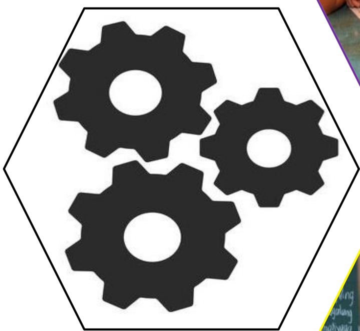
DEPARTMENT OF EDUCATION

General Physics 2

12




DIVISION OF PASIG CITY

General Physics 2 – Grade 12
Quarter 3 – Module 4: Electric Potential Energy
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Development Team of the Self-Learning Module

Writer:	**Sheryl V. Bonus**
Editor:	**Melvina S. Tarcena**
Reviewers:	**Melvina S. Tarcena**
Illustrator:	
Layout Artist:	**Bren Kylle A. Aveno**
Management Team:	**Ma. Evalou Concepcion A. Agustin** OIC-Schools Division Superintendent **Carolina T. Revera, CESE** Assistant Schools Division Superintendent **Manuel A. Laguerta EdD** Chief, Curriculum Implementation Division

Education Program Supervisors

Librada L. Agon EdD (EPP/TLE/TVL/TVE)
Liza A. Alvarez (Science/STEM/SSP)
Bernard R. Balitao (AP/HUMSS)
Joselito E. Calios (English/SPFL/GAS)
Norlyn D. Conde EdD (MAPEH/SPA/SPS/HOPE/A&D/Sports)
Wilma Q. Del Rosario (LRMS/ADM)
Ma. Teresita E. Herrera EdD (Filipino/GAS/Piling Larang)
Perlita M. Ignacio PhD (EsP)
Dulce O. Santos PhD (Kindergarten/MTB-MLE)
Teresita P. Tagulao EdD (Mathematics/ABM)

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General Physics 2

12

Quarter 3

Self-Learning Module 4

Electric Potential Energy

Introductory Message

For the facilitator:

Welcome to the General Physics 2 Grade 12 Self-Learning Module on Electric Potential Energy!

This Self-Learning Module was collaboratively designed, developed, and reviewed by educators from the Schools Division Office of Pasig City headed by its Officer-in-Charge Schools Division Superintendent, Ma. Evalou Concepcion A. Agustin, in partnership with the City Government of Pasig through its mayor, Honorable Victor Ma. Regis N. Sotto. The writers utilized the standards set by the K to 12 Curriculum using the Most Essential Learning Competencies (MELC) in developing this instructional resource.

This learning material hopes to engage the learners in guided and independent learning activities at their own pace and time. Further, this also aims to help learners acquire the needed 21st-century skills especially the 5 Cs, namely: Communication, Collaboration, Creativity, Critical Thinking, and Character while taking into consideration their needs and circumstances.

In addition to the material in the main text, you will also see this box in the body of the module:

Notes to the Teacher

This contains helpful tips or strategies that will help you in guiding the learners.

As a facilitator, you are expected to orient the learners on how to use this module. You also need to keep track of the learners' progress while allowing them to manage their learning. Moreover, you are expected to encourage and assist the learners as they do the tasks included in the module.

For the learner:

Welcome to the General Physics 2 Module on Electric Potential Energy!

This module was designed to provide you with fun and meaningful opportunities for guided and independent learning at your own pace and time. You will be enabled to process the contents of the learning material while being an active learner.

This module has the following parts and corresponding icons:

Expectations - This points to the set of knowledge and skills that you will learn after completing the module.

Pretest - This measures your prior knowledge about the lesson at hand.

Recap - This part of the module provides a review of concepts and skills that you already know about a previous lesson.

Lesson - This section discusses the topic in the module.

Activities - This is a set of activities that you need to perform.

Wrap-Up - This section summarizes the concepts and application of the lesson.

Valuing - This part integrates a desirable moral value in the lesson.

Posttest - This measures how much you have learned from the entire module.

EXPECTATIONS

At the end of this module, you are expected to:

A. relate the electric potential with work, potential energy, and electric field
B. solve problems involving electric potential energy and electric potentials in contexts such as, but not limited to, electron guns in CRT TV picture tubes and Van de Graaff generators; and
C. cite applications of electric potential in everyday lives.

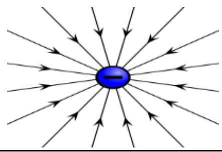
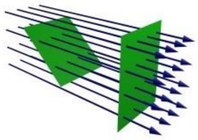
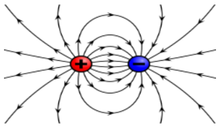
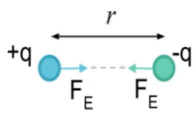
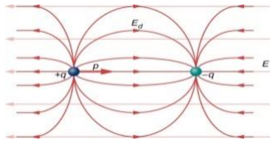
PRETEST

Directions: Choose the letter of the correct answer.

1. The quantity electric potential is defined as the amount of _______________ .
   A. force per unit charge
   B. electric potential energy
   C. force acting upon a charge
   D. potential energy per unit charge
2. Complete the following statement:
   When work is done on a positive test charge by an external force to move it from one location to another, potential energy ______________ and electric potential _________________ .
   A. increases, increases
   B. increases, decreases
   C. decreases, decreases
   D. decreases, increases
3. What is the standard SI unit for electric potential difference?
   A. Ampere
   B. Coulomb
   C. Joules
   D. Volt
4. What is the equation of electric potential?
   A. $V = d^2/f$
   B. $V = U/Q$
   C. $V = td$
   D. $V = kQq/r^2$
5. While touching the Van de Graaff generator, why does your hair fly up as the generator starts charging?
   A. Because the opposite charge is transferred to the hair.
   B. Because the charge of the generator is transferred to the hair.
   C. Because the charge of the hair is transferred to the generator.
   D. Because the opposite charge of the hair is transferred to the generator.

RECAP

Directions: Arrange the jumbled letters below each item to describe what is being shown in the picture.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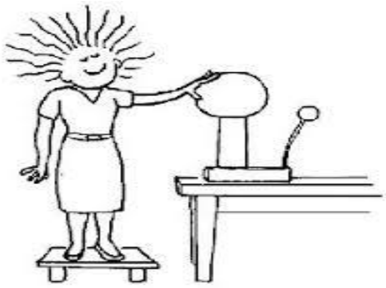
LESSON

Figure1: Touching a Van de Graaff Generator

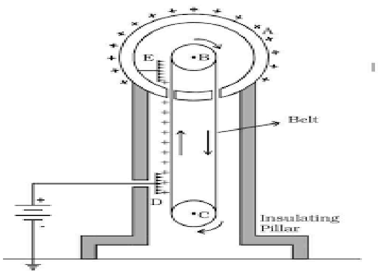


Did you ever experience touching a Van de Graaff generator? How did you feel? Why did your hair fly up as you can see on the picture?

https://lh3.googleusercontent.com/proxy/irJHsNfVmZJT26_nbHTWY7xphrSYaTfBHjCUVvu9_TNgAdIxw2HDwYxmnXMGG3ccSnTbMbDujfycKz10vtjydpeIRkI4rmLNAA

Electric Potential: Voltage

Figure2: Positively charged Van de Graaff Generator



https://thefactfactor.com/wp-content/uploads/2020/02/Van-de-graf-generator-01.png

Electric potential is the amount of work needed to move a unit charge from a reference point to a specific point against an electric field. Consider the electric field created by a positively charged Van de Graaff generator. The direction of the electric field is in the direction that a positive test charge would be pushed; in this case, the direction is outward away from the Van de Graaff sphere.

Work would be required to move a positive test charge towards the sphere against the electric field. The greater the charge on the test charge, the greater the repulsive force and the more work that would have to be done on it to move it the same distance.

The electric potential energy per charge is the total electric potential energy divided by the amount of charge. At any location the potential energy per charge – whatever the amount of charge – will be the same. We then define the electric potential V through the relation

$$Electric\ Potential\ = \frac{electric\ potential\ energy}{charge}$$

$$V\ =\ \frac{U}{q}$$

The potential difference between two points ΔV is often called the voltage and is given by

$$\Delta V\ =\ V_B\ -\ V_A\ =\ \frac{\Delta U}{q}$$

and $\quad \Delta U = q\mathbf{\Delta}\mathrm{V}$

The S.I unit measurement for electric potential is the volt (V) named after the Italian physicist Alessandro Volta. Since potential energy is measured in joules and charge is measured in coulombs,

$$1\ volt\ =\ 1\ \frac{joule}{coulomb}$$

Electric potential is also known as the amount of work needed to move a unit charge from a reference point to a specific point against an electric field, measured in Joules per Coulomb (J/C) or Volts (V).

Point Charge

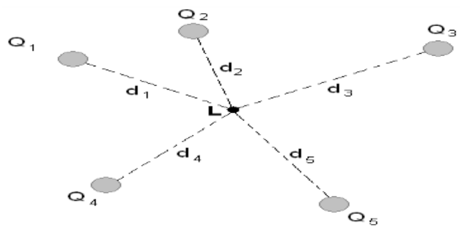
The electric potential at a distance r from a single point charge Q can be derived from the expression for its electric field ($E = kQ/r^2$). The result is

$$V\ =\ k\,\frac{Q}{r} \qquad\qquad V\ =\ \frac{1}{4\pi\mathcal{E}_0}\frac{Q}{r}$$

Superposition of Electric Potential

The electric potential at point L is the sum of voltages from each point charge (scalars).

Consider three charges q1, q2, q3. The electric potential due to these charges at any given point is the sum of the electric potentials of all the charges.



$$V\ =\ V_1\ +\ V_2\ +\ V_3$$

$$V\ =\ k\frac{q_1}{r_1}\ +\ k\frac{q_2}{r_2}\ +\ k\frac{q_3}{r_3}$$

https://s3-us-west-2.amazonaws.com/courses-images/wp-content/uploads/sites/1989/2017/06/13225948/encial-eletrico-resultante.png

Electric Potential Energy

Electric potential energy can be defined as the capacity for doing work that arises from position or configuration. In the electrical case, a charge will exert a force on any other charge and potential energy arises from any collection of charges. For example, if a charge Q is fixed at some point in space, any other positive charge which is brought close to it will experience a repulsive force and will therefore have potential energy. Where k is Coulomb's constant (9 x 10^9 Nm^2/C^2).

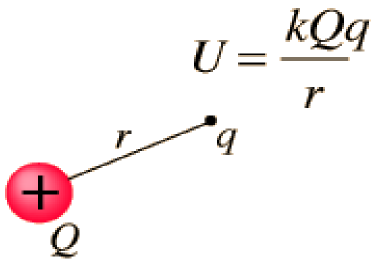


Table 1: Uniform electric field

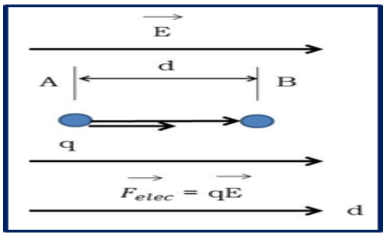
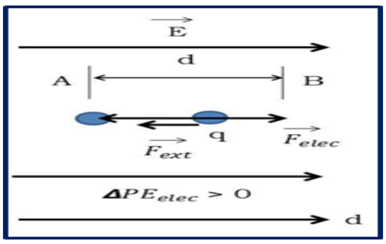
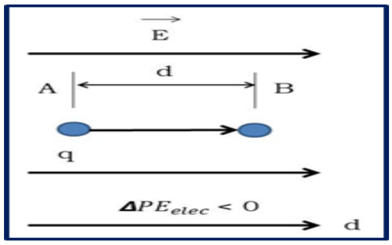
		
When q is positive, the electric force F is parallel to E	To move q from B to A, an external agent must exert a force F_{ext} to overcome the lectric force	If the charge moves back from A to B, the system gives up potential energy.

Table 1 shows a region of space in which the electric field is constant, so E has the same magnitude and direction at all points. A point charge q in this region experiences an electric force

$$F = qE$$

If charge q is positive, this force is parallel to E.

The work done by the electric force on the charge is W = F Δx

The electric force is conservative, so the work done on the charge is independent of the path it takes to go from A to B. The change in electric potential energy associated with a particular conservative force is equal to – W, where W is the work done by that force. So if the electric force does an amount of work on the charged particle, the change in electric potential energy is

$$\Delta U = -W$$

Combining the two equations, the electric potential energy when the charged particle moves from A to B in table 1 is

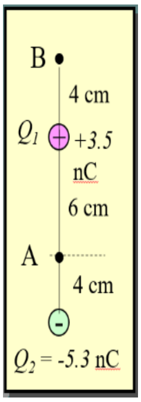
$$\Delta U = -W = -F_e d = -qEd$$

The equation gives the change in potential energy as the charge moves through a displacement Δx, in a region where the electric field is parallel to the displacement.

In electricity, it is usually more convenient to use the electric potential energy per unit charge, just called electric potential or voltage.

Sample Problem

1. Two charges Q_1=+3.5 nC and Q_2=-5.3 nC are separated by 10 cm. Calculate the electric potential at point B.



I. Given: $k=9x10^9\ Nm^2/C^2$
$Q_1=3.5x10^{-9}$ C
r_1=4cm=0.04m
$Q_2=-5.3x10^{-9}$ C
r_2=14cm=0.14m
V_B=?

II. Formula: $V_B = \frac{kQ_1}{r_1} + \frac{kQ_2}{r_2}$

III. Solution: $V_B = \frac{kQ_1}{r_1} + \frac{kQ_2}{r_2}$

$$V_B = \frac{9x10^9 Nm^2/C^2(3.5x10^{-9}C)}{0.04\ m} + \frac{9x10^9 Nm^2/C^2(-5.3x10^{-9}C)}{0.14\ m}$$

$$V_B = 787.5V + (-340.7V)$$

$$V_B = 446.3V$$

2. A charge of q=-5.3 nC is accelerated from rest through a potential difference of 25V. What is the change in electric potential energy of the charge?

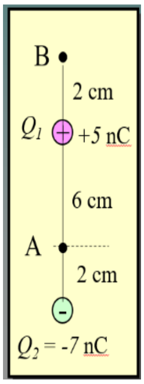
I. Given: $q=-5.3 \times 10^{-9}$ C

II. Formula: **Δ**U=q**Δ**V

III. Solution: **Δ**U=q**Δ**V
= -5.3×10^{-9} C (25V)
= -1.35×10^{-7} J

ACTIVITIES

Activity 1: Electric Potential



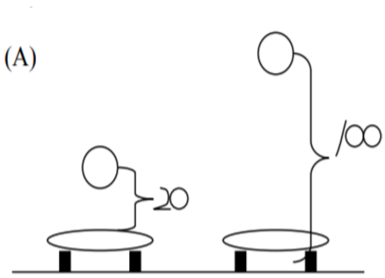
1. Two charges Q_1=+5nC and Q_2=-7nC are separated by 8 cm. Calculate the electric potential at point A. Refer to the figure to the right.
2. A research Van de Graaf generator has a 2.50 mm diameter sphere with a charge of 6.00 µC on it.
   A. What is the potential near its surface?
   B. At what distance from its center is the potential 1.50 MV?

Activity 2: Electric Potential Energy

1. Two-point charges Q_1 = 4.5 µC and Q_2 = 8.5 µC are initially very far apart. They are then brought together, with a final separation of 3.5 mm. How much work does it take to bring them together?
2. An electron is accelerated from rest through a potential difference of 15V. What is the change in electric potential energy of the electron?
3. In nuclear fission, a nucleus splits roughly in half.
   A. What is the potential 4.00 x 10^{-14} m from a fragment that has 50 protons in it? (p=+1.602x10^{-19} C)
   B. What is the potential energy of a similarly charged fragment at this distance?

Activity 3: Electric Potential Demonstration

Showing potential energy differences for the earth's gravitational field can be shown visually. Showing electrical potential (energy) difference is harder to visually show and understand. Use the gravity analogy to establish the electrical potential difference concept.



(a) Drop an object (ex: baseball) from rest from 20 cm above a pie tin on spacers. Observe.

(b) Reposition the pie tin and spacers to a different location and again drop the ball from 20 cm. Observe.

(c) Drop the same ball onto pie tin 2, but from 100 cm above pie tin 2 and observe.

Guide Questions:

1. Compare the noise created by the object dropped from 20 cm above and the created after the pie tin repositioned.
2. Compare the noise created by the object dropped from 20 cm above the pie tin and the object dropped from 100 cm above the pie tin.
3. What is the GPE difference (ΔU) of the object dropped at two different distances from the pie tin?
4. What does the sound created by the object in situation number 1 indicate?

WRAP-UP

Match quantities in Column A to their corresponding formula/value in Column B.

A	B
1. Electric Potential	A. $9x10^9$ Nm^2/C^2
2. Electric Potential Energy	B. $\Delta U=-qEd$
3. Superposition of Electric Potential	C. $V=kq_1/r + kq_2/r + kq_3/r$
4. Change in electric potential energy	D. $U=kQq/r$
5. Coulomb's constant	E. $V=U/q$

VALUING

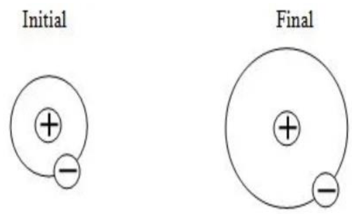
We have all observed the awe-inspiring beauty and power of a good electrical storm. The flashes of lightning, followed at varying time intervals by a clash of thunder, can be both fascinating and frightening. What is lightning? How are thunderclouds capable of producing the impressive electrical discharges that we see? What happens in an electrical storm?

https://cdn.pixabay.com/photo/2020/03/15/15/59/lightning-4934064_1280.jpg

POSTTEST

Directions: Write the letter of the correct answer.

1. Which of the following describes electric potential energy?
   A. The capacity for doing work which arises from position or configuration.
   B. The amount of work needed to move a unit charge.
   C. Electric potential per unit charge.
   D. Charge per unit distance.
2. What is the standard SI unit for electric potential energy?
   A. Joules
   B. Volt
   C. Coulomb
   D. Ampere
3. In which situation would the system have the most electric potential energy?
   A. Initial, more energy when together.
   B. Initial, more energy when apart.
   C. Final, more energy when together.
   D. Final, more energy when apart.



4. What is the potential energy if a +4 nC charge moves from infinity to point A, 5 cm away from a +3 µC charge?
   A. 1.35 X 10^{-3} J
   B. 2.16 x 10^{-3} J
   C. 3.43 x 10^{-2} J
   D. 4.12 x 10^{-2} J
5. Which of the following is not an example of electric potential energy?
   A. An incandescent light bulb is turned off.
   B. A cell phone that is turned off.
   C. A television that is turned on.
   D. Solar cells at night.

KEY TO CORRECTION

PRETEST	POSTTEST	RECAP	WRAP-UP
1.D	1.A	1.ELECTRIC CHARGE	1.E
2.A	2.A	2.ELECTRIC FLUX	2.D
3.D	3.D	3.ELECTRIC FIELD	3.C
4.B	4.B	4.ELECTRIC FORCE	4.B
5.B	5.C	5.ELECTRIC DIPOLE	5.A
Activity 1		Activity 2	
1. -2400 V		1. 98.36 J	
2. A. 43.2 MV		2.-2.403 J	
2. B. 0.036 m		3. A. 1.8 MV	
		3. B. 1.44 x 10^{-11} J	

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