THE $\underset{\rightarrow}{E}$ – FIELD (COULOMB) / GRAVITATIONAL FIELD

FORCE BETWEEN TWO POINT CHARGES

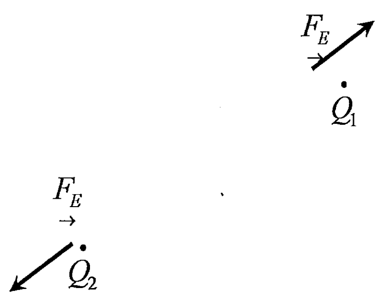
$$\underset{\rightarrow}{F_E} = k_e \frac{Q_1 Q_2}{r^2}\hat{r}$$

$$k_e = 9x10^9 \frac{N-m^2}{C^2}$$

Q_1, Q_2 same sign

$\underset{\rightarrow}{F_E} \parallel +\hat{r}$

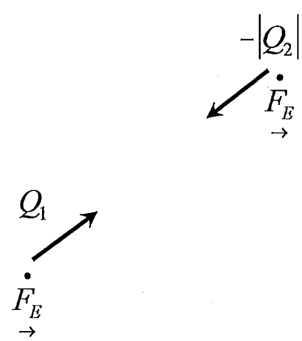
REPULSIVE (BOTH FORCES OUTWARD)



Q_1, Q_2 have opposite signs.

$\underset{\rightarrow}{F_E} \parallel -\hat{r}$ (BOTH FORCES INWARD)

ATTRACTIVE



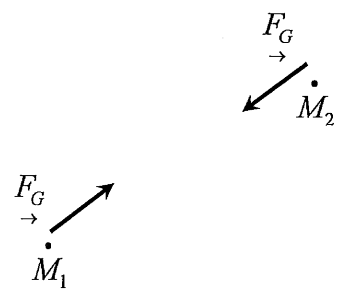
FORCE BETWEEN TWO POINT MASSES

$$\underset{\rightarrow}{F_G} = -\frac{GM_1M_2}{r^2}\hat{r}$$

$$G = 6.7x10^{-11}\frac{N-m^2}{(kg)^2}$$

$\underset{\rightarrow}{F_G}$ ALWAYS ATTRACTIVE

$\underset{\rightarrow}{F_G} \parallel -\hat{r}$ (BOTH FORCES INWARD)



NOTICE THAT THE FORCES OCCUR AS ACTION-REACTION PAIRS IN EVERY CASE.

$\left[\underset{\rightarrow}{F_{12}} = -\underset{\rightarrow}{F_{21}}\right]$ The EQUATIONS REPRESENT TWO FORCES.

Many Point Charges Force on Q_i

$$\vec{F}_i = k_e \sum_{j \neq i} \frac{Q_i Q_j}{r_{ij}^2} \hat{r}_{ij}$$

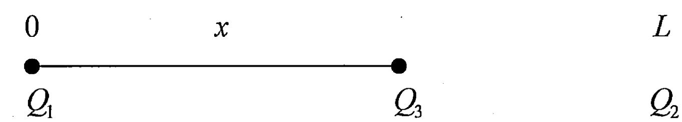
Note: Right side involves addition of vectors.

<u>SPECIAL CASES</u>

1. Q_1 at x=0, Q_2 at x=L. Where to locate Q_3 so $\vec{F}_3$ force on Q_3 is zero.

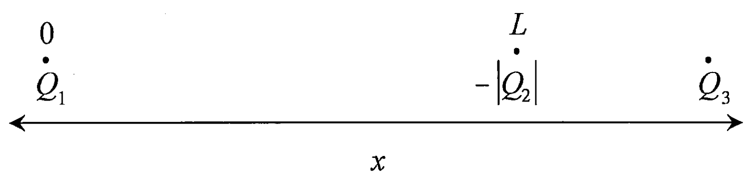
Q_3 must be on the line joining Q_1 *and* Q_2.

$$x = \frac{L}{1 + \sqrt{\frac{Q_2}{Q_1}}}$$

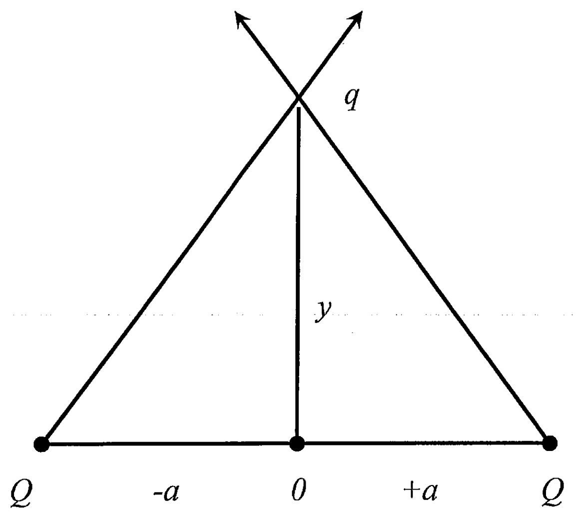


2. Q_1 at x=0, $-|Q_2|$ at x=L. $\vec{F}_3$ will be zero if

$$x = \frac{L}{\sqrt{\frac{Q_1}{Q_2}} - 1} \quad \textit{when } Q_1 > |Q_2|$$



3. Q at x=-a, Q at x= +a. What is force on q at (0, y)



$$\vec{F}_E(y) = \frac{2k_eQy}{(y^2+a^2)^{3/2}}\hat{y}$$

What if we have $-|q|$ at $(0, y)$

$$\frac{-2k_e|q|Qy\,\hat{y}}{(y^2+a^2)^{3/2}}$$

Let us make $y \ll a$.

In this case, force is proportional to displacement y and opposite to it so $-|q|$ will show Linear Harmonic oscillations.

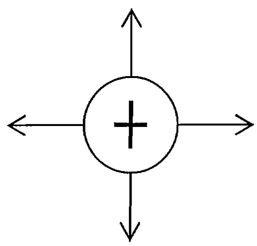
QUESTION: Why is there a force between two charges(masses) when they are far apart from one another.

To answer this we develop the concept of a FIELD

COULOMB $\vec{E}$- FIELD	*GRAVITATIONAL $(\vec{G}_F)$ FIELD*
If there is a charge Q sitting at x=0, the space around it is not empty. Q creates a coulomb $\vec{E}$ field which permeates all of space. If you place a test charge q in this $\vec{E}$ field, it experiences a force $\vec{F}_E = q\vec{E}$	If there is a mass M sitting at x=0, the space around it is not empty. M creates a gravitational $(\vec{G}_F)$ field which permeates all of space. If you place a test mass m in the $\vec{G}$ field it experiences a force $\vec{F}_G = m\vec{G}_F$

1. Single +ive charge Q at r=0.

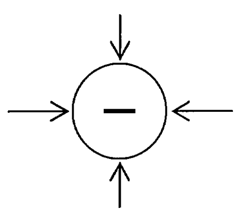
$$\underset{\to}{E} = \frac{k_e Q}{r^2}\hat{r}$$



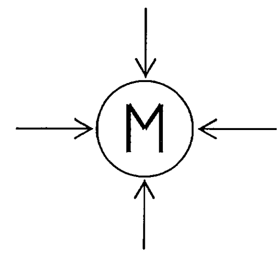
Acts like a "source" of an $\underset{\to}{E}$ field which points radially outward

2. Single –ive charge at r=0.

$$\underset{\to}{E} = -\,k_e\frac{|Q|}{r^2}\hat{r}$$



Acts like a "sink" of $\underset{\to}{E}$ field which pts. Radially inward.

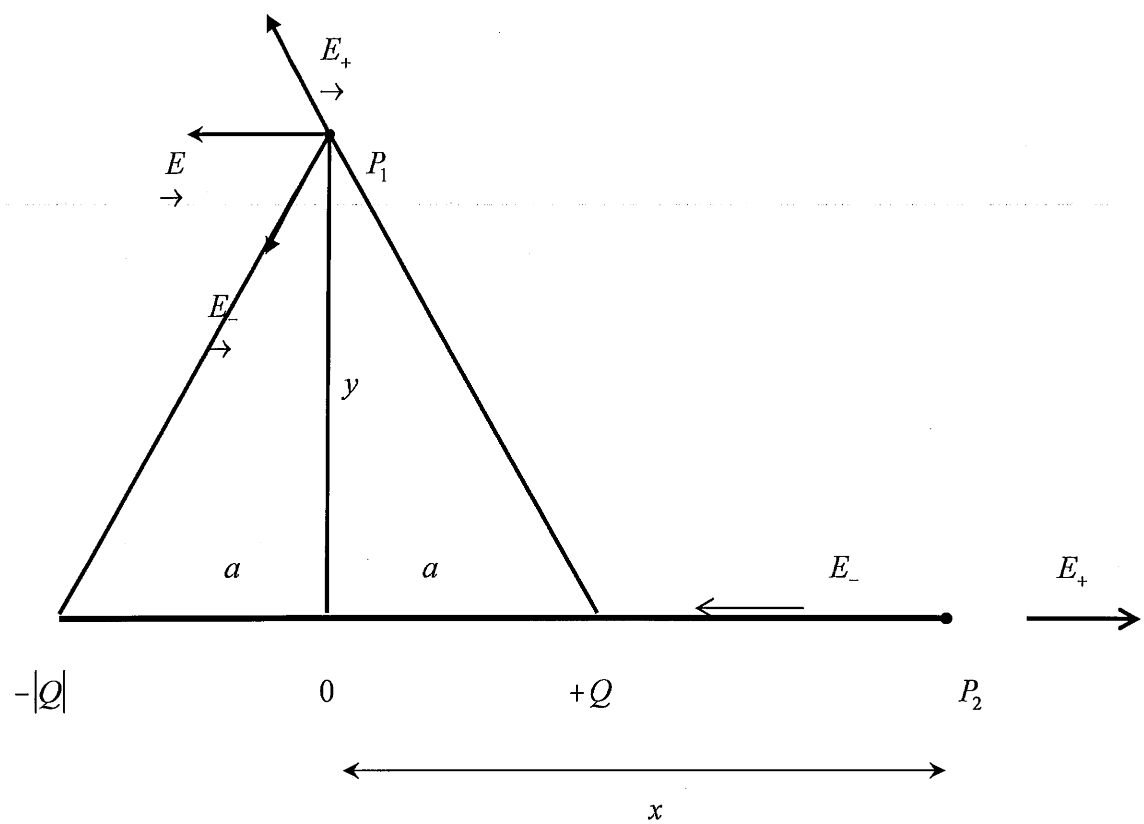


$$\underset{\to}{G_F} = -\frac{GM}{r^2}\hat{r}$$

ALWAYS INWARD RADIALLY.

3. $\underset{\to}{E}$ field of Dipole: $-|Q|$ *at x=-a*

$+Q$ *at* $x = a$



at $P_1 = (0, y)$ $\quad \underset{\to}{E}(y) = -\frac{k_e 2aQ}{(y^2 + a^2)^{3/2}}\hat{x}$

at $P_2 = (x, 0)$ $\quad \underset{\to}{E}(x) = -\frac{k_e 4aQx}{\left(x^2 - a^2\right)^2}$

Next, define dipole moment $\underset{\to}{p} = 2aQ\hat{x}$

When *x,y* >>*a* that is far away from dipole

$$\underset{\to}{E}(y) = \frac{-k_e \underset{\to}{p}}{y^3}$$

$$\underset{\to}{E}(x) = \frac{2k_e \underset{\to}{p}}{x^3}$$