Introduction: Electric Force, Field & Potential

Unit: Electric Force, Field & Potential

Topics covered in this chapter:

This chapter discusses static electric charges, how they behave, and how they relate to each other.

- *Electric Charge* and *Coulomb's Law* describe the behavior of individual charged particles and their effects on each other.
- *Electric Fields* describes the behavior of an electric force field on charged particles.
- *Electric Field Vectors* and *Equipotential Lines & Maps* describe ways of representing electric fields in two dimensions.

Standards addressed in this chapter:

MA Curriculum Frameworks (2016):

HS-PS2-4. Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.

HS-PS3-1. Use algebraic expressions and the principle of energy conservation to calculate the change in energy of one component of a system when the change in energy of the other component(s) of the system, as well as the total energy of the system including any energy entering or leaving the system, is known. Identify any transformations from one form of energy to another, including thermal, kinetic, gravitational, magnetic, or electrical energy, in the system.

HS-PS3-2. Develop and use a model to illustrate that energy at the macroscopic scale can be accounted for as either motions of particles and objects or energy stored in fields.

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HS-PS3-5. Develop and use a model of magnetic or electric fields to illustrate the forces and changes in energy between two magnetically or electrically charged objects changing relative position in a magnetic or electric field, respectively.

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AP® Physics 2 Learning Objectives:

1.B.1.1: The student is able to make claims about natural phenomena based on conservation of electric charge. [**SP 6.4**]

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. [**SP 6.4**, **7.2**]

1.B.2.2: The student is able to make a qualitative prediction about the distribution of positive and negative electric charges within neutral systems as they undergo various processes. [**SP 6.4**, **7.2**]

1.B.2.3: The student is able to challenge claims that polarization of electric charge or separation of charge must result in a net charge on the object. [**SP 6.1**]

1.B.3.1: The student is able to challenge the claim that an electric charge smaller than the elementary charge has been isolated. [**SP 1.5**, **6.1**, **7.2**]

2.C.1.1: The student is able to predict the direction and the magnitude of the force exerted on an object with an electric charge *q* placed in an electric field using the mathematical model of the relation between an electric force and an electric field: ; a vector relation.[**SP 6.4**, **7.2**] E� EF � � q �

2.C.1.2: The student is able to calculate any one of the variables — electric force, electric charge, and electric field — at a point given the values and sign or direction of the other two quantities.[**SP 2.2**]

2.C.2.1: The student is able to qualitatively and semi-quantitatively apply the vector relationship between the electric field and the net electric charge creating that field. [**SP 2.2**, **6.4**]

2.C.3.1: The student is able to explain the inverse square dependence of the electric field surrounding a spherically symmetric electrically charged object. [**SP 6.2**]

2.C.4.1: The student is able to distinguish the characteristics that differ between monopole fields (gravitational field of spherical mass and electrical field due to single point charge) and dipole fields (electric dipole field and magnetic field) and make claims about the spatial behavior of the fields using qualitative or semi-quantitative arguments based on vector addition of fields due to each point source, including identifying the locations and signs of sources from a vector diagram of the field. [**SP 2.2**, **6.4**, **7.2**]

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2.C.4.2: The student is able to apply mathematical routines to determine the magnitude and direction of the electric field at specified points in the vicinity of a small set (2–4) of point charges, and express the results in terms of magnitude and direction of the field in a visual representation by drawing field vectors of appropriate length and direction at the specified points. [**SP 1.4**, **2.2**]

2.C.5.1: The student is able to create representations of the magnitude and direction of the electric field at various distances (small compared to plate size) from two electrically charged plates of equal magnitude and opposite signs, and is able to recognize that the assumption of uniform field is not appropriate near edges of plates. [**SP 1.1**, **2.2**]

2.C.5.2: The student is able to calculate the magnitude and determine the direction of the electric field between two electrically charged parallel plates, given the charge of each plate, or the electric potential difference and plate separation. [**SP 2.2**]

2.C.5.3: The student is able to represent the motion of an electrically charged particle in the uniform field between two oppositely charged plates and express the connection of this motion to projectile motion of an object with mass in the Earth's gravitational field. [**SP 1.1**, **2.2**, **7.1**]

2.E.1.1: The student is able to construct or interpret visual representations of the isolines of equal gravitational potential energy per unit mass and refer to each line as a gravitational equipotential. [**SP 1.4**, **6.4**, **7.2**]

2.E.2.1: The student is able to determine the structure of isolines of electric potential by constructing them in a given electric field. [**SP 6.4**, **7.2**]

2.E.2.2: The student is able to predict the structure of isolines of electric potential by constructing them in a given electric field and make connections between these isolines and those found in a gravitational field. [**SP 6.4**, **7.2**]

2.E.2.3: The student is able to qualitatively use the concept of isolines to construct isolines of electric potential in an electric field and determine the effect of that field on electrically charged objects. [**SP 1.4**]

2.E.3.1: The student is able to apply mathematical routines to calculate the average value of the magnitude of the electric field in a region from a description of the electric potential in that region using the displacement along the line on which the difference in potential is evaluated. [**SP 2.2**]

2.E.3.2: The student is able to apply the concept of the isoline representation of electric potential for a given electric charge distribution to predict the average value of the electric field in the region. [**SP 1.4**, **6.4**]

3.A.2.1: The student is able to represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation. [**SP 1.1**]

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3.A.3.2: The student is able to challenge a claim that an object can exert a force on itself. [**SP 6.1**]

3.A.3.3: The student is able to describe a force as an interaction between two objects and identify both objects for any force. [**SP 1.4**]

3.A.3.4: The student is able to make claims about the force on an object due to the presence of other objects with the same property: mass, electric charge. [**SP 6.1**, **6.4**]

3.A.4.1: The student is able to construct explanations of physical situations involving the interaction of bodies using Newton's third law and the representation of action-reaction pairs of forces. [**SP 1.4**, **6.2**]

3.A.4.2: The student is able to use Newton's third law to make claims and predictions about the action-reaction pairs of forces when two objects interact. [**SP 6.4**, **7.2**]

3.A.4.3: The student is able to analyze situations involving interactions among several objects by using free-body diagrams that include the application of Newton's third law to identify forces. [**SP 1.4**]

3.B.1.3: The student is able to re-express a free-body diagram representation into a mathematical representation and solve the mathematical representation for the acceleration of the object. [**SP 1.5**, **2.2**]

3.B.1.4: The student is able to predict the motion of an object subject to forces exerted by several objects using an application of Newton's second law in a variety of physical situations. [**SP 6.**4, **7.2**]

3.B.2.1: The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively. [**SP 1.1**, **1.4**, **2.2**]

3.C.2.1: The student is able to use Coulomb's law qualitatively and quantitatively to make predictions about the interaction between two electric point charges. [**SP 2.2**, **6.4**]

3.C.2.2: The student is able to connect the concepts of gravitational force and electric force to compare similarities and differences between the forces. [**SP 7.2**]

3.C.2.3: The student is able to use mathematics to describe the electric force that results from the interaction of several separated point charges (generally 2–4 point charges, though more are permitted in situations of high symmetry). [**SP 2.2**]

3.G.1.2: The student is able to connect the strength of the gravitational force between two objects to the spatial scale of the situation and the masses of the objects involved and compare that strength to other types of forces. [**SP 7.1**]

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3.G.2.1: The student is able to connect the strength of electromagnetic forces with the spatial scale of the situation, the magnitude of the electric charges, and the motion of the electrically charged objects involved. [**SP 7.1**]

4.E.3.1: The student is able to make predictions about the redistribution of charge during charging by friction, conduction, and induction. [**SP 6.4**]

4.E.3.2: The student is able to make predictions about the redistribution of charge caused by the electric field due to other systems, resulting in charged or polarized objects. [**SP 6.4**, **7.2**]

4.E.3.3: The student is able to construct a representation of the distribution of fixed and mobile charge in insulators and conductors. [**SP 1.1**, **1.4**, **6.4**]

4.E.3.4: The student is able to construct a representation of the distribution of fixed and mobile charge in insulators and conductors that predicts charge distribution in processes involving induction or conduction. [**SP 1.1**, **1.4**, **6.4**]

4.E.3.5: The student is able to plan and/or analyze the results of experiments in which electric charge rearrangement occurs by electrostatic induction, or is able to refine a scientific question relating to such an experiment by identifying anomalies in a data set or procedure. [**SP 3.2**, **4.1**, **4.2**, **5.1**, **5.3**]

5.A.2.1: The student is able to define open and closed systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations. [**SP 6.4**, **7.2**]

5.B.2.1: The student is able to calculate the expected behavior of a system using the object model (*i.e.,* by ignoring changes in internal structure) to analyze a situation. Then, when the model fails, the student can justify the use of conservation of energy principles to calculate the change in internal energy due to changes in internal structure because the object is actually a system. [**SP 1.4**, **2.1**]

5.C.2.1: The student is able to predict electric charges on objects within a system by application of the principle of charge conservation within a system. [**SP 6.4**]

5.C.2.2: The student is able to design a plan to collect data on the electrical charging of objects and electric charge induction on neutral objects and qualitatively analyze that data. [**SP 4.2**, **5.1**]

5.C.2.3: The student is able to justify the selection of data relevant to an investigation of the electrical charging of objects and electric charge induction on neutral objects. [**SP 4.1**]

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Topics from this chapter assessed on the SAT Physics Subject Test:

- **Electric Fields, Forces, and Potentials**, such as Coulomb's law, induced charge, field and potential of groups of point charges, and charged particles in electric fields

1. Electric Charge
2. Electric Force
3. Electric Field
4. Electric Potential
5. Conductors and Insulators

Skills learned & applied in this chapter:

- Working with isolines.

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