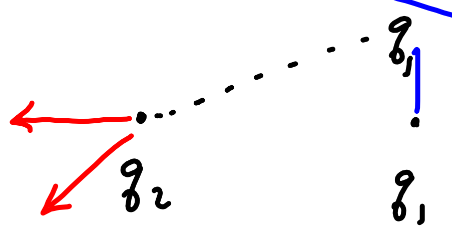
The electric field

The Coulomb force. $q_1, q_2 > 0$

acts instantaneously

"action-at-a-distance"

needs to be revised



what happens if

q_2 is on the moon?

q_1 electric q_2

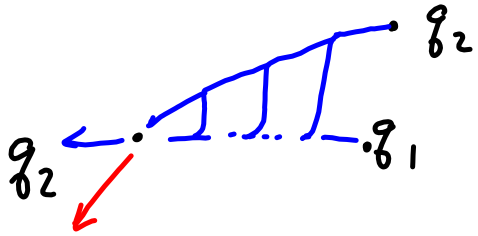
charge $\longrightarrow$ field $\longleftarrow$ charge

each charge produces an electric field

and all charges only interact

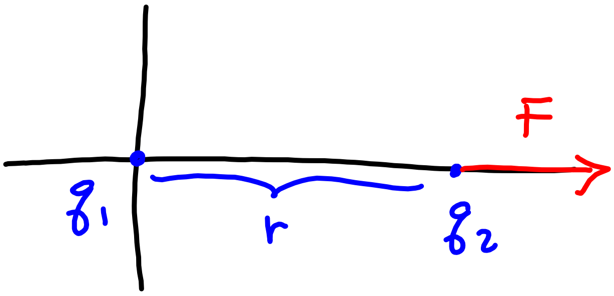
with the electric field at

its location.



The electric field produced by a pt charge

$q_1, q_2 > 0$

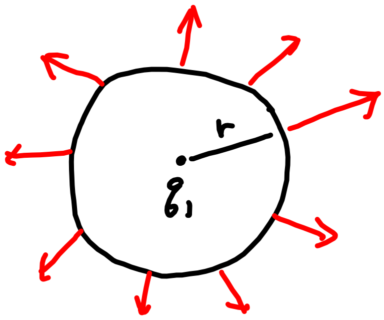


$$F_{21} = \frac{k q_1 q_2}{r^2} = q_2 \left(\frac{k q_1}{r^2} \right)$$

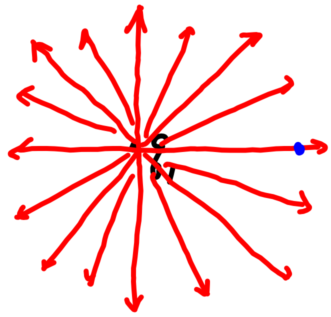
force on 2 by 1

$$= q_2 E_1$$

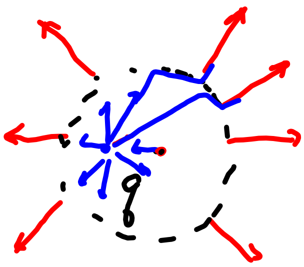
← electric field produced by q_1



$$E = \frac{k q_1}{r^2}$$

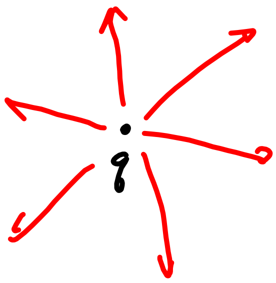


$F_{21} = q_2 E_1$

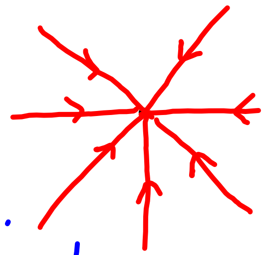


$$\vec{F} = q \vec{E}(r)$$

if $q > 0$ if $q < 0$



$$\vec{E}(r) = \frac{kq}{r^2}$$



negative

direction determined by q

>0 outward

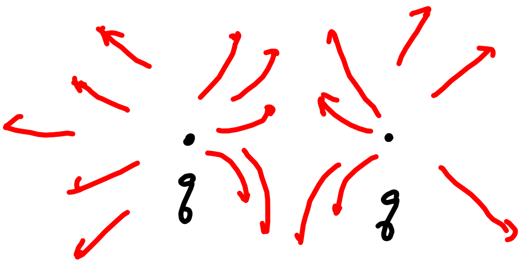
<0 inward

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

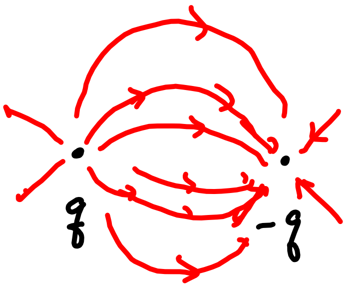
$$\vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 + \cdots$$

for more than one charge.

for two charge $q > 0$



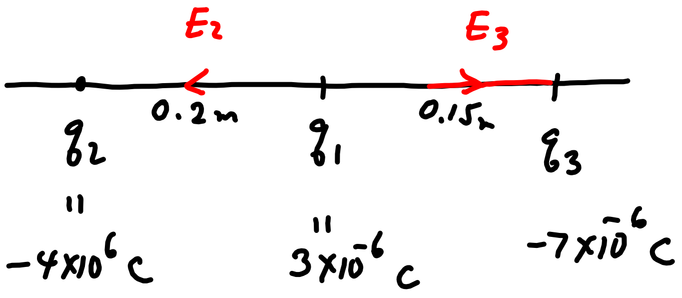
repulsion



attraction

Ex 2' three charges in a line

find Electric field at q_2



What is the electric at q_1 produced by q_2, q_3

E_1 E_3 at q_2

$$E_3 = \frac{k q_3}{r^2} = \frac{9\times10^9 \; 7\times10^{-6}}{(.15)^2} = 2.8\times10^6 \, N/C$$

$$E_1 = \frac{k q_1}{(.2)^2} = 6.75\times10^5 \, N/C$$

$$E_2 = \frac{k q_2}{(.2)^2} = \frac{9\times10^9 \; 4\times10^{-6}}{(.2)^2} = 9\times10^5 \, N/C$$

$$E_3 = \frac{k q_2}{(.35)^2} = 5.14\times10^5 \, N/C$$

at q_1 E_2 E_3

$$E_3 - E_2 = 2.8\times10^6 - 0.9\times10^6 = 1.9\times10^6 \, N/C$$

The force on q_1 is therefore

$$F_1 = q_1 (1.9\times10^6 \, N/C) = 5.7 \, N$$

($q_1 = 3\times10^{-6}$)

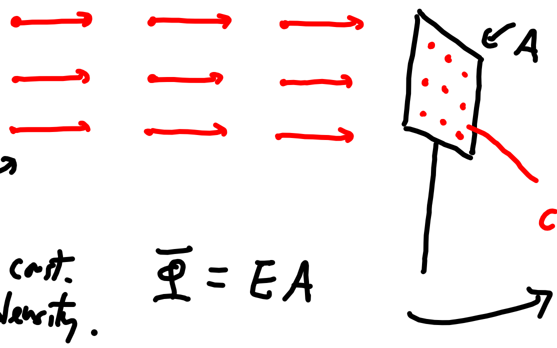
$$E_3 - E_1 = (5.14 - 6.75)\times10^5 \, N/C = -1.61\times10^5 \, N/C$$

What is the electric field on q_2 ?

Electric flux + Gauss' Law

Suppose we have a const electric field

can be produce by a sheet of uniform charge.



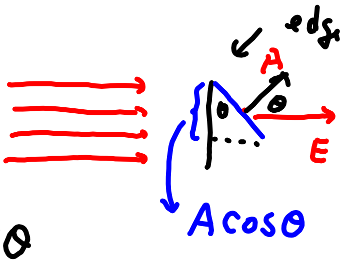
think about as flow of const. arrows with density.

$E \sim \# \text{arrow}/m^2$

$\Phi = EA$

catch # of arrow.

edge-wise



$\Phi = EA\cos\theta$

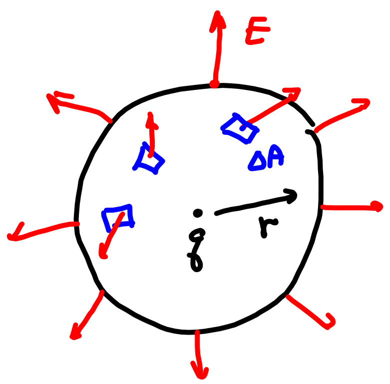
if $\theta = 0$

$A \perp \vec{E}$ $\quad \Phi = EA$

$\theta = 90$

$A \parallel \vec{E}$ $\quad \Phi = 0$

The electric flux of a pt charge

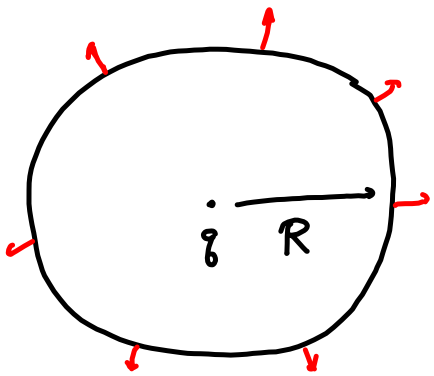


spherical surface

$\Delta \Phi = E \Delta A$

Total flux over the entire close surface

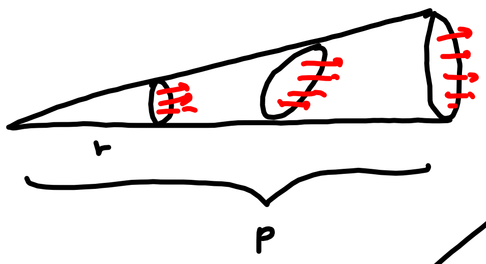
$\Phi = \sum_i \Delta \Phi = E \sum \Delta A = E\, 4\pi r^2$

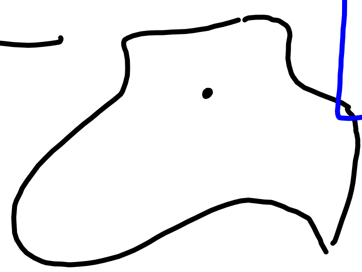


$\Phi = \frac{kq}{\cancel{r^2}} 4\pi \cancel{r^2} = \boxed{4\pi k q = \Phi}$

ind. of the size of the surface.

ind. of the shape of the surface



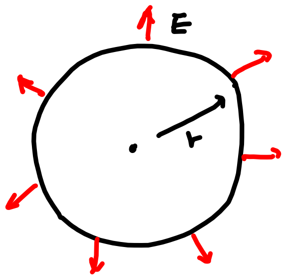


$\boxed{\Phi = 4\pi k q_{\text{enclosed}}}$

Gauss' Law

Application of Gauss' Law :

1) pt charge

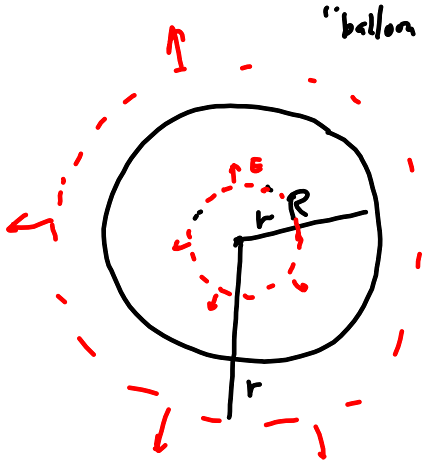


$\Phi = 4\pi k q$

$= E \cancel{4\pi} r^2 = \cancel{4\pi} k q$

$E(r) = \frac{kq}{r^2}$

2) Uniform charge shell with total charge Q
"balloon



at $r < R$

$\Phi = 4\pi k q_{enclosed}$

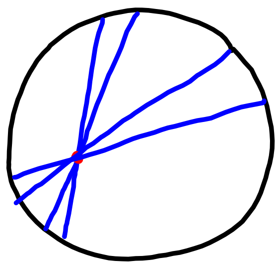
$4\pi r^2 E = 4\pi k \cdot 0$

$E = 0$ at $r < R$

at $r > R$

$4\pi r^2 E = 4\pi k Q$

$E(r) = \frac{kQ}{r^2}$ at $r > R$

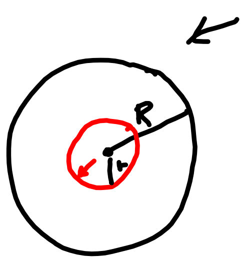


By the similar argument:

Can find the electric field due

3) to solid sphere of uniform charge.

Q total $\rho = \frac{Q}{\frac{4}{3}\pi R^3}$



at $r > R$ $E(r) = \frac{kQ}{r^2}$

at $r < R$

$E\, 4\pi r^2 = 4\pi k \,(q_{enclo})$

$= 4\pi k \,\rho\, \frac{4}{3}\pi r^3$

$E = \cancel{4\pi} k \frac{Q}{\cancel{\frac{4}{3}\pi} R^3} \frac{\cancel{\frac{4}{3}\pi} r^3}{\cancel{4\pi} r^2}$

$= k \frac{Q}{R^3} r$