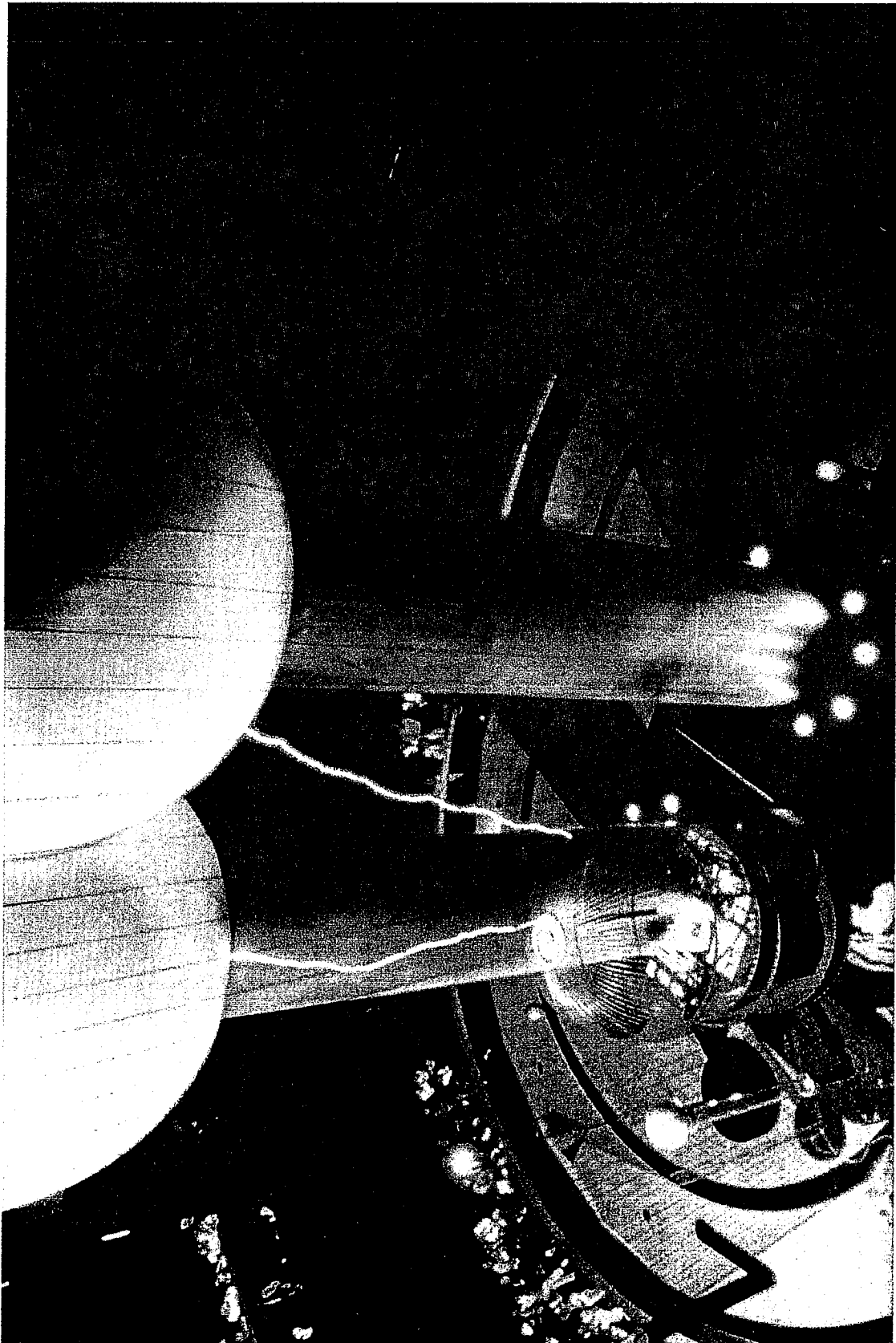


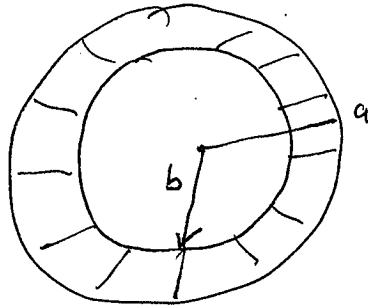
Lecture 5



Chapter 25 Opener Physics for Engineers and Scientists 3/e  
Hank Morgan/Photo Researchers, Inc.

# Surface Charges on a conductor

Sphere



Charge  $q_c$  on the conductor

How is this charge distributed?

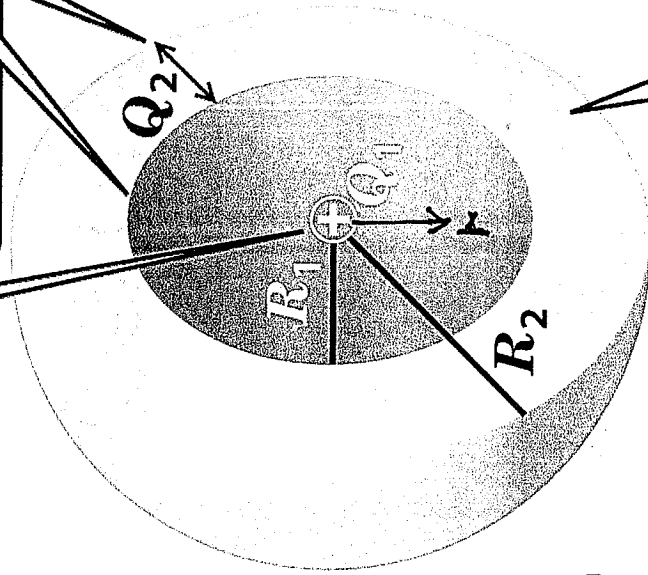
- (a) Uniformly throughout the conductor
  - (b) On both the outer and inner surfaces
  - (c) On only the inner surfaces
  - (d) On only the outer surfaces
-

Point charge  $Q_1$  is at center of spherical shell cavity.

Conducting shell has net charge  $Q_2$  on its surfaces.

How much charge is on the outer surface of the conductor?

What happens to the surface charge on the conductor if  $Q_1$  moves from the center  
 (with  $r < R_1$ )  
 (with  $r > R_1$ )



(1)  $Q_2$ ; (2)  $Q_2 - Q_1$ ;

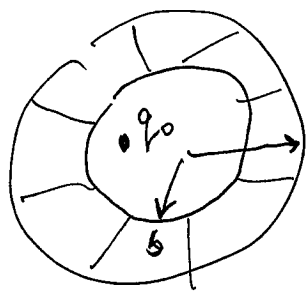
(3)  $Q_2 + Q_1$  (4) Indeterminate

We know  $E = 0$  inside a conductor.

How much charge on the inner shell of the conductor?

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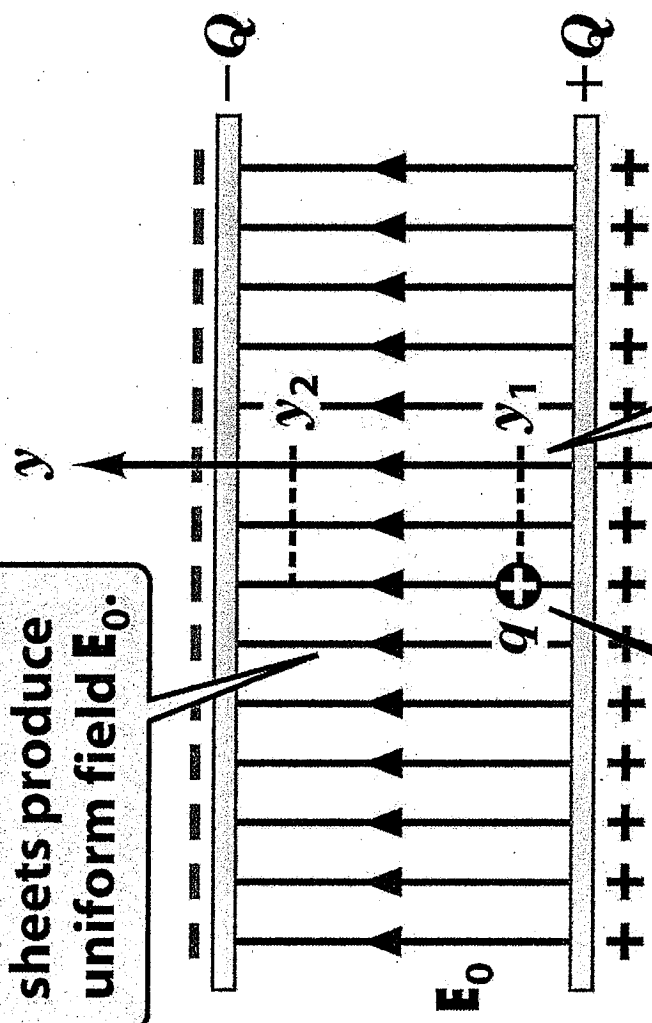
Which of the following is true if the charge  $q_0$  is not at the center of the spherical conductor, which carries a total charge  $q_c$ .



charge  $q_c$  on conductor

- (a) The total charge on the inner surface of the conductor is  $-q_0$
- (b) The total charge on the outer conductor is  $q_c + q_0$
- (c) The surface charge density is not uniform on either surface of the conductor
- (d) all of these
- (e) none of these

Large parallel sheets produce uniform field  $E_0$ .



Potential energy decreases in proportion to distance  $y$ .

To slowly push positive charge  $q$  from negative to positive plate requires external work  $W=qE_0d$

**Reversed field direction  
results in opposite location  
for higher potential energy.**

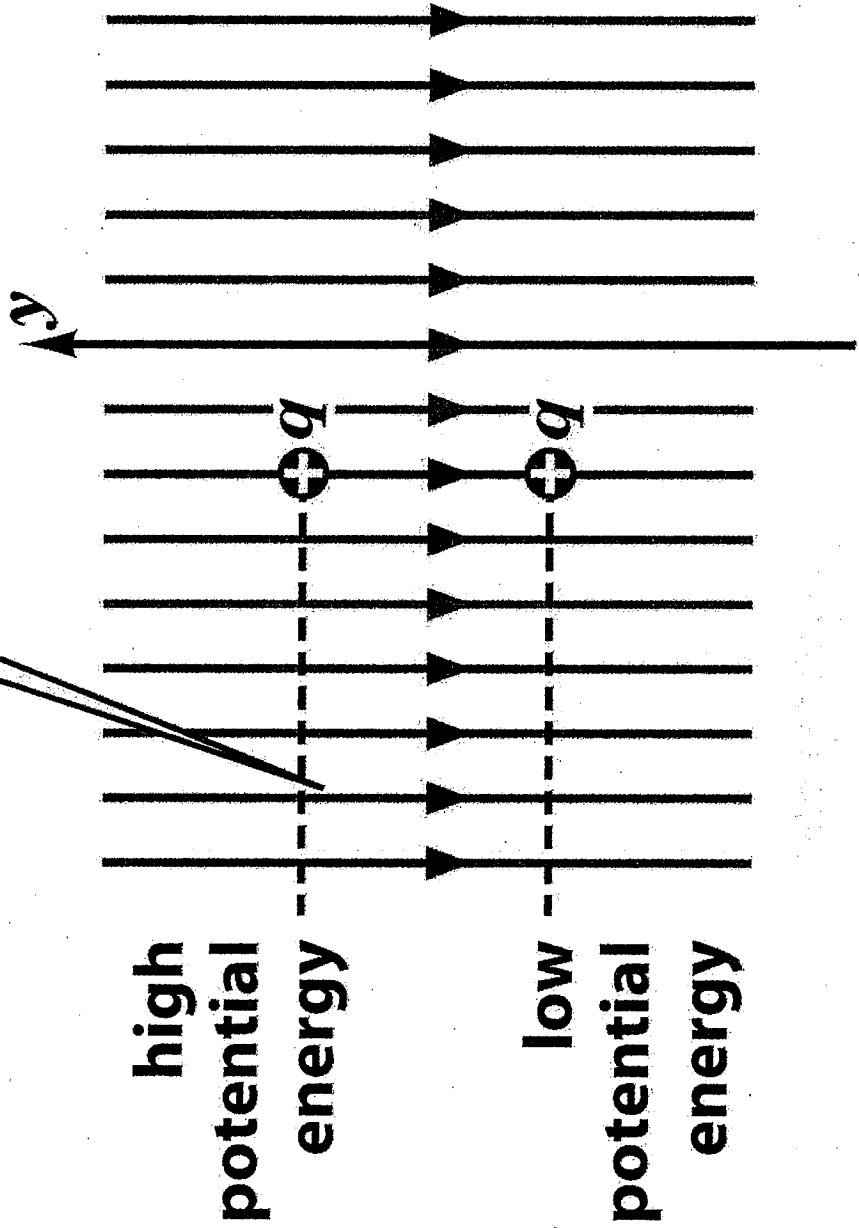


Figure 25-2b Physics for Engineers and Scientists 3/e  
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**Positive  $q$  "falls upward"  
in upward electric field.**

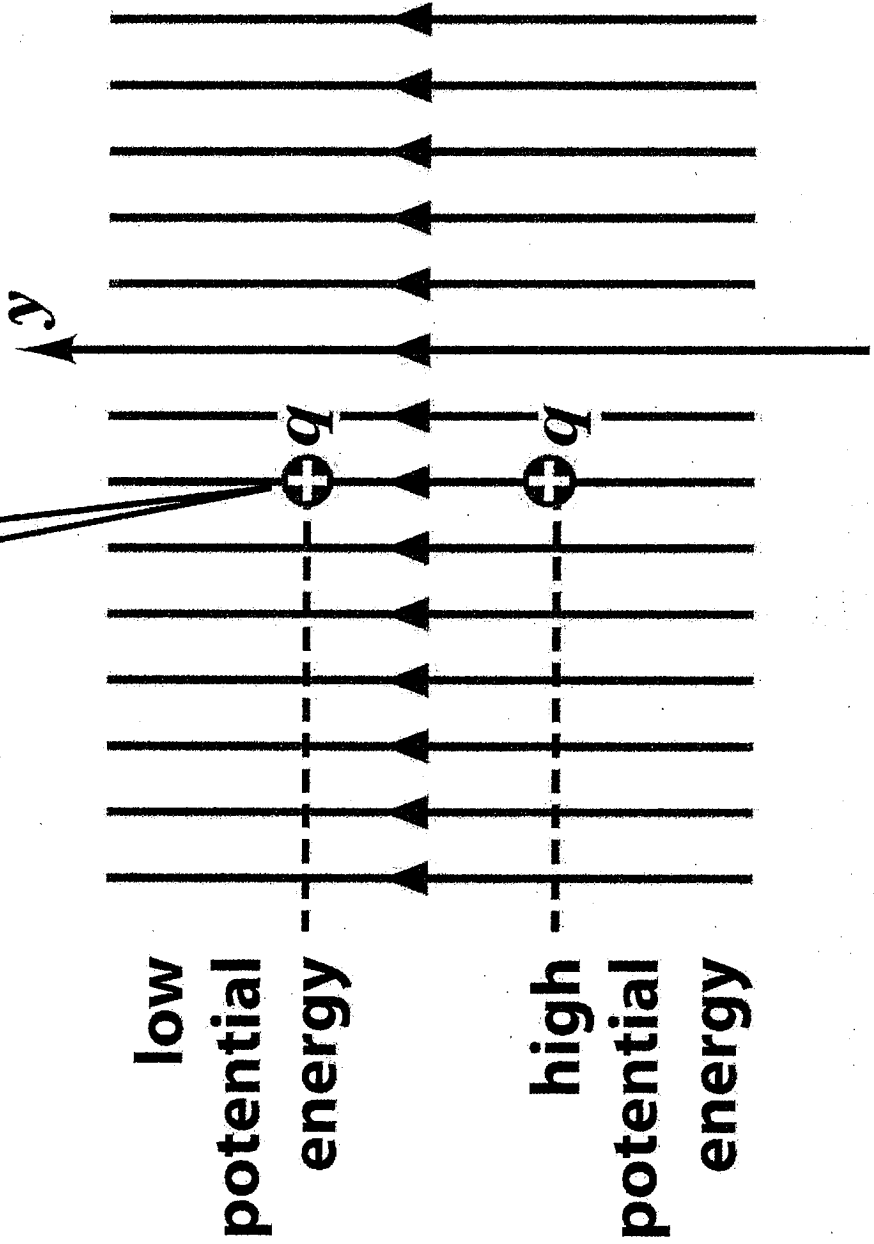


Figure 25-2a Physics for Engineers and Scientists 3/e  
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**A negative charge also has the opposite direction for higher potential energy.**

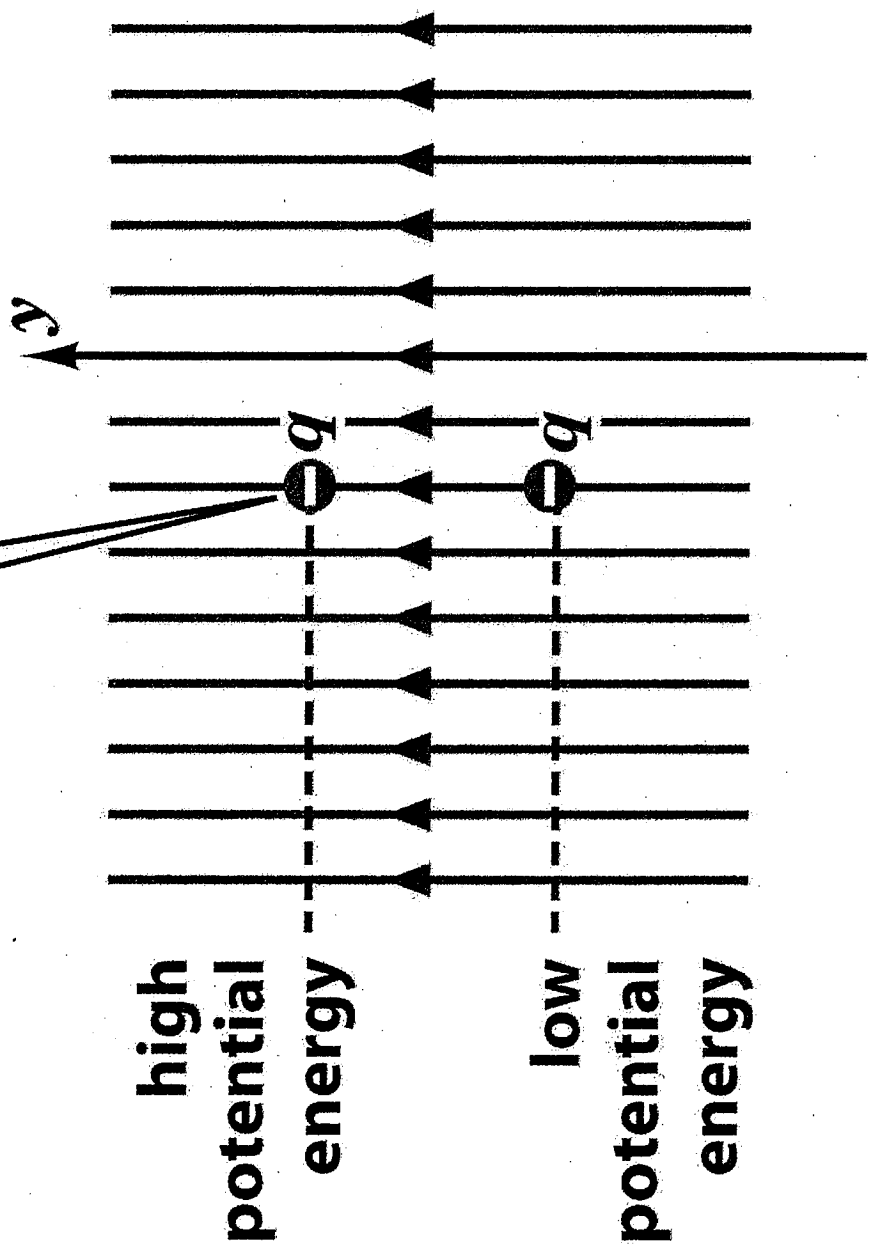
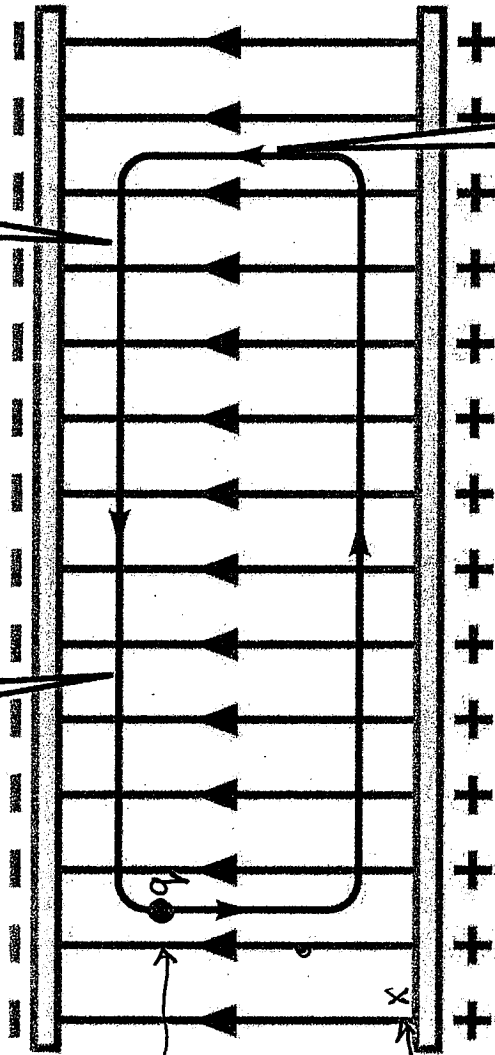


Figure 25-2c Physics for Engineers and Scientists 3/e  
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**Electric field is perpendicular to horizontal segments.**

**We consider the work done as a positive charge moves around an imagined path.**



**Electric field is parallel to one vertical segment, antiparallel to the other.**

start here  
 $V(y) = -E \cdot y$   
 ↑  
 electrical potential

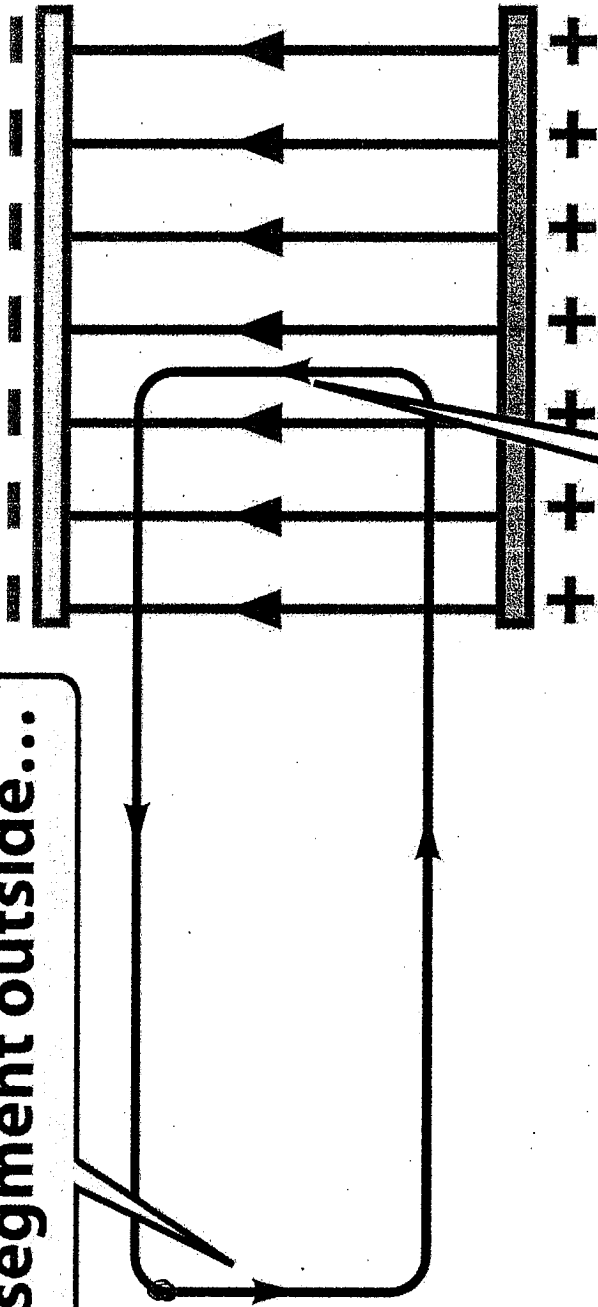
The work on charge done by external force to reach a point, is the potential energy of charge at that point.

The potential energy per unit charge is the electrical potential of that point  $V_1$

Figure 25-3a Physics for Engineers and Scientists 3/e © 2007 W. W. Norton & Company, Inc.

An apparent discrepancy

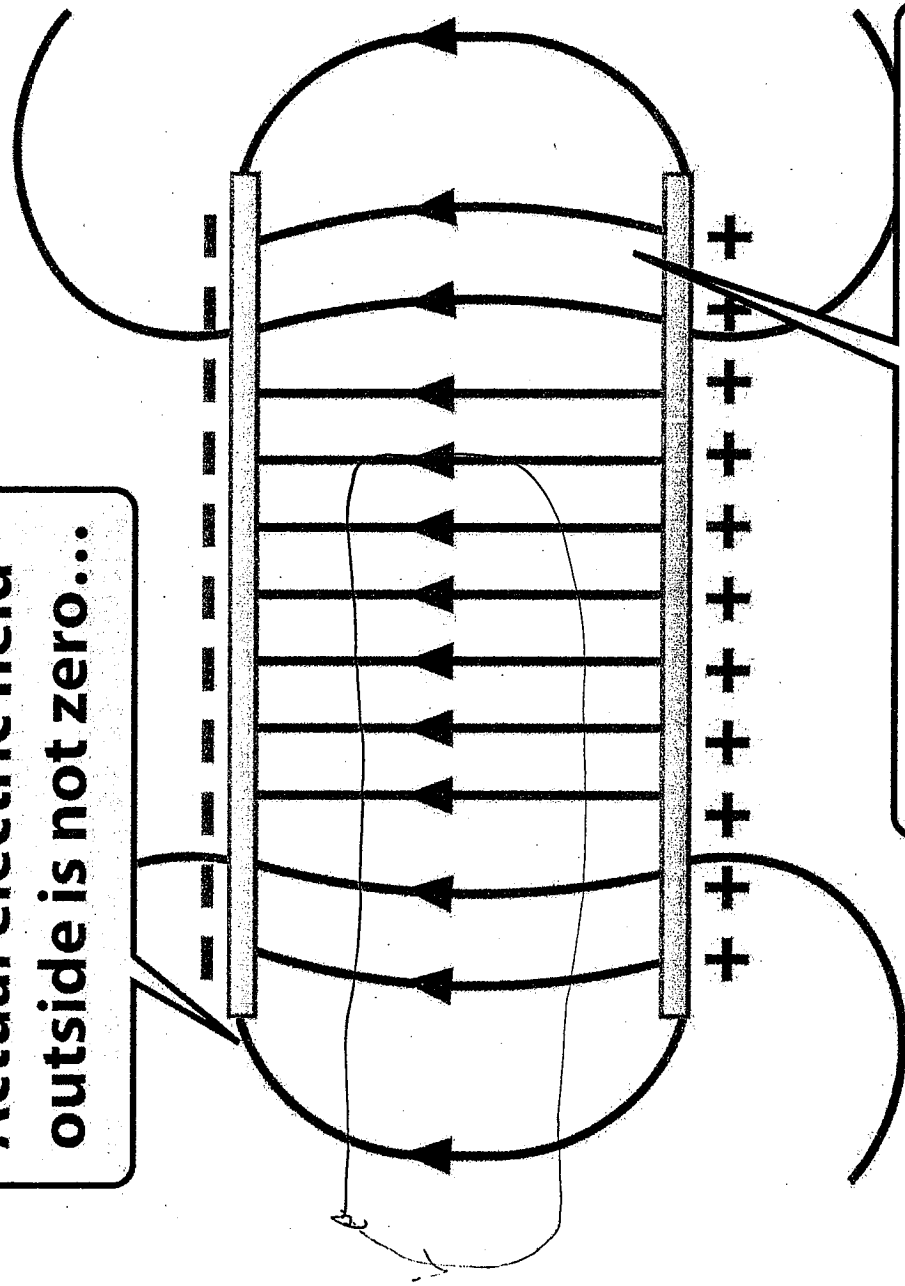
**For a path with one vertical segment outside...**



**...the segment in the field appears to provide the only contribution to the work!**

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**Actual electric field outside is not zero...**

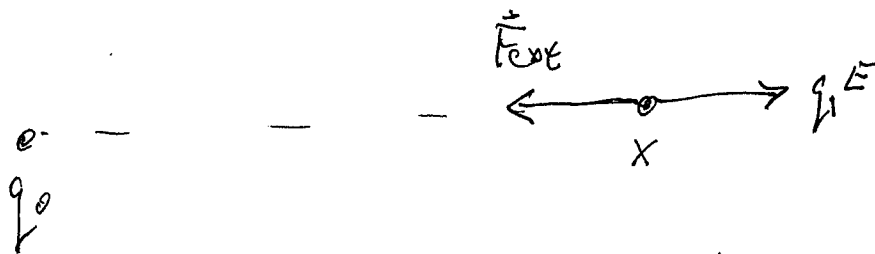


**...and actual field inside is not uniform near edge.**

These stray fields allows the work to be done on a charge in a closed path to be zero (if there is no friction)

Figure 25-4 Physics for Engineers and Scientists 3/e  
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Derive external work done by  
 on charge  $q_1$ , to bring  
 from infinity to a  
 distance  $x$  from charge  $q_0$



$$\vec{F}_{\text{ext}} = -q_1 \vec{E} = -q_1 \frac{kq_0 \hat{x}}{x^2}$$

$$W = \int_{\infty}^x \vec{F}_{\text{ext}}(\vec{x}') \cdot d\vec{x}' = -q_0 q_1 k \int_{\infty}^x \frac{dx'}{x'^2} = \frac{q_0 q_1 k}{x}$$

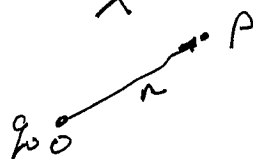
$$= -q_1 \int_{\infty}^x \vec{E}(\vec{x}') \cdot d\vec{x}'$$

The work done by the ~~pot~~ conservative external force, is the change of potential energy of particle 2

$$U(x) - U(\infty) = U(x) = \frac{q_0 q_1 k}{x}$$

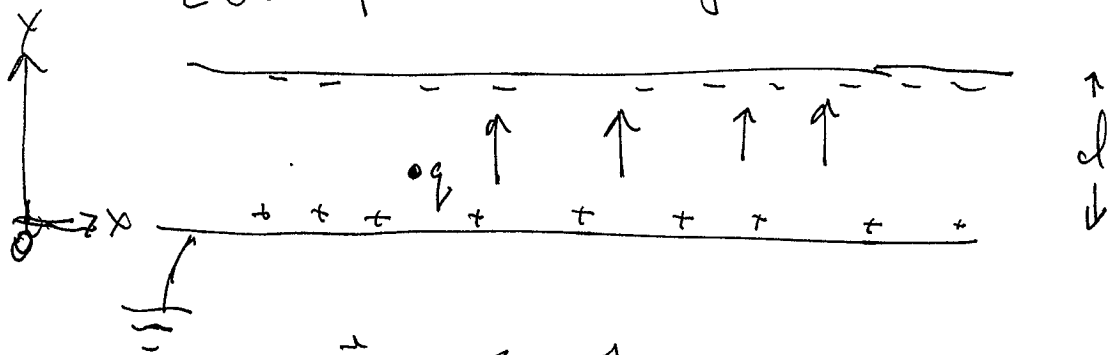
Electric Potential =  $\frac{\text{Potential Energy}}{q_1} = \frac{kq_0}{x}$

More general  $U(\vec{r}) = \frac{kq_0}{r}$



Potential across a capacitor  
plate

After one plate is considered  
zero potential (grounded)



$$\vec{E} = \frac{\sigma}{\epsilon_0} \hat{y}$$

$$W = -q \int_0^y E dy$$

$$= -q \frac{\sigma}{\epsilon_0} \int_0^y dx = -\frac{q\sigma}{\epsilon_0} y = U(y)$$

Potential energy of charge (with respect  
to grounded positive plate)

$$U(y) = -\frac{q\sigma}{\epsilon_0} y \equiv qV(y)$$

$$V(y) = -\frac{\sigma}{\epsilon_0} y$$

Potential of negative plate is

$$V(d) = -\frac{\sigma}{\epsilon_0} d$$

If there is only electric force on charge, then electric force does work that is converted to kinetic energy

$P_2$

$ds$   
Use energy conservation theorem

$F$

$$W_i = \frac{qq'}{4\pi\epsilon_0 r_0}$$

$$W_f = PE_f + KE_f = \frac{qq'}{4\pi\epsilon_0 s} + \frac{1}{2}mv^2$$

$P_1$

$q$

$q'$

Charge  $q'$  exerts an electric force on charge  $q$ .

Electric force does work on charge  $q$  as it moves along radial path from  $P_1$  to  $P_2$ .

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$$\frac{1}{2}mv^2 = \frac{qq'}{4\pi\epsilon_0} \left[ \frac{1}{r_0} - \frac{1}{s} \right]$$

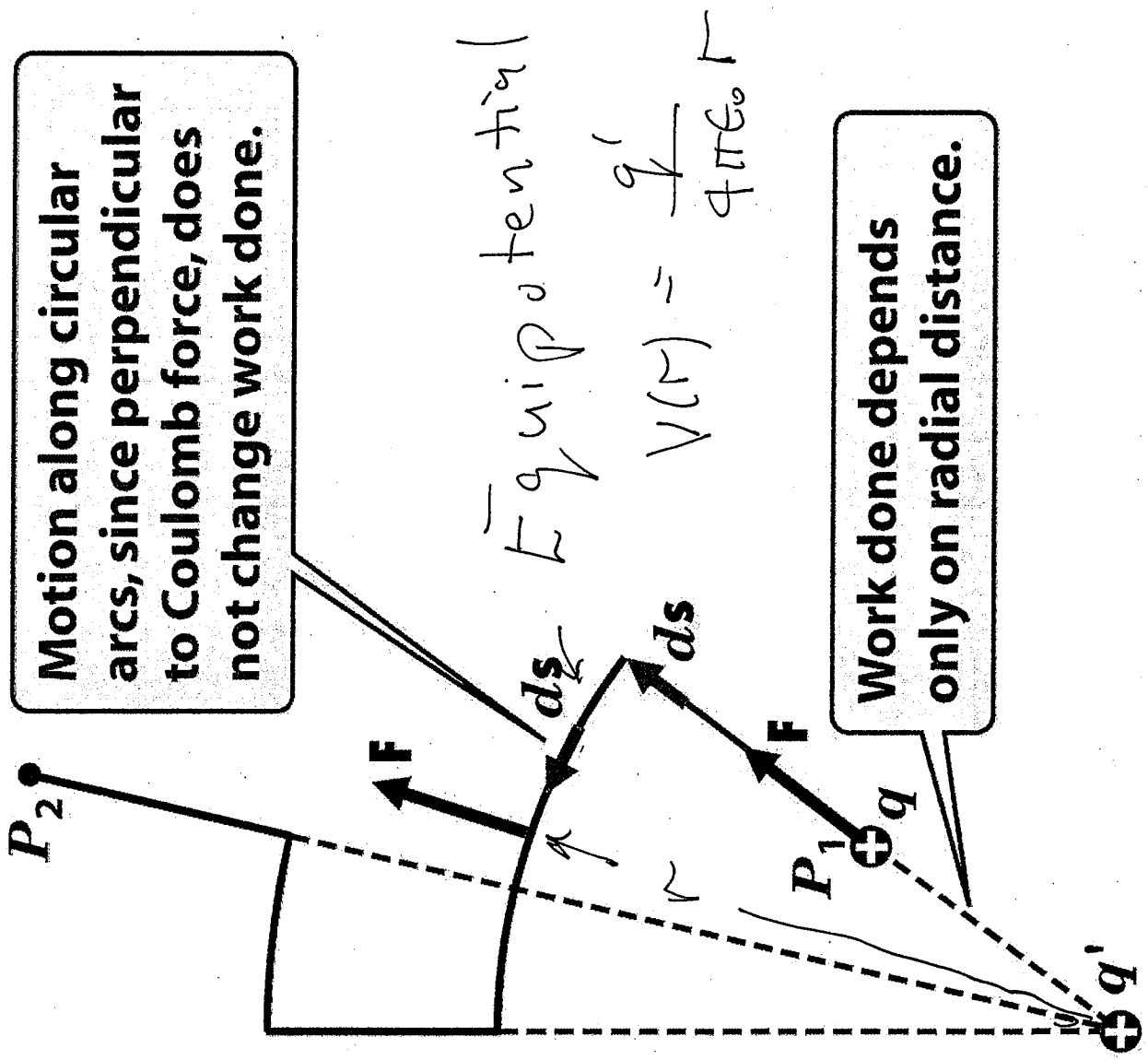


Figure 25-7 Physics for Engineers and Scientists 3/e  
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