Announcements

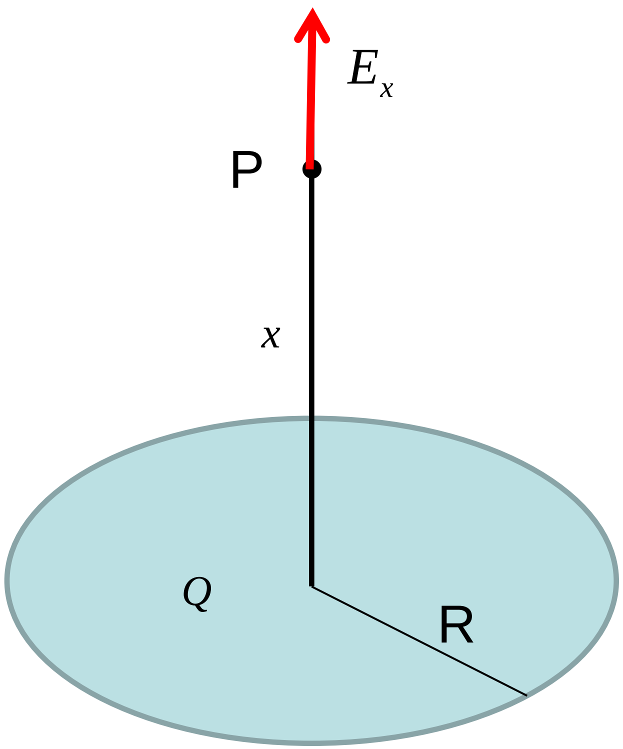
Formulae and Constants (continued)

Fundamental Constants		
$k = 8.99 \cdot 10^9 \frac{\mathrm{Nm}^2}{\mathrm{C}^2}$	$\varepsilon_0 = 8.85 \cdot 10^{-12} \frac{\mathrm{C}^2}{\mathrm{Nm}^2}$	$\mu_0 = 4\pi \cdot 10^{-7} \frac{\mathrm{Tm}}{\mathrm{A}}$
$e = 1.602 \cdot 10^{-19}\mathrm{C}$	$m_e = 9.11 \cdot 10^{-31}\mathrm{kg}$	$m_p = 1.67 \cdot 10^{-27}\mathrm{kg}$

Kinematics and Dynamics			
$\sum \vec{F} = m\vec{a}$	$x = x_0 + v_{x0}t + \frac{1}{2}a_x t^2$	$v_x = v_{x0} + a_x t$	$v_{xf}^2 = v_{xi}^2 + 2a_x \Delta x$

Mathematical Formulae & Prefixes			
milli $(m) = 10^{-3}$	micro $(\mu) = 10^{-6}$	nano $(n) = 10^{-9}$	pico $(p) = 10^{-12}$
$C = 2\pi r$	$A_{CIRCLE} = \pi r^2$	$A_{SPHERE} = 4\pi r^2$	
$V_{SPHERE} = \frac{4}{3}\pi r^3$	$A_{CYL} = 2\pi r L$	$V_{CYL} = \pi r^2 L$	
$ax^2 + bx + c = 0 \to x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$	$\int \frac{dx}{\sqrt{x^2 + a^2}} = \ln\left(x + \sqrt{x^2 + a^2}\right)$		
$\int \frac{dx}{\sqrt{a^2 - x^2}} = \arcsin\frac{x}{a}$	$\int \frac{dx}{x^2 + a^2} = \frac{1}{a}\arctan\frac{x}{a}$		
$\int \frac{dx}{(x^2 + a^2)^{3/2}} = \frac{1}{a^2}\frac{x}{\sqrt{x^2 + a^2}}$	$\int \frac{x\,dx}{(x^2 + a^2)^{3/2}} = -\frac{1}{\sqrt{x^2 + a^2}}$		

$$E_x = \frac{1}{4\pi\varepsilon_0} 2\pi\sigma x \int_{r=0}^{R} \frac{r\,dr}{\left(r^2 + x^2\right)^{3/2}}$$



Go to an integral table and look for

$$\int \frac{x\,dx}{\left(x^2 + a^2\right)^{3/2}} = ?$$

$$\int \frac{x\,dx}{\left(x^2 + a^2\right)^{3/2}} = -(x^2 + a^2)^{-1/2}$$

$$E_x = \frac{\sigma}{2\varepsilon_0}\left(1 - \frac{x}{\sqrt{x^2 + R^2}}\right)$$

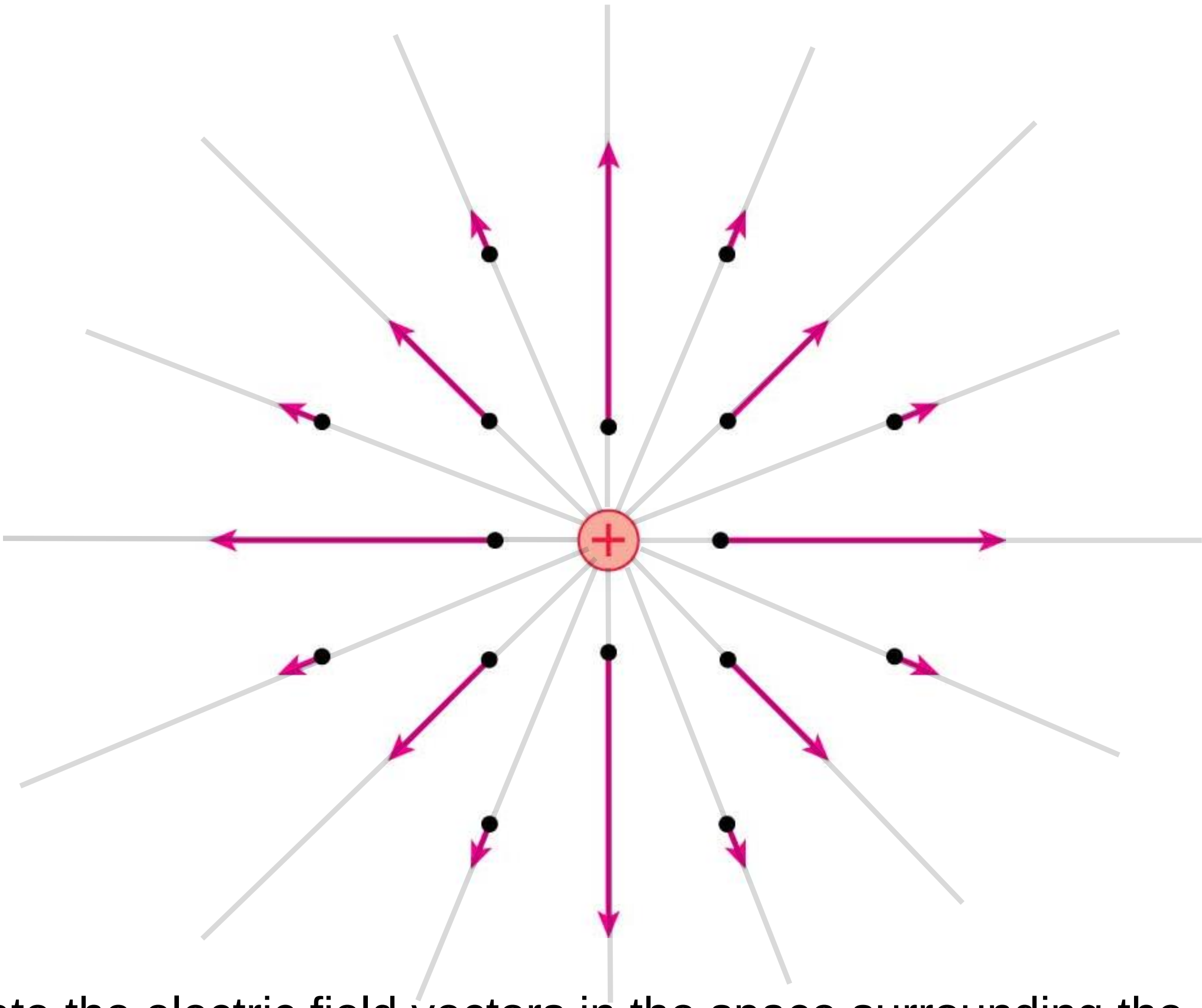
Last time

- Electric field of a thin charged disk at a point along the axis of the disk
- Electric field of a dipole on its axis
- Electric field vectors and lines for a point charge

This time

- Tophat questions
- More on electric field vectors and lines for a point charge
- Electric field vectors and lines for a dipole
- Electric field vectors and lines for two like charges
- General properties of electric field lines

Electric field vectors and lines due to a positive point charge

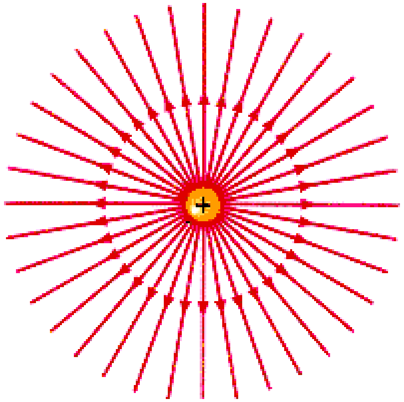


$$\vec{E} = \frac{k_e |q|}{r^2}\hat{r}$$

Arrows indicate the electric field vectors in the space surrounding the + point charge. The direction and size of the arrows indicate the direction and the strength of the electrostatic field, respectively.

We draw field lines by drawing tangents to the electric field vectors in such a way that field lines do not cross each other.

Observations



1. This is a three dimensional pattern.

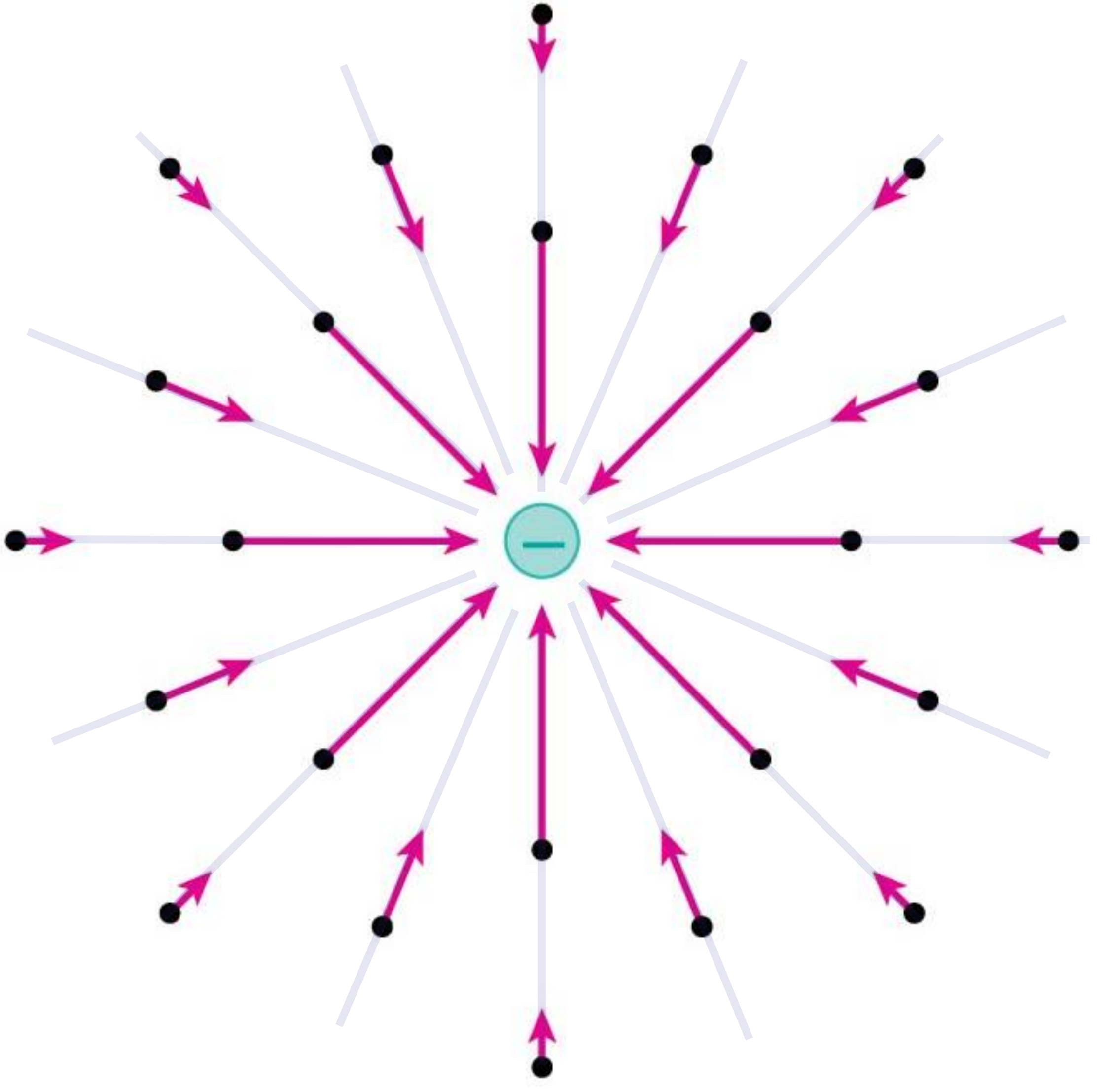
2. The magnitude of the electric field is represented by the density of the field lines, closer to the charge higher density of the field lines and farther away from the charge lower density of the field lines.

3. In this case, we say field lines are radial.

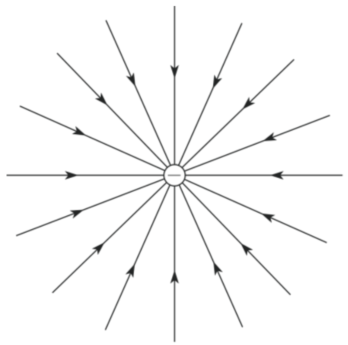
4. For an isolated point charge field lines and field vectors coincide.

5. Field lines originate at the positive charge.

Electric field vectors and lines due to a negative point charge



Observations



1. This is a three dimensional pattern.

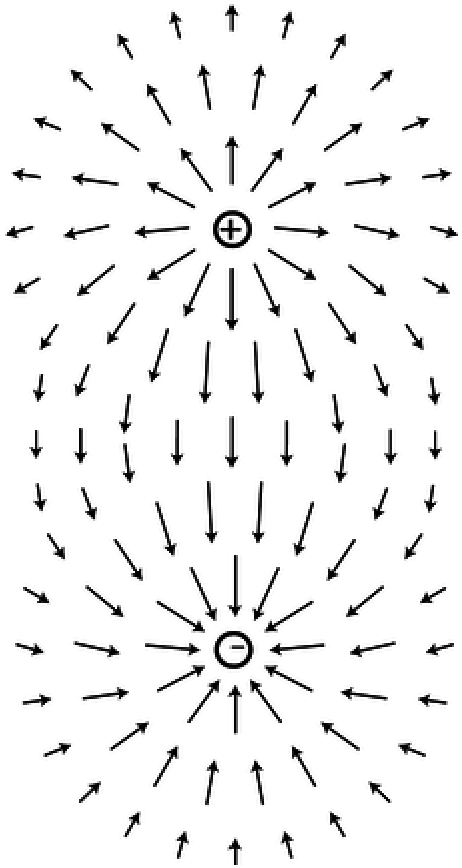
2. The magnitude of the electric field is given by the density of the field lines, closer to the charge higher density of the field lines and farther away from the charge lower density of the field lines.

3. In this case, we say field lines are radial.

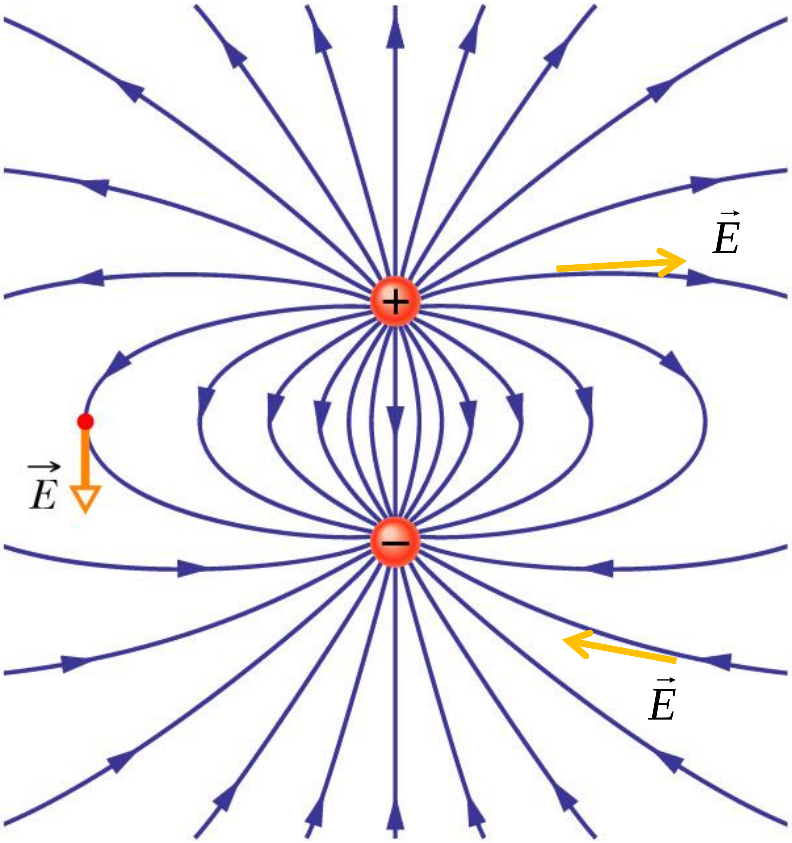
4. For an isolated point charge field lines and field vectors coincide.

5. Field lines terminate at the negative charge.

Electric field vectors and lines for a dipole



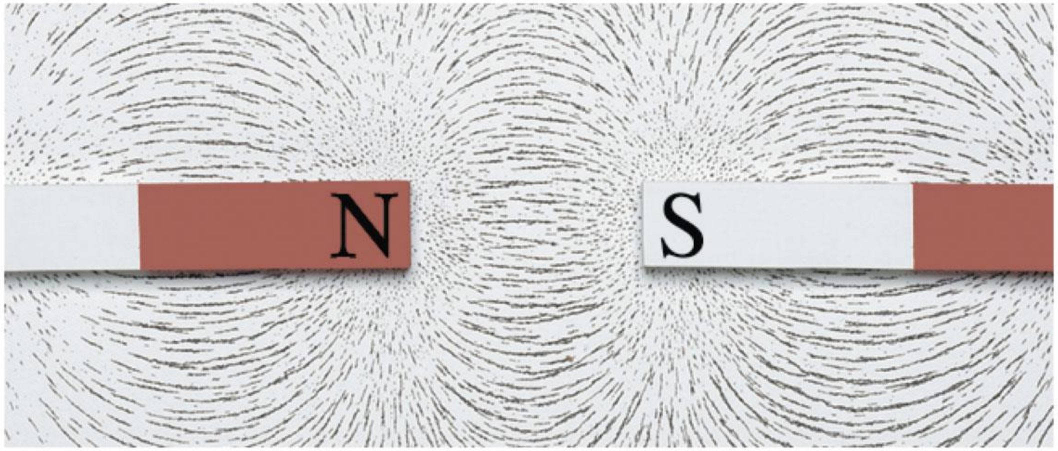
Electric field vectors



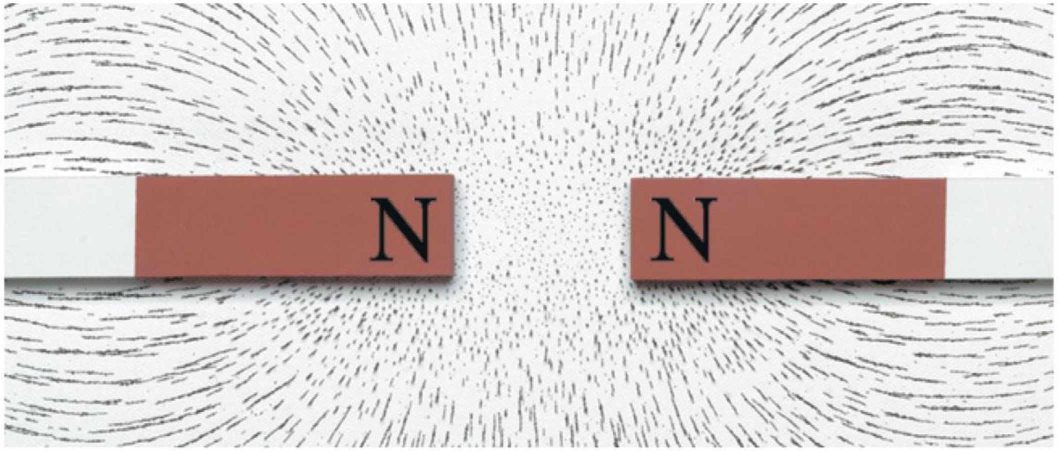
Electric field lines

Field lines are obtained by drawing tangents to the electric field vectors.
Electric field lines cannot cross each other.

Visualizing E-field: field lines



Magnetic field lines



You are already familiar with the idea that magnets set up a magnetic field. This can be demonstrated with iron filings on paper over top of a magnet.

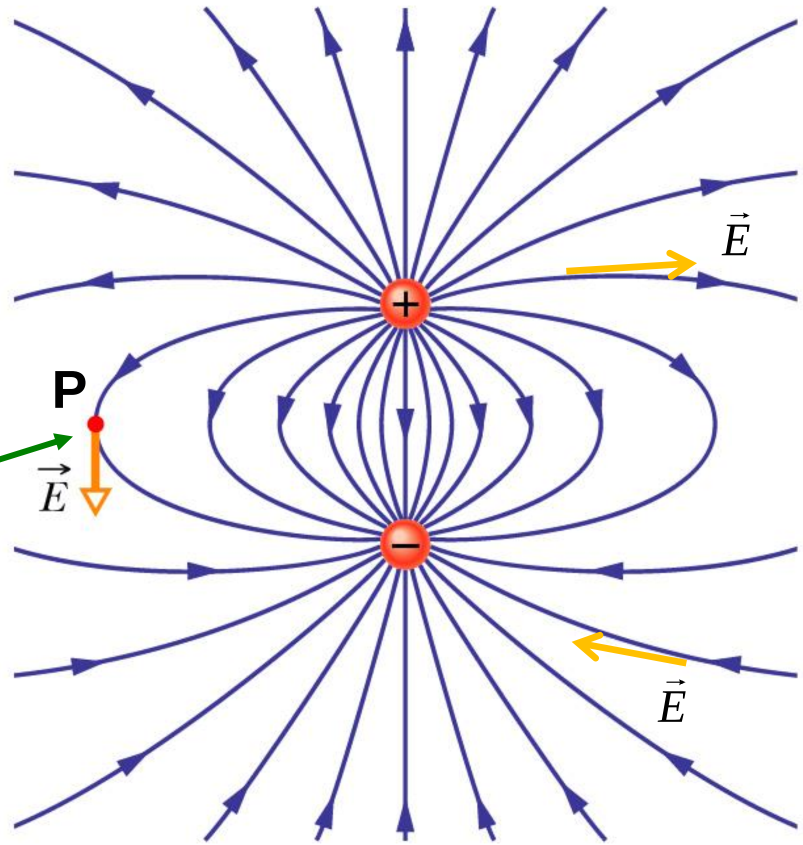
Electric fields also have “field lines”.

Electrostatic field lines for a dipole

Consider the electric field that develops between two positive point charges.

The field lines originate from the positive charge and terminate on the negative charge and must not cross each other.

The direction of the electric field at the point P is the **tangent** to the curved field line at that point.

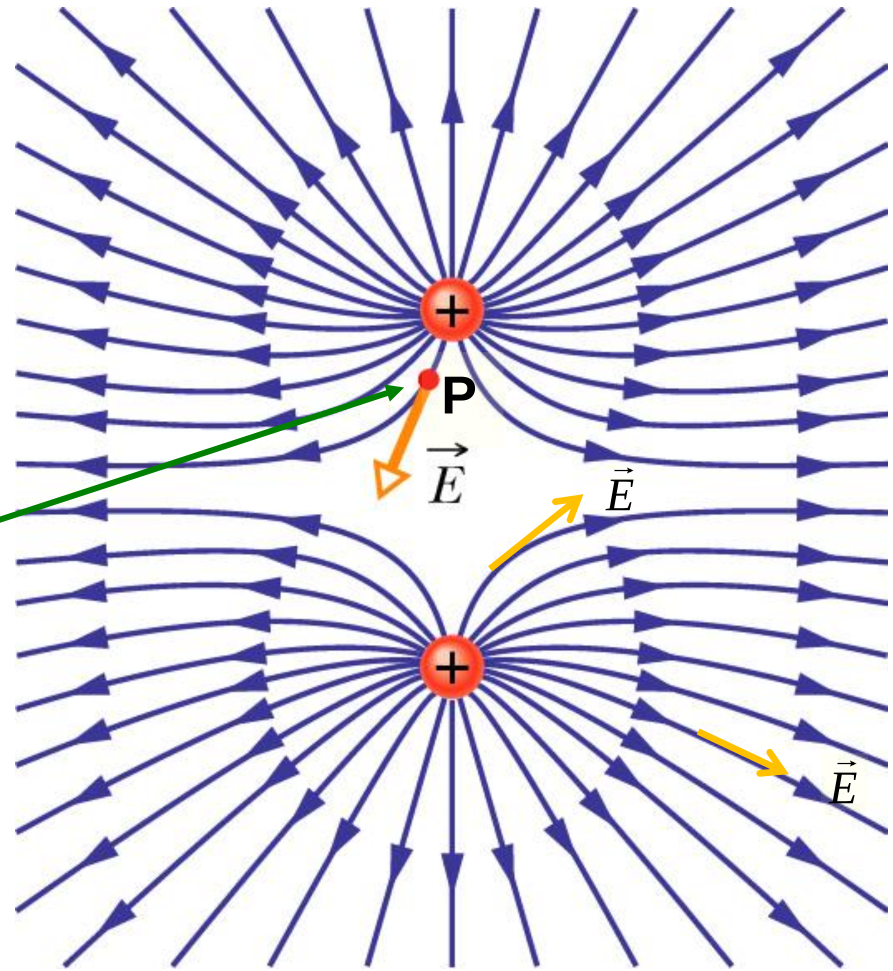


Electrostatic Field for Two Point Charges

Consider the electric field that develops between two positive point charges.

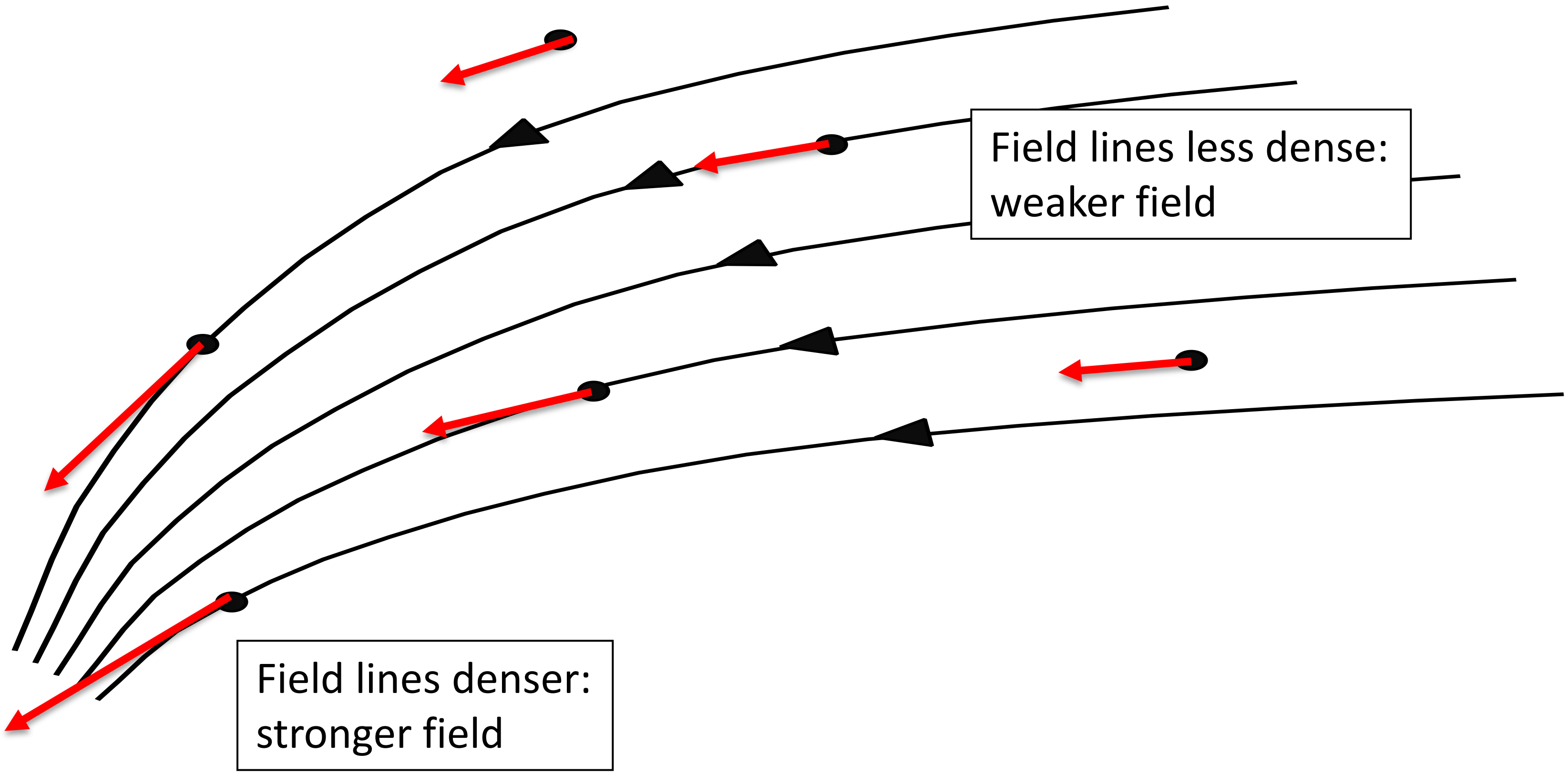
The field lines originate on the positive charge and terminate on distant (unspecified) negative charges and must not cross each other.

The direction of the electric field at the point P is the **tangent** to the curved field line at that point.



How would the electric field pattern be different for two negative point charges?

Electric Field Lines

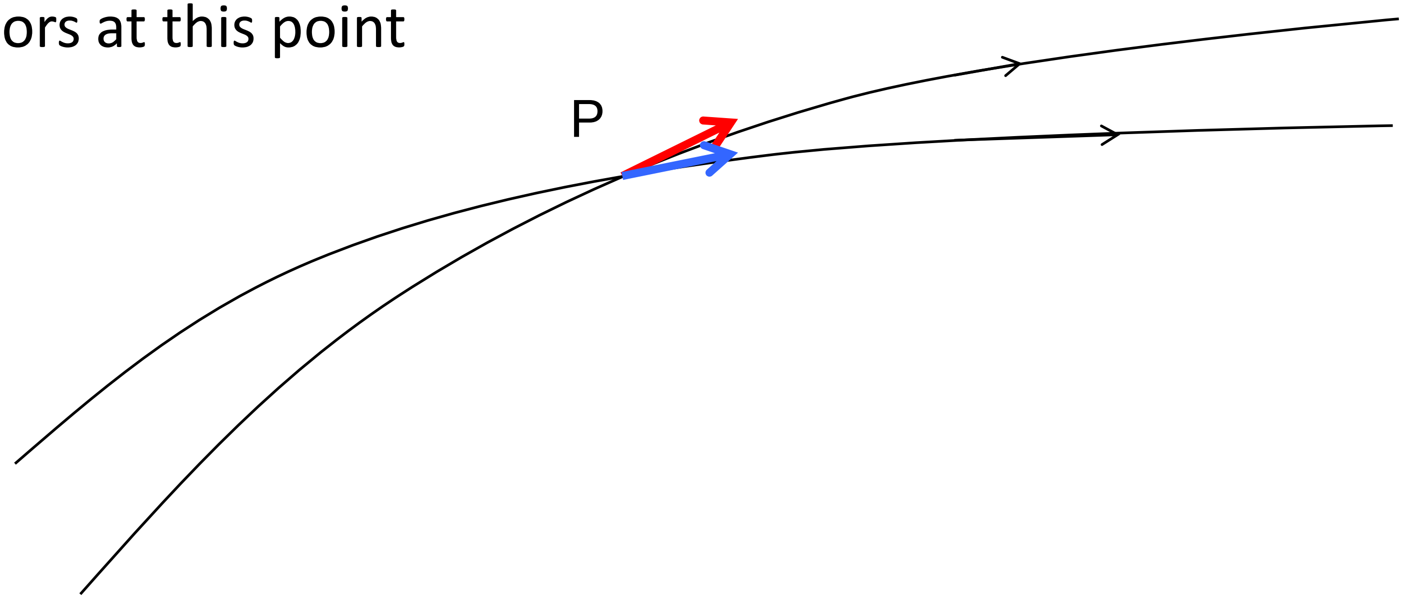


Electric field lines are continuous curves. The electric field vectors are tangent to the field lines (red arrows).

The denser the field lines, the stronger the field (magnitude of E)

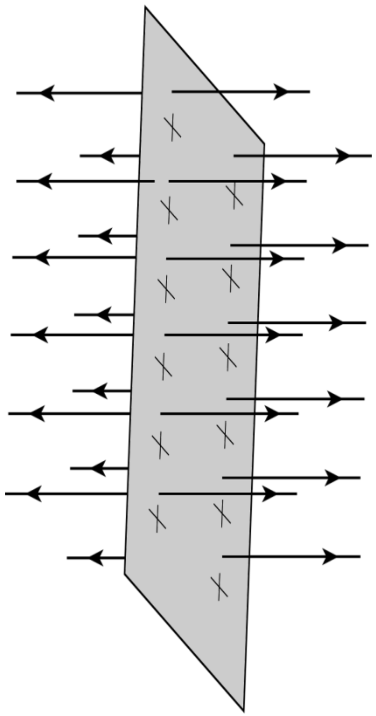
Electric Field Lines Can't Cross

Two electric field
vectors at this point



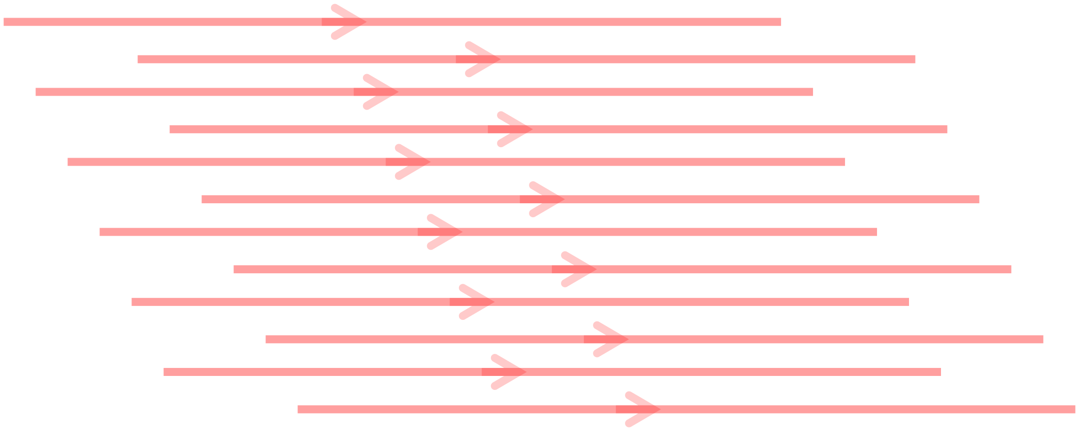
If field lines crossed, the electric field at that point would not be single valued and therefore not defined. Remember that electric field is a measurable physical quantity.

Electric field lines for a large sheet of charge



$$E = \frac{\sigma}{2\varepsilon_0}$$

Sometimes we show only the electric field lines but not the charge generating the electric field.

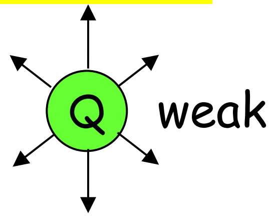


$$\vec{E} = \text{constant}$$

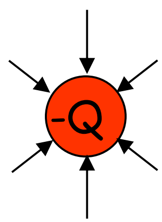
Field Lines

The dos and don’ts of electric field lines

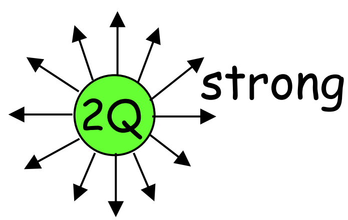
Field lines ***start*** on positive charges.



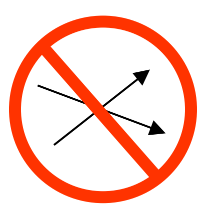
Field lines ***stop*** on negative charges.



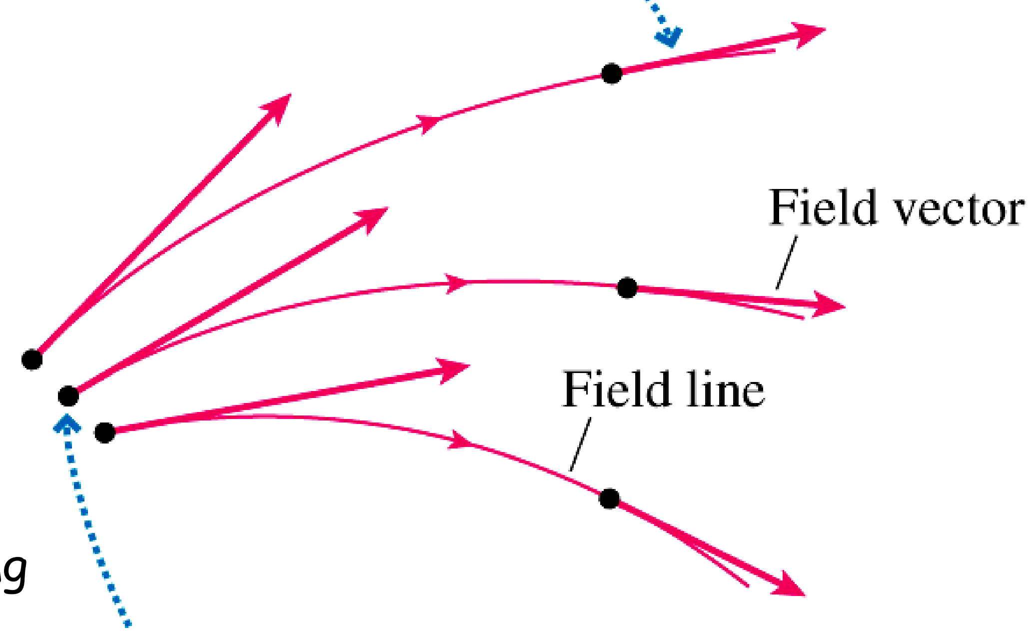
More charge more field lines.



Field lines never cross.



The electric field vector is tangent to the electric field line.



The electric field is stronger where the electric field vectors are longer and where the electric field lines are closer together.