Course Updates

http://www.phys.hawaii.edu/~varner/PHYS272-Spr10/physics272.html

Professor Gary Varner
Updated 1/13/2010

News:

- True ***news*** -- **we will have a grader**
- No labs first week of class (begin week of Jan. 18 - 22)
- In order to complete the online homework, you must register for a Mastering Physics account
- Please refresh link below regularly to get updated assignments
- Online part of Assignment I (VARNERPHYS272) in Mastering Physics **due Monday, Jan. 18, 2009**
- **Turn in 21.57 and 21.74 for grading**
- **Hand-in homework first thing Wednesday, Jan. 20, 2009**

Electric Charge

Source of electric and magnetic phenomena.

Will study E&M much of the semester.

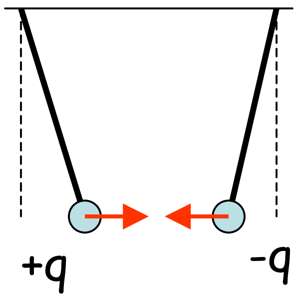
A.) Generating: rubbing transfers charge.

- glass with silk
- lucite with fur

Two types of charge (+ and -).

Ben Franklin (1706 – 1790): charge on glass rod is +.

Like charges repel.
Unlike charges attract.



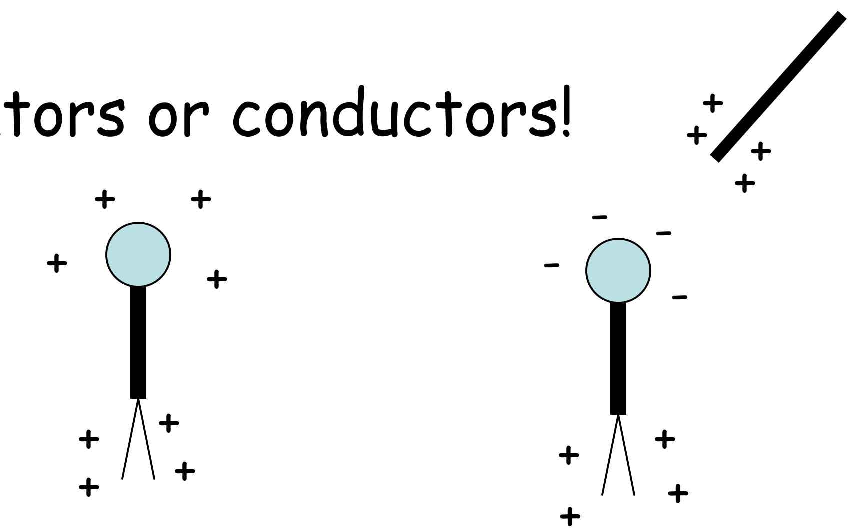
Demo: Pith ball

Conductors and Insulators

Insulators – charge (electrons) not free to move.
Examples: glass, porcelin.

Conductors – electrons free to move.
Example: Copper – 1 free electron per atom.

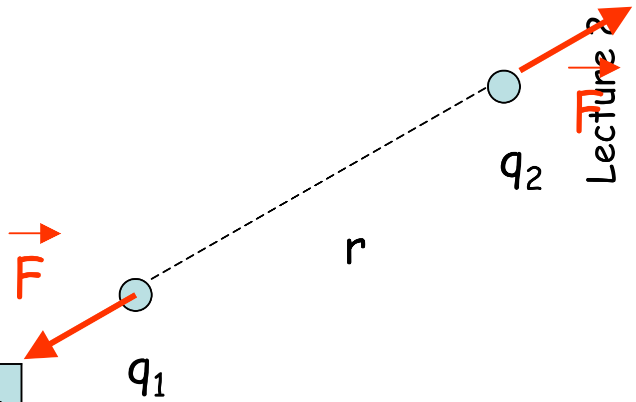
There are no perfect insulators or conductors!



Demo: Electroscope

Demo: Charging by induction.

Coulombs Law



Applies to point charges.

magnitude

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

$k = 8.99 \times 10^9 \ \mathrm{N\,m^2/C^2}$
$\approx 9 \times 10^9 \ \mathrm{N\,m^2/C^2}$

$\varepsilon_0 = 8.85 \times 10^{-12} \ \mathrm{C^2/Nm^2}$

direction: along line between two charges
attractive if unlike charges
repulsive if like charges

Looks like:

$$F_G = \frac{G m_1 m_2}{r^2}$$

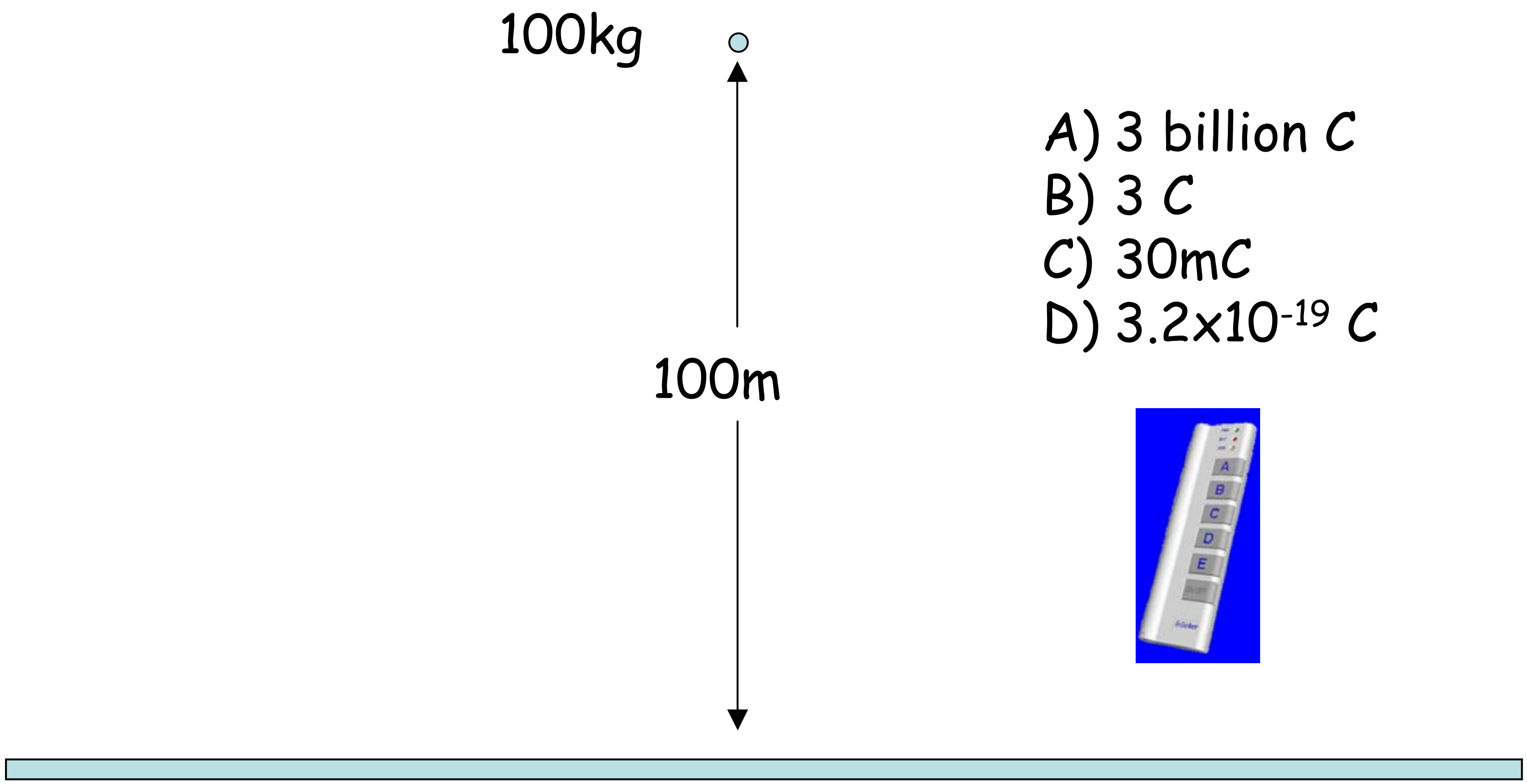
F is a vector!

Note forces are equal and opposite (Newton's Third Law)

Up in the Sky… it's Coulomb Man!

100kg -- how much to levitate 100 meters skyward ?

Up in the Sky… it's Coulomb Man!



A) 3 billion C
B) 3 C
C) 30mC
D) 3.2×10^{-19} C

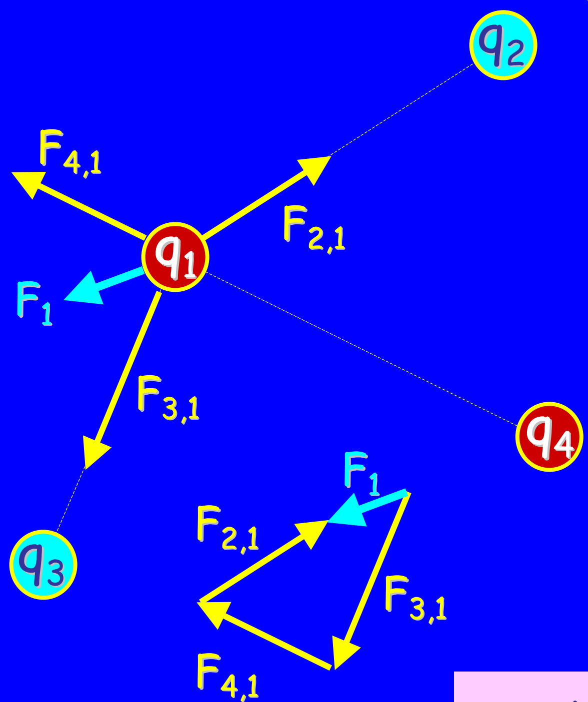
100kg -- how much to levitate 100 meters skyward ?

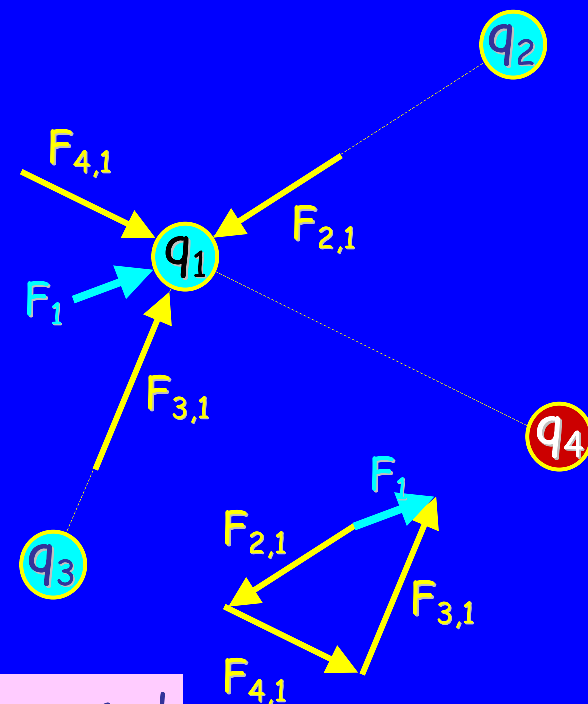
Up in the Sky… it's Coulomb Man! (but not for long!)

Why ?

Coulomb's Law (to sum up)

If there are more than two charges present, the total force on any given charge is just the vector sum of the forces due to each of the other charges:





$+q_1 \to -q_1$ ⇒ direction reversed

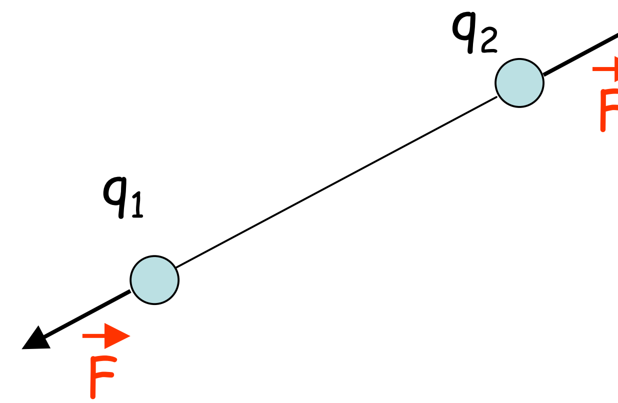
MATH:

$$\vec{F}_1 = \frac{kq_1q_2}{r_{12}^2}\hat{r}_{12} + \frac{kq_1q_3}{r_{13}^2}\hat{r}_{13} + \frac{kq_1q_4}{r_{14}^2}\hat{r}_{14} \quad \Rightarrow \quad \vec{E} = \frac{\vec{F}_1}{q_1} = \frac{kq_2}{r_{12}^2}\hat{r}_{12} + \frac{kq_3}{r_{13}^2}\hat{r}_{13} + \frac{kq_4}{r_{14}^2}\hat{r}_{14}$$

Electric Field

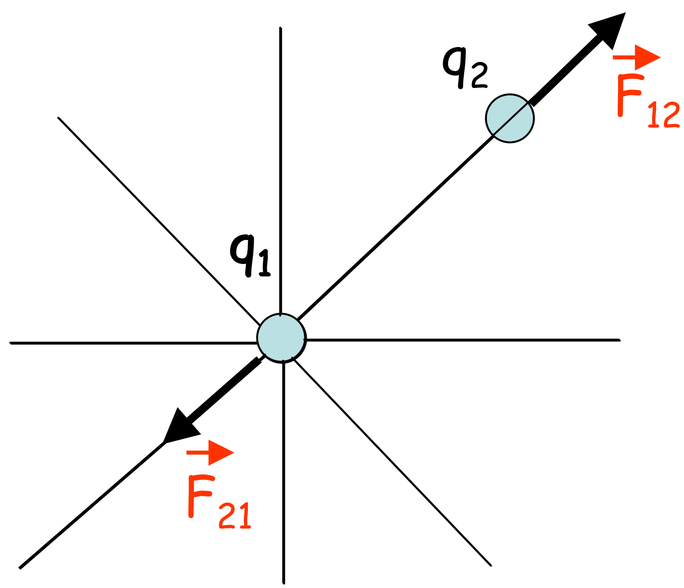
Coulomb's Law – Problem:

Action at a distance: speed of propagation not considered.



Another approach:

1. Charge in space creates electric field. $\vec{E}$
2. Field acts on 2nd charge.



Field propagates through space with speed of light.

Electric fields

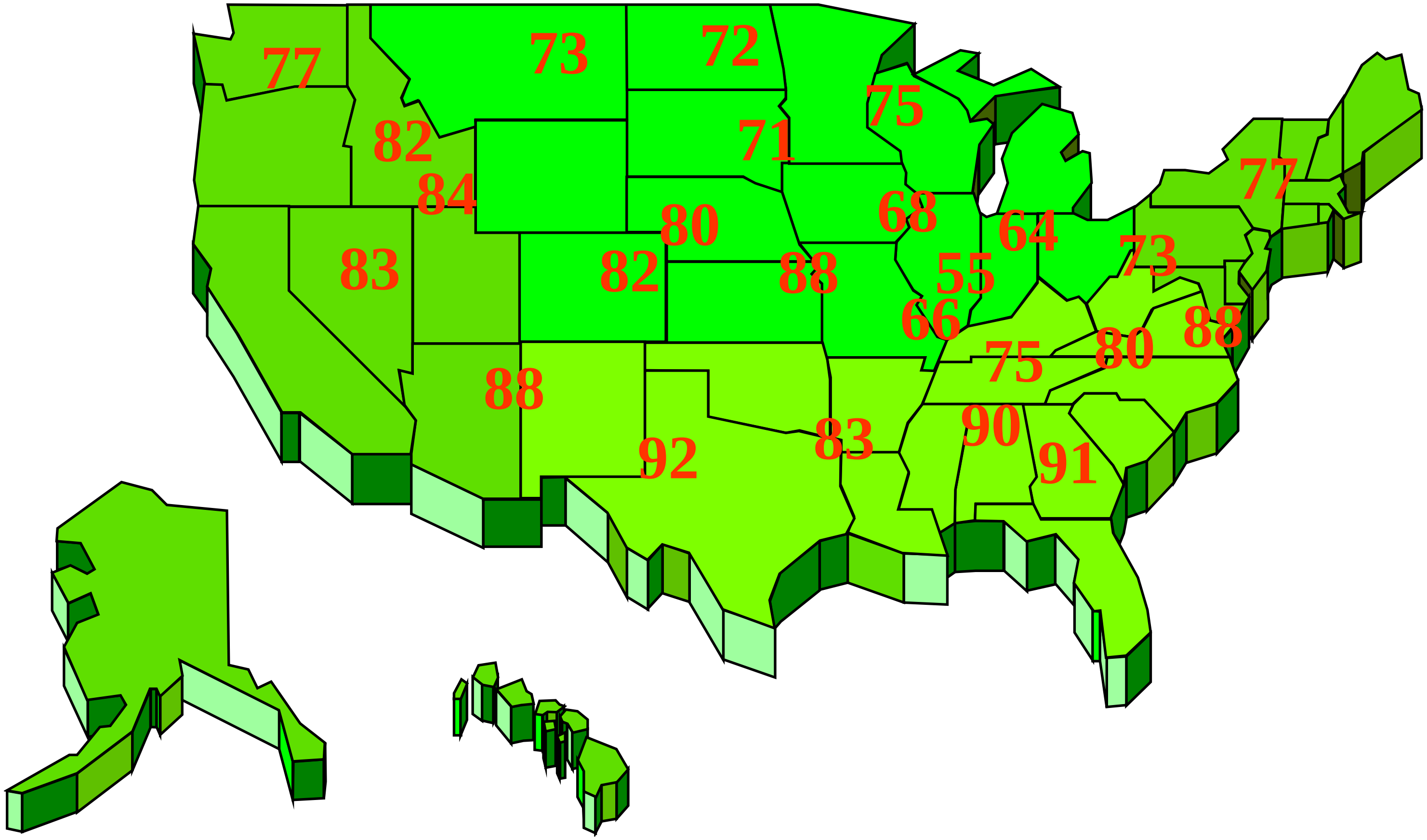
What is a Field?

A **FIELD** is something that can be defined **anywhere in space**

- A field represents some **physical quantity** (e.g., temperature, wind speed, force) that is a **function** of 3-D **spatial position** (x,y,z)

- It can be a scalar field (e.g., temperature field)
- It can be a vector field (e.g., force field or electric field)

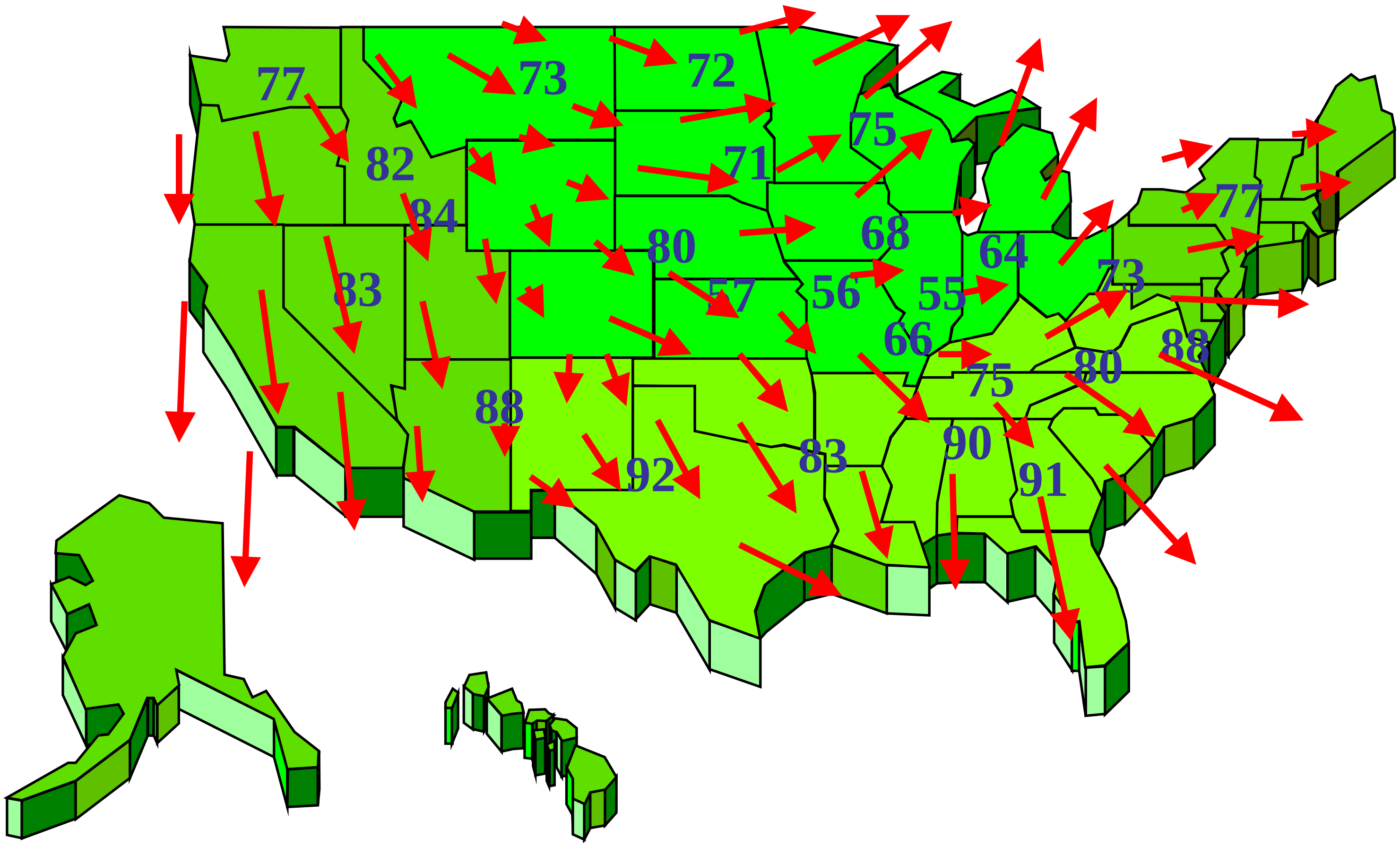
A Scalar Field



These isolated temperatures *sample* the scalar field
(you only learn the temperature at the point you choose,
but *T* is defined everywhere (*x*, *y*))

A Vector Field

Wind speed (length, direction)

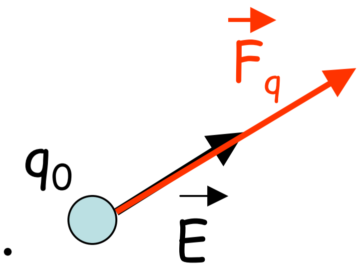


That would require a vector field
(you learn both wind speed and direction)

Electric Field

$\vec{E}$ How to determine?

Put small test charge at point in space.



$$\vec{E} = \frac{\vec{F}_{q_0}}{q_0}$$

units: N/C

Direction? What if q_0 is negative?

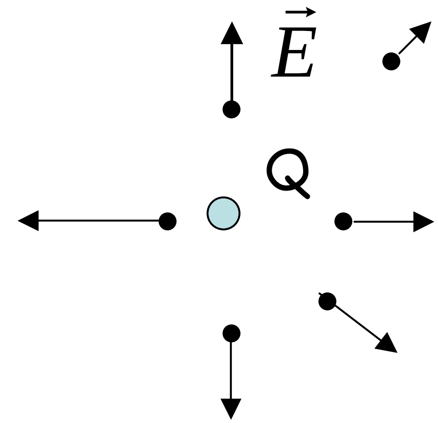
Why small test charge?

More accurately:

$$\vec{E} = \lim_{q_0 \to 0} \frac{\vec{F}_{q_0}}{q_0}$$

Electric Field

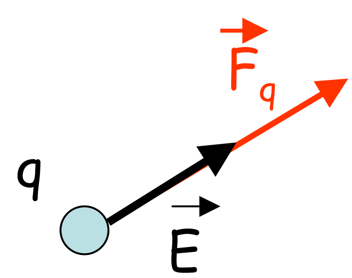
Can place test charge at many points to map $\vec{E}$



Example: Electric Field around charge Q.

Force on charge at point in electric field?

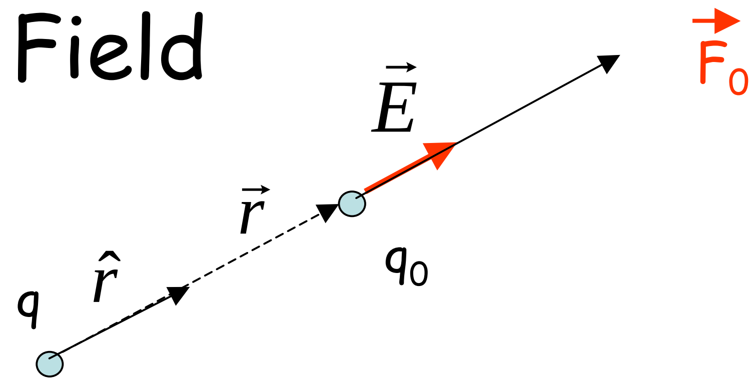
$$\vec{F}_q = q\vec{E}$$



Electric Field

$\vec{E}$ for point charge q?

Can calculate:



$$E = \frac{F_{q_0}}{q_0} = \frac{\dfrac{|qq_0|}{4\pi\varepsilon_0 r^2}}{q_0} = \frac{|q|}{4\pi\varepsilon_0 r^2}$$

magnitude

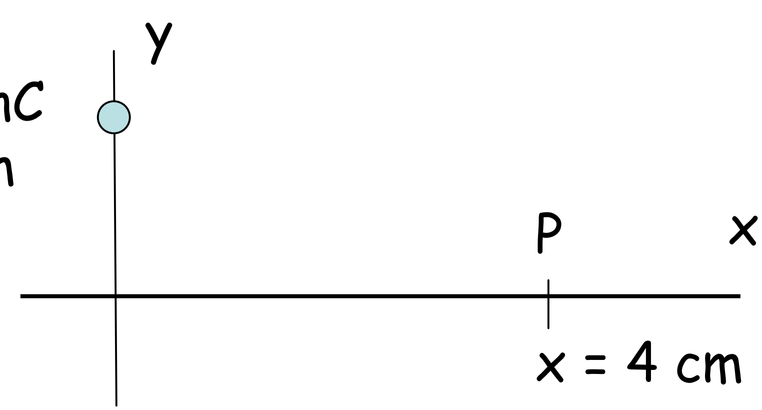
$$\vec{E} = \frac{q}{4\pi\varepsilon_0\, r^2}\hat{r}$$

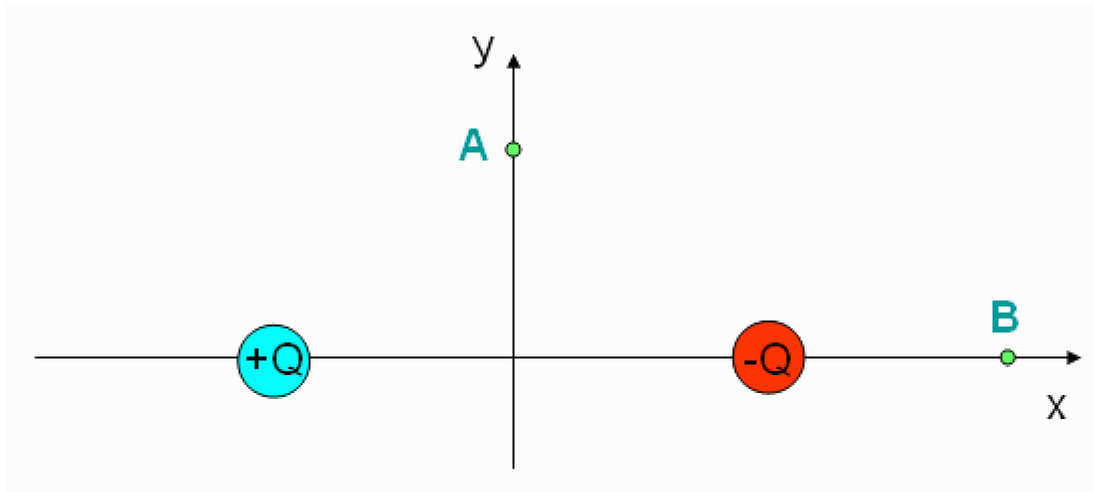
magnitude and direction.

r defined from q!

Example: a.) E at P?

q_1 = 60 nC
y_1 = 3 cm



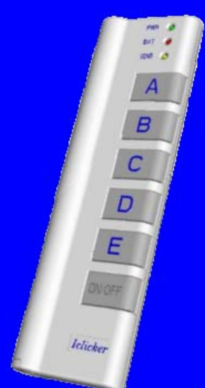


Two equal, but opposite charges are placed on the x axis. The positive charge is placed at to the left of the origin and the negative charge is placed to the right, as shown in the figure above.

1) What is the direction of the electric field at point B?

○ Up ○ Down ○ Left ○ Right ○ Zero

A B C D E

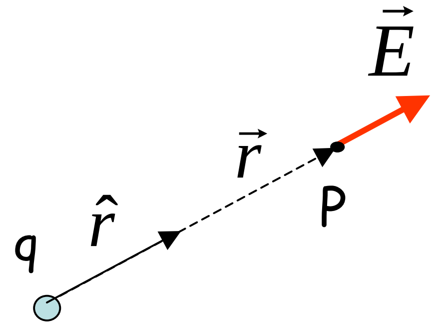


"B is closer to -Q than to +Q, so the effect of -Q's charge will be greater than +Q. Since B is positive, it will move to the left due to the attractive force of -Q on it."

Electric Field

$\vec{E}$ for point charge q:

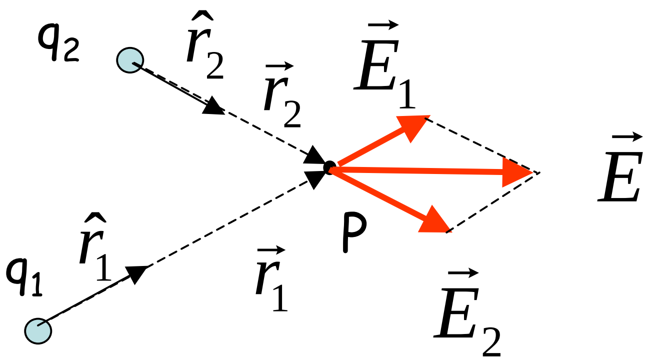
$$\vec{E} = \frac{q}{4\pi\varepsilon_0\, r^2}\hat{r}$$



What if more than one charge?

Use superposition.

$$\vec{E} = \frac{q_1}{4\pi\varepsilon_0\, r_1^2}\hat{r}_1 + \frac{q_2}{4\pi\varepsilon_0\, r_2^2}\hat{r}_2$$



$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\sum_i \frac{q_i}{r_i^2}\hat{r}_i$$

Electric Field

The electric field ***E*** at a point in space is defined as the force per unit charge at that point.

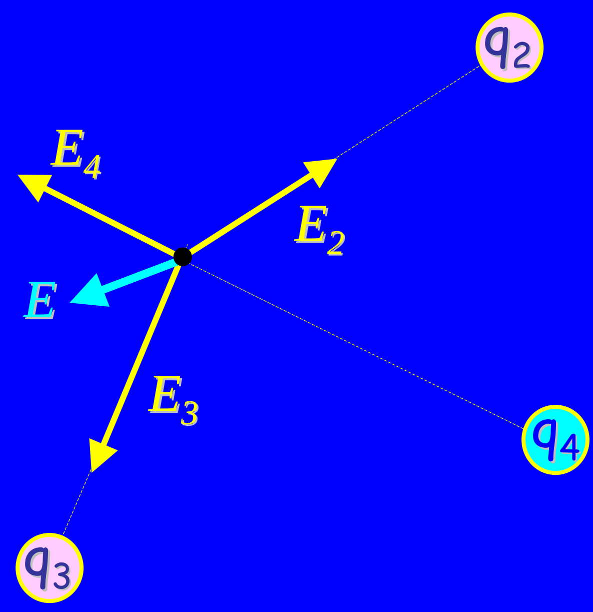
$$\vec{E} \equiv \frac{\vec{F}}{q}$$

Electric field due to a point charged particle

$$\vec{E} = k\frac{Q}{r^2}\hat{r}$$

Superposition

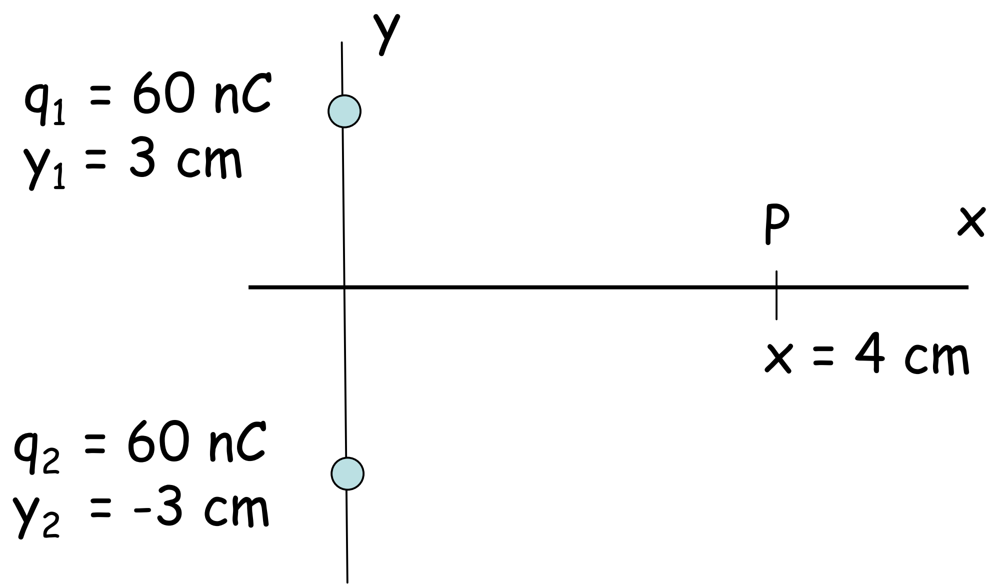
$$\vec{E} = \sum_i k\frac{Q_i}{r_i^2}\hat{r}_i$$



Field points toward negative and
Away from positive charges.

Using Symmetry: Electric Field

Example: a.) $\vec{E}$ at P?

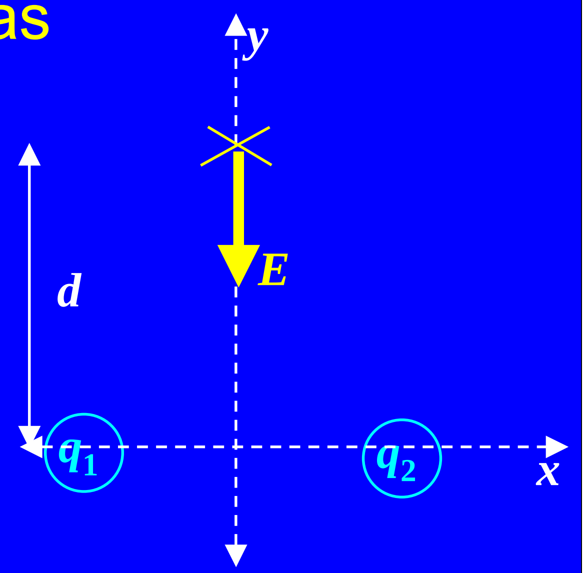


b.) Force on 3rd charge q_0 = 2 nC at P?

Exercise (UIL2A2)

Two charges, q_1 and q_2, fixed along the x-axis as shown produce an electric field, E, at a point $(x,y)=(0,d)$ which is directed along the negative y-axis.

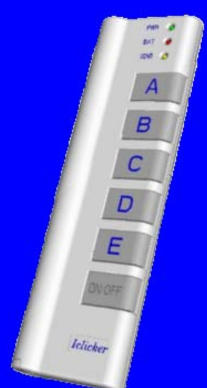
- Which of the following is true?



(a) Both charges q_1 and q_2 are positive

(b) Both charges q_1 and q_2 are negative

(c) The charges q_1 and q_2 have opposite signs



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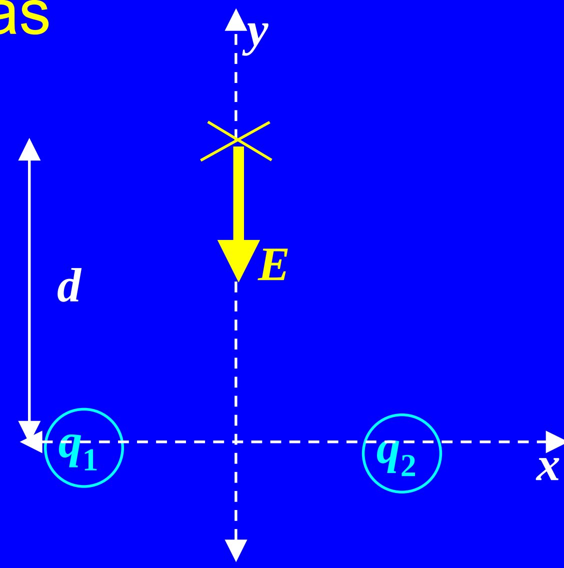

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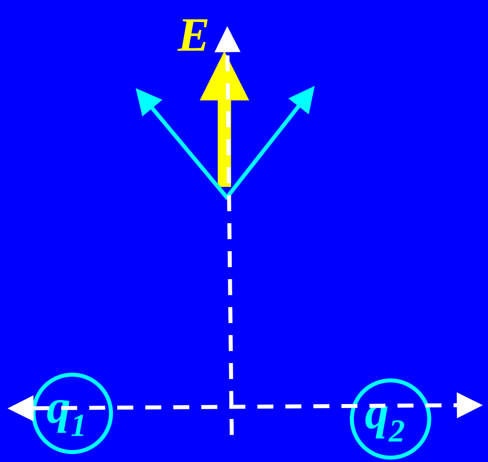
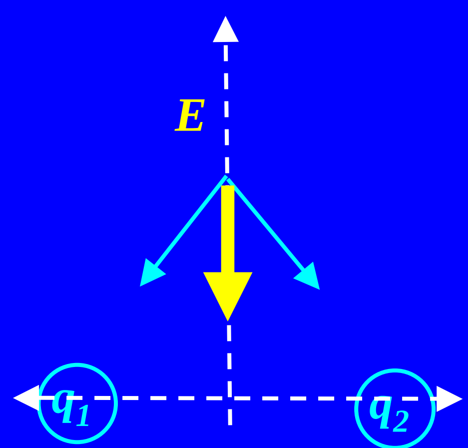
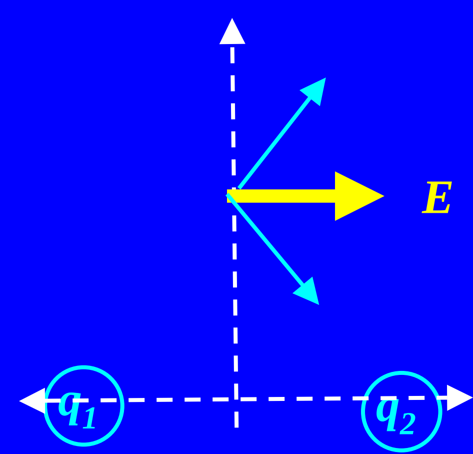


(a)



(b)



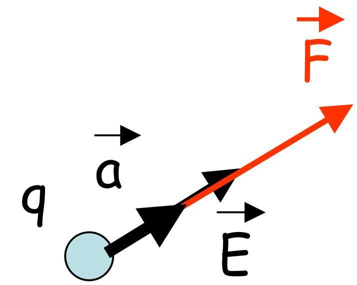
(c)

Motion of a charged particle in an electric field

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

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

$$(\vec{a} = \sum \frac{\vec{F}}{m} = \frac{q}{m}\sum \vec{E})$$



Where used?

Example: An electron, starting from rest, is accelerated in a uniform electric field of 8×10^4 N/C. Find its speed after traveling 5 cm.

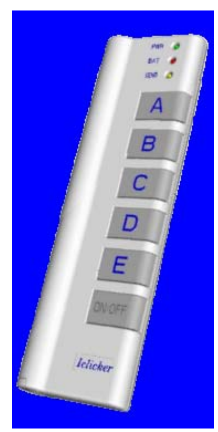
Motion of Charge

A positive test charge q is released from rest at distance r away from a charge of +Q and a distance 2r away from a charge of +2Q. How will the test charge move immediately after being released?

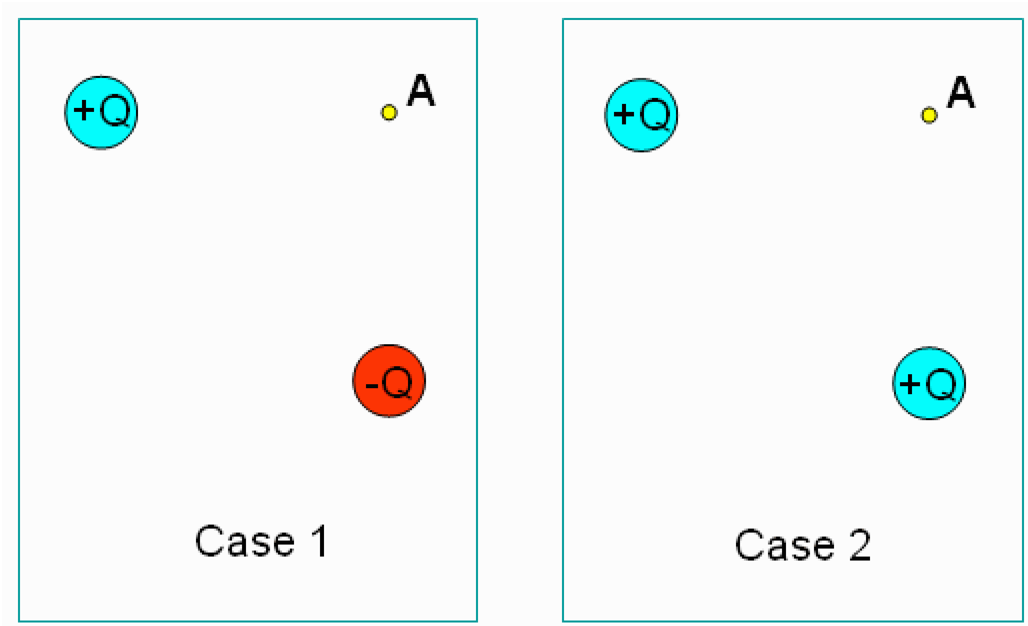
8) How will the test charge move immediately after being released?

- ○ to the left
- ○ to the right
- ○ stay still
- ○ other

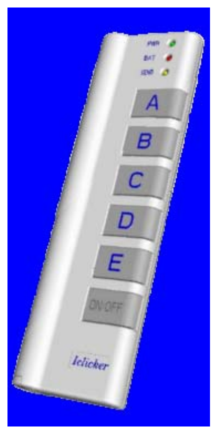
A B C D



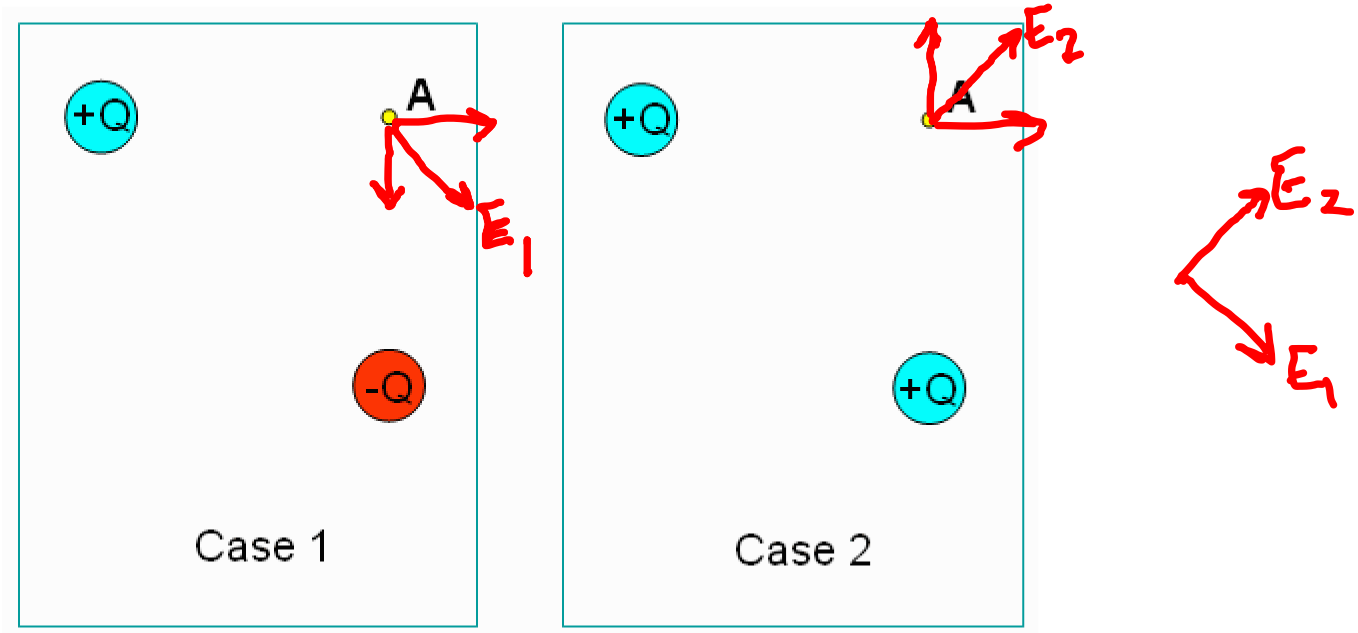
6) In which of the two cases shown below is the magnitude of the elctric field at the point labeled A the largest?

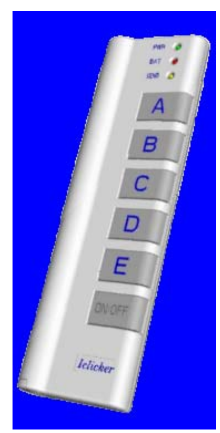


A) Case 1
B) Case 2
C) Same



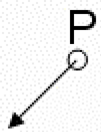
6) In which of the two cases shown below is the magnitude of the elctric field at the point labeled A the largest?



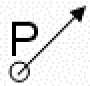


Example

What is the direction of the electric field at point P, the unoccupied corner of the square?



(a)



(b)

E = 0

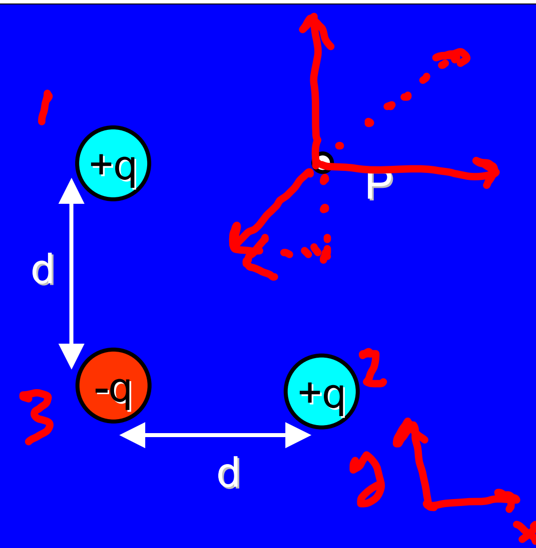
(c)

Can't tell until know value of d

(d)

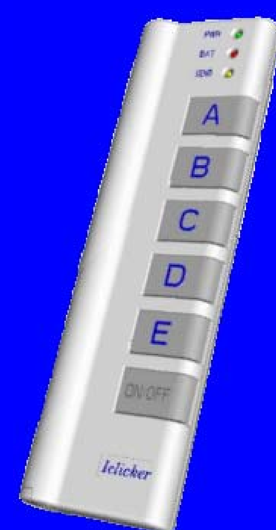
Can't tell until know values of d and q.

(e)



- Calculate E at point P.

$$\vec{E} = \sum_i k \frac{Q_i}{r_i^2} \hat{r}_i$$

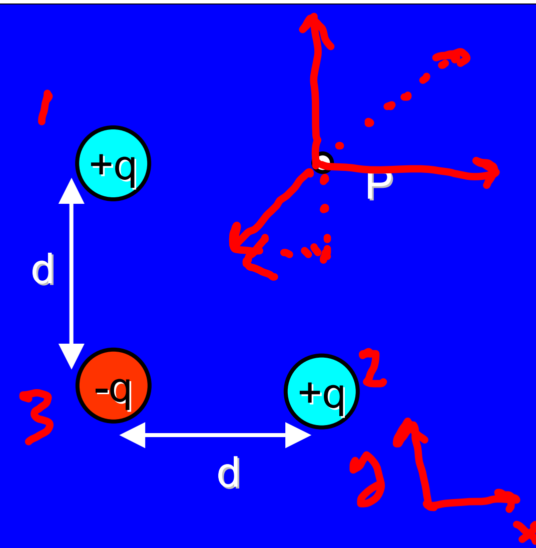


Example

"I would hope for more example calculations involving Coulomb's law and electric field strength."

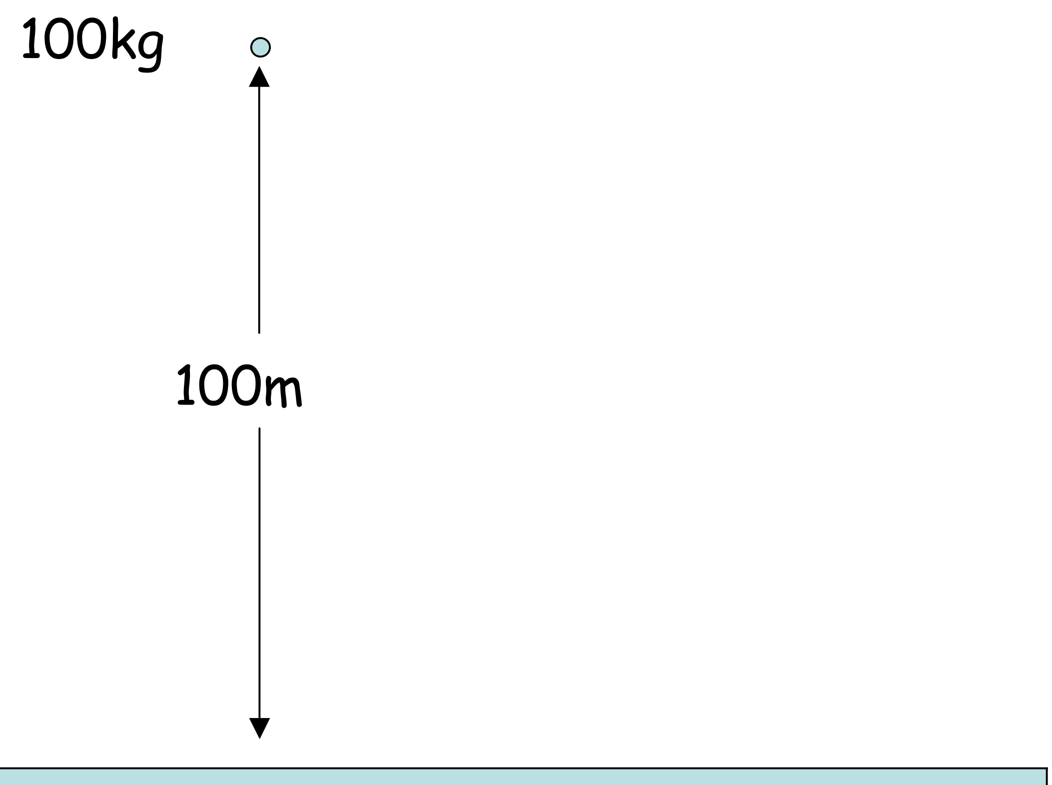
What is the direction of the electric field at point P, the unoccupied corner of the square?

(a) (b) (c) E = 0 (d) Can't tell until know value of d (e) Can't tell until know values of d and q.



- Calculate E at point P. $\vec{E} = \sum_i k \frac{Q_i}{r_i^2} \hat{r}_i$

Coulomb Man – Hall of Fame or Shame?



What will be his fate?

Hint: maybe another name