PHYSICS 272
Electric & Magnetic Interactions

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Today

- General Course Information
- Charges, forces, and electric field.

Announcements

Prof Carlson's Office Hours:

Mondays and Wednesdays, 10:30am-11:30am

Find everything you need in Blackboard:

Lectures
Lecture Audio (Boilercast)
Syllabus
Homework (WebAssign)
Labs
Course Calendar
iClicker registration

Access Blackboard using your Purdue career account

https://mycourses.purdue.edu

Syllabus & General Information:

This is a 4 credit hour course.

Expect to spend $2 \times 4 = 8$ hours outside of class time:

- Reading the textbook
- Homework (HW)
- Recitation
- Lab assignments

Syllabus & General Information:

Evening Exams (2)	30%
Final Exam	20%
Labs	15%
Homework (WebAssign)	15%
Clicker questions	5
Recitation	15%
TOTAL	100%

We will use an absolute grading scale with values as given on the syllabus. Earn 89%, and you are guaranteed to get at least an A- .

Syllabus & General Information:

Reminders:

For help with homework problems, go to the Physics Learning Center in Room 12 (PHYS Bldg) during the assigned hours. Schedule can be found on the home page. It is staffed by trained teaching assistants assigned to this course. Use it!

1. Extensions can be granted for Homework assignments, if you have a good reason and don't abuse the privilege. Download form under "HW Extension request" from Blackboard.

2. To request an Excused Grade for a quiz, lab, recitation, or an exam due to a valid reason (illness, etc), download "Absentee Report" from the course web site. Do this in advance if at all possible. Advance notification is required for Evening Exams and the Final.

Syllabus & General Information:

Academic Honesty

You are encouraged to work on homework together – discussing ideas and concepts reinforces the material for everyone involved in the conversation. Just be sure that what you turn in is your own work that you fully understand.

The following are examples of cheating:

- Any effort to represent somebody else's work as your own, or allowing your work to be represented as somebody else's
- Having somebody else solve assigned problems for you
- Entering iClicker responses for anybody else
- Being in possession of more than one iClicker in lecture

Read the syllabus.

Got an iClicker?

Turn the Power on.

After the question is declared "Open", choose one:

CLICKER POLL (not graded):

A. I got 8 or more hours of sleep last night

B. I got 7 hours of sleep last night

C. I got 5 or 6 hours of sleep last night

D. I got less than 5 hours of sleep last night

E. Sleep? What's sleep?

"Clicker Poll"
= Not Graded ☺

NOTE: From now on, always bring your iClicker to lecture with you. The ***clicker questions*** count towards 5% of your grade.

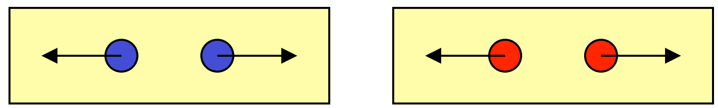
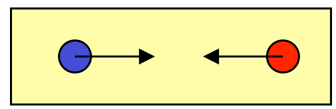
<u>iClicker questions may be asked any time during lecture: don't be late!</u>

Key Ideas in Chapter 14: Electric Field

- **A charged particle makes an electric field at every location in space (except its own location).**
- **The electric field due to one particle affects other charged particles.**
- **The electric force on a charged particle is proportional to the net electric field at the location of that particle.**
- **The Superposition Principle:**
  - The net electric field at any location is the vector sum of the individual electric fields of all charge particles at other locations.
  - The field due to one charged particle is not changed by the presence of other charged particles.
- **An electric dipole consists of two particles with charges equal in magnitude and opposite in sign, separated by a short distance.**
- **Changes in electric fields travel at the speed of light ("retardation").**

Point Charges

Key Idea: Charges exert forces on each other

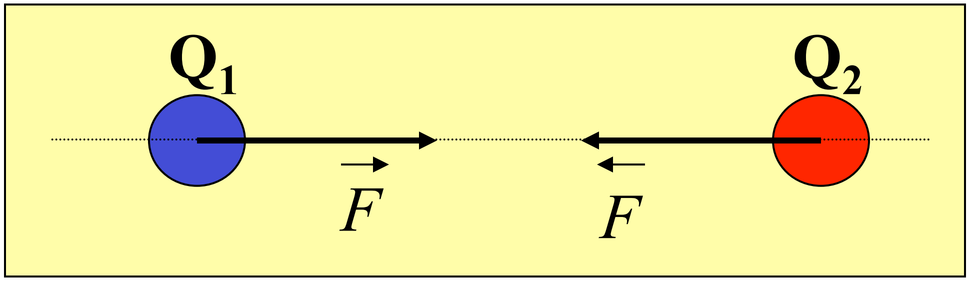
- Two types: *positive* and *negative*
- Like charges: repel 
- Opposite charges: attract 
- Charge is **quantized** in units of e

- Point charge: Size is small compared to the distance between it and other objects of interest

- Electric charge is an **intrinsic property** of the fundamental particles that everything is made of

The Coulomb Force Law

Key Idea: Charges exert forces on each other



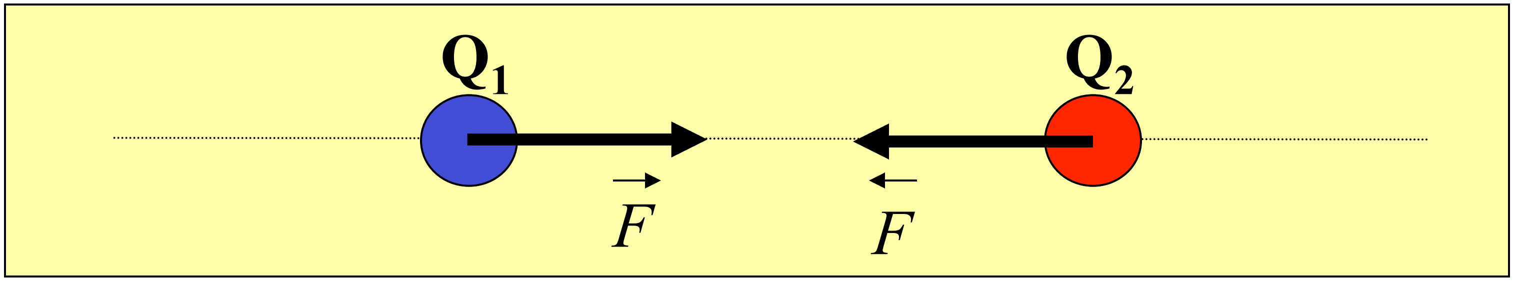
$$\left|\vec{F}\right| = F = \frac{1}{4\pi\varepsilon_0}\frac{\left|Q_1 Q_2\right|}{r^2}$$

Magnitude of Force is:

Proportional to the magnitude of each charge
Inversely proportional to the distance squared

The Coulomb Force Law

Key Idea: Charges exert forces on each other



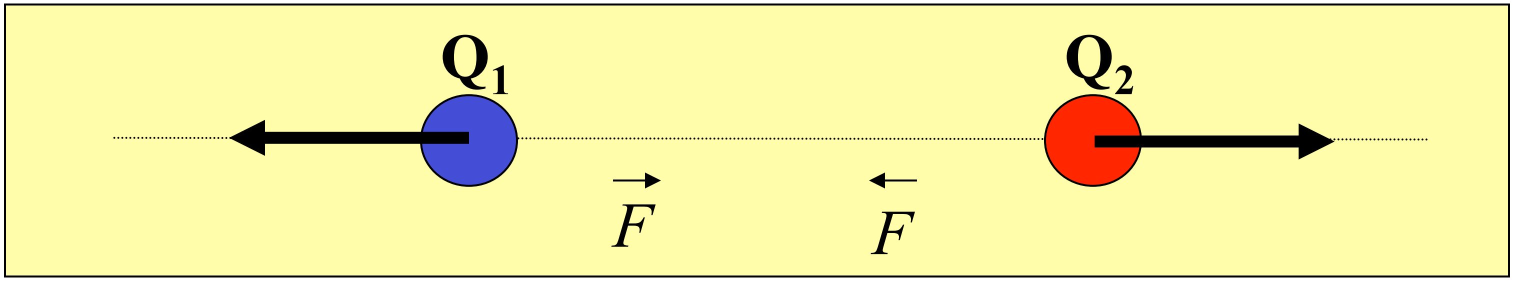
$$\vec{F} = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r^2}\hat{r}$$

Direction of Force is:

ATTRACTIVE if charges have OPPOSITE sign

The Coulomb Force Law

Key Idea: Charges exert forces on each other



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

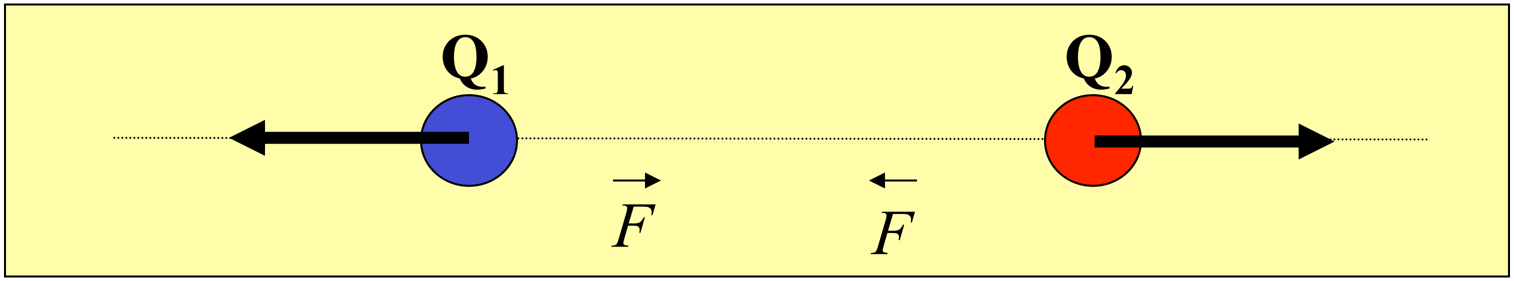
Direction of Force is:

ATTRACTIVE if charges have OPPOSITE sign

REPULSIVE if charges have SAME sign

The Coulomb Force Law

Key Idea: Charges exert forces on each other



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

Direction of Force is:

ATTRACTIVE if charges have OPPOSITE sign

REPULSIVE if charges have SAME sign

Always acts along a line connecting the charges

Units and Constants

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

SI units of electric charge: Coulomb, C

Constants:

$\varepsilon_0 = 8.85\text{x}10^{-12}\ \text{C}^2/\text{N}\cdot\text{m}^2$ permittivity constant

$1/4\pi\varepsilon_0 = 9\text{x}10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2$

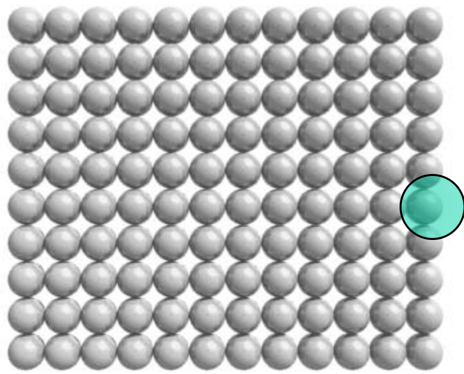
$e = 1.602\text{x}10^{-19}\ \text{C}$

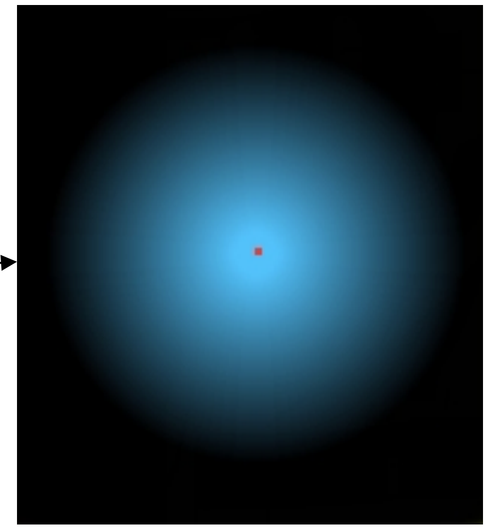
Electrons:	**Q = -e**
Protons:	**Q = +e**

Structure of Atom

Matter consists of atoms

1 cm^3 : ~10^{24} atoms

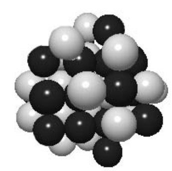




1Å=10^{-10}m

Nucleus of the iron atom

Size: ~10^{-15} m



Atoms are 99.999999999999% EMPTY SPACE

The Concept of Electric Field

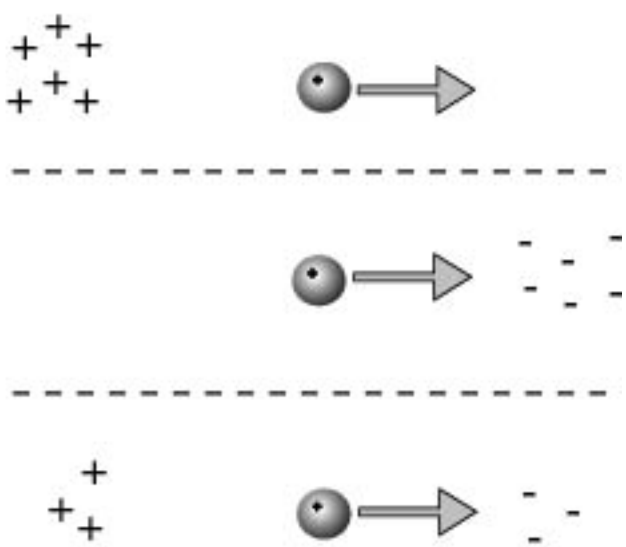
Key Idea: A charged particle makes an electric field at every location in space

Accelerates at 9.8 m/s^2 – why?

The Concept of Electric Field

Key Idea: A charged particle makes an electric field at every location in space

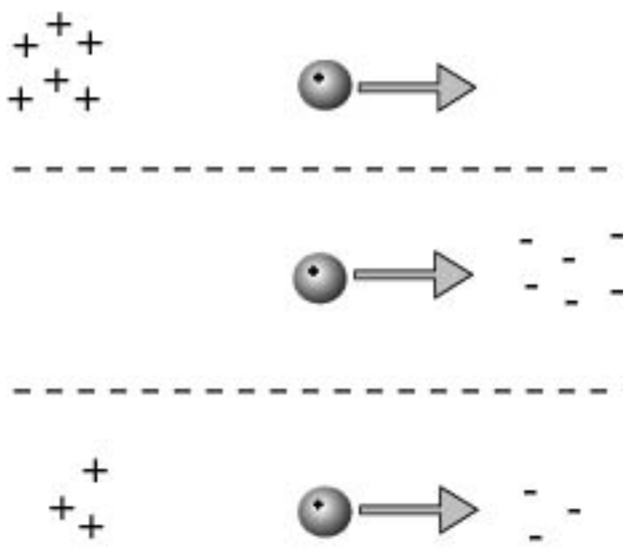
Accelerates at 10^{11} m/s^2 – why?



Many charge configurations could cause the motion

Electric Field

Key Idea: A charged particle makes an electric field at every location in space

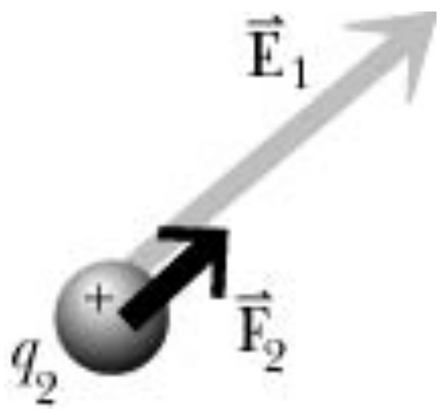


Something is already there, waiting to push any charge.

An Electric Field created by other charges is present throughout space at all times, whether or not there is another charge around to feel its effect.

Definition of Electric Field

Key Idea: A charged particle makes an electric field at every location in space



$$F = \frac{1}{4\pi\varepsilon_0}\frac{|q_1 q_2|}{r^2}$$

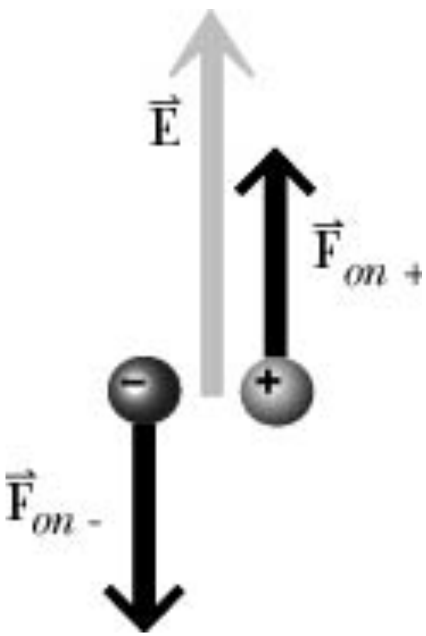
$$F = q_2\left(\frac{1}{4\pi\varepsilon_0}\frac{|q_1|}{r^2}\right)$$

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

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

Electric Field

Key Idea: A charged particle makes an electric field at every location in space



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

F due to given E points in correct direction, whether q is (+) or (-)

$$\vec{E} \equiv \vec{E}(x, y, z, t)$$

FIELD:
Any physical quantity that varies in space

Electric field has units of Newtons per Coulomb: [N/C]

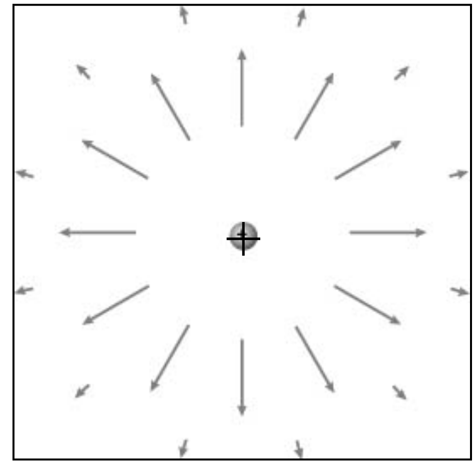
The Electric Field of a Point Charge

Key Idea: A charged particle makes an electric field at every location in space

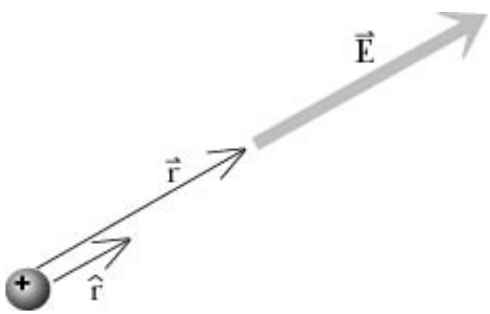
$$F = q_2\left(\frac{1}{4\pi\varepsilon_0}\frac{|q_1|}{r^2}\right)$$

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

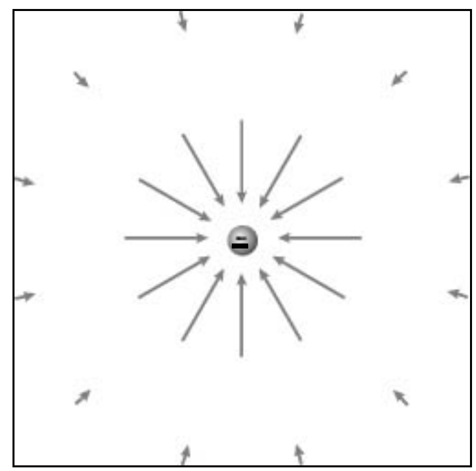
$$E_1 = \frac{1}{4\pi\varepsilon_0}\frac{|q_1|}{r^2}$$



Including direction:



$$\vec{E}_1 = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r^2}\hat{r}$$

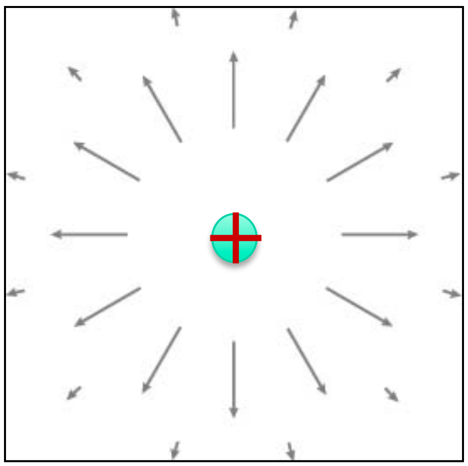


13_E_point_charge_drag.py

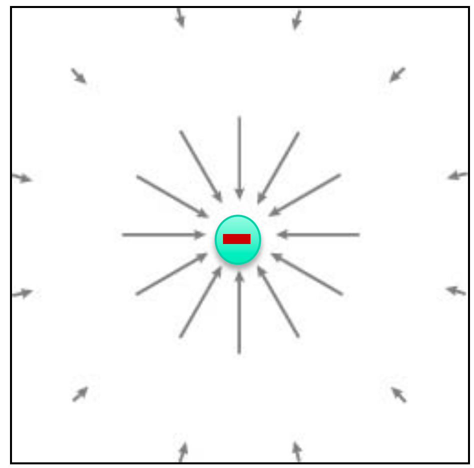
Which way does the field point?

Key Idea: A charged particle makes an electric field at every location in space

Here is a useful mnemonic:



Positive people care about others



Negative people care only about themselves

Example

Key Idea: A charged particle makes an electric field at every location in space

$$\vec{E}_1 = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r^2}\hat{r}$$

Problem: A particle with charge q_1=2 nC = 2 x 10^{-9} C is located at the origin. What is the electric field due to this particle at a location <-0.2,-0.2,-0.2> m?

Solution:

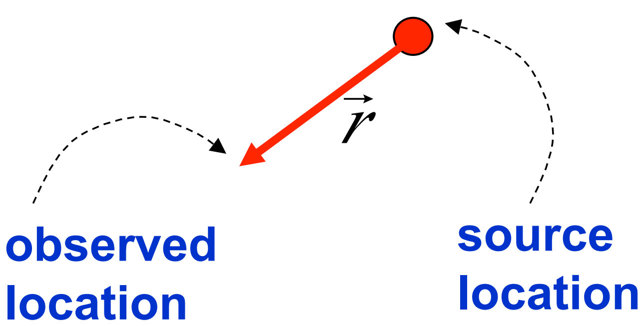
1. Distance and direction:

$$\vec{r} = \langle observed\_location \rangle - \langle source\_location \rangle$$

$$\vec{r} = \langle -0.2, -0.2, -0.2 \rangle - \langle 0,0,0 \rangle = \langle -0.2, -0.2, -0.2 \rangle$$

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

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



Example Problem

Key Idea: A charged particle makes an electric field at every location in space

$$\vec{E}_1 = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r^2}\hat{r} \qquad |\vec{r}| = 0.35\text{m} \qquad \hat{r} = \langle -0.57, -0.57, -0.57\rangle$$

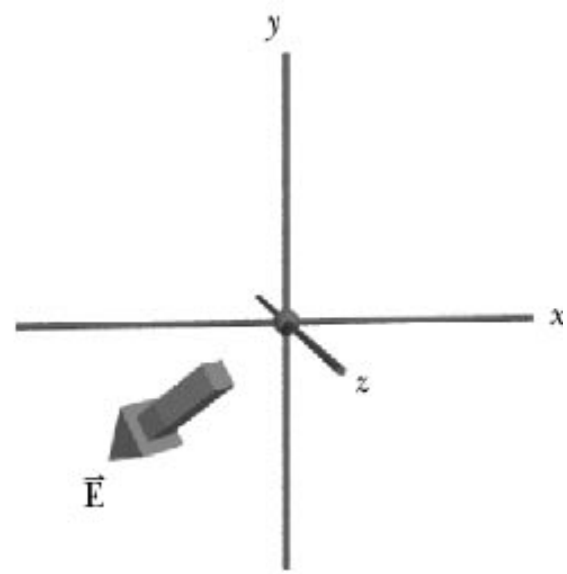
2. The magnitude of the electric field:

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2} = \left(9\times10^9\,\frac{\text{Nm}^2}{\text{C}^2}\right)\left(\frac{2\times10^{-9}\text{C}}{0.35^2\text{m}^2}\right) = 147\,\frac{\text{N}}{\text{C}}$$

3. The electric field in vector form:

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

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

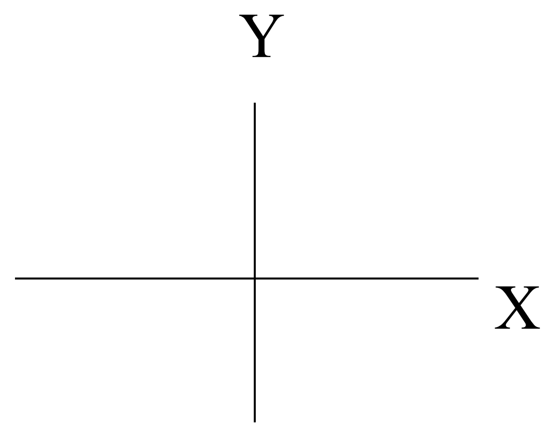


Forces due to an Electric Field

Key Idea: A charged particle makes an electric field at every location in space

$$\vec{E} = \vec{F} / q \qquad \textit{Electron:}\ q = -e$$

Problem: The electric field at a particular location is <-300,0,0> N/C. What force would an electron experience if it were placed in this location?



Solution:

$$\vec{F} = -e\vec{E} = -1.6 \times 10^{-19}\,\mathrm{C}\langle -300,0,0\rangle\,\mathrm{N/C}$$

$$\vec{F} = \langle 4.8 \times 10^{-17},0,0\rangle\,\mathrm{N}$$

Key Ideas in Chapter 14: Electric Field

- **A charged particle makes an electric field at every location in space (except its own location).**
- **The electric field due to one particle affects other charged particles.**
- **The electric force on a charged particle is proportional to the net electric field at the location of that particle.**
- **The Superposition Principle:**
  - The net electric field at any location is the vector sum of the individual electric fields of all charge particles at other locations.
  - The field due to one charged particle is not changed by the presence of other charged particles.
- **An electric dipole consists of two particles with charges equal in magnitude and opposite in sign, separated by a short distance.**
- **Changes in electric fields travel at the speed of light ("retardation").**