Chapter 25

Electric Potential

Outline

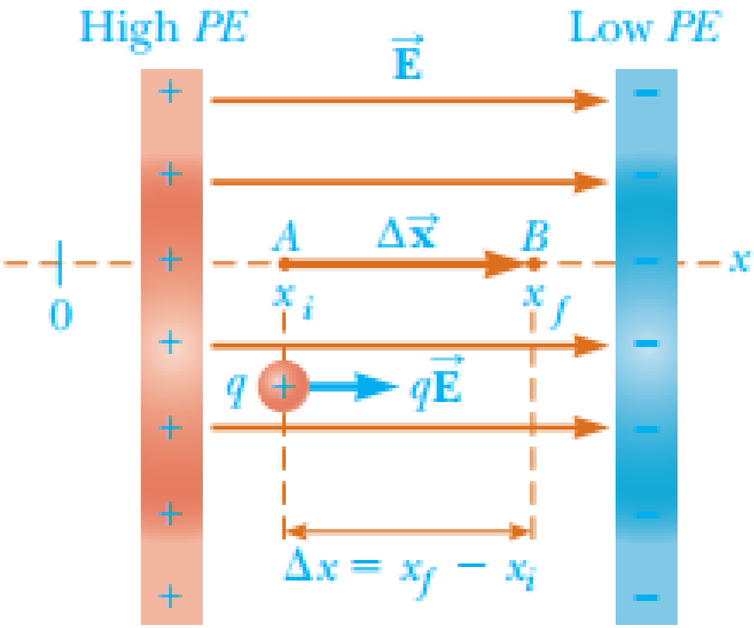
- **25.1 Potential difference and electric Potential**
- **25.2 Potential Difference and electric field**
- **25.3 Electric Potential and Potential energy due to point charges**

25.1 Potential difference and electric Potential

➢ When a charge *q* moves in a uniform electric field E from point A to point B, the work done by the field on the charge is equal to the negative of the work done by the external agent causing the displacement.

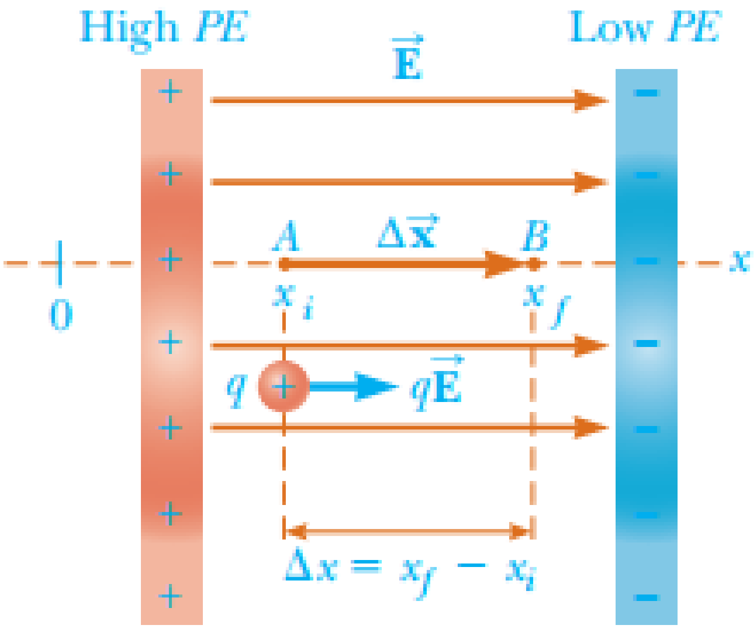
➢ When analyzing electric and magnetic fields, it is common practice to use the notation ds to represent an infinitesimal displacement vector

$$\Delta U = -q_0 \int_A^B \mathbf{E} \cdot d\mathbf{s}$$



25.1 Potential difference and electric Potential

- When a charge q moves in a uniform electric field E from point A to point B, the work done by the field on the charge is equal to the negative of the work done by the external agent causing the displacement.



- When analyzing electric and magnetic fields, it is common practice to use the notation ds to represent an infinitesimal displacement vector

$$\Delta U = -q_0 \int_A^B \mathbf{E} \cdot d\mathbf{s}$$

25.1 Potential difference and electric Potential

- Potential difference between two points in E field is defined as the change in potential energy of the system when a test charge is moved between the points divided by the test charge

$$V = \frac{U}{q_0}$$

$$\Delta V \equiv \frac{\Delta U}{q_0} = -\int_A^B \mathbf{E} \cdot d\mathbf{s}$$

- ***The potential difference (ΔV)*** between A and B *depends only on the source charge distribution* (consider points A and B without the presence of the test charge), while the ***difference in potential energy (ΔU) exists only*** *if a test charge is moved between the point*

25.1 Potential difference and electric Potential

- Units of Potential Difference:

$$\left[\frac{\text{Joules}}{\text{Coulomb}}\right]=\left[\frac{\text{J}}{\text{C}}\right]=\text{Volt}=\text{V}$$

- ***1J of work must be done to move a 1-C charge through a potential difference of 1V.***

- ***Therefore, we can interpret the electric field as a measure of the rate of change with position of the electric potential***

25.1 Potential difference and electric Potential

- ***<u>What is an electron Volt (eV)?</u>***

- *The energy a charge-field system gains or loses when a charge of magnitude e(electron or a proton) is moved through a potential difference of 1V*

$$1\ \mathrm{eV} = 1.60 \times 10^{-19}\ \mathrm{C \cdot V} = 1.60 \times 10^{-19}\ \mathrm{J}$$

25.1 Potential difference and electric Potential

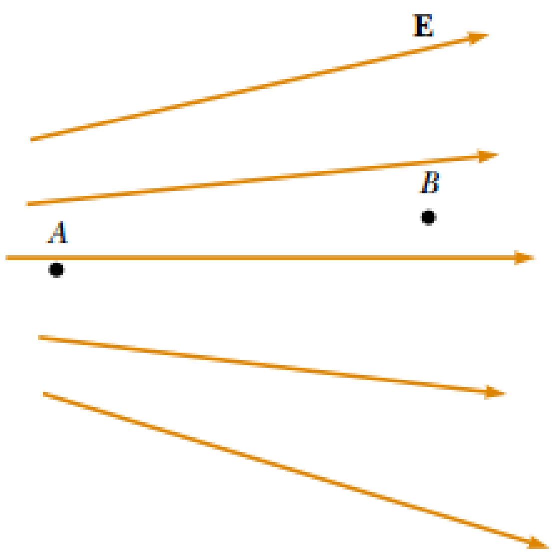
- ***Quick Quiz 23.6***

In this figure, a negative charge is placed at A and then moved to B. The change in potential energy of the charge–field system for this process is

1- *Positive*

2- Negative

3- Zero



25.1 Potential difference and electric Potential

- ***Example***

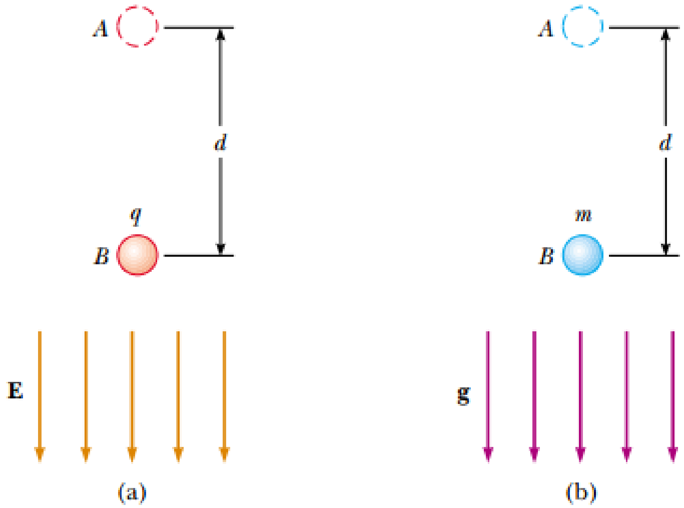
A proton is released from rest at x =2.00 cm in a constant electric field with magnitude 1.50x 103 N/C, pointing in the positive x-direction.

(a) Calculate the change in the electric potential energy associated with the proton when it reaches X=5.00 cm.

(b) An electron is now fired in the same direction from the same position. What is its change in electric potential energy associated with the electron if it reaches x= 12.0 cm?

(c) If the direction of the electric field is reversed and an electron is released from rest at x=3.00 cm, by how much has the electric potential energy changed when the electron reaches X= 7.00 cm?

25.2 Potential Differences in a Uniform Electric Field



$$V_B - V_A = \Delta V = -\int_A^B \mathbf{E} \cdot d\mathbf{s} = -\int_A^B (E \cos 0°)\, ds = -\int_A^B E\, ds$$

Because E is constant, we can remove it from the integral sign; this gives

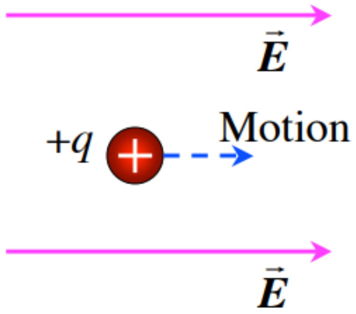
$$\Delta V = -E \int_A^B ds = -Ed \qquad (25.6)$$

The negative sign indicates that the electric potential at point B is lower than at point A; that is, $V_B < V_A$. **Electric field lines always point in the direction of decreasing electric potential,** as shown in Figure 25.2a.

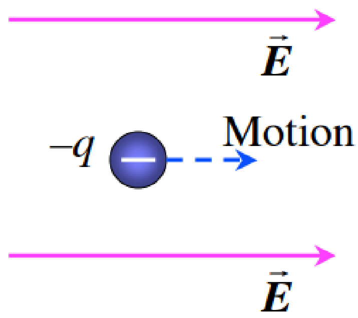
25.2 Potential Differences in a Uniform Electric Field

- A system consisting of a positive charge and an electric field loses electric potential energy when the charge moves in the direction of the field
- An electric field does work on a positive charge when the charge moves in the direction of the electric field
- As the charged particle gains kinetic energy, the charge–field system loses an equal amount of potential energy.
- A system consisting of a negative charge and an electric field gains electric potential energy when the charge moves in the direction of the field

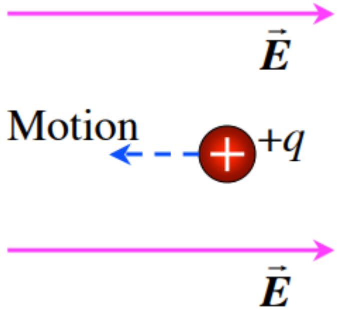
25.2 Potential Differences in a Uniform Electric Field



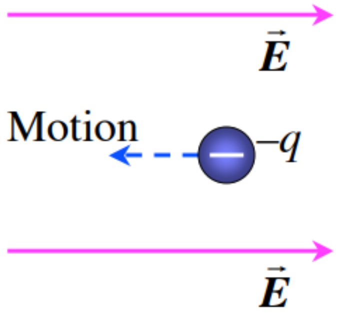
The field does positive work on it and *the potential energy decreases* $(\Delta U = -)$



The field does negative work on it and the potential energy increases$(\Delta U = +)$



The field does negative work on it and the potential energy increases$(\Delta U = +)$

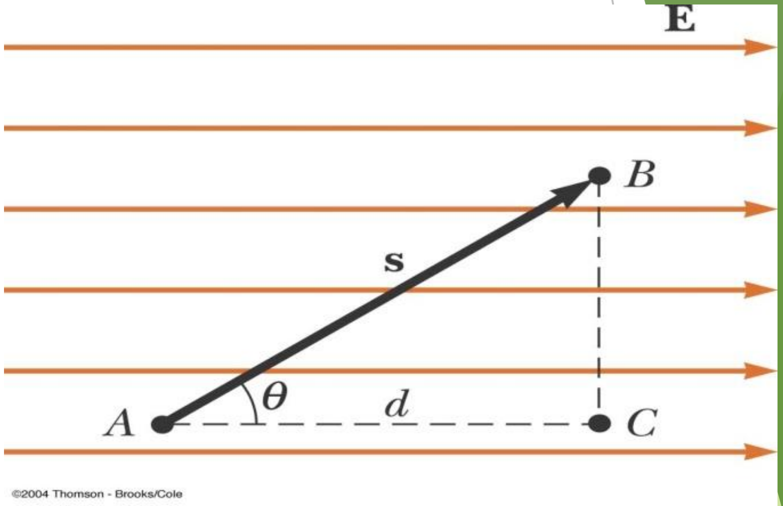


The field does positive work on it and *the potential energy decreases* $(\Delta U = -)$

25.2 Potential Differences in a Uniform Electric Field

Equipotential surface

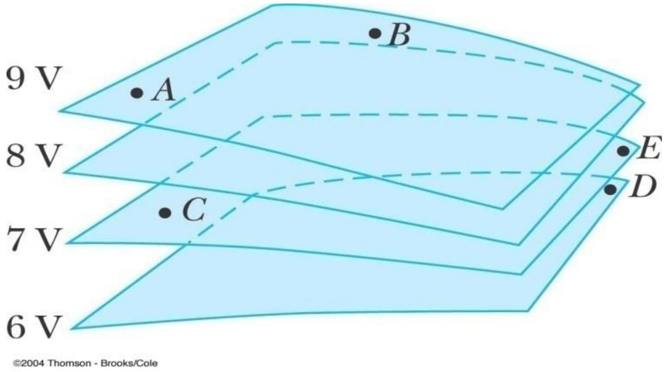
$V_B = V_C$



25.2 Potential Differences in a Uniform Electric Field

- ***Quick Quiz 25.3***

The labeled points in the Figure are on a series of equipotential surfaces associated with an electric field. Rank (from greatest to least) the work done by the electric field on a positively charged particle that moves from A to B; from B to C; from C to D; from D to E.



25.2 Potential Differences in a Uniform Electric Field

- ***Quick Quiz 26.3***

For the equipotential surfaces in this figure, what is the approximate direction of the electric field?

1/ Out of the page

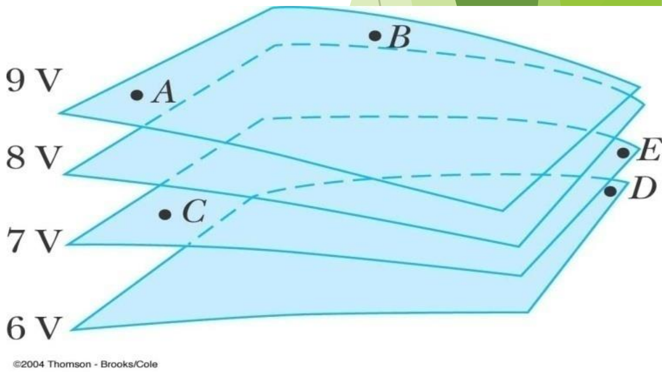
2/ Into the page

3/ Toward the right edge of the page

4/ Toward the left edge of the page

5/ Toward the top of the page

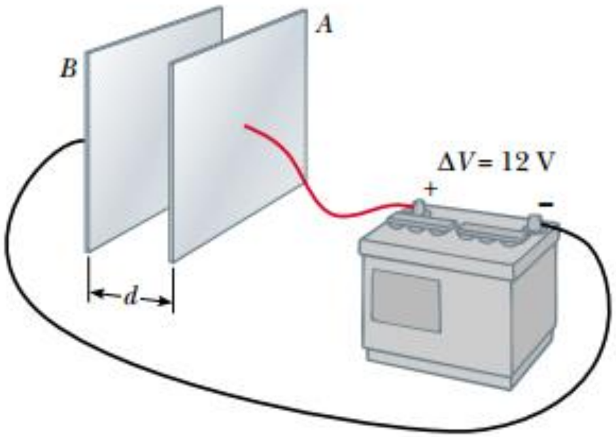
6/ Toward the bottom of the page



25.2 Potential Differences in a Uniform Electric Field

- ***Example 25.1***

A battery produces a specified potential difference ΔV between conductors attached to the battery terminals. A12-V battery is connected between two parallel plates, as shown in in the Figure. The separation between the plates is d=0.30cm, and we assume the electric field between the plates to is uniform. Find the magnitude of the electric field between the plates



25.2 Potential Differences in a Uniform Electric Field

- ***Example 25.2***

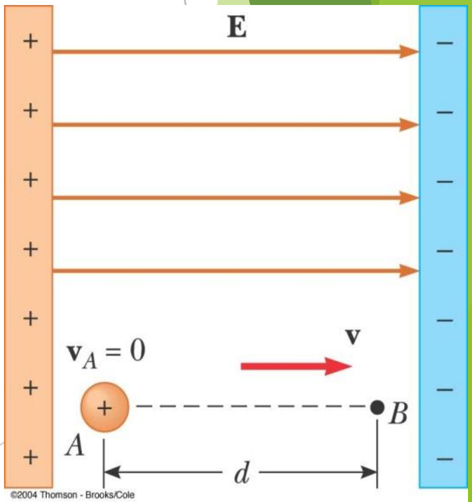
A proton is released from rest in a uniform electric field that has a magnitude of 8.0×10^4 V/m (Fig. 25.6). The proton undergoes a displacement of 0.50 m in the direction of **E**.

(A) Find the change in electric potential between points *A* and *B*.

(B) Find the change in potential energy of the proton–field system for this displacement.

(C) Find the speed of the proton after completing the 0.50 m displacement in the electric field.

What if the situation is exactly the same as that shown in the Figure, but no proton is present? Could both parts (A)and (B)of this example still be answered?



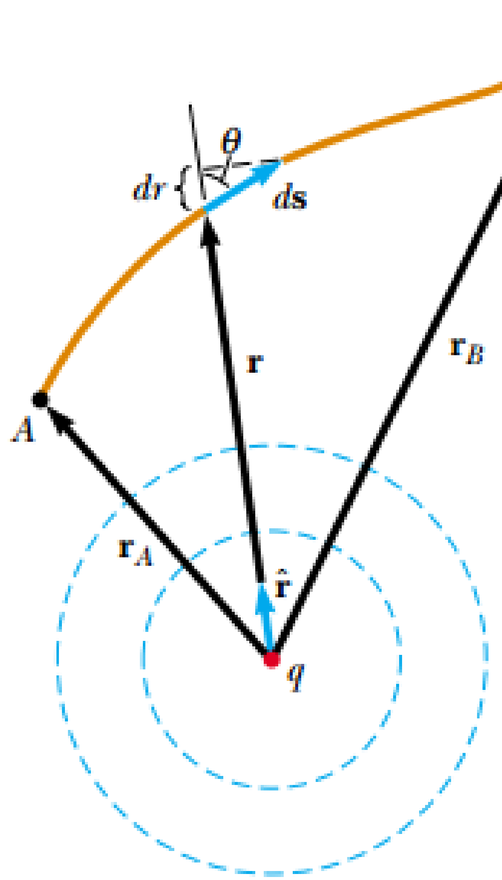
25.3 Electric Potential and Potential Energy Due to Point Charges

- The electric potential created by a point charge *q* at any distance *r* from the charge is given by

$$V_{ba} = V_b - V_a = -\int_a^b \vec{E} \cdot d\vec{s}$$

$$V_{ba} = V_b - V_a = -\frac{kq}{r^2} \int_a^b \hat{r} \cdot d\vec{s}$$

$$V = k_e \frac{q}{r}$$

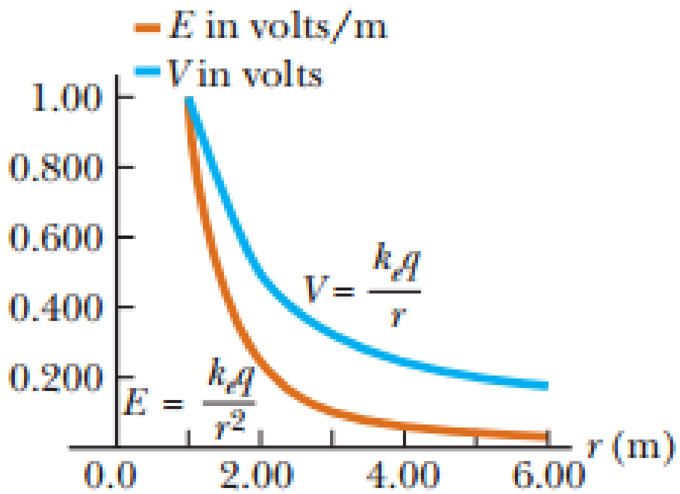


25.3 Electric Potential and Potential Energy Due to Point Charges

- The total electric potential at some point P due to several point charges is the sum of the potentials due to the individual charge

$$V = k_e \sum_i \frac{q_i}{r_i}$$

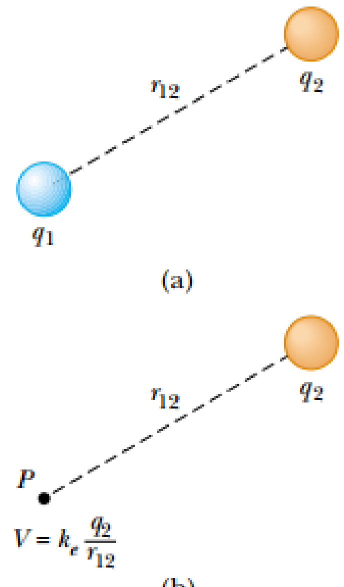
$$V_\infty = 0$$



25.3 Electric Potential and Potential Energy Due to Point Charges

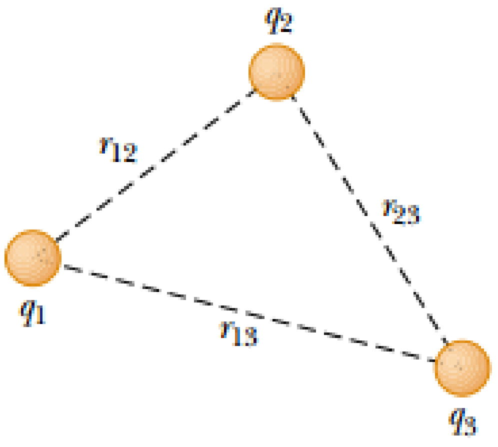
- *The potential energy of a system of two charged particles*

$$U = k_e \frac{q_1 q_2}{r_{12}}$$



- *The potential energy of a system of Three charged particles*

$$U = k_e \left(\frac{q_1 q_2}{r_{12}} + \frac{q_1 q_3}{r_{13}} + \frac{q_2 q_3}{r_{23}} \right)$$



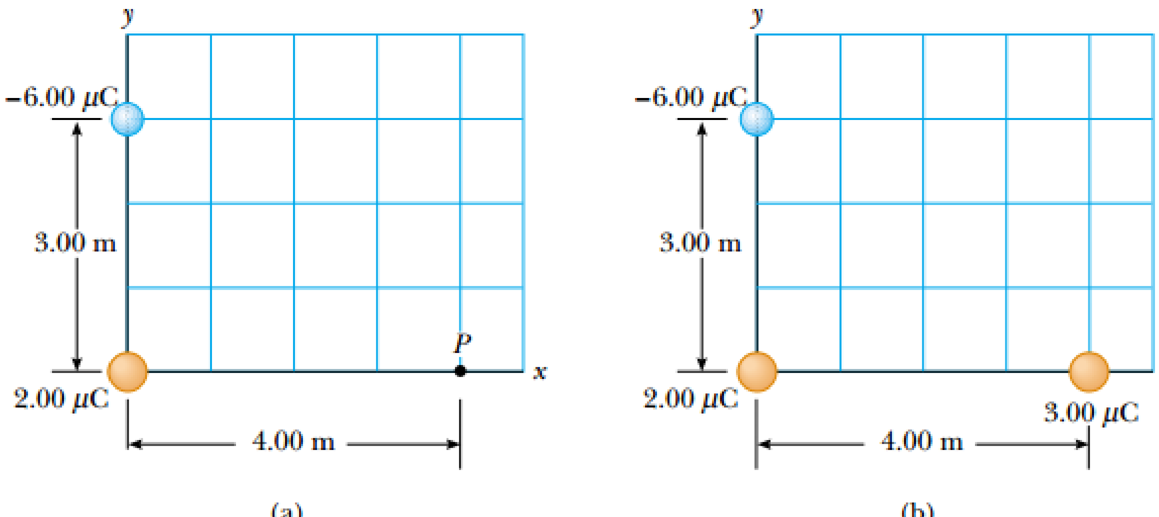
25.3 Electric Potential and Potential Energy Due to Point Charges

➢ ***Example 25.3***

A charge $q_1 = 2.00\ \mu C$ is located at the origin, and a charge $q_2 = -6.00\ \mu C$ is located at (0, 3.00) m, as shown in Figure 25.12a.

(A) Find the total electric potential due to these charges at the point *P*, whose coordinates are (4.00, 0) m.

(B) Find the change in potential energy of the system of two charges plus a charge $q_3 = 3.00\ \mu C$ as the latter charge moves from infinity to point *P* (Fig. 25.12b).



Chapter Problems

1) A proton is moved from the negative plate to the positive plate of a parallel-plate arrangement. The plates are 1.5cm apart, and the electric field is uniform with a magnitude of 1500N/C.

a) How much work would be required to move a proton from the negative to the positive plate?

b)What is the potential difference between the plates?

c) If the proton is released from rest at the positive plate, what speed will it have just before it hits the negative plate?

Problem 5 Page 787

A uniform electric field of magnitude 290 V/m is directed in the positive x direction. A +13.0 µC charge moves from the origin to the point (x, y) = (20.0 cm, 50.0 cm). What is the change in the potential energy of the charge field system?

Chapter Problems

Problem 16 Page 788

Given two 2.00-μC charges, as shown in Figure P25.16, and a positive test charge $q = 1.28 \times 10^{-18}$ C at the origin, (a) what is the net force exerted by the two 2.00-μC charges on the test charge q? (b) What is the electric field at the origin due to the two 2.00-μC charges? (c) What is the electric potential at the origin due to the two 2.00-μC charges?

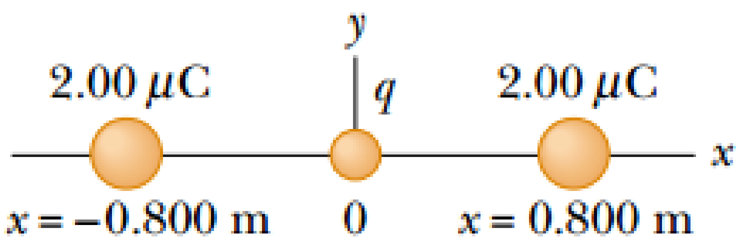


Figure P25.16

Chapter Problems

Problem 17 Page 788

At a certain distance from a point charge, the magnitude of the electric field is 500 V/m and the electric potential is –3.00 kV. (a) What is the distance to the charge? (b) What is the magnitude of the charge?

Problem 20 Page 789

Two point charges, Q1=5.00nC and Q2=3.00nC, are separated by 35.0cm. (a) What is the potential energy of the pair? What is the significance of the algebraic sign of your answer? (b) What is the electric potential at a point midway between the charges?

Chapter Problems

7) A charge $q = -4.0\ \mu C$ is moved 0.25 m horizontally to point **P** in a region where an electric field is 150 V/m and directed vertically as shown. What is the change in the electric potential energy of the charge?

شحنة 0.25 q= -4.0 µC تحركت مسافة ٠,٢٥ متر أفقيا إلى نقطة P في المنطقة المجال الكهربائي هو ١٥٠ V/m والموجهة عموديا كما هو مبين .ما هو التغيير في مجال الطاقة الكهربائية للشحنة

a) -2.4×10^{-3} J
b) $+1.5 \times 10^{-4}$ J
c) -1.5×10^{-4} J
d) $+2.4 \times 10^{-3}$ J
e) zero joules