PHYS 1444 – Section 002
Lecture #4

Wednesday, Sept. 4, 2019

Dr. Jaehoon Yu

- Ch 21
  - The Electric Field & Field Lines
  - Electric Fields and Conductors
  - Motion of a Charged Particle in an E Field

Today's homework is homework #3, due 11pm, Tuesday, Sept. 10!!

Announcements

- Homework:
  - All of you have registered to the homework system! Good job!
  - 5 of you, however, did not submit HW#1.
  - DO NOT WAIT until you are done! Please input your answers as you solve problems!
- 1st Term Exam
  - In class, Wednesday, Sept. 18: DO NOT MISS THE EXAM!
  - CH1.1 to what we learn on Monday, Sept. 16 + Appendices A1 – A8
  - You can bring your calculator but it must not have any relevant formula pre-input
  - BYOF: You may bring a one 8.5x11.5 sheet (front and back) of handwritten formulae and values of constants for the exam
  - No derivations, word definitions, or solutions of any problems !
  - No additional formulae or values of constants will be provided!
- Physics department colloquium today at 4pm, SH100
  - Dr. Zdzislaw Musielak
- Submit the special project now!

PHYSICS DEPARTMENT

UNIVERSITY OF TEXAS AT ARLINGTON

Colloquium:

Origin of Fundamental Equations of Modern Physics

I present novel methods that allow deriving the fundamental equations known in modern physics. The methods are based on the Principle of Relativity and the Principle of Analyticity. Using these methods, I find new fundamental equations of physics and discuss possible roles of these equations in current and future physical theories. Specifically, I apply the new equations to account for Dark Matter and Dark Energy, which constitute 95% of all matter and energy of the Universe, and also discuss relevance of these equations to the multiple universe hypothesis

Dr. Zdzislaw Musielak

UTA Physics Department

WEDNESDAY, SEPTEMBER 4
4PM ROOM 100 SCIENCE HALL
REFRESHMENTS AT 3:30 IN 108 SCIENCE HALL

UNIVERSITY OF TEXAS ARLINGTON

Special Project #2 – Angels & Demons

- Compute the total possible energy released from an annihilation of xx-grams of anti-matter and the same quantity of matter, where xx is the last two digits of your SS#. (20 points)
  - Use the famous Einstein's formula for mass-energy equivalence
- Compute the power output of this annihilation when the energy is released in yy ns, where yy is the first two digits of your SS#. (10 points)
- Compute how many cups of gasoline (8MJ) this energy corresponds to. (5 points)
- Compute how many months of world electricity usage (3.6GJ/mo) this energy corresponds to. (5 points)
- Due at the beginning of the class Monday, Sept. 23

The Coulomb Force Refresher

$$F \propto \frac{Q_1 \times Q_2}{r^2} \quad \xrightarrow{\text{Formula}} \quad F = k\frac{Q_1 Q_2}{r^2}$$

- Is Coulomb force a scalar quantity or a vector quantity? Unit?
  - A vector quantity. The unit is Newtons (N)!
- The direction of electric (Coulomb) force is always along the line joining the two objects.
  - If the two charges are the same: forces are directed away from each other.
  - If the two charges are opposite: forces are directed toward each other.
- Coulomb force is precise to 1 part in 10^{16}.
- Unit of charge is called Coulomb, C, in SI.
- The value of the proportionality constant, k, in SI unit is $k = 8.988 \times 10^{9}\ \mathrm{N \cdot m^2}/C^2$
- Thus, 1C is the charge that gives **F~9x10^{9}N** of force when placed 1m apart from each other.

$$k = 1/4\pi\varepsilon_0$$

$$\varepsilon_0 = 1/4\pi k = 8.85 \times 10^{-12}\ C^2/N \cdot m^2$$

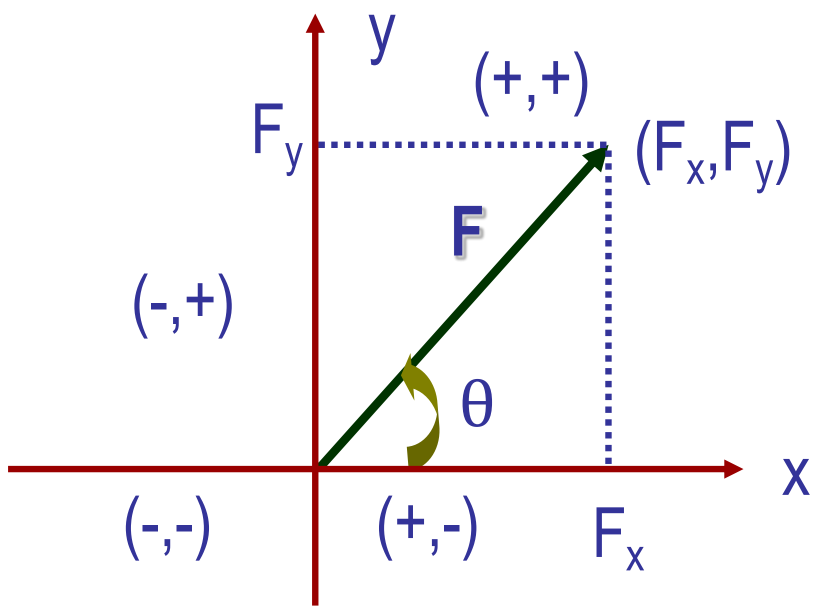
$$F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r^2}$$

The Elementary Charge

$$e = 1.602 \times 10^{-19}\ C$$

Reminder: Components and Unit Vectors

Coordinate systems are useful in expressing vectors in their components



$$\left.\begin{array}{l} F_x = \left|\vec{F}\right| \cos\theta \\ F_y = \left|\vec{F}\right| \sin\theta \end{array}\right\} \text{Components}$$

$$\left|\vec{F}\right| = \sqrt{F_x^2 + F_y^2} \quad \} \text{ Magnitude}$$

$$\left|\vec{F}\right| = \sqrt{\left(\left|\vec{F}\right|\cos\theta\right)^2 + \left(\left|\vec{F}\right|\sin\theta\right)^2}$$

$$= \sqrt{\left|\vec{F}\right|^2\left(\cos^2\theta + \sin^2\theta\right)} \quad = \left|\vec{F}\right|$$

Reminder: Unit Vectors

- Unit vectors are the ones that tells us the directions of the components
- **Dimensionless**
- **Magnitudes are exactly 1**
- Unit vectors are usually expressed in **i, j, k** or

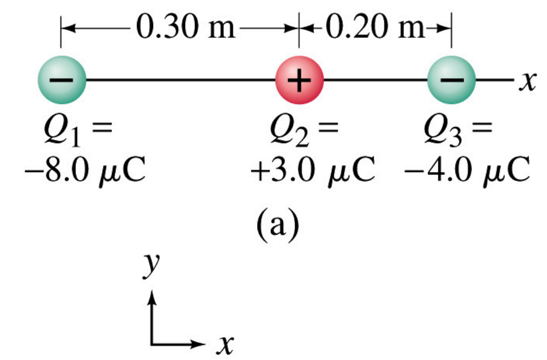
$$\vec{i},\ \vec{j},\ \vec{k}$$

So the vector **F** can be re-written as

$$\boxed{\vec{F} = F_x \vec{i} + F_y \vec{j} = \left|\vec{F}\right| \cos\theta \vec{i} + \left|\vec{F}\right| \sin\theta \vec{j}}$$

Example 21.2

- **Three charges on a line.** Three charged particles are arranged in a line as shown in the figure. Calculate the net electrostatic force on particle 3 (the -4μC on the right) due to the other two charges.



What is the force that Q_1 exerts on Q_3?

$$F_{13x} = k\frac{Q_1 Q_3}{L^2} = \frac{\left(9.0\times10^9\ N\cdot m^2/C^2\right)\left(-4.0\times10^{-6}C\right)\left(-8.0\times10^{-6}C\right)}{\left(0.5m\right)^2} = 1.2N$$

What is the force that Q_2 exerts on Q_3?

$$F_{23x} = k\frac{Q_2 Q_3}{L^2} = \frac{\left(9.0\times10^9\ N\cdot m^2/C^2\right)\left(-4.0\times10^{-6}C\right)\left(3.0\times10^{-6}C\right)}{\left(0.2m\right)^2} = -2.7N$$

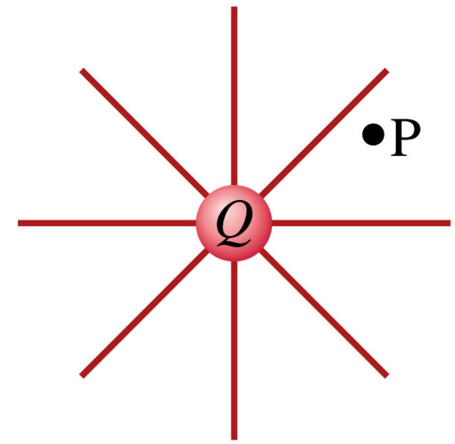
Using the vector sum of the two forces

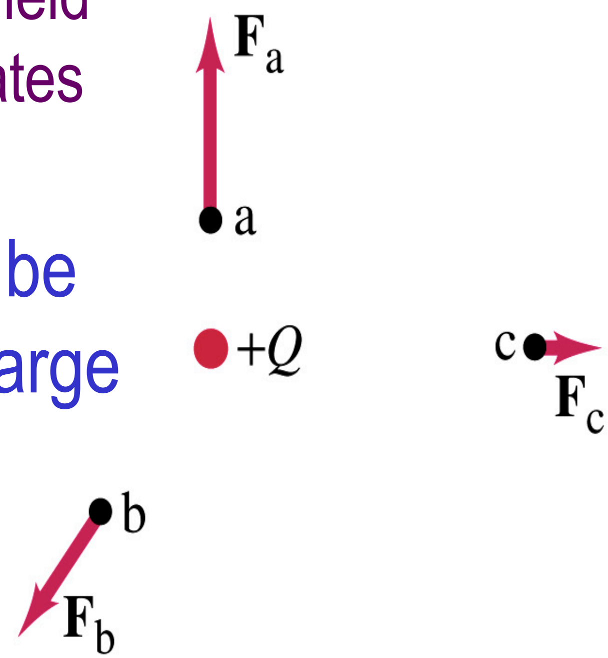
$$F_x = F_{13x} + F_{23x} = 1.2 + \left(-2.7\right) = -1.5\left(N\right) \quad F_y = 0\left(N\right)$$

$$\vec{F} = -1.5\vec{i}\ (N)$$

The Electric Field

- Both gravitational and electrostatic forces act over a distance without contacting objects ➔ What kind of forces are these?
  - Field forces
- Michael Faraday developed an idea of field.
  - Faraday (1791 – 1867) argued that the electric field extends outward from every charge and permeates through all of space.
- Field by a charge or a group of charges can be inspected by placing a small positive test charge in the vicinity and measuring the force on it.





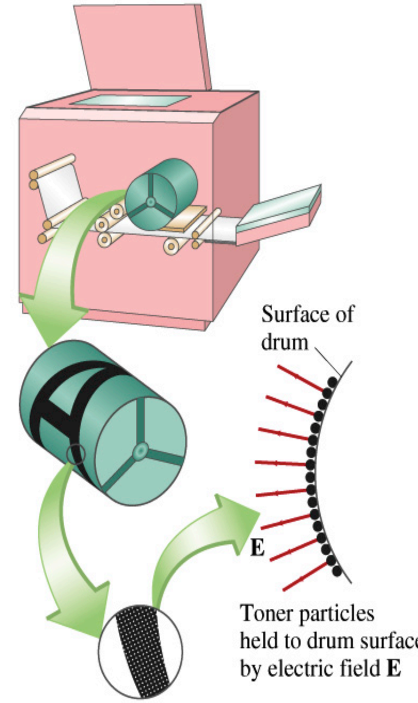
The Electric Field

- The electric field at any point in space is defined as the force exerted on a tiny positive test charge (e.g., q) divide by the magnitude of the test charge $\vec{E} = \frac{\vec{F}}{q}$
  - Electric force per unit charge
- What kind of quantity is the electric field?
  - Vector quantity. Why?
- What is the unit of the electric field?
  - N/C
- What is the magnitude of the electric field by a single point charge Q at a distance r from it?

$$E = \frac{F}{q} = \frac{kQq/r^2}{q} = \frac{kQ}{r^2} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$$

Example 21 – 5

- **Electrostatic copier**. An electrostatic copier works by selectively arranging positive charges (in a pattern to be copied) on the surface of a non-conducting drum, then gently sprinkling negatively charged dry toner (ink) onto the drum. The toner particles temporarily stick to the pattern on the drum and are later transferred to paper and "melted" to produce the copy. Suppose each toner particle has a mass of 9.0×10^{-16}kg and carries the average of 20 extra electrons to provide an electric charge. Assuming that the electric force on a toner particle must exceed twice its weight in order to ensure sufficient attraction, compute the required electric field strength near the surface of the drum.



The electric force must be the same as twice the gravitational force on the toner particle.

So we can write $F_e = qE = 2F_g = 2mg$

Thus, the magnitude of the electric field is

$$E = \frac{2mg}{q} = \frac{2\cdot\left(9.0\times10^{-16}\,kg\right)\cdot\left(9.8\,m/s^2\right)}{20\left(1.6\times10^{-19}\,C\right)} = 5.5\times10^{3}\,N/C.$$