SPH4U UNIVERSITY PHYSICS

ELECTRIC, GRAVITATIONAL, & ... FIELDS

- Electric Fields (P.334-337)

Electric Fields

Almost everywhere you go you will find a device that, in one way or another, uses electric fields. An electric field is what causes the electric force.

Electric Fields

At the dentist's office, the X-ray machine uses an electric field to accelerate electrons as part of the process for producing X-rays. At coal-burning power plants, electric fields in smokestack scrubbers remove soot and other pollutants before gases are released into the air. Even when you are speaking into a telephone or listening to the other person on the line, electric fields help convert sound to electricity and back to sound again.

Electric Fields

ELECTRIC FIELD (ε)

- field of force that exists in a region of space around a charged object
- is a vector quantity
- exerts attractive/repulsive force on other charged objects

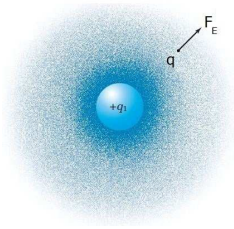
NOTE!

LCDs use changing electric fields to alter the crystal's optical properties, creating images.

Electric Fields

For example, the diagram illustrates the generation of an electric field, ε, by a charge, q_1. The density of the shading designates the strength of the field. If a second positive charge, q, is introduced into the field at point P, it is the field that interacts with q to produce the electric force.

$$F_E = q\varepsilon$$

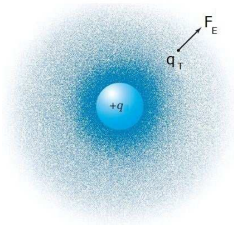


NOTE!

If q_1 were negative the electric field and force would be in the opposite direction.

Electric Fields

To describe the field around a charge, q, it is convenient to use the concept of a positive test charge. By definition, a ***test charge****, q_T, is a point charge with a magnitude so much smaller than the source charge that any field generated by the test charge itself is negligible in relation to the field generated by the source charge. In this case:*



$$F_E = q_T\varepsilon \quad \& \quad F_E = \frac{kqq_T}{r^2}$$

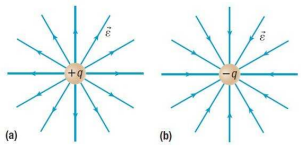
$$q_T\varepsilon = \frac{kqq_T}{r^2}$$

$$\varepsilon = \frac{kq}{r^2}$$

Electric Fields

NOTE!

Electric fields point away from positive charges (a) and toward negative charges (b). This convention is based on using a positive test charge to determine direction.



Electric Field Intensity

ELECTRIC FIELD INTENSITY (ε)

$$\varepsilon = \frac{kq}{r^2} = \frac{F_{\vec{E}}}{q}$$

where ε is the electric field intensity near a point charge (N/C)
k is Coulomb's constant (8.99×10^9 N·m²/C²)
q is the point charge (C)
r is the distance between the point charge & ... (m)

NOTE!

This equation applies only to the field surrounding an isolated point charge.

Electric Field Intensity

PRACTICE

1. A positive test charge, $q_T = +2.0 \times 10^{-9}$ C, is placed in an electric field and experiences a force of 4.0×10^{-9} N[W].
   (a) What is the electric field intensity at the location of the test charge?

(a) ε = 2.0 N/C[W]

Electric Field Intensity

PRACTICE

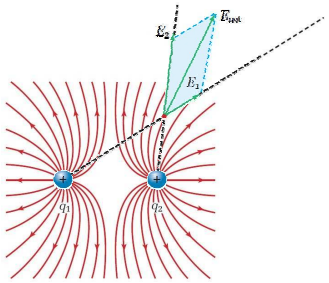
1. A positive test charge, q_T = +2.0 x 10^{-9} C, is placed in an electric field and experiences a force of 4.0 x 10^{-9} N[W].
   (b) Predict the force that would result if the test charge were replaced by a charge of q_T = +9.0 x 10^{-6} C.

(b) F_E = 1.8 x 10^{-5} N[W] ($F_E = q_T\varepsilon$)

Electric Field Intensity

NOTE!

When more than one electric source charge is present, the electric field vector at a point is the vector sum of the electric fields attributable to each source charge considered separately. Since the field lines are often curved, this vector will be tangent to the field line at that point.



Electric Field Intensity – 1D

PRACTICE

2. Two point charges (q_1 = +3.3 x 10^{-9} C and q_2 = -1.0 x 10^{-8} C) are located 45 cm apart.
   (a) A positive test charge is located between q_1 and q_2 and 27 cm from q_1 along a line connecting q_1 and q_2. What is the net electric field intensity on the positive test charge?

(a) ε_{net} = 3.2 x 10^3 N/C[E]

Electric Field Intensity – 1D

PRACTICE

2. Two point charges (q_1 = +3.3 x 10^{-9} C and q_2 = -1.0 x 10^{-8} C) are located 45 cm apart.
   (b) A new charge of +2.0 x 10^{-12} C is placed at P. Determine the electric force on this new charge.

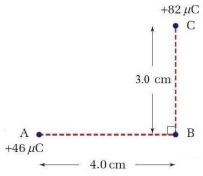
(b) F_E = 6.4 x 10^{-9} N[E] ($F_E = q\varepsilon_{net}$)

Electric Field Intensity – 2D

PRACTICE

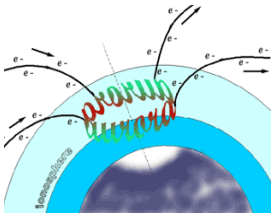
3. In the diagram, A and C are situated as shown. What is the magnitude and direction of the electric field intensity at point B?

ε_{AB} = 2.6 x 10^{8} N/C[E]
ε_{CB} = 8.2 x 10^{8} N/C[S]
ε_{net} = 8.6 x 10^{8} N/C[E72°S]



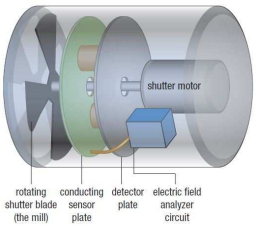
Applications of … – Earth's Electric Field

Energy from the Sun bombards Earth's upper atmosphere. Some of this energy strips electrons from atoms, leaving a region of positively charged ions and free electrons – the ionosphere. In contrast to the ionosphere, Earth's surface is more negatively charged. Both areas tend to stay charged, so that a permanent electric field exists throughout the atmosphere.



Applications of … – Earth's Electric Field

*One device, called an **electric field mill**, or just field mill, is widely used to measure Earth's electric field. A field mill makes use of the uniform electric field between two parallel conducting plates and detects changes in the field strength at a given location.*

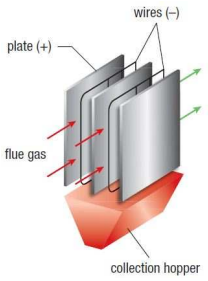


Applications of … – Electrostatic Precipitator

During the Industrial Age, heavily polluted air resulted from the smoke pouring out of chimneys and smokestacks. Most of these emissions, called flue gases because they passed through the flues of chimneys, consisted of clear gases such as nitrogen and carbon dioxide. However, tiny particles of carbon, sulfur compounds and dust produced by various chemical processes combined with the gases to give the air its smoky appearance.

Applications of … – Electrostatic Precipitator

*Today, industrial processes continue to pollute our air. In recent years, though, devices called **electrostatic precipitators** have reduced the numbers of particles released into the atmosphere. Electrostatic precipitators use electric fields to remove extremely small particles of soot, dust, and ash from the flue gases and other emissions produced by combustion, smelting, and refining.*



Applications of … – Electric Fields in Nature

Electric fields are also produced by animals. These fields are often weak and produced by ordinary actions, such as motion in the muscles. Some animals have organs that detect and respond to these weak electric fields. Hammerhead sharks, for example, detect fields as low as 6 N/C in fish that hide beneath the sand or in tunnelled shelters along ocean bottoms.

Applications of Electric Fields

APPLICATIONS OF ELECTRIC FIELDS

- X-ray machines, LCD displays, telephones, particle accelerators, ...
- electrostatic precipitators remove extremely small particles of soot, dust and ash from flue gases
- some organisms can detect the weak electric fields of other organisms
- musical instruments such as a Theremin

✔ Check Your Learning

TEXTBOOK

P.337 Q.2,3

WIKI (EGM FIELDS)

✎.... 4U3 - QUIZ#1 (Electric Fields - Part 1)