Electrostatics

Course- PHY 2105 / PHY 105

Lecture 12

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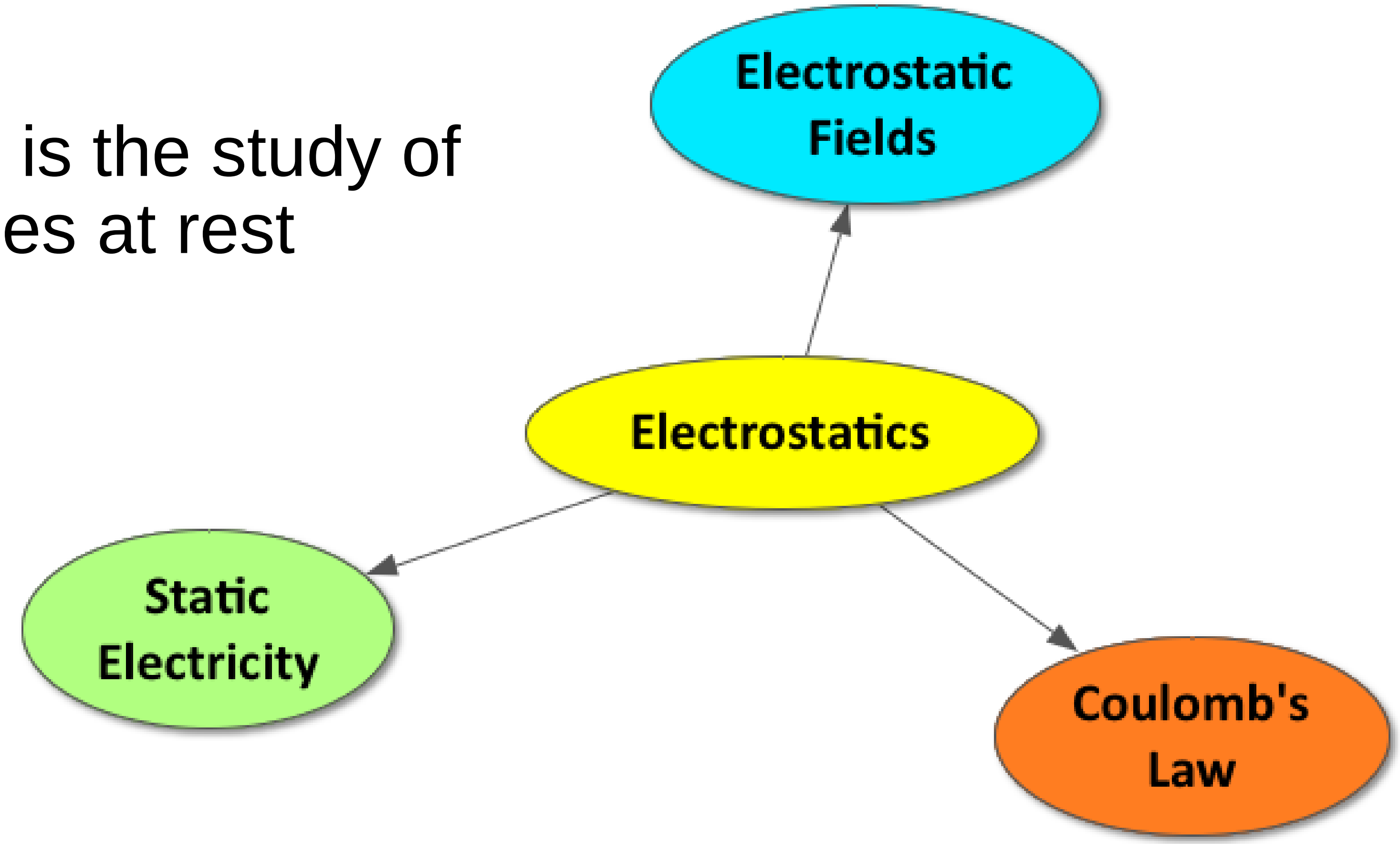
Electrostatics

Electrostatics is the study of electric charges at rest



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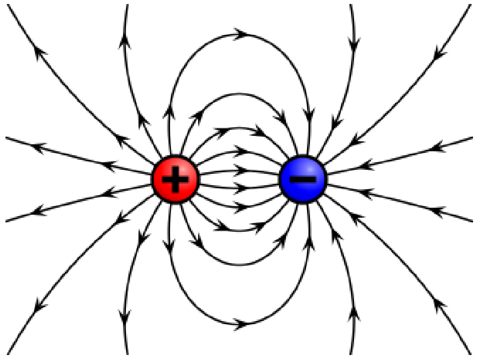
Electric Force

The electric force on a charged body is exerted by the electric field created by *other* charged bodies.

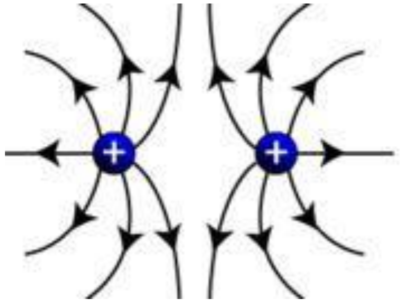
❑ The force acts without physical contact between the two objects

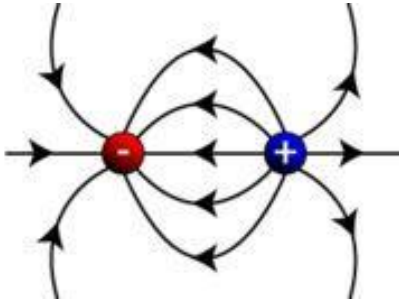
❑ The force can be either attractive or repulsive



$$\text{When two charged bodies are brought together} = \begin{cases} \text{positive - positive} & \text{repel} \\ \text{negative - negative} & \text{repel} \\ \text{positive - negative} & \text{attract.} \end{cases}$$

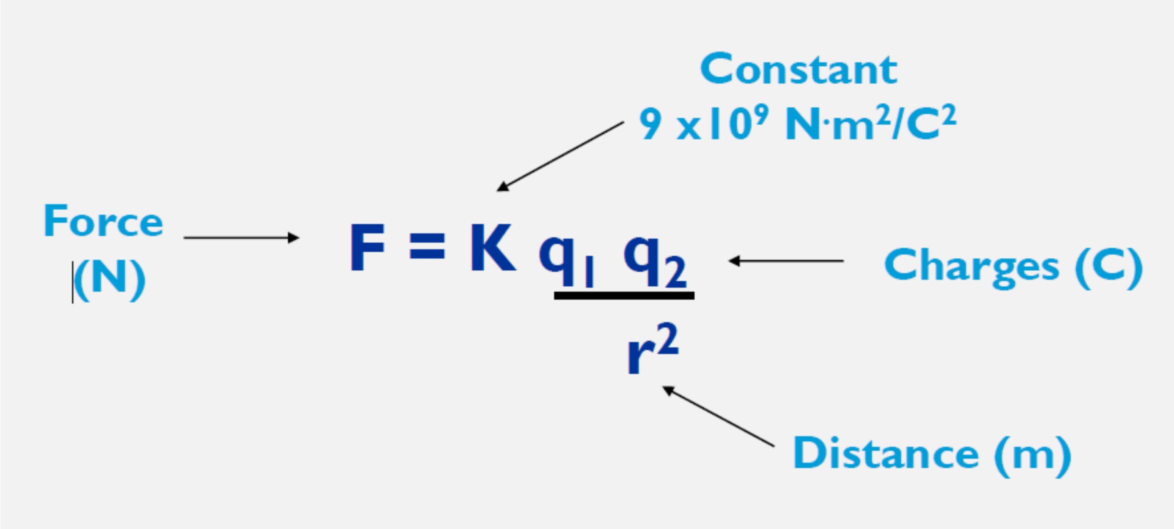
Electric field lines help visualize the electric field. Field lines begin on a positive charge and terminate on a negative charge. Electric field lines are parallel to the direction of the electric field





Coulomb’s Law

The electrostatic force between two charged object is directly proportional to the product of the amount of charges and inversely proportional to the square of the distance between them



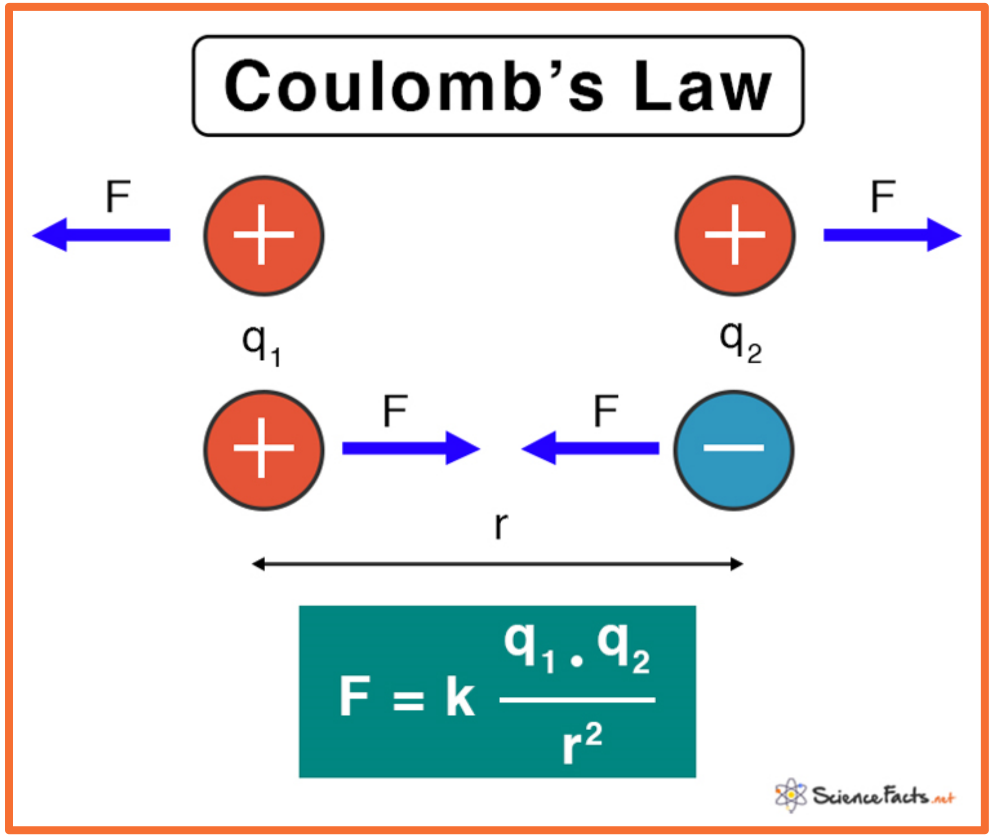
$$k = \frac{1}{4\pi\varepsilon_0}$$

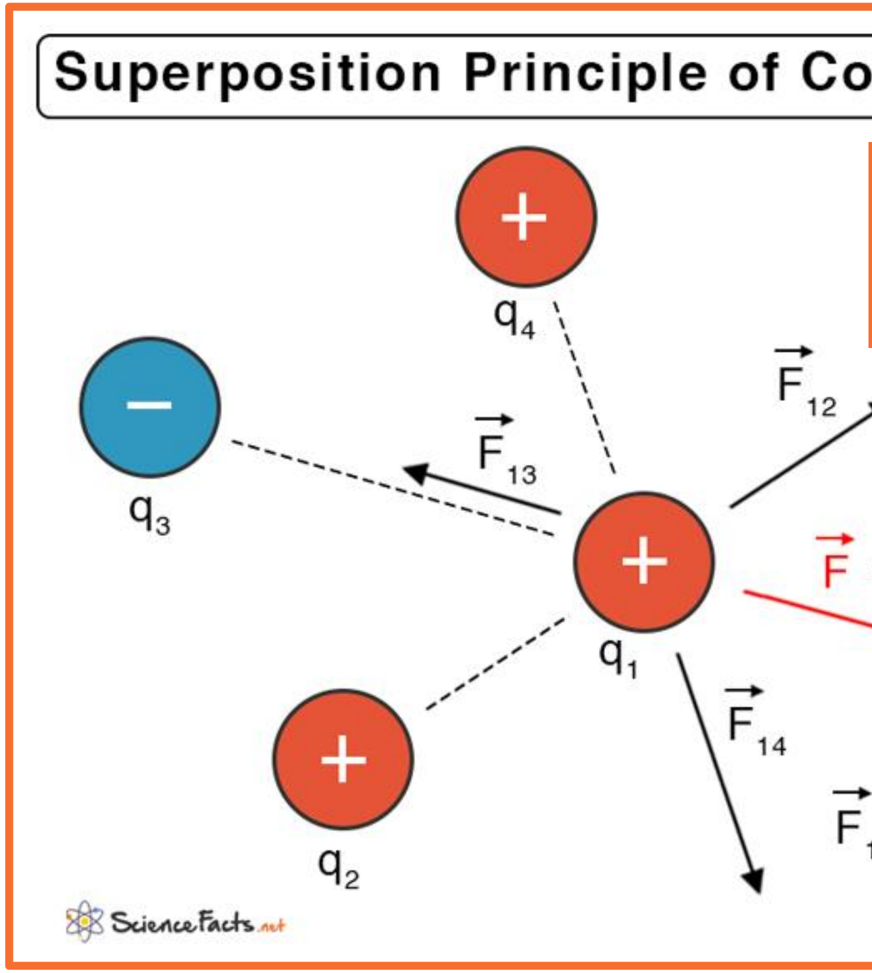
- *Experimental law*
- *Valid for point charges only*
- *Obeys Inverse Square Law*
- *Valid for only charges at rest*

$$Electrostatic\ constant, k = 9 \times 10^9 \frac{Nm^2}{C^2}$$

$$Permittivity\ constant, \varepsilon_0 = 8.854 \times 10^{-12} \frac{C^2}{Nm^2}$$

Coulomb's Law: Superposition

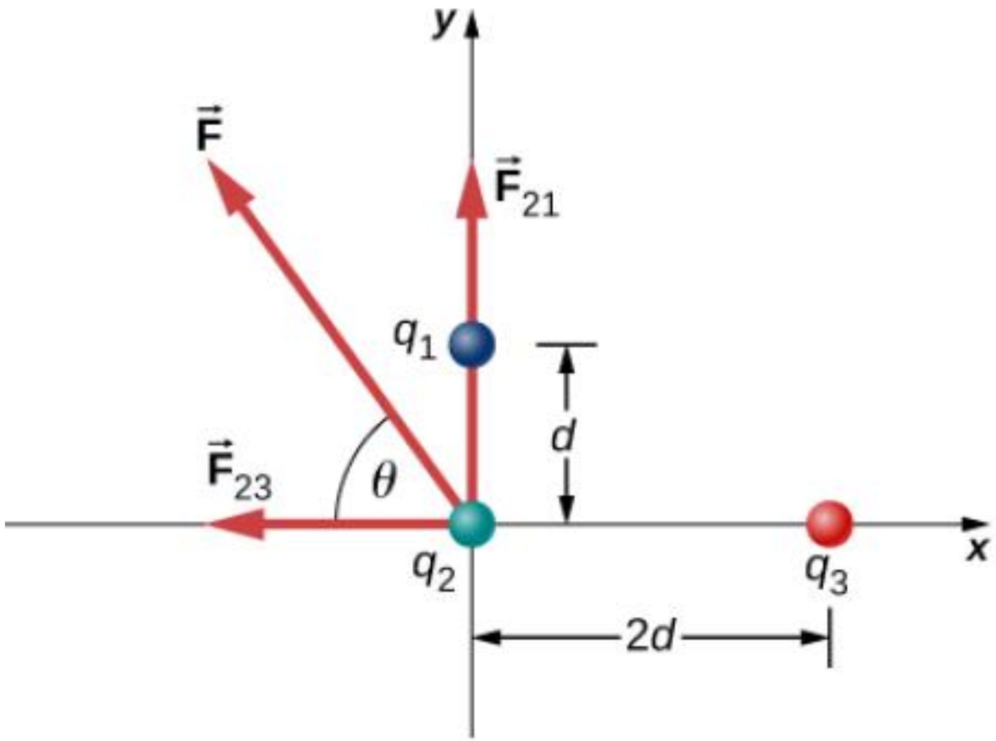




$$\vec{F_{ij}} = \sum_{\substack{i=1 \\ i\neq j}}^{N} \frac{k q_i q_j}{{r_{ij}}^2}$$

Example 11.4

The charges q1 and q2 are fixed in place; q3 is free to move. Given q1=2e, q2=-3e, and q3=-5e, and d= 200nm, what is the net force on the middle charge q2?



$$F = \sqrt{F_x^2 + F_y^2}$$

$$\begin{aligned} F_x &= -F_{23} = -\frac{1}{4\pi\varepsilon_0}\frac{q_2 q_3}{r_{23}^2} \\ &= -\left(8.99 \times 10^9 \,\frac{\mathrm{N{\cdot}m^2}}{\mathrm{C^2}}\right)\frac{\left(4.806 \times 10^{-19}\ \mathrm{C}\right)\left(8.01 \times 10^{-19}\ \mathrm{C}\right)}{\left(4.00 \times 10^{-7}\ \mathrm{m}\right)^2} \\ &= -2.16 \times 10^{-14}\ \mathrm{N} \end{aligned}$$

$$\begin{aligned} F_y &= F_{21} = \frac{1}{4\pi\varepsilon_0}\frac{q_2 q_1}{r_{21}^2} \\ &= \left(8.99 \times 10^9 \,\frac{\mathrm{N{\cdot}m^2}}{\mathrm{C^2}}\right)\frac{\left(4.806 \times 10^{-19}\ \mathrm{C}\right)\left(3.204 \times 10^{-19}\ \mathrm{C}\right)}{\left(2.00 \times 10^{-7}\ \mathrm{m}\right)^2} \\ &= 3.46 \times 10^{-14}\ \mathrm{N}. \end{aligned}$$

We find that

F= 4.08x10^-14 N at angle -58°

$$F = \sqrt{F_x^2 + F_y^2} = 4.08 \times 10^{-14}\ \mathrm{N}$$

at an angle of

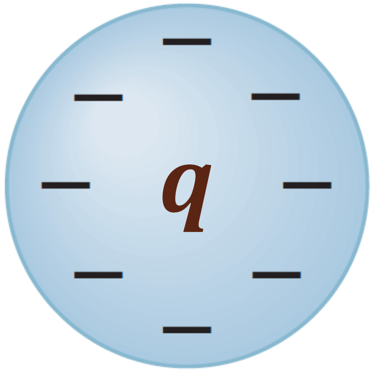
$$\phi = \tan^{-1}\left(\frac{F_y}{F_x}\right) = \tan^{-1}\left(\frac{3.46 \times 10^{-14}\ \mathrm{N}}{-2.16 \times 10^{-14}\ \mathrm{N}}\right) = -58^\circ,$$

that is, 58° above the $-x$-axis, as shown in the diagram.

Electric Field

$$F = q_0 E$$

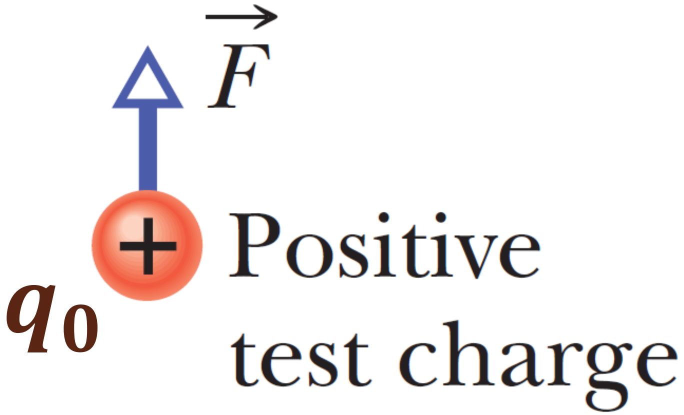
A charge has an effect on its surroundings. The area where it has an effect is generally called an *Electric field.* If any other charge enters that area, it feels an electrostatic Coulomb force.



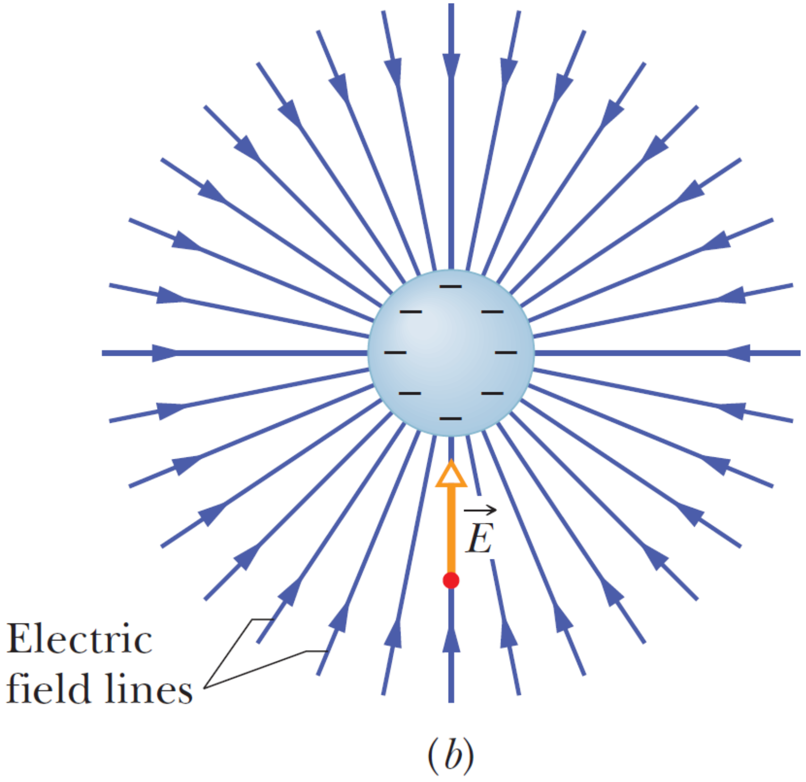
$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\,\hat{r}$$

for point test charges only

The electric force on a charged body is exerted by the electric field created by *other* charged bodies.



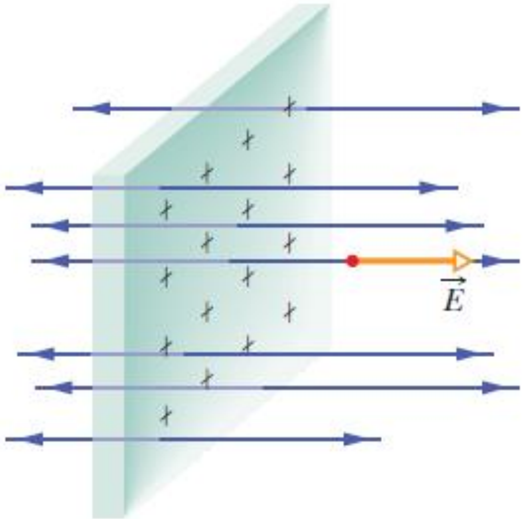
Electric Field Lines



Michael Faraday introduced the idea of electric field and electric field lines. The rules for drawing electric fields lines are these:

(1) At any point, the electric field vector must be tangent to the electric field line through that point and in the same direction.

(2) In a plane perpendicular to the field lines, the relative density of the lines represents the relative magnitude of the field there, with greater density for greater magnitude.



Electric field lines extend away from positive charge (where they originate) and toward negative charge (where they terminate)

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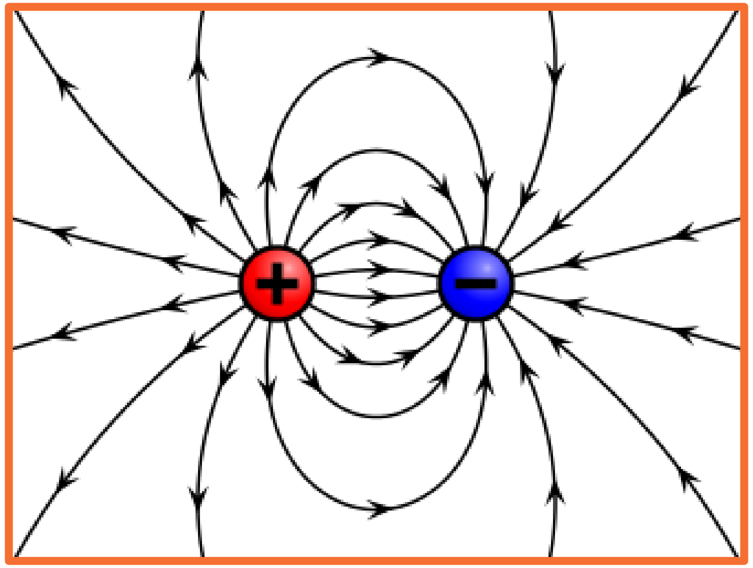
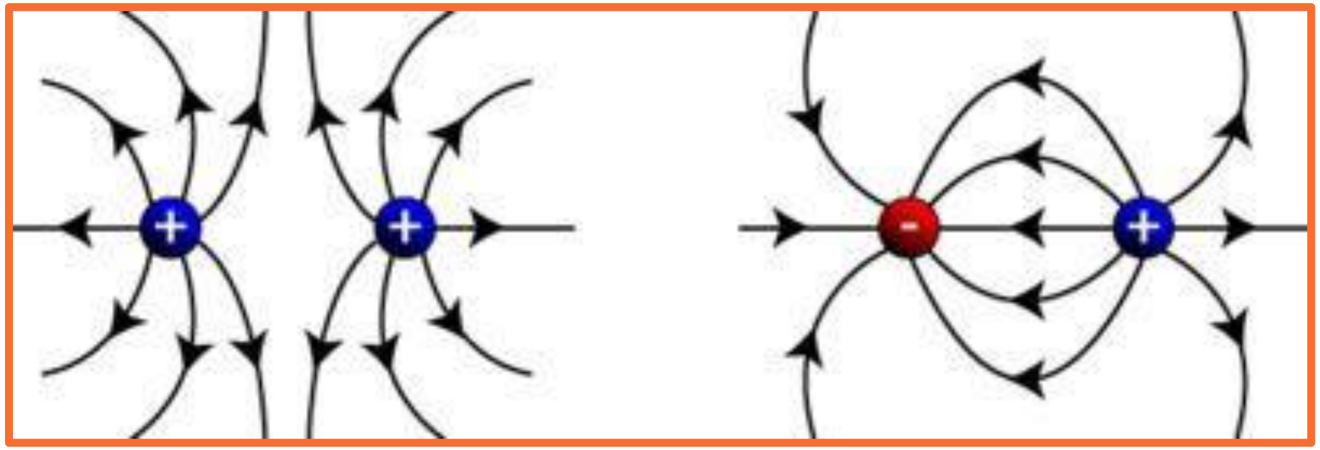
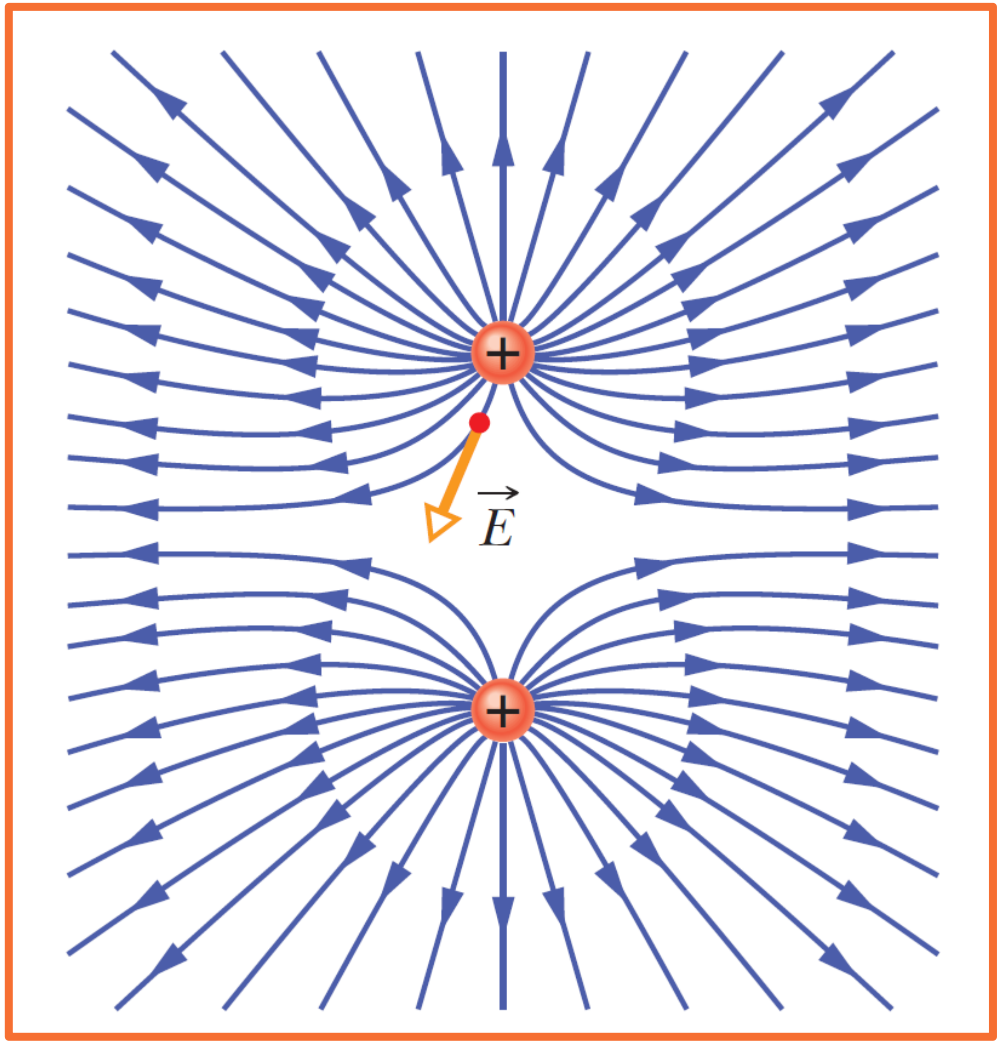
Field Lines

$$E = \frac{1}{4\pi\varepsilon_0}\frac{|q|}{r^2}$$







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Electric field due to a dipole

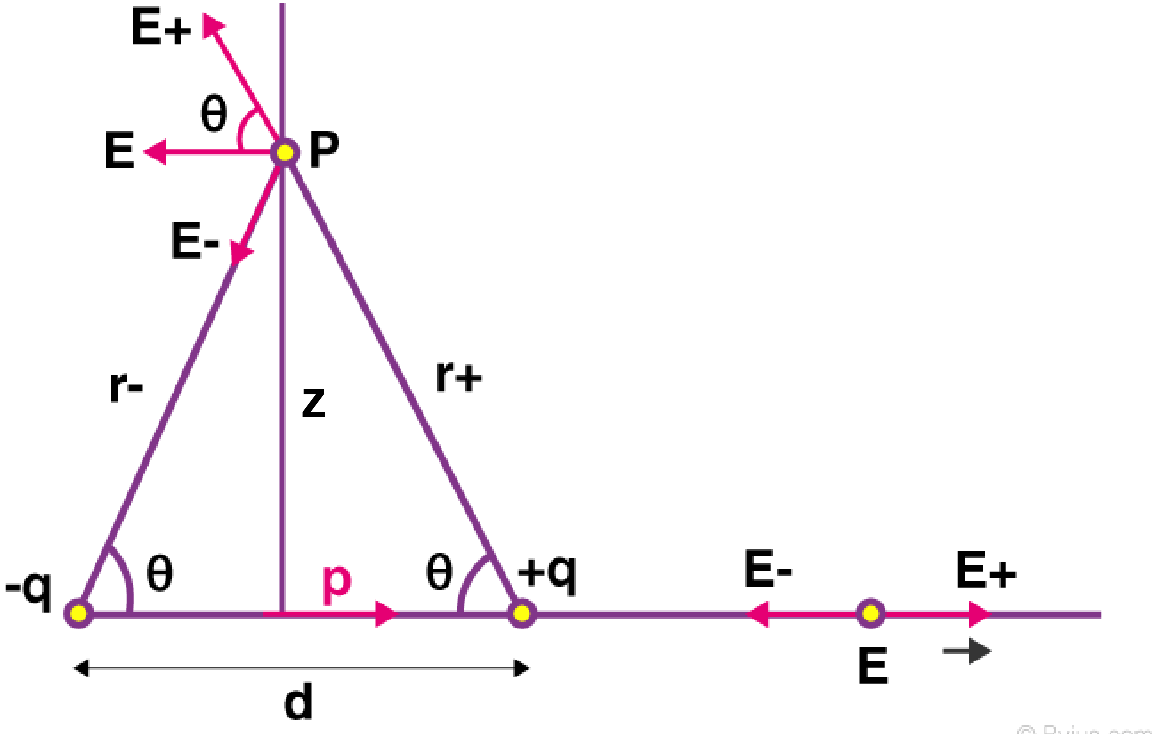
Pairs of point charges with equal magnitude and opposite sign are called *electric dipoles*

At any point

$$\boxed{E = \frac{1}{4\pi\varepsilon_0}\frac{p}{z^3}}$$

Along the dipole axis

$$\boxed{E = \frac{1}{4\pi\varepsilon_0}\frac{2p}{z^3}}$$



Where, dipole moment, p=qd

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