American University Of The Middle East

CH. 13
Electric Field

CH. 13 – Electric Field: Study Guide

➢ Concepts, Definitions, and Formulas:

- Coulomb Force Law (Statement + Formula): Sec. 13.2, P.514
- Definition of Electric Field (Statement + Formula): Sec. 13.2, P.517
- Electric Field of a point a charge (Statement + Formula): Sec. 13.4, P.519
- The superposition principles (Statement + Formula): Sec. 13.5, P. 523
- Electric field at location on the dipole axis (Formula): Sec. 13.6, P. 525
- Electric field at location on the perpendicular axis (Formula): Sec. 13.6, P. 527
- Electric dipole moment (Formula): Sec. 13.6, P. 531

➢ Problem Solving:

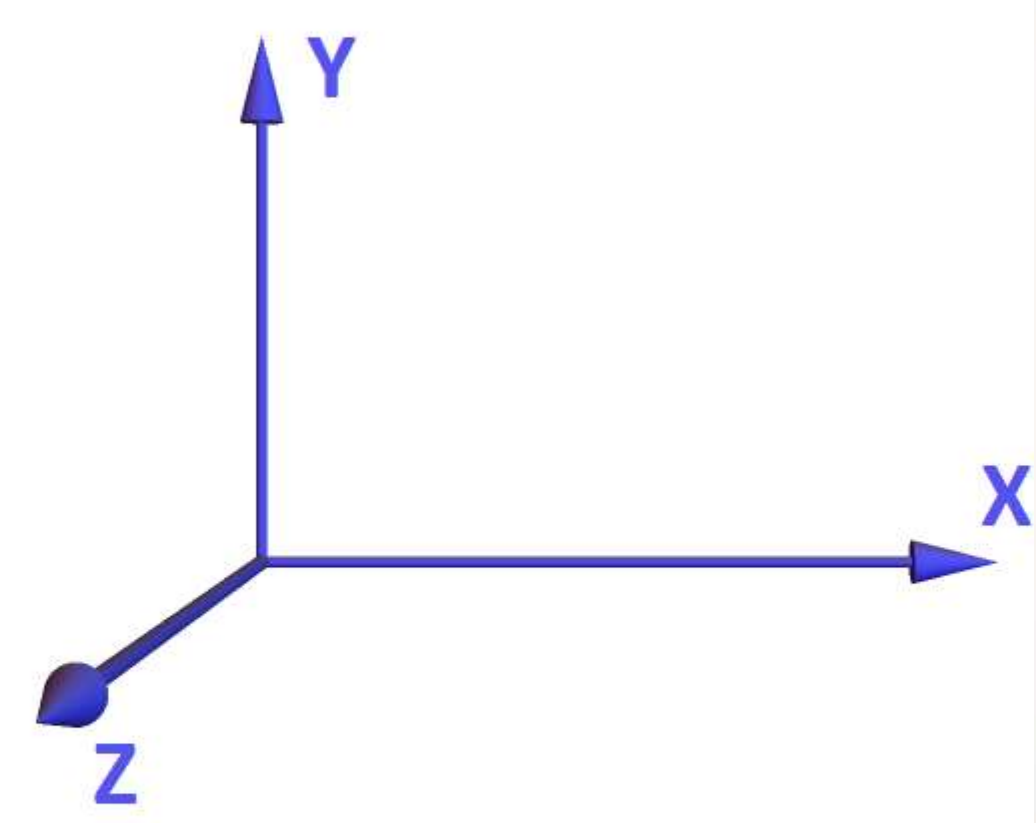
- Examples – From the Textbook (4): Electric Force and Electric Field, Field of a particle, electric Field and Force Due to Two Charges, and Dipole and Charged Ball.
- Checkpoints – From the Textbook (4): 3, 6, 8 and 14
- Problems (6):
  - Problem 48: P. 542
  - Problem 57: P. 543
  - Problem 59: P. 543
- Extra Examples and Problems – From the Slides.

OBJECTIVES

- Relate Mathematically electric field and force.
- Calculate the 3D electric field at a particular location due to a collection of point charges.
- Explain the approximations made in deriving expressions for the electric field of a dipole, and use these approximate expressions appropriately.
- Graphically represent the magnitude and direction of the electric field of a dipole with arrows, at locations in a plane containing the dipole.
- Create a computational model to compute and display the electric field of a collection of point charges in 3D, and predict the motion of a charged particle that interacts with this field.

Axes Orientation

- We will adopt the following orientation for the x, y, and z axes.
- The right direction is +x. The left direction is –x.
- The upward direction is +y. The downward direction is –y.
- The outward direction is +z. The inward direction is –z.



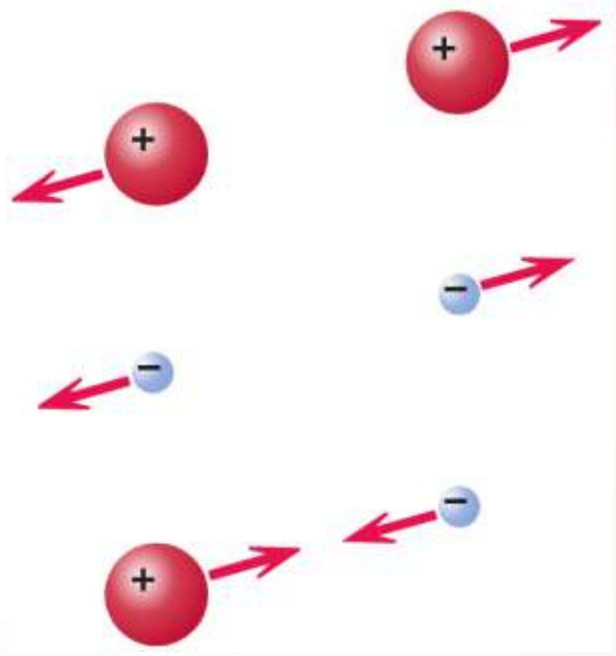
Coulomb Force Law for Point Charges

- Point Charges

- The Coulomb Force Law for Point charges:

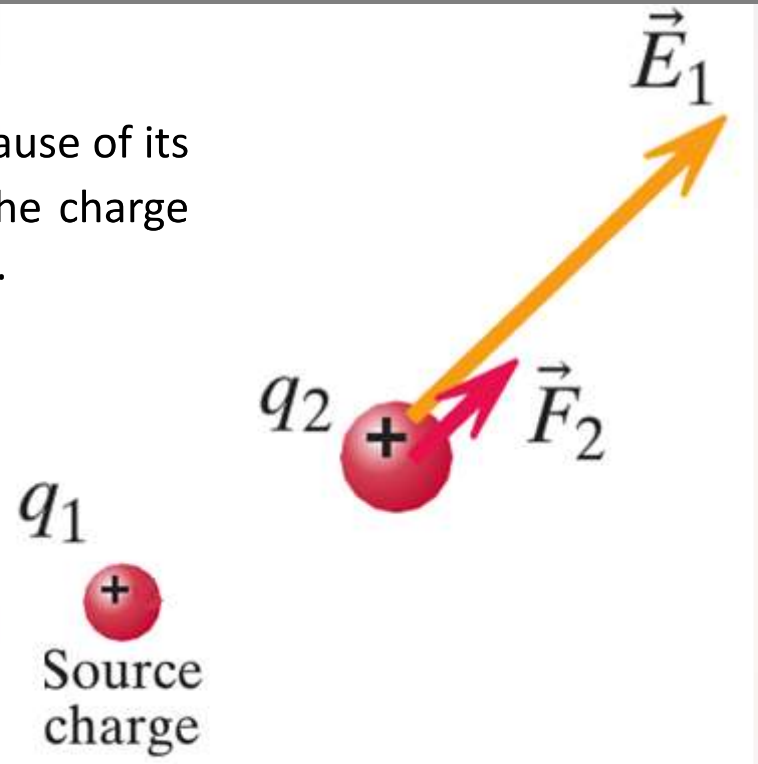
$$|\vec{F}| = F = \frac{1}{4\pi\varepsilon_0}\frac{|Q_1 Q_2|}{r^2}$$

- Units and Constants



- Two protons repel each other;
- Two electrons repel each other;
- A proton and an electron attract each other;

A particle with charge q_2 experiences a force $\vec{F}_2$ because of its interaction with the electric field $\vec{E}_1$ produced by the charge particle (or all other charged particles) in the vicinity.



DEFINITION OF ELECTRIC FIELD

$$\vec{F}_2 = q_2 \vec{E}_1$$

EXAMPLE **Electric Force and Electric Field**

The charge of an alpha particle (a helium nucleus, consisting of two protons and two neutrons) is $2e = 2(1.6 \times 10^{-19}\text{ C})$. An alpha particle at a particular location experiences a force of $\langle 0, -9.6 \times 10^{-17}, 0 \rangle$ N. What is the electric field at that location? If the alpha particle were removed and an electron were placed at that location, what force would the electron experience?

Solution To find the field we divide the force on the alpha particle by the charge of the alpha particle:

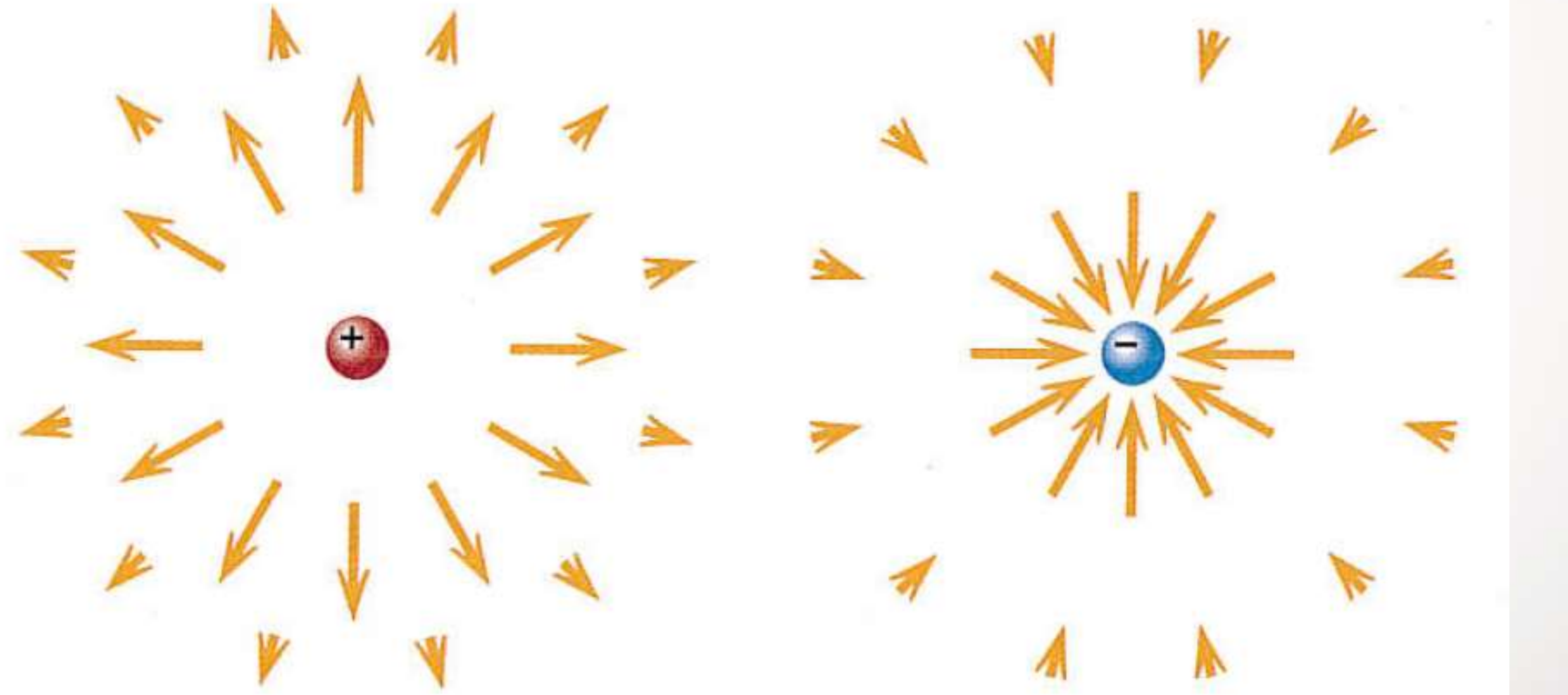
$$\vec{E} = \frac{\vec{F}}{q}$$

$$\vec{E} = \frac{\langle 0, -9.6 \times 10^{-17}, 0 \rangle \text{ N}}{2(1.6 \times 10^{-19}\text{ C})} = \langle 0, -300, 0 \rangle \text{ N/C}$$

Patterns of Electric Field Near Point Charges

Electric field is a **vector field**.

A way of visualizing electric field patterns

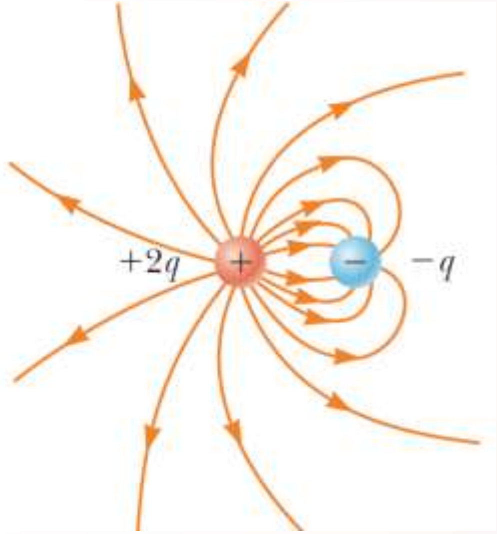


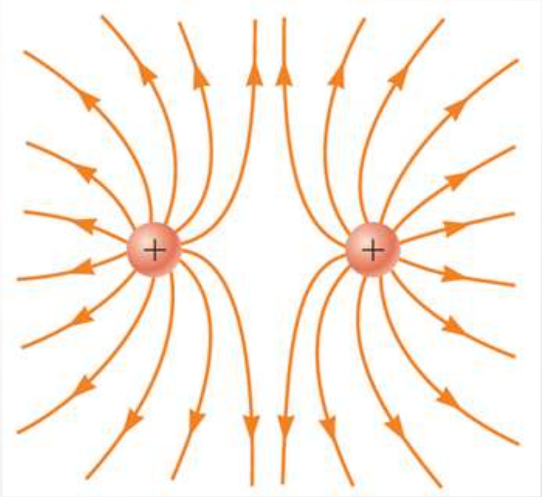
For a positive point charge, the electric field point radially outward.

For a negative point charge, the electric field point radially inward.

A convenient way of visualizing electric field patterns is to draw lines, called **electric field lines.**

- The electric field vector $\vec{E}$ is tangent to the electric field line at each point.
- The line has a direction, indicated by an arrowhead, that is the same as that of the electric field vector.
- The lines must begin on a positive charge and terminate on a negative charge.
- The number of lines drawn leaving a positive charge or approaching a negative charge is proportional to the magnitude of the charge.
- No two field lines can cross.
- In the case of an excess of one type of charge, some lines will begin or end infinitely far away.

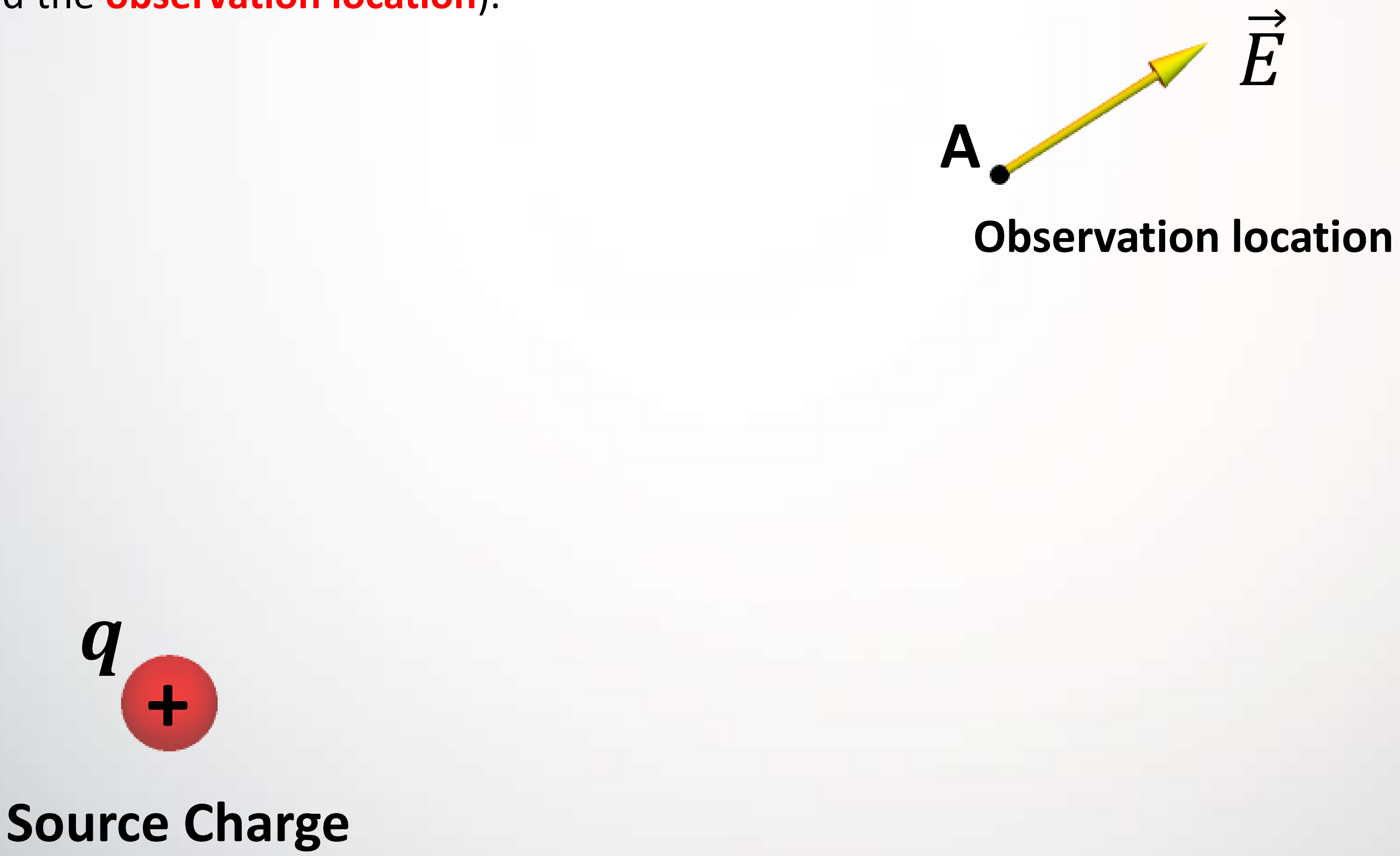




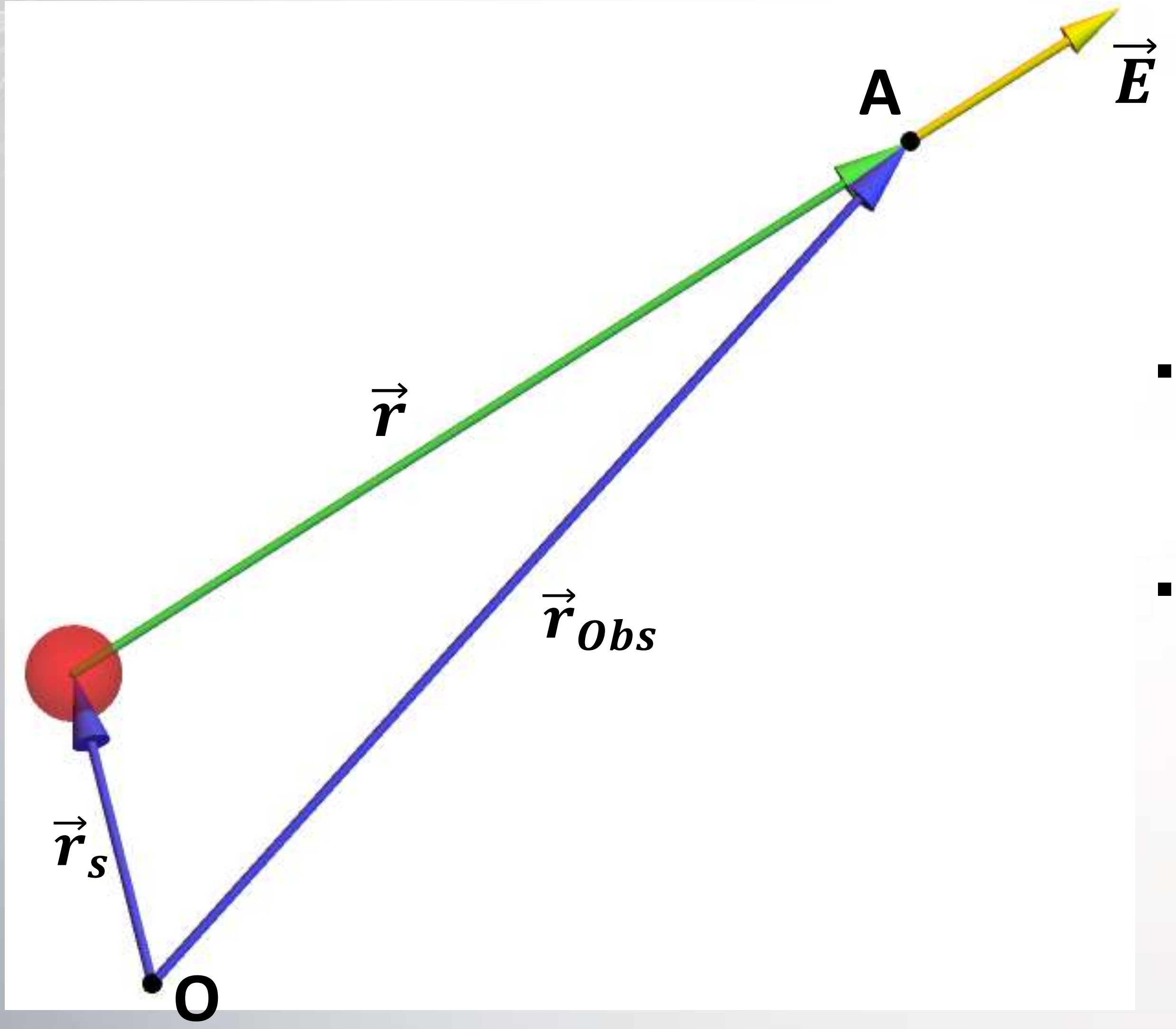
Reference in the textbook: Chapter 13.4

- In 1784, the French Physicist Charles-Augustin de Coulomb formulated a law to calculate the electric field of a point charge. The law is called **<u>Coulomb's law</u>**.

- In the example below, a positive point charge q (called **source**) creates an electric field $\vec{E}$ at point A (called the **observation location**).



- To calculate $\vec{E}$, it is important to know: the **position of the source** $\vec{r}_s$ and the **position of the observation location** $\vec{r}_l$.

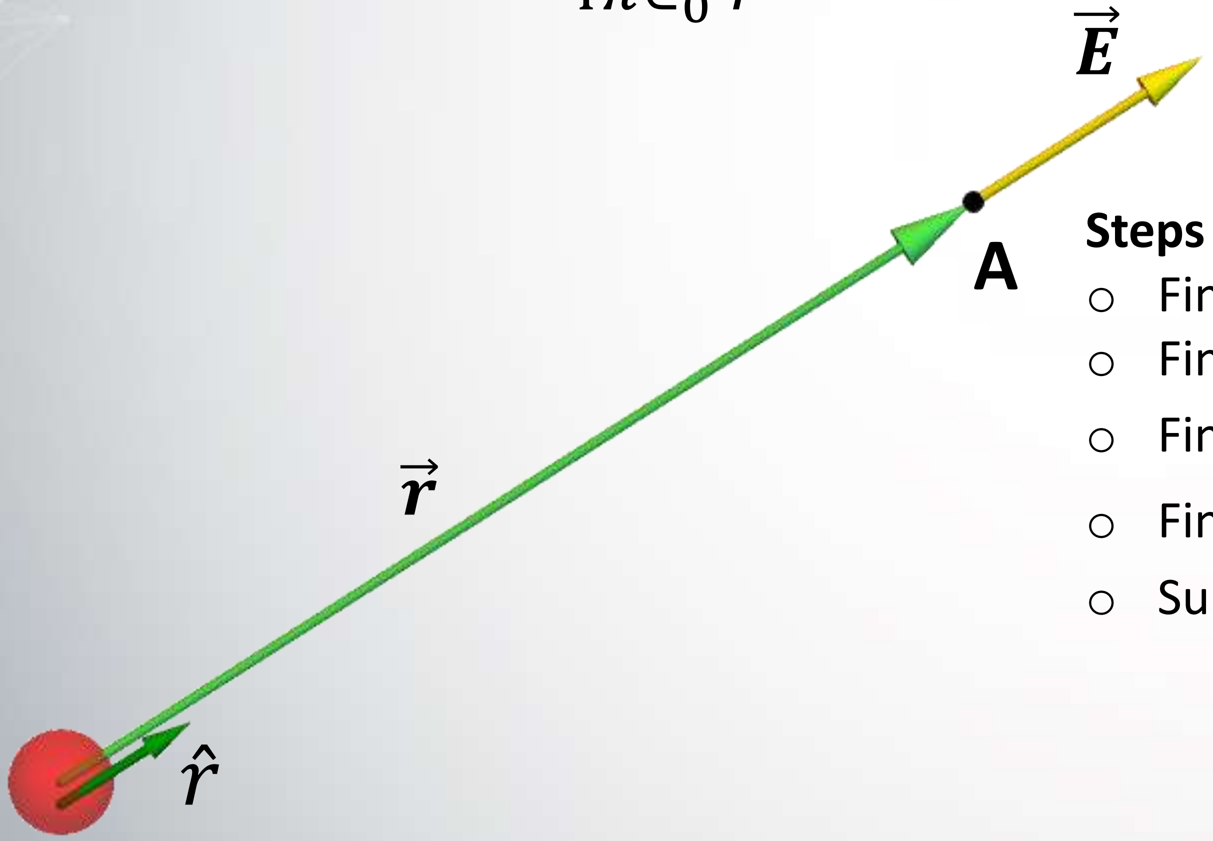


- $\vec{r}$ is the position of the observation point relative to the source.
- Always

$$\vec{r} = \vec{r}_O - \vec{r}_s$$

- Coulomb's law:

$$\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\hat{r}$$



Steps in applying Coulomb's law:

- Find $\vec{r}_s$ and $\vec{r}_O$ from the given.
- Find $\vec{r} = \vec{r}_O - \vec{r}_s$.
- Find $r = |\vec{r}| = \sqrt{x^2 + y^2 + z^2}$.
- Find $\hat{r} = \frac{\vec{r}}{r}$.
- Substitute in Coulomb's law.

Checkpoint 3 A particle with charge +1 nC (a nanocoulomb is 1×10^{-9} C) is located at the origin. What is the electric field due to this particle at a location $\langle 0.1,0,0\rangle$ m?

$\vec{r}_O = \langle 0.1, 0, 0\rangle\, m$ (location where I want to find the electric field)
$\vec{r}_S = \langle 0, 0, 0\rangle\, m$ (location of the charge: source of the electric field)

- $\vec{r} = \vec{r}_O - \vec{r}_S = \langle 0.1, 0, 0\rangle - \langle 0, 0, 0\rangle = \langle 0.1, 0, 0\rangle\, m$
- $r = |\vec{r}| = \sqrt{0.1^2 + 0^2 + 0^2} = 0.1\, m$
- $\hat{r} = \frac{\vec{r}}{r} = \frac{\langle 0.1,0,0\rangle}{0.1} = \langle 1, 0, 0\rangle$
- $\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\hat{r} = (9 * 10^9) * \frac{(1*10^{-9})}{0.1^2} * \langle 1, 0, 0\rangle = \langle 9 * 10^{-2}, 0, 0\rangle$ *(N/C)*

Reference in the textbook: Page 520

EXAMPLE **Field of a Particle**

A particle with charge $+2\text{nC}$ (a nanocoulomb is 1×10^{-9} C) is located at the origin. What is the electric field due to this particle at a location $\langle -0.2, -0.2, -0.2 \rangle$ m?

Solution

$$\vec{r} = \langle \text{observation location} \rangle - \langle \text{source location} \rangle$$

$$= \langle -0.2, -0.2, -0.2 \rangle \text{ m} - \langle 0,0,0 \rangle \text{m}$$

$$\vec{r} = \langle -0.2, -0.2, -0.2 \rangle \text{m}$$

$$|\vec{r}| = \sqrt{(-0.2)^2 + (-0.2)^2 + (-0.2)^2}\text{m} = 0.35 \text{ m}$$

$$\hat{r} = \frac{\vec{r}}{|\vec{r}|} = \frac{\langle -0.2, -0.2, -0.2 \rangle \text{ m}}{0.35 \text{ m}} = \langle -0.57, -0.57, -0.57 \rangle$$

$$\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2} = \left(9 \times 10^9 \frac{\text{N m}^2}{\text{C}^2}\right)\left(\frac{2 \times 10^{-9}\text{C}}{0.35^2 \text{ m}^2}\right) = 147 \frac{\text{N}}{\text{C}}$$

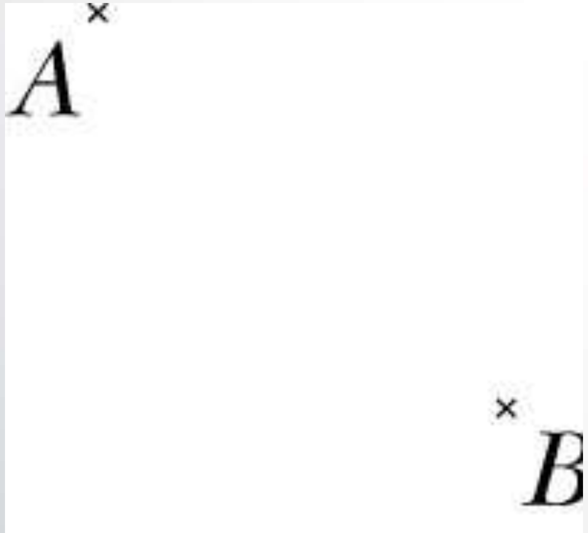
$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$$

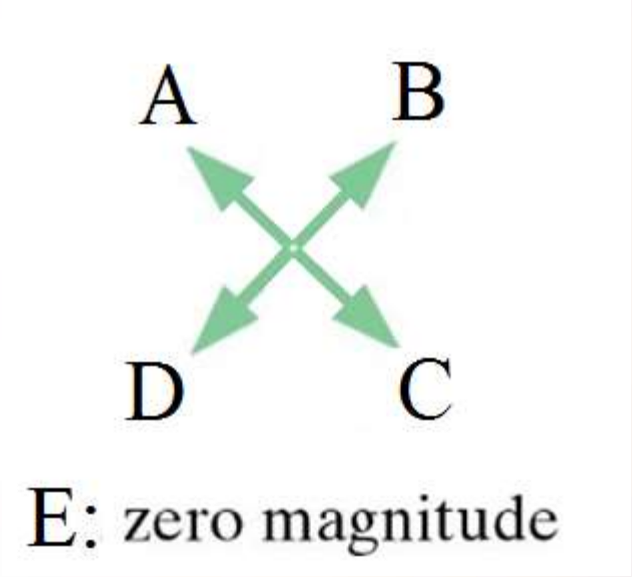
$$= \left(147 \frac{\text{N}}{\text{C}}\right)\langle -0.57, -0.57, -0.57 \rangle$$

$$= \langle -84, -84, -84 \rangle \frac{\text{N}}{\text{C}}$$

Concept Question – 1

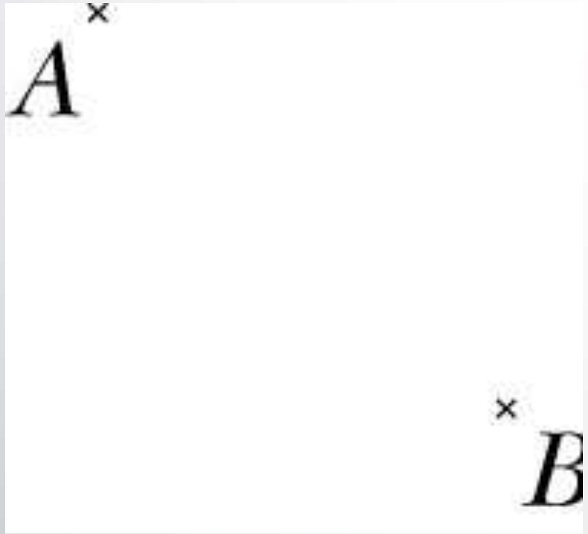
An electron is placed at location *A*. What is the direction of the electric field at location B, due to the electron?

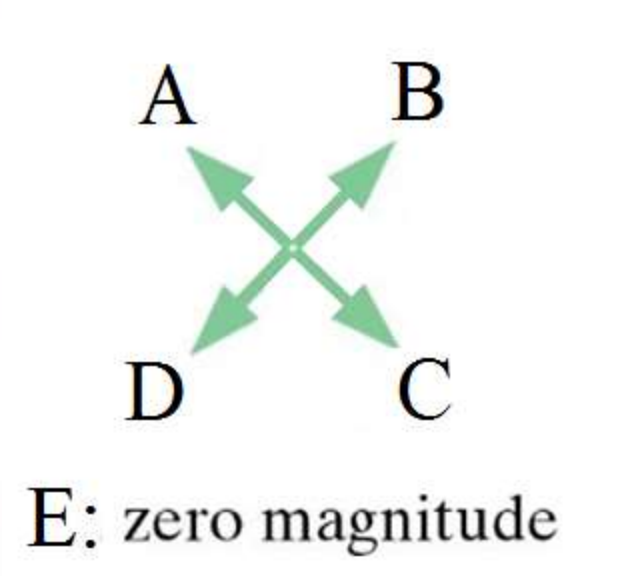




Concept Question - 2

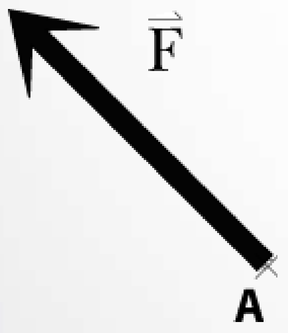
An electron is placed at location A and a proton is placed at location B. What is the direction of the electric force on the proton due to the electron?



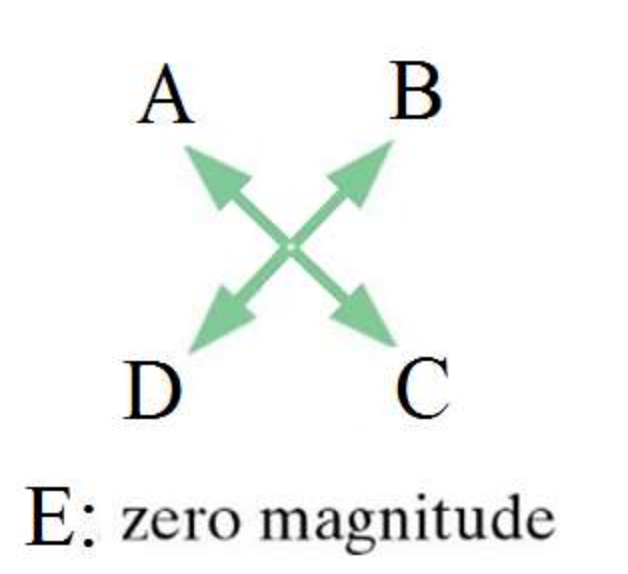


Concept Question - 3

A proton placed at location *A* experiences an electric force in the direction shown below.

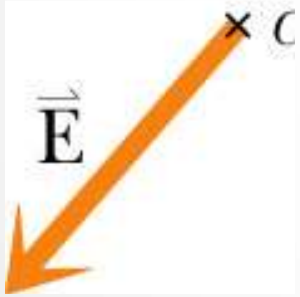


What is the direction of the electric field at location *A*?



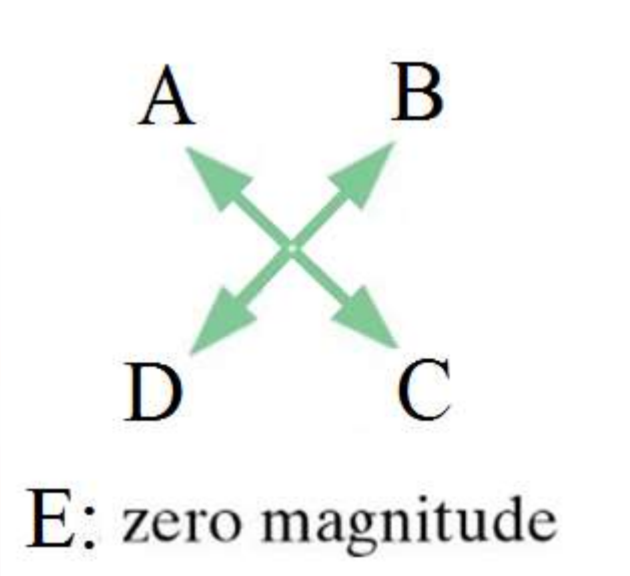
Concept Question - 4

At location *C* there is an electric field in the direction indicated, due to charges not shown.



A chloride ion (Cl^-) is placed at location C.

What is the direction of the electric force on the chloride ion?



Tutoring Notes – PHYS 272: Week 2 – Lecture 1

Concept questions (Slides 15 to 18)

- **Concept question 1:**

An electron is placed at location *A*. The electron is charged negatively, so the electric field that will be created is inward. At location B, the Electric field will be created on B and going towards the electron; therefore it will be from B to A ➔ Answer A

- **Concept question 2:**

An electron (negative charge) is placed at location A and a proton (positive charge) is placed at location B. Two charges of opposite signs will attract each other, the electric force on the proton due to the electron should be applied on the proton (point B) and directed towards the electron (point A) ➔ Answer A

- **Concept question 3:**

A proton placed at location *A*. The relation between $\vec{F}$ and $\vec{E}$ is $\vec{F} = q * \vec{E}$, the charge for the proton is positive ($q > 0$), therefore $\vec{F}$ and $\vec{E}$ must have the same direction. ➔ Answer A

- **Concept question 4:**

A chloride ion (Cl^-) is placed at location C. The relation between $\vec{F}$ and $\vec{E}$ is $\vec{F} = q * \vec{E}$, the chloride ion is charged negatively ($q < 0$), therefore $\vec{F}$ should be in the opposite direction of $\vec{E}$. ➔ Answer B