Unit 11: Electricity and Magnetism – Electric Circuits

OBJECTIVES

Big Idea 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.

Enduring Understanding 1.B: Electric charge is a property of an object or system that affects its interactions with other objects or systems containing charge.

Essential Knowledge 1.B.1: Electric charge is conserved. The net charge of a system is equal to the sum of the charges of all the objects in the system.

a. An electrical current is a movement of charge through a conductor.

b. A circuit is a closed loop of electrical current.

Learning Objective 1.B.1.1: The student is able to make claims about natural phenomena based on conservation of electric charge.

Learning Objective 1.B.1.2: The student is able to make predictions, using the conservation of electric charge, about the sign and relative quantity of net charge of objects or systems after various charging processes, including conservation of charge in simple circuits.

Big Idea 4: Interactions between systems can result in changes in those systems.

Enduring Understanding 4.E: The electric and magnetic properties of a system can change in response to the presence of, or changes in, other objects or systems.

Essential Knowledge 4.E.4: The resistance of a resistor and the capacitance of a capacitor can be understood from the basic properties of electric fields and forces as well as the properties of materials and their geometry.

a. The resistance of a resistor is proportional to its length and inversely proportional to its cross-sectional area. The constant of proportionality is the resistivity of the material.

b. The capacitance of a parallel plate capacitor is proportional to the area of one of its plates and inversely proportional to the separation between its plates. The constant of proportionality is the product of the dielectric constant, κ, of the material between the plates and the electric permittivity,ε_0 .

c. The current through a resistor is equal to the potential difference across the resistor divided by its resistance.

d. The magnitude of charge of one of the plates of a parallel plate capacitor is directly proportional to the product of the potential difference across the capacitor and the capacitance. The plates have equal amounts of charge of opposite sign.

Learning Objective 4.E.4.1: The student is able to make predictions about the properties of resistors and/or capacitors when placed in a simple circuit based on the geometry of the circuit element and supported by scientific theories and mathematical relationships.

Learning Objective 4.E.4.2: The student is able to design a plan for the collection of data to determine the effect of changing the geometry and/or materials on the resistance or capacitance of a circuit element and relate results to the basic properties of resistors and capacitors.

Learning Objective 4.E.4.3: The student is able to analyze data to determine the effect of changing the geometry and/or materials on the resistance or capacitance of a circuit element and relate results to the basic properties of resistors and capacitors.

Essential Knowledge 4.E.5: The values of currents and electric potential differences in an electric circuit are determined by the properties and arrangement of the individual circuit elements such as sources of emf, resistors, and capacitors.

Learning Objective 4.E.5.1: The student is able to make and justify a quantitative prediction of the effect of a change in values or arrangements of one or two circuit elements on the currents and potential differences in a circuit containing a small number of sources of emf, resistors, capacitors, and switches in series and/or parallel.

Learning Objective 4.E.5.2: The student is able to make and justify a qualitative prediction of the effect of a change in values or arrangements of one or two circuit elements on currents and potential differences in a circuit containing a small number of sources of emf, resistors, capacitors, and switches in series and/or parallel.

Learning Objective 4.E.5.3: The student is able to plan data collection strategies and perform data analysis to examine the values of currents and potential differences in an electric circuit that is modified by changing or rearranging circuit elements, including sources of emf, resistors, and capacitors.

Big Idea 5: Changes that occur as a result of interactions are constrained by conservation laws.

Enduring Understanding 5.B: The energy of a system is conserved.

Essential Knowledge 5.B.3: A system with internal structure can have potential energy. Potential energy exists within a system if the objects within that system interact with conservative forces.

a. The work done by a conservative force is independent of the path taken. The work description is used for forces external to the system. Potential energy is used when the forces are internal interactions between parts of the system.

b. Changes in the internal structure can result in changes in potential energy. Examples should include mass-spring oscillators and objects falling in a gravitational field.

c. The change in electric potential in a circuit is the change in potential energy per unit charge.

Learning Objective 5.B.3.1: The student is able to describe and make qualitative and/or quantitative predictions about everyday examples of systems with internal potential energy.

Learning Objective 5.B.3.2: The student is able to make quantitative calculations of the internal potential energy of a system from a description or diagram of that system.

Learning Objective 5.B.3.3: The student is able to apply mathematical reasoning to create a description of the internal potential energy of a system from a description or diagram of the objects and interactions in that system.

Essential Knowledge 5.B.9: Kirchhoff 's loop rule describes conservation of energy in electrical circuits. [The application of Kirchhoff 's laws to circuits is introduced in Physics 1 and further developed in Physics 2 in the context of more complex circuits, including those with capacitors.]
a. Energy changes in simple electrical circuits are conveniently represented in terms of energy change per charge moving through a battery and a resistor.
b. Since electric potential difference times charge is energy, and energy is conserved, the sum of the potential differences about any closed loop must add to zero.
c. The electric potential difference across a resistor is given by the product of the current and the resistance.
d. The rate at which energy is transferred from a resistor is equal to the product of the electric potential difference across the resistor and the current through the resistor.
e. Energy conservation can be applied to combinations of resistors and capacitors in series and parallel circuits.

Learning Objective 5.B.9.1: The student is able to construct or interpret a graph of the energy changes within an electrical circuit with only a single battery and resistors in series and/or in, at most, one parallel branch as an application of the conservation of energy (Kirchhoff 's loop rule). [1]

Learning Objective 5.B.9.2: The student is able to apply conservation of energy concepts to the design of an experiment that will demonstrate the validity of Kirchhoff 's loop rule ($\sum\Delta V = 0$) in a circuit with only a battery and resistors either in series or in, at most, one pair of parallel branches. [2]

Learning Objective 5.B.9.3: The student is able to apply conservation of energy (Kirchhoff 's loop rule) in calculations involving the total electric potential difference for complete circuit loops with only a single battery and resistors in series and/or in, at most, one parallel branch. [3]

Learning Objective 5.B.9.4: The student is able to analyze experimental data including an analysis of experimental uncertainty that will demonstrate the validity of Kirchhoff 's loop rule ($\sum\Delta V = 0$).

Learning Objective 5.B.9.5: The student is able to use conservation of energy principles (Kirchhoff 's loop rule) to describe and make predictions regarding electrical potential difference, charge, and current in steady-state circuits composed of various combinations of resistors and capacitors.

Learning Objective 5.B.9.6: The student is able to mathematically express the changes in electric potential energy of a loop in a multi-loop electrical circuit and justify this expression using the principle of the conservation of energy

Learning Objective 5.B.9.7: The student is able to refine and analyze a scientific question for an experiment using Kirchhoff 's loop rule for circuits that includes determination of internal resistance of the battery and analysis of a non-ohmic resistor.

Learning Objective 5.B.9.8: The student is able to translate between graphical and symbolic

[1] This is the limit for AP Physics 1 but NOT for AP Physics 2.
[2] Same comment
[3] Same comment

representations of experimental data describing relationships among power, current, and potential difference across a resistor.

Essential Knowledge 5.C.3: Kirchoff's junction rule describes the conservation of electric charge in electrical circuits. Since charge is conserved, current must be conserved at each junction in the circuit. Examples should include circuits that combine resistors in series and parallel. [Physics 1: covers circuits with resistors in series, with at most one parallel branch, one battery only. Physics 2: includes capacitors in steady-state situations. For circuits with capacitors, situations should be limited to open circuit, just after circuit is closed, and a long time after the circuit is closed.]

Learning Objective 5.C.3.1: The student is able to apply conservation of electric charge (Kirchhoff 's junction rule) to the comparison of electric current in various segments of an electrical circuit with a single battery and resistors in series and in, at most, one parallel branch and predict how those values would change if configurations of the circuit are changed. [4]

Learning Objective 5.C.3.2: The student is able to design an investigation of an electrical circuit with one or more resistors in which evidence of conservation of electric charge can be collected and analyzed. [5]

Learning Objective 5.C.3.3: The student is able to use a description or schematic diagram of an electrical circuit to calculate unknown values of current in various segments or branches of the circuit. [6]

Learning Objective 5.C.3.4: The student is able to predict or explain current values in series and parallel arrangements of resistors and other branching circuits using Kirchhoff 's junction rule and relate the rule to the law of charge conservation.

Learning Objective 5.C.3.5: The student is able to determine missing values and direction of electric current in branches of a circuit with resistors and NO capacitors from values and directions of current in other branches of the circuit through appropriate selection of nodes and application of the junction rule.

Learning Objective 5.C.3.6: The student is able to determine missing values and direction of electric current in branches of a circuit with both resistors and capacitors from values and directions of current in other branches of the circuit through appropriate selection of nodes and application of the junction rule.

Learning Objective 5.C.3.7: The student is able to determine missing values, direction of electric current, charge of capacitors at steady state, and potential differences within a circuit with resistors and capacitors from values and directions of current in other branches of the circuit.

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[5] Same comment
[6] Same comment

PROCEDURE:

1. Phase 1: Electric Circuit Basics
   - Notes: Roman numeral I
   - Develop and solve multiple practice problems.
   - Problem Packet 1
   - Homework 1: Chapter 20 Problems 1, 3 (Review electric potential energy.), 21, 39-43, 49, and 51-53
2. Phase 2: Circuit Geometry with Resistors only
   - Notes: Roman numeral IIA
   - Develop and solve multiple practice problems.
   - Problem Packet 2
   - Homework 2: Chapter 20 Conceptual Questions 9-11, 13 and Problems 58 - 62, 65 (For 65, fill out the entire RIVP chart.)
3. Phase 3: R-C Circuit Geometry
   - Notes: Roman numeral IIB, IIC, and III
   - Develop and solve multiple practice problems.
   - Homework 3: Chapter 20 Conceptual Questions 14, 15 and Problems 68, 69, 75, and 86-88, and 90

LABORATORY COMPONENT: RC Circuit