Electric Field-I

Phy 108 course
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Learning Objectives (Electric Field Topics)

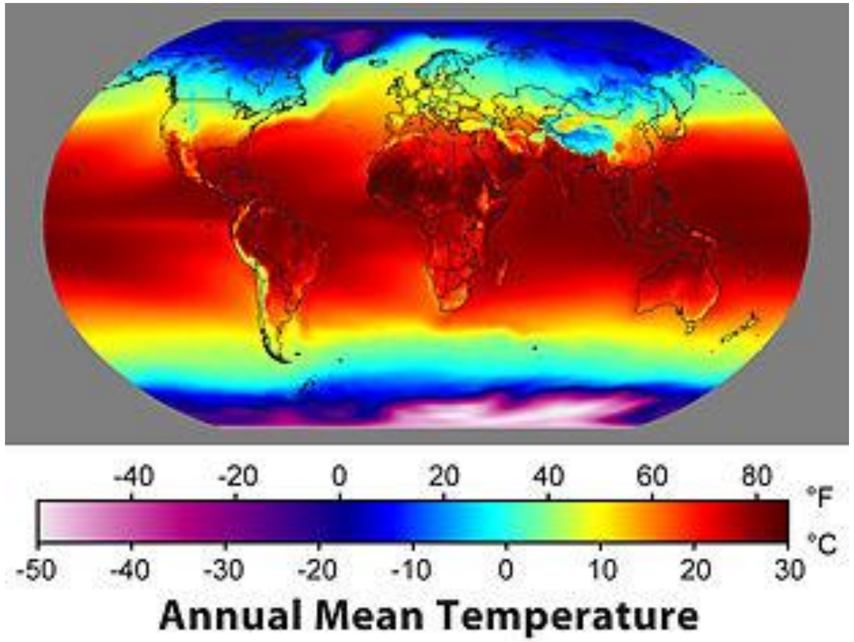
By the end of these lessons, students should be able to:

- ❑ **Define** electric field as a vector field created by charged objects.
- ❑ **Describe** the direction and strength of electric fields from point charges (positive and negative).
- ❑ **Apply** Coulomb’s Law to calculate the electric field due to a point charge.
- ❑ **Explain** the superposition principle for multiple charges.
- ❑ **Interpret** electric field lines and understand their significance in field strength and direction.
- ❑ **Distinguish** between scalar and vector fields with physical examples (e.g., temperature vs. electric field).
- ❑ **Analyze** electric fields generated by:
    - ❑ **Point charges**
    - ❑ **Electric dipoles**
    - ❑ **Continuous charge distributions** (line, surface, and volume)
- ❑ **Calculate** torque and potential energy of a dipole in an electric field.
- ❑ **Solve** problems involving the electric field on axes of rings, disks, and infinite sheets.
- ❑ **Relate** real-world applications like microwaves, DNA base pairing, and lightning to electric field theory.

A lot of different fields are used in science and engineering.

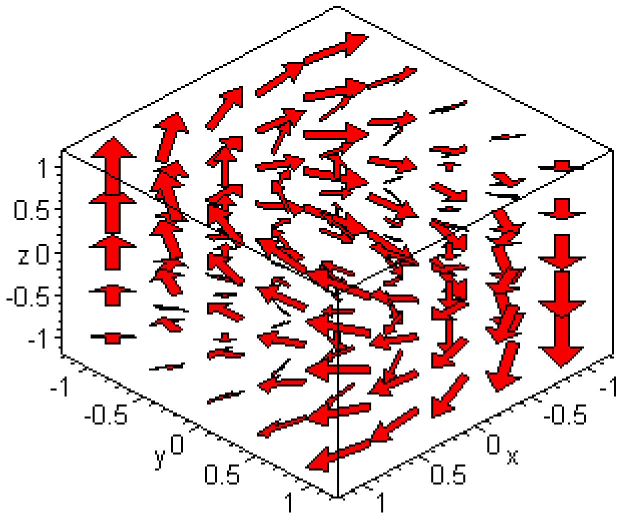
Scalar Field

Scalar field is a function of a space whose value at each point is a scalar quantity.
For example, annual mean temperature presentation is showing the temperature over the Globe. Similarly, we could define a *pressure field* in a swimming pool. Such fields are examples of *scalar fields* because temperature and pressure are scalar quantities, having only magnitudes and not directions.

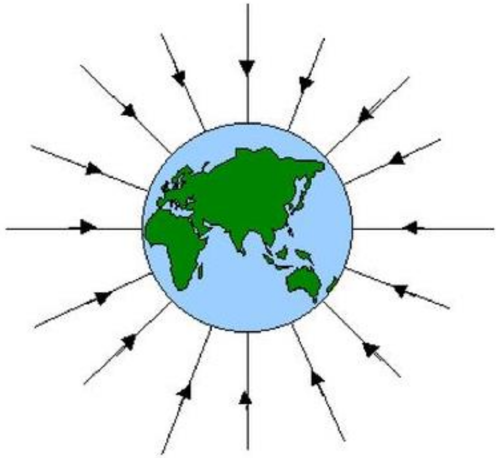


Vector Field

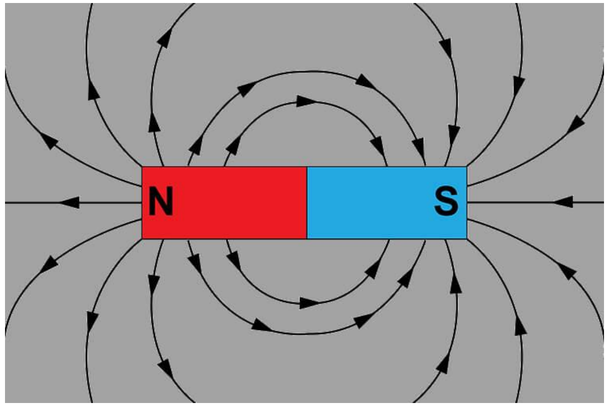
In contrast, vector field is a function of a space whose value at each point is a vector quantity.



- The space around a charge is altered to create an **electric field**.
- The alteration of space around a mass is called the **gravitational field.**
- The alteration of space around a magnet is called the **magnetic field.**



Gravitational field lines in space pull masses towards the earth (which is still straight down).



This dramatic photograph captures a lightning bolt striking a tree near some rural homes. Lightning is associated with very strong electric fields in the atmosphere.

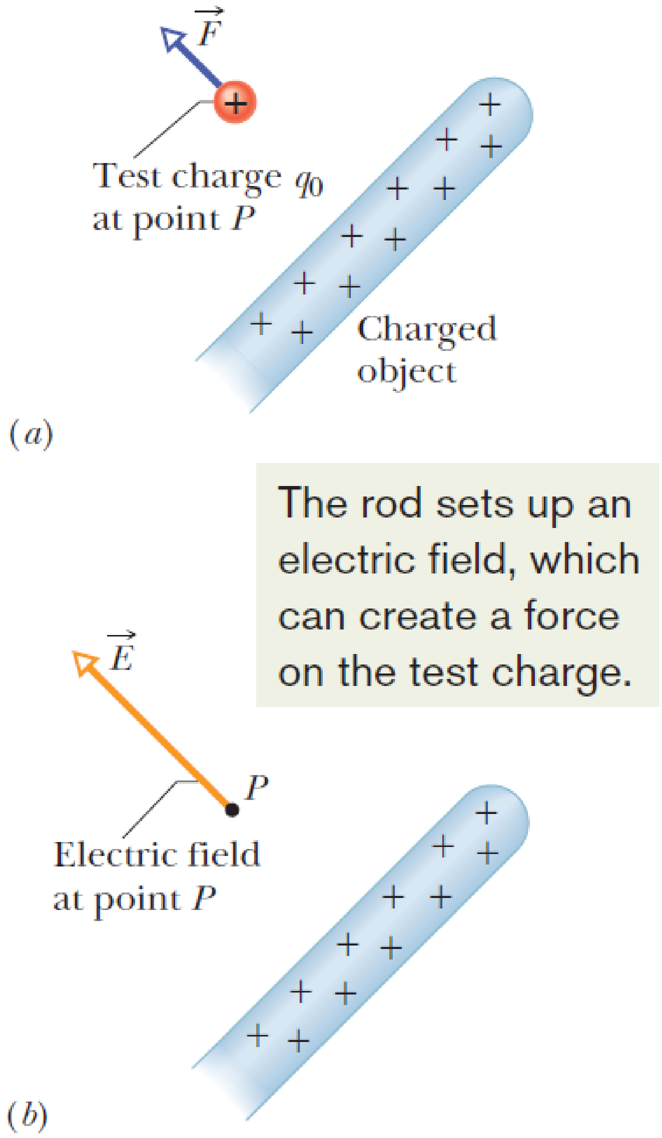
Electric field

A force field is defined as a property of space in which a material object experiences a force.

Above earth, we say there is a gravitational field at P. Because a mass *m* experiences a downward force at that point.

The direction of the field is determined by the force.

No force, no field; No field, no force!



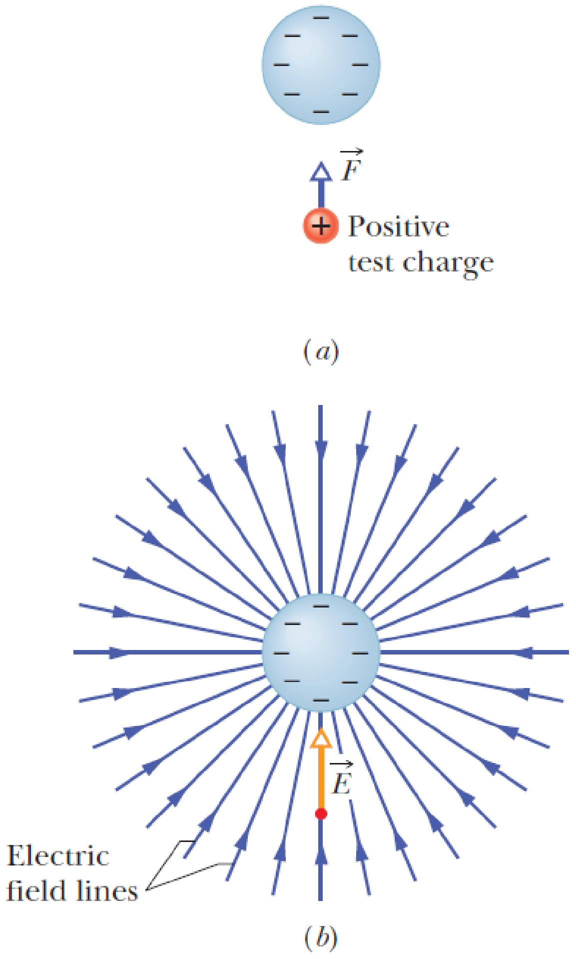
Electric field

Let us consider a point charge Q placed in vacuum, at the origin O. If we place another small point charge q_0(called test charge) at a point P, where $OP = r$, then the charge Q will exert a force on q as per Coulomb's law,

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

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

(Electric field)



A test charge is used to test the field. We want the charge to be small so that it does not disturb the object's charge distribution.

- The units are newtons/coulomb, N/C.
- The magnitude E of the electric field is called the electric field strength.

https://www.compadre.org/osp/EJSS/4504/289.htm#:~:text=A%20test%20charge%20is%20like,field%20at%20a%20given%20point.

Concept of TEST CHARGE

It shows you the force that a positive charge would feel at a given location, but it does not change the surrounding field.

In other words, the test charge shows you the direction and magnitude of the electric field at a given point.

A **test charge** is an arbitrarily small point charge which can be imagined to be introduced into an electric field or magnetic field for the purpose of investigating the theoretical force on that **test charge**.

Electric field and Gravitational Field

In the case of electrostatic force,

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

Thus the electric field at a specific point

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

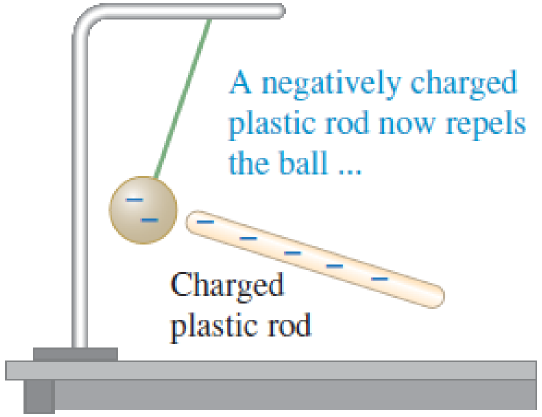
In the case of gravitational force,

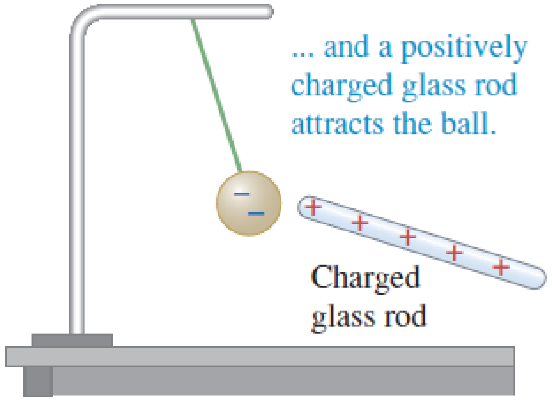
$$\vec{F} = m\vec{g}$$

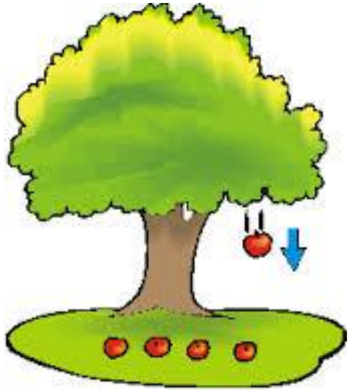
Thus the gravitational field at a specific point,

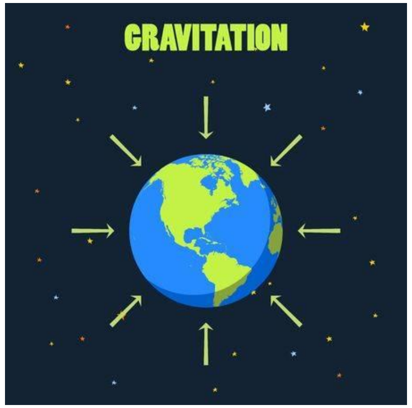
$$\vec{g} = \frac{\vec{F}}{m}$$

If $\vec{g}$ is known at every point above the earth then the force $\vec{F}$ on a given mass can be found.

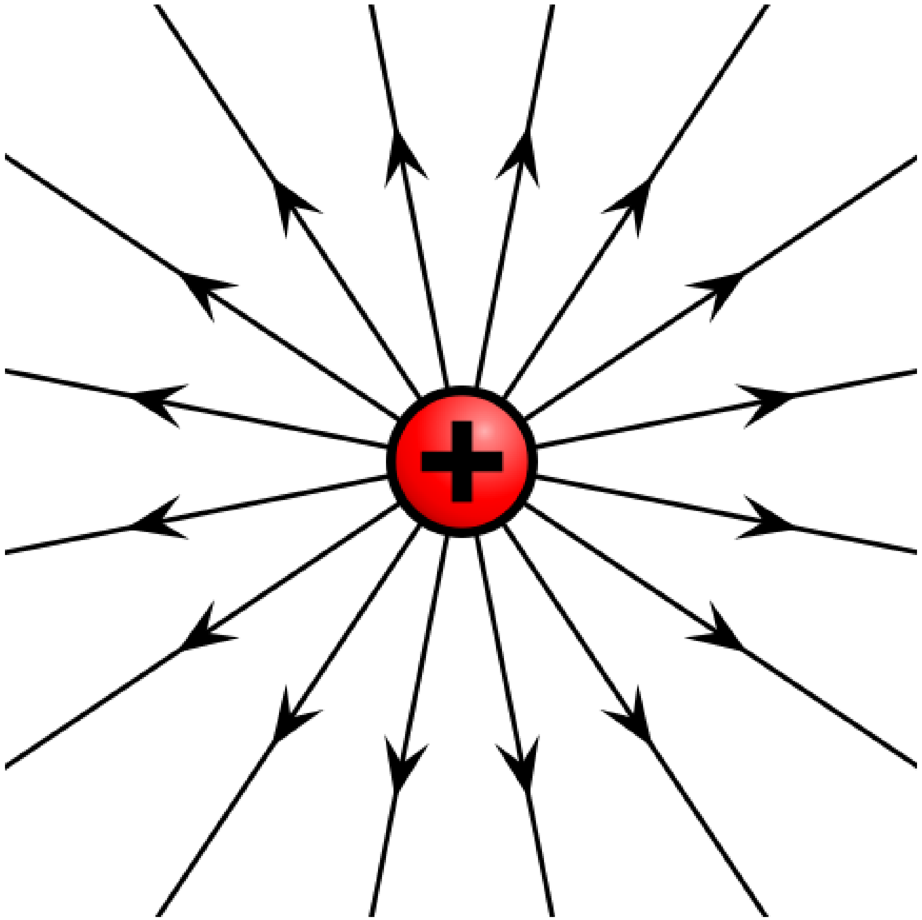






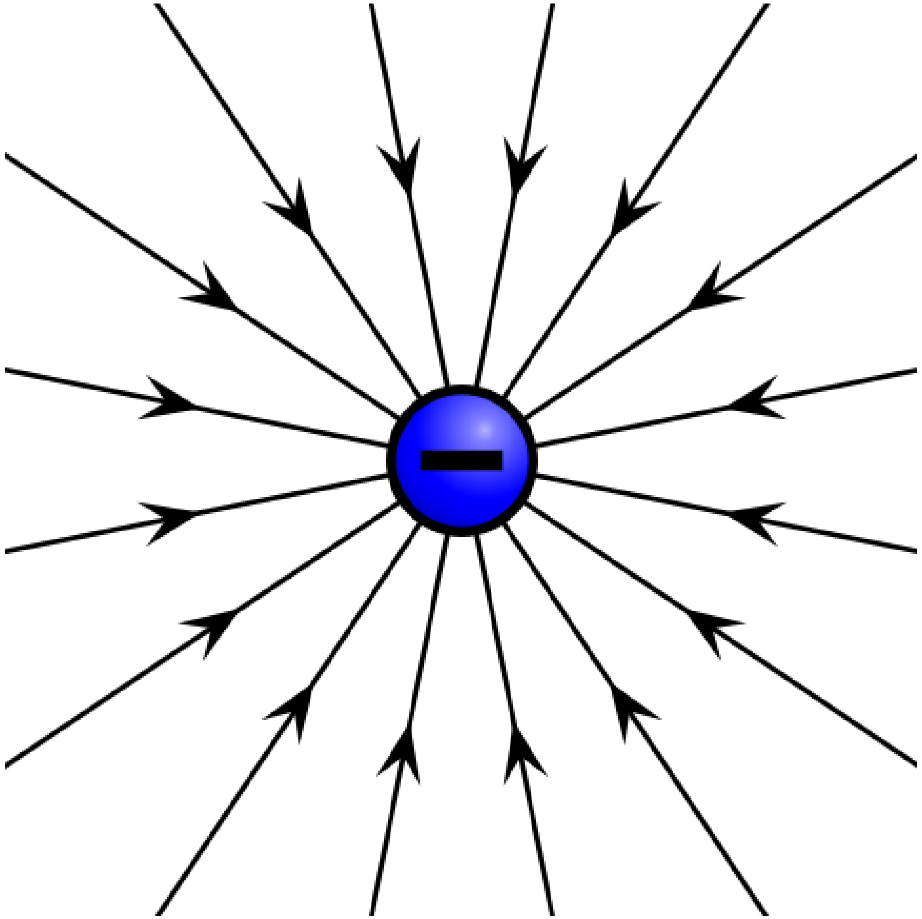


Electric field lines



Electric field of positive point charge

The electric field of a positively charged particle points radially away from the charge.



Electric field of negative point charge

The electric field of a negatively charged particle points radially toward the particle.

http://physics.bu.edu/~duffy/HTML5/EField.html

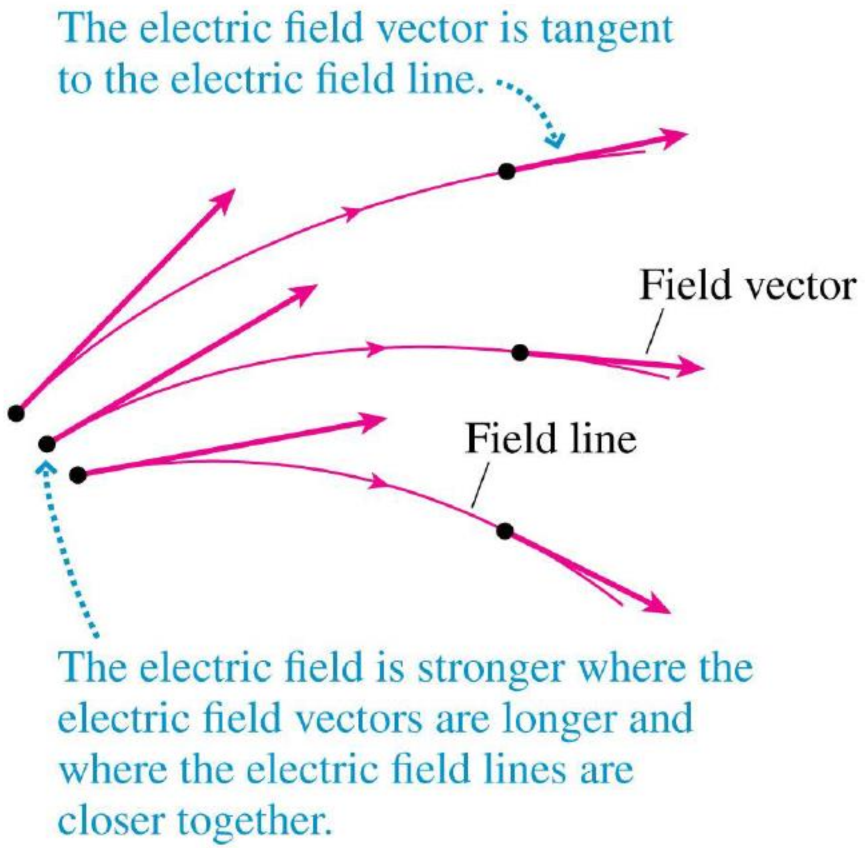
Electric Field Lines

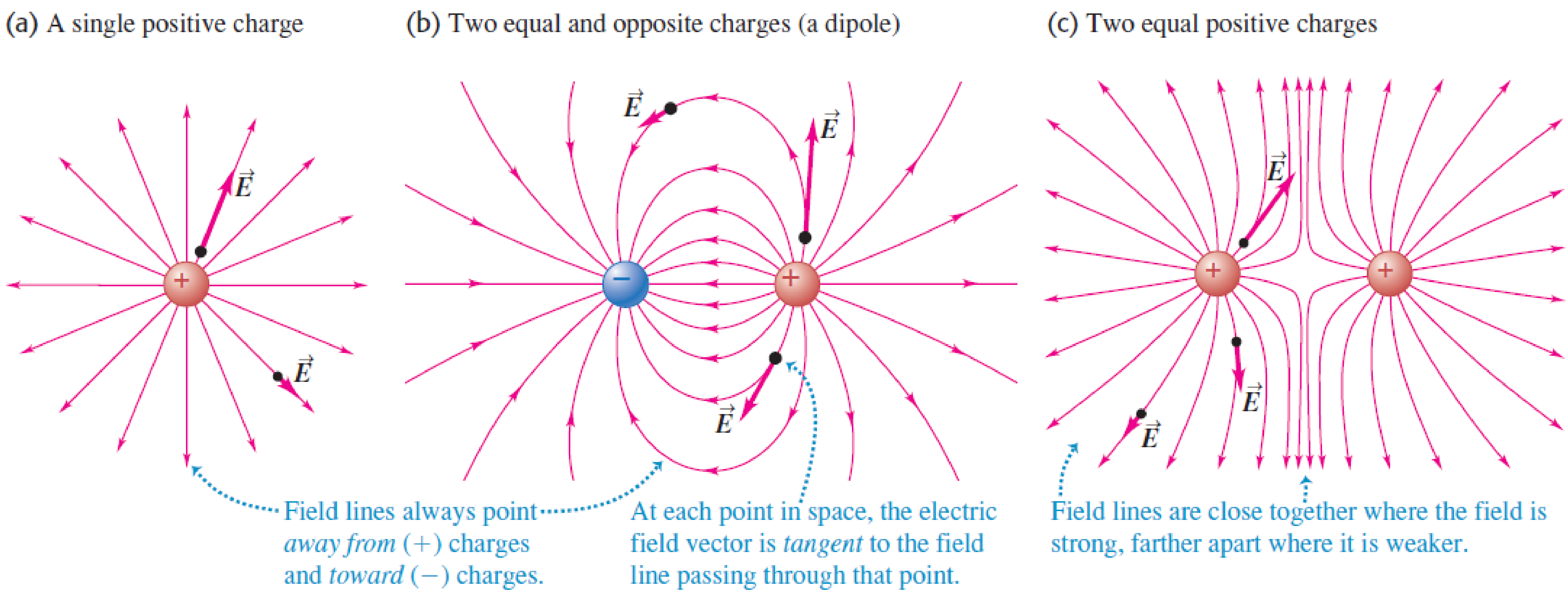
The concept of an electric field can be a little elusive because you can't see an electric field directly. Electric field *lines* can be a big help for visualizing electric fields and making them seem more real.

An **electric field line** is an imaginary line or curve drawn through a region of space so that its tangent at any point is in the direction of the electric-field vector at that point.

The spacing of the lines must be such that they are close together where the field is strong and far apart where the field is weak.

At any particular point, the electric field has a unique direction, so only one field line can pass through each point of the field. In other words, *field lines never intersect.*



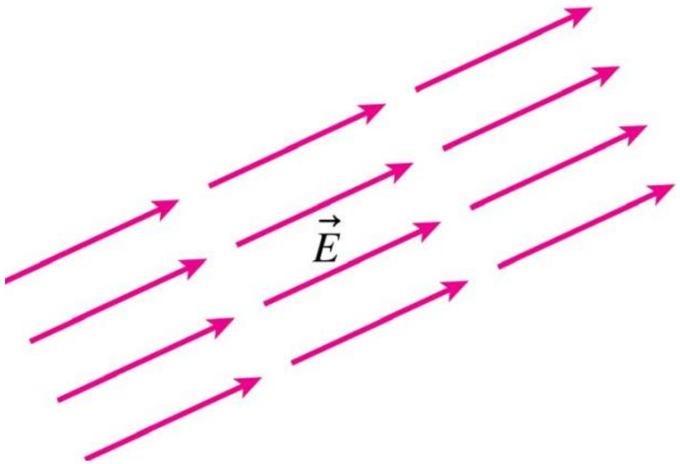


The electric filed is strong between the charges, as exhibited by the high concentration of field lines connecting them.

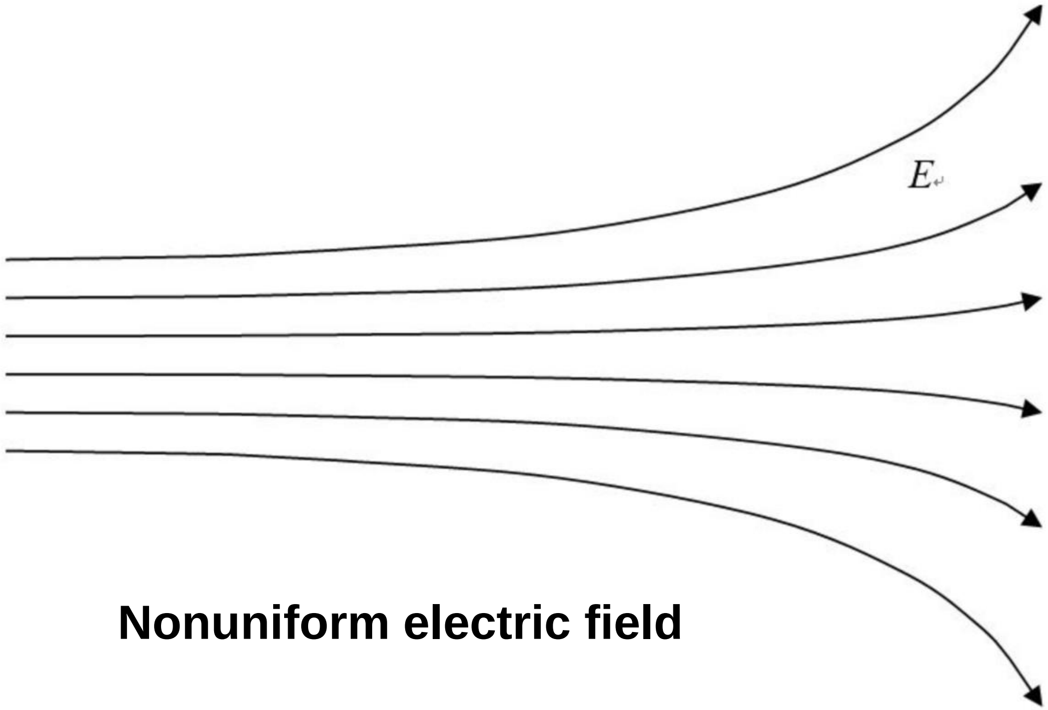
The electric field is weak between like charges (the concentration of field lines is low between them).

https://javalab.org/en/electric_field_line_en/

The figure shows an electric field that is the *same*—in strength and direction—at every point in a region of space.

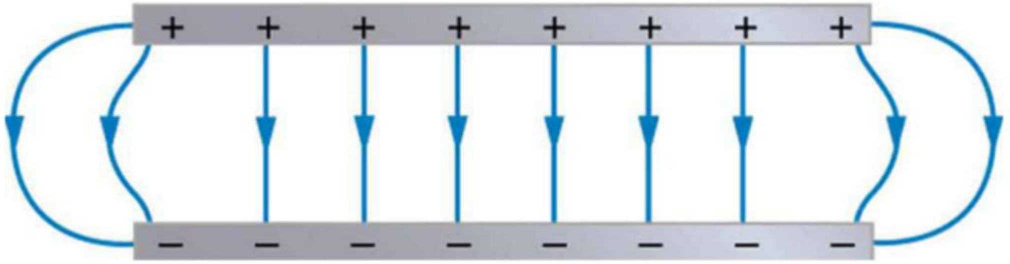


Uniform electric field



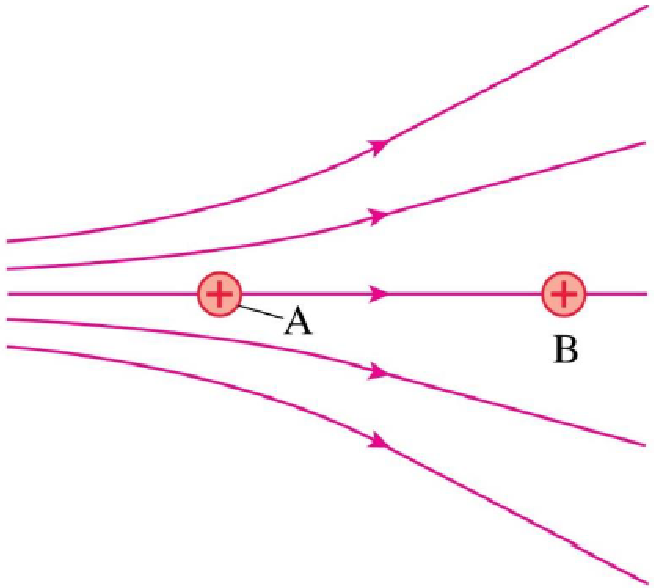
Nonuniform electric field

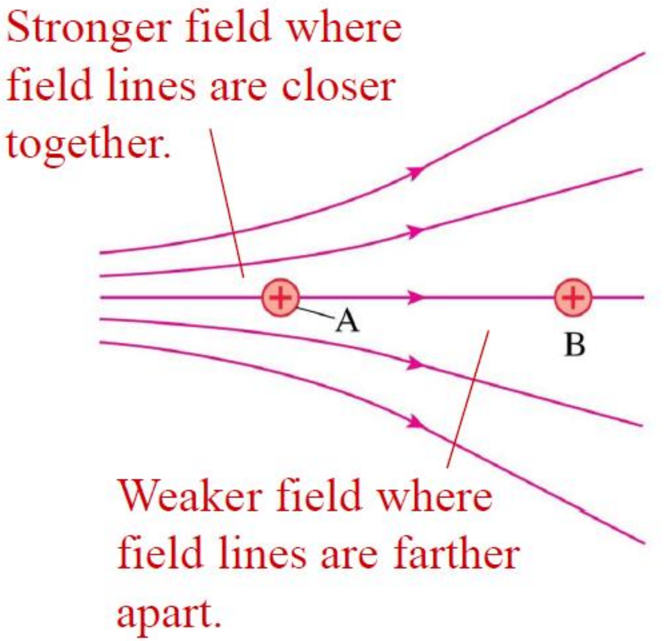
The easiest way to produce a uniform electric field is with a parallel-plate capacitor.



Two protons, A and B, are in an electric field. Which proton has the larger acceleration?

A. Proton A
B. Proton B
C. Both have the same acceleration.





Sharks have the ability to locate prey (such as flounder and other bottom-dwelling fish) that are completely hidden beneath the sand at the bottom of the ocean.

They do this by sensing the weak electric fields produced by muscle contractions in their prey. Sharks derive their sensitivity to electric fields (a "sixth sense") from jelly-filled canals in their bodies.

These canals end in pores on the shark's skin (shown in this photograph). An electric field as weak as $5 \times 10^{-7} N/C$ causes charge flow within the canals and triggers a signal in the shark's nervous system. Because the shark has canals with different orientations, it can measure different components of the electric-field vector and hence determine the direction of the field.

https://www.youtube.com/watch?v=JDPFR6n8tAQ

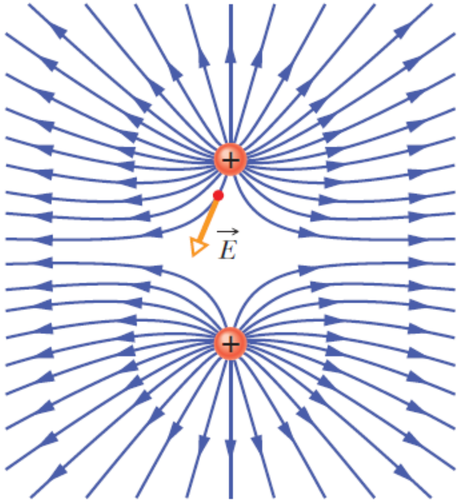
The Electric Field Due to a Point Charge

1. The electric field, a vector, exists at every point in space. Electric field diagrams will show a sample of vectors, but there is an electric field vector at every point whether one is shown or not.

2. If the probe charge q is positive, the electric field vector points in the same direction as the force on the charge; if negative, the electric field vector points opposite the force.

3. The electric field does not depend on the magnitude of the charge used to probe the field. The electric field depends only on the source charges that create the field.

The Electric Field Due to a Point Charge



The force on test charge q' is given by Coulomb's law:

$$\vec{F} = \frac{kqq'}{r^2} \text{ (away from } q\text{)}$$

The electric field due to the charge q' is:

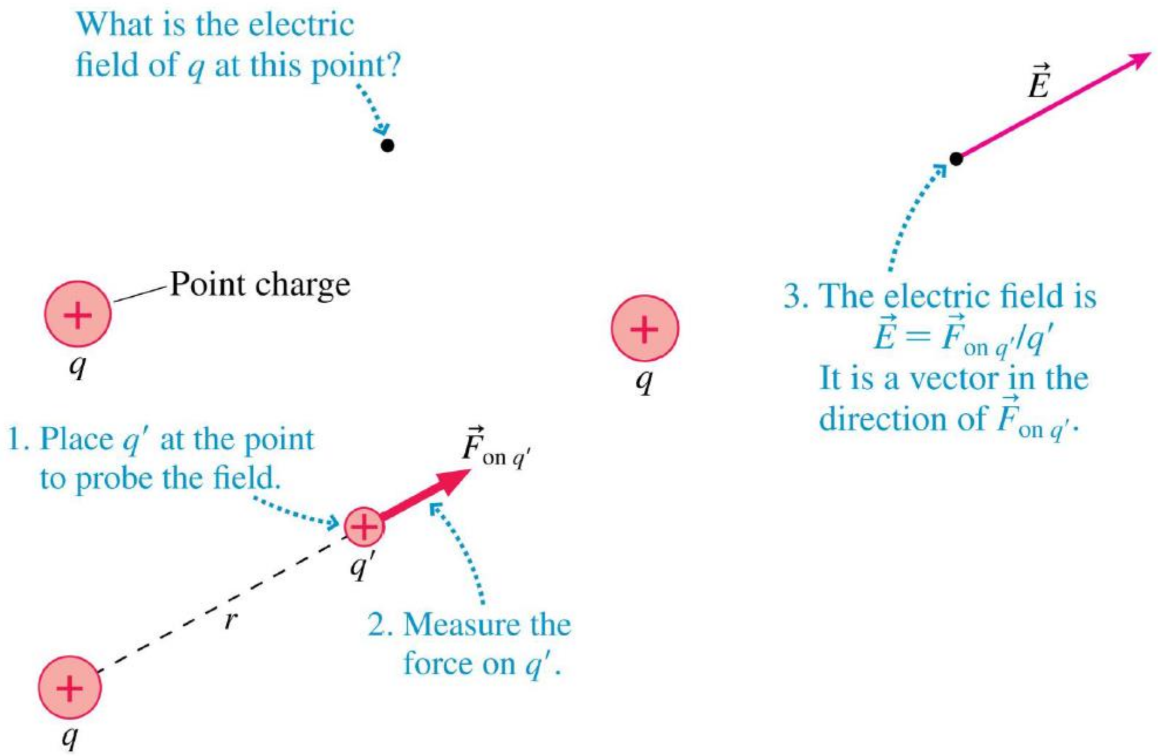
$$\vec{E} = \frac{kq}{r^2} \text{ (away from } q\text{)}$$

$$\vec{E} = \frac{kq}{r^2} \text{ (away from } q \text{ if } q > 0\text{)}$$

$$\vec{E} = \frac{kq}{r^2} \text{ (towards } q \text{ if } q < 0\text{)}$$

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

Gives magnitude of E. We must think about the direction separately.



The Electric Field Due to group of charges

In general, if several electric fields are set up at a given point by several charged particles, we can find the net field by placing a positive test particle q_0 at the point and then writing out the force acting on it due to each particle, such as due to particle 1. Forces obey the principle of superposition, so we just add the forces as vectors:

$$\vec{F}_0 = \vec{F}_{0,1} + \vec{F}_{0,2} + \vec{F}_{0,3} + \cdots + \vec{F}_{0,n}$$

Corresponding electric field,

$$\vec{E} = \vec{F}_0/q_0 = \vec{F}_{0,1}/q_0 + \vec{F}_{0,2}/q_0 + \vec{F}_{0,3}/q_0 + \cdots + \vec{F}_{0,n}/q_0$$

Thus,

$$\vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 + \cdots + \vec{E}_n$$

The electric field due to multiple charges is the vector sum of the electric field due to each of the charges.

The Electric Field Due to group of charges

Thus,

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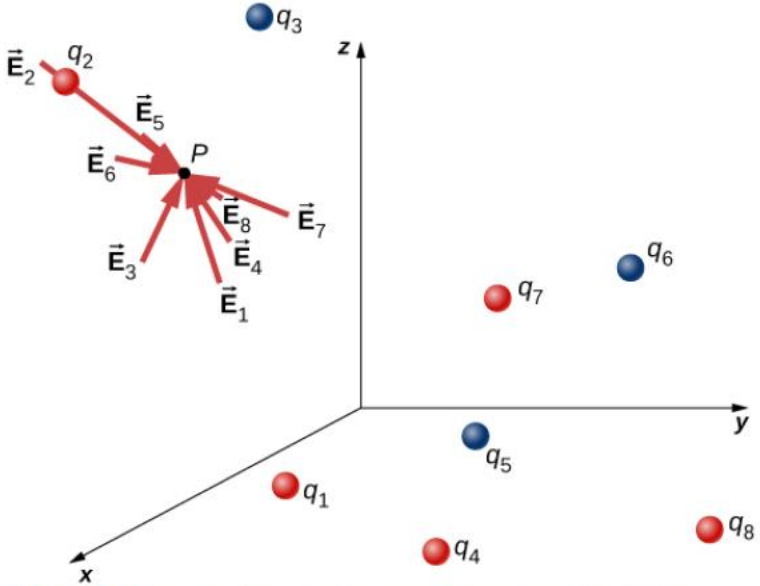


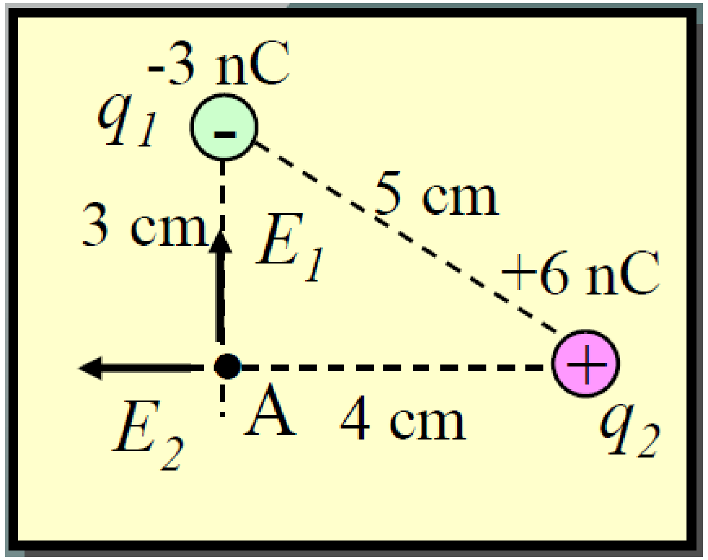
Figure 5.18 Each of these eight source charges creates its own electric field at every point in space; shown here are the field vectors at an arbitrary point *P*. Like the electric force, the net electric field obeys the superposition principle.

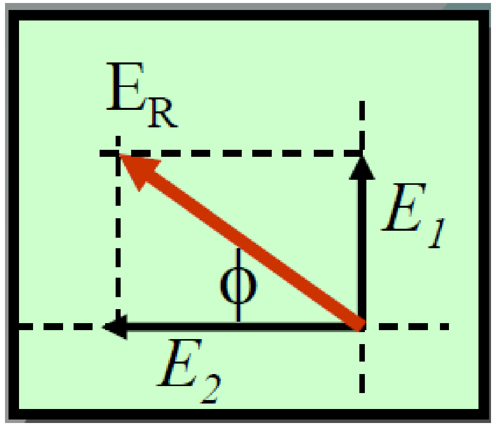
https://iwant2study.org/lookangejss/05electricitynmagnetism_11efield/ejss_model_twopointcharges01/twopointcharges01_Simulation.xhtml

TABLE 20.2 Typical electric field strengths

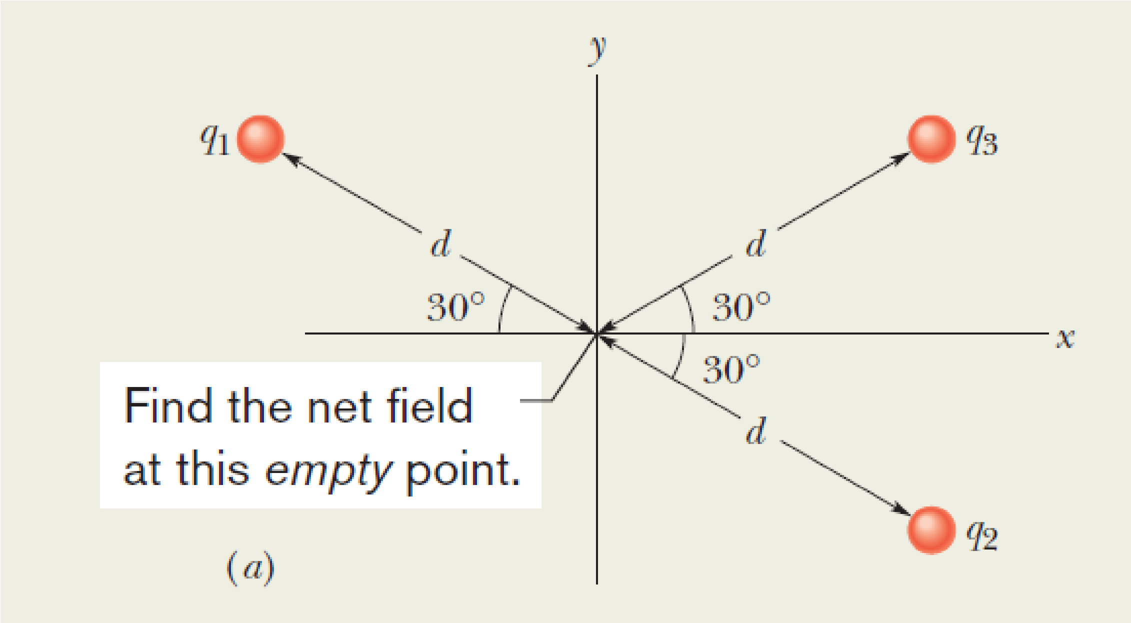
Field	Field strength (N/C)
Inside a current-carrying wire	10^{-2}
Earth's field, near the earth's surface	10^{2}
Near objects charged by rubbing	10^{3} to 10^{6}
Needed to cause a spark in air	10^{6}
Inside a cell membrane	10^{7}
Inside an atom	10^{11}

Find the resultant field at point A due to the -3 nC charge and the +6 nC charge arranged as shown.

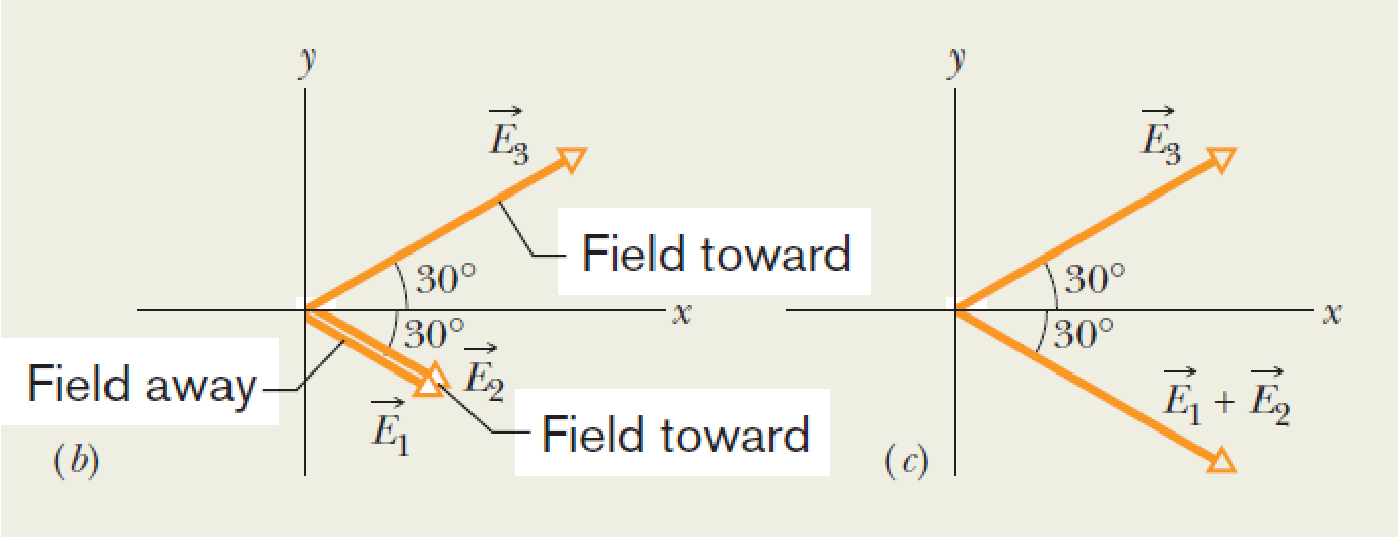




Sample Problem: 22.01

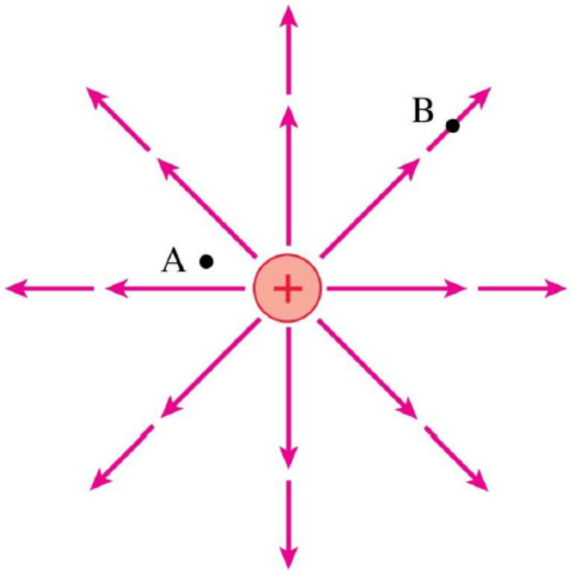


three particles with charges $q_1 = 2Q$, $q_2 = -2Q$, and $q_3 = -4Q$, each a distance d from the origin.



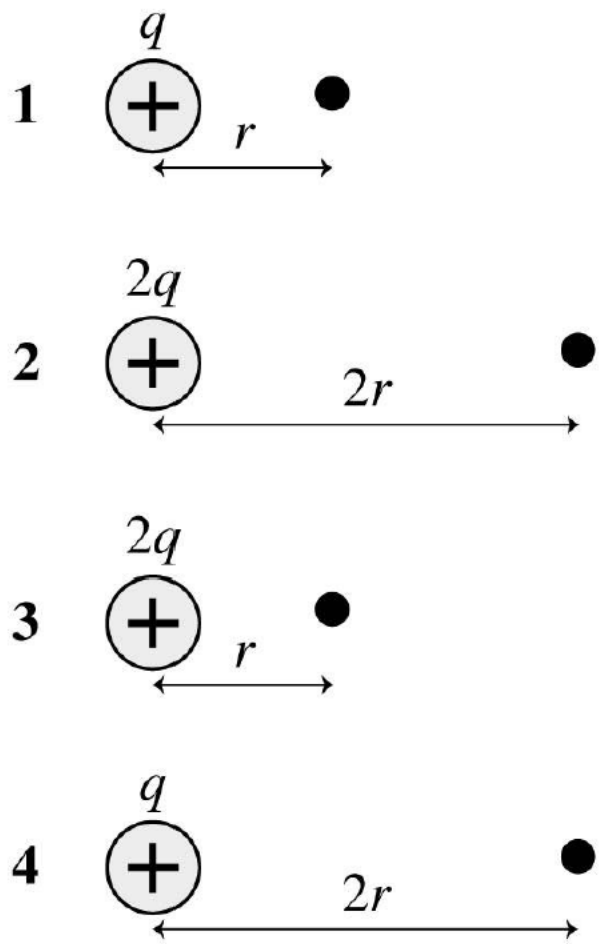
At which point is the electric field stronger?

A. Point A
B. Point B
C. Not enough information to tell

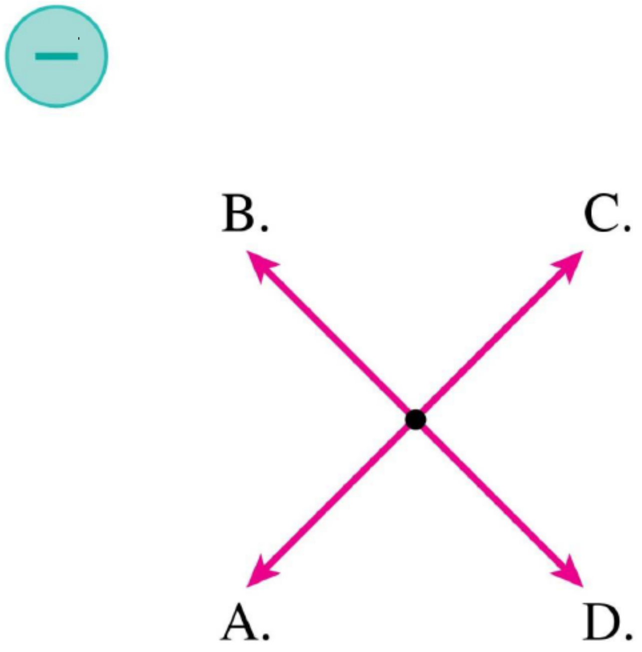


Rank in order, from largest to smallest, the magnitudes of the electric field at the black dot.

A. 3, 2, 1, 4
B. 3, 1, 2, 4
C. 1, 4, 2, 3
D. 3, 1, 2, 4

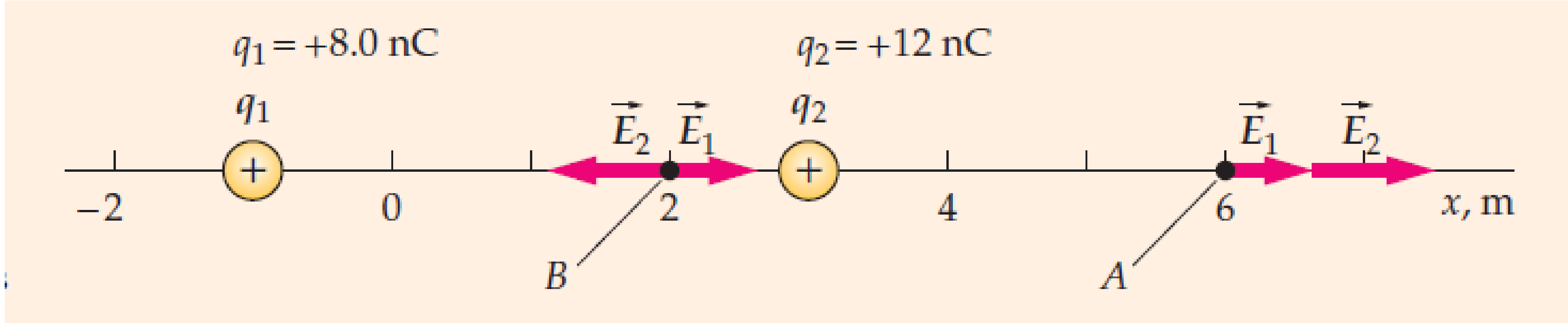


Which is the electric field at the dot?



E. None of these.

A positive point charge $q_1 = +8.0$ nC is on the x axis at $x = x_1 = -1.0$ m, and a second positive point charge $q_2 = +12$ nC is on the x axis at $x = x_2 = 3.0$ m. Find the net electric field (*a*) at point *A* on the x axis at $x = 6.0$ m, and (*b*) at point *B* on the x axis at $x = 2.0$ m.



Summary Topic

- Identify that at every point in the space surrounding a charged particle, the particle sets up an electric field $\vec{E}$, which is a vector quantity and thus has both magnitude and direction.

- For a given point in the electric field of a charged particle, identify the direction of the field vector when the particle is positively charged and when it is negatively charged.

- If more than one electric field is set up at a point, draw each electric field vector and then find the net electric field by adding the individual electric fields as vectors (not as scalars).

- If more than one charged particle sets up an electric field at a point, the net electric field is the *vector* sum of the individual electric fields—electric fields obey the superposition principle.