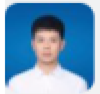

潘泽昊 Zehao PAN 09:58

各位老师早上好，本周还请提醒学生尽快选择实验课，及注意相应开课人数下限，感谢各位老师

October 2024

Mo	Tu	We	Th	Fr	Sa	Su
30	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31	1	2	3
4	5	6	7	8	9	10

[Announcement] Pre-Scheduled Dates for the Make-Up Class Sessions in Fall 2024-25

AR Academic Registry Services HKUST(GZ)
To all students gz; All Staff
Cc Academic Registry Services HKUST(GZ); ARS HKUST(GZ)-Course Registration; Rita Huihui ZHOU; Pengpeng FU

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Dear Faculty, Students, and other Colleagues,

This is a kind reminder on the make-up dates of classes missing due to the coming Mid-Autum Festival. The pre-schedul

Pre-Scheduled Date	Class Missing Date
14 Sep. 2024	16 Sep. 2024
12 Oct. 2024	17 Sep. 2024

Same classrooms will be pre-booked for the class sections originally scheduled on 16 & 17 Sep. 2024.

UFUG 1504: Honors General Physics II

Chapter 24

Electric Potential

Summary (1 of 5)

Electric Potential

- The electric potential V at point P in the electric field of a charged object:

$$V = \frac{-W_\infty}{q_0} = \frac{U}{q_0},$$ **Equation (24-2)**

Electric Potential Energy

- Electric potential energy U of the particle-object system:

$$U = qV.$$ **Equation (24-3)**

- If the particle moves through potential ΔV :

$$\Delta U = q\Delta V = q\left(V_f - V_i\right).$$ **Equation (24-4)**

Summary (2 of 5)

Mechanical Energy

- Applying the conservation of mechanical energy gives the change in kinetic energy:

$$\Delta K = -q\Delta V.$$

Equation (24-9)

- In case of an applied force in a particle

$$\Delta K = -q\Delta V + W_{\text{app}}.$$

Equation (24-11)

- In a special case when $\Delta K = 0$:

$$W_{\text{app}} = q\Delta V \quad \left(\text{for } K_i = K_f\right).$$

Equation (24-12)

Summary (3 of 5)

Finding *V* from $\vec{E}$

- The electric potential difference between two point *I* and *f* is:

$$V_f - V_i = -\int_i^f \vec{E} \cdot d\vec{s}, \qquad \textbf{Equation (24-18)}$$

Potential due to a Charged Particle

- due to a single charged particle at a distance r from that particle :

$$V = \frac{1}{4\pi\varepsilon_0} \frac{q}{r} \qquad \textbf{Equation (24-26)}$$

- due to a collection of charged particles

$$V = \sum_{i=1}^{n} V_i = \frac{1}{4\pi\varepsilon_0} \sum_{i=1}^{n} \frac{q_i}{r_i}. \qquad \textbf{Equation (24-27)}$$

Summary (4 of 5)

Potential due to an Electric Dipole

- The electric potential of the dipole is

$$V = \frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{r^2}$$

Equation (24-30)

Potential due to a Continuous Charge Distribution

- For a continuous distribution of charge:

$$V = \frac{1}{4\pi\varepsilon_0}\int\frac{dq}{r}$$

Equation (24-32)

Summary (5 of 5)

Calculating $\vec{E}$ from V

- The component of $\vec{E}$ in any direction is:

$$E_s = -\frac{\partial V}{\partial s}.$$

Equation (24-40)

Electric Potential Energy of a System of Charged Particle

- For two particles at separation r:

$$U = W = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r}.$$

Equation (24-46)

24-1 Electric Potential (4 of 8)

The electric potential V at a point P in the electric field of a charged object is

$$V = \frac{-W_\infty}{q_0} = \frac{U}{q_0}$$

where W_∞ is the work that would be done by the electric force on a positive test charge q_0 were it brought from an infinite distance to P, and U is the electric potential energy that would then be stored in the test charge–object system.

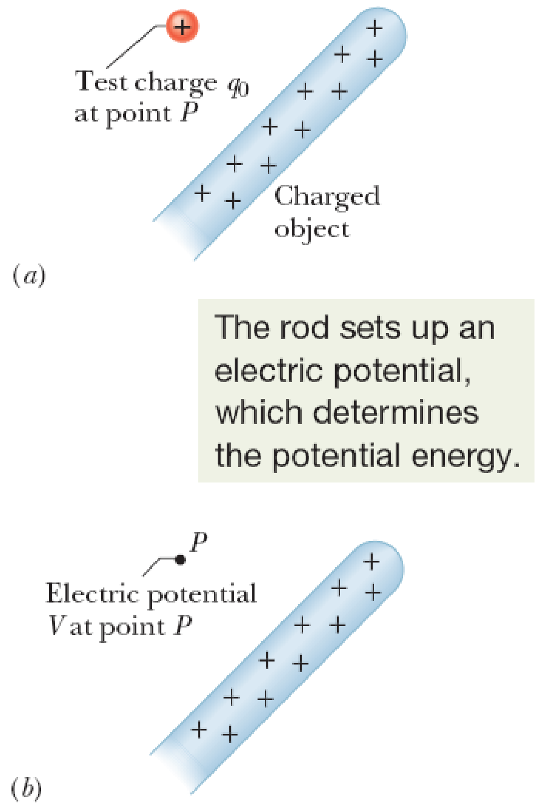


Figure 24-2 (*a*) A test charge has been brought in from infinity to point P in the electric field of the rod. (*b*) We define an electric potential V at P based on the potential energy of the configuration in (*a*).

24-1 Electric Potential (5 of 8)

If a particle with charge q is placed at a point where the electric potential of a charged object is V, the electric potential energy U of the particle–object system is

$$V = \frac{U}{q_0} \Rightarrow U = qV.$$

24-1 Electric Potential (7 of 8)

Change in Electric Potential. If the particle moves through a potential difference ΔV, the change in the change in the electric potential energy is

$$\Delta U = q\Delta V = q\left(V_f - V_i\right).$$

Work by the Field. The work W done by the electric force as the particle moves from i to f:

$$W = -\Delta U = -q\,\Delta V = -q\left(V_f - V_i\right).$$

24-1 Electric Potential (8 of 8)

Conservation of Energy. If a particle moves through a change ΔV in electric potential without an applied force acting on it, applying the conservation of mechanical energy gives the change in kinetic energy as

$$\Delta K = -q\,\Delta V = -q\left(V_f - V_i\right).$$

Work by an Applied Force. If some force in addition to the electric force acts on the particle, we account for that work

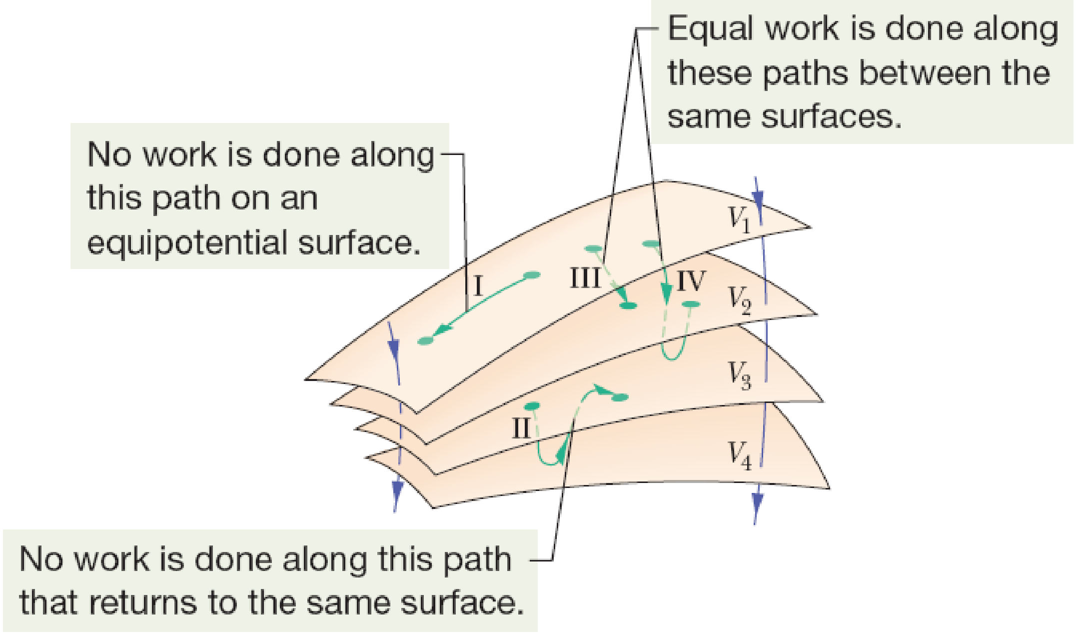
$$(\text{initial energy}) + (\text{work by applied force}) = (\text{final energy})$$

$$U_i + K_i + W_{\text{app}} = U_f + K_f.$$

$$\Delta K = -\Delta U + W_{\text{app}} = -q\,\Delta V + W_{\text{app}}.$$

24-2 Equipotential Surfaces and the Electric Field (3 of 6)

Adjacent points that have the same electric potential form an **equipotential surface**, which can be either an imaginary surface or a real, physical surface.

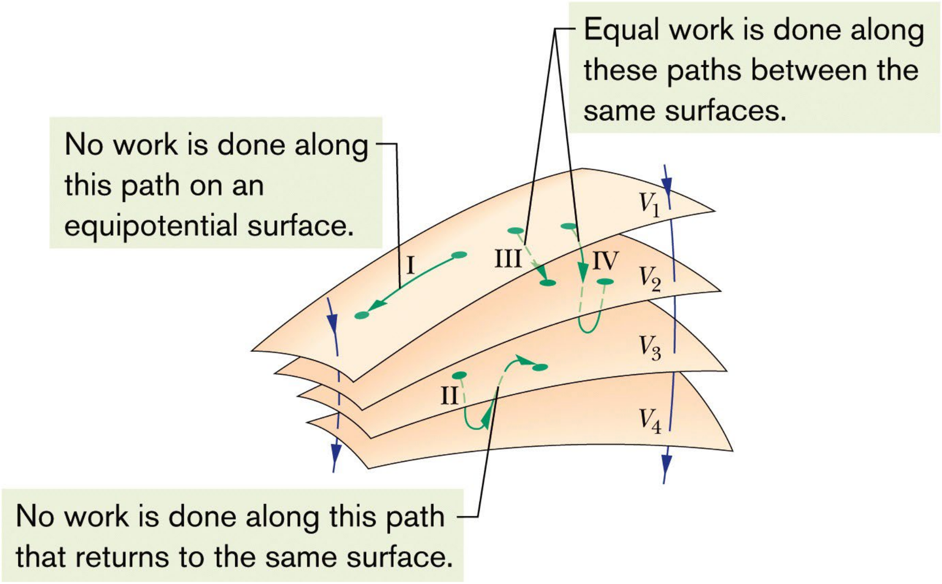


24-2 Equipotential Surfaces and the Electric Field (4 of 6)

Figure shows a family of equipotential surfaces associated with the electric field due to some distribution of charges.

The work done by the electric field on a charged particle as the particle moves from one end to the other of paths **I** and **II** is zero because each of these paths begins and ends on the same equipotential surface and thus there is no net change in potential. $\Delta V = 0$

The work done as the charged particle moves from one end to the other of paths **III** and **IV** is not zero but has the same value for both these paths because the initial and final potentials are identical for the two paths; that is, paths **III** and **IV** connect the same pair of equipotential surfaces. $\Delta V = \text{same}$



$$W = -\Delta U = -q\ \Delta V = -q(V_f - V_i).$$

24-2 Equipotential Surfaces and the Electric Field (5 of 6)

The electric potential difference between two points *i* and *f* is

$$V_f - V_i = -\int_i^f \vec{E} \cdot d\vec{s},$$

$$\vec{F} = q_0 \vec{E}$$

$$dW = \vec{F} \cdot d\vec{s} \quad \Longrightarrow \quad dW = q_0 \vec{E} \cdot d\vec{s}$$

$$W = -q(V_f - V_i).$$

$$W = q_0 \int_i^f \vec{E} \cdot d\vec{s}. \quad \Longrightarrow \quad V_f - V_i = -\int_i^f \vec{E} \cdot d\vec{s},$$

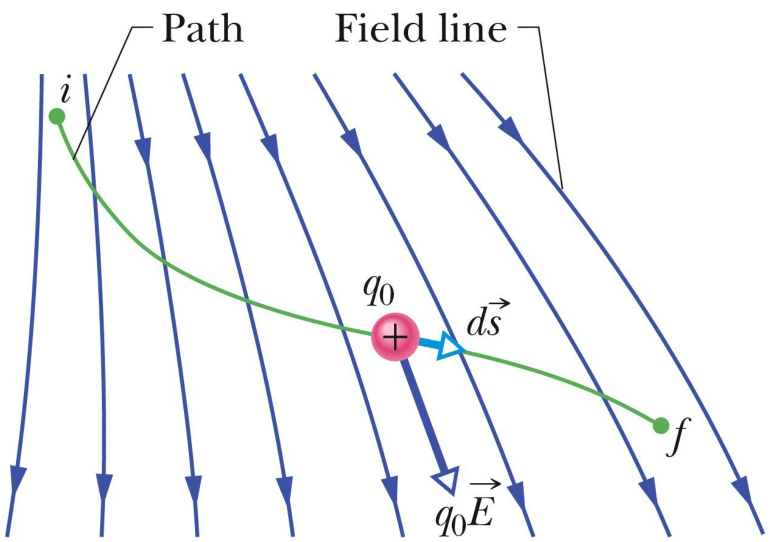


Figure 24-6 A test charge q_0 moves from point i to point f along the path shown in a nonuniform electric field. During a displacement $d\vec{s}$, an electric force $q_0\vec{E}$ acts on the test charge. This force points in the direction of the field line at the location of the test charge.

24-2 Equipotential Surfaces and the Electric Field (5 of 6)

The electric potential difference between two points i and f is

$$V_f - V_i = -\int_i^f \vec{E} \cdot d\vec{s},$$

where the integral is taken over any path connecting the points If the integration is difficult along any particular path, we can choose a different path along which the integration might be easier. If we choose $V_i = 0$, we have, for the potential at a particular point,

$$V = -\int_i^f \vec{E} \cdot d\vec{s}.$$

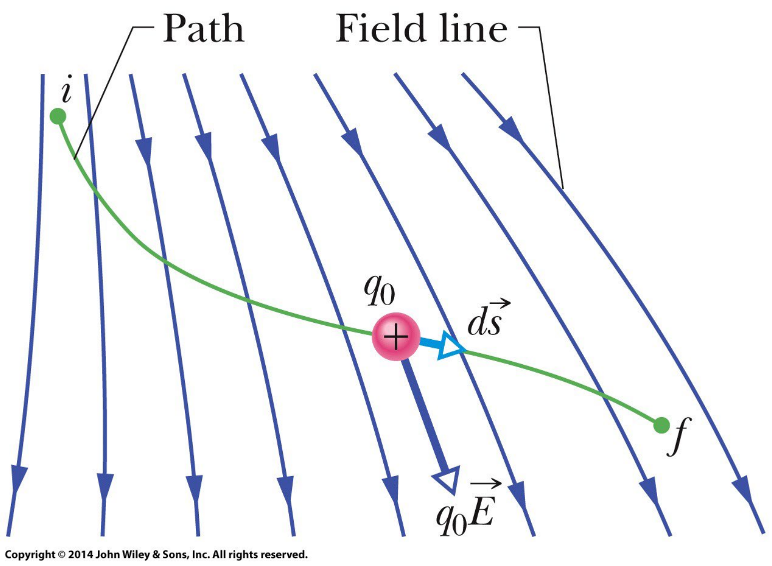


Figure 24-6 A test charge q_0 moves from point i to point f along the path shown in a nonuniform electric field. During a displacement $d\vec{s}$, an electric force $q_0\vec{E}$ acts on the test charge. This force points in the direction of the field line at the location of the test charge.

24-2 Equipotential Surfaces and the Electric Field (6 of 6)

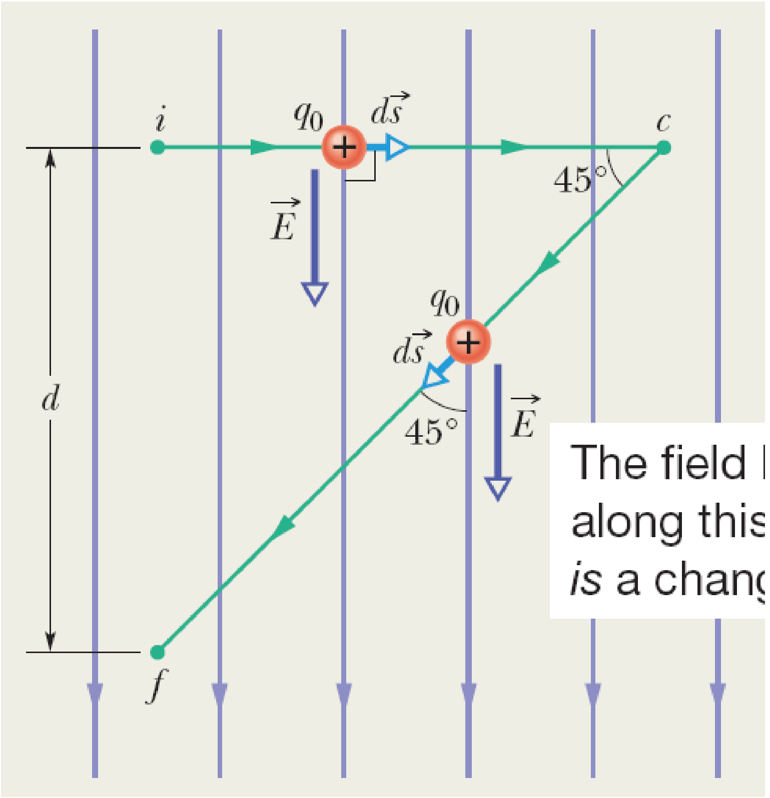
$$V = -\int_i^f \vec{E} \cdot d\vec{s}.$$

In a uniform field of magnitude E, the change in potential from a higher equipotential surface to a lower one, separated by distance Δx, is

$$\Delta V = -E\,\Delta x.$$

24-2 Equipotential Surfaces and the Electric Field (6 of 6)

Figure shows two points i and f in a uniform electric field $\vec{E}$. The points lie on the same electric field line (not shown) and are separated by a distance d. Now find the potential difference $V_f - V_i$ by moving the positive test charge q_0 from i to f along the path icf shown in Figure.



24-2 Equipotential Surfaces and the Electric Field (6 of 6)

Figure 24-8 shows two points i and f in a uniform electric field $\vec{E}$. The points lie on the same electric field line (not shown) and are separated by a distance d. Now find the potential difference $V_f - V_i$ by moving the positive test charge q_0 from i to f along the path icf shown in Fig. 24-8b.

Two lines: ic and cf

ic — the angle θ between $\vec{E}$ and $d\vec{s}$ is 90°, so the dot product $\vec{E} * d\vec{s}$ is 0.

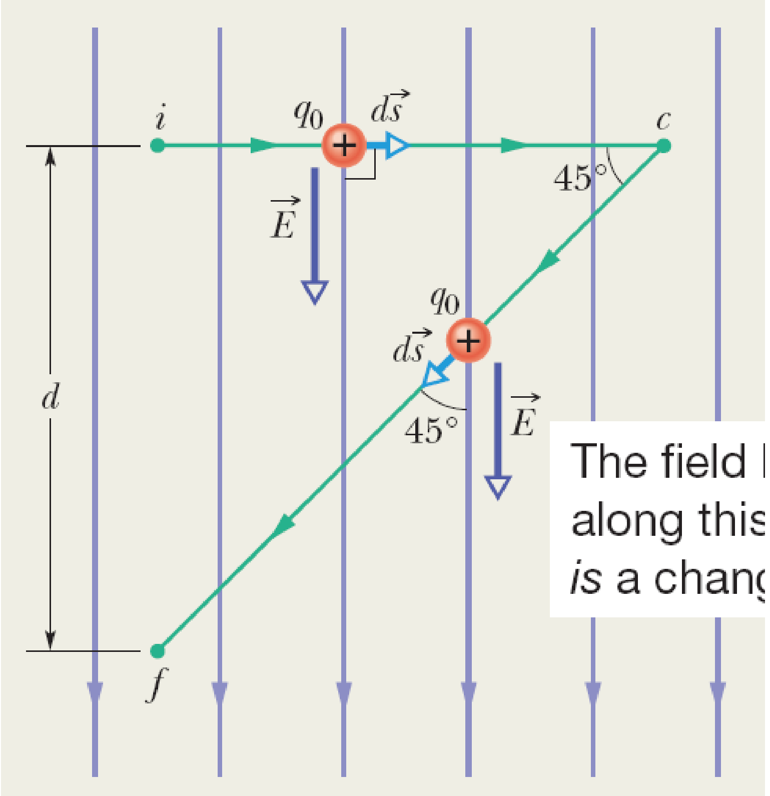
$$V_c - V_i = 0.$$

cf — $\theta = 45°$

$$V_f - V_i = -\int_c^f \vec{E} \cdot d\vec{s} = -\int_c^f E(\cos 45°)\, ds$$

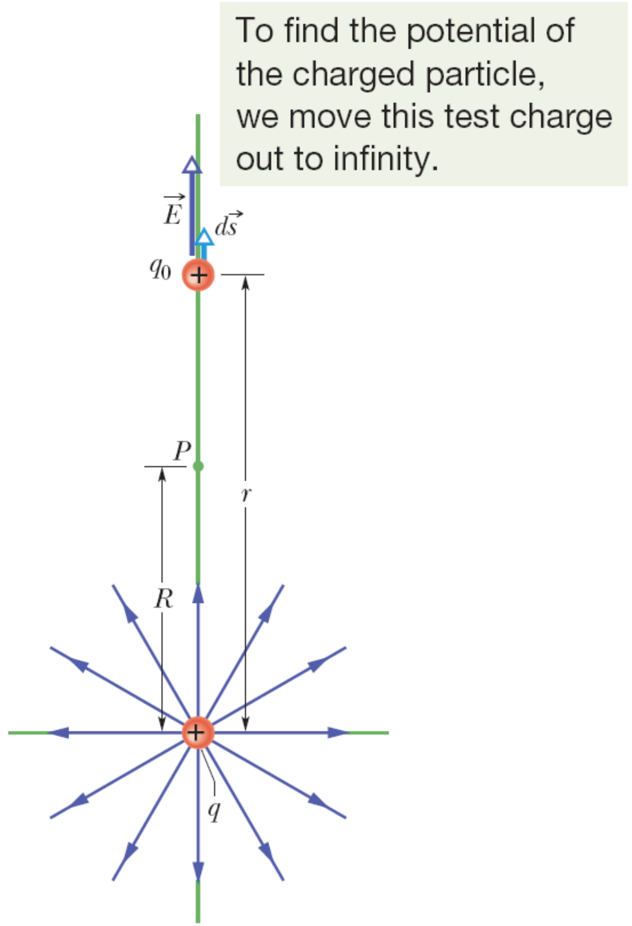
$$= -E(\cos 45°) \int_c^f ds.$$

$$= -E(\cos 45°) \frac{d}{\cos 45°} = -Ed.$$



24-3 Potential due to a Charged Particle (3 of 6)

In this figure the particle with positive charge q produces an electric field $\vec{E}$ and an electric potential V at point P. We find the potential by moving a test charge q_0 from P to infinity. The test charge is shown at distance r from the particle, during differential displacement $d\vec{s}$.



24-3 Potential due to a Charged Particle (3 of 6)

We know that the electric potential difference between two points *i* and *f* is

$$V_f - V_i = -\int_i^f E\, d\vec{s},$$

For radial path

$$V_f - V_i = -\int_R^\infty E\, dr.$$

The magnitude of the electric field at the site of the test charge

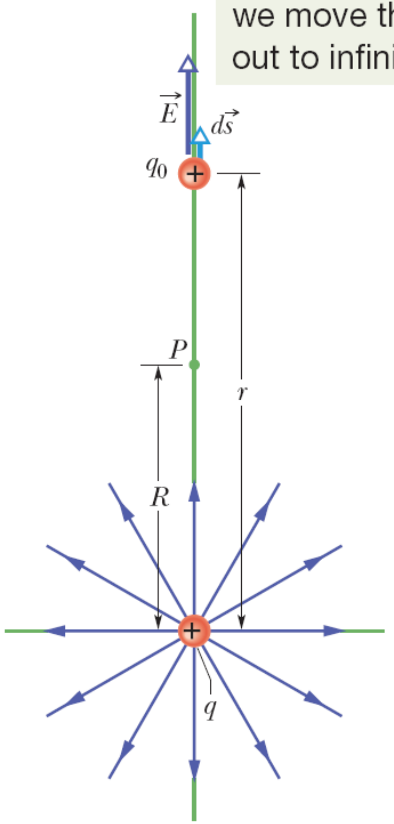
$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}.$$

We set $V_f = 0\,(\text{at }\infty)$

and $V_i = V\,(\text{at }R)$

$$0 - V = -\frac{q}{4\pi\varepsilon_0}\int_R^\infty \frac{1}{r^2}\,dr = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r}\right]_R^\infty$$

To find the potential of the charged particle, we move this test charge out to infinity.



24-3 Potential due to a Charged Particle (4 of 6)

Solving for V and switching R to r, we get

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

In this figure the particle with positive charge q produces an electric field $\vec{E}$ and an electric potential V at point P. We find the potential by moving a test charge q_0 from P to infinity. The test charge is shown at distance r from the particle, during differential displacement $d\vec{s}$.

24-3 Potential due to a Charged Particle (5 of 6)

Potential due to a group of Charged Particles

The potential due to a collection of charged particles is

$$V = \sum_{i=1}^{n} V_i = \frac{1}{4\pi\varepsilon_0} \sum_{i=1}^{n} \frac{q_i}{r_i} \quad (n \text{ charged particles}).$$

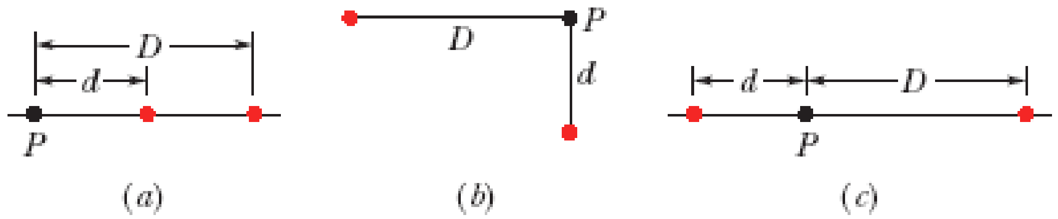
Thus, the potential is the algebraic sum of the individual potentials, with no consideration of directions.

A positively charged particle produces a positive electric potential. A negatively charged particle produces a negative electric potential.

24-3 Potential due to a Charged Particle (6 of 6)

Checkpoint 3

The figure here shows three arrangements of two protons. Rank the arrangements according to the net electric potential produced at point P by the protons, greatest first.



Answer: $$V = \sum_{i=1}^{n} V_i = \frac{1}{4\pi\varepsilon_0} \sum_{i=1}^{n} \frac{q_i}{r_i} \quad (n \text{ charged particles}).$$

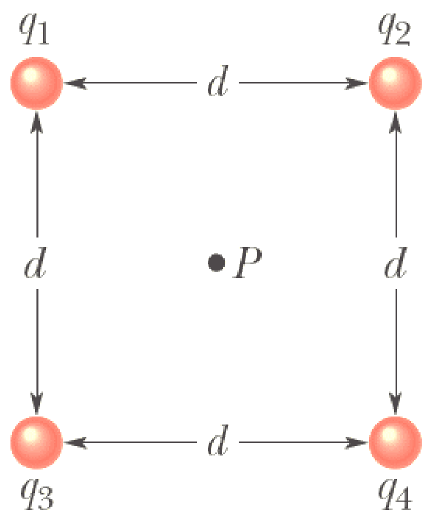
Same net potential (a) = (b) = (c)

24-3 Potential due to a Charged Particle (6 of 6)

What is the electric potential at point P, located at the center of the square of charged particles shown in Fig. 24-11a? The distance d is 1.3 m, and the charges are

$$q_1 = +12 \text{ nC}, \qquad q_3 = +31 \text{ nC},$$

$$q_2 = -24 \text{ nC}, \qquad q_4 = +17 \text{ nC}.$$



24-3 Potential due to a Charged Particle (6 of 6)

24-3 Potential due to a Charged Particle (6 of 6)

Calculations: From Eq. 24-27, we have

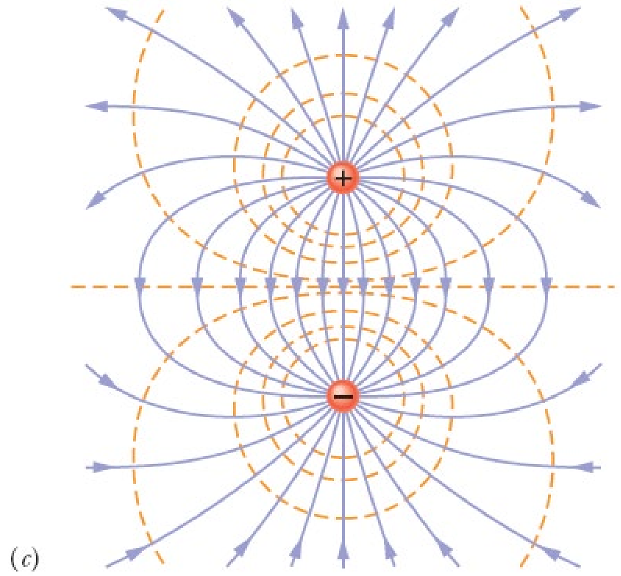
$$V = \sum_{i=1}^{4} V_i = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1}{r} + \frac{q_2}{r} + \frac{q_3}{r} + \frac{q_4}{r}\right).$$

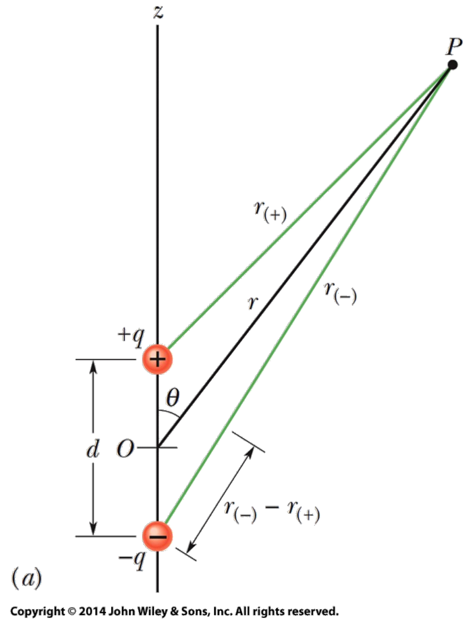
The distance r is $d/\sqrt{2}$, which is 0.919 m, and the sum of the charges is

$$q_1 + q_2 + q_3 + q_4 = (12 - 24 + 31 + 17) \times 10^{-9}\ \text{C}$$
$$= 36 \times 10^{-9}\ \text{C}.$$

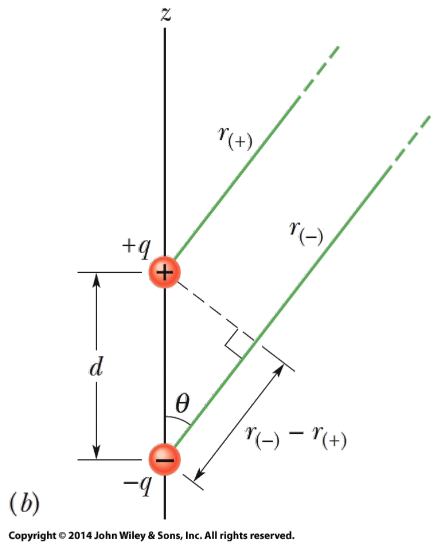
Thus,
$$V = \frac{(8.99 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(36 \times 10^{-9}\ \text{C})}{0.919\ \text{m}}$$
$$\approx 350\ \text{V}. \qquad \text{(Answer)}$$

24-4 Potential due to a Electric Dipole (4 of 4)



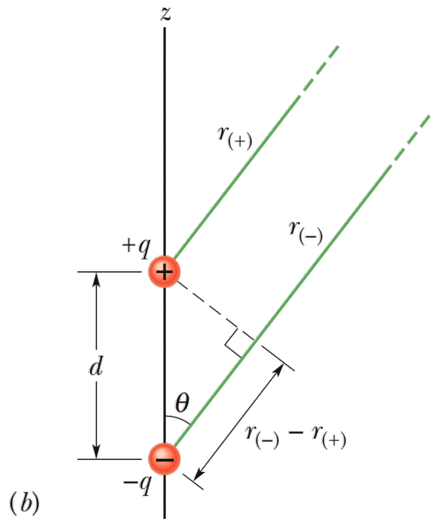


(a) Point P is a distance r from the midpoint O of a dipole. The line OP makes an angle θ with the dipole axis.



(b) If P is far from the dipole, the lines of lengths $r_{(+)}$ and $r_{(-)}$ are approximately parallel to the line of length r, and the dashed black line is approximately perpendicular to the line of length $r_{(-)}$.

24-4 Potential due to a Electric Dipole (2 of 4)



The net potential at P is given by

$$V = \sum_{i=1}^{2} V_i = V_{(+)} + V_{(-)} = \frac{1}{4\pi\varepsilon_0}\left(\frac{q}{r_{(+)}} + \frac{-q}{r_{(-)}}\right)$$

$$= \frac{q}{4\pi\varepsilon_0}\frac{r_{(-)} - r_{(+)}}{r_{(-)}r_{(+)}}.$$

We can approximate the two lines to P as being parallel and their length difference as being the leg of a right triangle with hypotenuse d .

Also, that difference is so small that the product of the lengths is approximately r^2.

Hence $r_{(-1)} - r_{(+)} \approx d\cos\theta$ and $r_{(-)}r_{(+)} \approx r^2$.

24-4 Potential due to a Electric Dipole (3 of 4)

$$V = \frac{q}{4\pi\varepsilon_0}\frac{r_{(-)} - r_{(+)}}{r_{(-)}r_{(+)}}. \quad \& \quad r_{(-1)} - r_{(+)} \approx d\cos\theta \quad \text{and} \quad r_{(-)}r_{(+)} \approx r^2.$$

We can approximate V to be

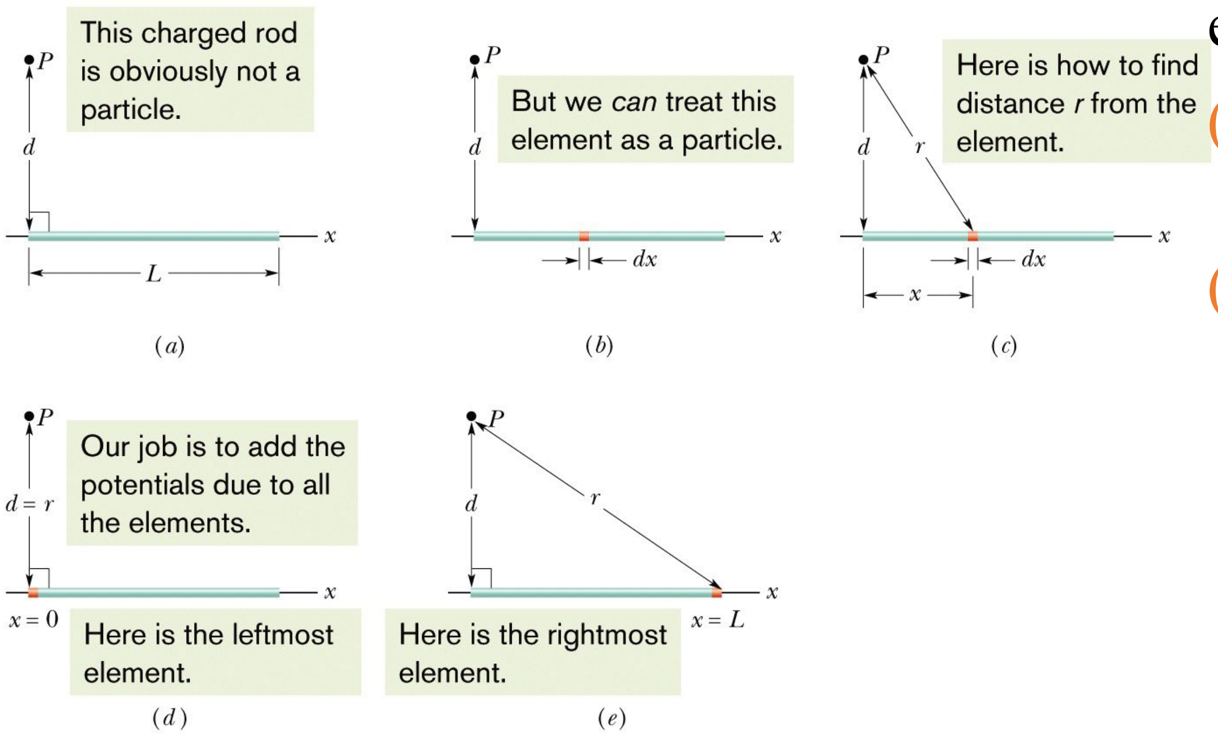
$$V = \frac{q}{4\pi\varepsilon_0}\frac{d\cos\theta}{r^2},$$

where θ is measured from the dipole axis

And since $p=qd$, we have

$$V = \frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{r^2} \quad \text{(electric dipole)}$$

24-5 Potential due to a Continuous Charge Distribution (2 of 8)



For a continuous distribution of charge (over an extended object), the potential is found by

(1) dividing the distribution into charge elements dq that can be treated as particles and then

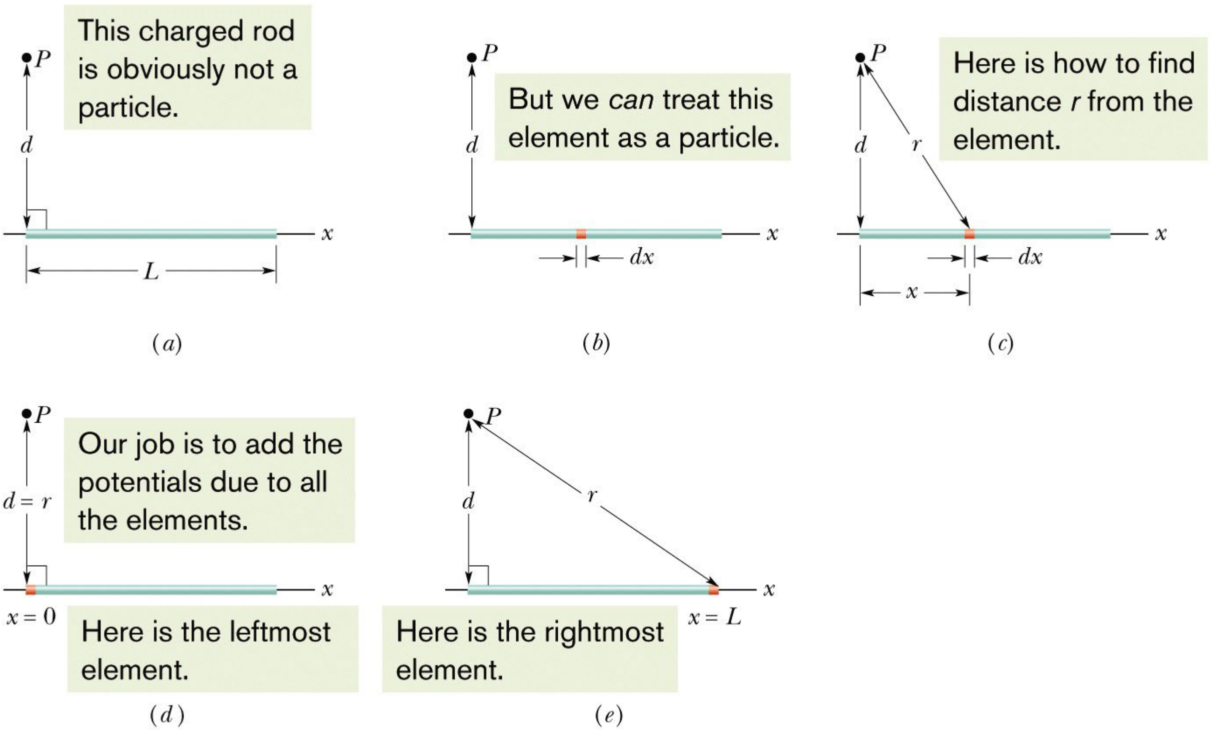
(2) summing the potential due to each element by integrating over the full distribution:

$$V = \int dV = \frac{1}{4\pi\varepsilon_0}\int \frac{dq}{r}.$$

We now examine two continuous charge distributions, a line and a disk.

24-5 Potential due to a Continuous Charge Distribution (3 of 8)

Q3 Line of Charge



$$V = \frac{\lambda}{4\pi\varepsilon_0} \ln\left[\frac{L + \left(L^2 + d^2\right)^{\frac{1}{2}}}{d}\right].$$

24-5 Potential due to a Continuous Charge Distribution (3 of 8)

Line of Charge

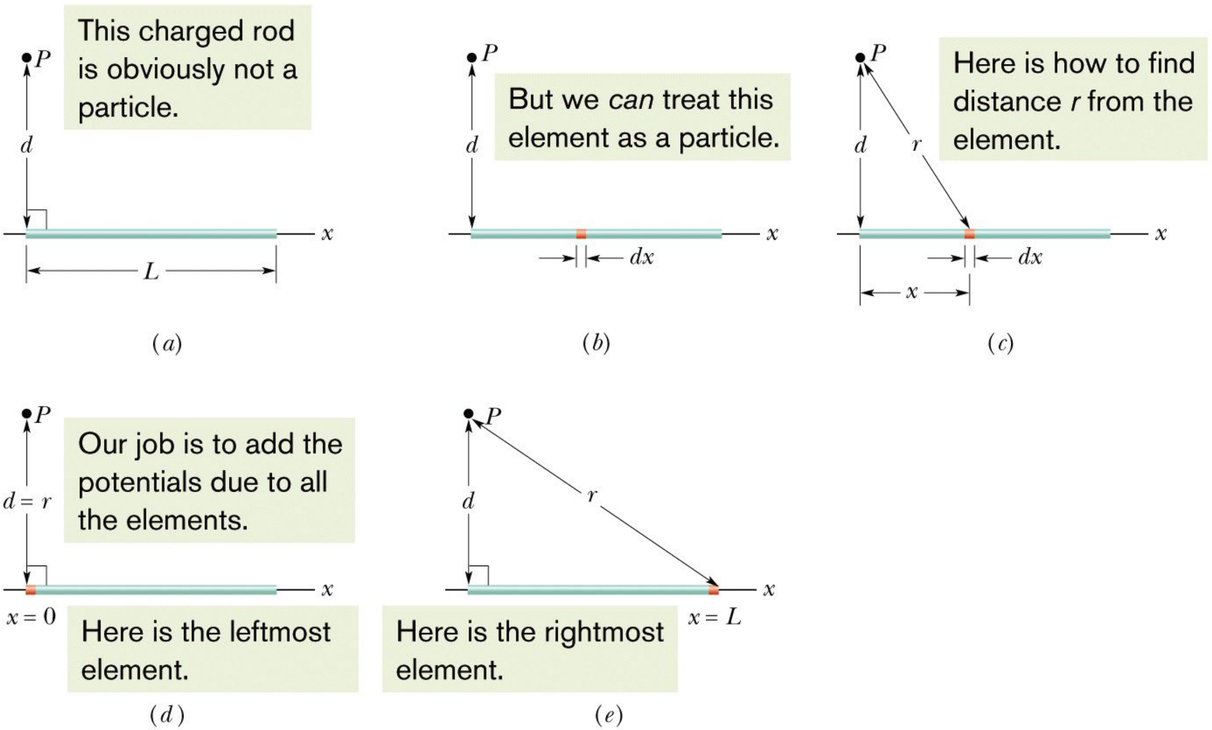


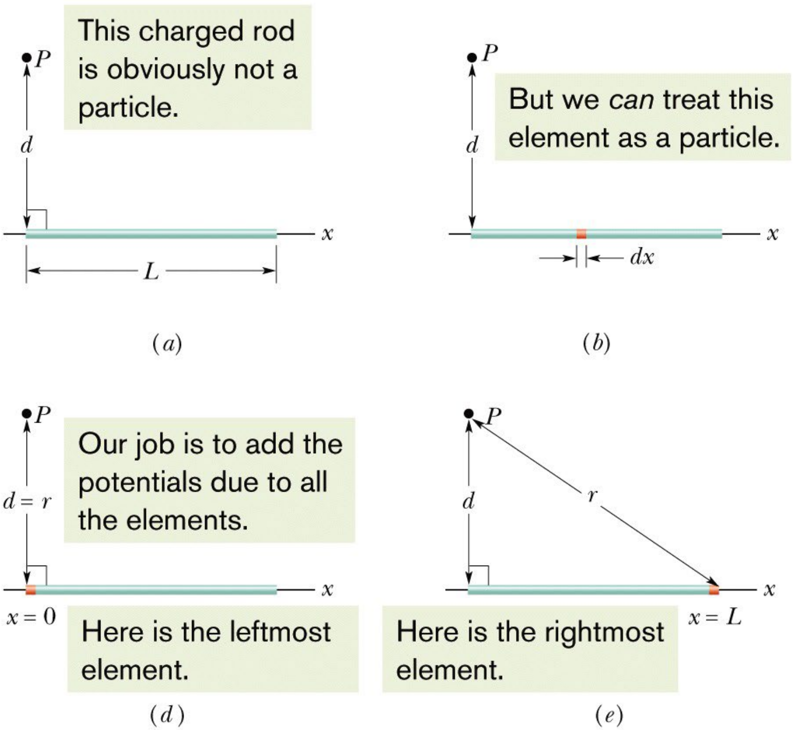
Fig. a has a thin conducting rod of length L. As shown in fig. b the element of the rod has a differential charge of

$$dq = \lambda\, dx.$$

This element produces an electric potential dV at point P (fig c) given by

$$dV = \frac{1}{4\pi\varepsilon_0}\frac{dq}{r} = \frac{1}{4\pi\varepsilon_0}\frac{\lambda\, dx}{\left(x^2 + d^2\right)^{\frac{1}{2}}}.$$

24-5 Potential due to a Continuous Charge Distribution (3 of 8)



Tips: $\int \frac{dx}{x} = \ln|x|$

$\ln A - \ln B = \ln(A/B)$

$$V = \int dV = \int_0^L \frac{1}{4\pi\varepsilon_0} \frac{\lambda}{(x^2 + d^2)^{\frac{1}{2}}} dx$$

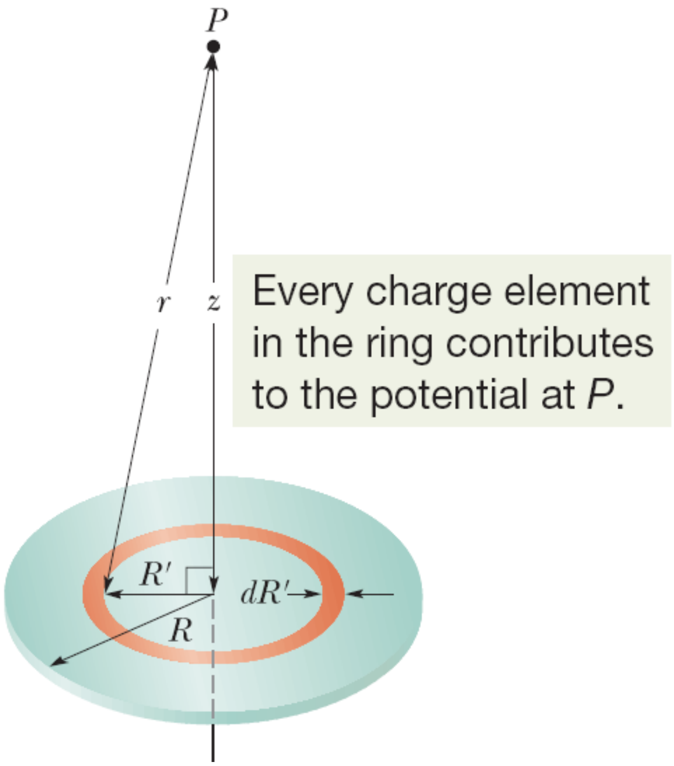
$$= \frac{\lambda}{4\pi\varepsilon_0} \int_0^L \frac{dx}{(x^2 + d^2)^{1/2}}$$

$$= \frac{\lambda}{4\pi\varepsilon_0} \left[\ln\left(x + (x^2 + d^2)^{1/2} \right) \right]_0^L$$

$$= \frac{\lambda}{4\pi\varepsilon_0} \left[\ln\left(L + (L^2 + d^2)^{1/2} \right) - \ln d \right]$$

$$V = \frac{\lambda}{4\pi\varepsilon_0} \ln\left[\frac{L + (L^2 + d^2)^{\frac{1}{2}}}{d} \right].$$

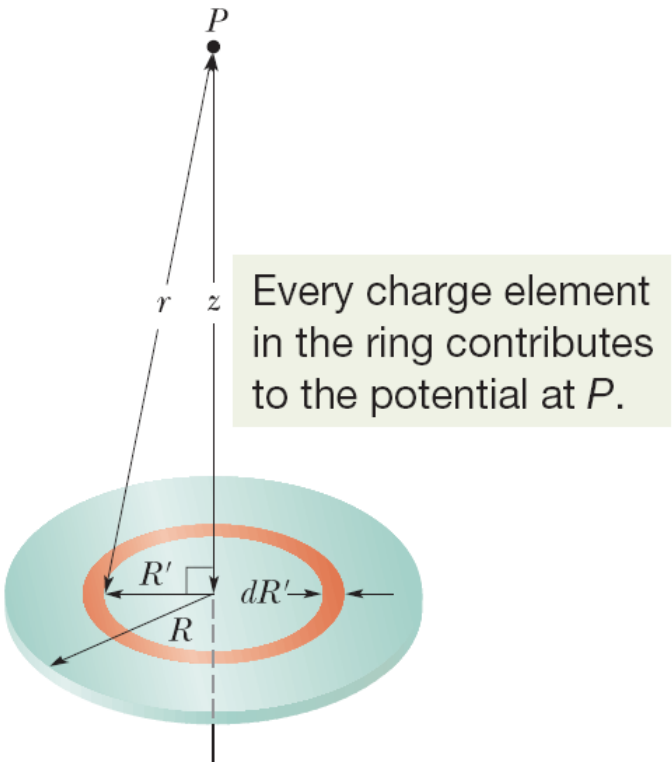
24-5 Potential due to a Continuous Charge Distribution (6 of 8)



Q4 Charged Disk

$$V = \frac{\sigma}{2\varepsilon_0}\left(\sqrt{z^2 + R^2} - z\right)$$

24-5 Potential due to a Continuous Charge Distribution (6 of 8)



Charged Disk

In figure, consider a differential element consisting of a flat ring of radius R' and radial width dR'. Its charge has magnitude

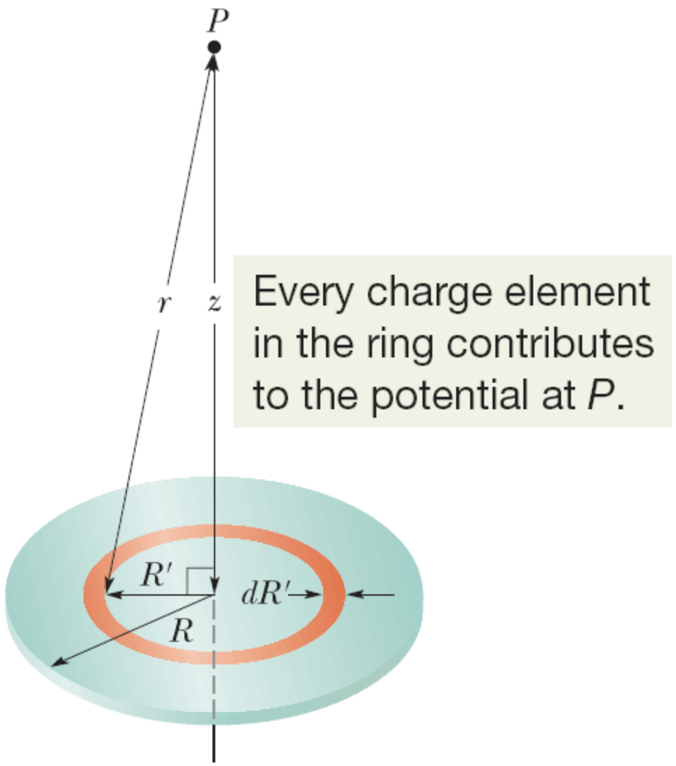
$$dq = \sigma\left(2\pi R'\right)\left(dR'\right),$$

in which $(2\pi R')(dR')$ is the upper surface area of the ring. The contribution of this ring to the electric potential at P is

$$dV = \frac{1}{4\pi\varepsilon_0}\frac{dq}{r} = \frac{1}{4\pi\varepsilon_0}\frac{\sigma\left(2\pi R'\right)\left(dR'\right)}{\sqrt{z^2 + R'^2}}.$$

24-5 Potential due to a Continuous Charge Distribution (7 of 8)

$$dV = \frac{1}{4\pi\varepsilon_0}\frac{dq}{r} = \frac{1}{4\pi\varepsilon_0}\frac{\sigma(2\pi R')(dR')}{\sqrt{z^2 + R'^2}}.$$



We find the net potential at *P* by adding (via integration) the contributions of all the rings from *R'*=0 to *R'*=*R*:

$$V = \int dV = \frac{\sigma}{2\varepsilon_0}\int_0^R \frac{R'\,dR'}{\sqrt{z^2 + R'^2}} = \frac{\sigma}{2\varepsilon_0}\left(\sqrt{z^2 + R^2} - z\right).$$

Note that the variable in the second integral is *R'* and not *z*

24-6 Calculating the Field from the Potential (2 of 3)

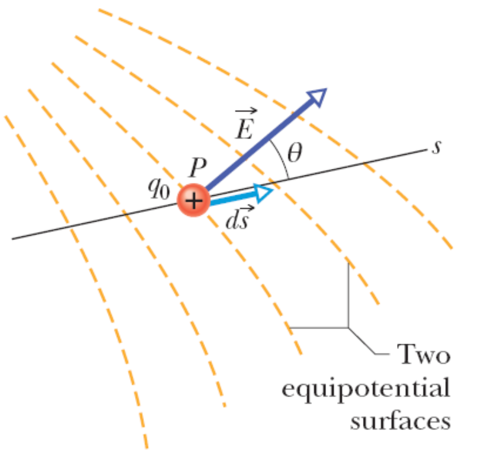


Figure 24-17 A test charge q_0 moves a distance $d\vec{s}$ from one equipotential surface to another. (The separation between the surfaces has been exaggerated for clarity.) The displacement $d\vec{s}$ makes an angle θ with the direction of the electric field $\vec{E}$.

Suppose that a positive test charge q_0 moves through a displacement $d\vec{s}$ from one equipotential surface to the adjacent surface. The work the electric field does on the test charge during the move is $-q_0\,dV$. On the other hand the work done by the electric field may also be written as the scalar product $\left(q_0\vec{E}\right)\cdot d\vec{s}$. Equating these two expressions for the work yields

$$-q_0 dV = q_0 E\left(\cos\theta\right) ds,$$

or

$$E\cos\theta = -\frac{dV}{ds}.$$

Since $E\cos\theta$ is the component of $\vec{E}$ in the direction of $d\vec{s}$, we get,

$$E_s = -\frac{\partial V}{\partial s}.$$

24-6 Calculating the Field from the Potential (2 of 3)

$$E_s = -\frac{\partial V}{\partial s}.$$

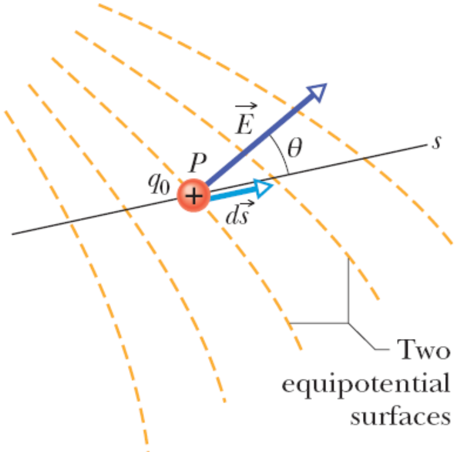
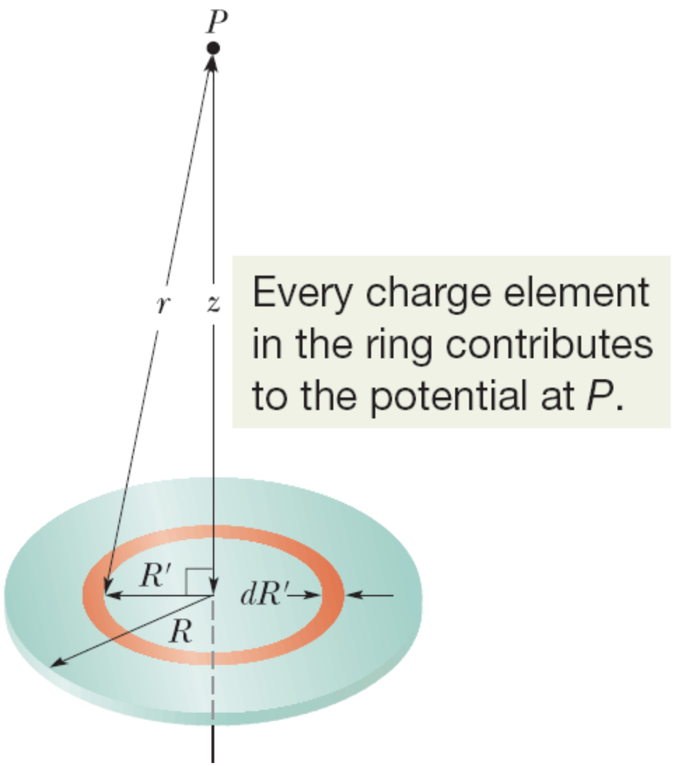


Figure 24-17 A test charge q_0 moves a distance $d\vec{s}$ from one equipotential surface to another. (The separation between the surfaces has been exaggerated for clarity.) The displacement $d\vec{s}$ makes an angle θ with the direction of the electric field $\vec{E}$.

If we take the s axis to be, in turn, the x, y, and z axes, we find that the x, y, and z components of E at any point are

$$E_x = -\frac{\partial V}{\partial x}; \qquad E_y = -\frac{\partial V}{\partial y}; \qquad E_z = -\frac{\partial V}{\partial z}.$$

24-6 Calculating the Field from the Potential (2 of 3)



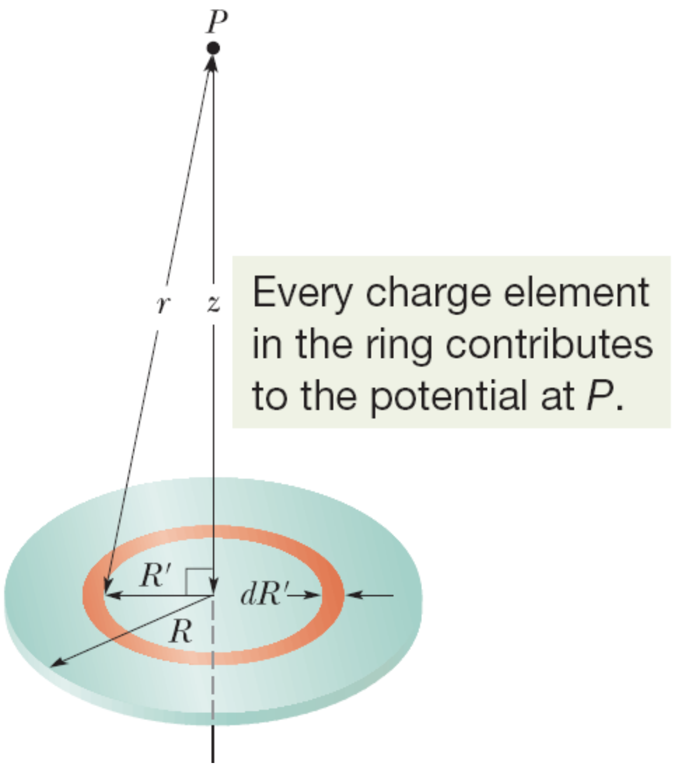
$$E_s = -\frac{\partial V}{\partial s}.$$

The electric potential at any point on the central axis of a uniformly charged disk is given by

$$V = \frac{\sigma}{2\varepsilon_0}\left(\sqrt{z^2 + R^2} - z\right)$$

Q5 derive an expression for the electric field at any point on the axis of the disk.

24-6 Calculating the Field from the Potential (2 of 3)



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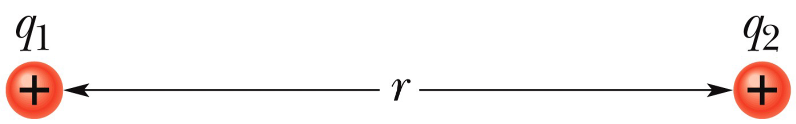
$$V = \frac{\sigma}{2\varepsilon_0}\left(\sqrt{z^2 + R^2} - z\right)$$

Q5 derive an expression for the electric field at any point on the axis of the disk.

$$E_z = -\frac{\partial V}{\partial z} = -\frac{\sigma}{2\varepsilon_0}\frac{d}{dz}\left(\sqrt{z^2 + R^2} - z\right)$$

$$= \frac{\sigma}{2\varepsilon_0}\left(1 - \frac{z}{\sqrt{z^2 + R^2}}\right).$$

24-7 Electric Potential Energy of a System of Charged Particles (3 of 4)



Two charges held a fixed distance r apart.

The total potential energy of a system of particles is the sum of the potential energies for every pair of particles in the system.

$$U_f - U_i = q_1(V_f - V_i).$$

The initial potential energy is $U_i = 0$

$$V_f = \frac{1}{4\pi\varepsilon_0}\frac{q_2}{r}.$$

Hence $$U = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r} \quad \text{(two-particle system)}.$$

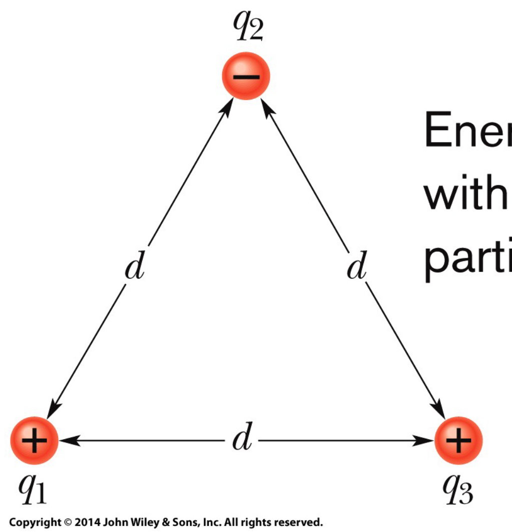
24-7 Electric Potential Energy of a System of Charged Particles (4 of 4)

Potential energy of a system of three charged particles

Figure 24-19 shows three charged particles held in fixed positions by forces that are not shown. What is the electric potential energy U of this system of charges? Assume that d =12 cm and that

$$q_1 = +q, \quad q_2 = -4q, \quad \text{and} \quad q_3 = +2q,$$

in which q =150 nC.



Energy is associated with each pair of particles.

24-7 Electric Potential Energy of a System of Charged Particles (4 of 4)

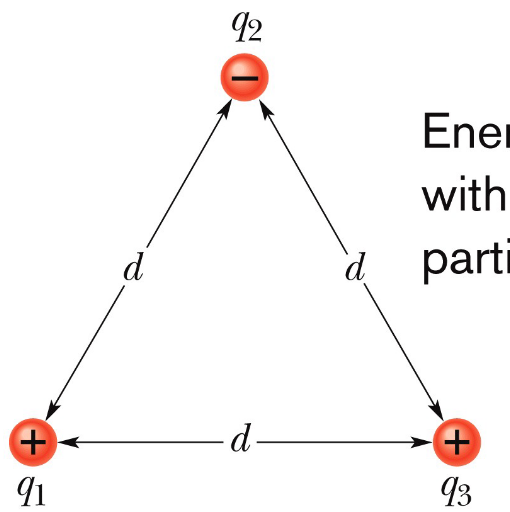
Potential energy of a system of three charged particles

Tips: The total potential energy of a system of particles is the sum of the potential energies for every pair of particles in the system.

$$U_{12} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{d}$$

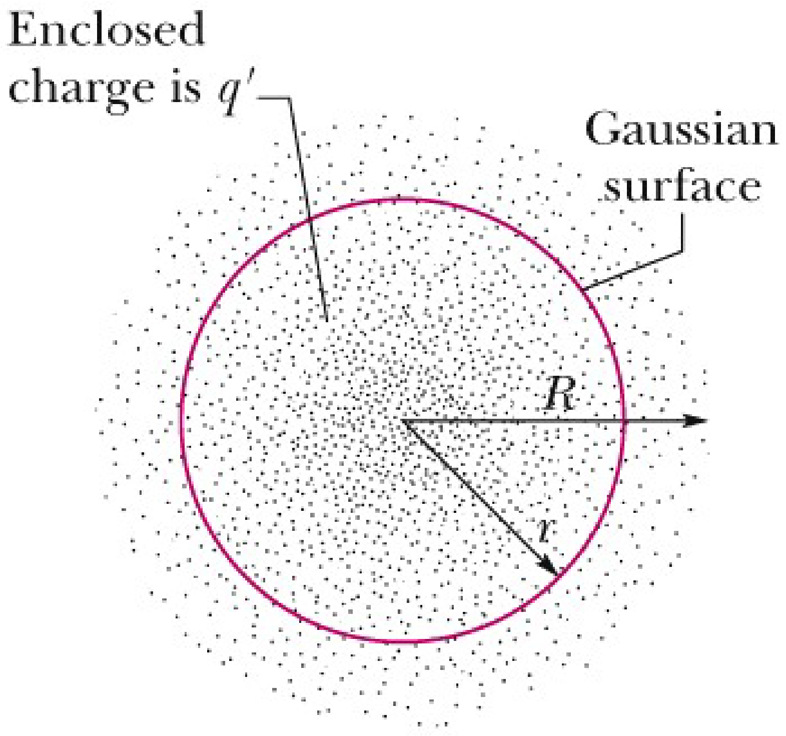
$$U_{13} + U_{23} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_3}{d} + \frac{1}{4\pi\varepsilon_0}\frac{q_2 q_3}{d}.$$

$$\begin{aligned}
U &= U_{12} + U_{13} + U_{23} \\
&= \frac{1}{4\pi\varepsilon_0}\left(\frac{(+q)(-4q)}{d} + \frac{(+q)(+2q)}{d} + \frac{(-4q)(+2q)}{d}\right) \\
&= -\frac{10q^2}{4\pi\varepsilon_0 d} \\
&= -\frac{(8.99\times 10^9\ \mathrm{N\cdot m^2/C^2})(10)(150\times 10^{-9}\ \mathrm{C})^2}{0.12\ \mathrm{m}} \\
&= -1.7\times 10^{-2}\ \mathrm{J} = -17\ \mathrm{mJ}. \qquad \text{(Answer)}
\end{aligned}$$



Energy is associated with each pair of particles.

Remind: **23-6 Applying Gauss' Law: Spherical Symmetry** (6 of 6)



The dots represent a spherically symmetric distribution of charge of radius R, whose volume charge density ρ is a function only of distance from the center. The charge is assumed to be fixed in position.

When r > R, treat it like a particle with charge q

$$E = \left(\frac{q}{4\pi\varepsilon_0 r^2}\right)$$

How to calculate the E when r < R?

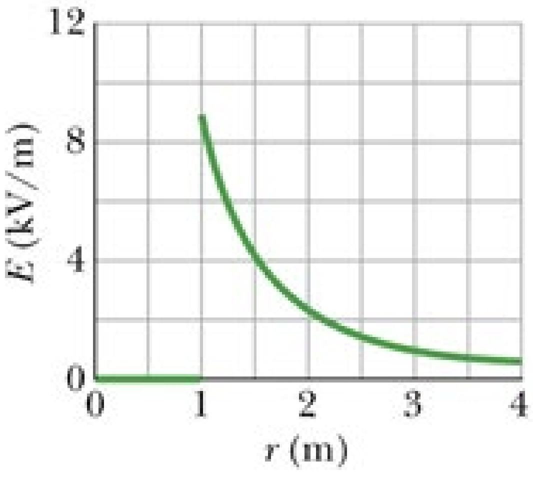
we separately consider the charge inside it and the charge outside it.

But outside it is 0 because shell theory II.

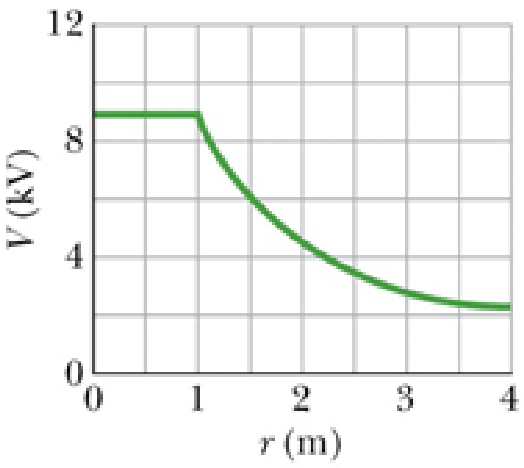
Inside: q' represent that enclosed charge, volume charge density ρ *is same*

$$\frac{q'}{\frac{4}{3}\pi r^3} = \frac{q}{\frac{4}{3}\pi R^3}. \Rightarrow E = \left(\frac{q}{4\pi\varepsilon_0 R^3}\right) r \qquad \text{(uniform charge, field at } r \le R\text{)}.$$

24-8 Potential of a Charged Isolated Conductor (3 of 4)



(b)



(a)

$$V_f - V_i = -\int_i^f \vec{E} \cdot d\vec{s}.$$

Since $E = 0$ for all points within a conductor, it follows directly that $V_f = V_i$ for all possible pairs of points i and f in the conductor

(b) A plot of $E(r)$ for the same shell.

(a) A plot of $V(r)$ both inside and outside a charged spherical shell of radius *1.0 m*.

24-8 Potential of a Charged Isolated Conductor (4 of 4)

It is wise to enclose yourself in a cavity inside a conducting shell, where the electric field is guaranteed to be zero. A car (unless it is a convertible or made with a plastic body) is almost ideal.

Courtesy Westinghouse Electric Corporation

Summary (1 of 5)

Electric Potential

- The electric potential V at point P in the electric field of a charged object: $U = qV.$

$$V = \frac{-W_\infty}{q_0} = \frac{U}{q_0},$$

Equation (24-2)

Electric Potential Energy

- Electric potential energy U of the particle-object system:

Equation (24-3)

- If the particle moves through potential ΔV:

$$\Delta U = q\Delta V = q\left(V_f - V_i\right).$$

Equation (24-4)

Summary (2 of 5)

Mechanical Energy

- Applying the conservation of mechanical energy gives the change in kinetic energy:

$$\Delta K = -q\Delta V.$$

Equation (24-9)

- In case of an applied force in a particle

$$\Delta K = -q\Delta V + W_{\text{app}}.$$

Equation (24-11)

- In a special case when $\Delta K = 0$:

$$W_{\text{app}} = q\Delta V \quad (\text{for } K_i = K_f).$$

Equation (24-12)

Summary (3 of 5)

Finding V from $\vec{E}$

- The electric potential difference between two point I and f is:

$$V_f - V_i = -\int_i^f \vec{E} \cdot d\vec{s}, \qquad \textbf{Equation (24-18)}$$

Potential due to a Charged Particle

- due to a single charged particle at a distance r from that particle :

$$V = \frac{1}{4\pi\varepsilon_0} \frac{q}{r} \qquad \textbf{Equation (24-26)}$$

- due to a collection of charged particles

$$V = \sum_{i=1}^{n} V_i = \frac{1}{4\pi\varepsilon_0} \sum_{i=1}^{n} \frac{q_i}{r_i}. \qquad \textbf{Equation (24-27)}$$

Summary (4 of 5)

Potential due to an Electric Dipole

- The electric potential of the dipole is

$$V = \frac{1}{4\pi\varepsilon_0} \frac{p\cos\theta}{r^2}$$

Equation (24-30)

Potential due to a Continuous Charge Distribution

- For a continuous distribution of charge:

$$V = \frac{1}{4\pi\varepsilon_0} \int \frac{dq}{r}$$

Equation (24-32)

Summary (5 of 5)

Calculating $\vec{E}$ from V

- The component of $\vec{E}$ in any direction is:

$$E_s = -\frac{\partial V}{\partial s}.$$

Equation (24-40)

$$U = W = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r}.$$

Electric Potential Energy of a System of Charged Particle

- For two particles at separation r:

Equation (24-46)