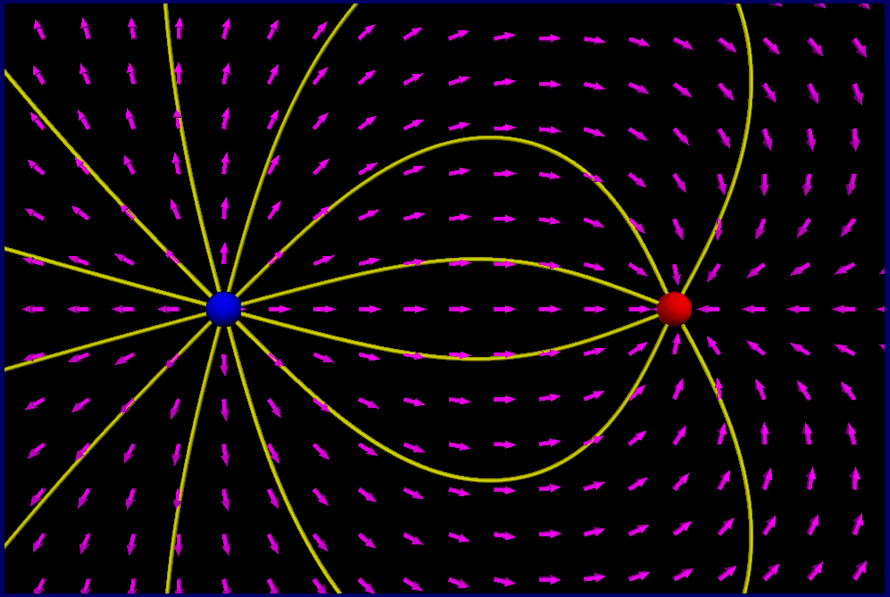
Physics 102: Lecture 02

Coulomb's Law and Electric Fields

Today we will …

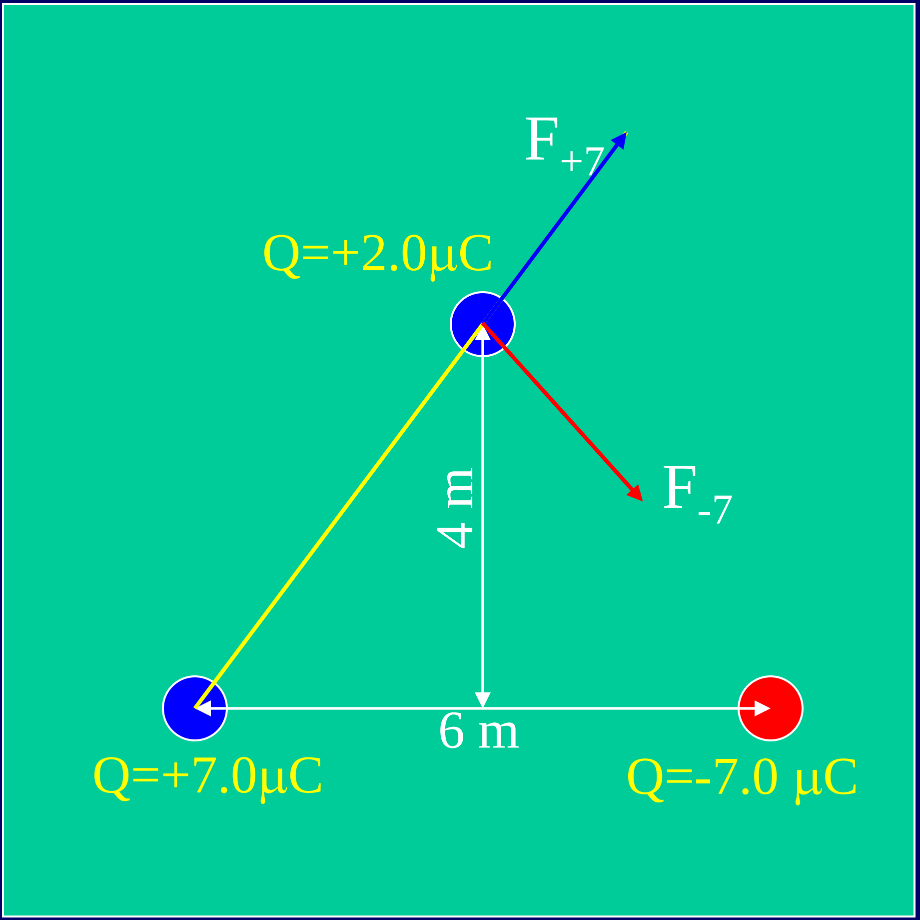
- get some practice using Coulomb's Law
- learn the concept of an Electric Field



Example

Coulomb Law practice: Three Charges

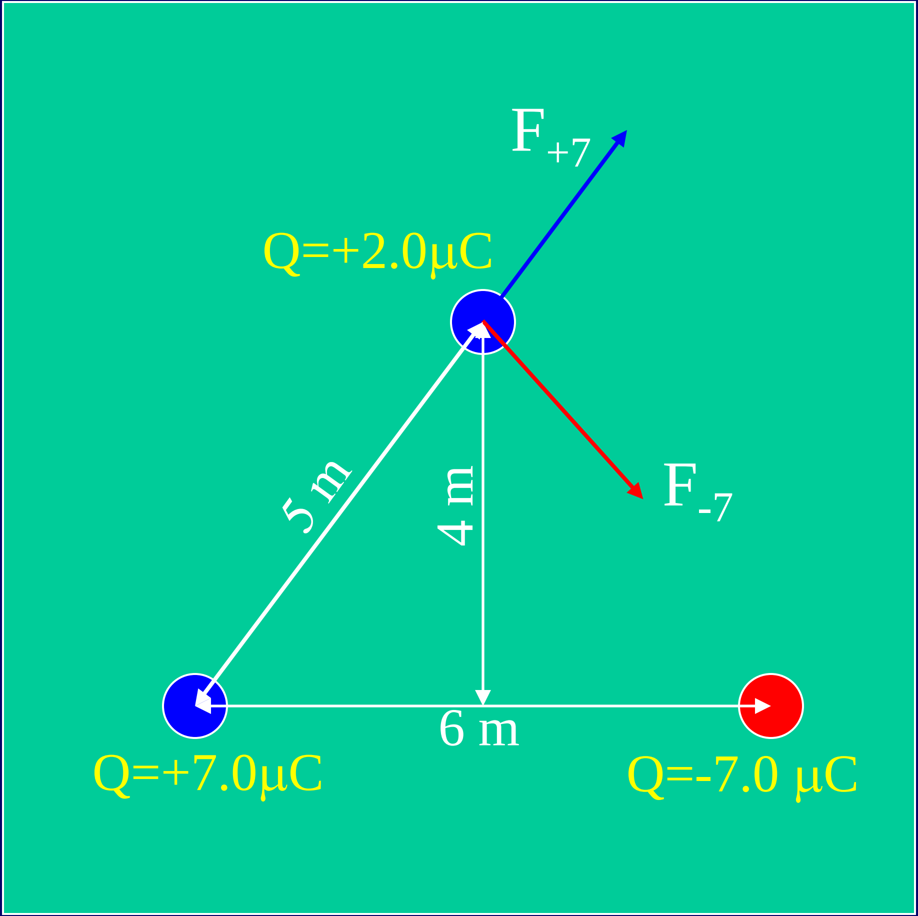
- Calculate force on +2μC charge due to other two charges
  - Draw forces
  - Calculate force from +7μC charge
  - Calculate force from –7μC charge
  - Add (VECTORS!)



Example

Three Charges – Calculate forces

- Calculate force on +2μC charge due to other two charges
  - Draw forces
  - Calculate force from +7μC charge
  - Calculate force from –7μC charge
  - Add (VECTORS!)
- Calculate magnitudes $F = k\frac{q_1 q_2}{r^2}$



$$F_{+7} = 9 \times 10^9 \frac{|2 \times 10^{-6}||7 \times 10^{-6}|}{5^2}$$

$$F_{-7} = 9 \times 10^9 \frac{|2 \times 10^{-6}||-7 \times 10^{-6}|}{5^2}$$

$$= 5 \times 10^{-3} N$$

Example

Three charges – Adding Vectors $F_{+7}+F_{-7}$

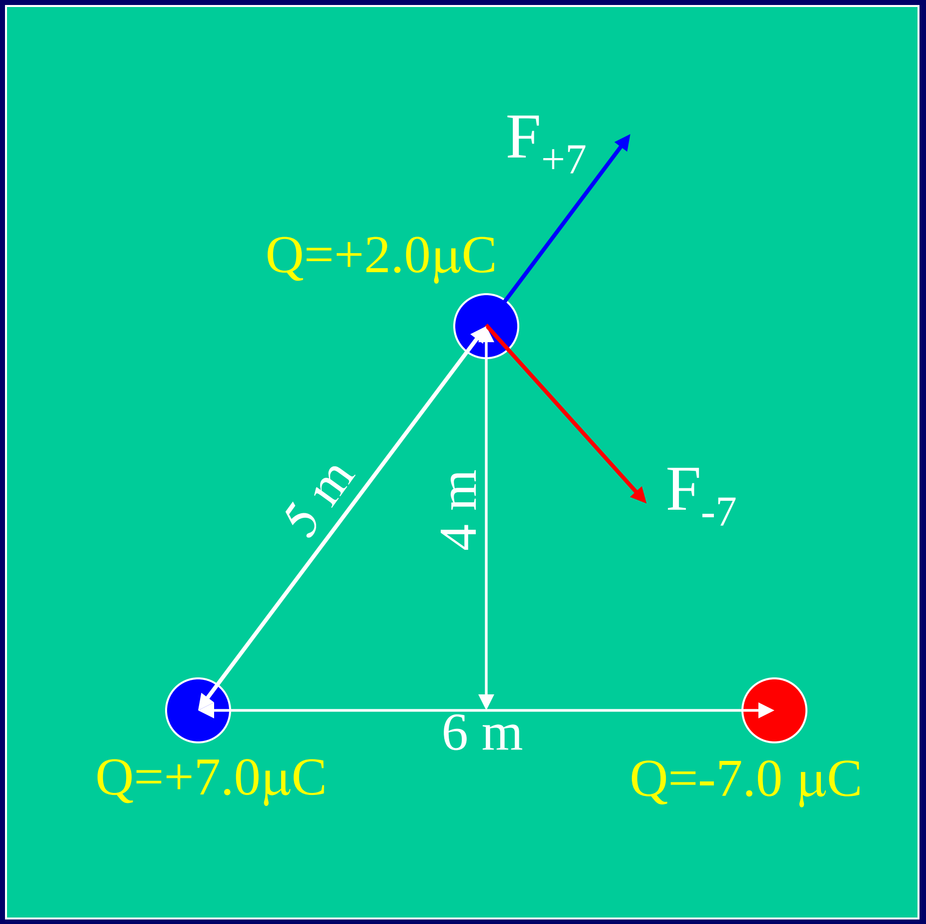
- Calculate components of vectors F_{+7} and F_{-7}:

$$F_{+7,x} = F_{+7}\cos\theta = 5\times10^{-3}N\,\frac{3}{5}$$

$$F_{+7,y} = F_{+7}\sin\theta = 5\times10^{-3}N\,\frac{4}{5}$$

$$F_{-7,x} = F_{-7}\cos\theta = 5\times10^{-3}N\,\frac{3}{5}$$

$$F_{-7,y} = -F_{-7}\sin\theta = -5\times10^{-3}N\,\frac{4}{5}$$



Example

Three charges – Adding Vectors $F_{+7}+F_{-7}$

- Add like components of vectors F_{+7} and F_{-7}:

$$F_x = F_{+7,x} + F_{-7,x} = 6 \times 10^{-3} N$$

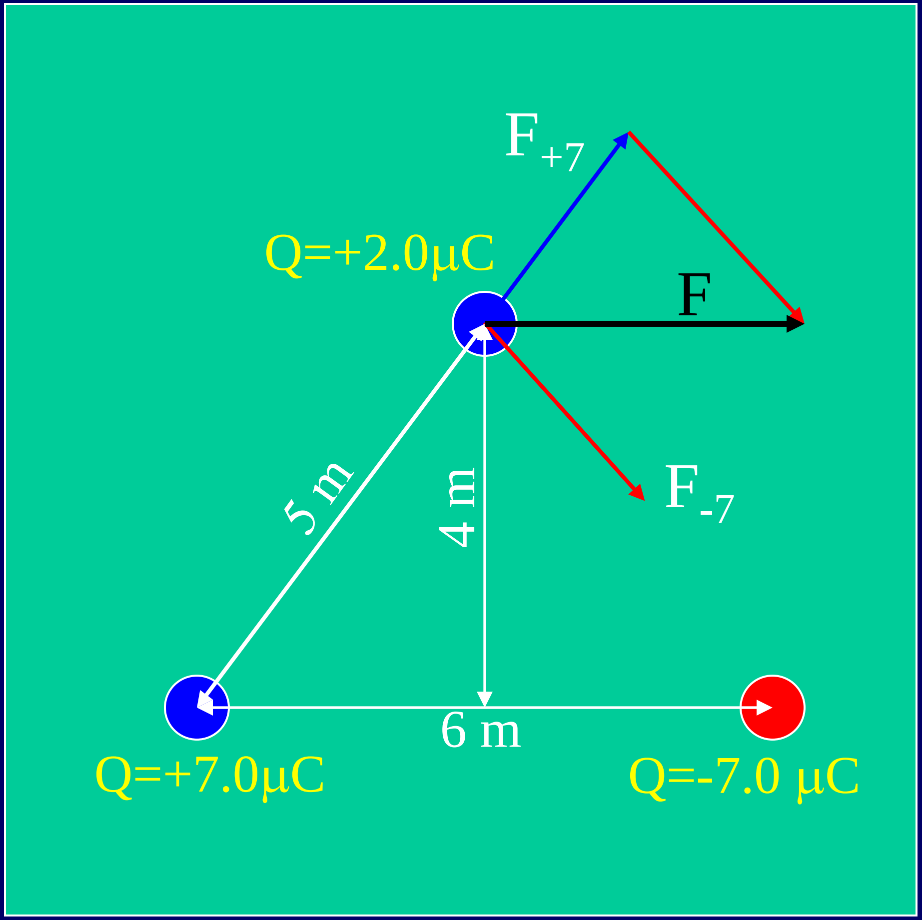
$$F_y = F_{+7,y} + F_{-7,y} = 0$$

- Final vector F has magnitude and direction

$$F = \sqrt{{F_x}^2 + {F_y}^2} = 6 \times 10^{-3} N$$

$$\varphi = \tan^{-1}\frac{F_y}{F_x} = 0$$

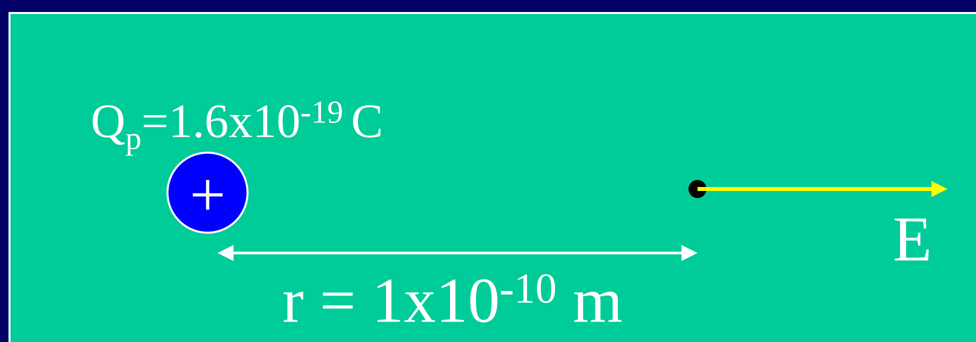
- Double-check with drawing



Electric Field

- Charged particles create electric fields.
  - Direction is the same as for the force that a + charge *would feel* at that location.
  - Magnitude given by: $E \equiv F/q = kq/r^2$

Example

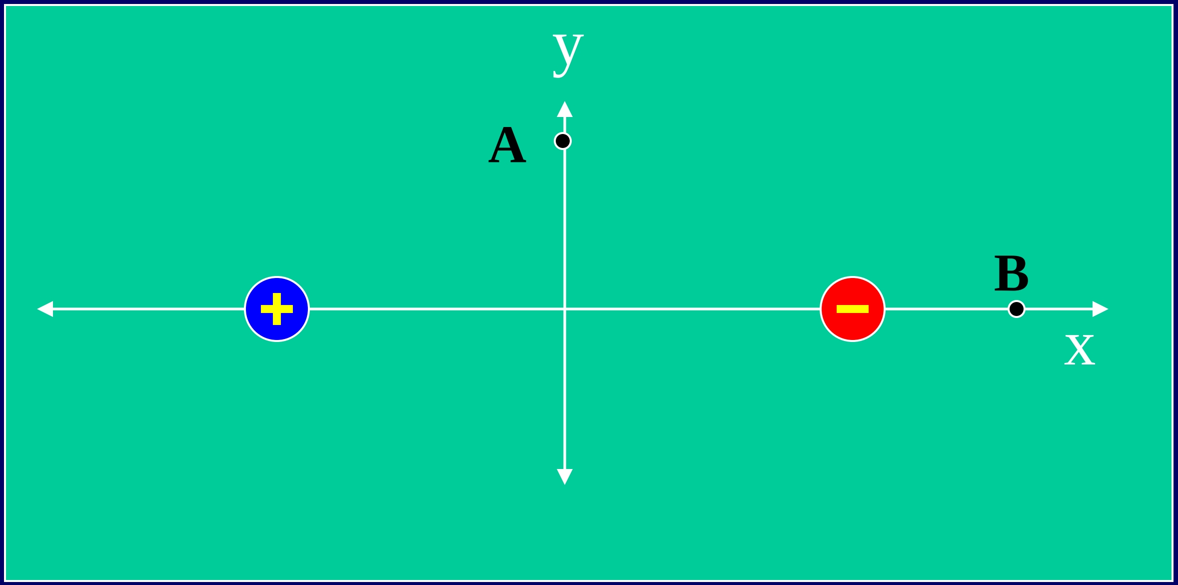


$E = (9\times10^{9})(1.6\times10^{-19})/(10^{-10})^{2}\ \text{N} = 1.4\times10^{11}\ \text{N/C}$ (to the right)

CheckPoint 1.1

What is the direction of the electric field at point A?

1) Up
2) Down
3) Left
4) Right
5) Zero



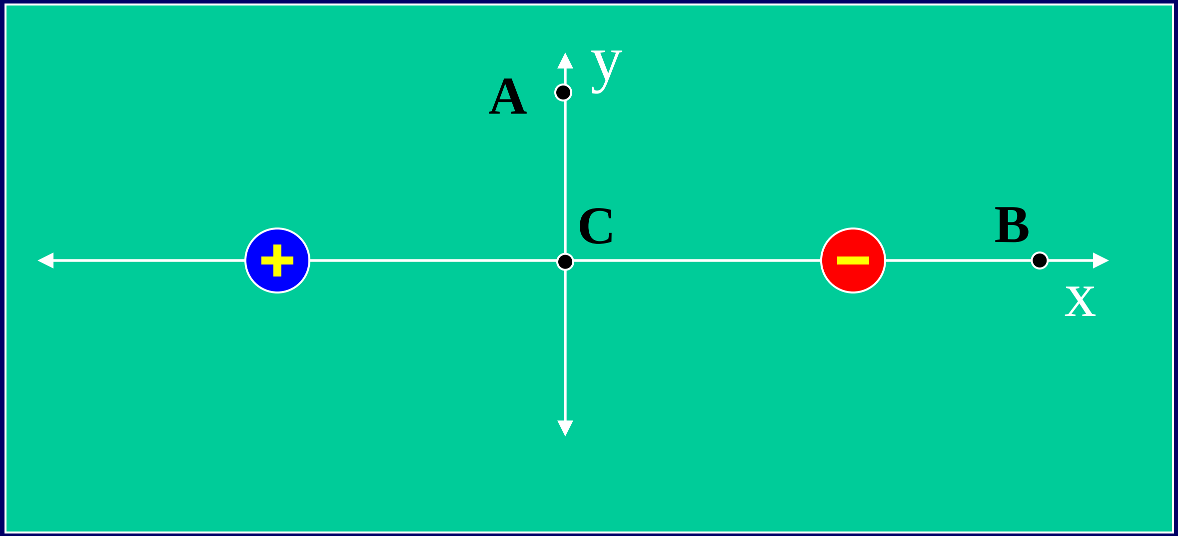
ACT: E Field

What is the direction of the electric field at point C?

A. Left

B. Right

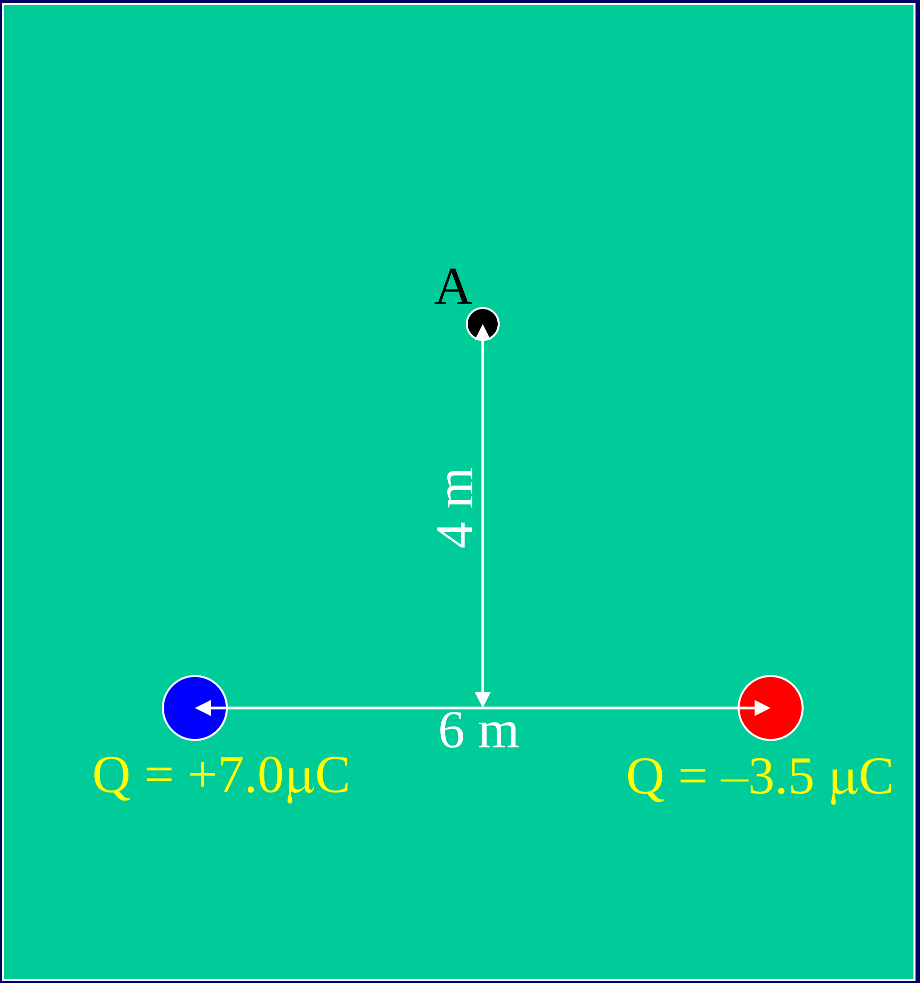
C. Zero



Example

E Field from 2 Charges

- Calculate electric field at point A due to two unequal charges
  - Draw electric fields
  - Calculate E from +7μC charge
  - Calculate E from –3.5μC charge
  - Add (VECTORS!)



Note: this is similar to (but a bit harder than) my earlier example.

We'll do some of this here… you try the rest at home!

Example

E Field from 2 Charges

- Calculate electric field at point A due to charges
  - Calculate E from +7μC charge
  - Calculate E from –3.5μC charge
  - Add*

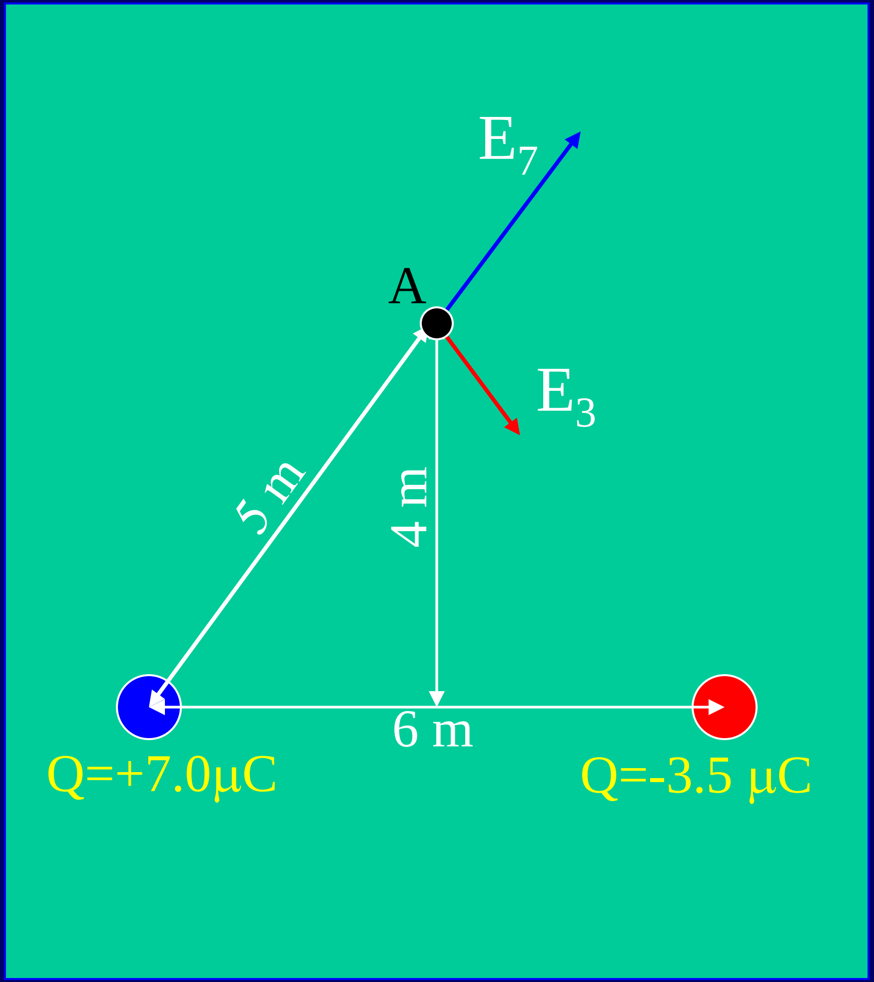
$$E = k\,q/r^2$$

$$E_7 = \frac{(9\times10^{9})(7\times10^{-6})}{25}\,N/C$$

$$E_7 = 2.5\times10^{+3}\,N/C$$

$$E_3 = \frac{(9\times10^{9})(3.5\times10^{-6})}{25}\,N/C$$

$$E_3 = 1.25\times10^{+3}\,N/C$$



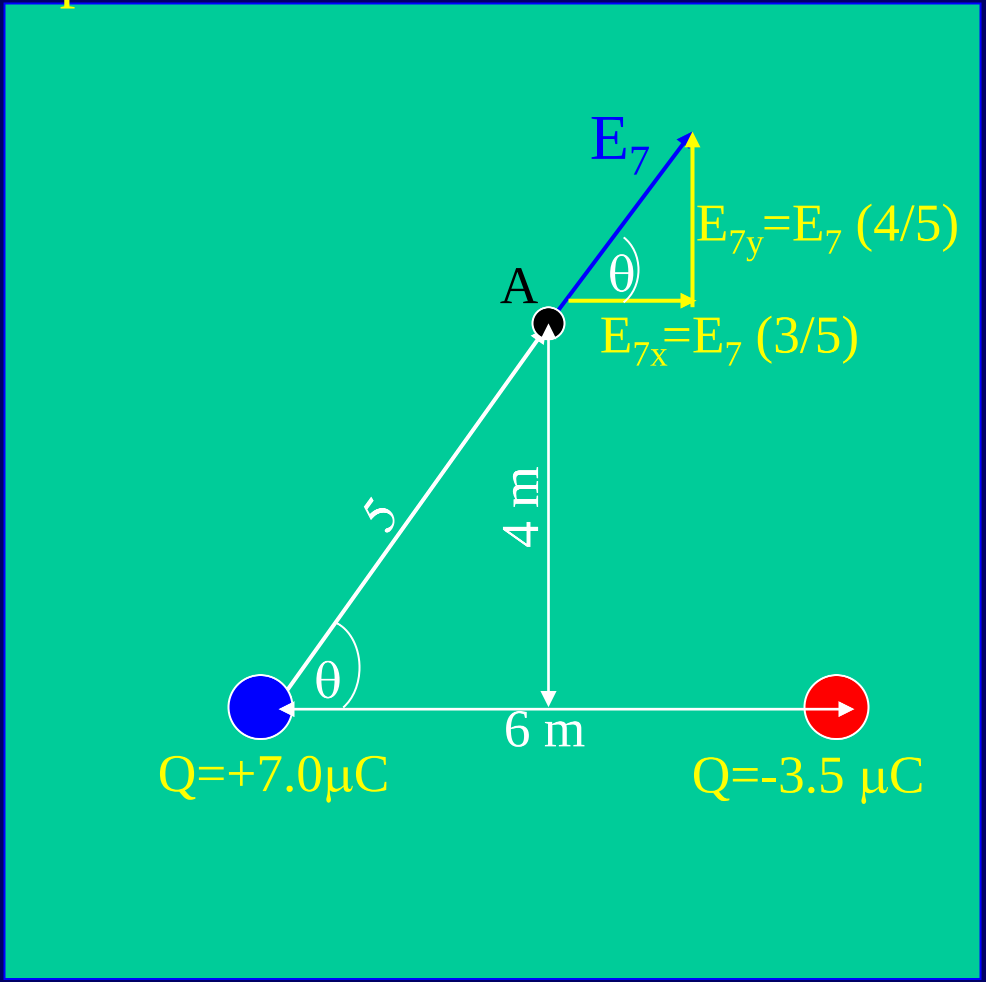
Example

Adding Vectors E_7+E_3

- Decompose into x and y components.

$$E_{7x} = E_7 \cos(\theta) = E_7\left(\frac{3}{5}\right)$$
$$= 1.5 \times 10^{+3} N/C$$

$$E_{7y} = E_7 \sin(\theta) = E_7\left(\frac{4}{5}\right)$$
$$= 2 \times 10^{+3} N/C$$



Example

Adding Vectors E_7+E_3

- Decompose into x and y components.
- Add components.

$$E_{7x} = 1.5 \times 10^{+3} N/C$$

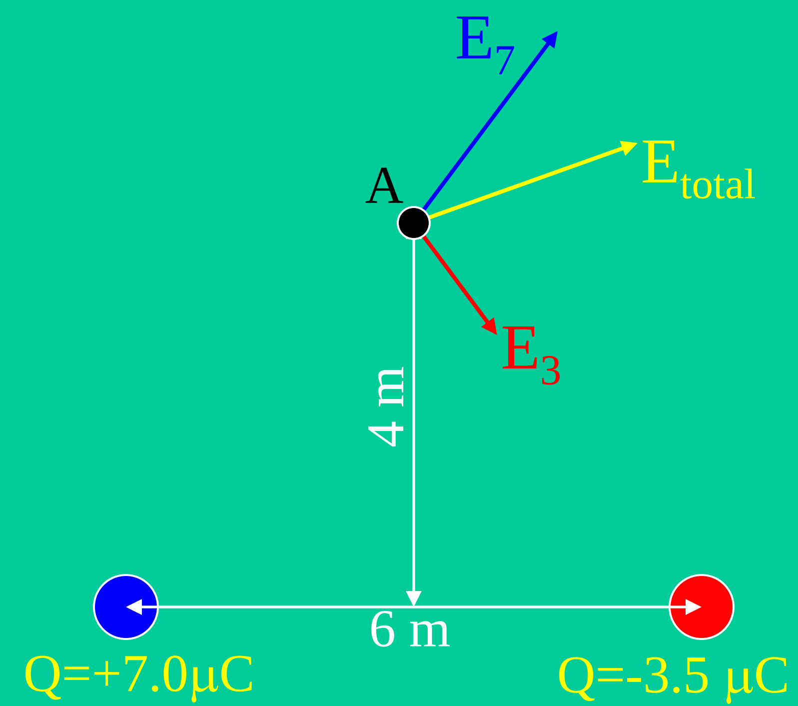
$$E_{3x} = 0.75 \times 10^{+3} N/C$$

$$E_{7y} = 2 \times 10^{+3} N/C$$

$$E_{3y} = -1 \times 10^{+3} N/C$$

$E_x = 2.25\times10^{+3}$ N/C

$E_y = 1.0\times10^{+3}$ N/C



$$|E| = \sqrt{E_x^2 + E_y^2} = 2.5 \times 10^{+3}\ N/C$$

Comparison:
Electric *Force* vs. Electric *Field*

- Electric Force (F) – the force felt by a charge at some location
- Electric Field (E) – found for a location only (any location) – tells what the electric force *would be* if a + charge were located there:

$$F = Eq$$

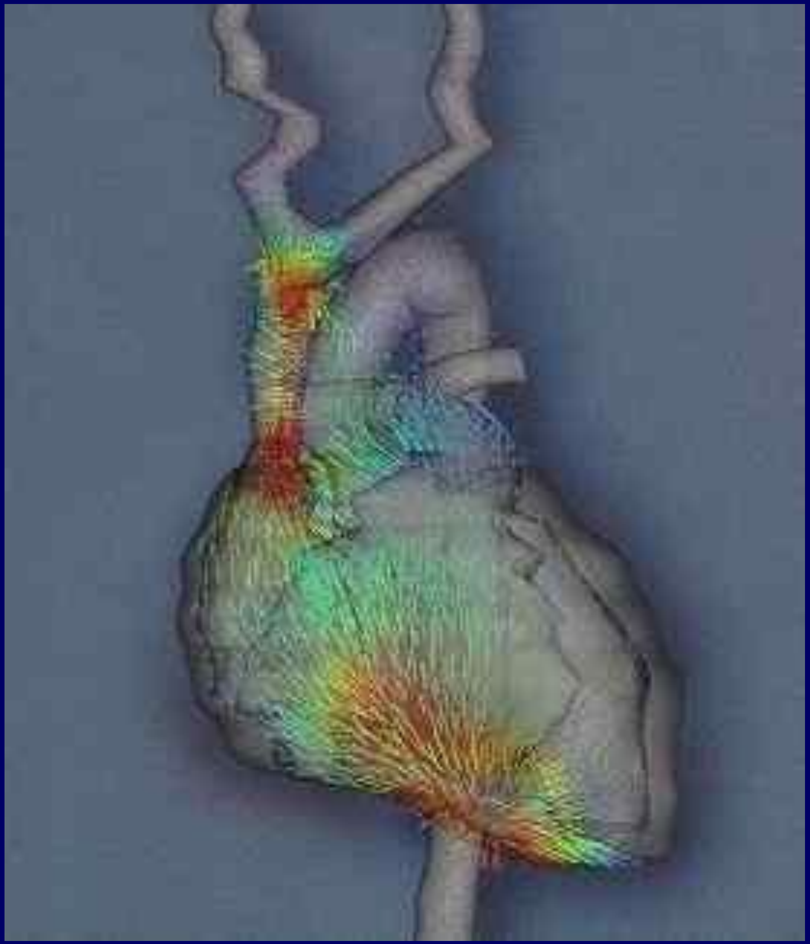
- Both are vectors, with magnitude and direction.

Ok, what is E actually good for?

Electric fields:

A useful record-keeping tool!

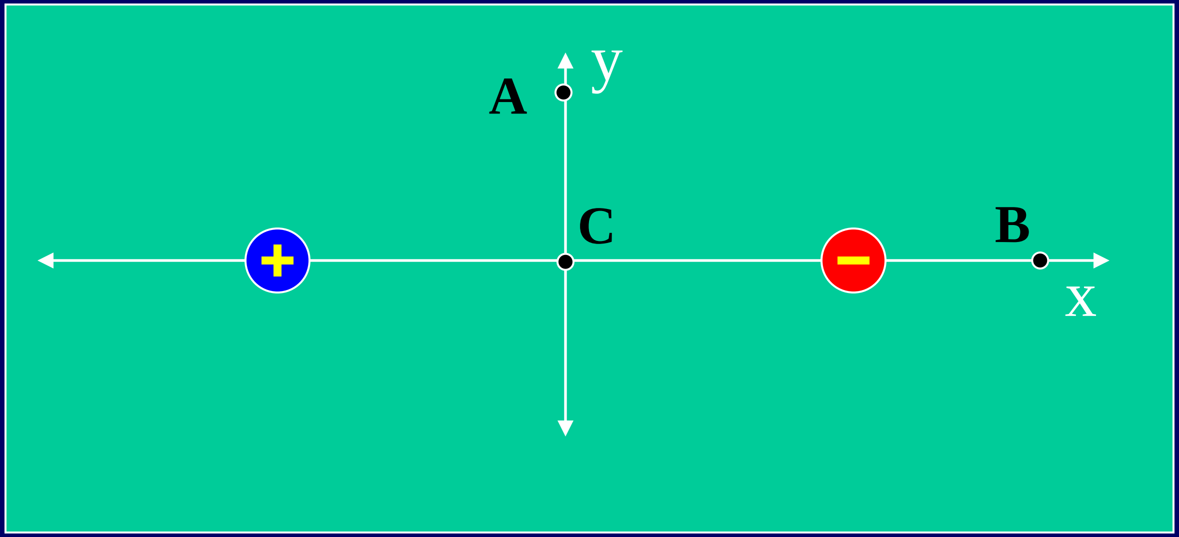
calculate once for fixed charges,
use to find force on other charges
(like ions/electrons in neurons,
heart tissue, and cell membranes)



Eisenberg, BU

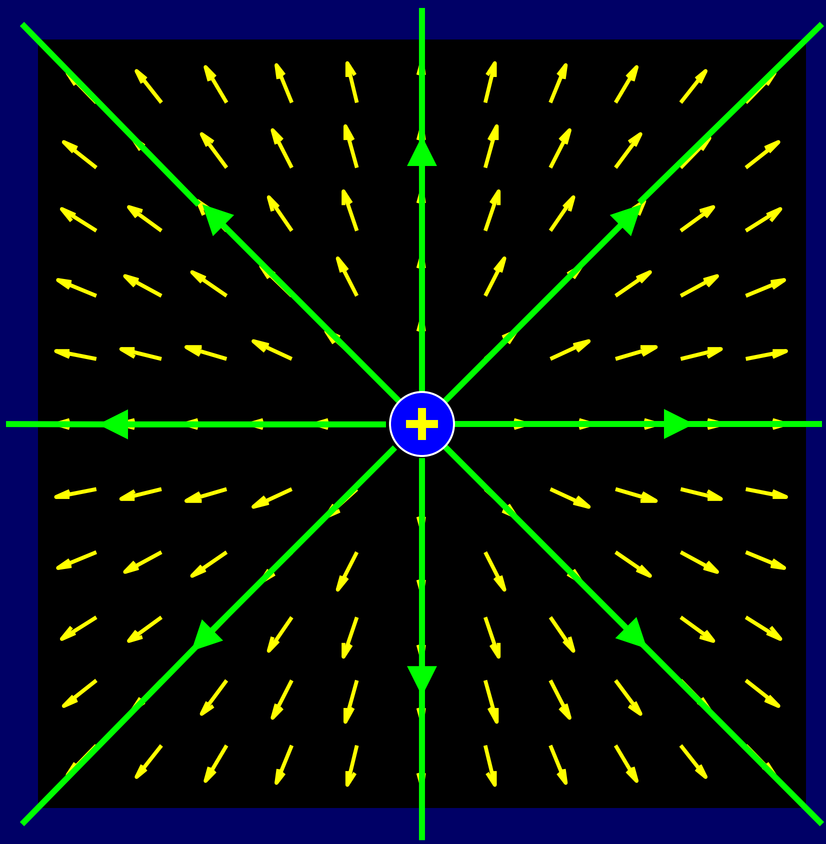
Electric Field Map

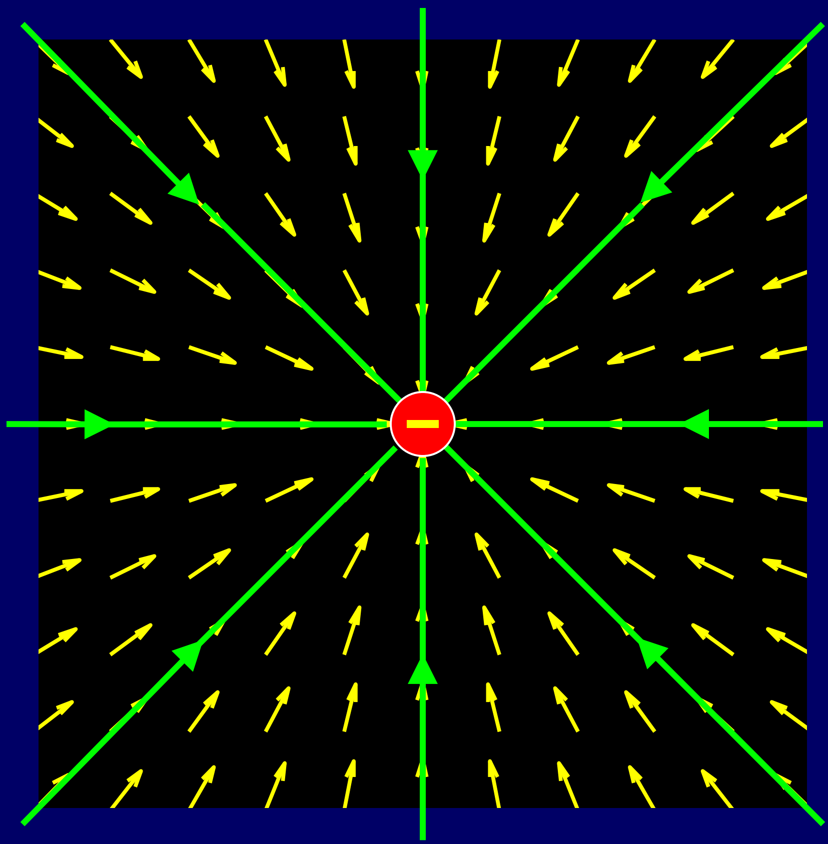
- Electric field defined at any location (you did three: A, B, C)



Electric Field Lines

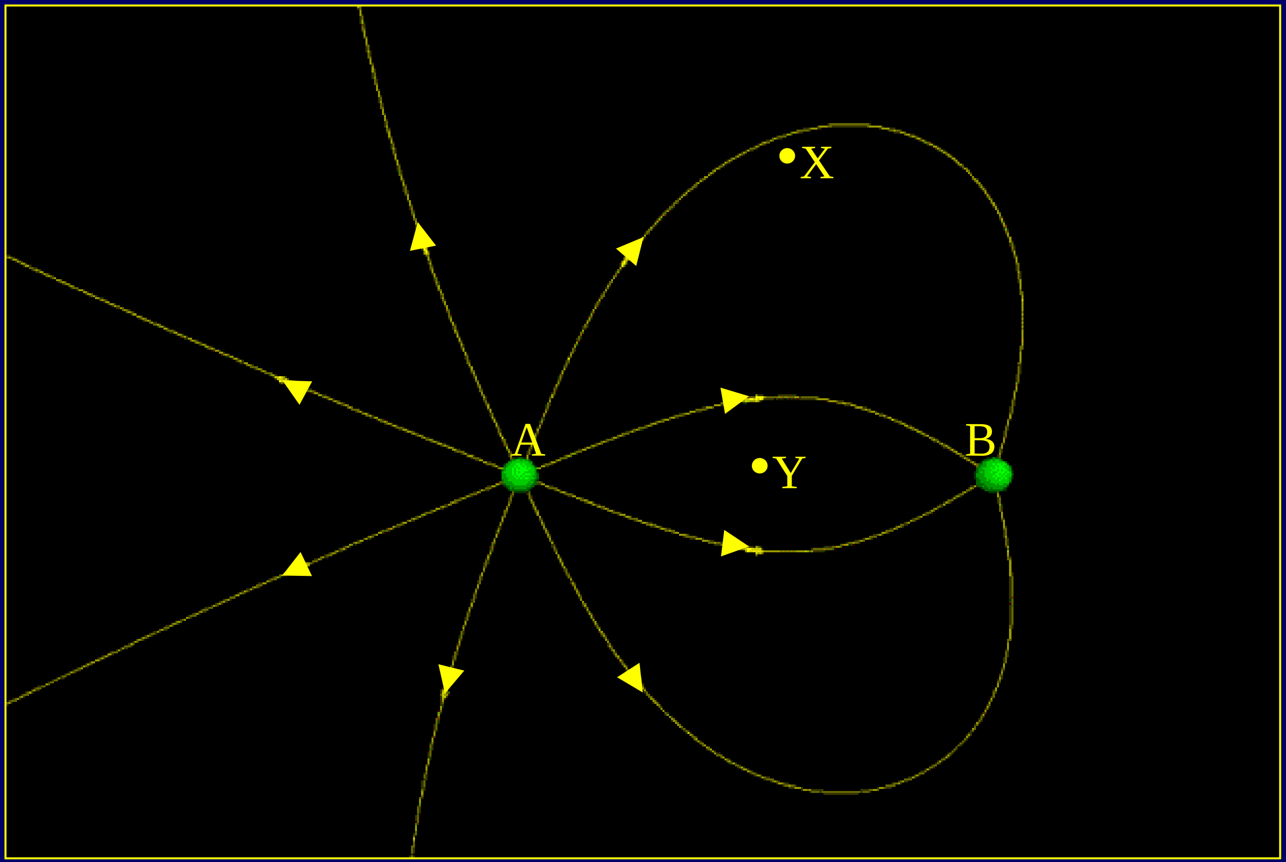
- Closeness of lines shows field strength (lines never cross)
- Number of lines at surface ∝ Q
- Arrow gives direction of E (Start on +, end on –)





This is becoming a mess!!!

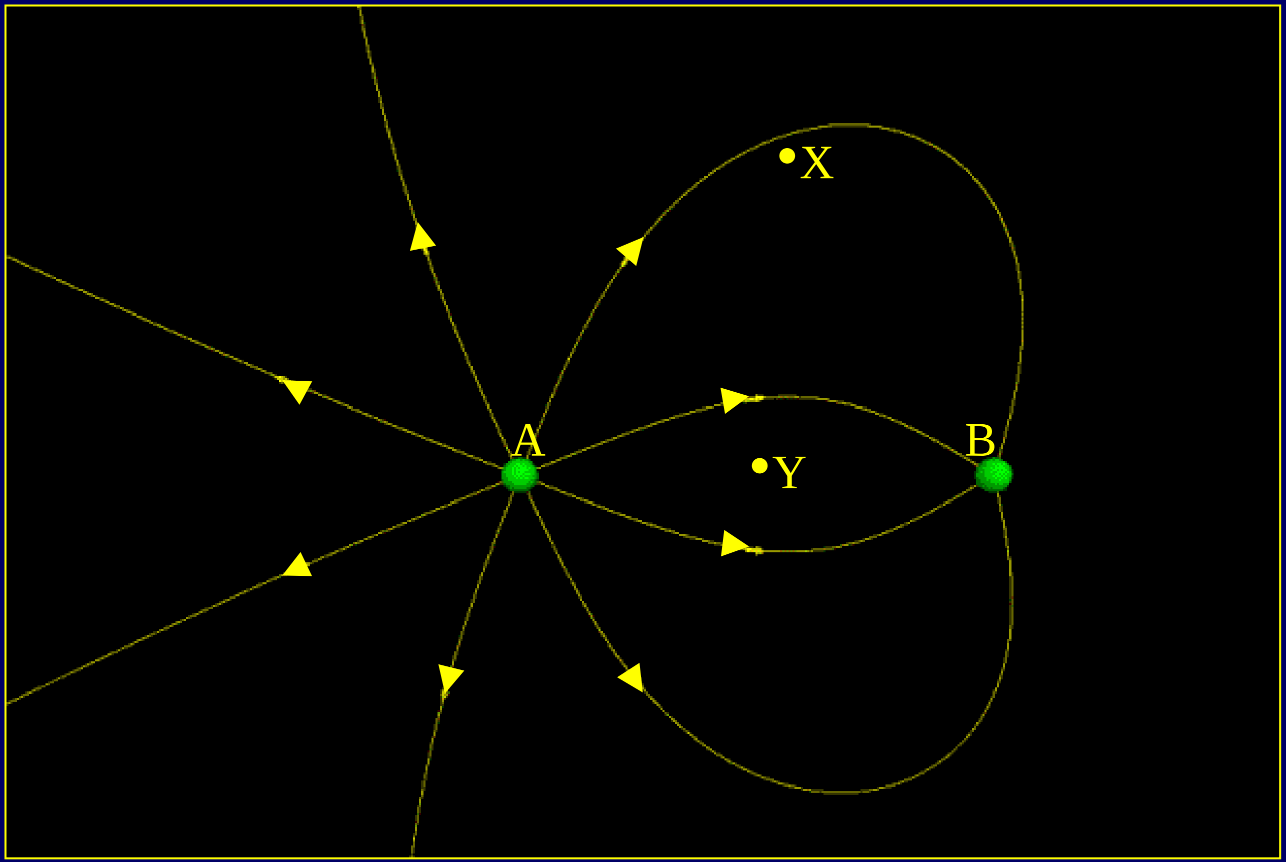
CheckPoint 2.1



Charge A is

1) positive 2) negative 3) unknown

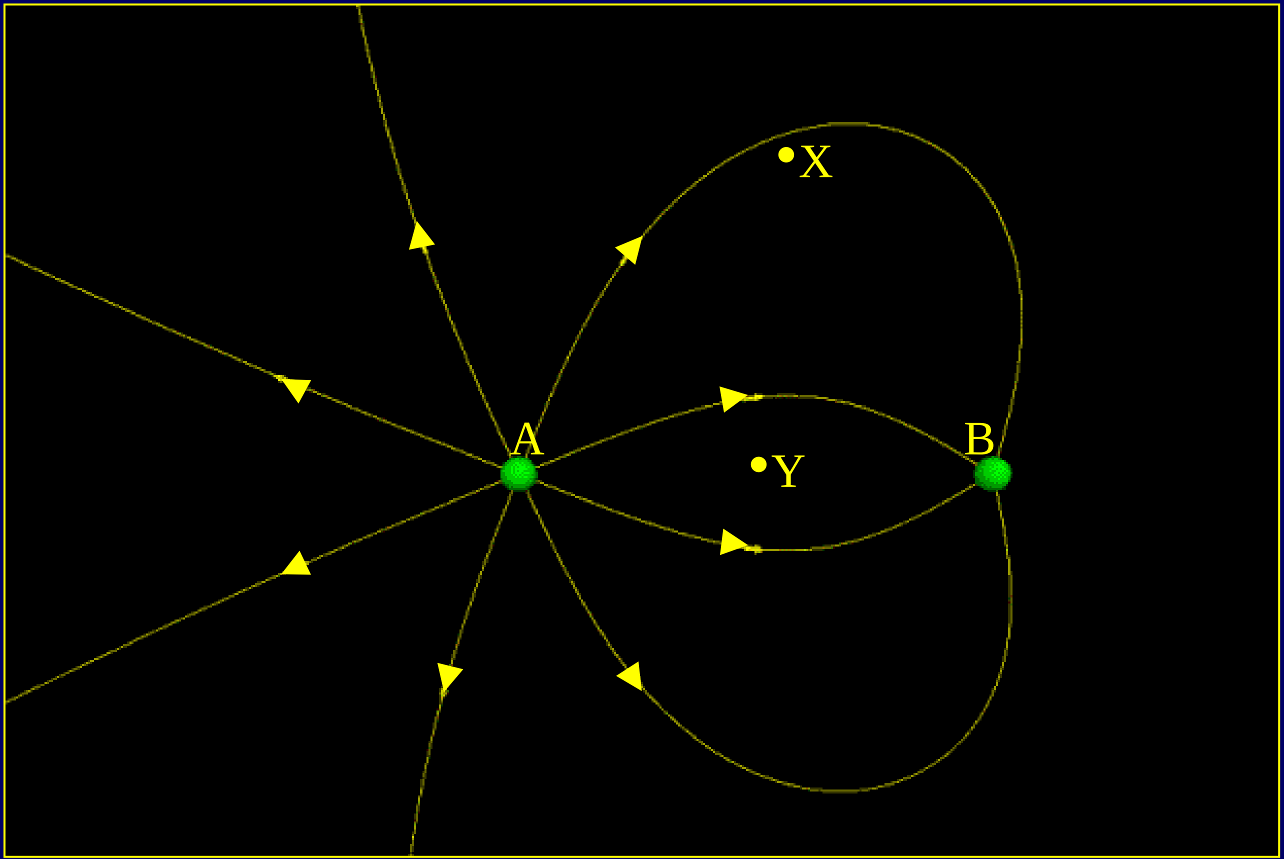
CheckPoint 2.2 / ACT



Compare the ratio of charges Q_A / Q_B

1) $Q_A = 0.5Q_B$ 2) $Q_A = Q_B$ 3) $Q_A = 2\ Q_B$

CheckPoint 2.3

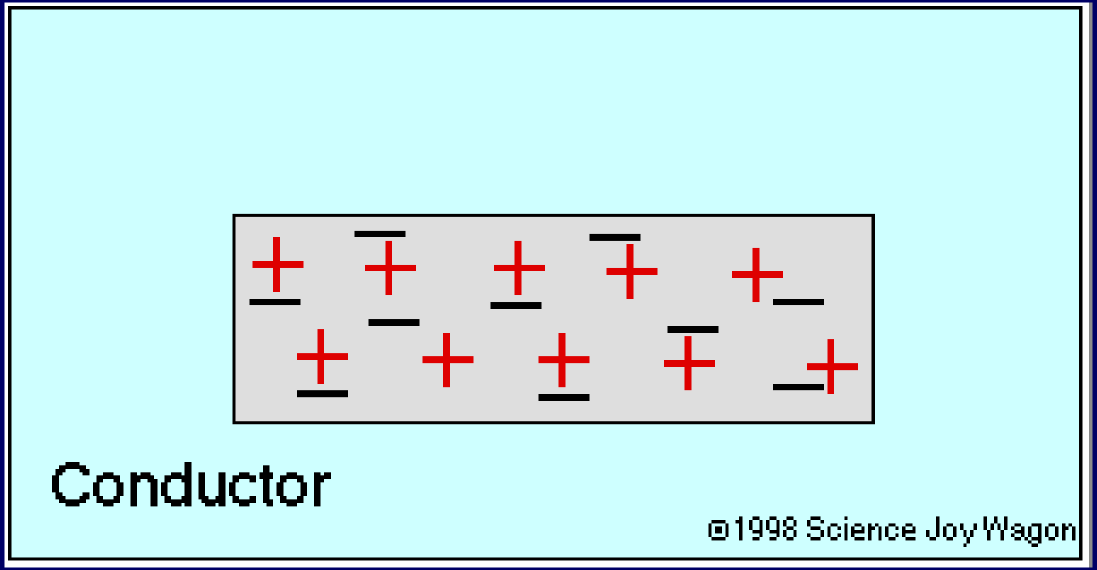


The magnitude of the electric field at point X is greater than at point Y

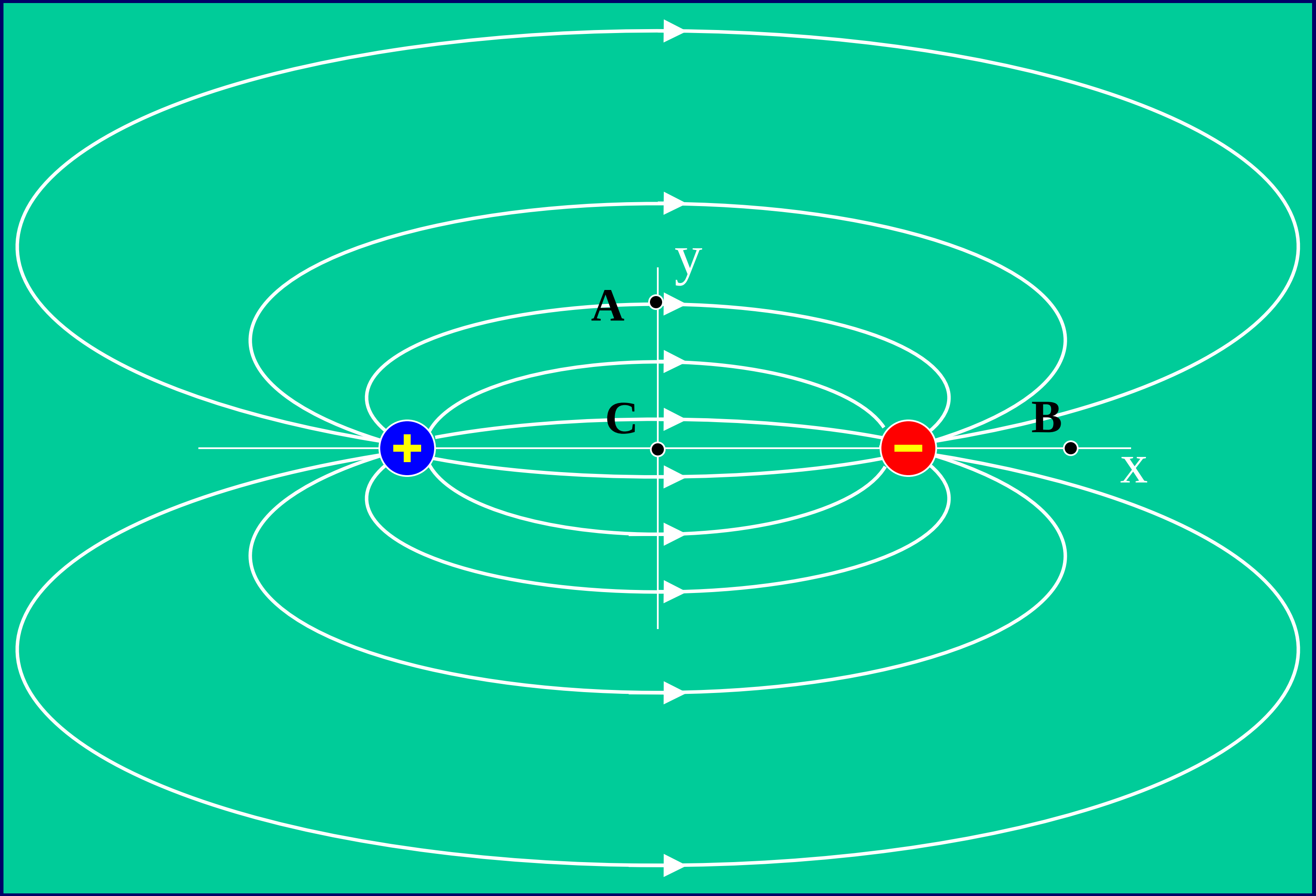
1) True 2) False

E inside of conductor

- Conductor ≡ electrons free to move
  - Electrons feels electric force - will move until they feel no more force (F=0)
  - F=Eq: if F=0 then E=0
- E=0 inside a conductor (Always!)



Demo: E-field from dipole



Recap

- E Field has magnitude <u>and</u> direction:
  - $E \equiv F/q$
  - Calculate just like Coulomb's law
  - Careful when adding vectors
- Electric Field Lines
  - Density gives strength (# proportional to charge.)
  - Arrow gives direction (Start + end on –)
- Conductors
  - Electrons free to move $\Rightarrow$ $E = 0$