EF02 ELECTRIC FIELDS

SPH4U

CH 7 – KEY IDEAS

- define and describe concepts and units related to electric and gravitational fields
- state Coulomb's law and Newton's law of universal gravitation, and analyze, compare, and apply them in specific contexts
- compare the properties of electric and gravitational fields by describing and illustrating the source and direction of the field in each case
- apply quantitatively the concept of electric potential energy and compare it to gravitational potential energy
- analyze quantitatively, and with diagrams, electric fields and electric forces in a variety of situations
- describe and explain the electric field inside and on the surface of a charged conductor and how the properties of electric fields can be used to control the electric field around a conductor
- perform experiments or simulations involving charged objects
- explain how the concept of a field developed into a general scientific model, and describe how it affected scientific thinking

EQUATIONS

- Electric Field

$$\vec{\varepsilon} = \frac{\vec{F}_E}{q}$$

FIELD THEORY

- **Field Theory:** the theory that explains interactions between bodies or particles in terms of fields
- **Field of Force:** a field of force exists in a region of space when an appropriate object placed at any point in the field experiences a force
  - Gravitational fields
  - Electric fields
  - Magnetic fields

ELECTRIC FIELD

- **Electric Field ($\vec{\varepsilon}$) [N/C]:** the region in which a force is exerted on an electric charge; the electric force per unit positive charge; a vector

$$\vec{\varepsilon} = \frac{\vec{F}_E}{q}$$

  - $\vec{F}_E$ – electric force [N]
  - q – magnitude of test charge placed in field [C]

ELECTRIC FIELDS – POINT CHARGES

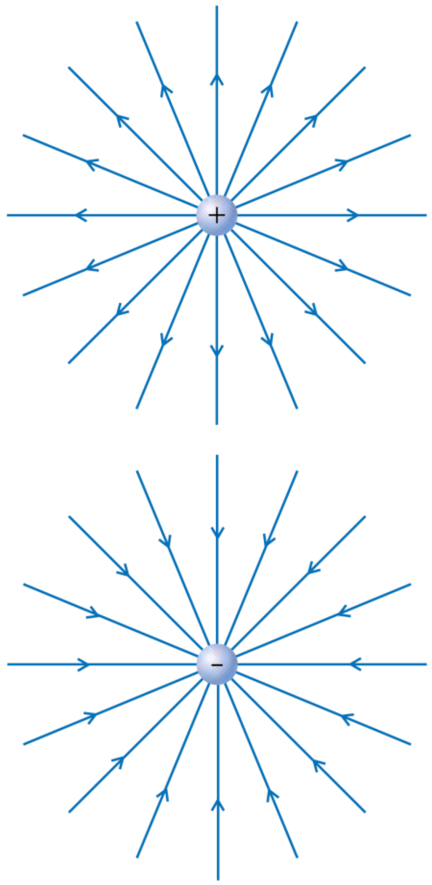
- For a sphere small enough to be considered a point charge

$$\varepsilon = \frac{F_E}{q}$$

$$\varepsilon = \frac{kQq}{r^2 q}$$

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

  - Q – charge of the sphere [C]

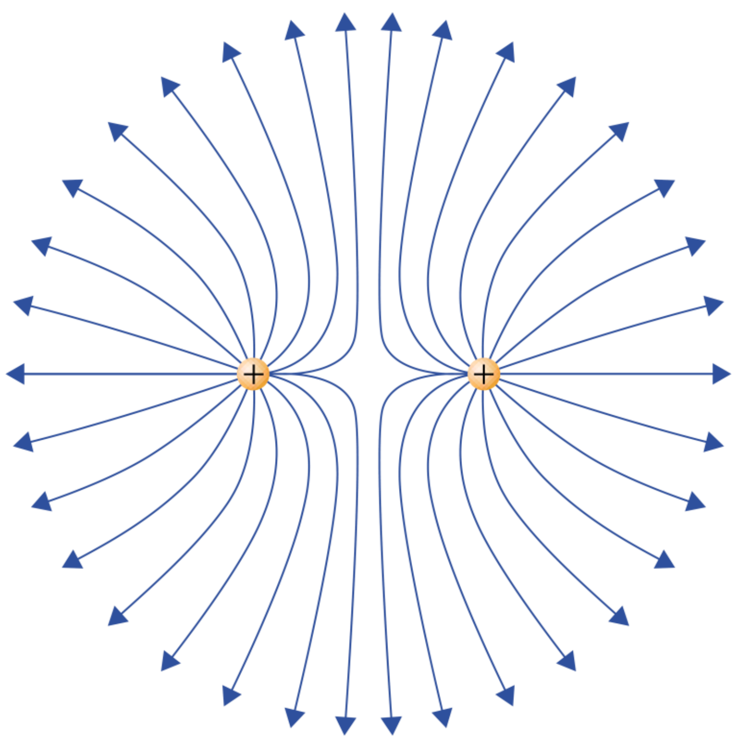


ELECTRIC FIELDS – CONT.

- What about when an object is larger than a point charge?
- What about when two or more charged objects interact?
- More complex fields occur in these cases
- **Superposition Principle:** the electric field at any point is the vector sum of the electric fields of all the point charges contributing to the net electric force at that point

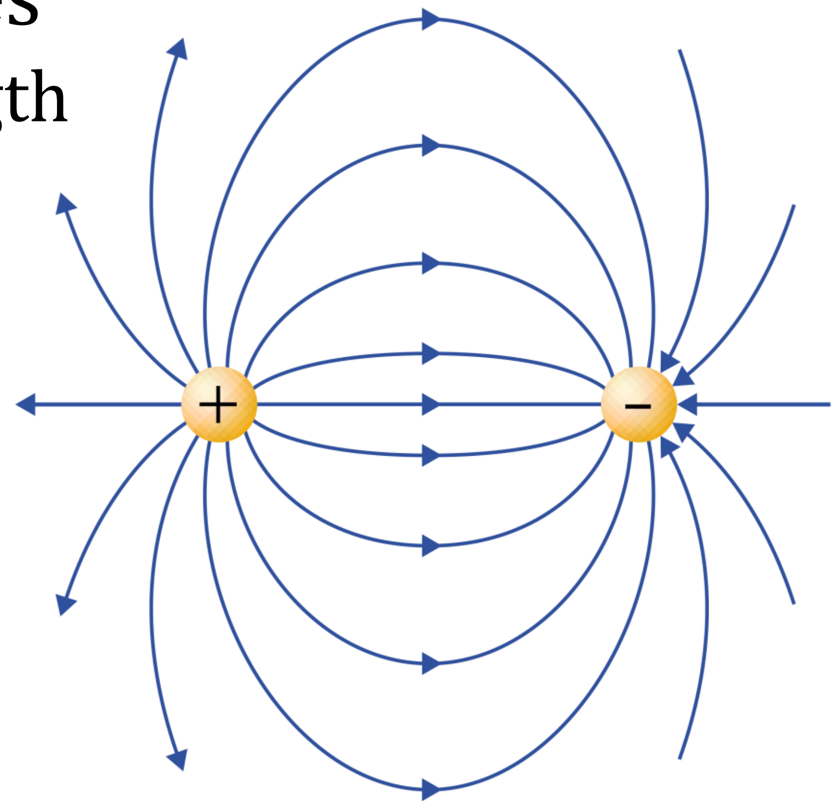
DRAWING ELECTRIC FIELDS

- Start on positive charges, end on negative charges
  - Diverge from positive point charges
  - Converge on negative point charges
- Field lines <u>never cross</u>
  - Represent net force; can’t have more than one net force in an area



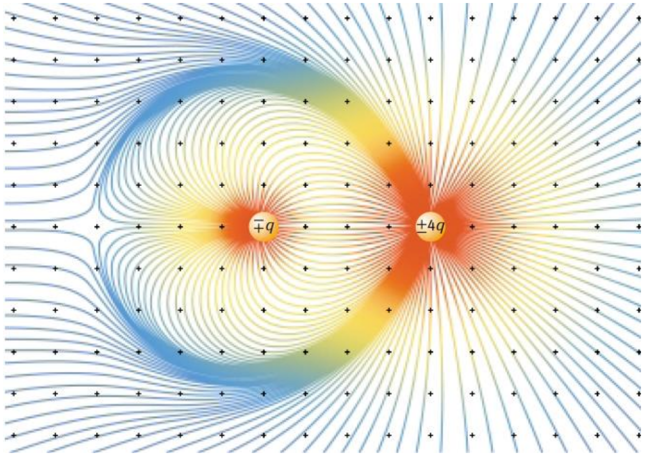
DIPOLES

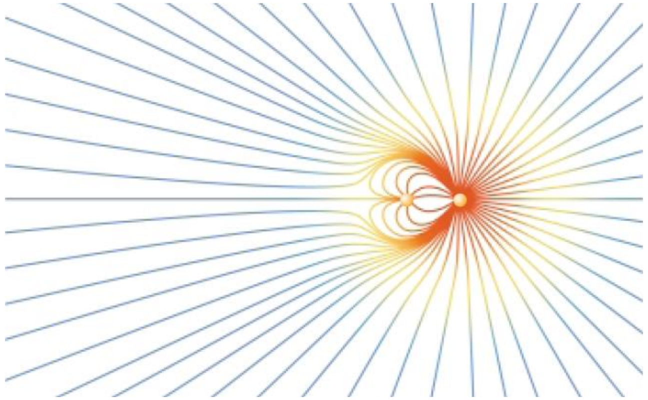
- **Dipole:** two equal and opposite charges
  - Density of lines indicates the field strength



UNEQUAL CHARGES

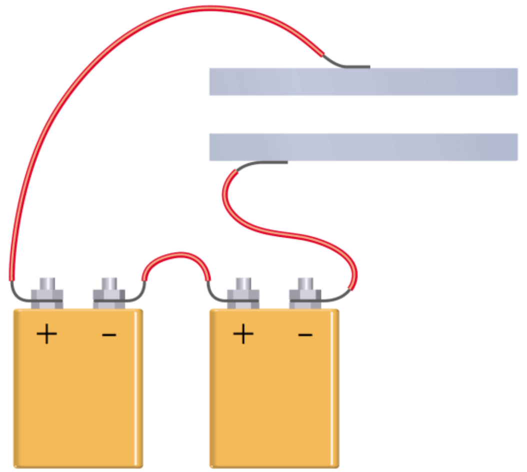
- If we have unequal charges, the field lines do not indicate strength; they are arbitrary
- We use colour (red=strong, blue=weak) to indicate field strength
- From a distance, the combined charges appear as a point charge with a magnitude equal to the net force

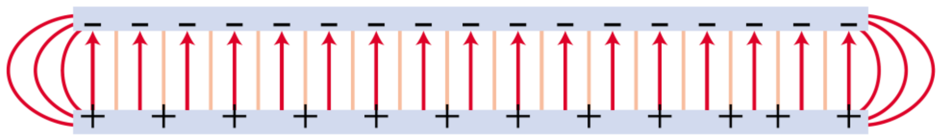




CONDUCTING PLATES

- The electric field in the region outside the parallel plates is zero (except for a slight bulging of the field near the edges of the plates—“edge effects”).
- The electric field is constant everywhere in the space between the parallel plates. The electric field lines are straight, equally spaced, and perpendicular to the parallel plates.
- The magnitude of the electric field at any point between the plates (except near the edges) depends only on the magnitude of the charge on each plate.
- $\varepsilon \propto q$, where q is the charge per unit area on each plate.





PROBLEM 1

What is the electric field 0.60 m away from a small sphere with a positive charge of 1.2×10^{-8} C?

PROBLEM 1 – SOLUTIONS

$q = 1.2 \times 10^{-8}$ C

$r = 0.60$ m

$\varepsilon = ?$

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

$$= \frac{(9.0 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2)(1.2 \times 10^{-8} \text{ C})}{(0.60 \text{ m})^2}$$

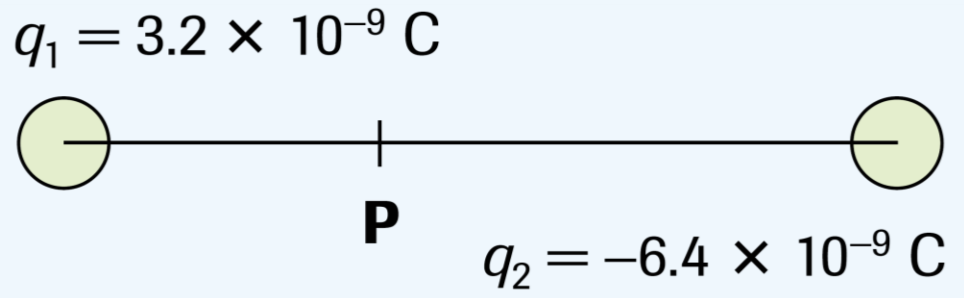
$$\varepsilon = 3.0 \times 10^2 \text{ N/C}$$

$$\vec{\varepsilon} = 3.0 \times 10^2 \text{ N/C [radially outward]}$$

The electric field is 3.0×10^2 N/C [radially outward].

PROBLEM 2

Two charges, one of 3.2×10^{-9} C, the other of -6.4×10^{-9} C, are 42 cm apart. Calculate the net electric field at a point P, 15 cm from the positive charge, on the line connecting the charges.

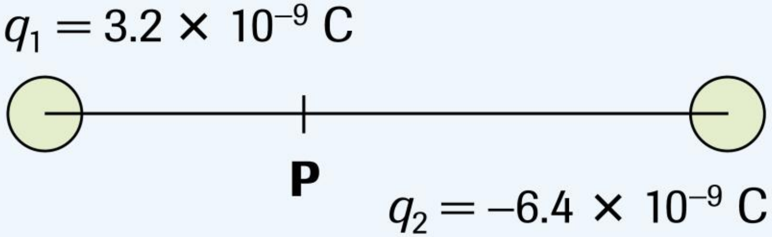


PROBLEM 2 – SOLUTIONS

$q_1 = 3.2 \times 10^{-9}$ C

$q_2 = -6.4 \times 10^{-9}$ C

$\sum \varepsilon = ?$



The net field at P is the vector sum of the fields $\vec{\varepsilon}_1$ and $\vec{\varepsilon}_2$ from the two charges. We calculate the fields separately, then take their vector sum:

$r_1 = 15 \text{ cm} = 0.15 \text{ m}$

$$\varepsilon_1 = \frac{kq_1}{r_1^{\,2}}$$

$$= \frac{(9.0 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2)(3.2 \times 10^{-9} \text{ C})}{(0.15 \text{ m})^2}$$

$$\varepsilon_1 = 1.3 \times 10^3 \text{ N/C}$$

$$\vec{\varepsilon}_1 = 1.3 \times 10^3 \text{ N/C [right]}$$

PROBLEM 2 – SOLUTIONS CONT.

$$r_2 = 42\text{ cm} - 15\text{ cm} = 27\text{ cm}$$

$$\varepsilon_2 = \frac{kq_2}{{r_2}^2}$$

$$= \frac{(9.0 \times 10^9\ \text{N·m}^2/\text{C}^2)(6.4 \times 10^{-9}\ \text{C})}{(0.27\ \text{m})^2}$$

$$\varepsilon_2 = 7.9 \times 10^2\ \text{N/C}$$

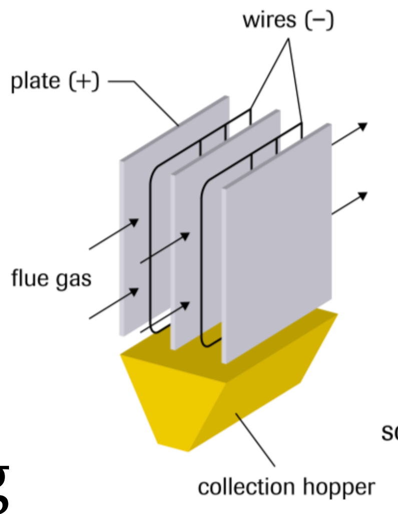
$$\vec{\varepsilon}_2 = 7.9 \times 10^2\ \text{N/C [right]}$$

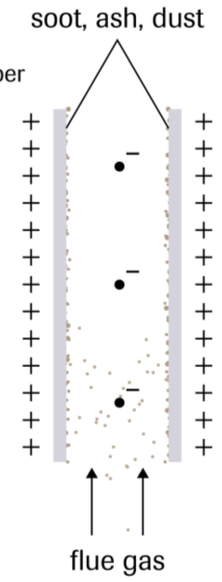
$$\sum\vec{\varepsilon} = \vec{\varepsilon}_1 + \vec{\varepsilon}_2 = 2.1 \times 10^3\ \text{N/C [right]}$$

The net electric field is 2.1×10^3 N/C [right].

ELECTROSTATIC PRECIPITATORS

- Electrostatic precipitators remove most of the tiny particles (about 99%) from emissions from burning fossil fuels (flue gas)
- The dirty flue gas is passed through a series of positively charged plates and negatively charged wires
- The negative charge on the wires is very large, ionizing the surrounding air particles
- Freed e^- move through the flue gas towards the positive plates, attaching to the tiny particles and charging them
- The now negatively charged particles attract to the positive plates, where they collect until they're shaken off into a collection hopper
  - Can be used as a filler used in making concrete





ELECTRIC FIELDS IN NATURE

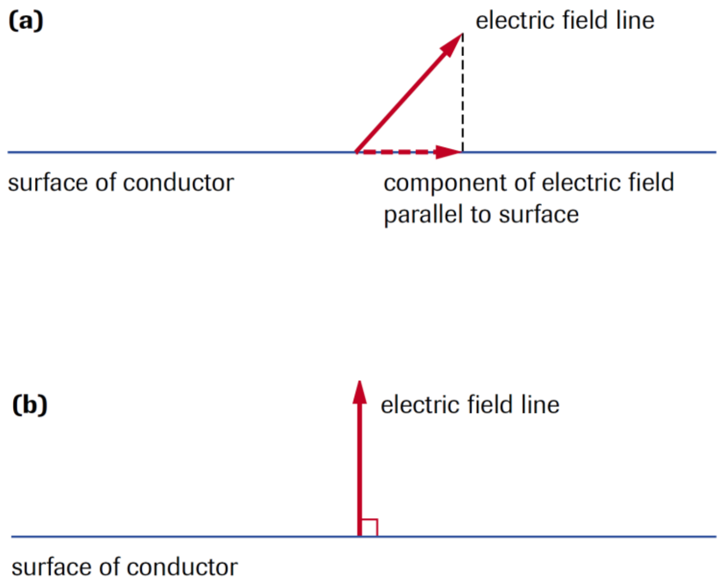
- Many animals can detect weak electric fields
  - Hammerhead sharks can detect the fields generated by the moving muscles of their prey (magnitude of 10^{-6} N/C)

SHIELDING FROM ELECTRIC FIELDS

- When e^- are added to a conductor <u>not</u> in an electric field, they distribute until they reach equilibrium and there is no net electric force
- Since there is no net force, there cannot exist an electric field inside the conductor

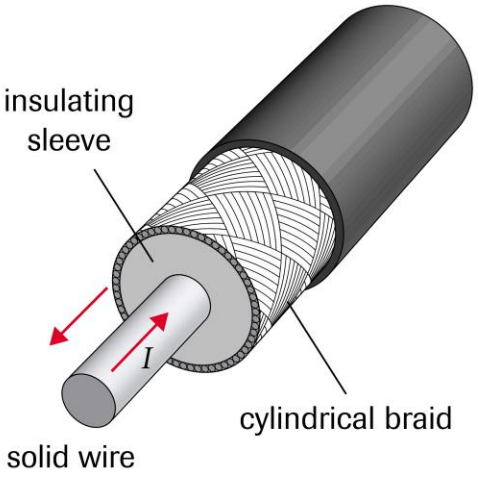
SHIELDING FROM ELECTRIC FIELDS – CONT.

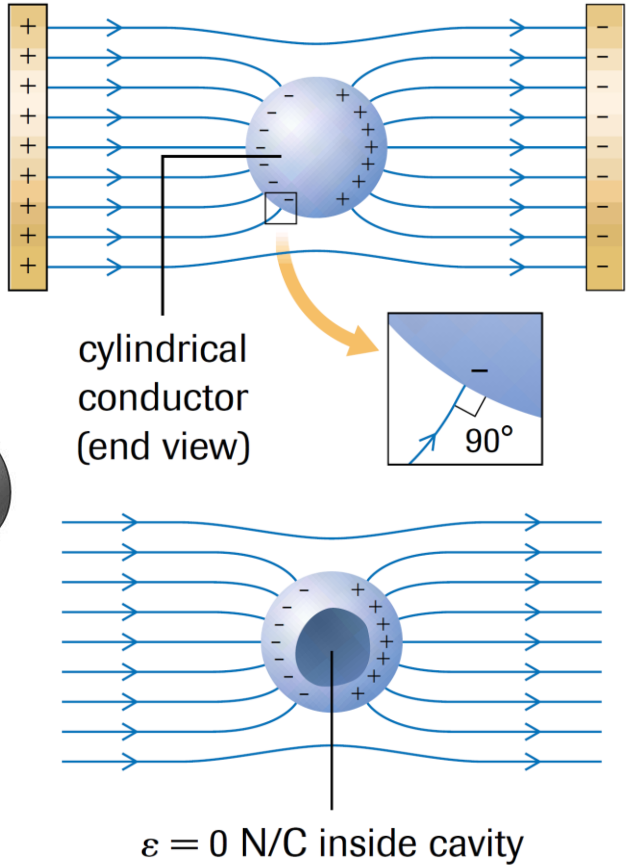
- For a conductor in an electric field, any field lines coming in contact with the surface have a parallel and perpendicular component
  - Parallel components create movement of charges on the surface ($W = F_{Ex} d \cos 0° = F_{Ex} d$)
  - Perpendicular do not ($W = F_{Ey} d \cos 90° = 0$)
- Any parallel component will cause free charges to move until they are at equilibrium
- Remaining field will be perpendicular to the surface



SHIELDING FROM ELECTRIC FIELDS – CONT.

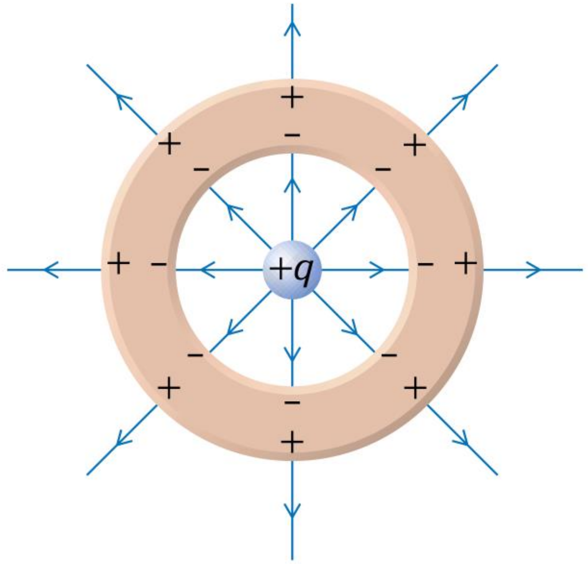
- Since all the forces are perpendicular to the surface, the conductor remains neutral
- There is no electric field inside the cavity of the conductor
- Coaxial cables have a braided metal layer to protect the inner core wire from external electric fields





INTERNAL ELECTRIC FIELDS

- We cannot use a neutral conductor to shield from an internal electric field
- A charged particle inside a neutral conductor will induce an opposite charge on the interior of the conductor
- This charge will cause an opposing charge (same as the charged particle) on the exterior of the conductor



SUMMARY – ELECTRIC FIELDS

- A field of force exists in a region of space when an appropriate object placed at any point in the field experiences a force.
- The electric $\vec{\varepsilon}$ field at any point is defined as the electric force per unit positive charge and is a vector quantity:

$$\vec{\varepsilon} = \frac{\vec{F}_E}{q}$$

- Electric field lines are used to describe the electric field around a charged object. For a conductor in static equilibrium, the electric field is zero inside the conductor; the charge is found on the surface; the charge will accumulate where the radius of curvature is smallest on irregularly-shaped objects; the electric field is perpendicular to the surface of the conductor.

PRACTICE

Readings

- Section 7.3 (pg 337)

Questions

- pg 347 #1-8