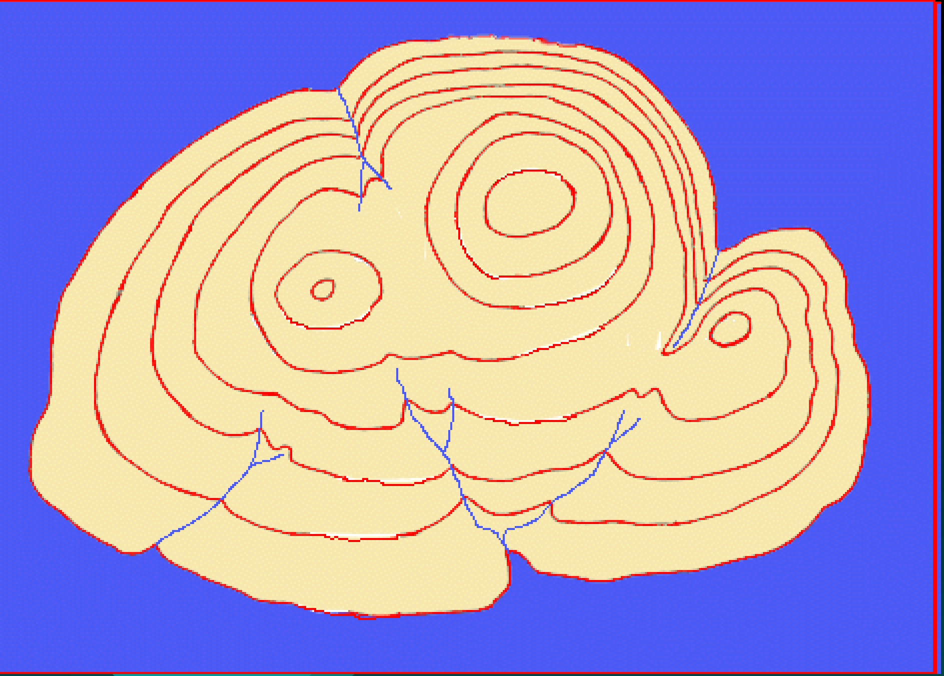
Electric Fields

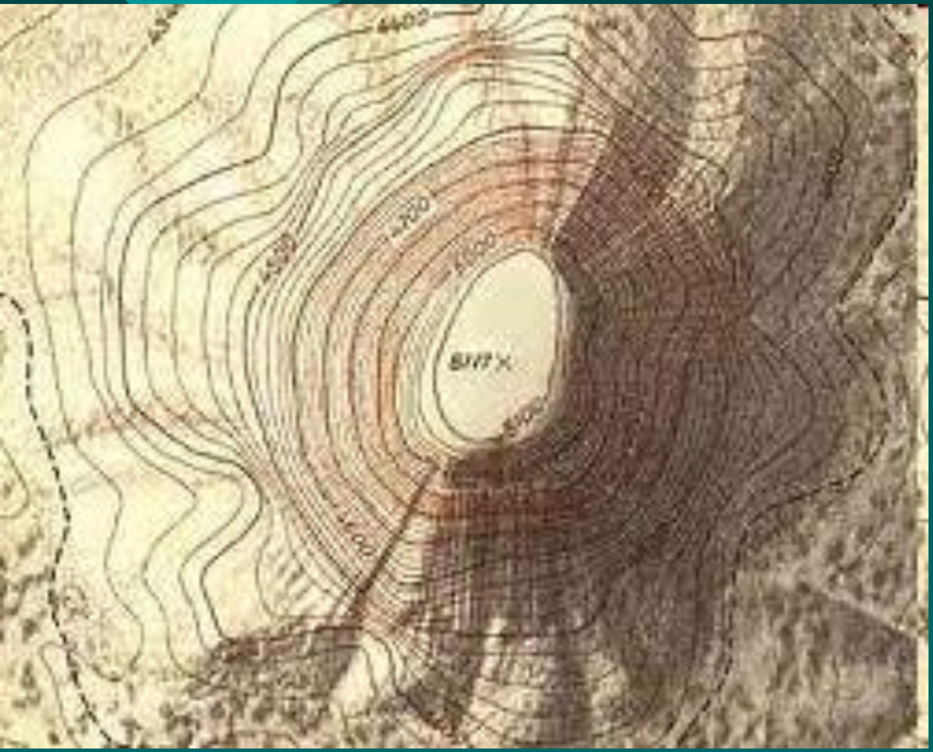
Electric Fields

Do you believe in gravity?

Do you believe that the mass of the Earth has an effect on the entire space around it, decreasing the farther you are from the core?

Do you believe that the higher up you are, the more potential you have for getting hurt if you fall?





Contour lines
In geography
are similar to
field lines in
electrostatics

What You Will Learn

- An electric field is like a force field.
- An electric field is a vector quantity.
- **An electric field provides the direction that a positive test charge will move if placed in the field**.
- An electric field is composed of a series of imaginary lines of force.

What you already know

- Coulomb's Law:

$$F_e = \frac{kqq_o}{r^2}$$

Note: q_o is much smaller than q! In theory, q_o is very close to zero

Electric Field

Gravity:

- $F_g = \frac{G\, m_1\, m_2}{r^2} = m_2 \frac{(G\, m_1)}{r^2} = m_2 a$

Electric Field:

- $F_e = \frac{k\, |q_1| q_2}{r^2} = q_2 \frac{(k\, q_1)}{r^2} = q_2 \mathbf{E}$

Electric Field

- The electric field is the electrostatic force that a positive test charge experiences divided by itself.
  - Think of it as the electrical acceleration!

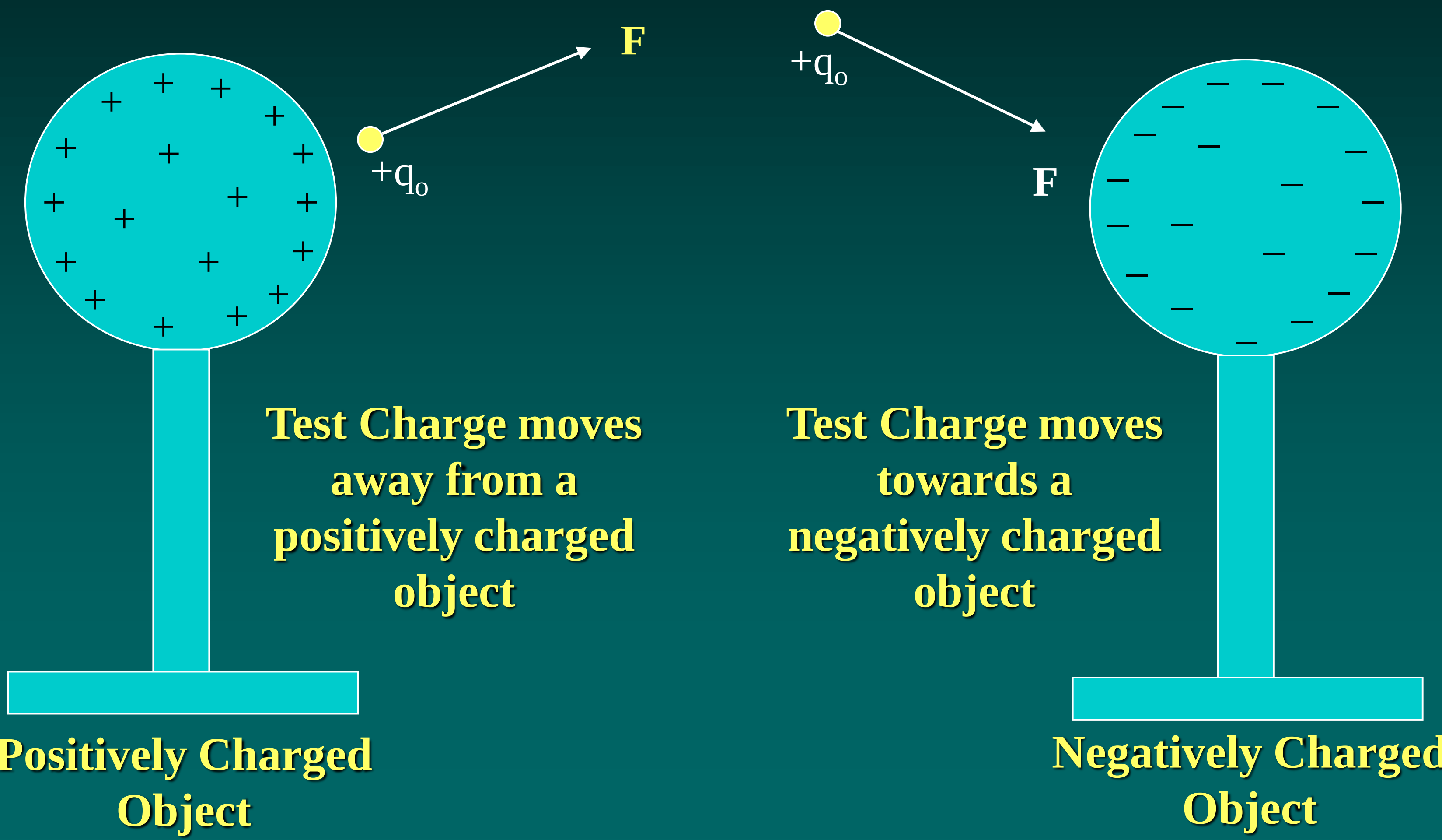
$$\mathbf{E} = \mathbf{F_e}/q_o = \frac{k\,|q|\,\cancel{q_o}}{r^2\,\cancel{q_o}} = \frac{k\,|q|}{r^2}$$

Note: The electric field is a vector quantity and therefore has magnitude and direction.

What is the Test Charge

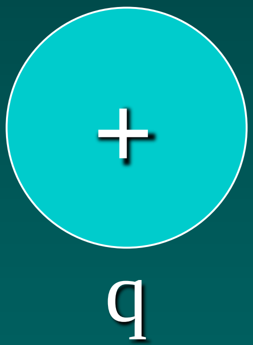
- It is small enough that it does not affect the field due to other charged objects.
- It will move towards or away from other charged objects depending on whether it is charged similarly or dissimilarly from other objects.

The Test Charge (Cont.)



Example

A positive charge of 4.0×10^{-5} C experiences a force of 0.36 N when located at a certain point. What is the electric field intensity at that point? → $F = Eq$ → $E = F/q$



$q = 4.0 \times 10^{-5}$C

$\mathbf{F_e} = 0.36$ N

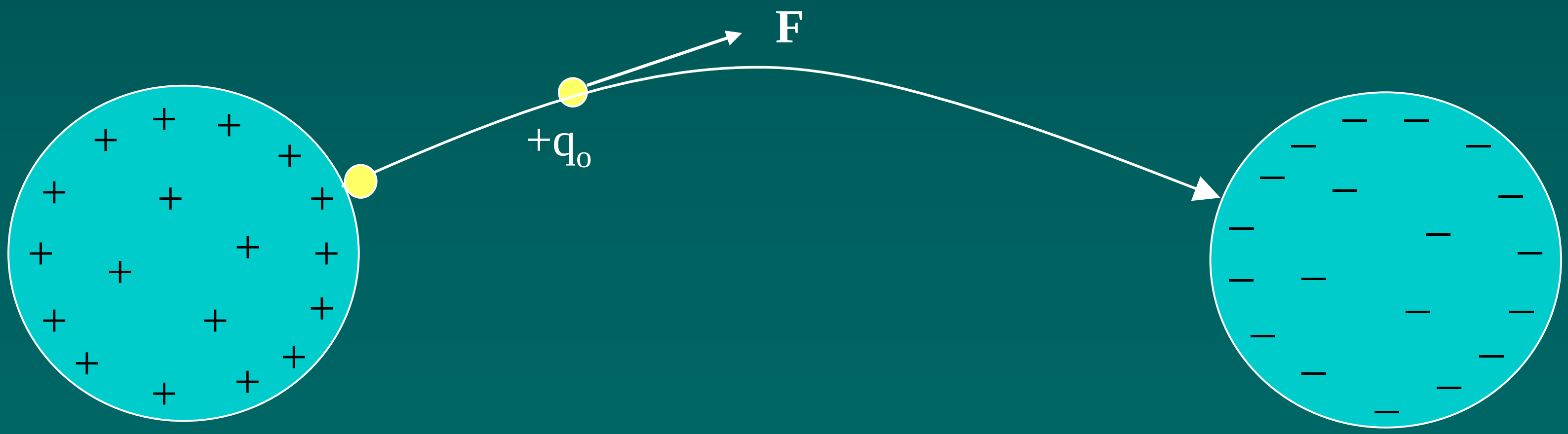
$\mathbf{E} = \mathbf{F_e}/q = 0.36 \text{ N} / 4.0 \times 10^{-5}$C

$\mathbf{E} = 9000$ N/C

Note: The electric field intensity says nothing about the magnitude of charge q, which is the source of the electric field that produces the force that charge q_o experiences.

Electric Field Lines

- Electric field lines, or lines of force, provide a map of the electric field at any point in space from a charge.
- Electric field lines show the path that a positive test charge would take if placed in the field.



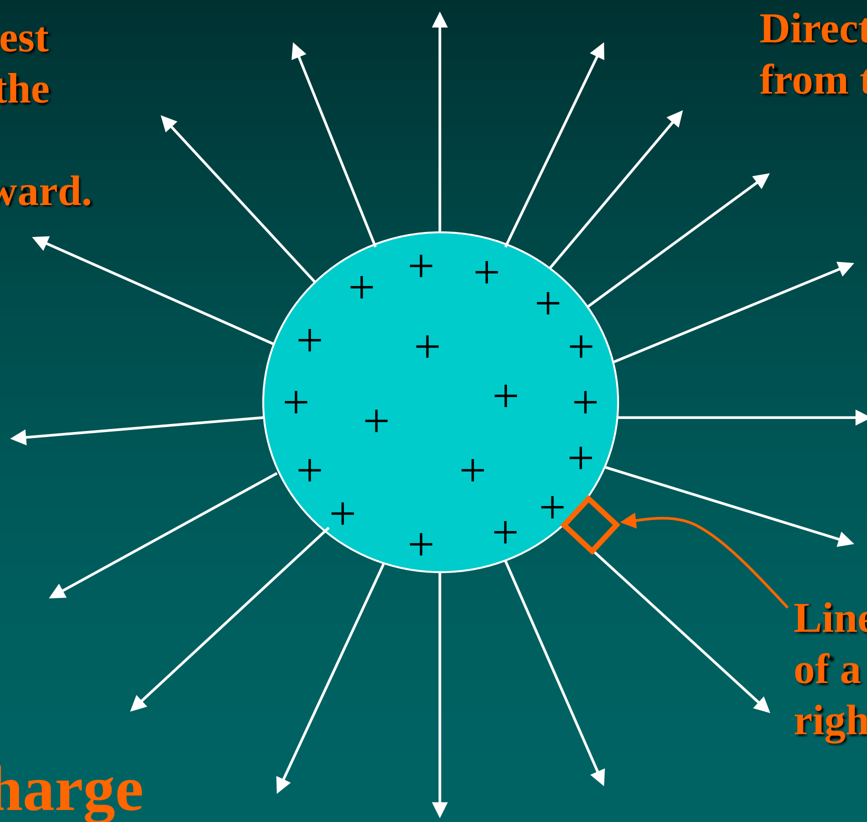
Electric Field Lines

- Electric field lines begin at positive charges and are always directed away from them towards negative charges.
- Electric field lines do not start or stop except at the surfaces of positive or negative charges.
- Electric field lines are always perpendicular (90°) to the surface where they start or end.
- Electric field lines never cross.
- The strength of the field is proportional to the magnitude of the charge and is directly related to the density of field lines
  - the more lines there are and the closer together they are, the stronger the field.

Electric Field Lines Due to a Point Charge

Density of lines is highest close to the surface of the charged object and decreases radially outward.

Direction of field is away from the positive charge.

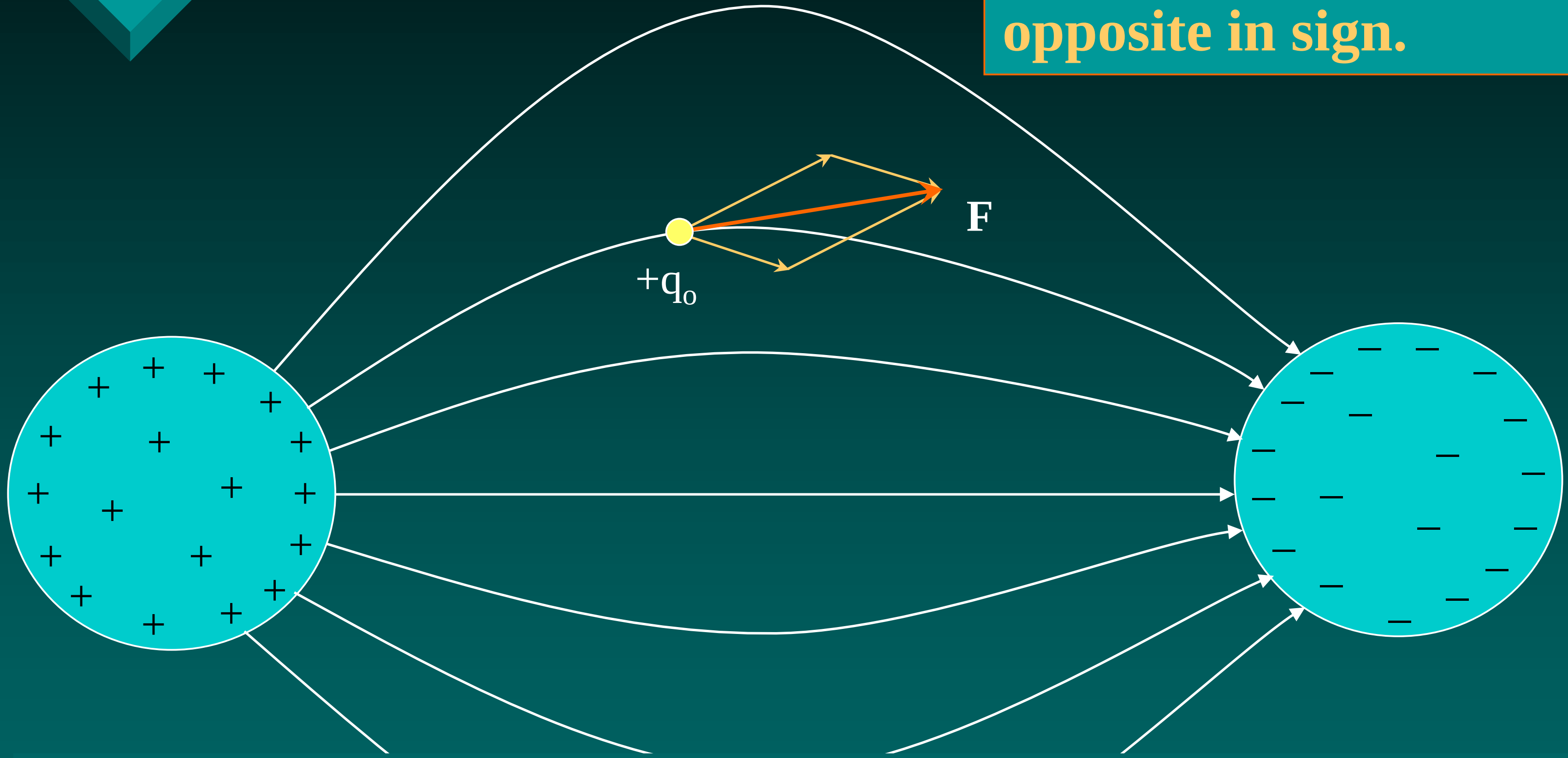


Lines intersect the surface of a charged particle at right angles.

Positive Charge

Electric Dipole

Note: An electric dipole consists of two charges equal in magnitude and opposite in sign.



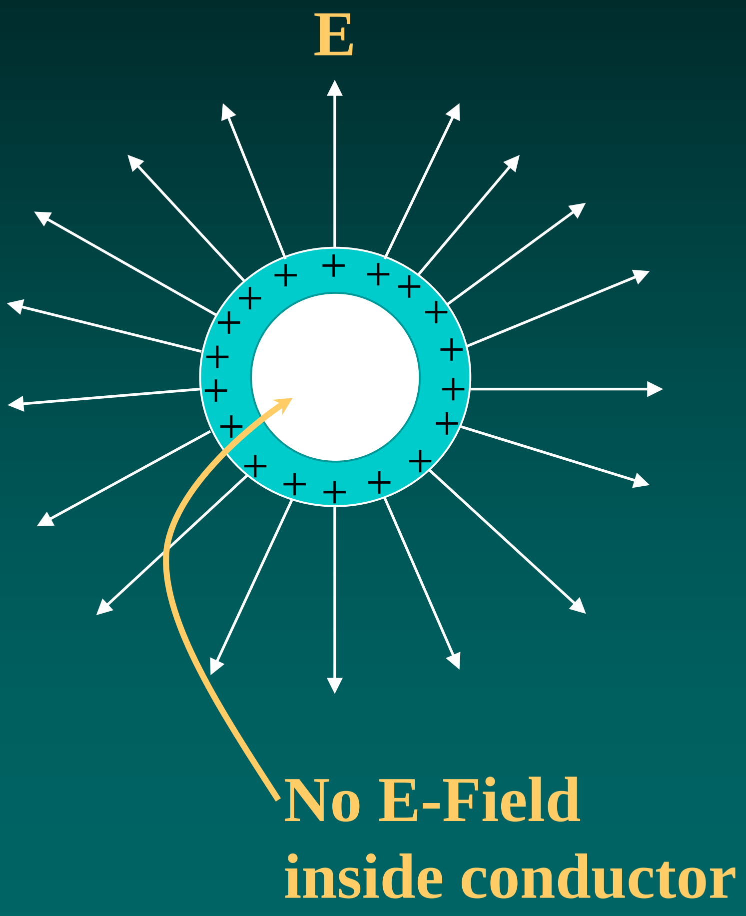
Note: Force on a test charge(q_o) is always tangent the field lines, and is the vector sum of the forces due to both charges of the dipole acting on it.

Examples from the Web

https://academo.org/demos/electric-field-line-simulator/

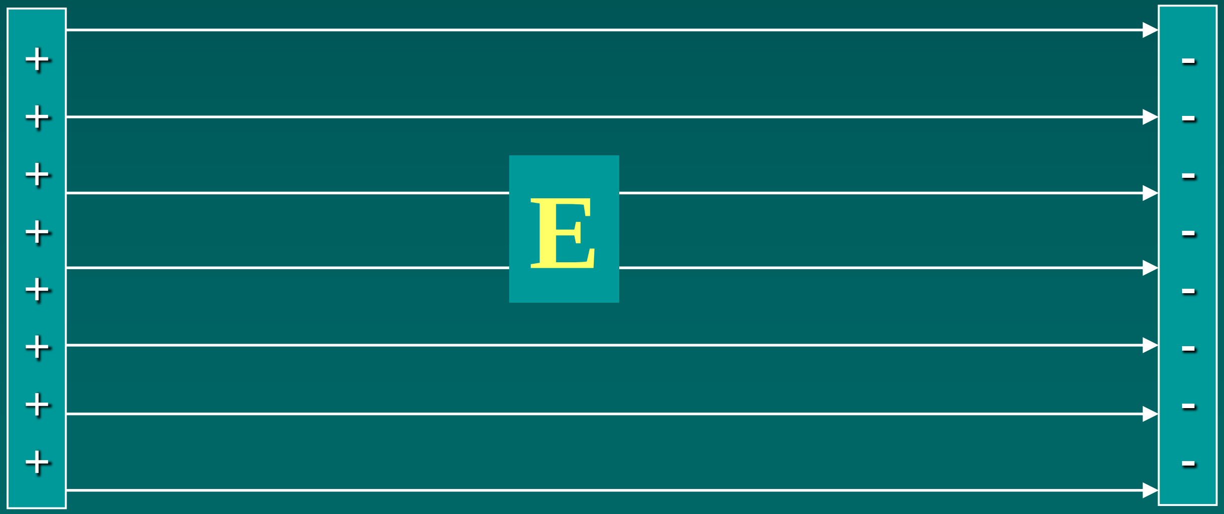
Electric Fields and Conductors

- At equilibrium, excess charges will reside on the surface of a conductor.
- The electric field is zero at any point within a conducting material at equilibrium.
- Charge within a conductor is shielded from external electric fields because they begin or terminate on the surface where excess charges reside.



Parallel Plate Capacitor

- The parallel plate capacitor is an energy storage device used in all kinds of electronics.
- Field lines in a parallel plate capacitor are evenly spaced and parallel to one another, indicating a uniform electric field.



Electrostatic Force and Distance

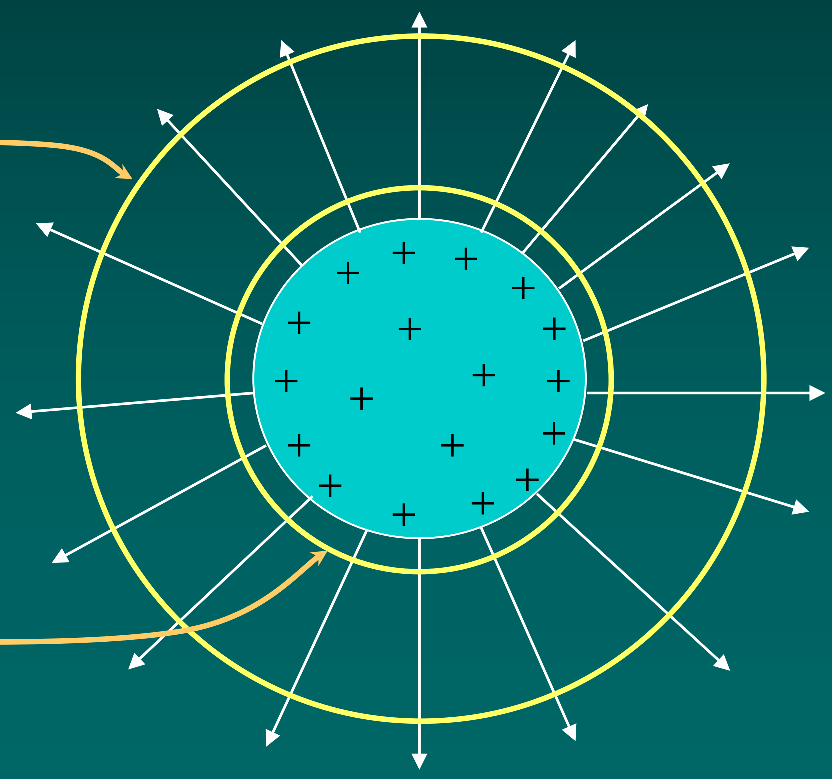
- For point charges:
  - The strength of the field decreases as the distance increases.

Weak Field

$$F_e = qE$$

$$F_e = q_o \frac{(kq)}{r^2}$$

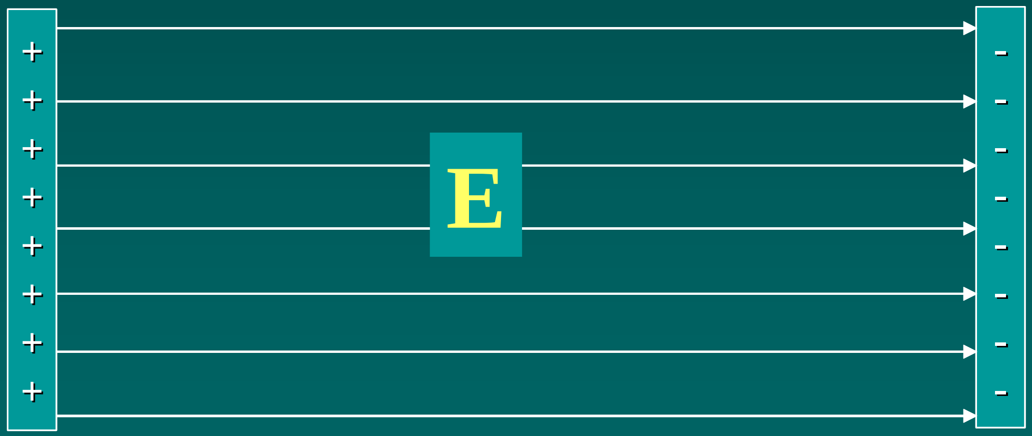
Strong Field



Electrostatic Force and Distance

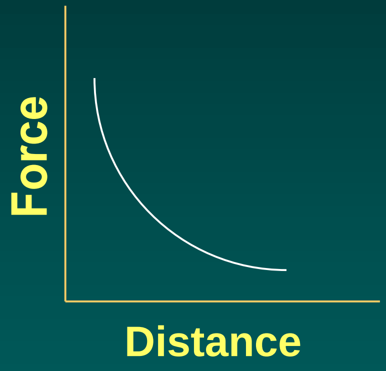
- For parallel plates:
  - The strength of the field is constant from one plate to the other.
  - Since E does not vary, the force will be constant.

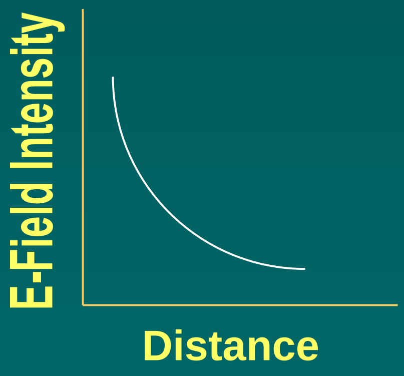
$$F = q_o E$$



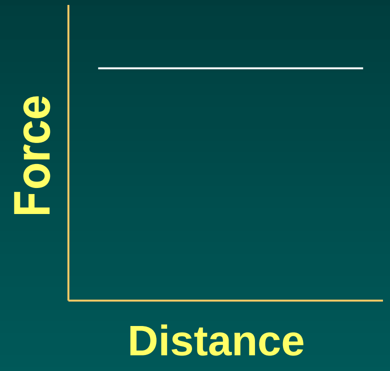
Force and Electric Field Strength vs. Distance

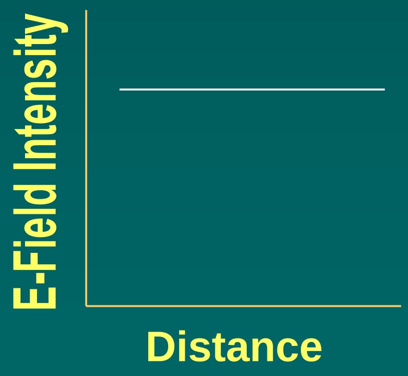
Point Charge





Parallel Plate





Example (Millikan Oil Drop Exp.)

An oil drop is negatively charged and weighs 8.5×10^{-14} N. The drop is suspended in an electric field intensity of 5.3×10^{1} N/C.

What is the charge on the drop?

$\mathbf{E}q = mg$

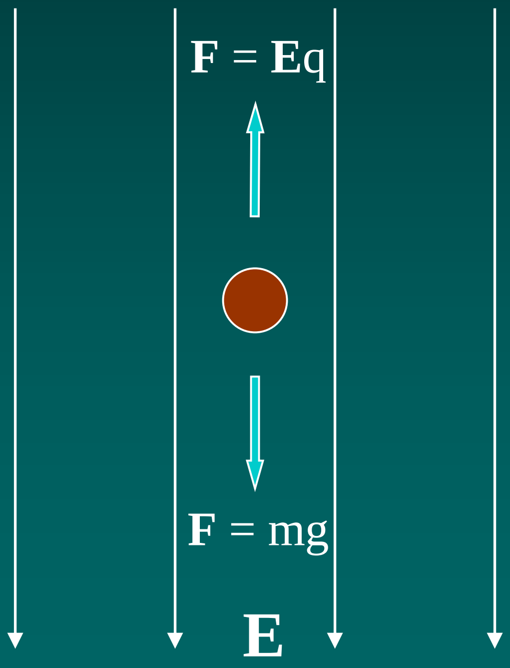
$q = mg/\mathbf{E} = \mathbf{F_g/E}$

$\mathbf{q = 8.5 \times 10^{-14}\ N/53\ N/C}$

$\mathbf{q = 1.6 \times}\ 10^{-15}\text{C}$

How many electrons is that?

~10,000 electrons



Key Ideas

- Electric fields exists around any conductor or insulator that contains a charge.
- The electric field intensity is a measure of the force on a test charge placed in the field.
- The strength of the field is proportional to the density of field lines.
- Field lines are perpendicular to all charged surfaces.
- The electric field is always directed away from positive charges and towards negative charges.