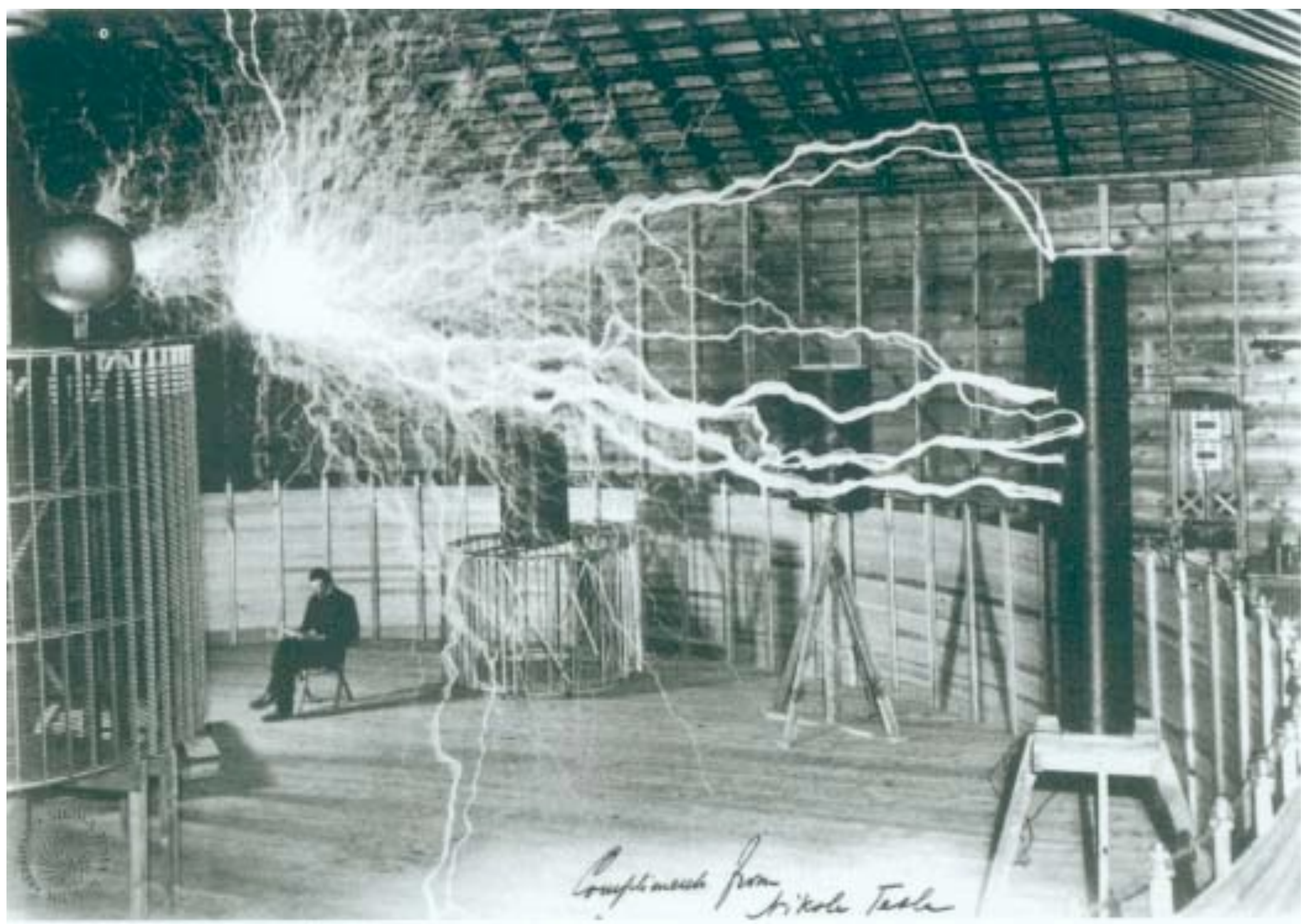
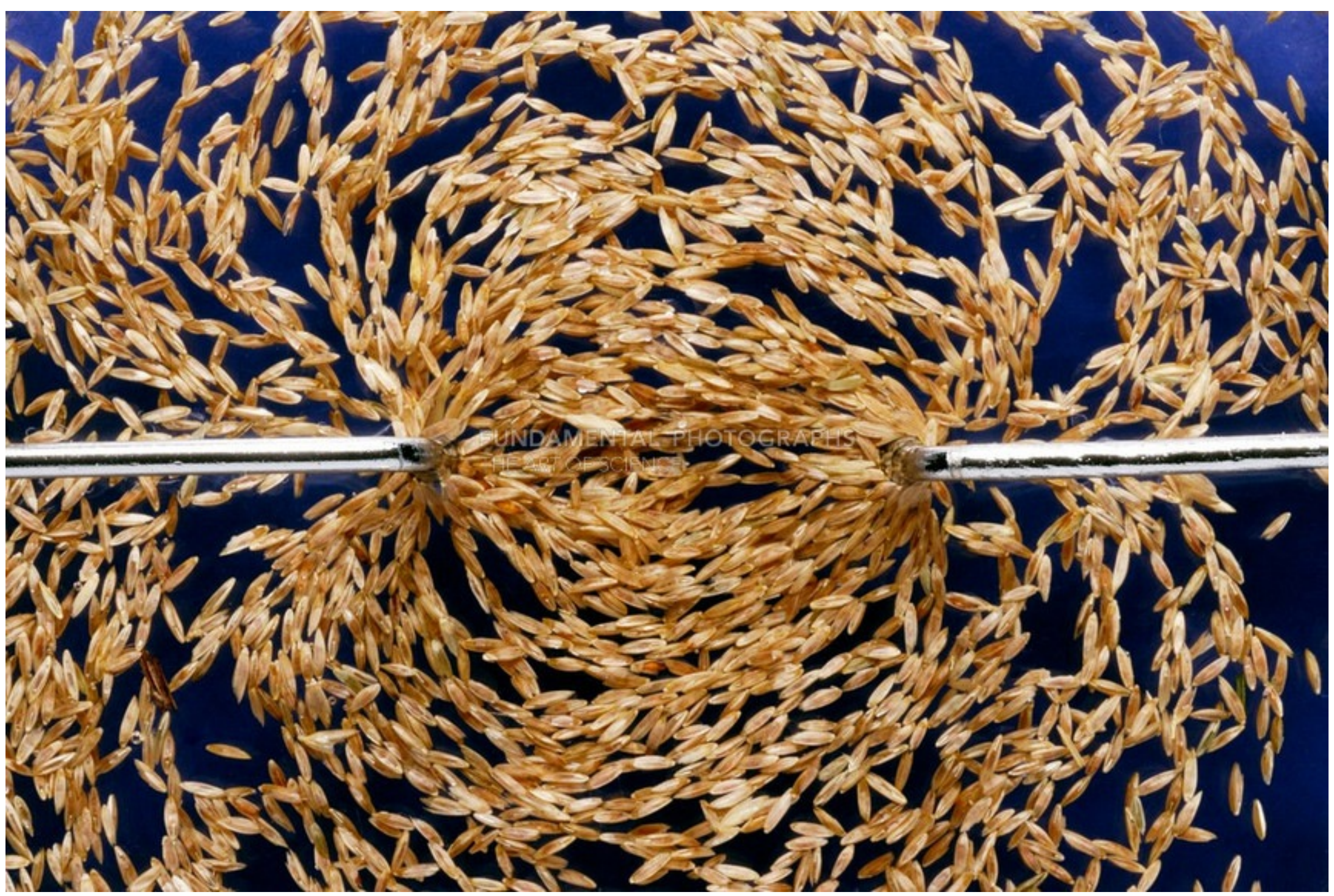
The Electric Field

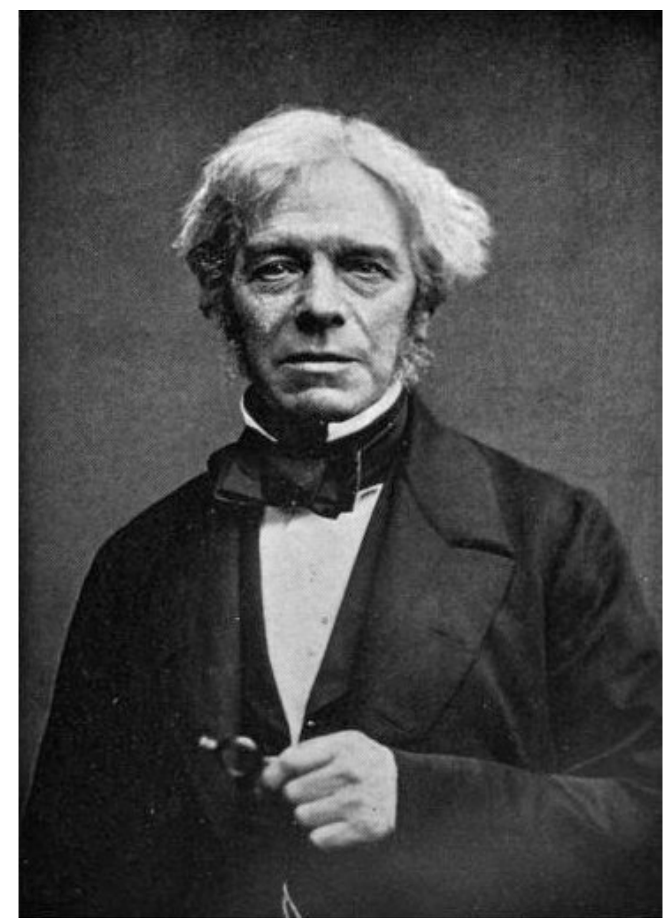


The Electric Field

Newtonian view: Charges A and B interact directly.

Faraday's Hypothesis: Charge A alters the space around it. This alteration affects B. Reality itself is made of a force that exist at every point in space (**a "force field"**).





We will see that **the field is a physical thing**, independent of charge!

The Electric Field

The electric field at a point is found by finding the force a test charge feels at that point and dividing the force by the charge of the test charge:

$$\vec{E}(x,y,z) \equiv \frac{\vec{F}_{\text{on } q} \text{ at } (x,y,z)}{q}$$

The electric field has units of N/C.

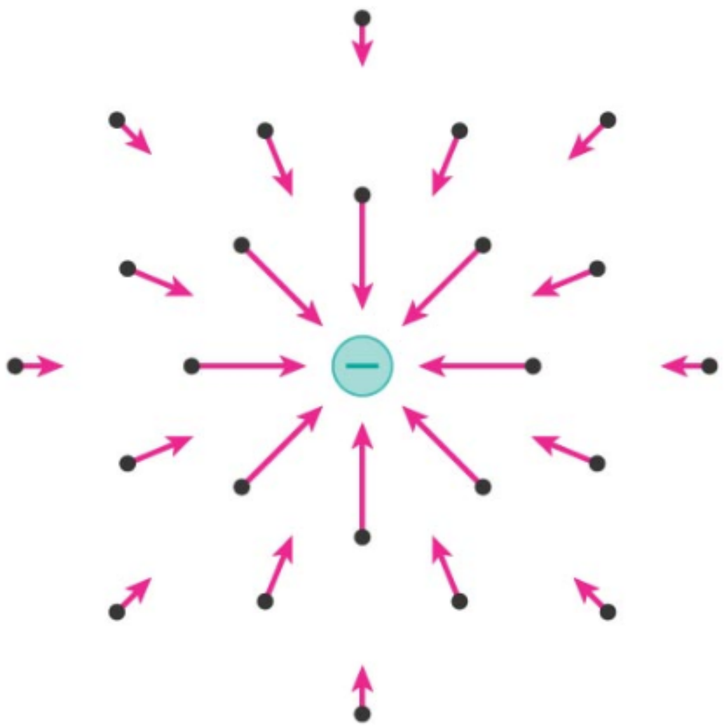
The electric field at a point in space points in the same direction that a positive charge would feel a force.

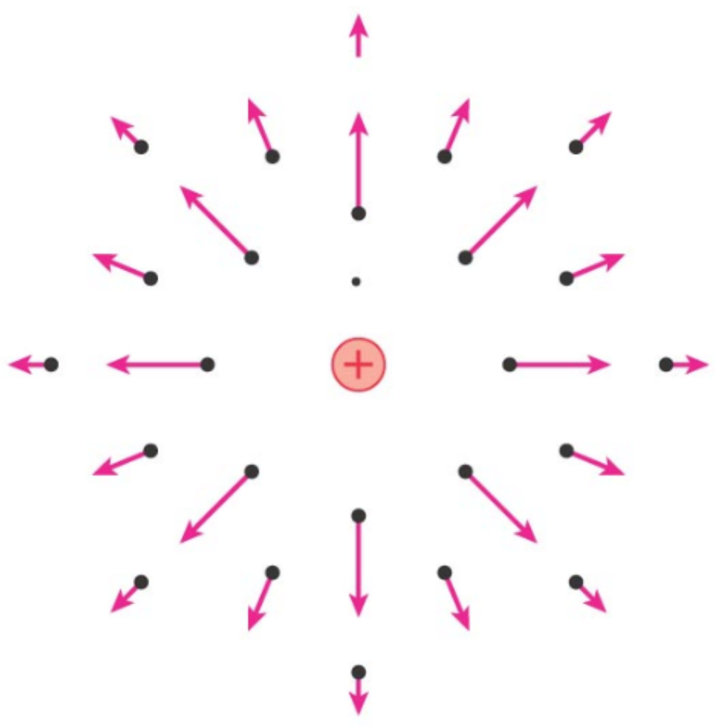
Charges and Fields PhET

Field of a Point Charge

The electric field of a point charge is then (using Coulomb's Law)

$$\vec{E} = \frac{\vec{F}_{qq'}}{q'} = k\frac{q}{r^2}\hat{r}$$





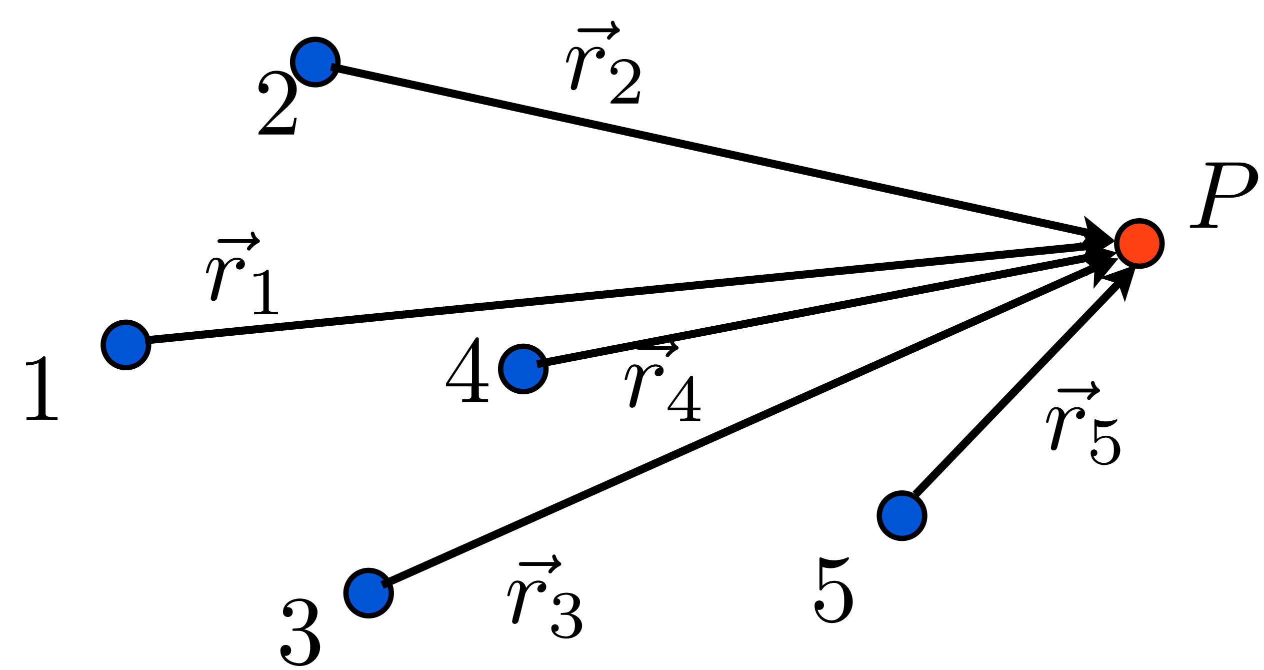
Visualization: Vector is strength and direction of field at the tail.

closer to charge, or greater charge = longer arrow

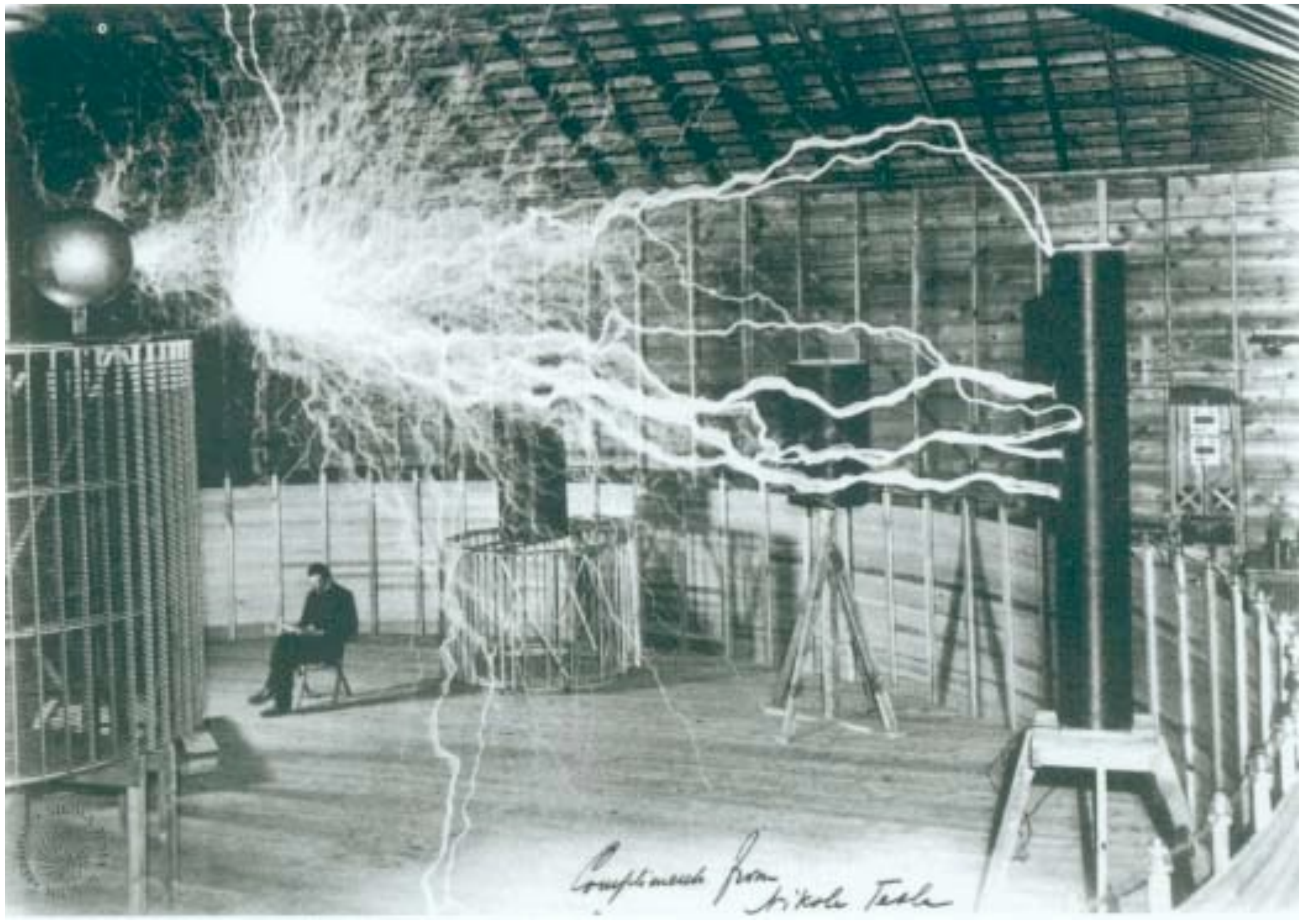
Superposition of Electric Fields

We can find the net field by the E-fields due to each individual charge.

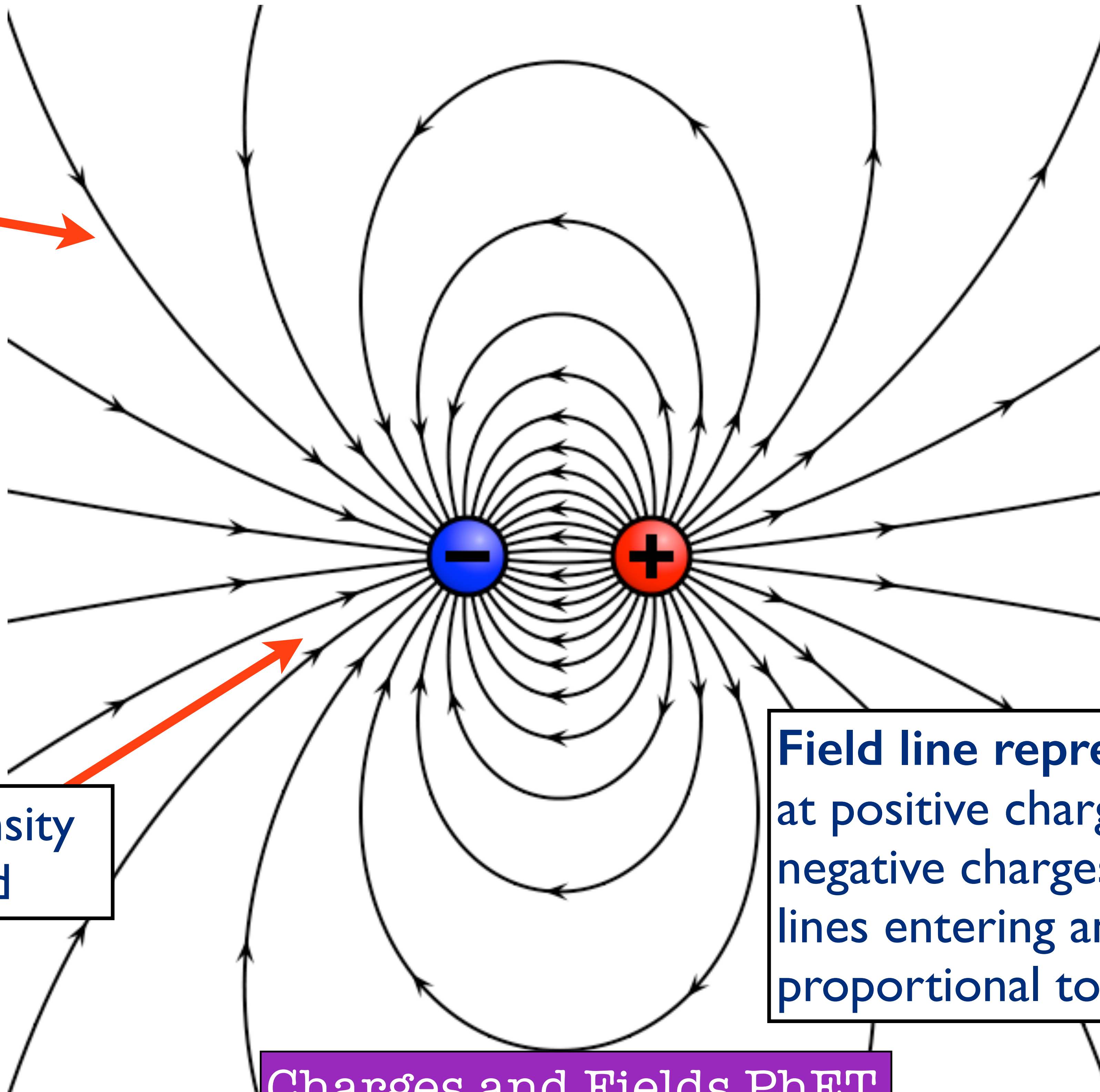
$$\vec{E}_{\text{net}} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 + \ldots = \sum_i \vec{E}_i$$



Electric Field Configurations



The Electric Dipole



Field lines never cross

Higher line density = Stronger field

Field line representation start at positive charges and end at negative charges. Number of lines entering and leaving are proportional to charge.

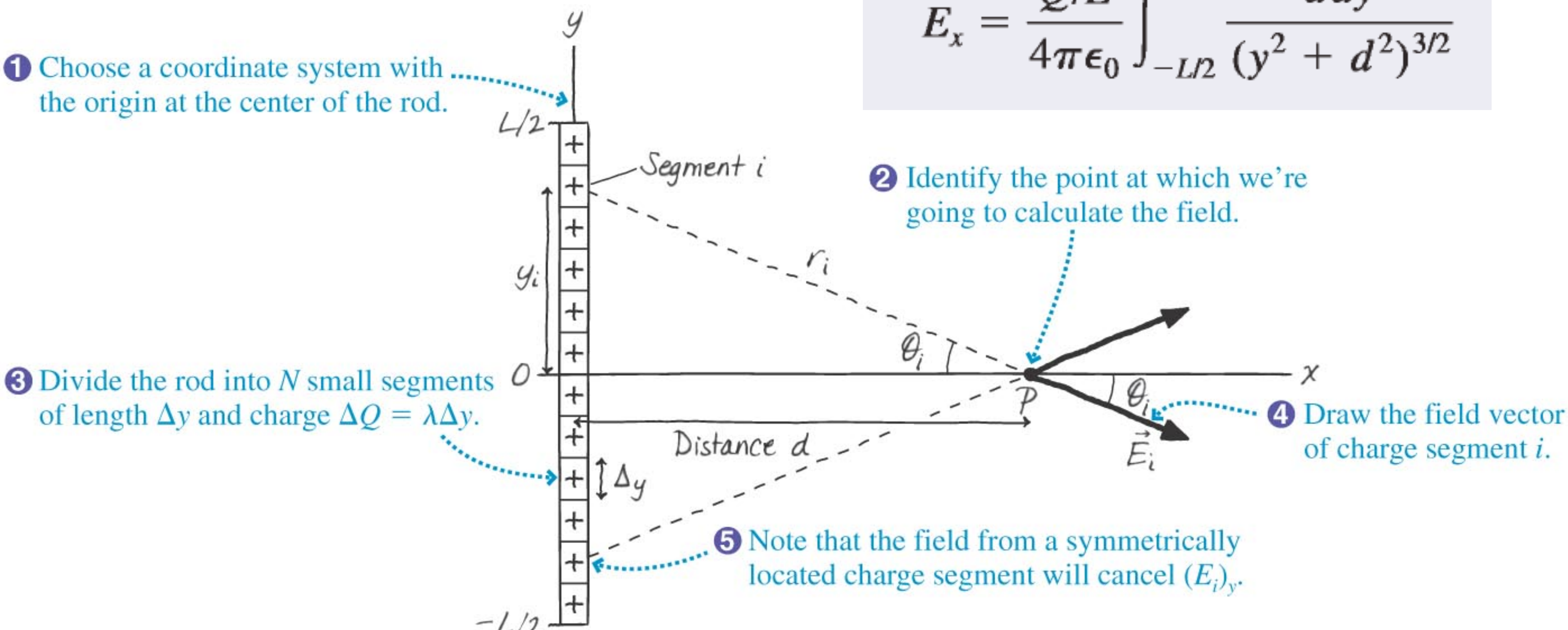
Charges and Fields PhET

Continuous Charge Distributions

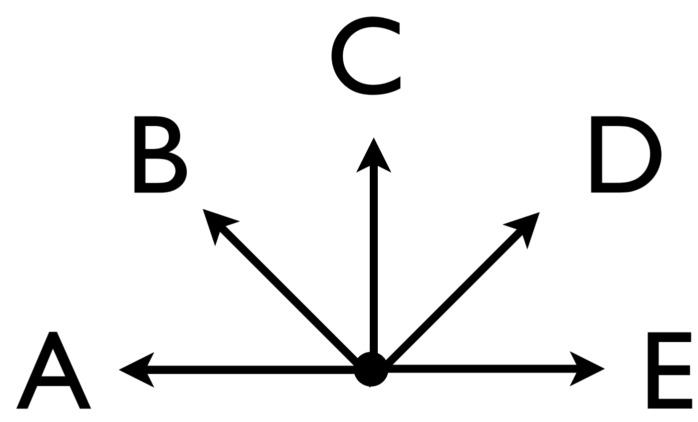
We used Coulomb's law for discrete charges, but it can be used with continuous charges as well (complicated though).

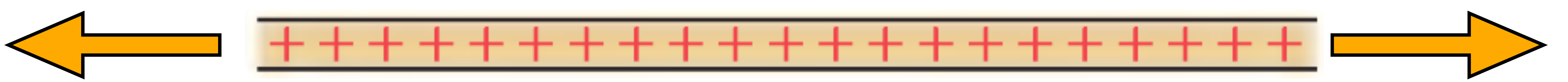
Consider a line of charge.

$$E_x = \frac{Q/L}{4\pi\epsilon_0}\int_{-L/2}^{L/2}\frac{d\,dy}{(y^2+d^2)^{3/2}}$$



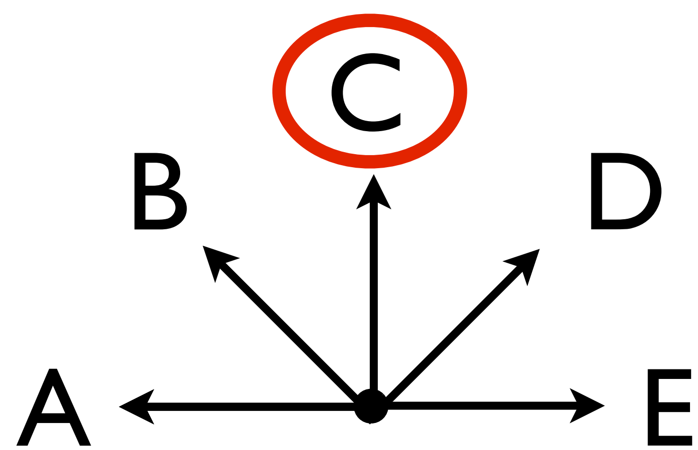
Infinite plane of charge





Consider a point above a **plane** of positive charge. In what direction does the electric field point? Be prepared to explain your answer.

Infinite plane of charge



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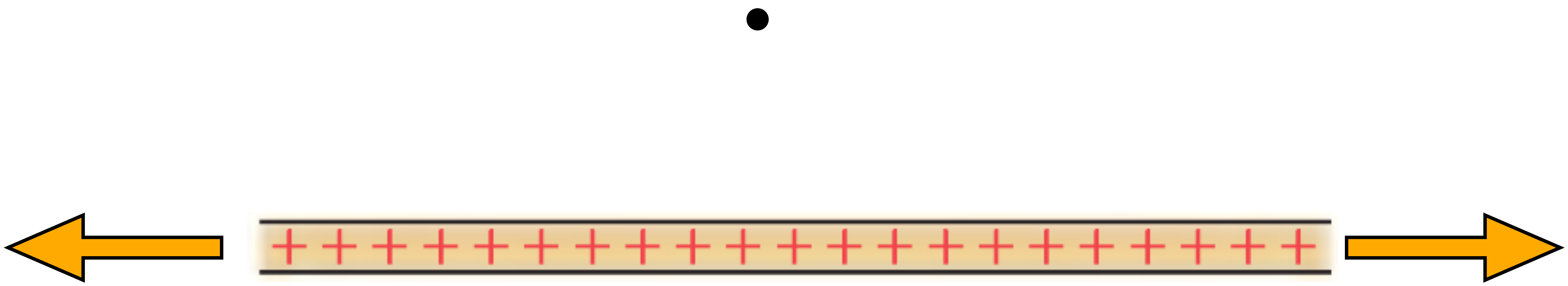
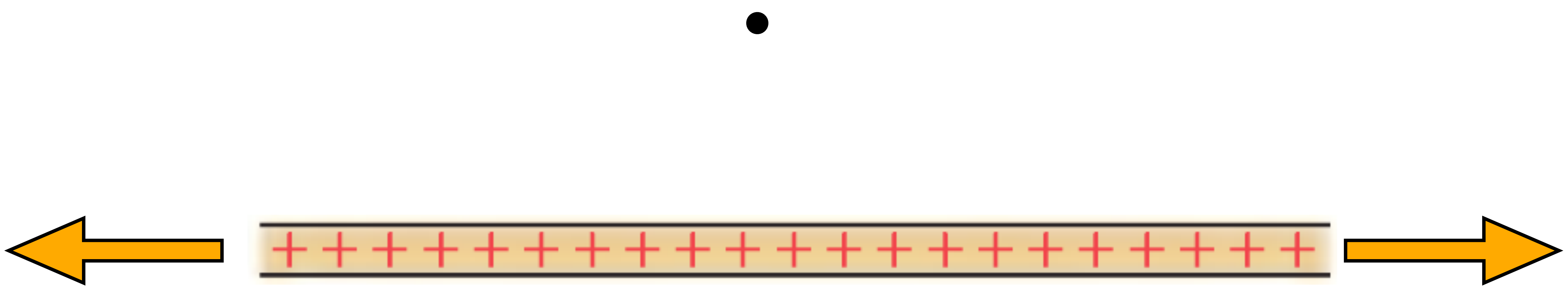


Consider a point above a plane of positive charge. The field at another point twice as far away from the plane is

a) stronger.
b) weaker.
c) the same.

Infinite plane of charge



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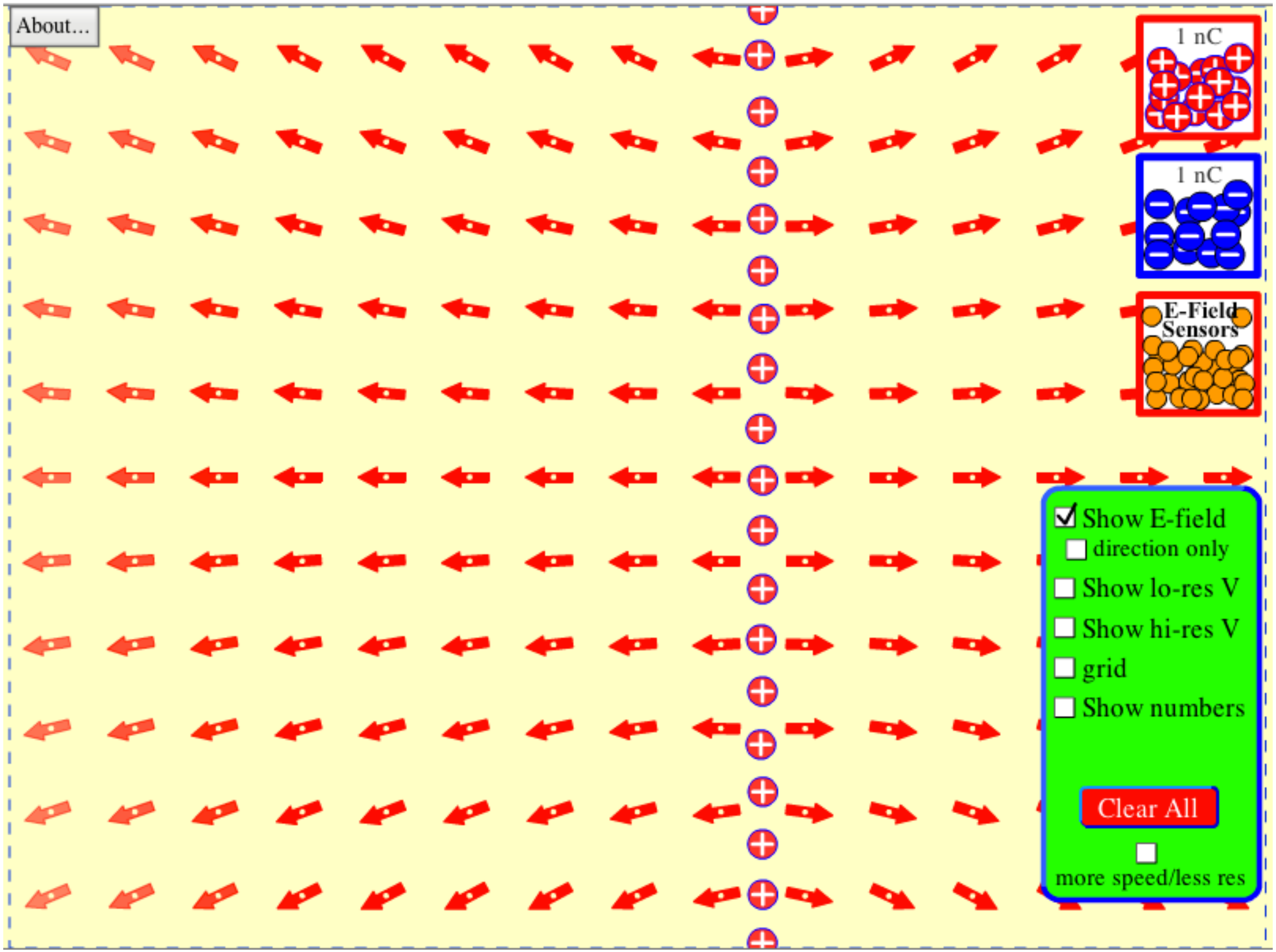
a) stronger.
b) weaker.
c) the same.

The infinite plane always looks the same (it stretches out to infinity) as you move further from it. This means that the field can't change, because nothing is really changing.

Field from a plane of charge

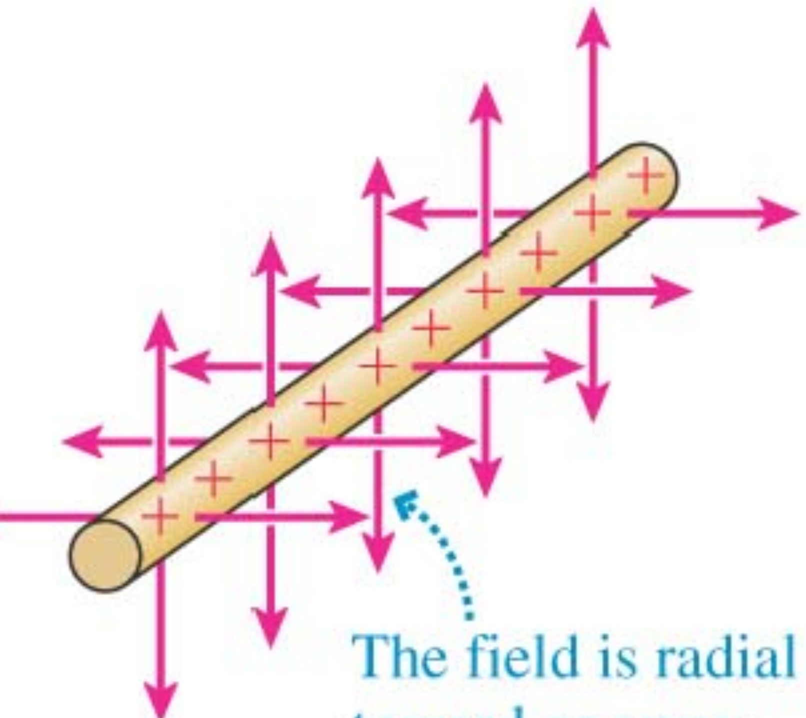


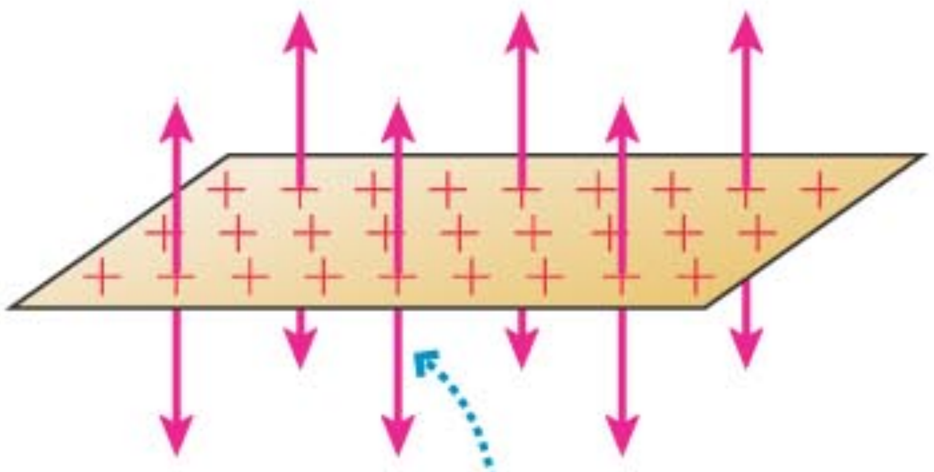
Three Basic Charge Distributions

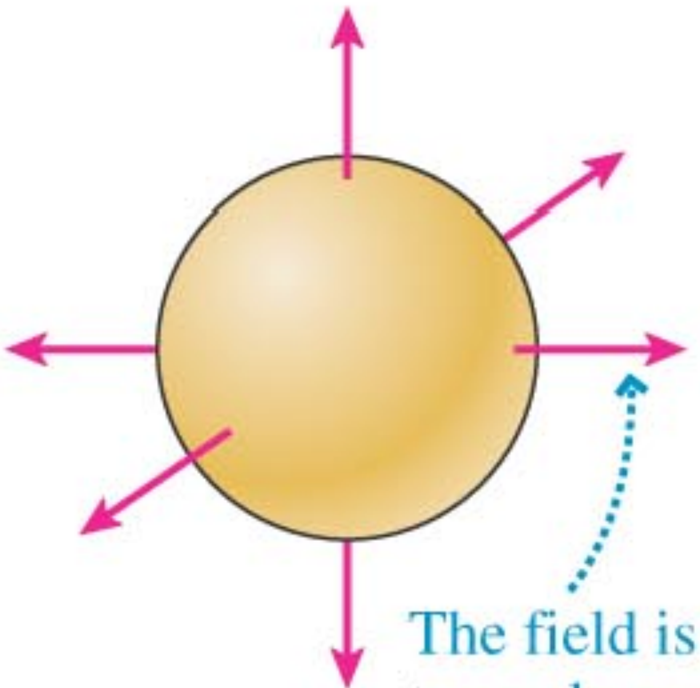
infinite line of charge

infinite plane of charge

sphere of charge (same as point charge)







$$E_{\text{line}} = \frac{1}{2\pi\epsilon_0}\frac{\lambda}{r}$$

$$E_{\text{plane}} = \frac{\eta}{2\epsilon_0}$$

$$E_{\text{sphere}} = \frac{1}{4\pi\epsilon_0}\frac{Q}{r^2}$$

$\lambda = \frac{Q}{\ell} =$ linear charge density

$\eta = \frac{Q}{A} =$ surface charge density