5 \times 10^{-5})/0.4]$

$= 0$ V

Highlight 2: Capacitance

A capacitor is an essential circuit component used in numerous electrical devices we use everyday. A capacitor is a device that can store an electric charge. They have various functions and are used in oscillators and sensing related devices. A capacitor consists of two charged plates of same size separated by a certain distance. When it is connected to a battery and electricity flows through, the two plates polarize, the plates each accumulate positive charge on the side connected to the positive power source end and the negative charge on the other plate connected to the negative power source end. Each capacitor has a capacitance, which is the ability of a capacitor to hold charge. The capacitance of a capacitor can only be affected by the characteristics of the capacitor, and the potential difference or current (topics later in the semester) do not affect it. Keep this in mind. It is a very common concept question. The capacitance can be calculated using the following equation. The unit for capacitance is farad(F). (named after one of my absolutely favorite physicist, Micheal Faraday. His story is inspiring. Please read up on him!)

$$C = K\epsilon_0 \frac{A}{d}$$

The capacitance affects the charge that the capacitor can hold. The charge that can be held by a capacitor can be calculate using the following.

$$Q = CV.$$

Something quick to note about the capacitance formula are the two constants. The epsilon represents the permittivity of free space, which is a constant. The K represents the dielectric constant. A dielectric is an insulating sheet of material that is covered over the capacitor. This affects the ability of the capacitor to hold charge. Each dielectric has its own dielectric constant. Air and vacuum have 1 as their dielectric constant. You will be using K =1 until unless you are told by the question that there is a different dielectric.

Because capacitors hold charge, they hold energy. The potential energy stored can be calculated using the follows.

$$\text{PE} = \tfrac{1}{2}QV = \tfrac{1}{2}CV^2 = \tfrac{1}{2}\frac{Q^2}{C}$$

Example

A camera flash unit stores energy in a 660 µF capacitor at 330 V. (a) How much electric energy can be stored?(b) What is the power output if nearly all this energy is released in 1.0 m.s?

Solution

(a)

PE = $(0.5)CV^2$

= $0.5(660 \times 10^{-6})(330)^2$

= 36 J

(b)

P = energy / time

= 36 / 0.001

= 36000 W

This semester, my resources will be a little heavy with text. Physics 2 requires a stronger base in concepts because it is critical to understand each concept and apply them. The formulas will be easy to work with once you better understand each concept.

CHECK YOUR LEARNING

1. **1.** A negative and a positive charge of the same magnitude are present in the spacing between two capacitor plates. The negative charge is place next to the negative plate and the positive charge is present at the positive plate. Which charge has the higher potential?
2. **2.** Suppose you have a simple circuit with a 12 V battery and a 1 μF capacitor. What will be the capacitance of the capacitor if the battery is swapped for a 6 V battery?'
3. **3.** Suppose you have a parallel circular plate capacitor in the circuit from Q2. Which of the following changes will increase the capacitance by a factor of 4?
   a. Apply 4 times the voltage
   b. Apply 2 times the voltage
   c. Change the distance between the plate by a factor of 4
   d. Increase the diameter of the plate by a factor of 2

For PHY 1430:

1. **1.** Derive the equation for the potential due to a ring of charges. (Common exam question type!!!!!!)

THINGS YOU MAY STRUGGLE WITH

1. **1.** Remember the difference between Electric Potential and Electric Potential Energy. These are not the same things. It's easy to confuse the two or forget the difference between them when looking at systems with charges because the word potential is used heavily.
2. **2.** Pay attention to the wording of the questions. Electric potential and Potential difference are two separate things. It's easy to get in the habit of seeing them as the same concept. The understanding of the difference will have a good impact later in the semester when you discuss electric circuits and current.
3. **3.** Capacitance is a physical property. Changing the potential difference DOES NOT change the capacitance. Capacitance can only be changed by changing the area of the plates, the distance between the plates and with the change in the dielectric present between the plates.
4. **4.** For the PHY1430 students, the calculus component of the electric potential will seem extremely daunting. Remember to practice those question types to get more comfortable with the process for deriving the equations through integration of the charge distribution. Become familiar with the constants for charge densities.

Thanks for checking out these weekly resources! Don't forget to check out our website for group tutoring times, video tutorials and lots of other resource: www.baylor.edu/tutoring ! Answers to check you learning questions are below!

Answers: 1) Both have the same potential, 2) 1 μF, 3) d. /1) derived eq. below. check ex23-8 for steps

$$\frac{1}{4\pi\epsilon_0}\frac{Q}{(x^2 + R^2)^{\frac{1}{2}}}$$

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