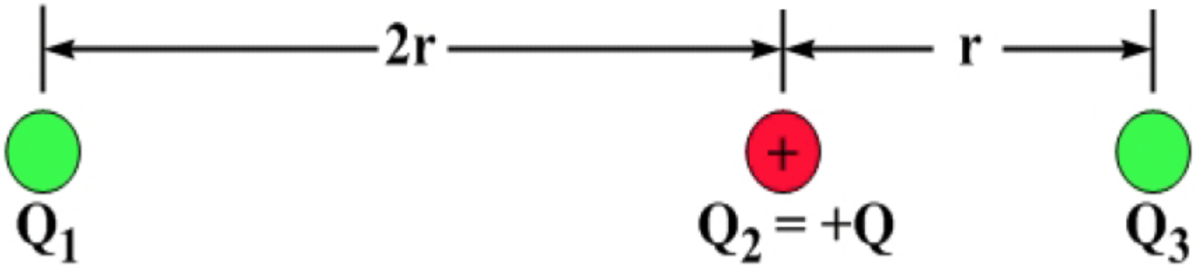


Ball 1 has an unknown charge and sign.
Ball 2 is positive, with a charge of +Q.
Ball 3 has an unknown non-zero charge and sign.

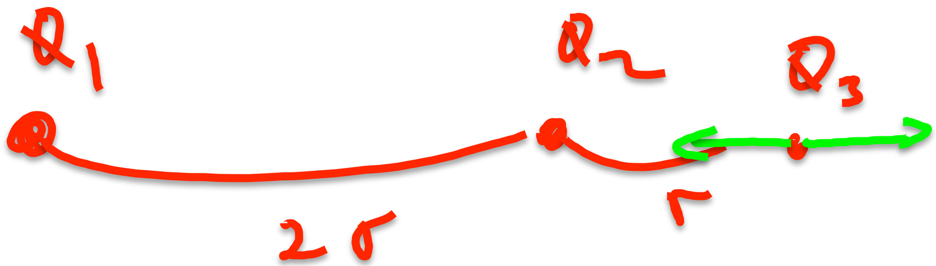
Ball 3 is in equilibrium - it feels no net electrostatic force due the other two balls.

What is the sign of the charge on ball 1?

Does the answer depend on the value of the charge 3?

1. Yes

2. No



$$|F_{31}| = |F_{32}|$$

$$k\frac{|Q_1 Q_3|}{(3r)^2} = k\frac{|Q_2 Q_3|}{r^2}$$

Does the answer depend on the value of the charge 3?

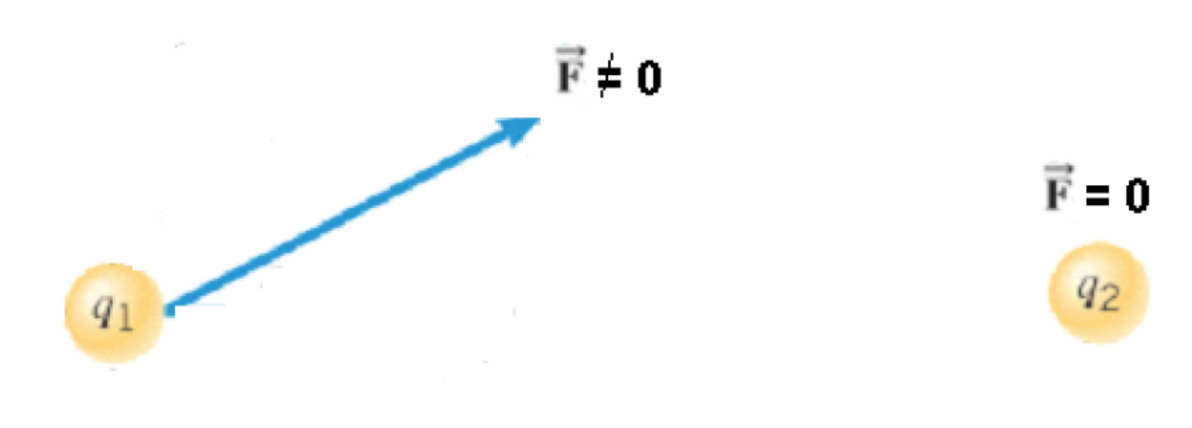
1. Yes
2. No

Electric Filed at a particular location describes …

1. the presence of a neutral object at that location
2. the presence of neutral object(s) around that location
3. the presence of a charge at that location
4. the presence of charge(s)around that location

5. the meaning of electric filed depends on a textbook
6. none of the above

Electric field



The first charge experiences non-zero electric force.

We say that *at the location of the first charge there is an electric field*.

The second charge does not experience a force.

We say that *at the location of the second charge there is no electric field* (electric field is zero).

What is a *definition* of electric field (strength)?

1. it equals the force acting on a negative test charge of -1 C

2. it equals the force acting on a positive test charge of 1 C

---

3. it equals $k\frac{Q}{r}$

4. it equals $k\frac{Q}{r^2}$

DEFINITION OF ELECRIC FIELD

The electric field that exists at a point is the electrostatic force experienced by a charge placed at that point divided by the charge itself:

$$\vec{\mathbf{E}} = \frac{\vec{\mathbf{F}}}{q_o}$$

SI Units of Electric Field: newton per coulomb (N/C)

Electric field acting on a charge q_0 (a test charge) is created by *other* charges (not by the charge q_0)!

There is nothing mysterious about electric field!

From the definition:

$$\vec{\mathbf{E}} = \frac{\vec{\mathbf{F}}}{q_o}$$

We have for the test charge $q_0 = 1$ C

$$\vec{\mathbf{E}} = \frac{\vec{\mathbf{F}}}{q_o} = \frac{\vec{\mathbf{F}}}{1} = \vec{\mathbf{F}}_{1C}$$

Electric field is just the force acting on the charge of +1 C.

If you want figure out the electric field created by some charges at some location, just insert a +1 C charge at that location and calculate the force on it!

MOST POSITIVE
Silk
Vinyl (PVC)
MOST NEGATIVE

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

1. You rub a small PVC sphere with silk, place it *here*, and observe the force to *the right*. What is the direction of electric field at that point?

1. to the left **2. to the right**

2. Now instead of your PVC sphere you place at the same location a small copper ball and feel the force to the left. What is the polarity of the charge on the ball?

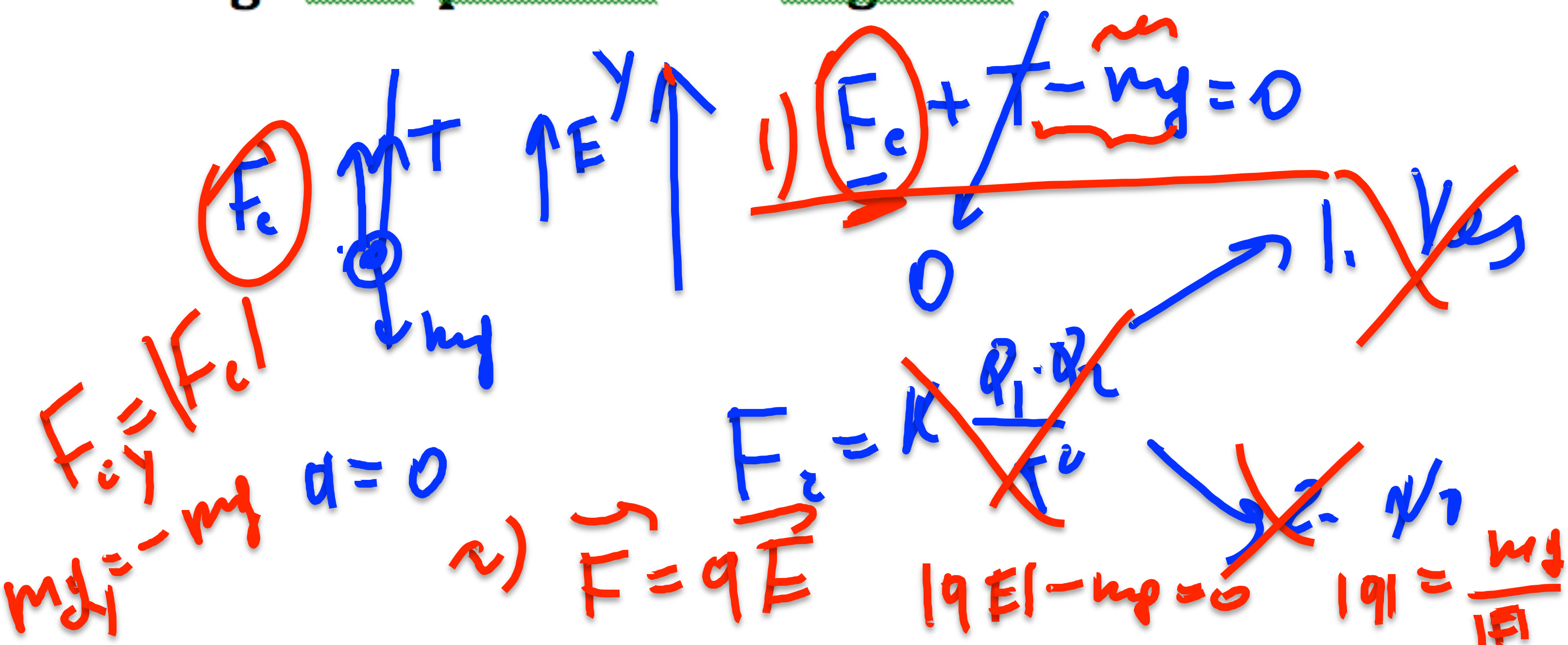
1. + **2. -**

3. How would you draw a picture for the electric field around a single *positive* charge?

4. How would you draw a picture for the electric field around a single *negative* charge?

A 0.400-g ball hangs from a thread in a uniform vertical electric field of 6.00 kN/C directed upward/downward. What is the charge on the ball if the tension in the thread is (a) zero and (b) 8.00 *m*N?

The charge is 1. positive 2. negative

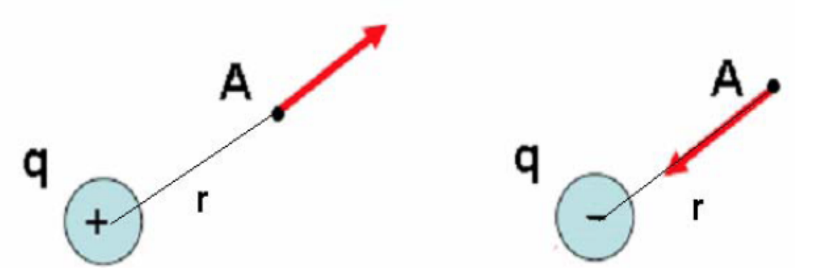


Remember!

Electric field *of a charge q* <u>at the point A</u>

is an arrow:

If q > 0	If q < 0
1) Which starts at the point A	
2) directs *from* the charge	2) directs *to* the charge
3) the *absolute value* of it $E = k\frac{\|q\|}{r^2}$	



The electric field does not depend on the test charge.

Source charge q:
(fixed in space)

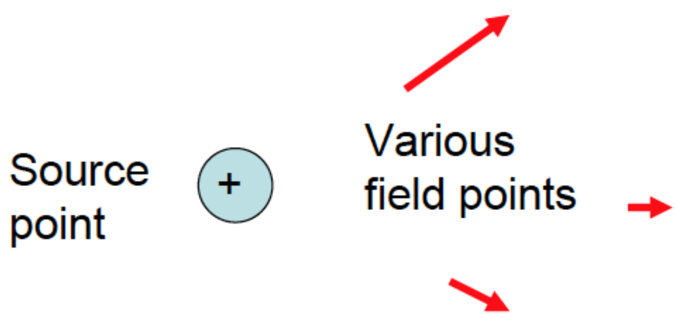
$$E = \frac{F}{|q_o|} = k\frac{|q||q_o|}{r^2}\frac{1}{|q_o|}$$

test charge q_o:
(at field point)

In this equation E represents ...
1. Actual value of the field
2. Absolute value of the field

$$E = k\frac{|q|}{r^2}$$

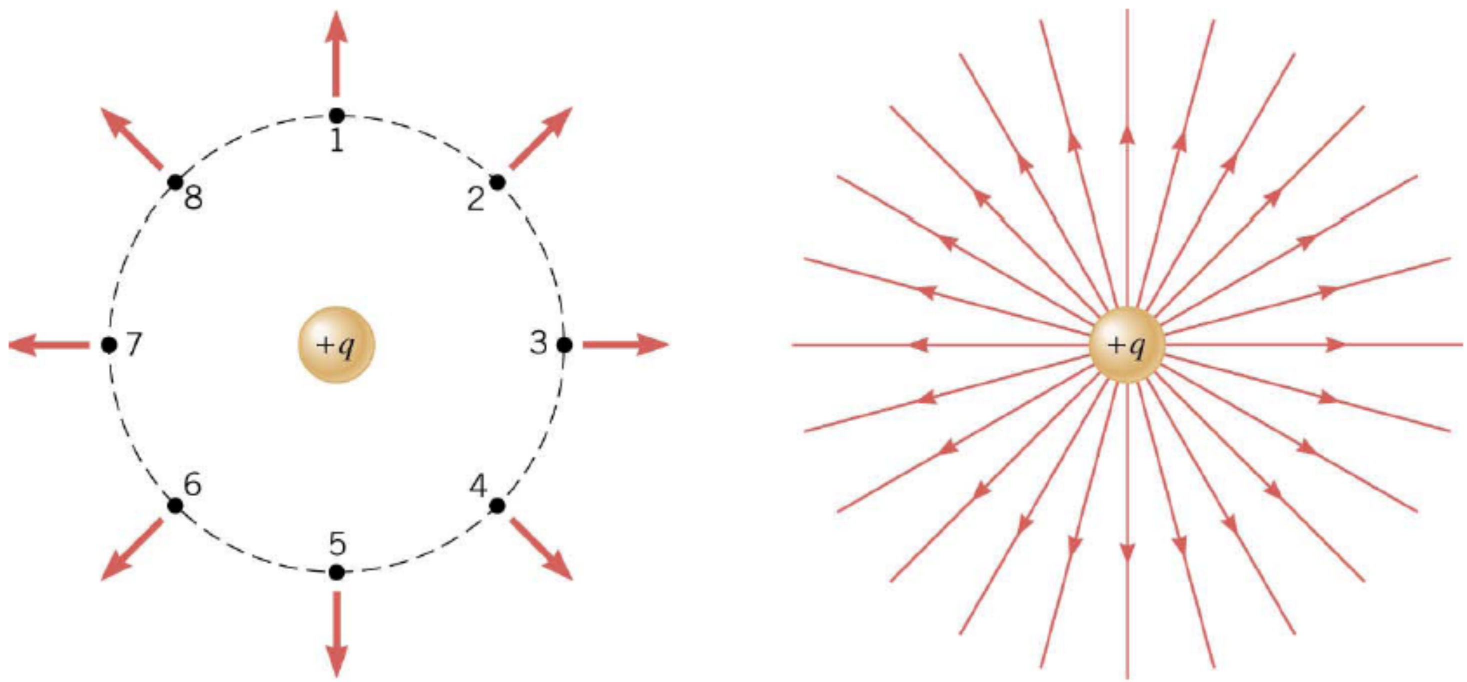
E at a field point a distance r from the source point.



$$\vec{\mathbf{E}} = \frac{\vec{\mathbf{F}}}{q_o} = \frac{\vec{\mathbf{F}}}{1} = \vec{\mathbf{F}}_{1C}$$

To test E field of a single charge we have to use *another* charge (1 C test charge) and measure force acting on it!

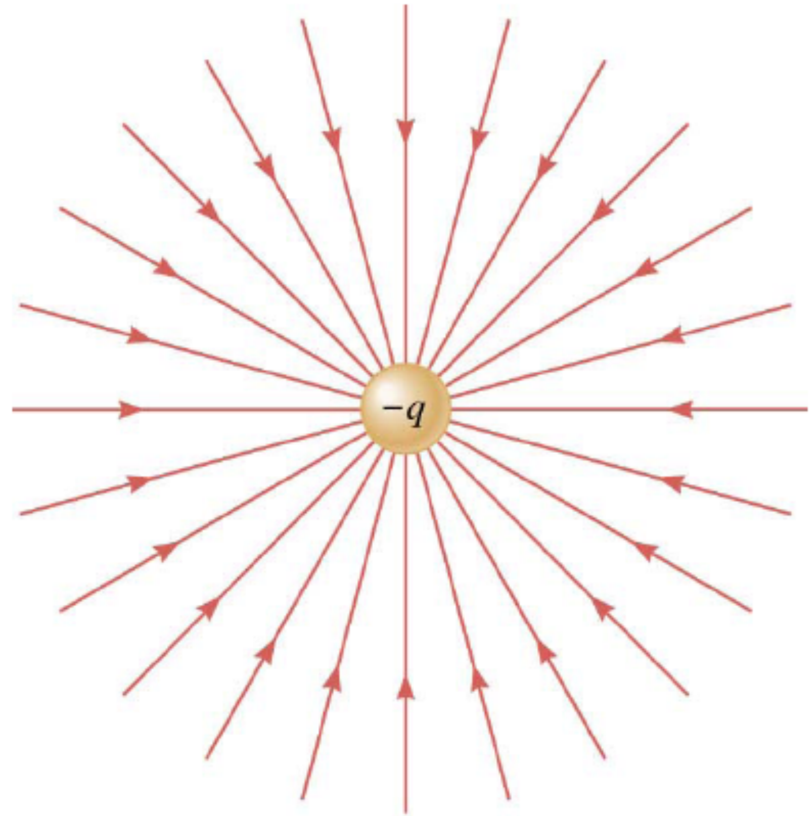
Electric field lines or ***lines of force*** provide a map of the electric field in the space surrounding electric charges.



(a) (b)

vectors

lines



Electric field lines are always directed away from positive charges and toward negative charges.

Rules for drawing electric field lines

1) Lines start at positive charges and directed from them

2) Lines end at negative charges and directed to them

3) Lines do not cross

4)Number of lines into or out of a charge should be proportional to that charge (for example, if one charge is 2Q and another is 6Q, the second charge has to have 3 times more lines then the first one)

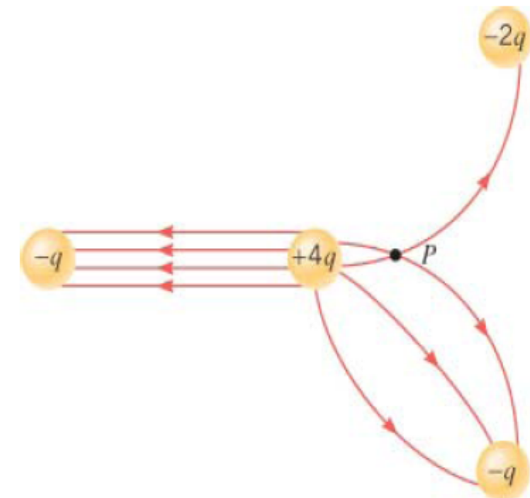
5)Lines should spread out when possible

6) The region with a larger value of E has more lines

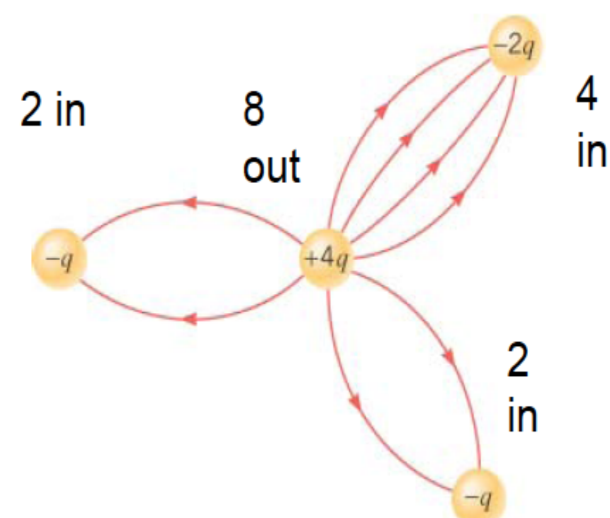
Drawing Electric Field Lines

There are three things wrong with part (a) of the drawing. What are they?

1) Lines shouldn't cross
2) Number of lines into or out of a charge should be proportional to that charge
3) Lines should spread out when possible

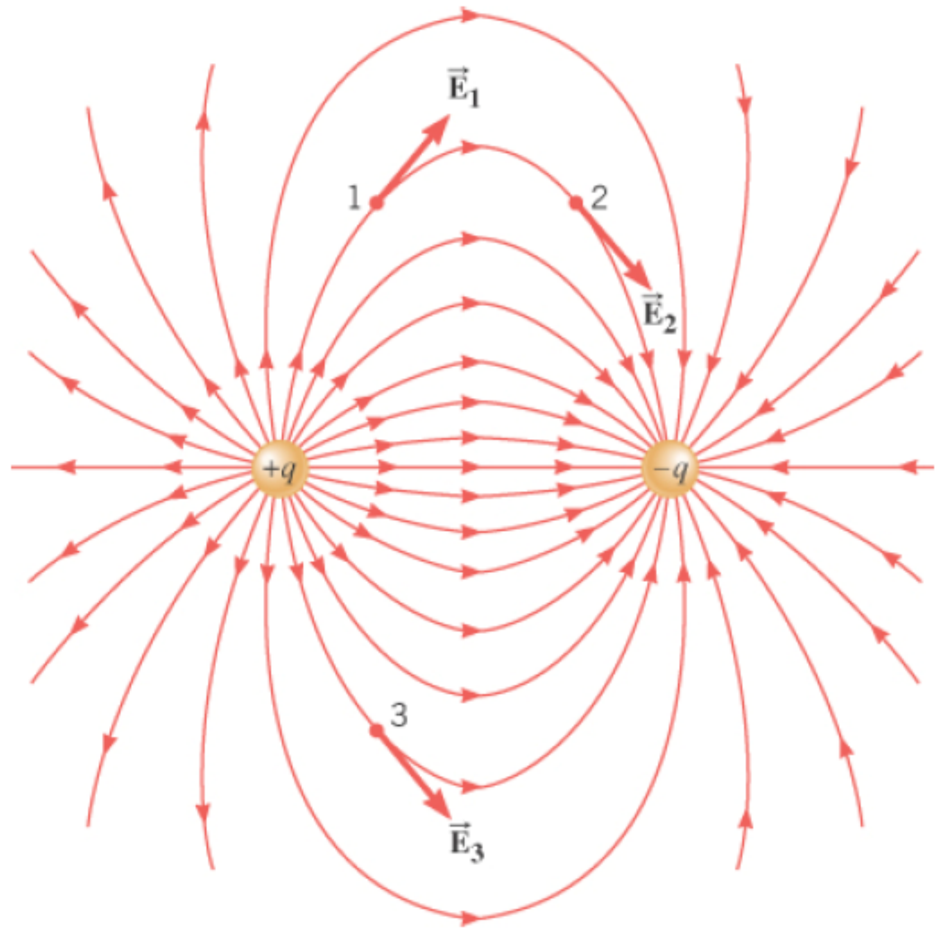


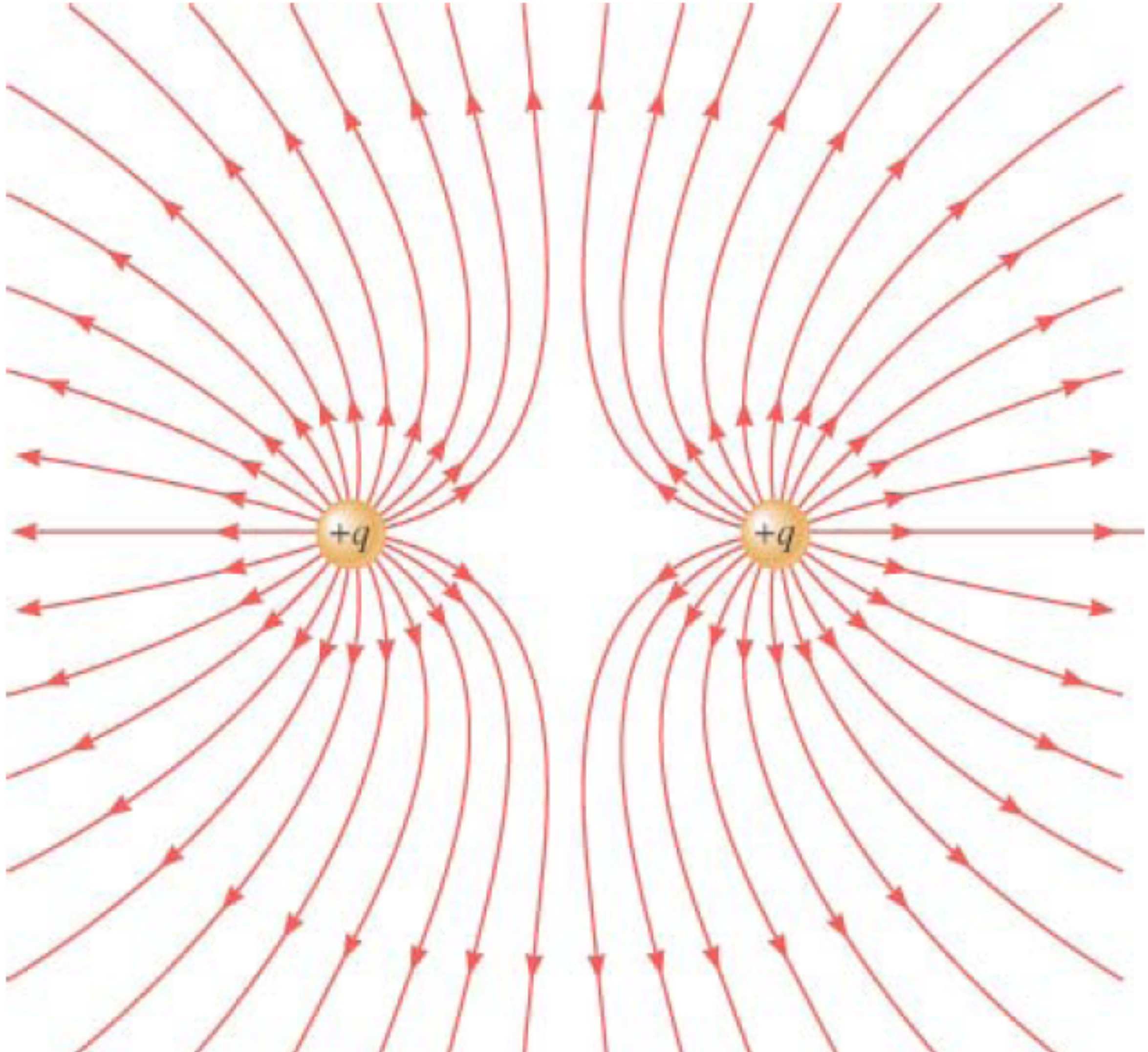
(a)



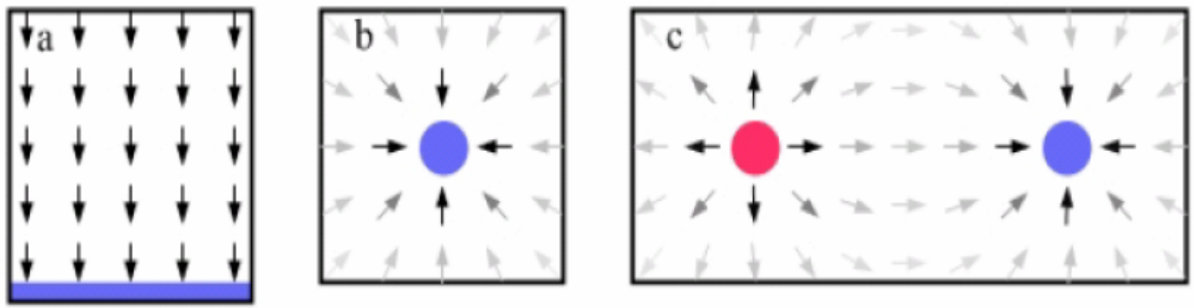
(b)

The number of lines leaving a positive charge or entering a negative charge is proportional to the magnitude of the charge.

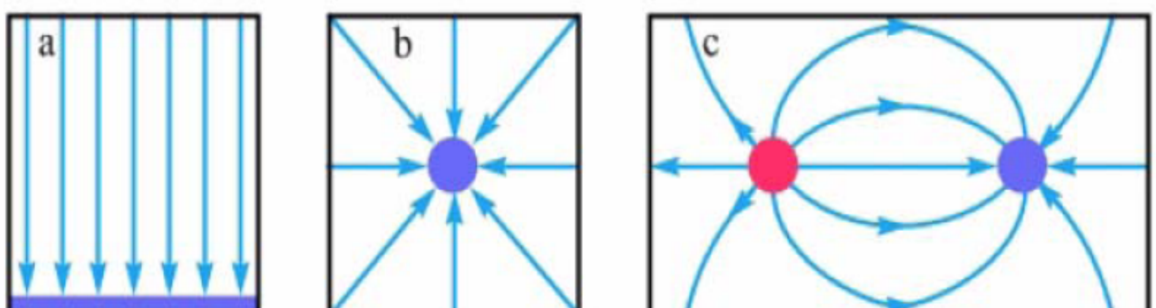



+q
+q

Electric field vectors



Electric field lines



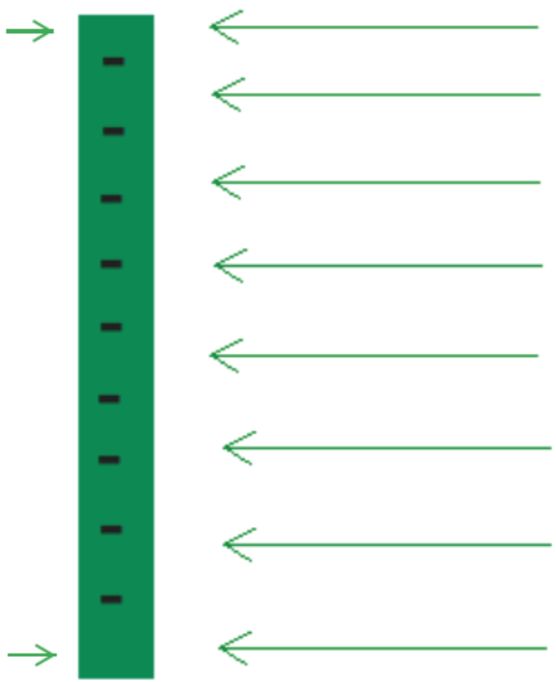
For one large plate with area A holding a uniformly distributed charge Q, its electric field is almost uniform and can be found as

$$k = \frac{1}{4\pi\varepsilon_o} = 9.0 \times 10^9 \ Nm^2/C^2$$

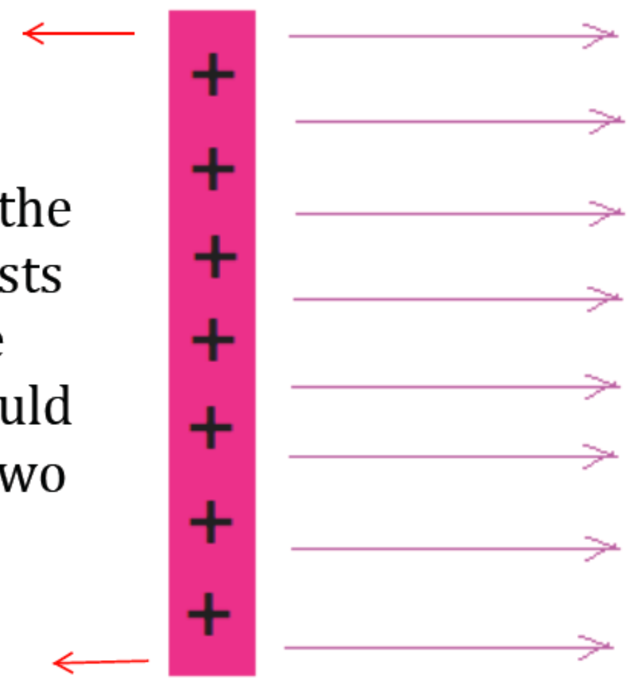
$$\varepsilon_0 = 8.85 \times 10^{-12} \ C^2/(Nm^2)$$

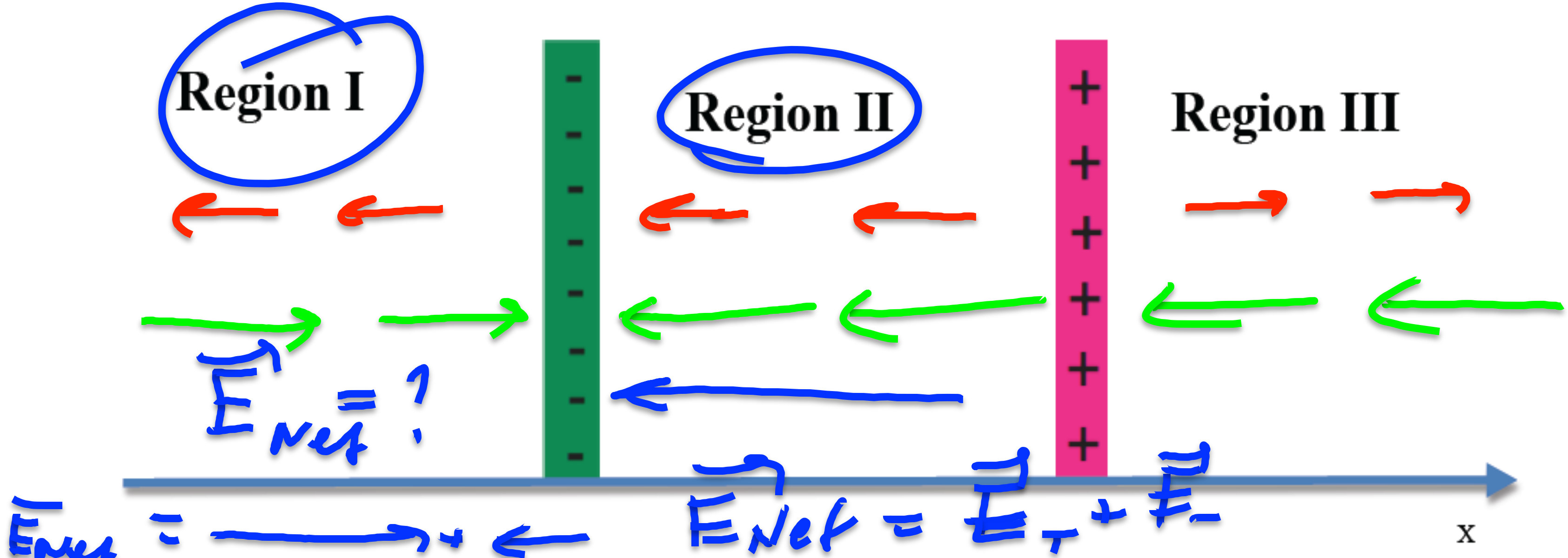
$$E = \frac{Q}{2\varepsilon_0 A} = \frac{\sigma}{2\varepsilon_0}$$ (For a single plate!)

$$\sigma = \frac{Q}{A}$$



(For a single plate the field, of course, exists on both sides of the plate, but what would you do if you had two charged plates?)





The picture shows two large plates with the same area but different charge: $Q_- = -2Q_+$. **How does E field look like if $Q_- = Q_+$?**

$|Q_-| = 2|Q_+|$ $|E_-| = 2 \cdot |E_+|$

Sketch the graph for X-component of the net field.

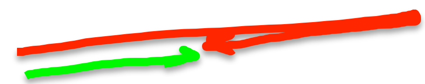
$$E = \frac{Q}{2\varepsilon_0 A}$$

(For a single plate!)

E-field between the plates points

1. to the right 2. to the left

$$E_{net} = \longrightarrow + \longleftarrow$$



1. $E_{net} \longleftarrow$
2. $E_{net} \longrightarrow$

$$E = \frac{Q}{2\varepsilon_0 A}$$

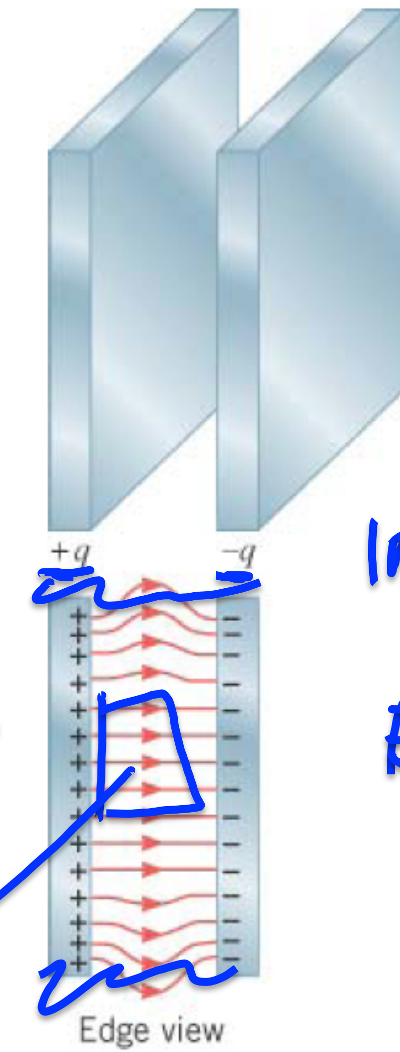
(For a single plate!)

$$E_{\text{Net}} = \frac{Q}{\varepsilon_0 A}$$

(Between the plates!)

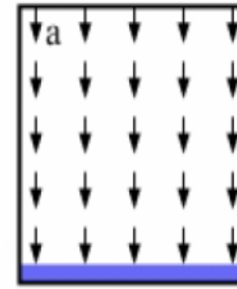
Electric field lines always begin on a positive charge and end on a negative charge and do not stop in midspace.

How does E field look like if $Q_- = Q_+$?

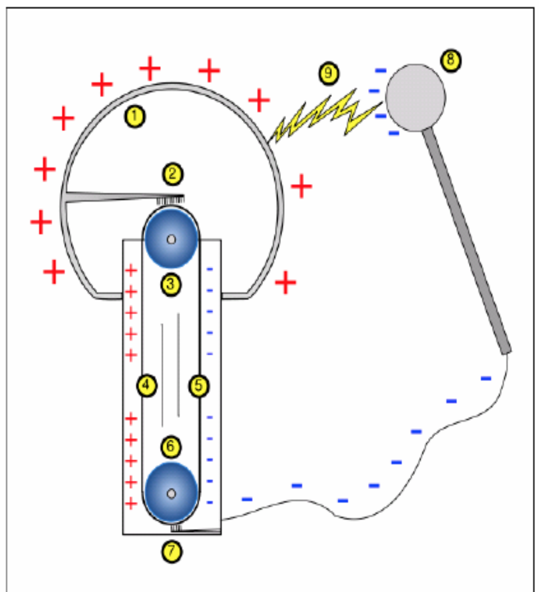


Let's take a look at electric field!

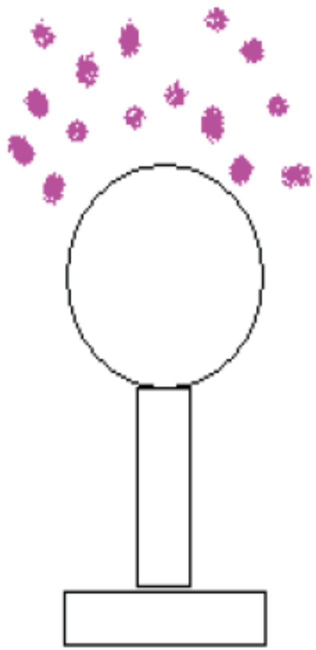
1. A seed viewer and a Wimshurst machine.



2. A Van der Graaf generator.



Van der Graaf Generator



$$W_{Net} = \tfrac{1}{2}mv_f^2 - \tfrac{1}{2}mv_o^2$$

The generator induces elecric field around the dome

Does tha electric field do any work on the peanuts?

1. Yes

2. No

3. Depends on the point of view

What do we know about energy?

What do we know about potential energy?

What do we know about kinetic energy?

Which equation correctly represents a connection between work W done by electric field on a charge and potential energy PE of the charge?

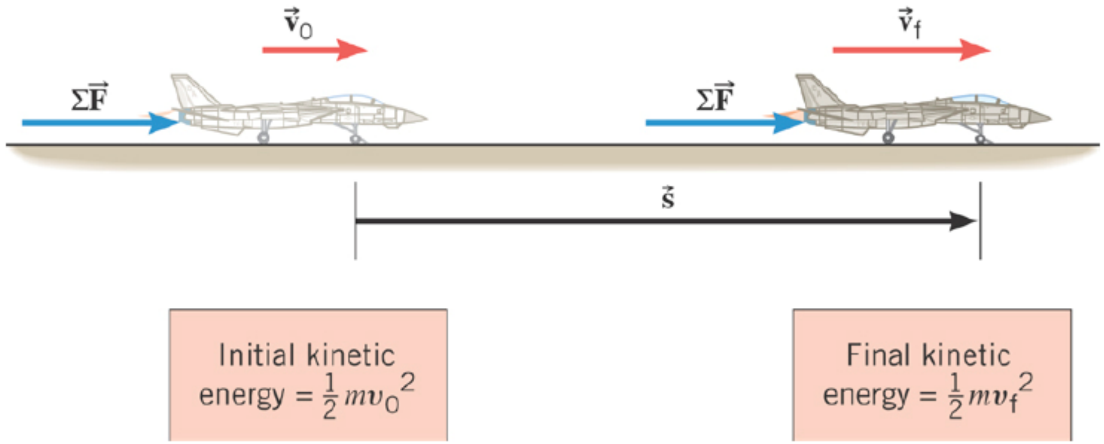
1. $$W_{El\ Field} = PE_{final} - PE_{initial}$$

2. $$W_{El\ Field} = PE_{initial} - PE_{final}$$

$W = V_i - V_f$

3. $$W_{El\ Field} = |PE_{final} - PE_{initial}|$$

REVIEW



THE WORK- KINETIC ENERGY THEOREM

When a net external force does work on and object,

the kinetic energy of the object changes according to

$$W_{Net} = \mathrm{KE_f} - \mathrm{KE_o} = \tfrac{1}{2}mv_f^2 - \tfrac{1}{2}mv_o^2$$

Helpful connections

$$W_{net\ on\ object} = KE_{final} - KE_{initial}$$

$$W_{conservative(field)} = PE_{initial} - PE_{final}$$

$$W_{field} = -W_{against\ field}$$

$$KE_{initial} + PE_{initial} + W_{non\ concervative} = KE_{final} + PE_{fi}$$

Potential energy of charge q in uniform electric field E can be written as …

1. $\frac{mV^2}{2}$

2. mgh

3. $\frac{kX^2}{2}$

4. qEx

5. $-qEx$

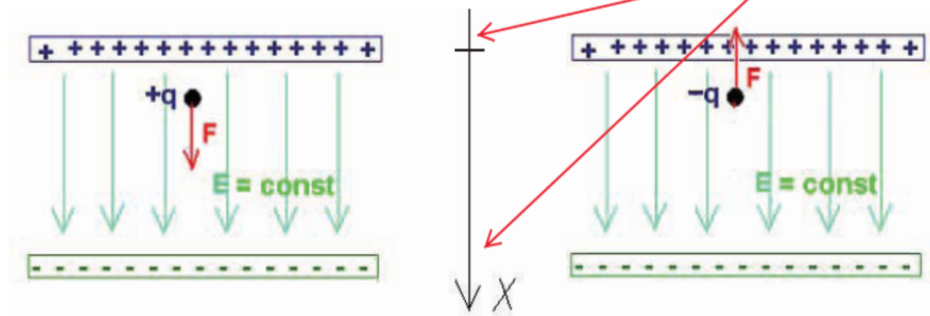
6. this question is ambiguous

Potential energy of a charge in a uniform electrostatic field

when a charge is in a uniform electrostatic filed,
it has a potential energy of:

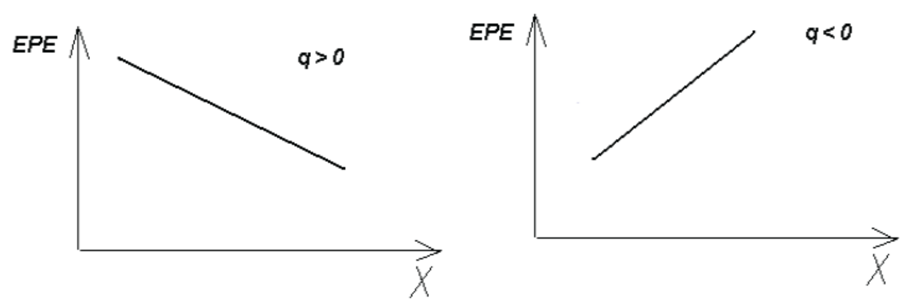
$EPE = -q*E*x$ [If1, If2, If3]

Three BIG IFs!!



The graph of potential energy of a charge a uniform filed is:

The same field, but different charges!



When released, a charge is moving in the direction of the *lower* potential energy.

Potential energy of a charge in a uniform electrostatic field

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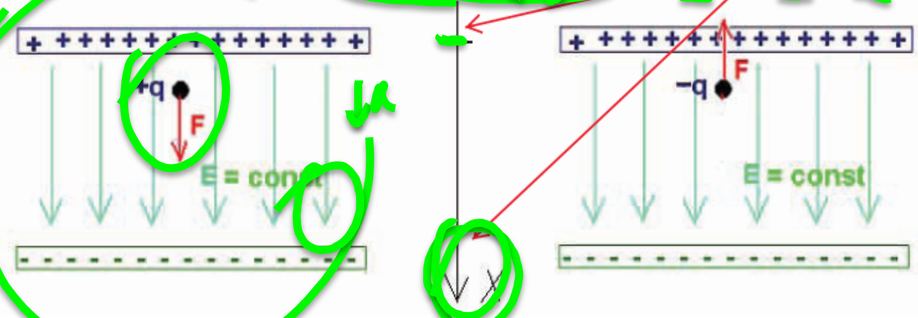

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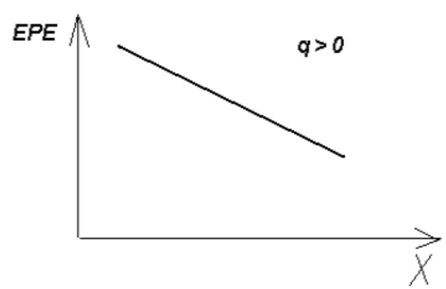
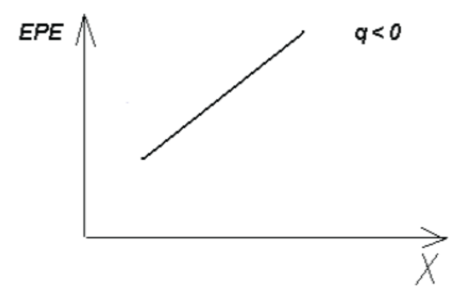




When released, a charge is moving in the direction of the *lower* potential energy.

What is a *definition* of electric potential?

1. it equals the energy of a negative test charge of -1 C

2. it equals the energy of a positive test charge of 1 C

3. it equals $k\frac{Q}{r}$

4. it equals $k\frac{Q}{r^2}$

Electric potential

Definition:

The physical quantity (variable)

$$V = EPE/q = U/q$$

$$U = q \cdot V$$
$$F = qE$$

is named *electric potential of the field at the given location*

(SI unit is J/C = V, volt)

If U is the potential energy of a charge q in an electrostatic field; the quantity $U/q = V$ is called *the potential* of the field.

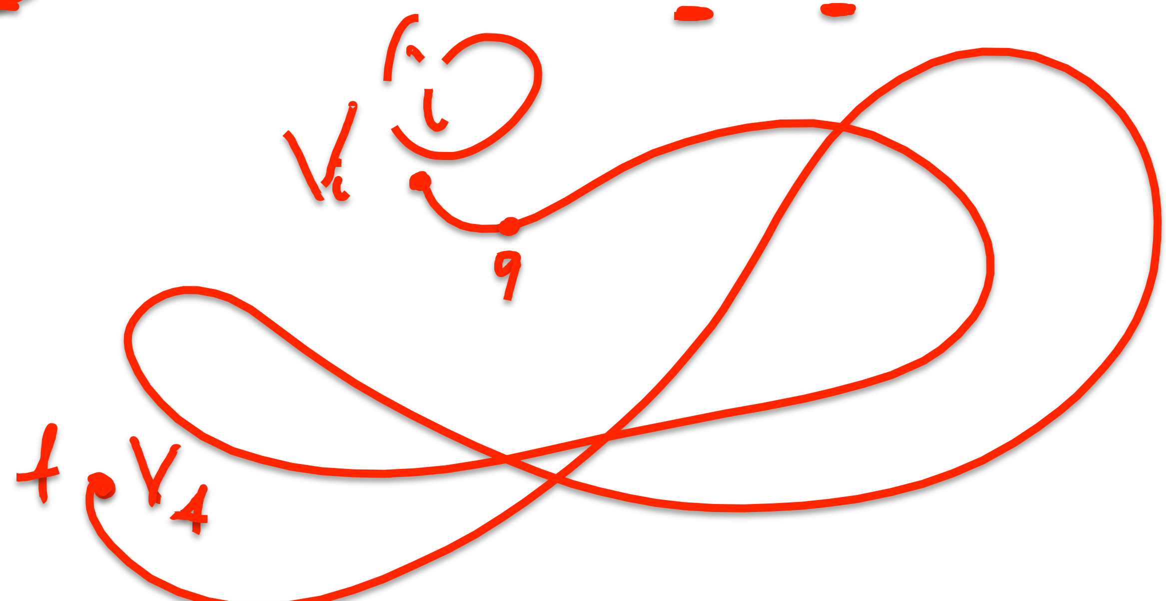
$$\text{IF } q = 1\text{ C} \Rightarrow \quad V = EPE_1/1 = U_1/1 = U_1$$

$$U = qV$$

When a charge *q* is being moved in an electric field, the work done *by electric field* on the charge is …

1. $W_{el\,f} = q \times (V_i - V_f)$
2. $W_{el\,f} = q \times (V_f - V_i)$
3. $W_{el\,f} = V \times (q_i - q_f)$
4. $W_{el\,f} = V \times (q_f - q_i)$

$W_{el} = U_i - U_f$



A connection between work and potential

Fact # 1: Work of electric force: $W_{El} = EPE_i - EPE_f$

Fact # 2: Potential energy of a charge: $EPE = qV$

=>

$$W_{El} = qV_i - qV_f = q(V_i - V_f) = -q(V_f - V_i) = -q\Delta V$$

$\Delta V = V_f - V_i$ is the change in the potential between two points in the field

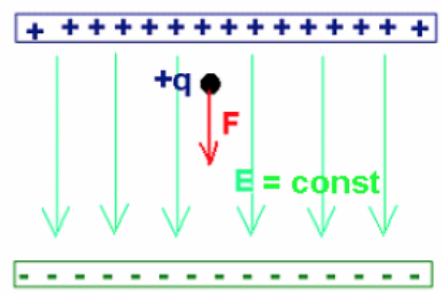
$|\Delta V|$ is called by many *a potential difference*

{sometimes it is convenient to remember that the absolute value of the work a field does on a charge:
$|W_{El}| = |q| * |\Delta V|$ }

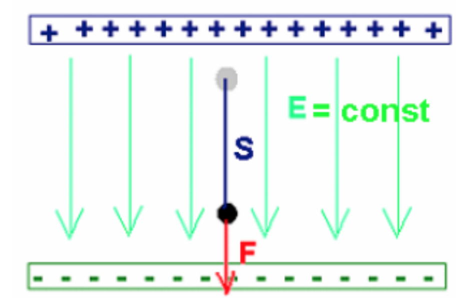
A point charge in a uniform electric field

(and no other forces)

Initial location



Final location



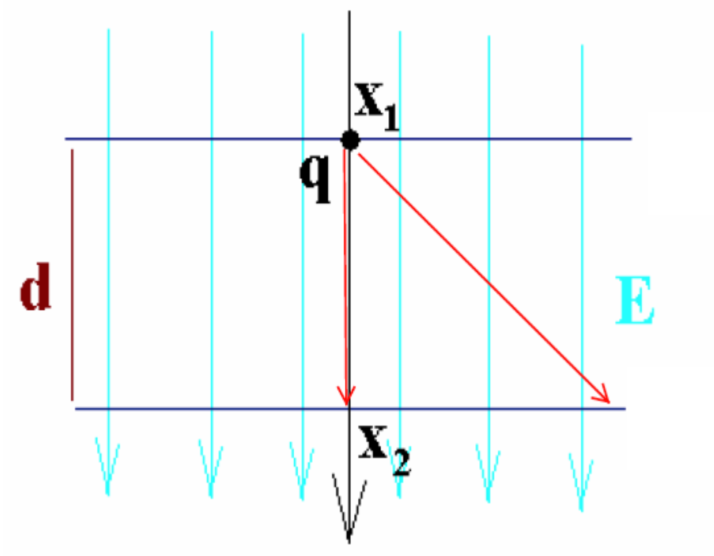
$F = qE$ is the Coulomb's force acting on the charge

S is the displacement of the charge

The work of the electric field/force is $W_{El} = F*S = q*E*S$

We can say that *electric field has an ability to do a work* on a charge.

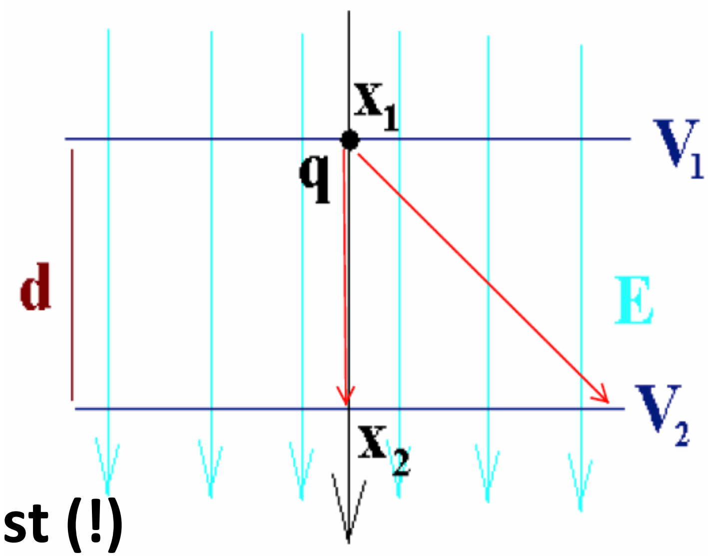
In other words, a charge in electric field *has a potential energy!*



In the picture on the left which arrow represents the path with more work done?

1. the long one
2. the short one
3. neither

Potential difference in a uniform electric field



V = const (!)

In the picture on the left which arrow represents the path with more work done?

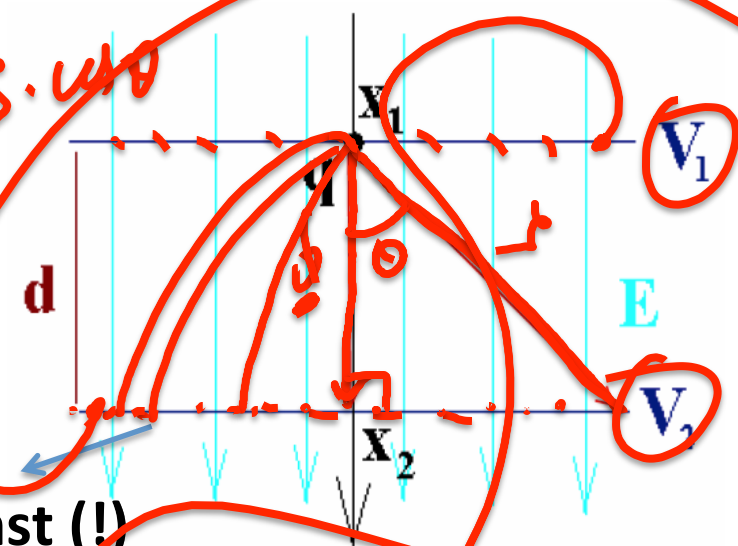
1. **the long one**
2. **the short one**
3. **neither**

$$W = F \cdot s\cos\theta$$

$$W_{El} = q(V_1 - V_2)$$

$V_1 - V_2 = Ed$ (Notice that $V_1 > V_2$, can you tell why?)

Potential difference in a uniform electric field



In the picture on the left which arrow represents the path with more work done?

1. the long one
2. the short one
3. neither

V = const (!)

$$W = F \cdot s\cos\theta$$

$$W_{El} = q(V_1 - V_2)$$

$V_1 - V_2 = Ed$ (Notice that $V_1 > V_2$, can you tell why?)

Electric potential

$$V = EPE/q = U/q$$

From this definition we can derive:

The potential energy U of a charge q in a field at the location with the electric potential V

$$U = EPE = qV$$

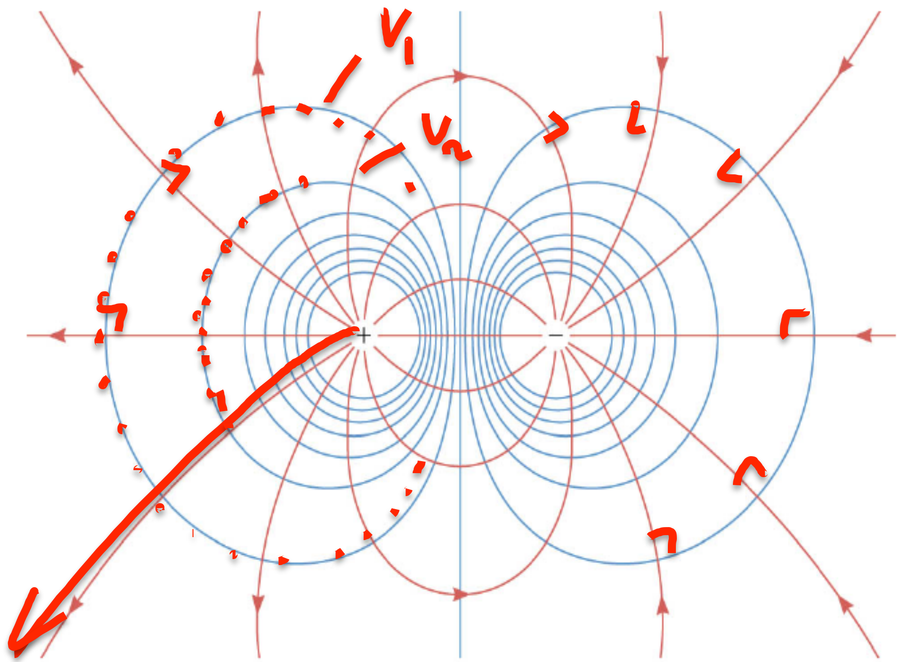
We can say now that *electrostatic field has at every point*:

1. Electric field $\boldsymbol{E}$ which creates a force $\boldsymbol{F} = q\boldsymbol{E}$ on a charge q located at that point

2. Electric potential V which creates potential energy $U = qV$

Equipotential Surfaces and Their Relation to the Electric Field:

A dipole



In the picture above:

1. red lines are equipotentials and blue lines are field lines
2. red lines are field lines and blue lines are equipotentials
3. it can be both