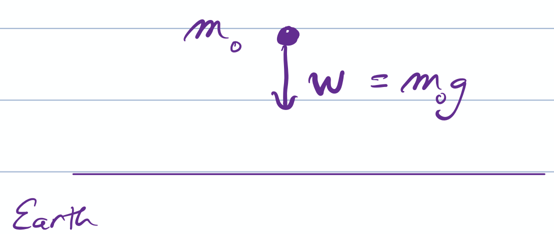
The electrostatic force involves action at a distance. How does that work?

q_1 creates an electric field in the space around it. q_0 responds to that field.

Gravitational Analogy

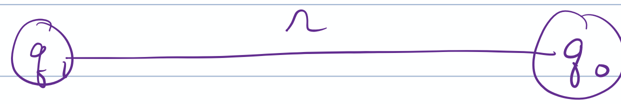


Earth creates a gravitational field "g". The m_0 then feels a force $W = m_0 g$.

$$g = \frac{W}{m_0} = 9.8 \text{ N/kg}.$$

Abstraction: "g" is there whether we are actively dropping a mass m_0 or not. Fields are real: Gravitational Waves!

Apply the analogy to electric forces.



$$F_{10} = \frac{k\,|q_1|\,|q_0|}{r^2}$$

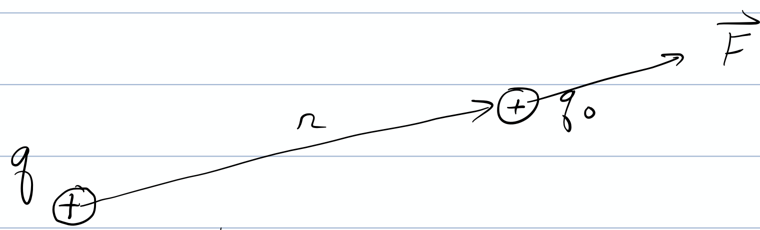
Electric Field: $\vec{E}$ at location of $q_0 \equiv \frac{\vec{F}}{q_0}$

magnitude $E = \frac{k\,|q_1|}{r^2}$ (electric field strength)

direction? The direction of the force a positive charge q_0 would experience.

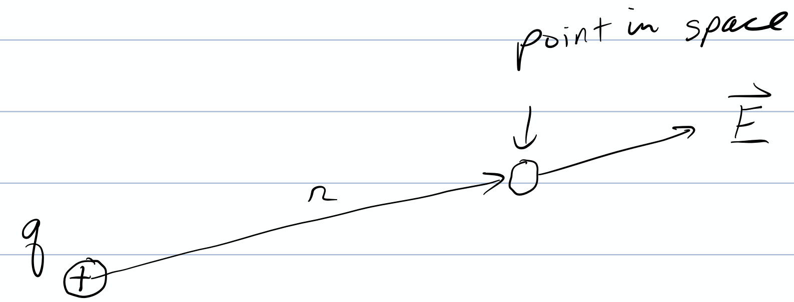
Units: $\frac{N}{C}$

$\vec{E}$ due to a point charge

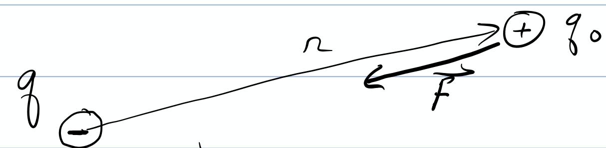


$$\vec{F} = \frac{k\,|q|\,|q_0|}{r^2}, \text{ away from } q$$

$$\vec{E} = \frac{\vec{F}}{|q_0|} = \frac{k\,|q|}{r^2}, \text{ away from } q$$

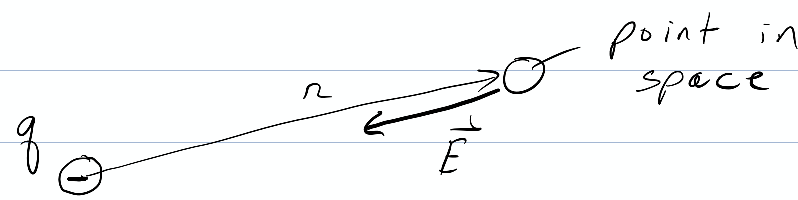


What if q is negative?



$$\vec{F} = \frac{K|q||q_0|}{r^2}, \text{ towards } q$$

$$\vec{E} = \frac{\vec{F}}{|q_0|} = \frac{K|q|}{r^2}, \text{ towards } q$$

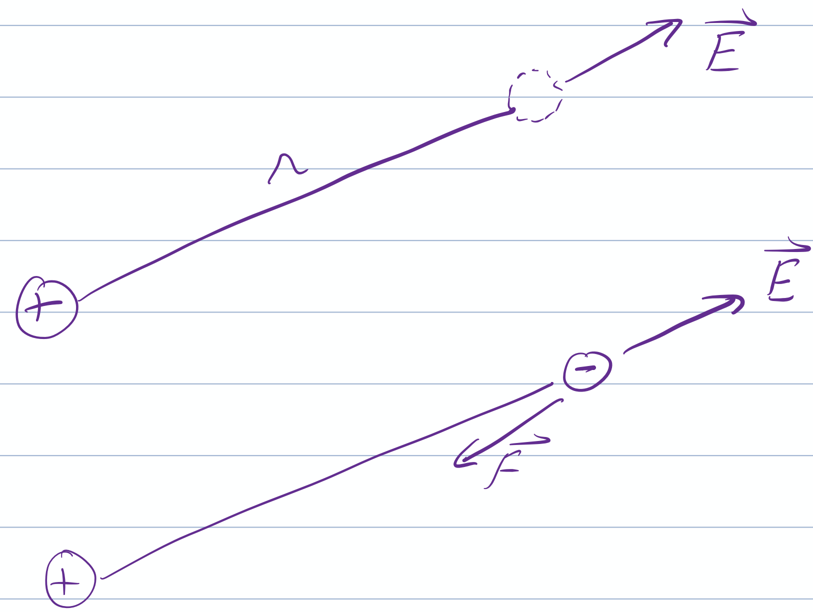


General Form:

$\vec{E}$ at a point a distance $\vec{r}$ away from a point charge:

$$\vec{E} = \frac{K|q|}{r^2}, \begin{cases} \text{away from } q \text{ if } q = \text{positive} \\ \text{towards } q \text{ if } q = \text{negative} \end{cases}$$

What if you put down a negative charge?



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

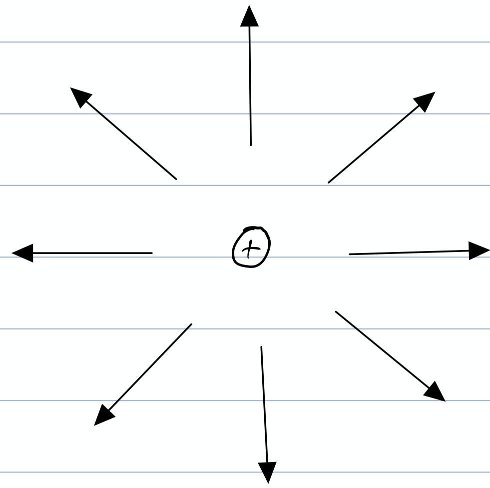
$\vec{F}$ ↑ towards

q ↑ negative

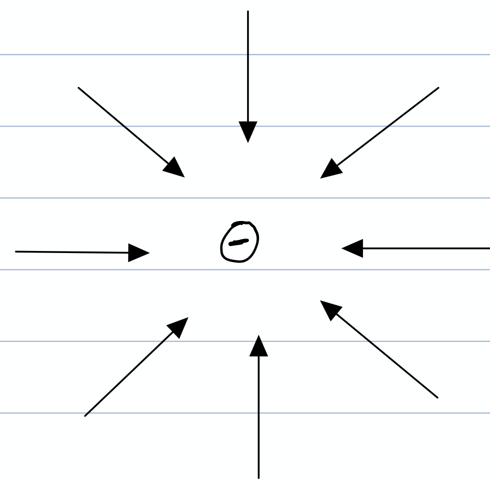
$\vec{E}$ ↑ away

Sketch:

points away from + charge

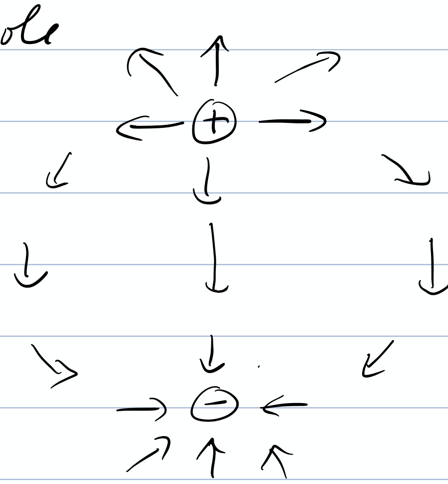


points towards − charge

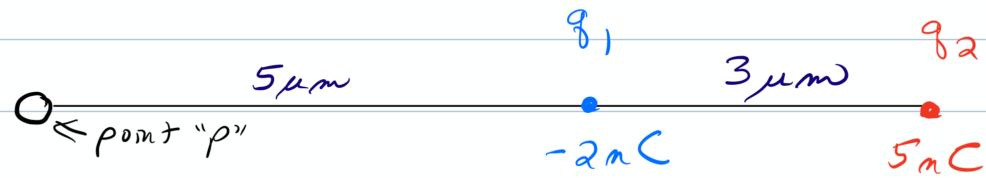


Multiple charges? Use superposition.

e.g. dipole

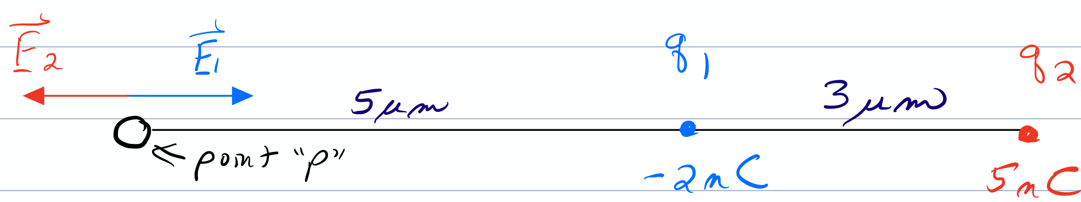


Revisit our line example:



Point "p" is an empty point in space. What is the electric field at "p" due to charges q_1 and q_2? $\vec{E} = \vec{E}_1 + \vec{E}_2$

Poll: directions of $\vec{E}_1$ and $\vec{E}_2$



$$E_1 = |\vec{E}_1| = \frac{K\,|q_1|}{r_1^2} = \frac{(9\times10^{9}\,Nm^2/c^2)(2\times10^{-9}\,c)}{(5\times10^{-6}\,m)^2}$$

$$E_1 = 7.200 \times 10^{11}\ N/C$$

$$E_2 = |\vec{E}_2| = \frac{K\,|q_2|}{r_2^2} = \frac{(9\times10^{9}\,Nm^2/c^2)(5\times10^{-9}\,c)}{(8\times10^{-6}\,m)^2}$$

$$E_2 = 7.031 \times 10^{11}\ N/C$$

Net: $E = E_1 - E_2 = 0.169 \times 10^{11}$ N/C

$E = 1.69 \times 10^{10}$ N/C (huge field!)

Suppose you now put a charge $q_0 = 3$ nC down at point P. What is the net force on q_0?

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

$$F = (3 \times 10^{-9} \text{ C})(1.69 \times 10^{10} \text{ N/C})$$

$$F = 51 \text{ N}$$ (positive, to the right.)

Suppose instead you put $q_4 = -4$ nC at P?

$$\vec{F}_4 = q_4 \vec{E}$$

$$F_4 = (-4 \times 10^{-9} \text{ C})(1.69 \times 10^{10} \text{ N/C})$$

$$F_4 = -68 \text{ N}$$ (to the left)

Two basic directions of inquiry:

1) How to calculate $\vec{E}$ (mag. + dir.)
2) What to do with it?

$\vec{F} = m\vec{a}$, work/energy

vector examples: ch20-E-vectors-1.pdf
ch20-E-vectors-2.pdf