10 Conductors and Capacitors

Content Area:	**Science**
Course(s):	**AP Physics C**
Time Period:	**Semester 2**
Length:	**3 weeks**
Status:	**Published**

Standards

SCI.HS.PS3.A	Definitions of Energy
SCI.HS.PS3.B	Conservation of Energy and Energy Transfer
SCI.HS-PS3-3	Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.
SCI.HS-PS3-1	Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
	Using Mathematics and Computational Thinking
	Systems and System Models
	Energy and Matter
	Constructing Explanations and Designing Solutions

AP Physics C Learning Objectives

Note: Learning Objectives are taken verbatim from the AP Physics C - Mechanics Course and Exam Description. The verb "describe" could refer to a variety of different methods of expression (e.g. words, diagrams, graphs, mathematical expressions), as appropriate.

Describe the charge distribution within a conductor.

Describe the movement of charge and the resulting interactions when conductors physically contact each other.

Describe the physical properties of a parallel-plate capacitor.

Describe how a dielectric inserted between the plates of a capacitor changes the properties of the capacitor.

Enduring Understandings

Fields predict and describe interactions.

Conservation laws constrain interactions.

There are electrical devices that store and transfer electrostatic potential energy.

An insulator has different properties than a conductor when placed in an electric field.

Essential Questions

Why does the little red light on the TV stay on for a second after the TV is turned off?

How does a camera flash used for photography work?

How can energy be stored for later use?

Knowledge and Skills

Topic 10.1 Electrostatics with Conductors

Knowledge:

- An ideal conductor is a material in which electrons are able to move freely.
- When a conductor is in electrostatic equilibrium, mutual repulsion of excess charge carriers results in those charge carriers residing entirely on the surface of the conductor.
- In a conductor with a negative net charge, excess electrons reside on the surface of the conductor.
- In a conductor with a positive net charge, the surface becomes deficient in electrons, and can be modeled as if positive charge carriers reside on the surface of the conductor.
- Excess charges will move to the surface of a conductor to create a state of electrostatic equilibrium within the conductor.
- The time interval over which charges reach electrostatic equilibrium within a conductor is so short as to be negligible.
- When a conductor reaches electrostatic equilibrium, all points on the surface of the conductor have the same electric potential, and the conductor becomes an equipotential surface.
- The charge density on the surface of a conductor will be greater where there are points or edges compared to planar areas.
- All excess charges reside on the surface of a conductor, which means there is no net charge in the interior of the conductor, and the electric field is zero within the conductor.
- The electric field is perpendicular to the outer surface of a conductor.
- A conductor can be polarized in the presence of an external electric field. This is a consequence of the conductor remaining an equipotential surface.
- Electrostatic shielding is the process of surrounding an area with a closed, conducting shell to create a region inside the conductor that is free from external electric fields.

Skills:

- Create diagrams, tables, charts, or schematics to represent physical situations.
- Compare physical quantities between two or more scenarios or at different times and locations in a single scenario.

- Apply an appropriate law, definition, theoretical relationship, or model to make a claim.
- Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws.

Topic 10.2 Redistribution of Charge between Conductors

Knowledge:

- When conductors are in electrical contact, charges will be redistributed such that the surfaces of each conductor are at the same electric potential.
- Ground is an idealized reference point that has zero electric potential and can absorb or provide an infinite amount of charge without changing its electric potential.
- Charge can be induced on a conductor by grounding the conductor in the presence of an external electric field.

Skills:

- Create diagrams, tables, charts, or schematics to represent physical situations.
- Derive a symbolic expression from known quantities by selecting and following a logical mathematical pathway.
- Compare physical quantities between two or more scenarios or at different times and locations in a single scenario.
- Apply an appropriate law, definition, theoretical relationship, or model to make a claim.

Topic 10.3 Capacitors

Knowledge:

- A parallel-plate capacitor consists of two separated parallel conducting surfaces that can hold equal amounts of charge with opposite signs.
- Capacitance relates the magnitude of the charge stored on each plate to the electric potential difference created by the separation of those charges.
- The capacitance of a capacitor depends only on the physical properties of the capacitor, such as the capacitor's shape and the material used to separate the plates.
- The capacitance of a parallel-plate capacitor is proportional to the area of one of its plates and inversely proportional to the distance between its plates. The constant of proportionality is the product of the dielectric constant of the material between the plates and the electric permittivity of free space.
- The electric field between two charged parallel plates with uniformly distributed electric charge, such as in a parallel-plate capacitor, is constant in both magnitude and direction, except near the edges of the plates.
- The magnitude of the electric field between two charged parallel plates, where the plate separation is much smaller than the dimensions of the plates, can be determined by applying Gauss's law and the principle of superposition.
- The electric field is proportional to the surface charge density on either plate of the capacitor.
- A charged particle between two oppositely charged parallel plates undergoes constant acceleration, and therefore its motion shares characteristics with the projectile motion of an object with mass in the gravitational field near Earth's surface.
- The electric potential energy stored in a capacitor is equal to the work done by an external force to separate that amount of charge on the capacitor.

- The electric potential energy stored in a capacitor is described by the equation .

Skills:

- Create qualitative sketches of graphs that represent features of a model or the behavior of a physical system.
- Derive a symbolic expression from known quantities by selecting and following a logical mathematical pathway.
- Predict new values or factors of change of physical quantities using functional dependence between variables.
- Apply an appropriate law, definition, theoretical relationship, or model to make a claim.

Topic 10.4 Dielectrics

Knowledge:

- In a dielectric material, electric charges are not as free to move as they are in a conductor. Instead, the material becomes polarized in the presence of an external electric field.
- The dielectric constant of a material relates the electric permittivity of that material to the permittivity of free space.
- The electric field created by a polarized dielectric is opposite in direction to the external field.
- The electric field between the plates of an isolated parallel-plate capacitor decreases when a dielectric is placed between the plates.
- The insertion of a dielectric into a capacitor may change the capacitance of the capacitor.

Skills:

- Create quantitative graphs with appropriate scales and units, including plotting data.
- Calculate or estimate an unknown quantity with units from known quantities by selecting and following a logical computational pathway.
- Predict new values or factors of change of physical quantities using functional dependence between variables.
- Create experimental procedures that are appropriate for a given scientific question.
- Apply an appropriate law, definition, theoretical relationship, or model to make a claim.

Transfer Goals

In Unit 8, students investigated why all objects have an electric charge. In Unit 10, students will examine how that charge can be stored. Conductors, capacitors, and dielectrics are presented to demonstrate that the ability of charge to move is dependent on the material composition of an object. In electronics, each of these are important based on the type of movement or desired object behavior. Additionally, this unit examines how the behavior of charges is impacted by electric fields. Students can benefit from opportunities (e.g., laboratory investigations or activities) to describe and examine the function of each of these elements, along with capacitors. Knowledge of conductors, capacitors, and dielectrics will prepare students for understanding how electric circuits work in Unit 11 and how they behave when one or more electrical element is altered or modified.

Assessments

https://docs.google.com/document/d/1wR7bQF-8AQoRrt0g4C3hKja0yjwDjC9_BiAmONWbTcI/edit?usp=sharing

Modifications

https://docs.google.com/document/d/1ODqaPP69YkcFiyG72fIT8XsUIe3K1VSG7nxuc4CpCec/edit?usp=sharing