

■ **Theme Music:**  
**Black-Eyed Peas**  
*Electric City*

■ **Cartoon:**  
**Randall Monroe**  
*XKCD*



WE WERE GOING TO USE THE TIME MACHINE TO PREVENT THE ROBOT APOCALYPSE, BUT THE GUY WHO BUILT IT WAS AN ELECTRICAL ENGINEER.

# Foothold ideas: Fields



- A *field* is a concept we use to describe anything that varies in space. It is a set of values assigned to each point in space (e.g., temperature or wind speed).
- A *force field* is an idea we use for non-touching forces. It puts a force vector at each point in space, summarizing the effect of all objects that would exert a force on a particular object placed at that point.
- A *gravitational, electric, or magnetic field* is a force field with something (a “coupling strength”) divided out so the field no longer depends on what test object is used.

$$\vec{g} = \frac{\vec{F}_{\text{acting on } m}}{m}$$

$$\vec{E} = \frac{\vec{F}_{\text{acting on } q}}{q}$$

Field is the value at a position in space “ $r$ ” assuming that the force is measured by placing the object at  $r$ .

# In Equations

$$\vec{F}_q = \vec{F}_{Q_1 \rightarrow q} + \vec{F}_{Q_2 \rightarrow q} + \vec{F}_{Q_3 \rightarrow q} + \vec{F}_{Q_4 \rightarrow q} + \dots$$

$$\vec{F}_q = \frac{k_C q Q_1}{r_1^2} \hat{r}_1 + \frac{k_C q Q_2}{r_2^2} \hat{r}_2 + \frac{k_C q Q_3}{r_3^2} \hat{r}_3 + \frac{k_C q Q_4}{r_4^2} \hat{r}_4 + \dots$$

where

$r_1$  = distance from  $Q_1$  to  $q$

$\hat{r}_1$  = direction from  $Q_1$  to  $q$  (mag. 1, no units!)

$r_2$  = distance from  $Q_2$  to  $q$

$\hat{r}_2$  = direction from  $Q_2$  to  $q$  (mag. 1, no units!)

...

# Making sense



- Notice that  $F_q/q$  does NOT depend on  $q$ !
- For one source charge

$$\vec{F}_q = \frac{k_C q Q_1}{r_1^2} \hat{r}_1 \qquad \vec{E}_q = \frac{\vec{F}_q}{q} = \frac{k_C Q_1}{r_1^2} \hat{r}_1$$

- For many sources

$$\vec{F}_q = \frac{k_C q Q_1}{r_1^2} \hat{r}_1 + \frac{k_C q Q_2}{r_2^2} \hat{r}_2 + \frac{k_C q Q_3}{r_3^2} \hat{r}_3 + \dots \qquad \vec{E}_q = \frac{\vec{F}_q}{q} = \frac{k_C Q_1}{r_1^2} \hat{r}_1 + \frac{k_C Q_2}{r_2^2} \hat{r}_2 + \frac{k_C Q_3}{r_3^2} \hat{r}_3 + \dots$$

- Why not? Why did I label  $E$  with a  $q$ ?