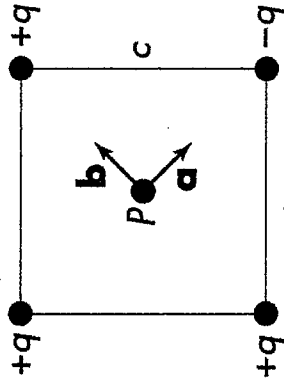


Lecture # 4

Electric Field Lines

# PhysiQuiz 23-1



The diagram here shows a square with charges as marked located at the vertices. What is the direction of the electric field at  $P$ , the center of the square? Assume the magnitudes of all charges are the same.

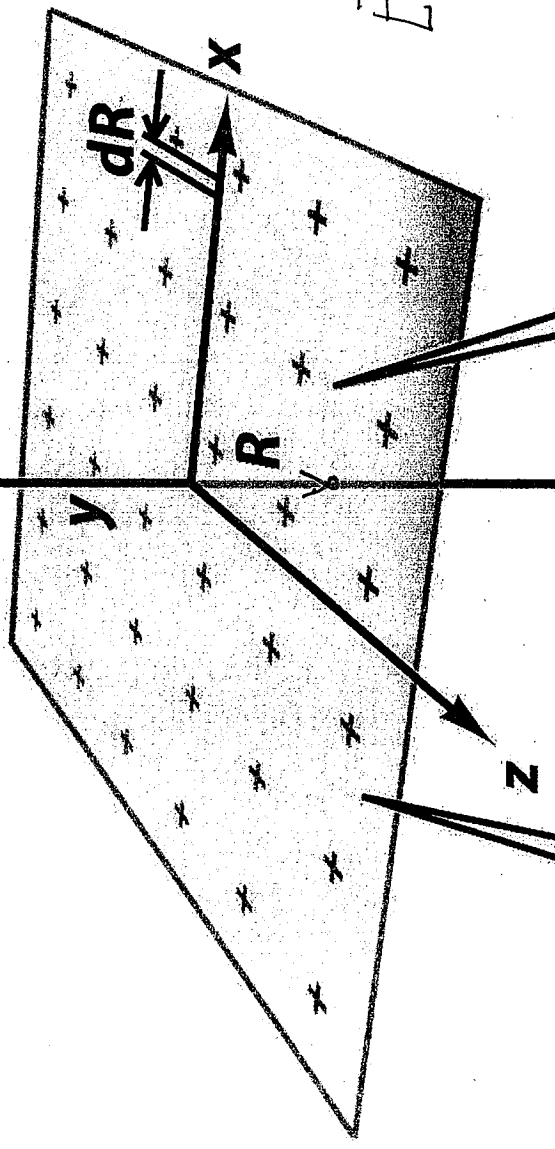
- | A             | B             | C             | D             |
|---------------|---------------|---------------|---------------|
| $+\mathbf{a}$ | $-\mathbf{a}$ | $+\mathbf{b}$ | $-\mathbf{b}$ |

**Extra:** Show that the magnitude of the electric field at  $P$  is  $E = 4kq/c^2$ , where  $c$  is the side of the square.

Each ring produces an electric field in contribution in y direction.

$$dE_y = \frac{\Delta q}{4\pi\epsilon_0} \frac{y}{[y^2 + R^2]^{3/2}}$$

$$\sigma = \frac{Q}{A} = \frac{\Delta Q}{2\pi R \Delta R}$$



Infinite sheet can be regarded as many concentric rings.

Each ring has circumference  $2\pi R$  and width  $dR$ .

$$Q = \sigma \Delta A = \sigma 2\pi R \Delta R$$

$$E_y = \int dE_y = \int_0^{\infty} \frac{\sigma 2\pi R dR y}{4\pi\epsilon_0 [y^2 + R^2]^{3/2}}$$

$$\therefore E_y = \frac{\sigma y}{2\epsilon_0}$$

We used 
$$I = \int_0^{\infty} \frac{dR y}{[y^2 + R^2]^{3/2}}$$
  
 let  $z = R/y$ , then  

$$I = \int_0^{\infty} \frac{dz z}{[z^2 + 1]^{3/2}}$$
  

$$= \left[ \frac{-1}{\sqrt{z^2 + 1}} \right]_0^{\infty} = 1$$

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**Electric field of negative sheet points toward the sheet on each side...**

**...and field due to positive sheet points away.**

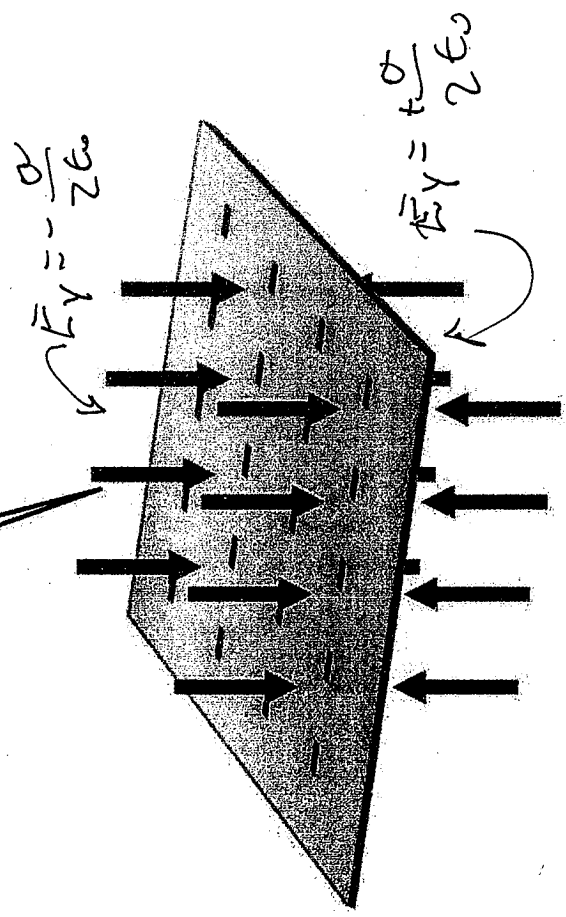
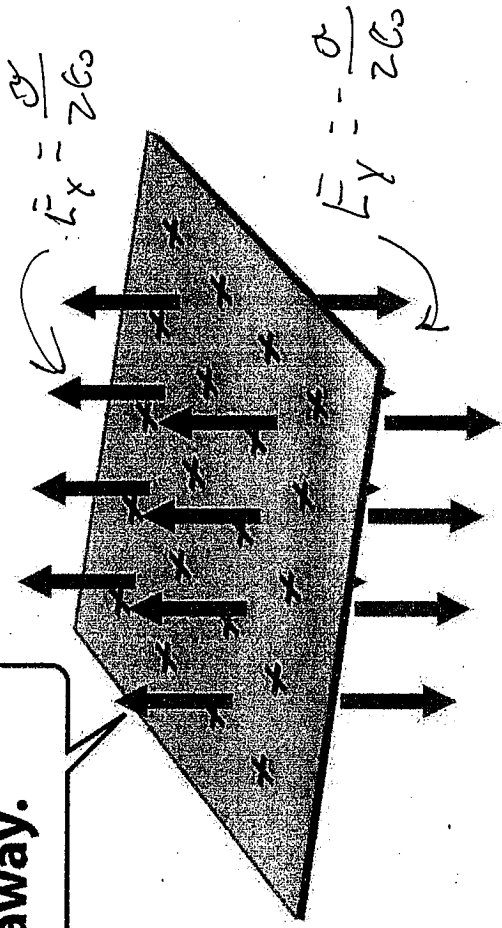


Figure 23-10a Physics for Engineers and Scientists 3/e  
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**For both sheets, net field cancels outside and doubles inside.**

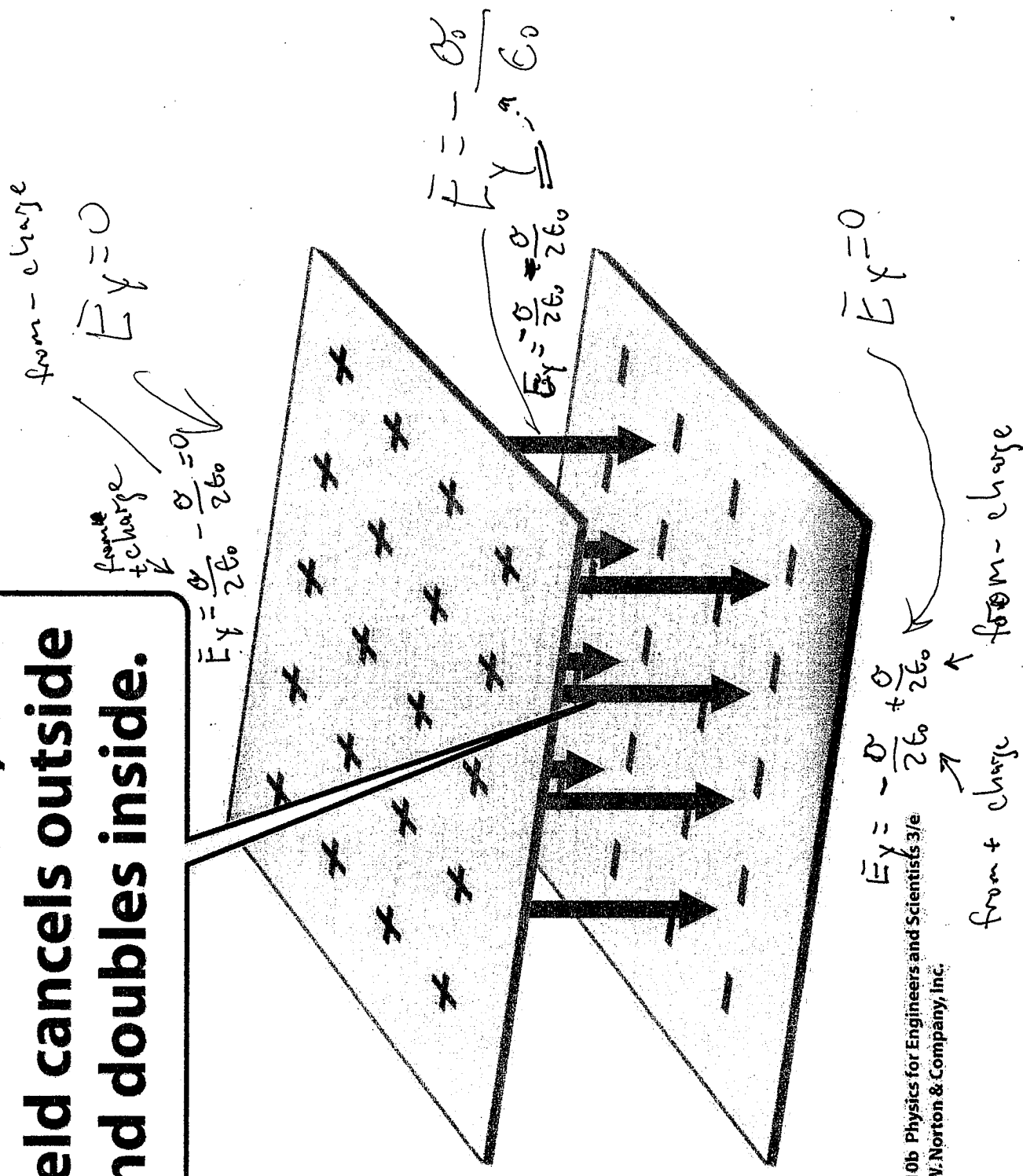
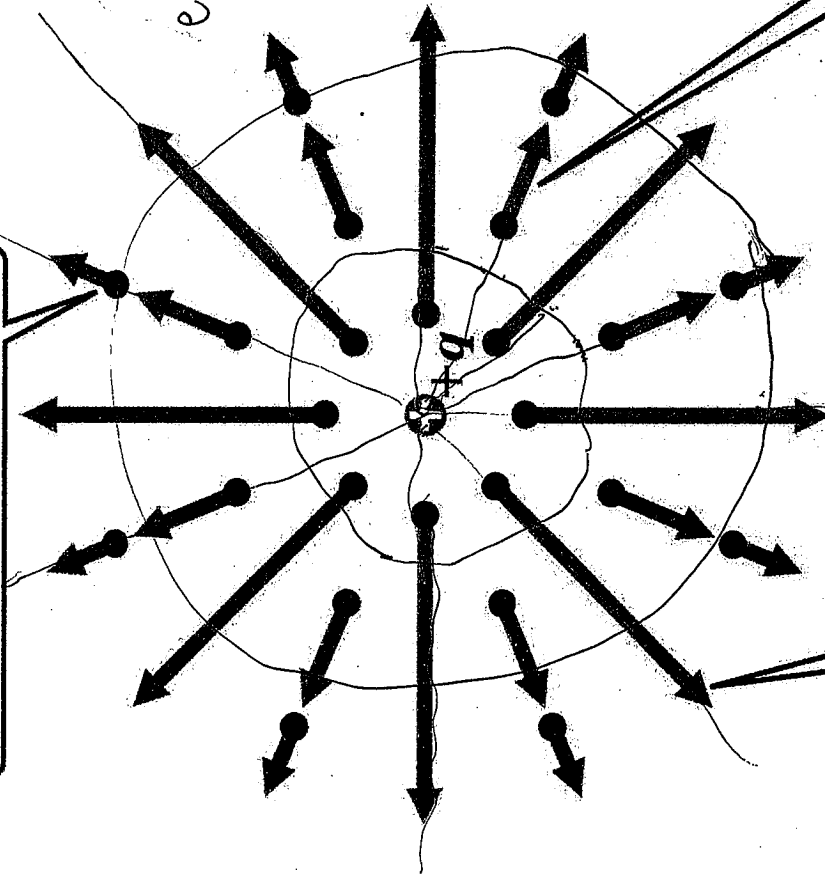


Figure 23-10b Physics for Engineers and Scientists 3/e  
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Electric field vectors are shown for a few representative points.

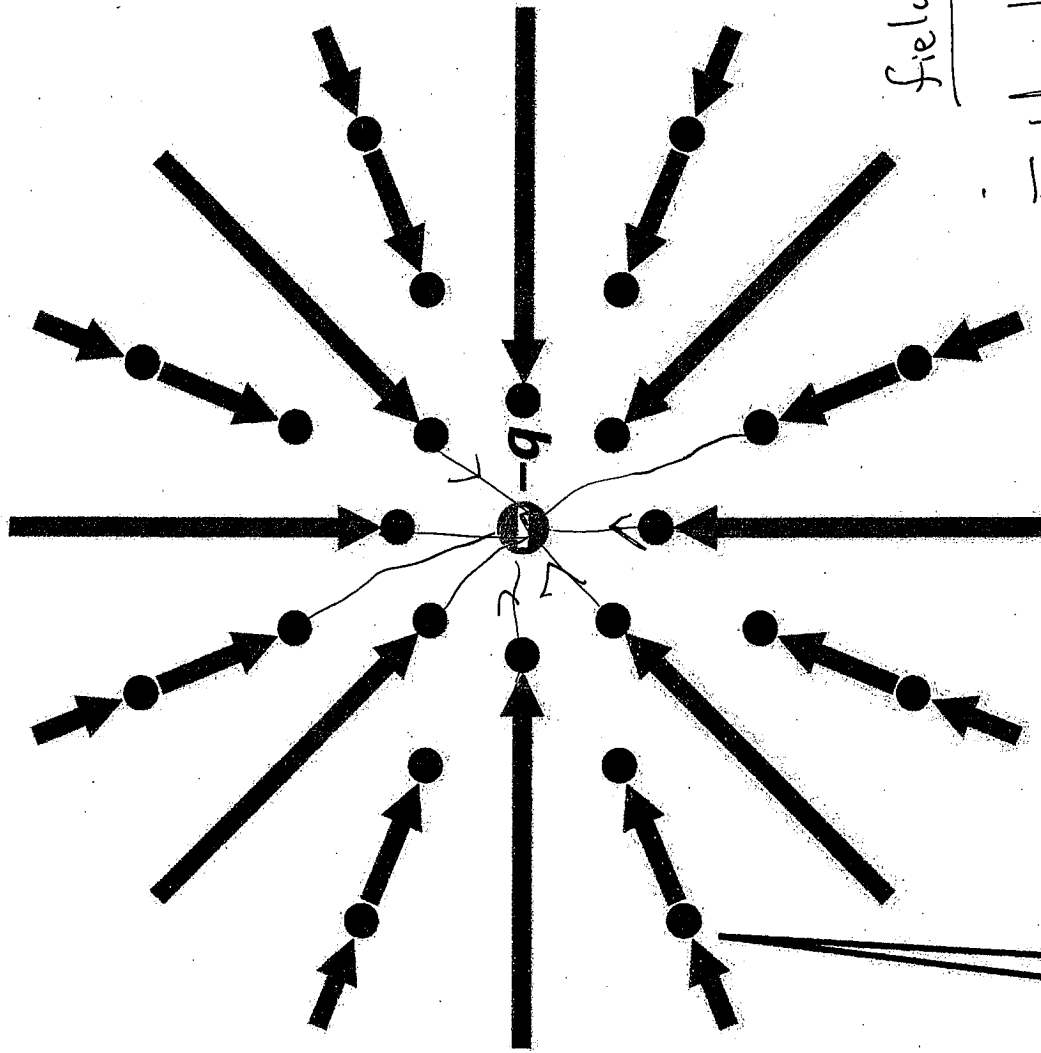


Field vectors point away from positive charge.

Magnitude of field vector decreases with inverse square of distance.

electric field lines in direction of  $\vec{E}$ -fields  
Field lines are more spaced the weaker the fields  
Fields start from + charge  
Fields don't intersect where there is no charge

Figure 23-12 Physics for Engineers and Scientists 3/e  
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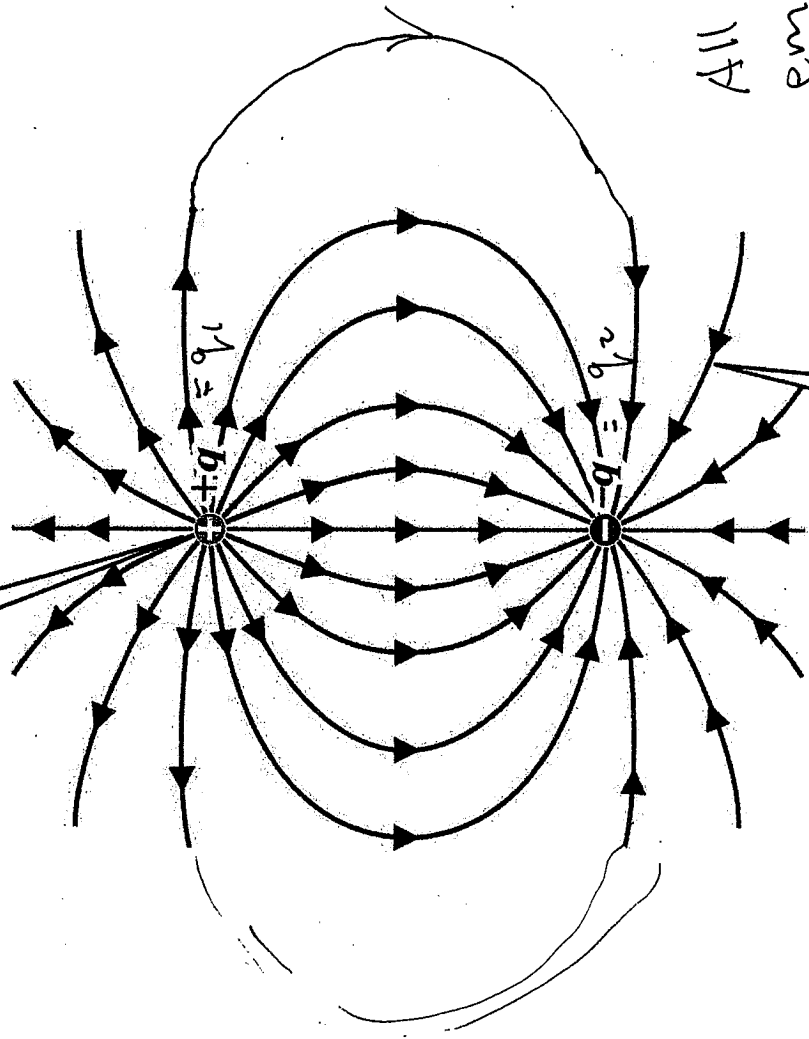
field lines:

Field lines end on  
negative charges

**Field vectors point  
toward negative charge.**

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Equal-magnitude positive and negative charges...



...have equal numbers of field lines.

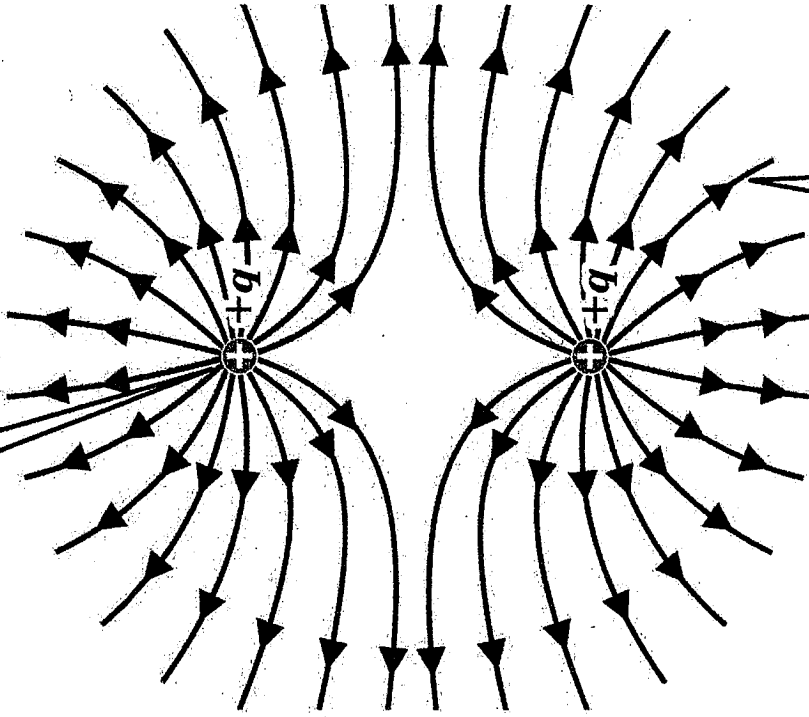
dipole  
 $(+q_1 = -q_2)$

All field lines  
emanating from  
 $q_1$  end on  $q_2$

Figure 23-17 Physics for Engineers and Scientists 3/e  
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Equal numbers of field lines...



...emerge from equal positive charges.

Field lines don't cross  
All field lines end at infinity

Figure 23-18 Physics for Engineers and Scientists 3/e  
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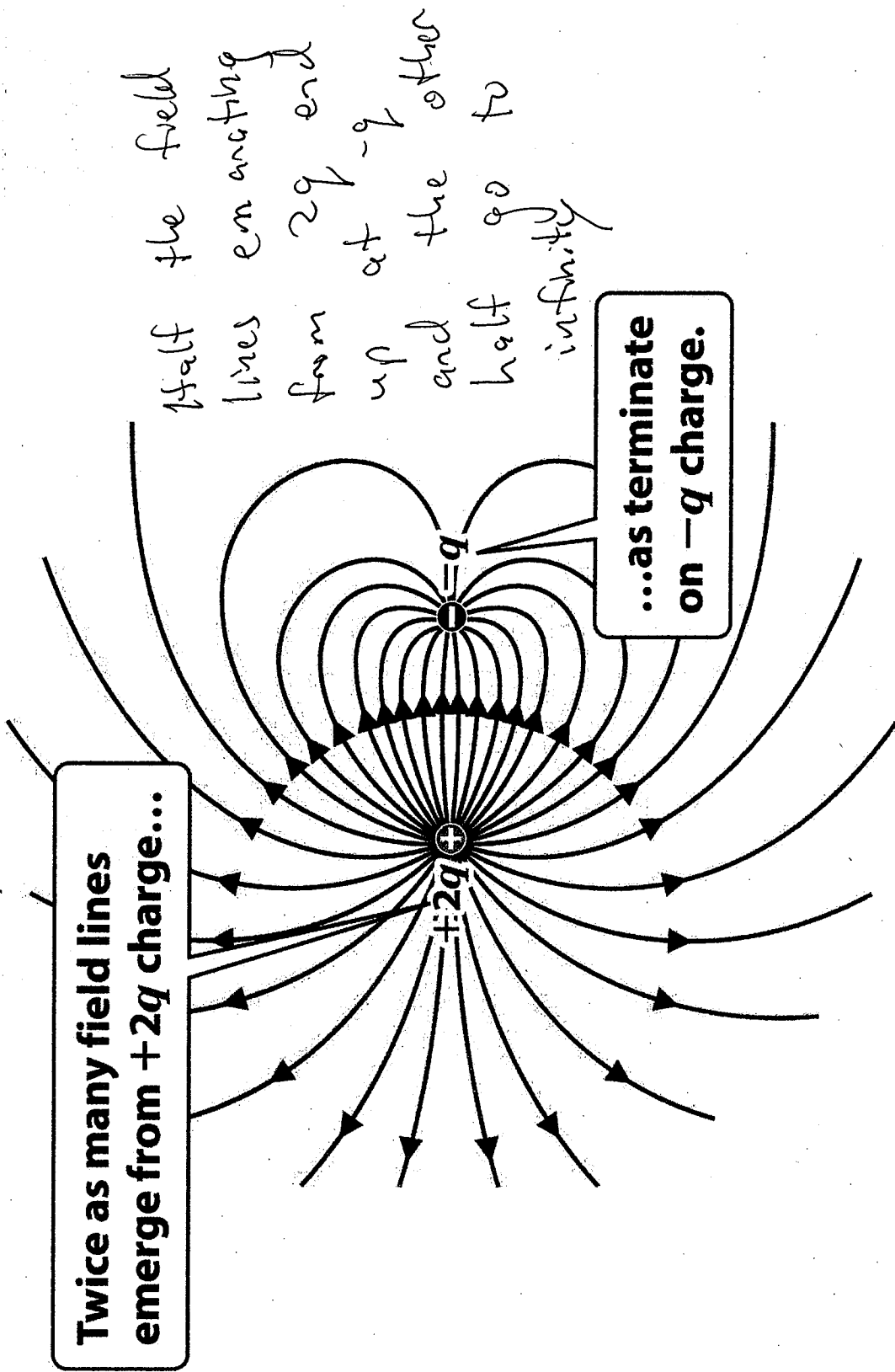
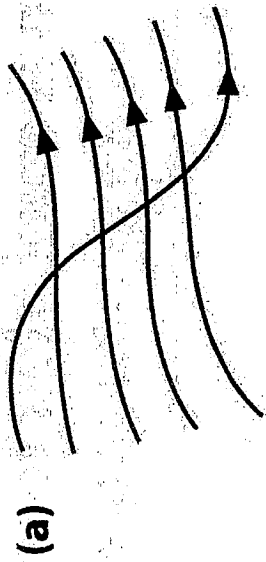


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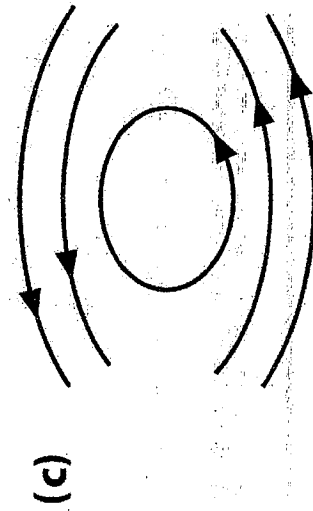


$\vec{B}$ -Field - don't cross

**These field line diagrams are incorrect. Why?**



E-field lines cannot begin where there is no charge



field lines do not close on themselves

Find  $\theta$ !

$$m \frac{dv_y}{dt} = e E_y \quad m \frac{dv_x}{dt} = 0$$

$$a_{y1} = \frac{e E_y}{m}, \quad v_{y1}(t) = v_{y0} + a_{y1} t = \frac{e E_y}{m} t$$

time to cross capacitor,  $T = d/v_0$

$$v_y(t) = e E_y d / m v_0$$

Uniform electric field causes projectile motion between plates.

Ions enter horizontally.

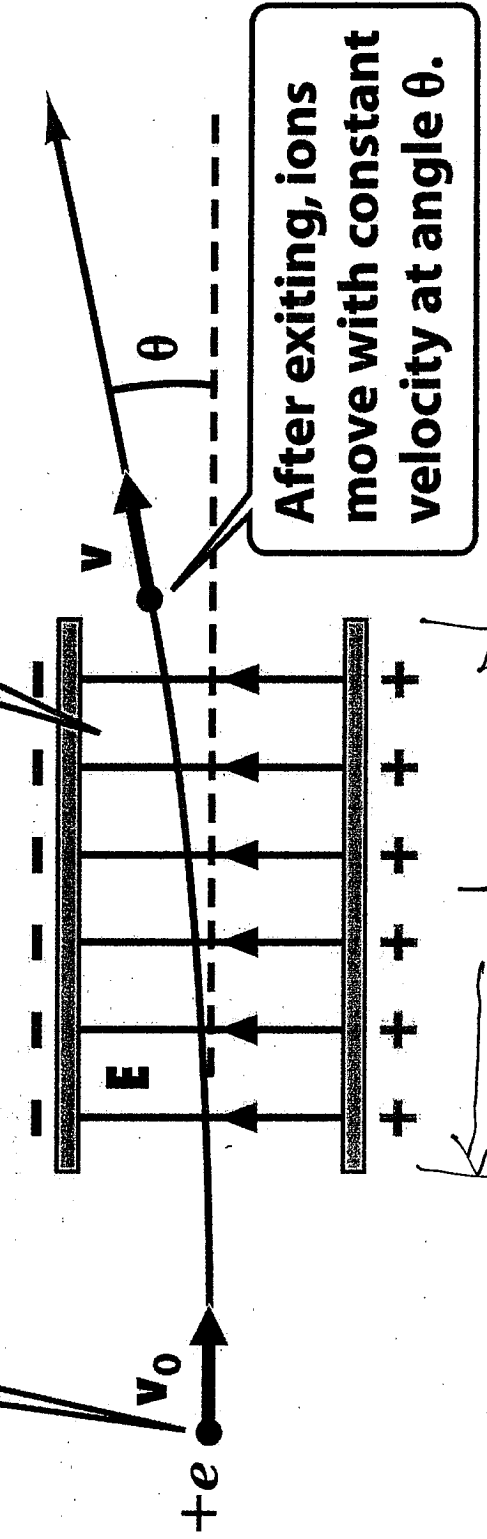


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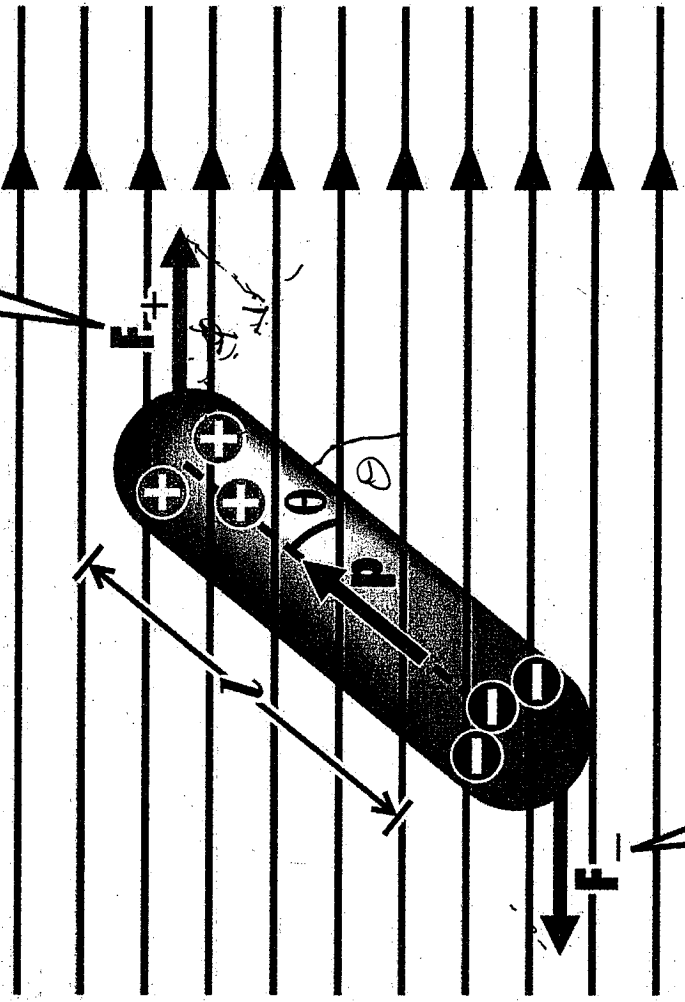
$$T = \frac{d}{v_0}$$

$$d = v_0 T$$

$$\tan \theta = \frac{v_y(T)}{v_x(T)} = \frac{e E_y d}{m v_0^2}$$

$\theta + \phi = 90^\circ$

In uniform external field, forces on dipole sum to zero...



...but tend to rotate dipole, so there is a net torque.

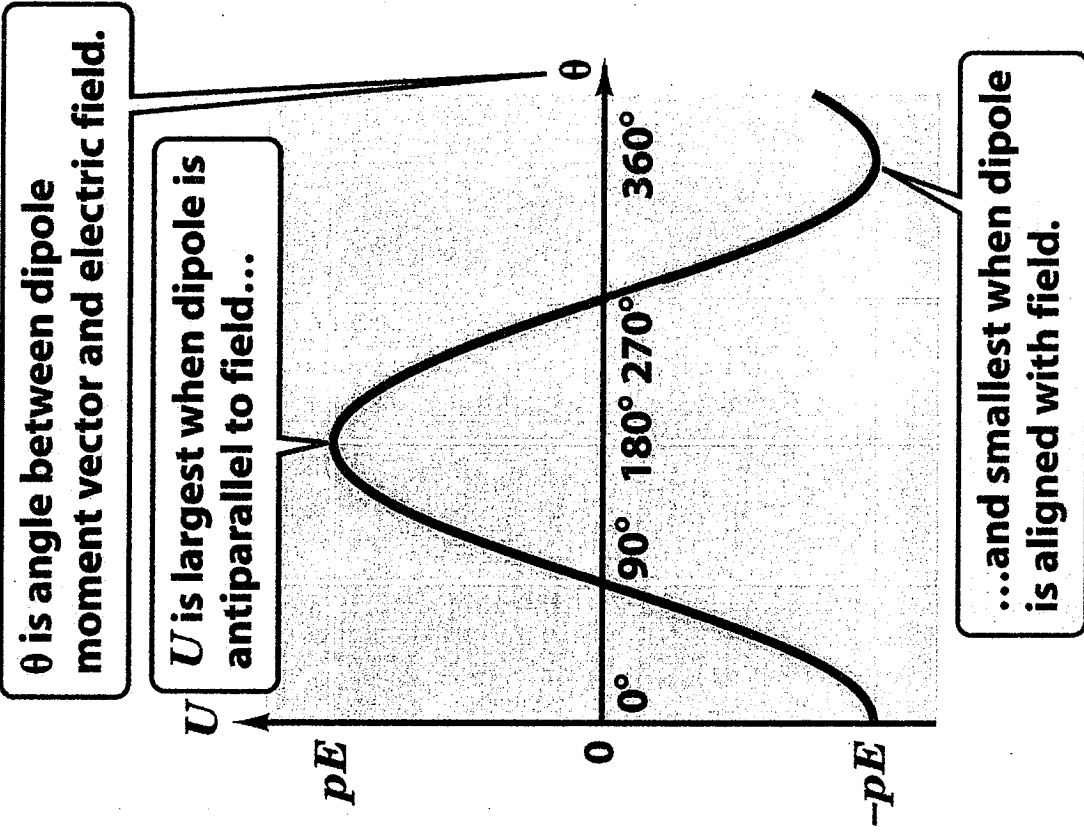
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torque  $\tau = qE \cos \phi = qE \sin \theta$

Dipole moment  $p = ql$

~~$\tau = p \cdot E$~~

$\tau = pE$



$$- \sin \theta$$

Figure 23-26 Physics for Engineers and Scientists 3/e  
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