Camp elèctric (I)

Introducció

Càrrega elèctrica: Magnitud física fonamental (longitud, temps, massa,…)
De dos signes
Conservada (energia)
Quantitzada $\pm e$ (sempre múltiples $\pm Ne$)

Partícules fonamentals de la matèria

Electró $-e$

$$m_e = 9.1096 \times 10^{-31}\ \mathrm{kg}$$

Protó e

$$m_p = 1.673 \times 10^{-27}\ \mathrm{kg} = 1836\, m_e$$

Unitat de càrrega: el coulomb (C)

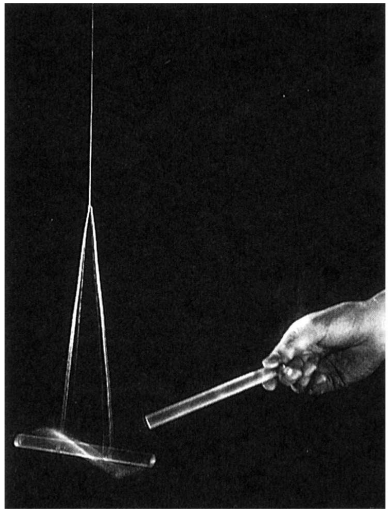
$$e = 1.6022 \times 10^{-19}\ \mathrm{C}$$

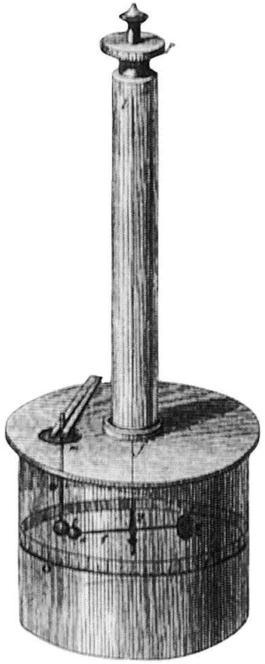
$$1\ \mathrm{C} = 6.2414 \times 10^{18}\ e$$

Exemple: a una moneda de coure de 3 g hi ha ~ 8.24×10^{23} electrons, i la seva càrrega total és -1.32×10^{5} C

La llei de Coulomb

Els cossos amb càrregues de signe contrari s'atreuen
i els que tenen càrregues del mateix signe es repel.leixen

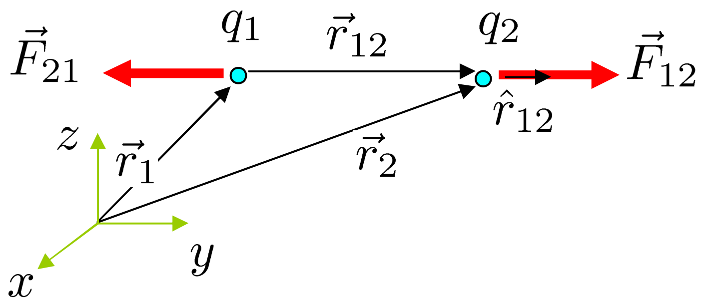




The force exerted by one point charge on another acts along the line between the charges. It varies inversely as the square of the distance separating the charges and is proportional to the product of the charges. The force is repulsive if the charges have the same sign and attractive if the charges have opposite signs.

COULOMB'S LAW

Càrregues '**puntuals**'



Vector de 1 a 2

$$\vec{r}_{12} = \vec{r}_2 - \vec{r}_1$$

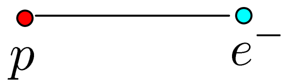
$$\hat{r}_{12} = \frac{\vec{r}_{12}}{r_{12}}$$ vector unitari

$$\boxed{\vec{F}_{12} = \underbrace{k}_{9 \cdot 10^9 \, \frac{\mathrm{N}}{\mathrm{m}^2\mathrm{C}^2}} \frac{q_1 q_2}{r_{12}^2} \hat{r}_{12}}$$

$$\vec{F}_{21} = k \frac{q_1 q_2}{r_{21}^2} \hat{r}_{21}$$

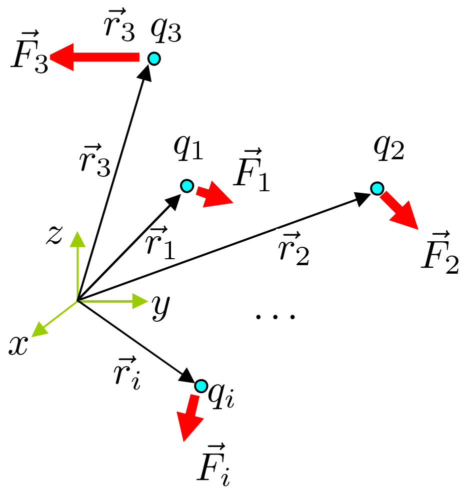
Davant la força de Coulomb la gravetat es menyspreable

$$\vec{F}_{12}^{(g)} = G \frac{m_1 m_2}{r_{12}^2} \hat{r}_{12}$$



$$\frac{F_{12}}{F_{12}^{(g)}} = \frac{ke^2}{G m_p m_e} = 2.27 \times 10^{39}$$

Més càrregues (superposició)

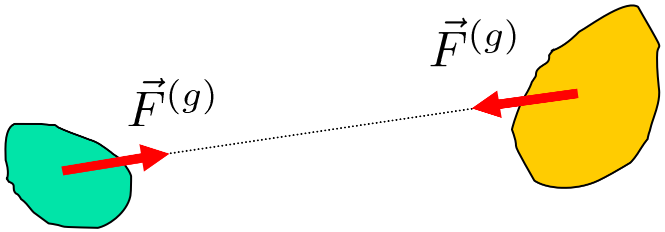


$$\vec{F}_i = \vec{F}_{1i} + \vec{F}_{2i} + \vec{F}_{3i} + \dots$$

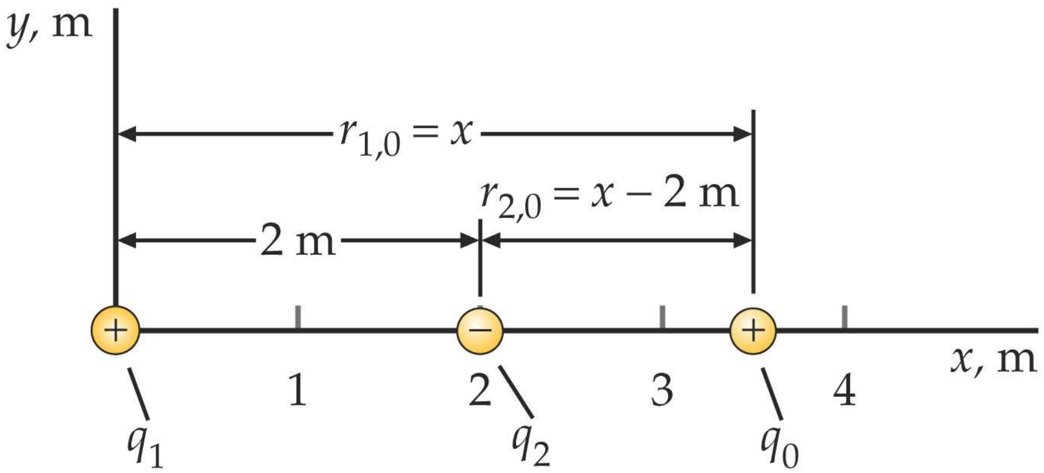
$$= \sum_{\substack{j=1 \\ (j \neq i)}}^{N} k \, \frac{q_j q_i}{r_{ji}^2} \, \hat{r}_{ji}$$

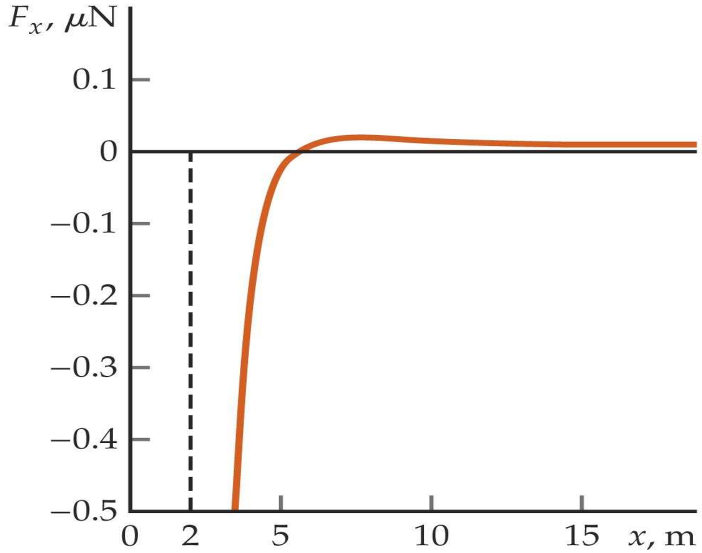
Compensació de càrregues al mon macroscòpic

Només forces gravitatòries



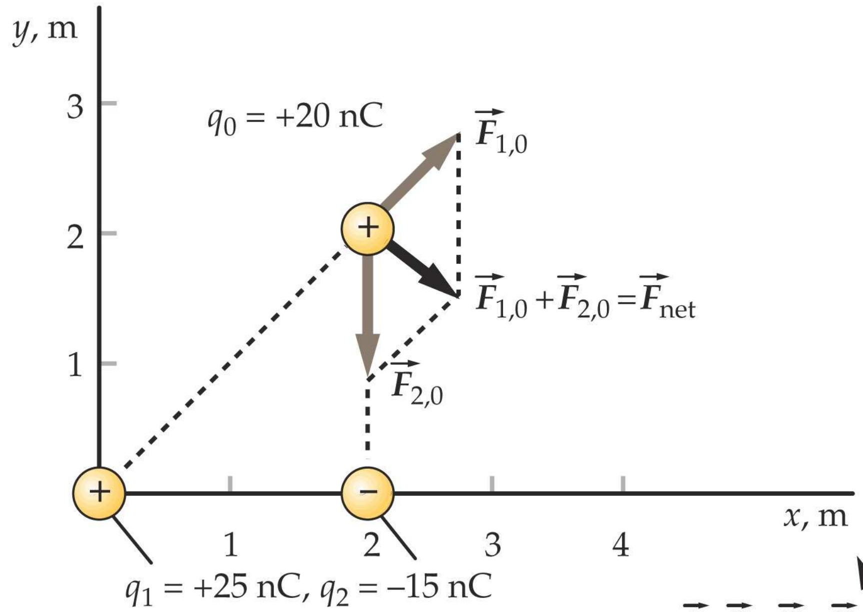
Exemple de força neta en una dimensió

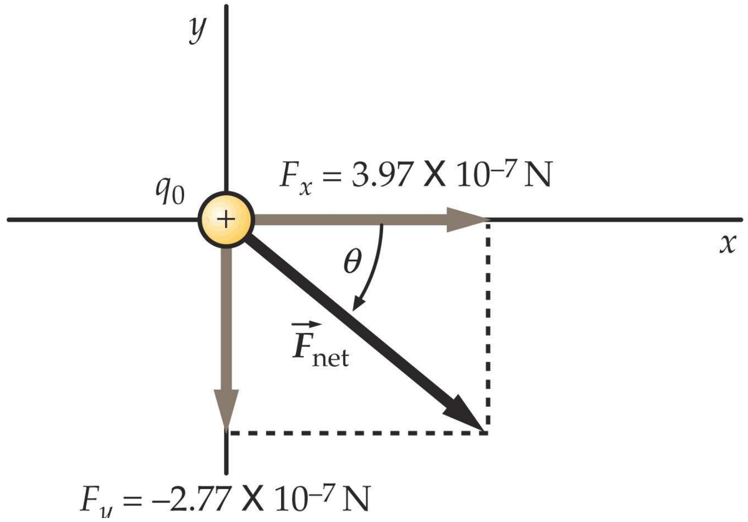




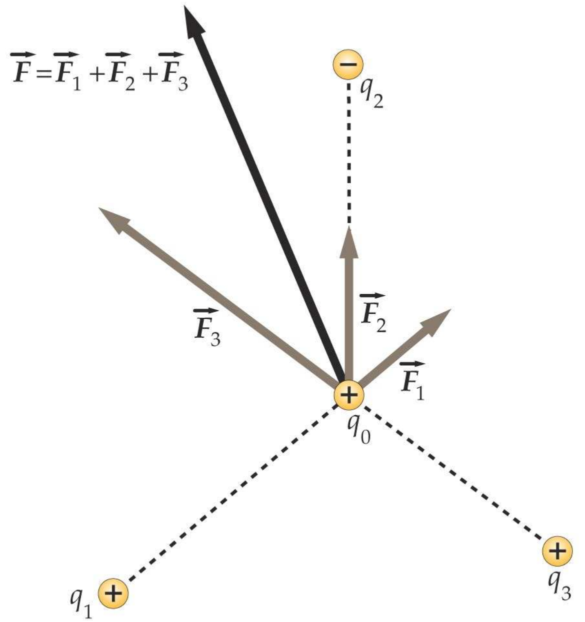
$$q_1 = 25 \text{ nC}$$
$$q_2 = -10 \text{ nC}$$

Exemple de força neta en dues dimensions





I en tres dimensions

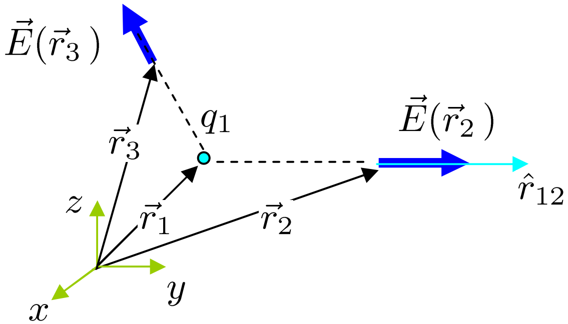


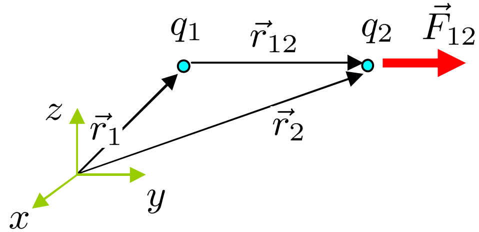
El camp elèctric

Interpretació de la llei de Coulomb:

q_1 crea un *camp vectorial* a tot l'espai $\vec{E}(\vec{r})$

q_2 experimenta una força $\vec{F}_{12}$ degut al camp de q_1





$$\vec{F}_{12} = q_2\,\vec{E}(\vec{r}_2) \qquad \vec{E}(\vec{r}_2) = k\frac{q_1}{r_{12}^2}\hat{r}_{12}$$

$$\vec{E}(\vec{r}_2) = k\frac{q_1}{r_{12}^3}\vec{r}_{12}$$

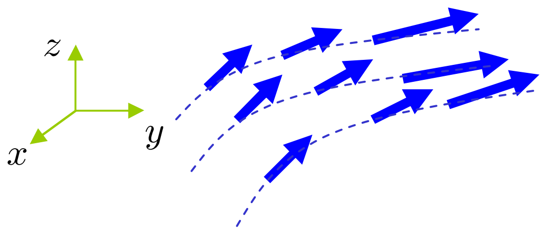
vector unitari de $\vec{r}_1$ a $\vec{r}_2$

$$\hat{r}_{12} = \frac{\vec{r}_{12}}{r_{12}}$$

Càrrega que crea el camp (font) i càrrega de prova

Es pot reinterpretar canviant els papers

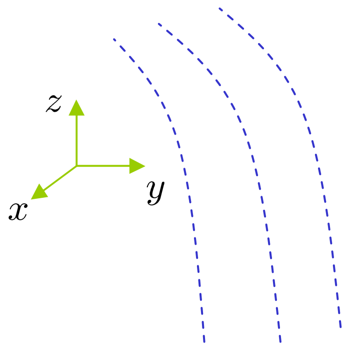
Camps vectorials: un vector a cada punt de l'espai



Línies de corrent

Camp de velocitats $\vec{v}(\vec{r})$

Camps escalars: un escalar a cada punt de l'espai

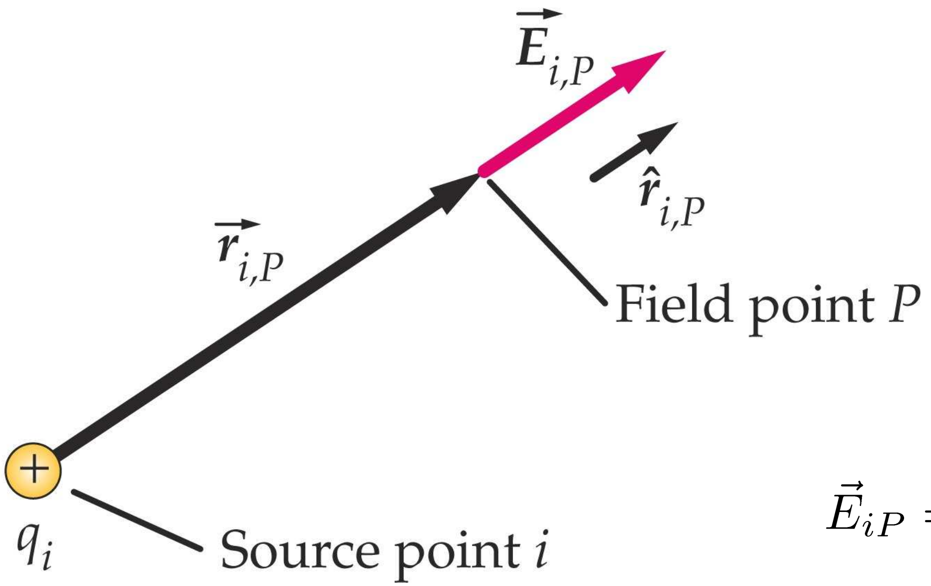


Línies de camp

Camp de temperatures $T(\vec{r})$

La permitivitat ϵ_0

$$k = \frac{1}{4\pi\epsilon_0}$$



$$\vec{E}_{iP} = \frac{q_i}{4\pi\epsilon_0 r_{iP}^2}\,\hat{r}_{iP} = \frac{q_i}{4\pi\epsilon_0 r_{iP}^3}\,\vec{r}_{iP}$$

Exemple: Si una càrrega de 5 nC experimenta una força de $2 \times 10^{-4}\,\mathrm{N}\,\vec{u}_x$, quin es el camp elèctric a seva posició ?

$$\vec{E} = \frac{\vec{F}}{q_0} = \frac{2 \times 10^{-4}\,\mathrm{N}\,\vec{u}_x}{5 \times 10^{-9}\,\mathrm{C}} = 4 \times 10^4\,\frac{\mathrm{N}}{\mathrm{C}}\,\vec{u}_x$$

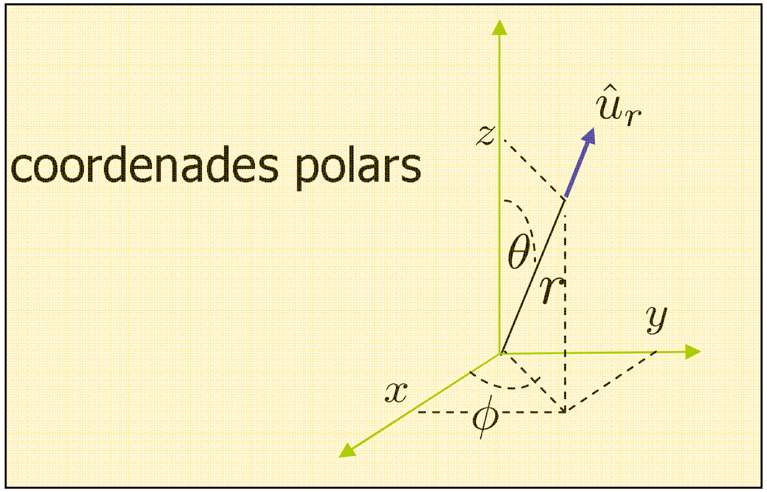
Unitat de camp elèctric

Ordres de magnitud

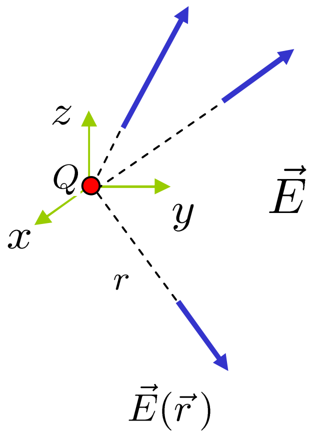
TABLE 21-2

Some Electric Fields in Nature

	E, N/C
In household wires	10^{-2}
In radio waves	10^{-1}
In the atmosphere	10^{2}
In sunlight	10^{3}
Under a thundercloud	10^{4}
In a lightning bolt	10^{4}
In an X-ray tube	10^{6}
At the electron in a hydrogen atom	6×10^{11}
At the surface of a uranium nucleus	2×10^{21}



Camp d'una càrrega puntual

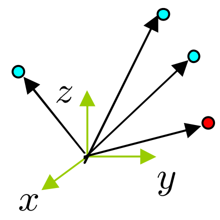


$$\vec{E}(\vec{r}) = \frac{Q}{4\pi\epsilon_0 r^2}\,\hat{u}_r$$

Més d'una càrrega (superposició)

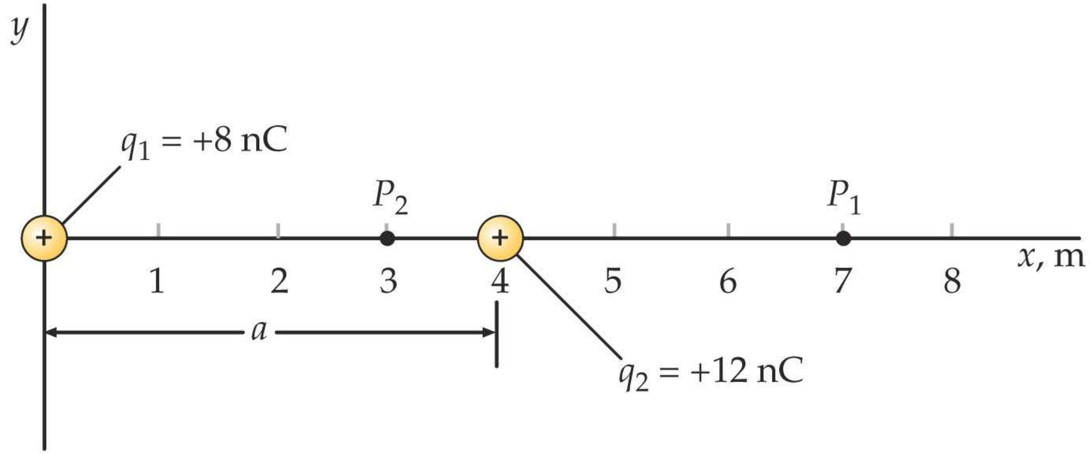
Càrregues font $(q_1, \vec{r}_1\ ),\ (q_2, \vec{r}_2\ ),\ \ldots\ (q_N, \vec{r}_N\ )$

Càrrega prova $(q_p, \vec{r}_p\ )$

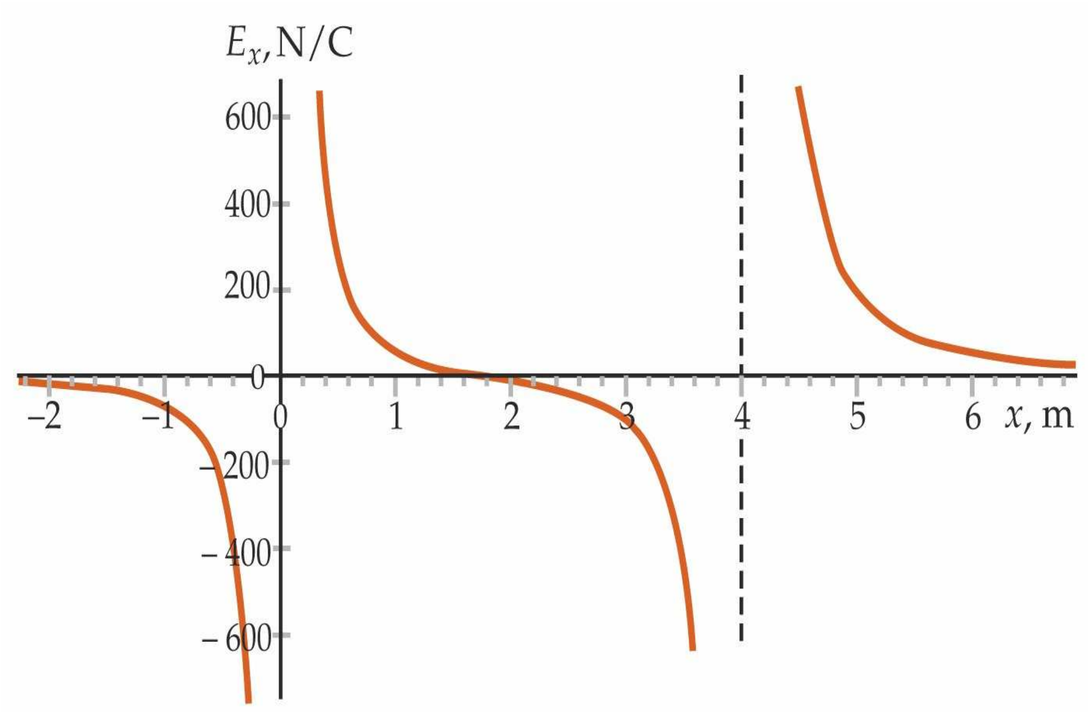


$$\vec{E}_p = \sum_{i=1}^{N} k\,\frac{q_i}{r_{ip}^2}\hat{r}_{ip} = \sum_{i=1}^{N} k\,\frac{q_i}{r_{ip}^3}\vec{r}_{ip}$$

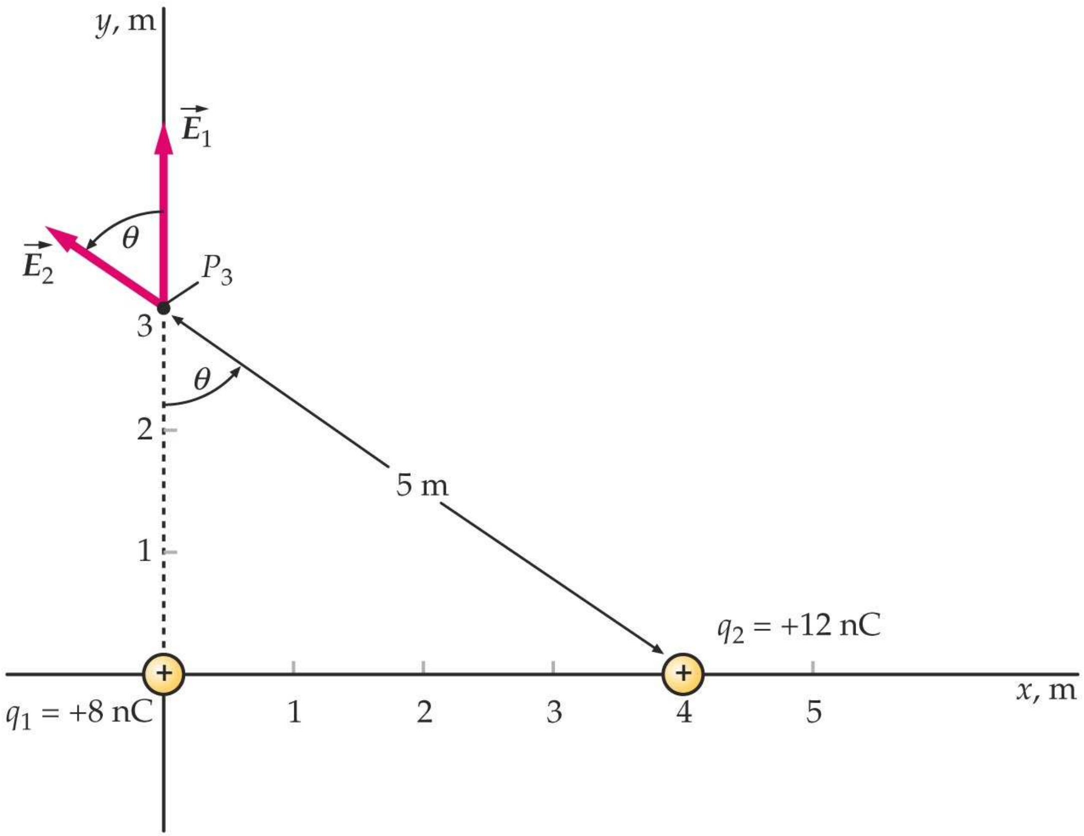
$$\vec{F}_p = q_p\,\vec{E}_p$$



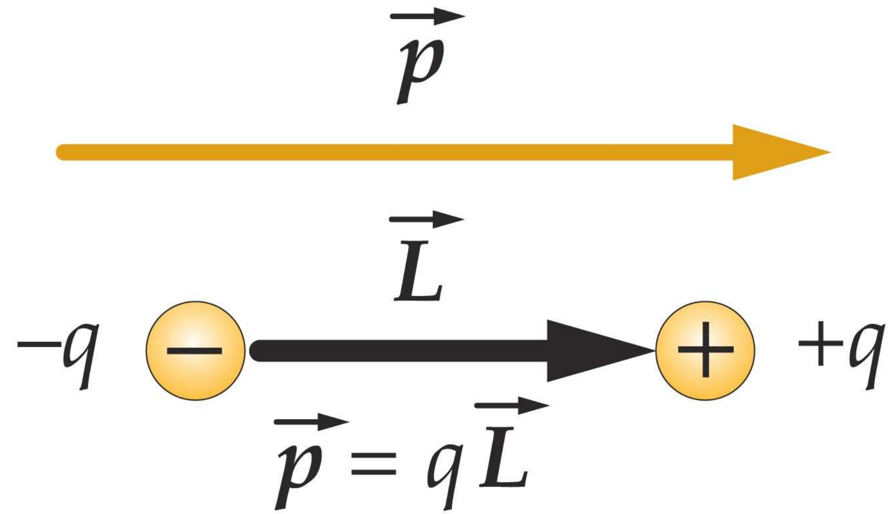
y
q_1 = +8 nC
P_2
P_1
1 2 3 4 5 6 7 8
x, m
a
q_2 = +12 nC



E_x, N/C
600
400
200
0
−200
−400
−600
−2 −1 0 1 2 3 4 5 6
x, m

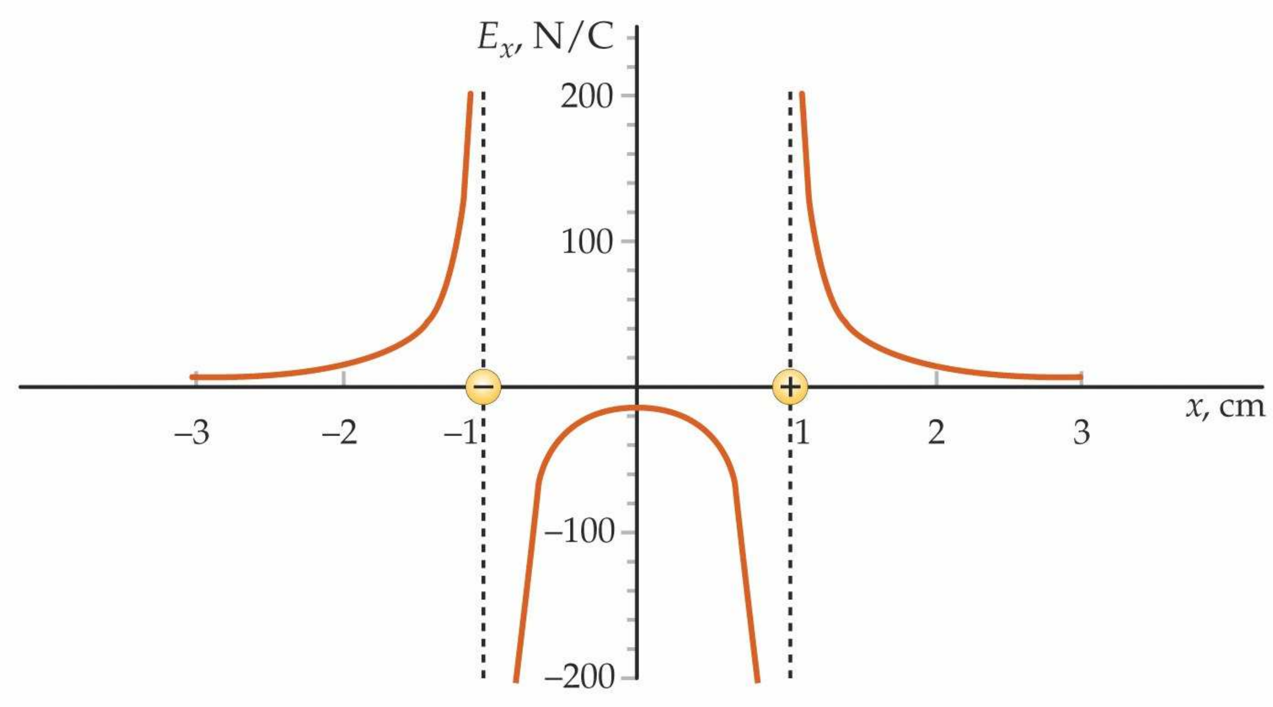


y, m
$\vec{E}_1$
θ
$\vec{E}_2$
P_3
3
θ
2
5 m
1
q_2 = +12 nC
+
+
x, m
q_1 = +8 nC
1
2
3
4
5



$$\vec{p} = q\vec{L} \qquad 21\text{-}9$$

DEFINITION—ELECTRIC DIPOLE MOMENT



A llargues distàncies

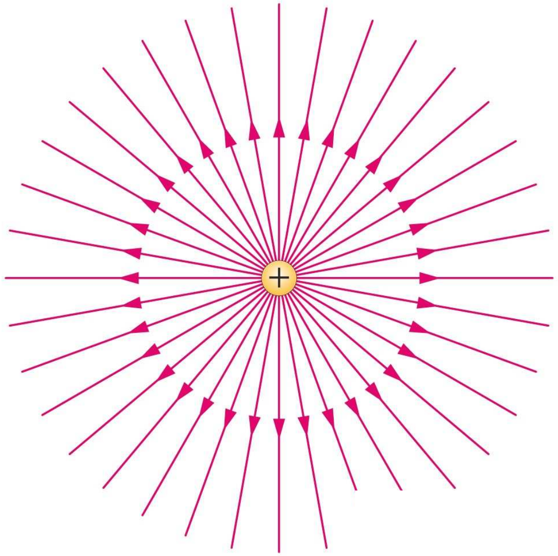
$$x \rightarrow \infty$$

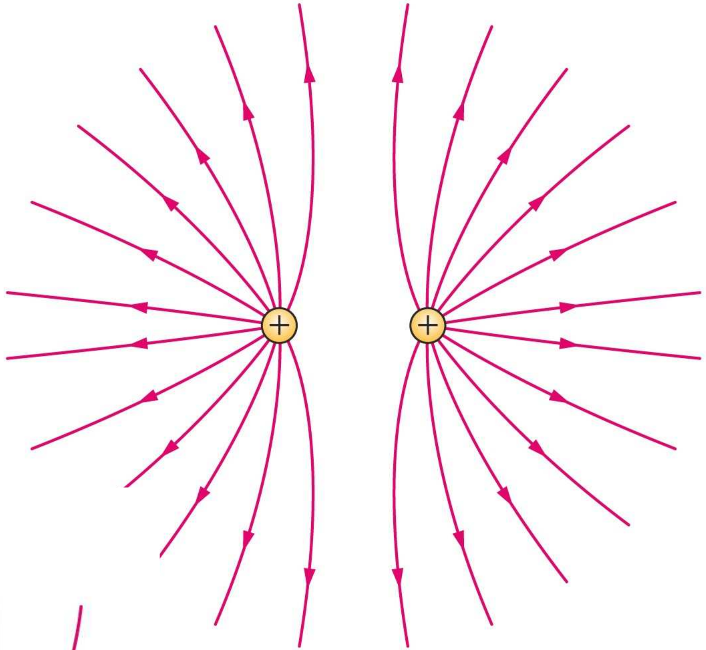
$$E_x = \frac{2kp}{|x|^3}$$

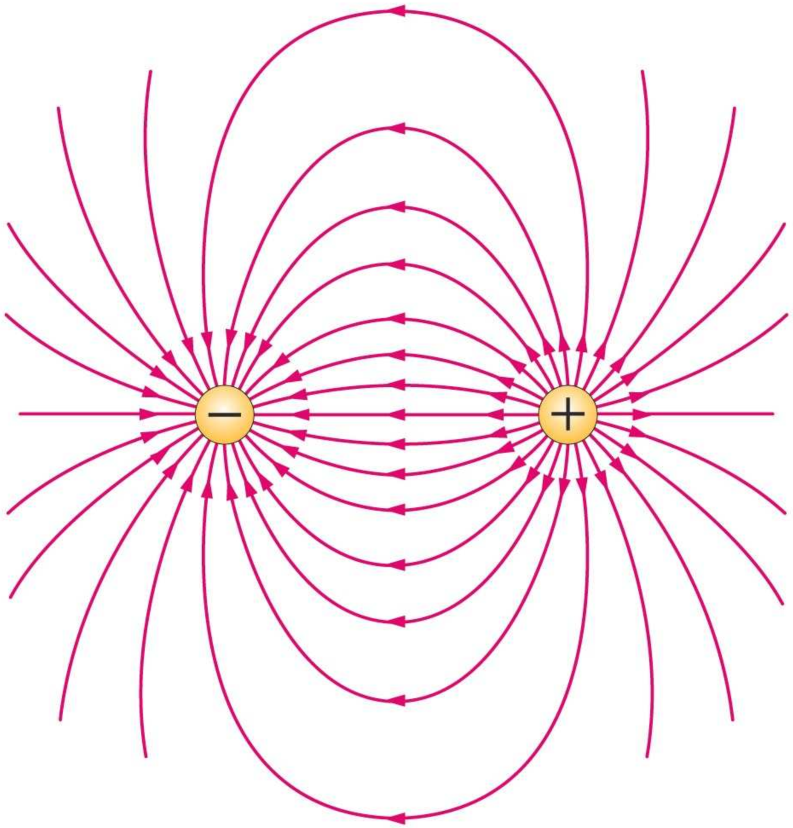
Línies de camp (elèctric)

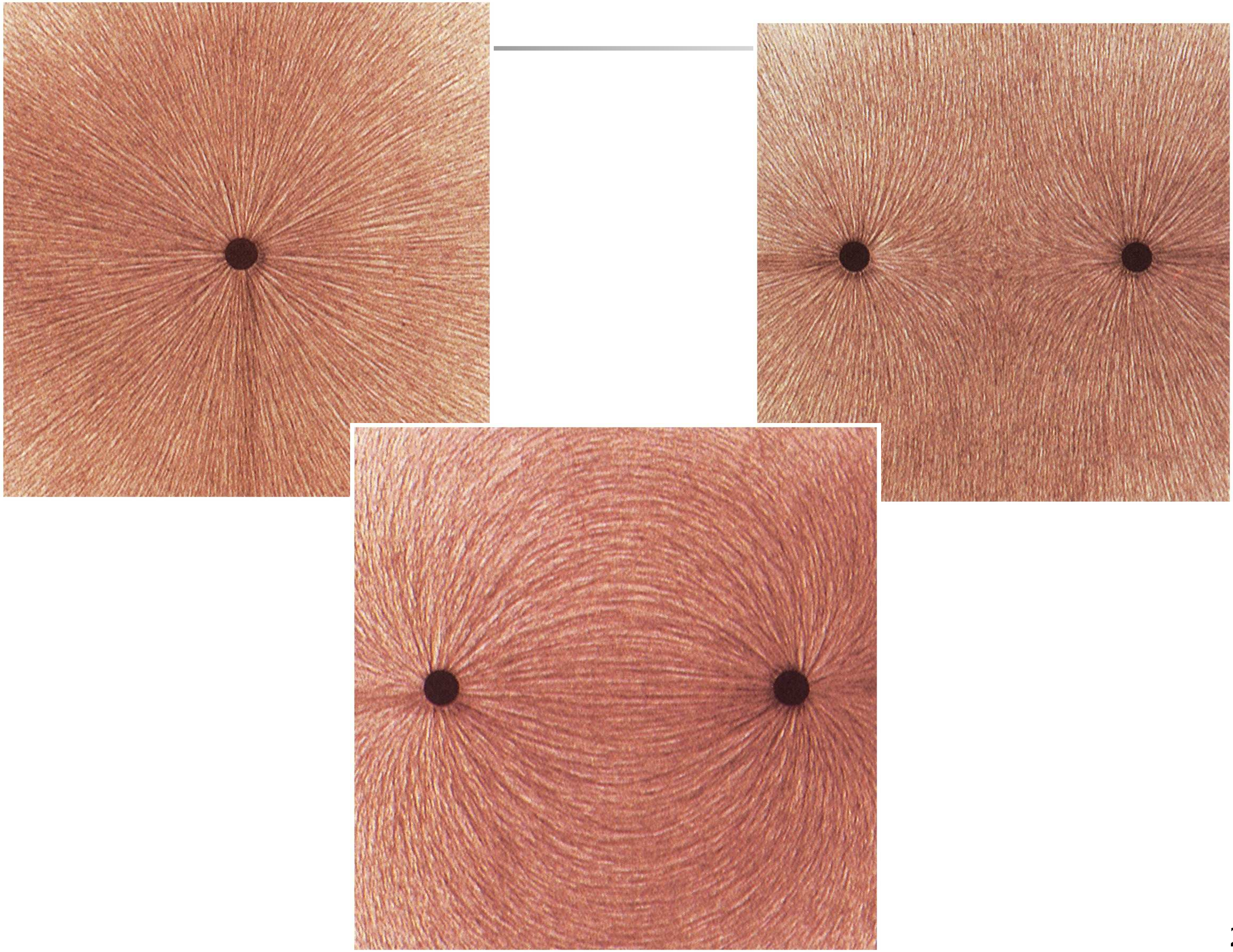
1. Electric field lines begin on positive charges (or at infinity) and end on negative charges (or at infinity).
2. The lines are drawn uniformly spaced entering or leaving an isolated point charge.
3. The number of lines leaving a positive charge or entering a negative charge is proportional to the magnitude of the charge.
4. The density of the lines (the number of lines per unit area perpendicular to the lines) at any point is proportional to the magnitude of the field at that point.
5. At large distances from a system of charges with a net charge, the field lines are equally spaced and radial, as if they came from a single point charge equal to the net charge of the system.
6. Field lines do not cross. (If two field lines crossed, that would indicate two directions for $\vec{E}$ at the point of intersection.)

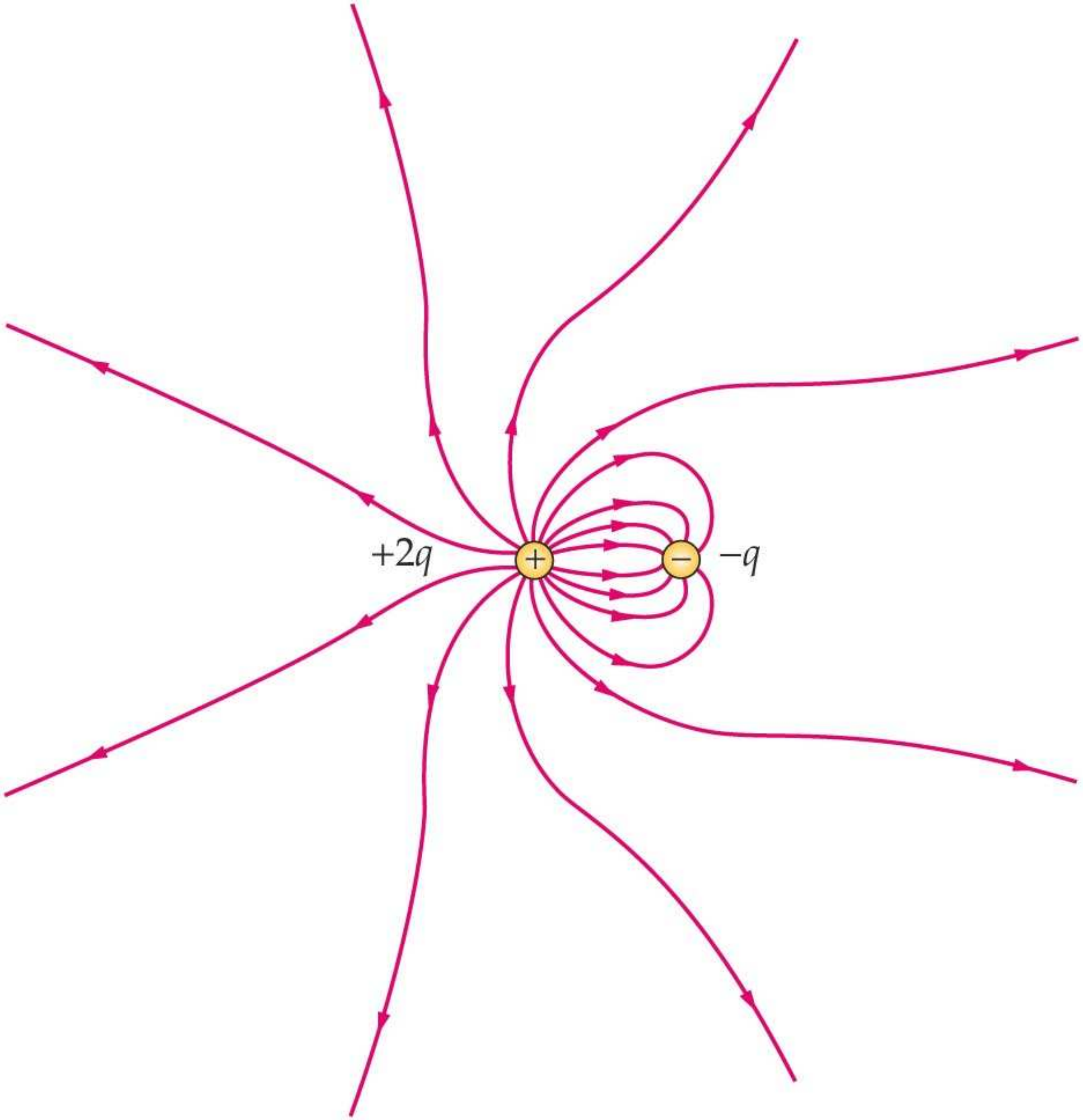
RULES FOR DRAWING ELECTRIC FIELD LINES



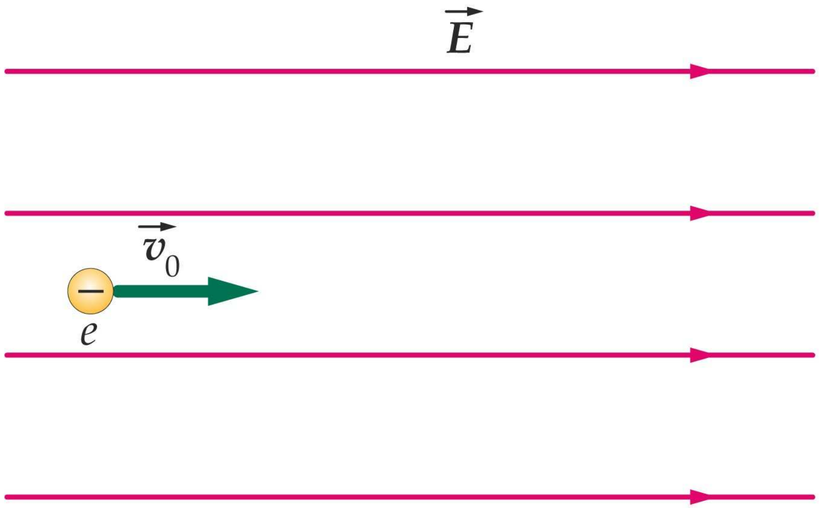







$+2q$
$-q$

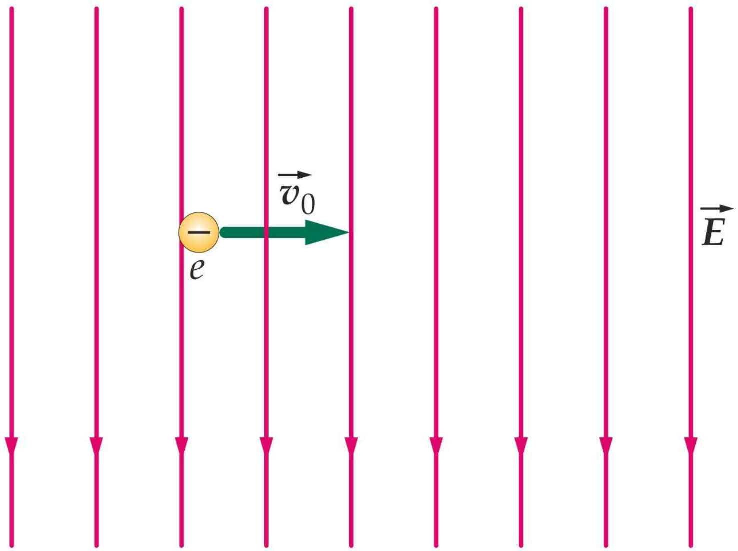
Moviments de càrregues dins camps electrics



$$a_x = -\frac{eE}{m} \qquad a_y = 0$$

$$v_x(t) = v_0 + a_x t \qquad v_y(t) = 0$$

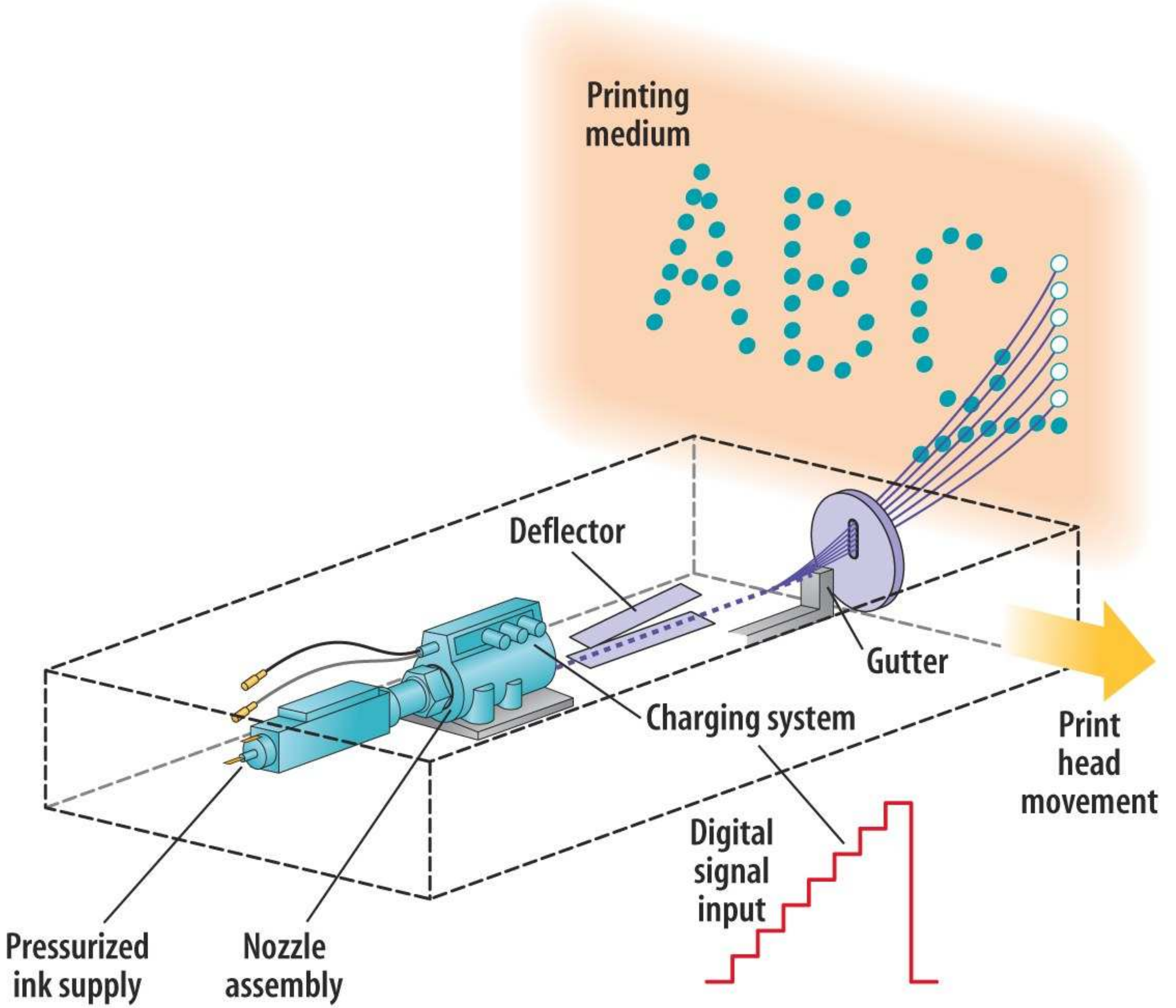
$$x(t) = x_0 + v_0 t + \frac{1}{2} a_x t^2 \qquad y(t) = y_0$$



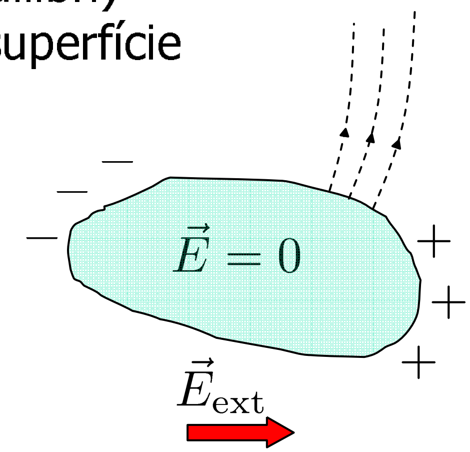
$$a_x = 0 \qquad a_y = -\frac{eE}{m}$$

$$v_x(t) = v_0 \qquad v_y(t) = a_y t$$

$$x(t) = x_0 + v_0 t \qquad y(t) = y_0 + \frac{1}{2} a_y t^2$$

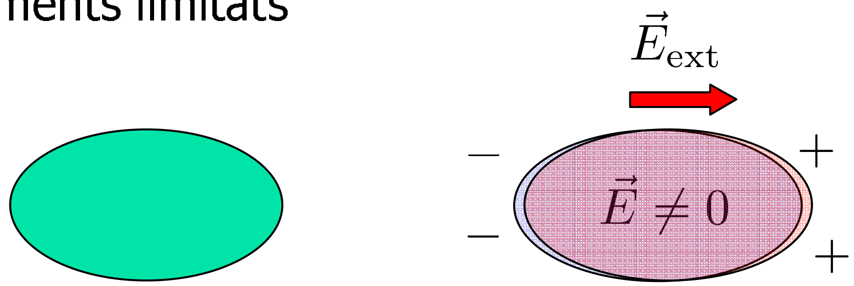

Printing medium
Deflector
Gutter
Charging system
Print head movement
Digital signal input
Pressurized ink supply
Nozzle assembly

Conductors: moviment lliure de cárregues a l’interior
càrregues a la superfície (equilibri)
línies de camp normals a la superfície

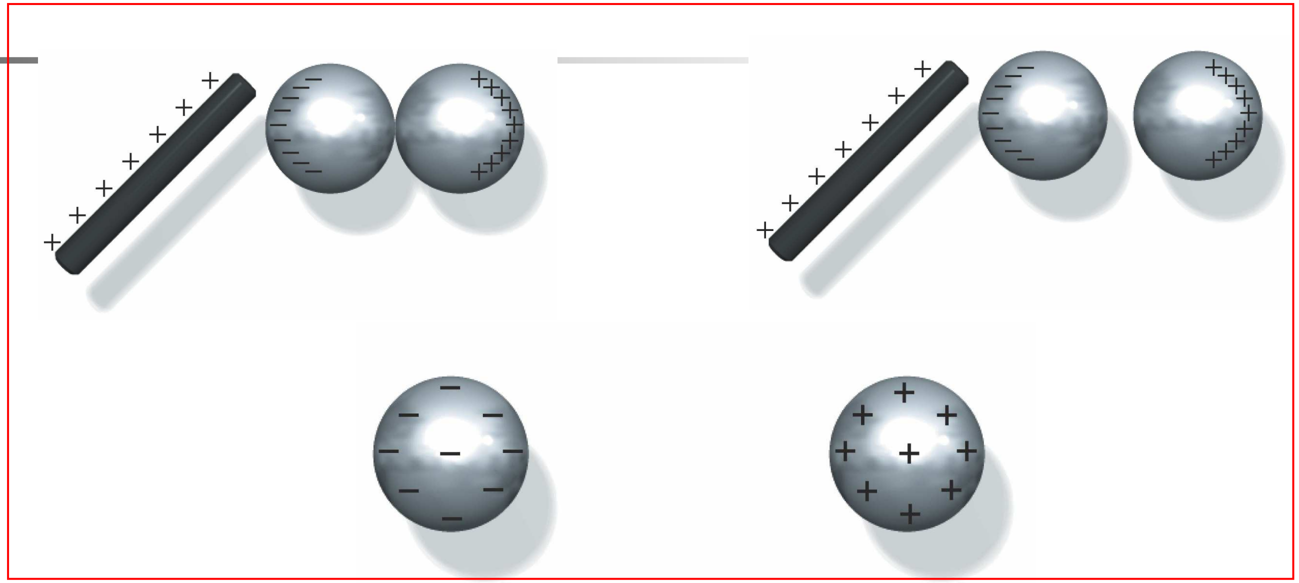


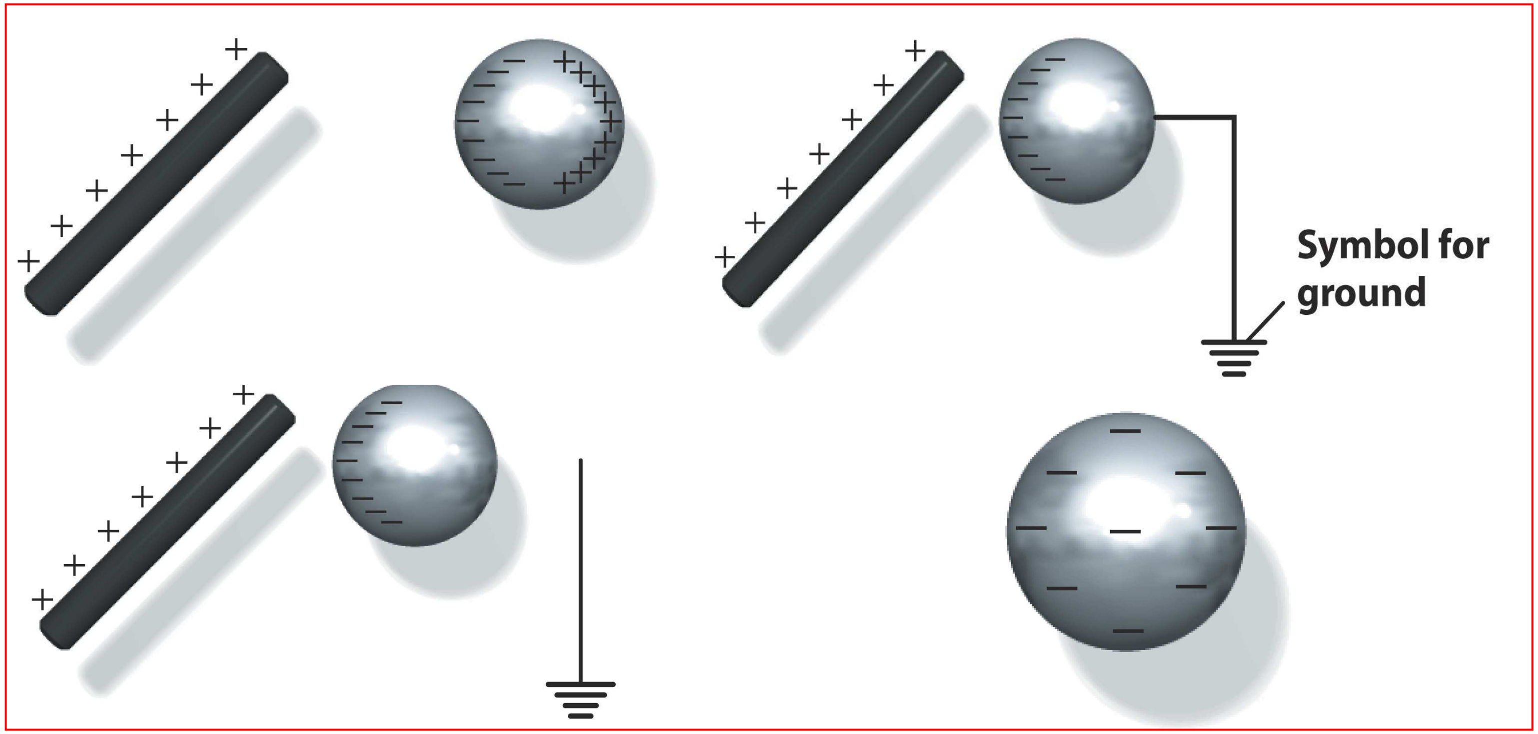
Aïllants: (dielèctrics)

Moviments limitats

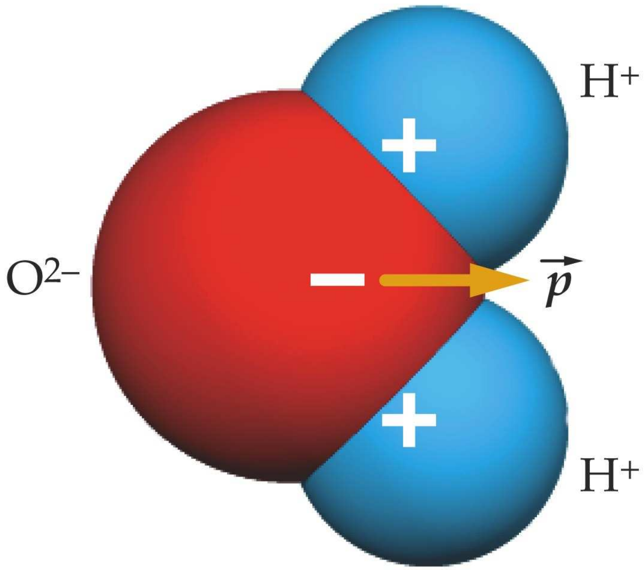


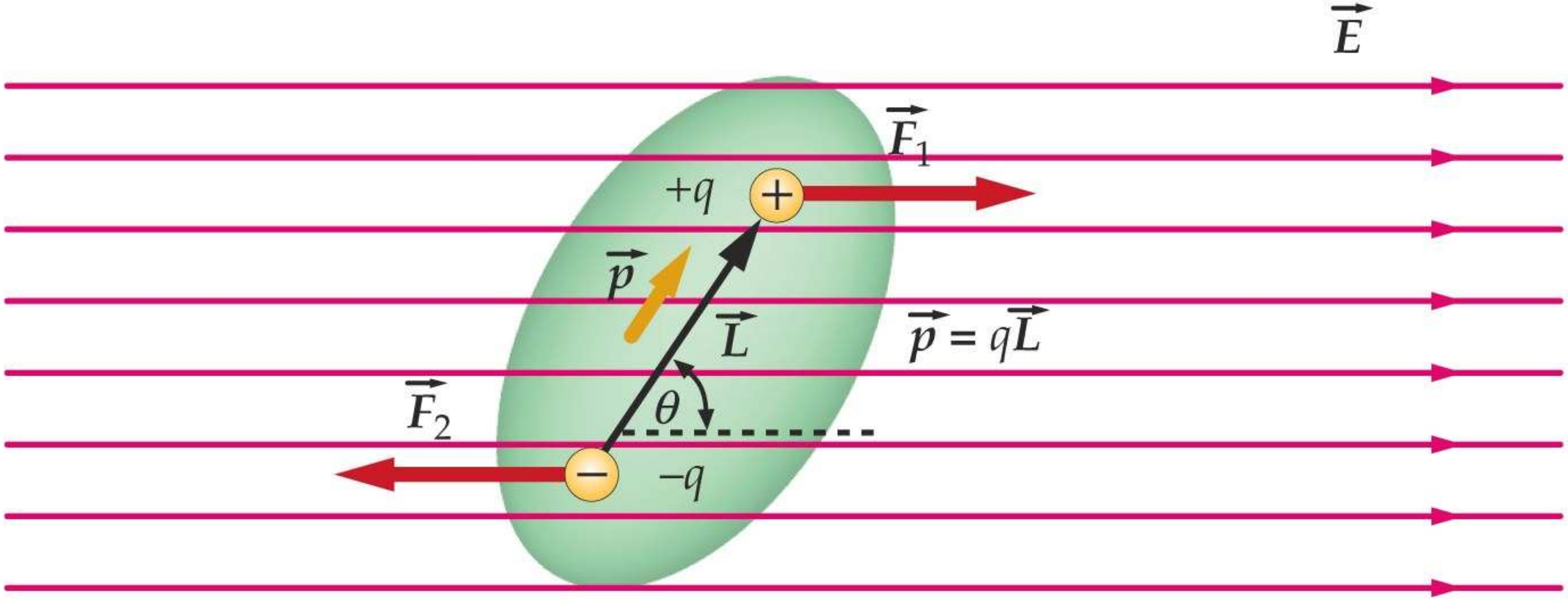
Càrrega de conductors per inducció





Electric Dipoles in Electric Fields

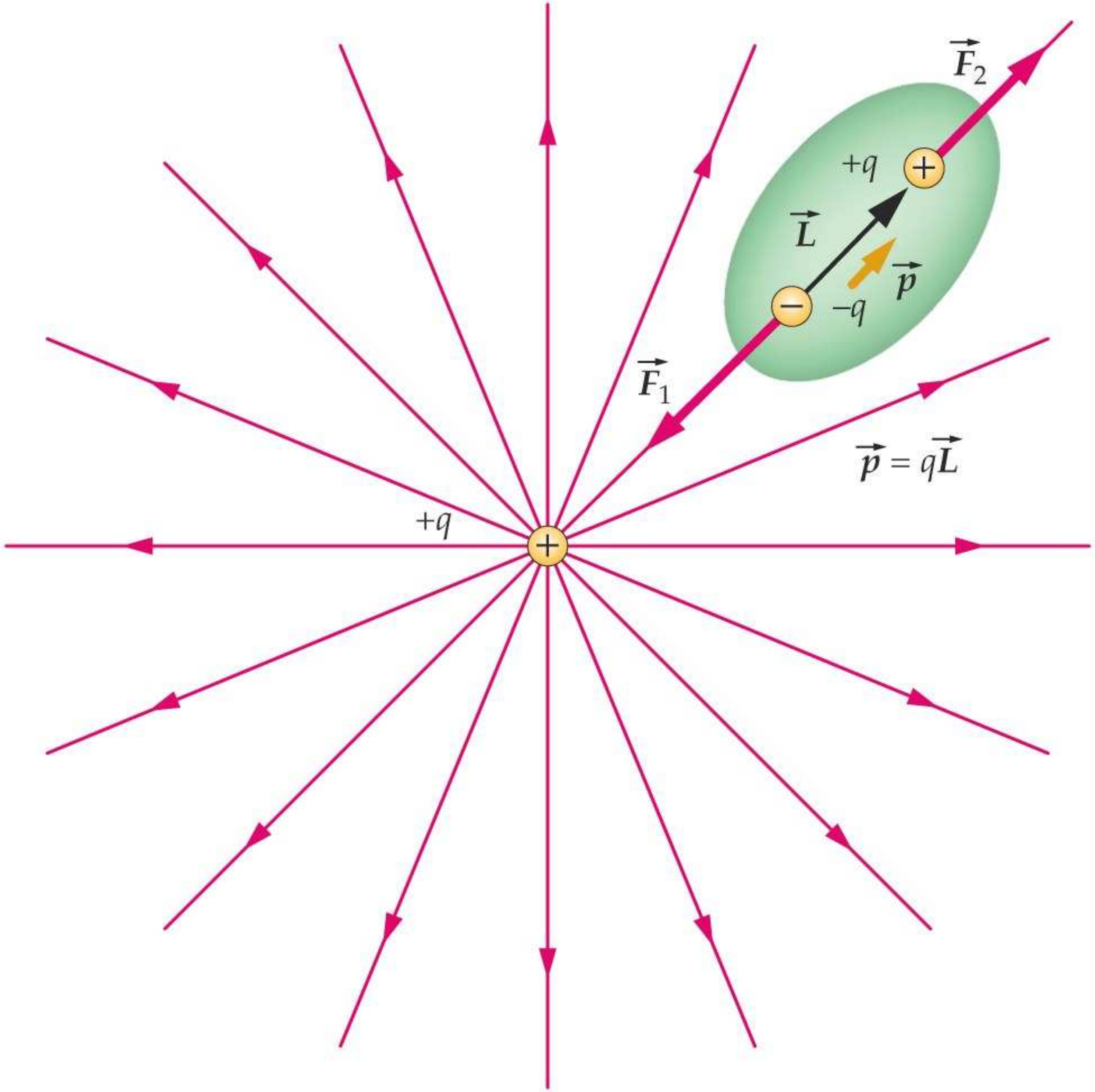




$$\tau = \vec{p} \times \vec{E}$$

$$U = -pE\cos\theta = -\vec{p}\cdot\vec{E} \qquad 21\text{-}12$$

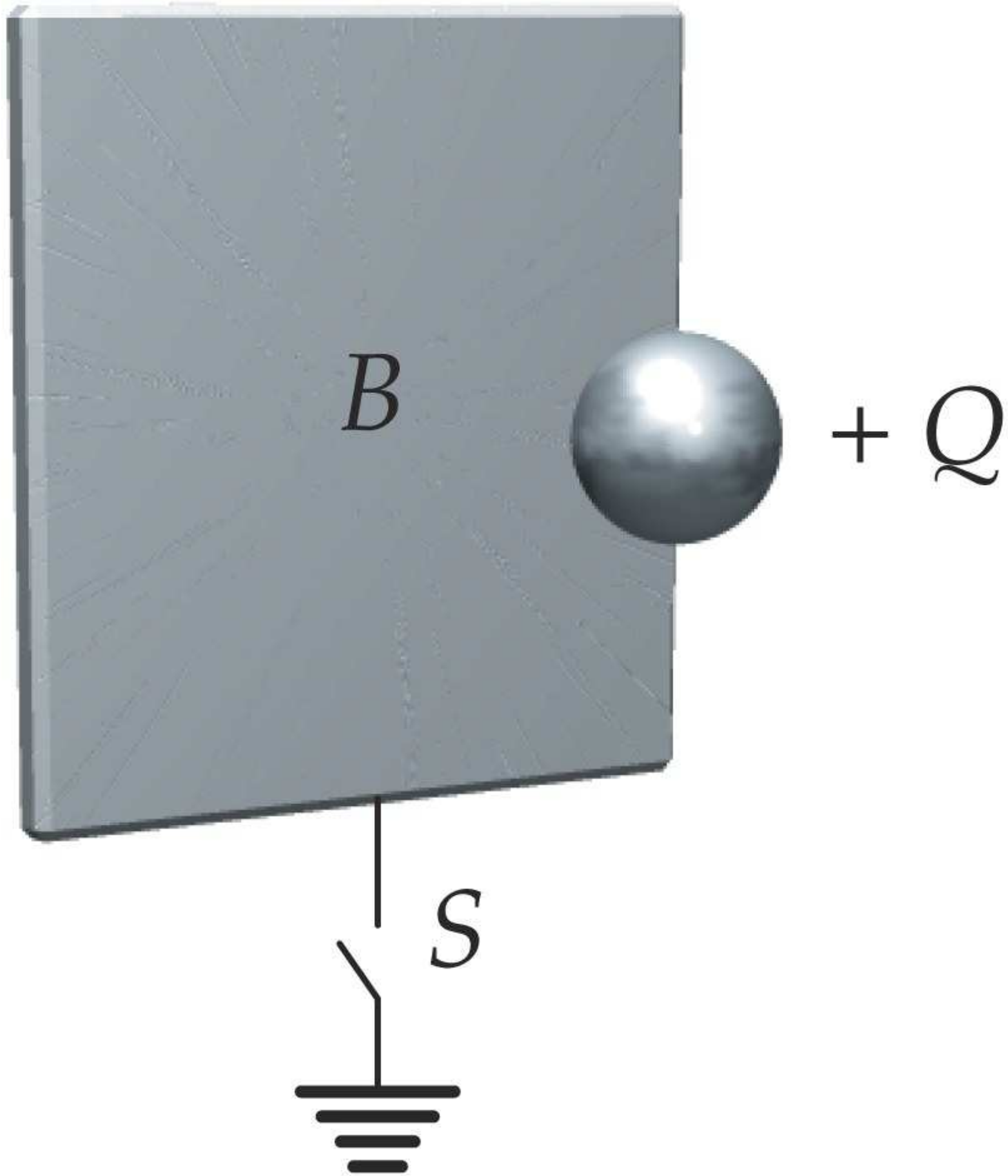
POTENTIAL ENERGY OF A DIPOLE IN AN ELECTRIC FIELD



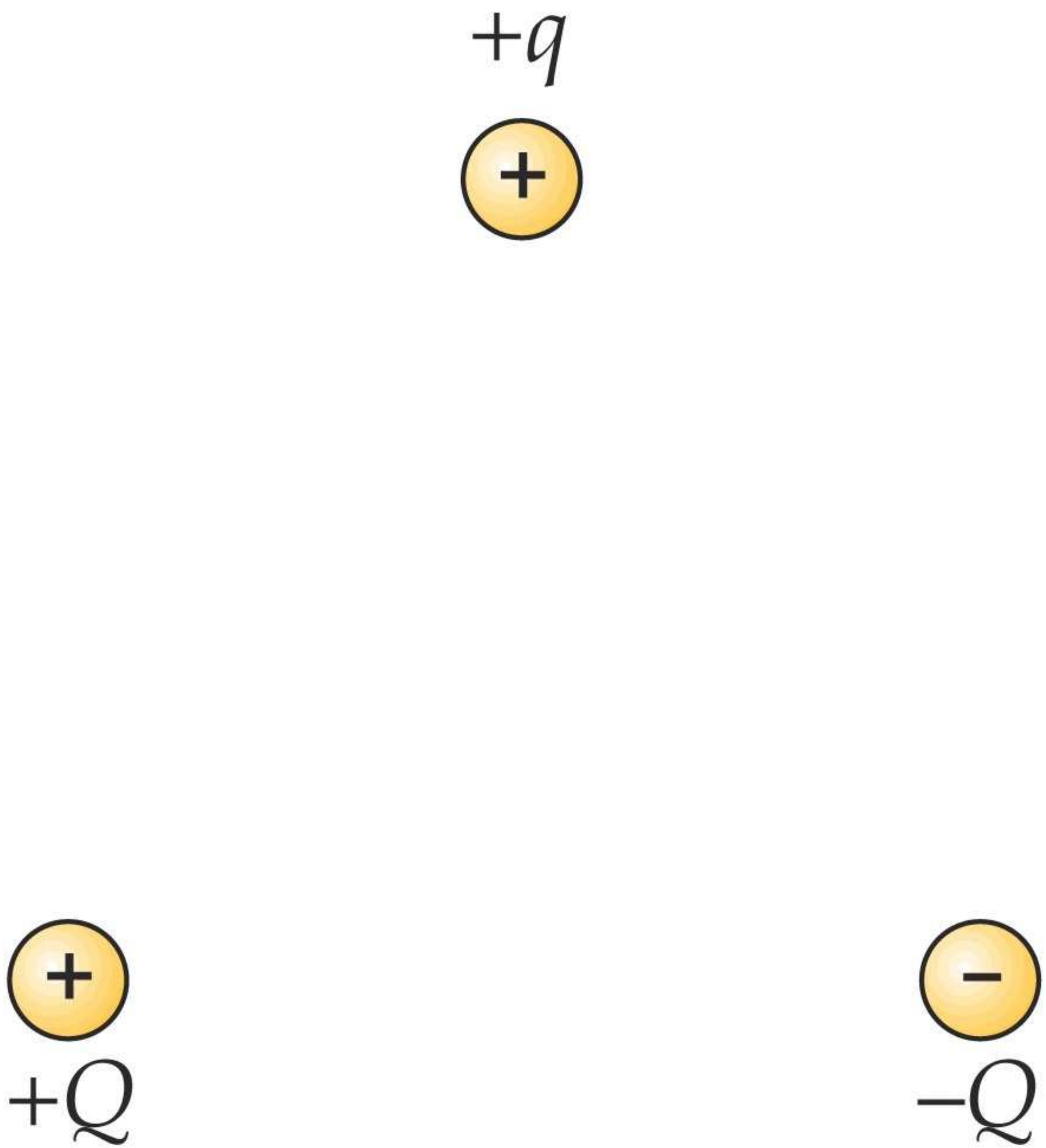
$\vec{F}_2$
$+q$
$\vec{L}$
$\vec{p}$
$-q$
$\vec{F}_1$
$\vec{p} = q\vec{L}$
$+q$

Problemes

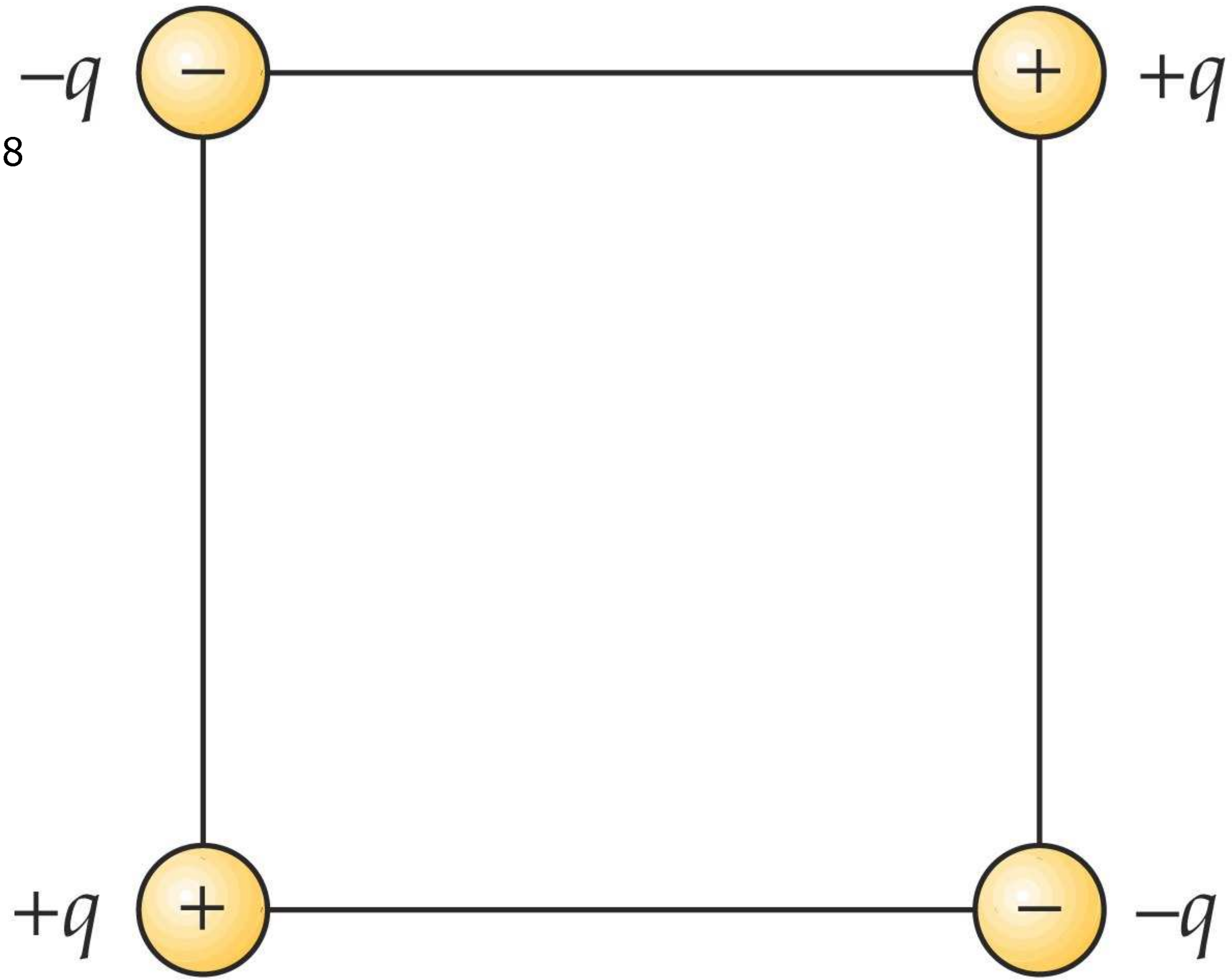
21.3



21.6



21.8



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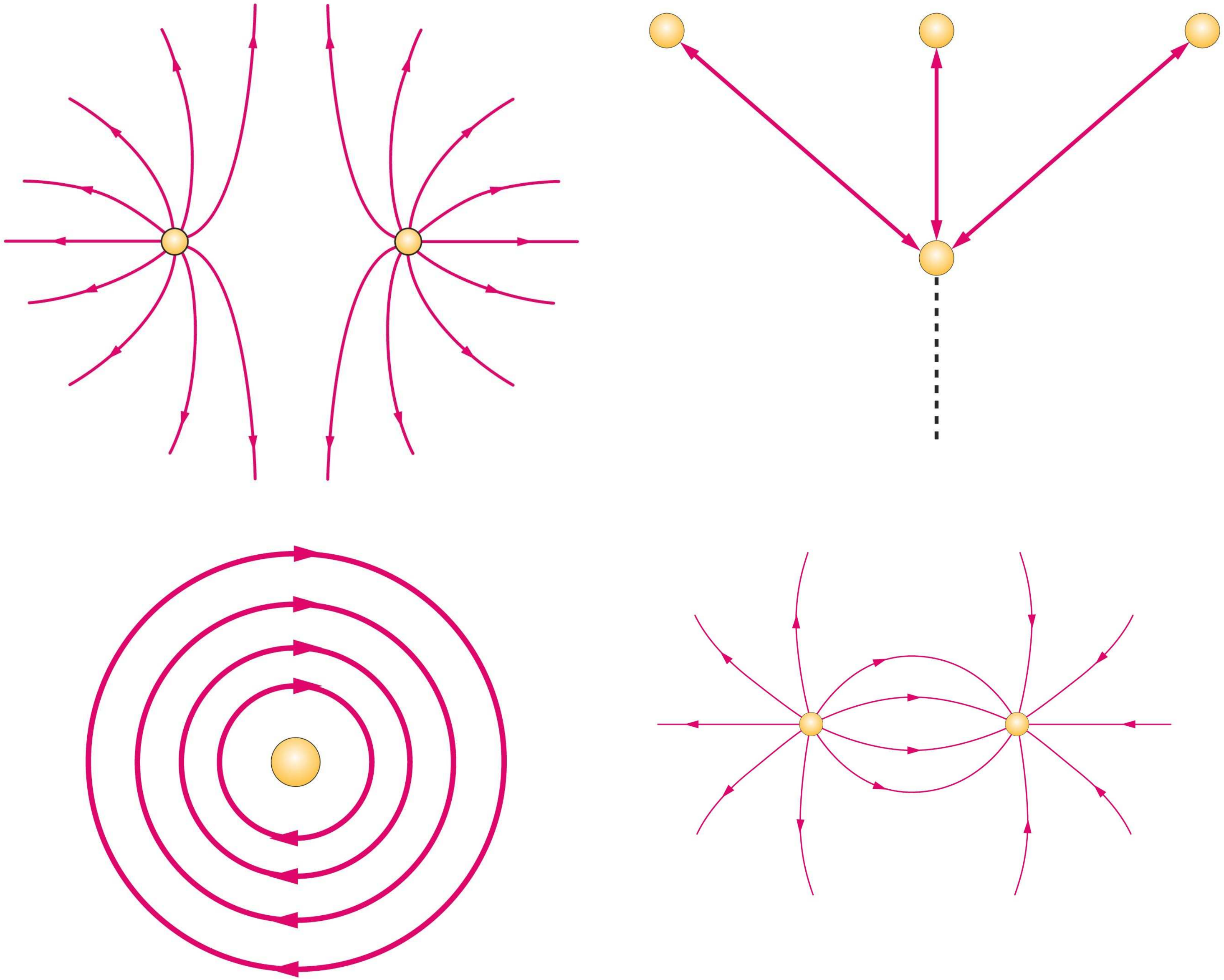

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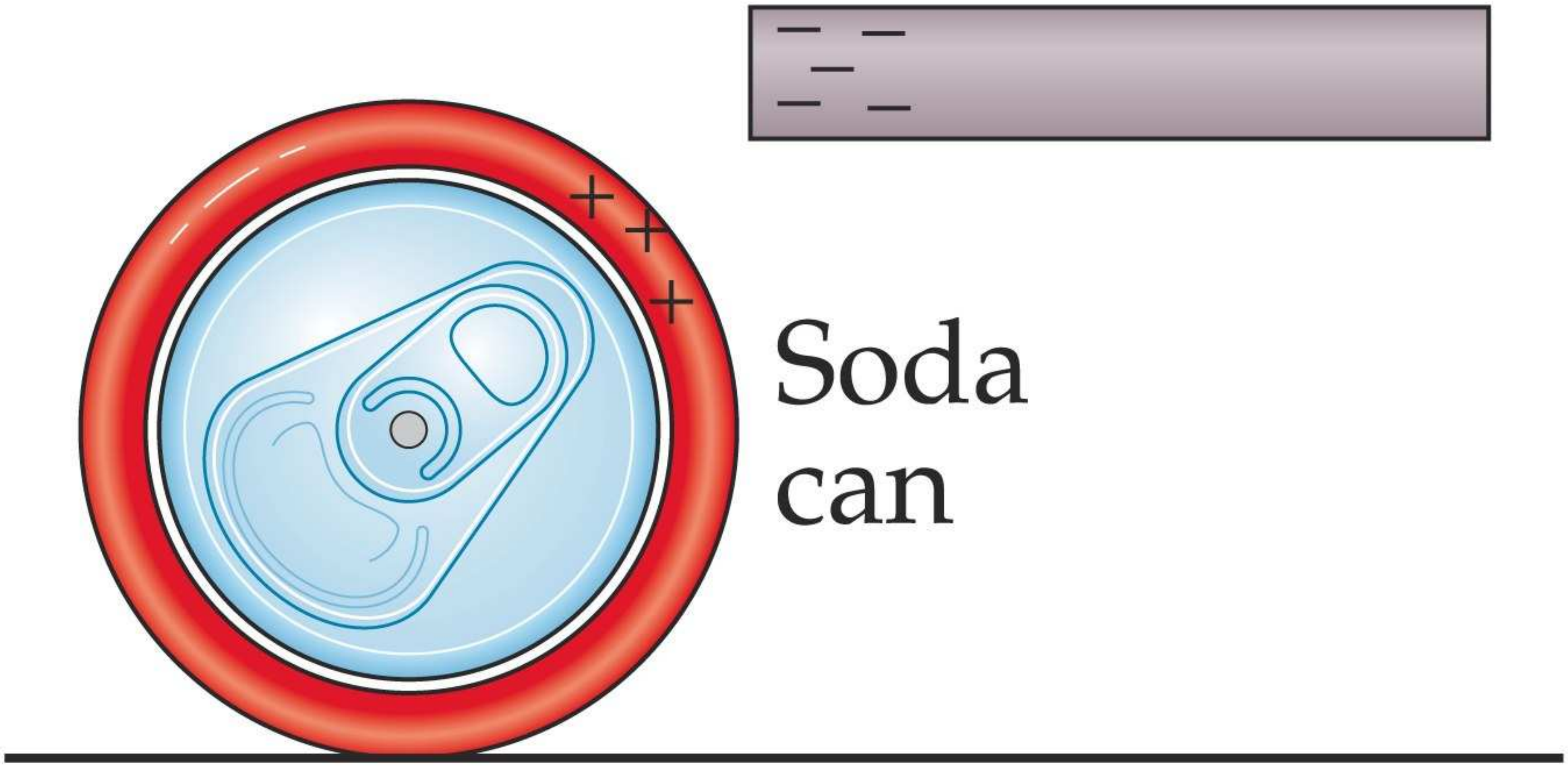

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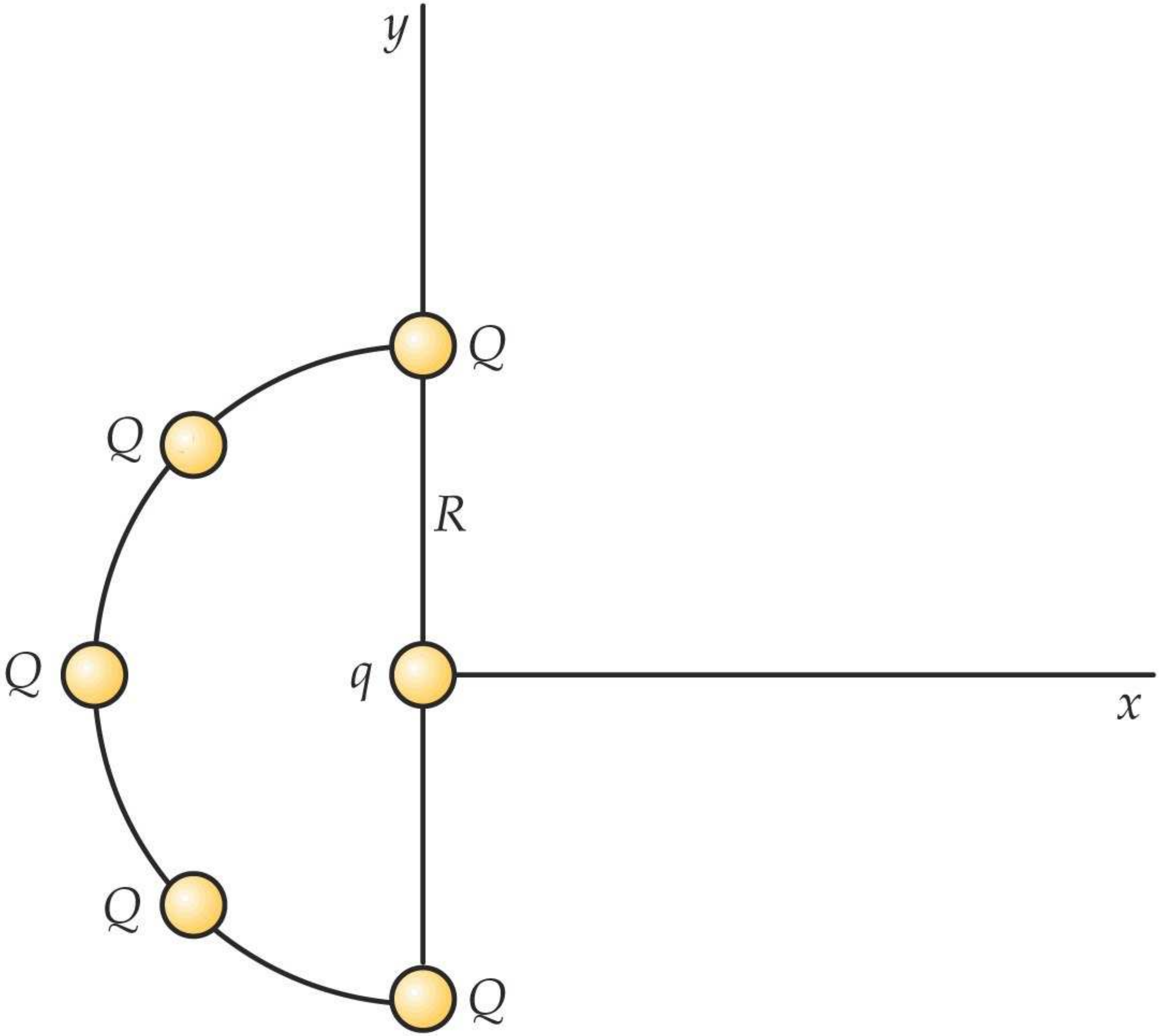

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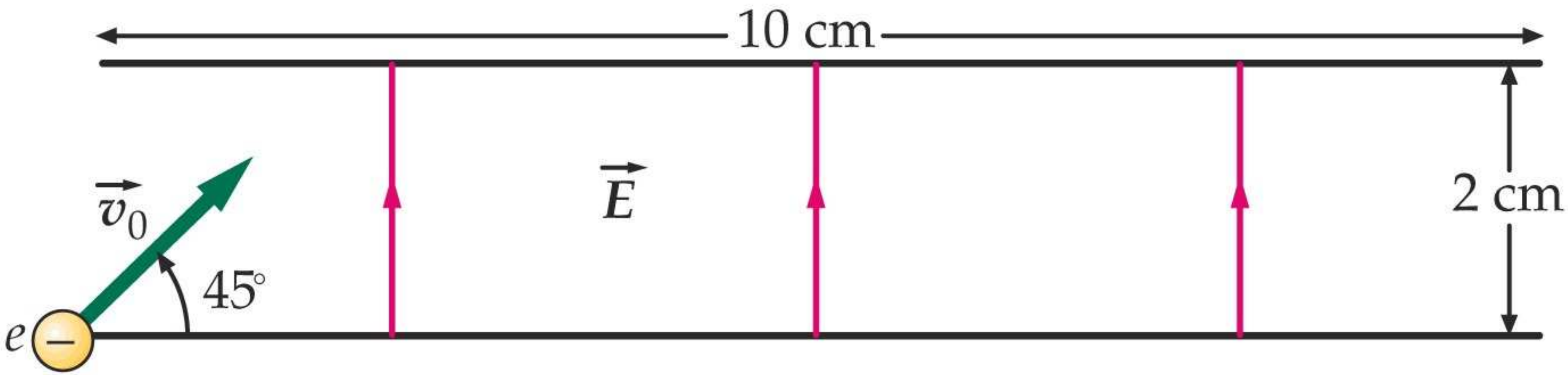
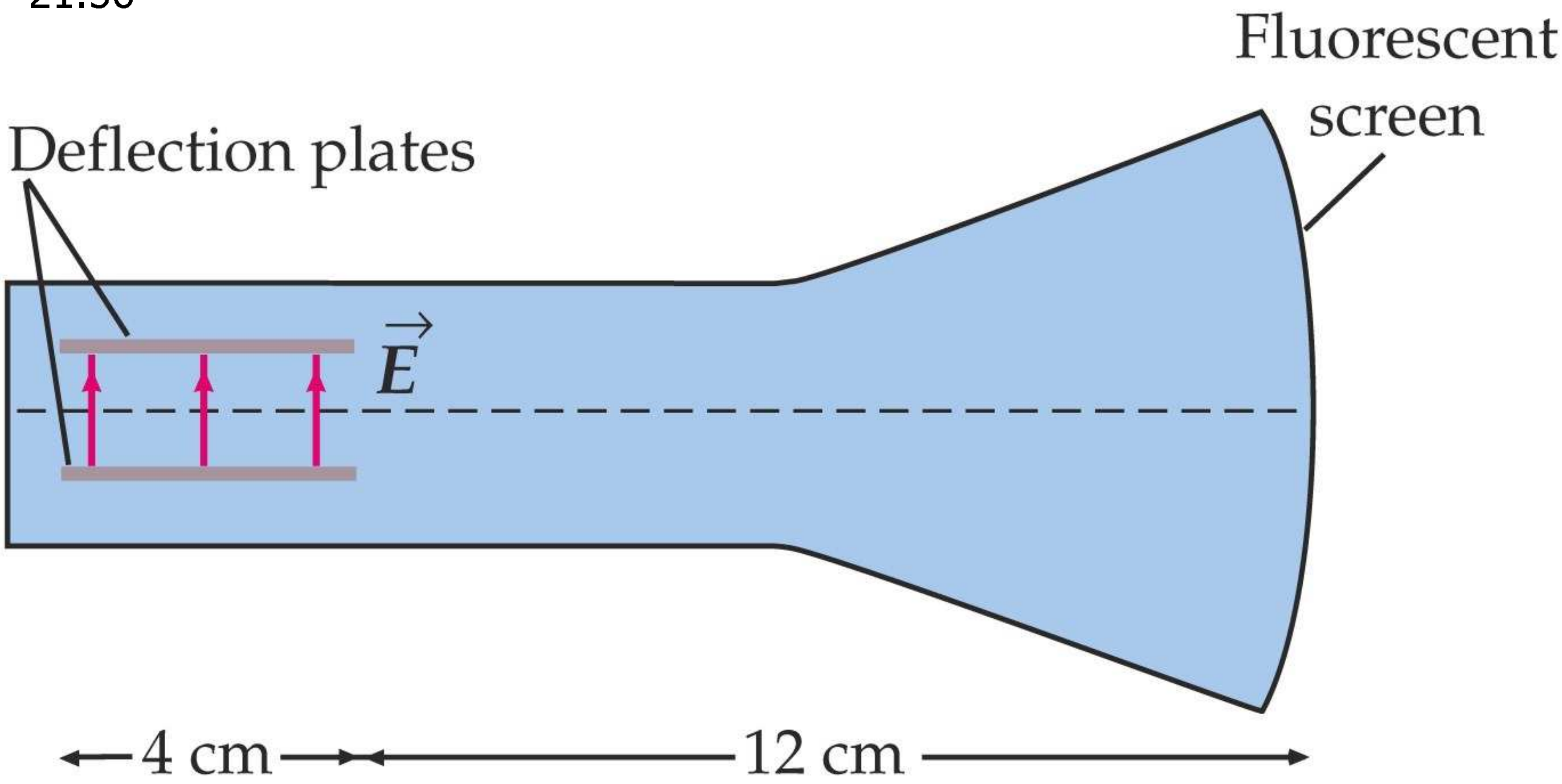
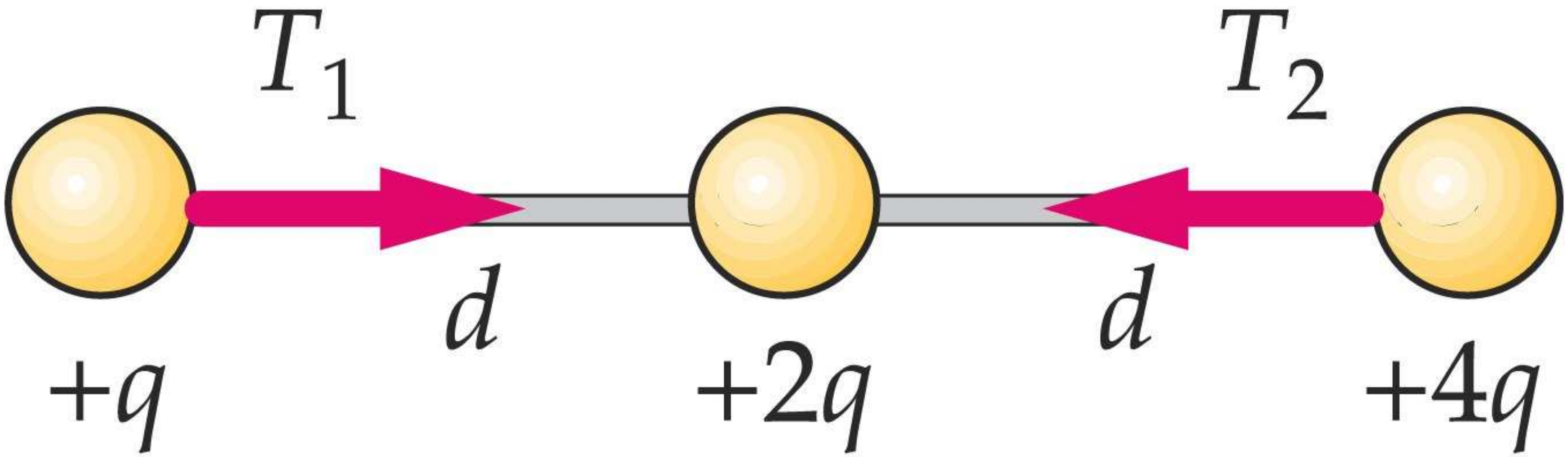


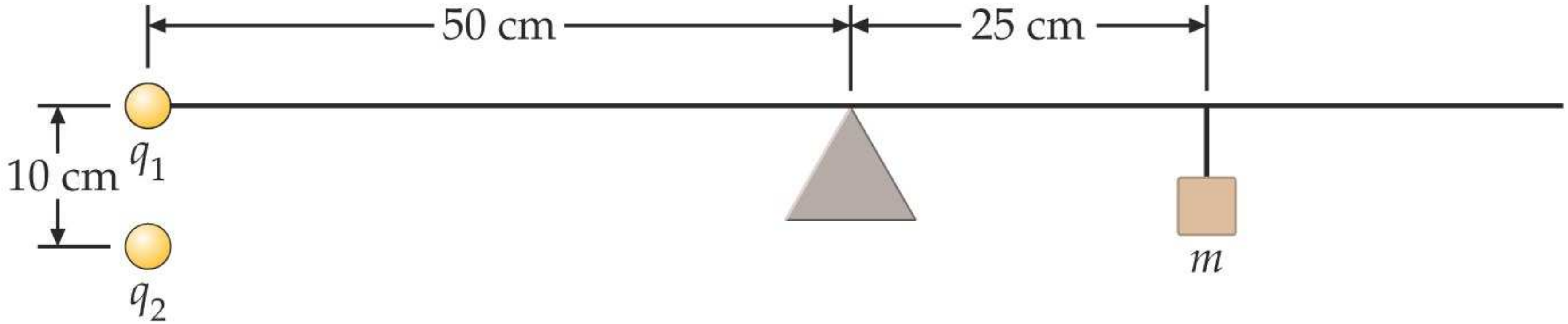
21.56



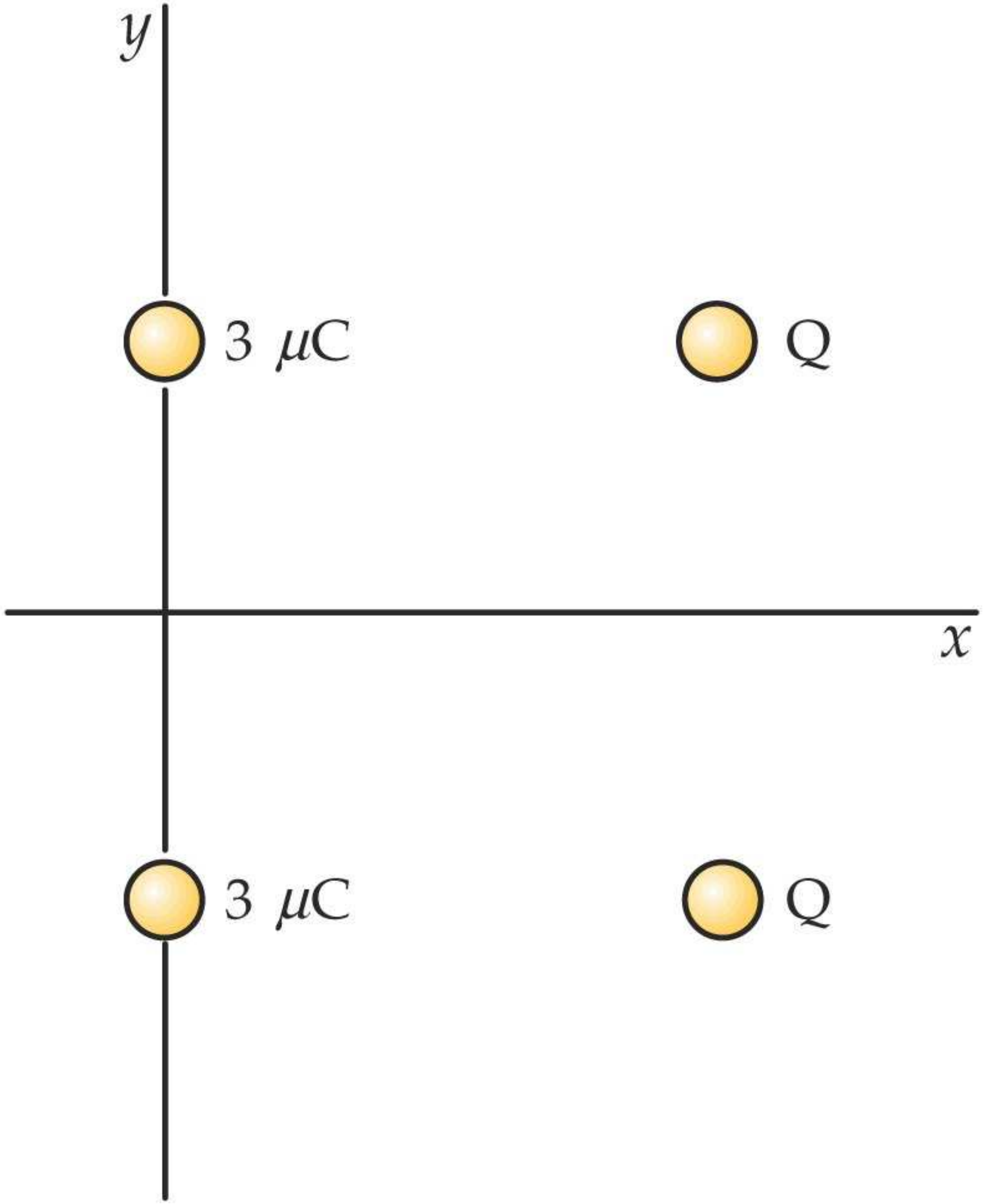
21.68



21.73



21.74



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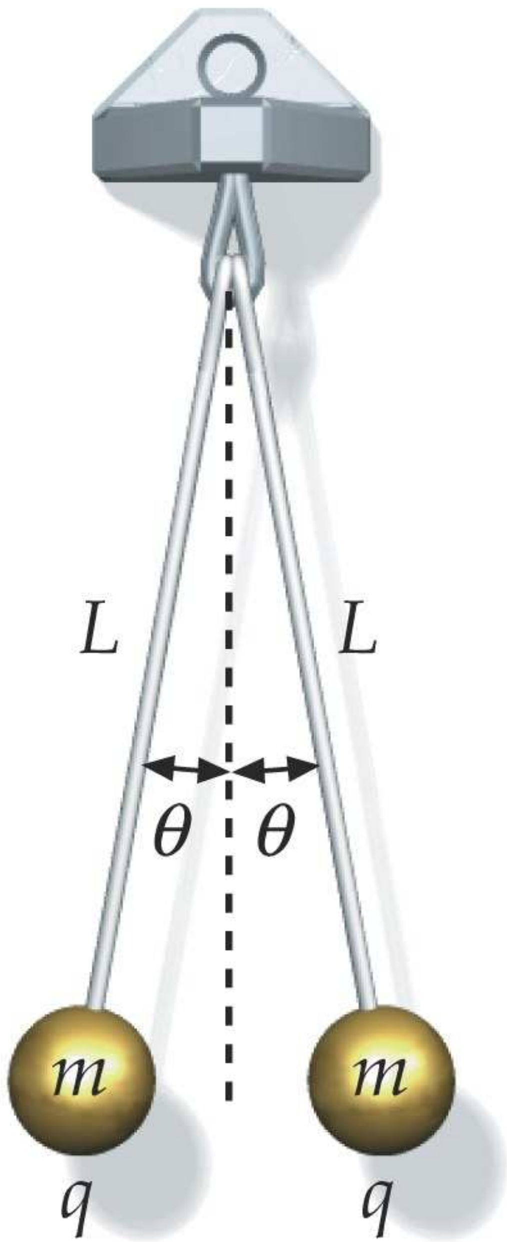
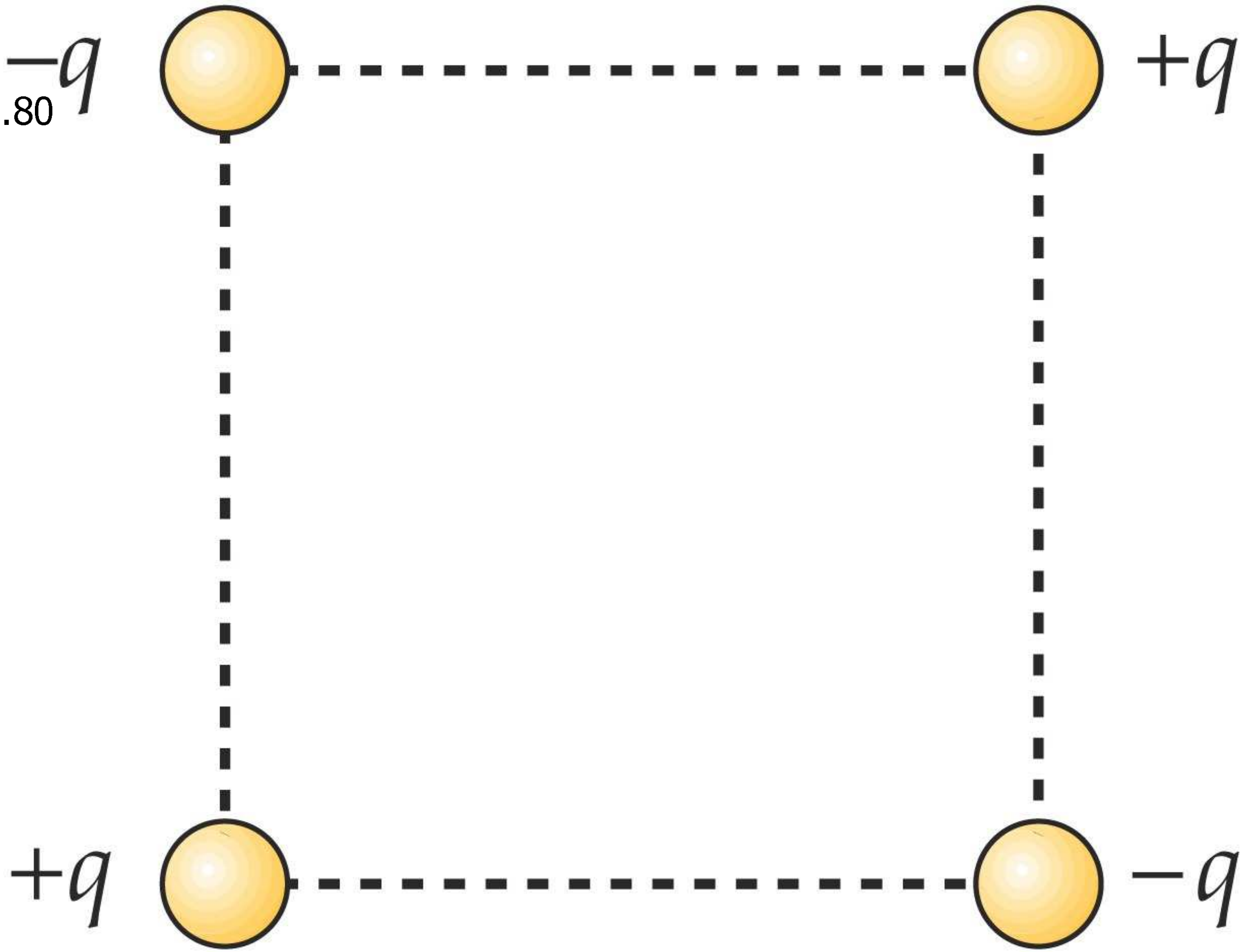


21.80



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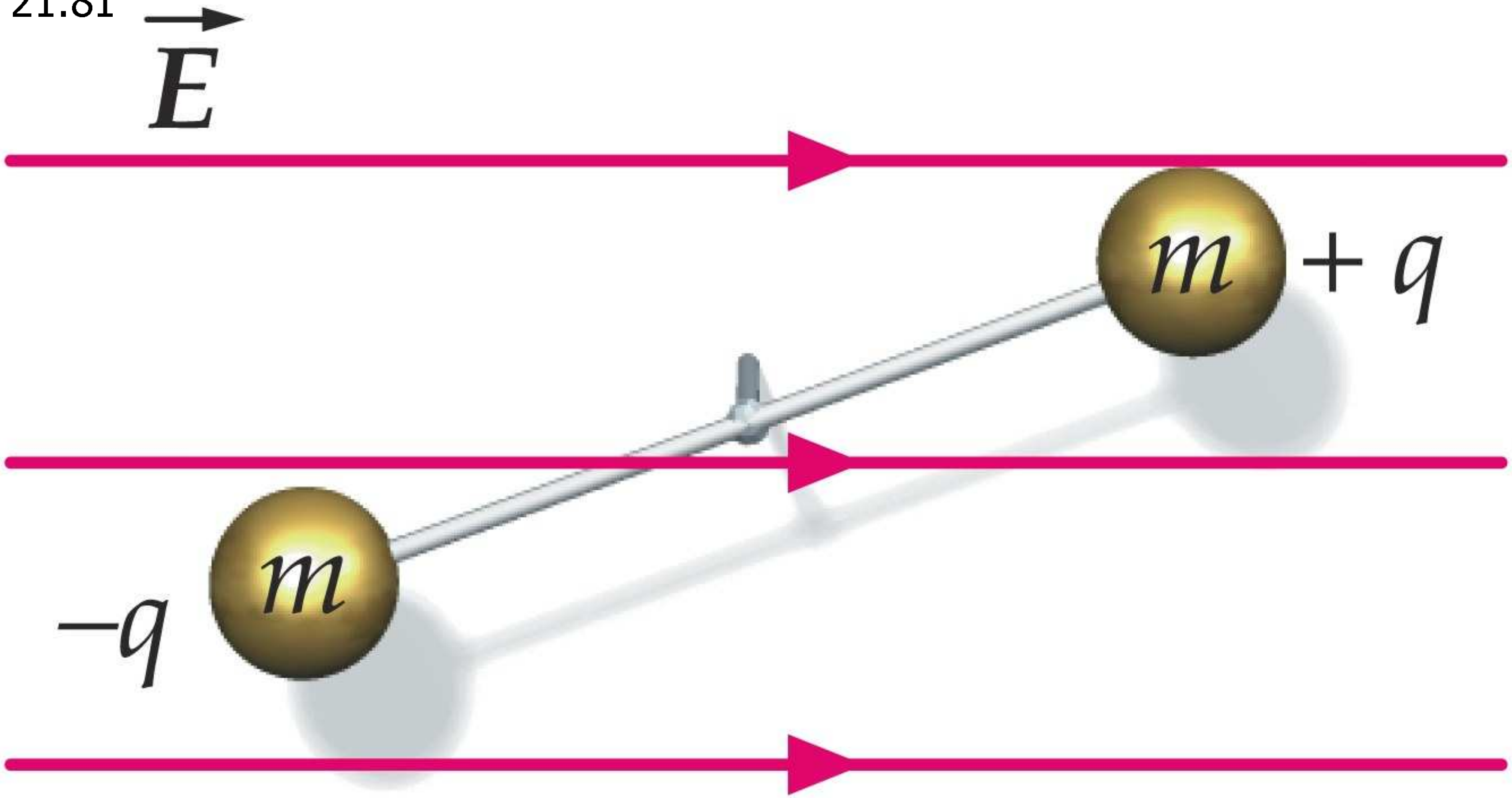

21.85

21.86