Electrostatics

Course- PHY 2105 / PHY 105

Lecture 18

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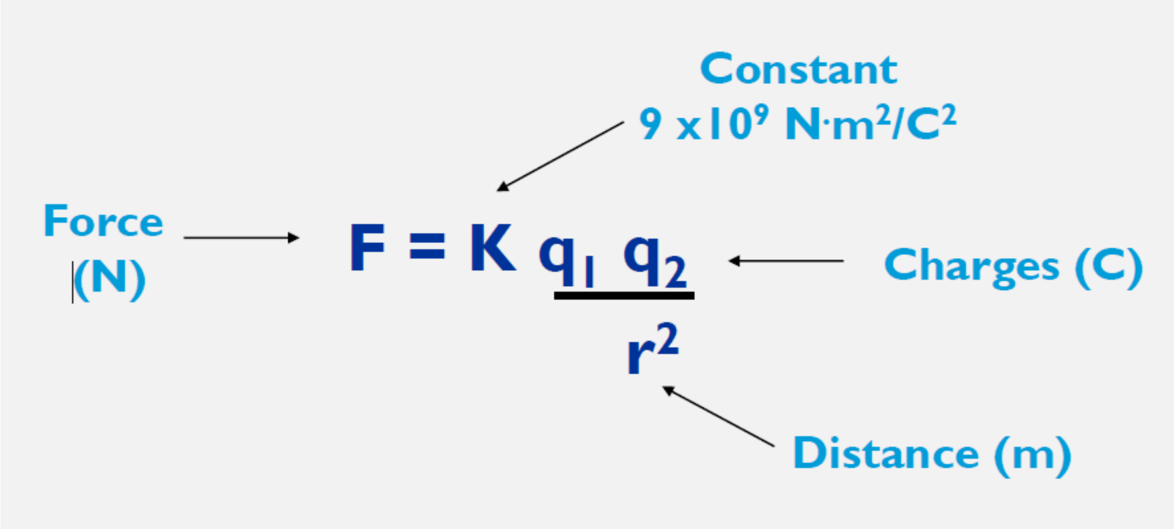
Coulomb’s Law

The electrostatic force between two charged object is directly proportional to the product of the amount of charges and inversely proportional to the square of the distance between them



$$k = \frac{1}{4\pi\varepsilon_0}$$

- *Experimental law*
- *Valid for point charges only*
- *Obeys Inverse Square Law*
- *Valid for only charges at rest*

$$Electrostatic\ constant, k = 9 \times 10^9 \frac{Nm^2}{C^2}$$

$$Permittivity\ constant, \varepsilon_0 = 8.854 \times 10^{-12} \frac{C^2}{Nm^2}$$

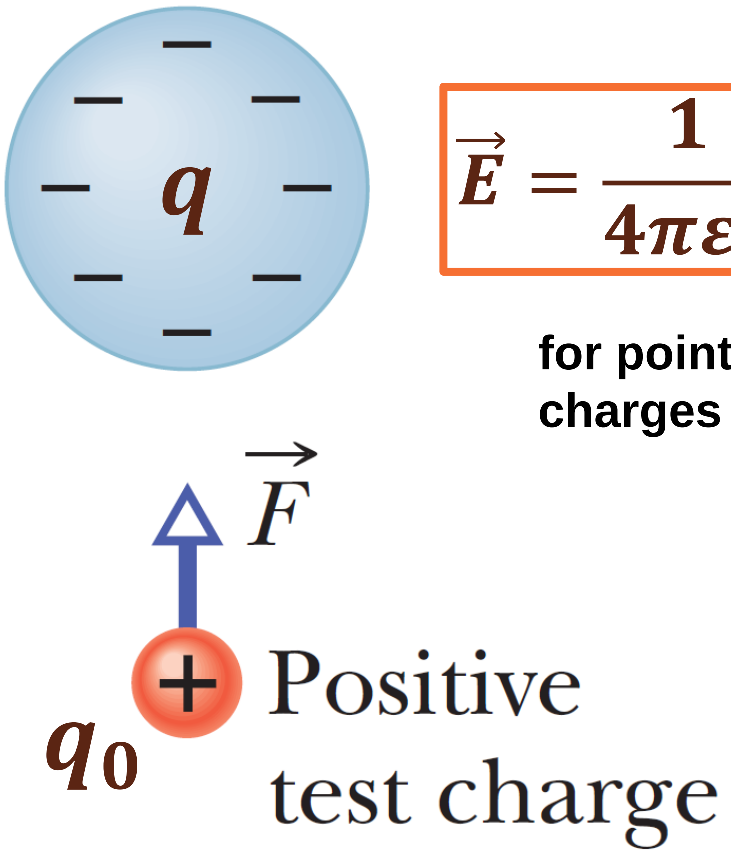
Electric Field

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

A charge has an effect on its surroundings. The area where it has an effect is generally called an *Electric field.* If any other charge enters that area, it feels an electrostatic Coulomb force.

$$\boxed{\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}}$$

for point test charges only



The electric force on a charged body is exerted by the electric field created by *other* charged bodies.

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Electric Potential

Relationship between work and potential energy:

$$W_{a \to b} = U_a - U_b = -(U_b - U_a) = -\Delta U$$

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 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

Electric Potential Energy

Change in electric potential: $\Delta V = V_f - V_i$

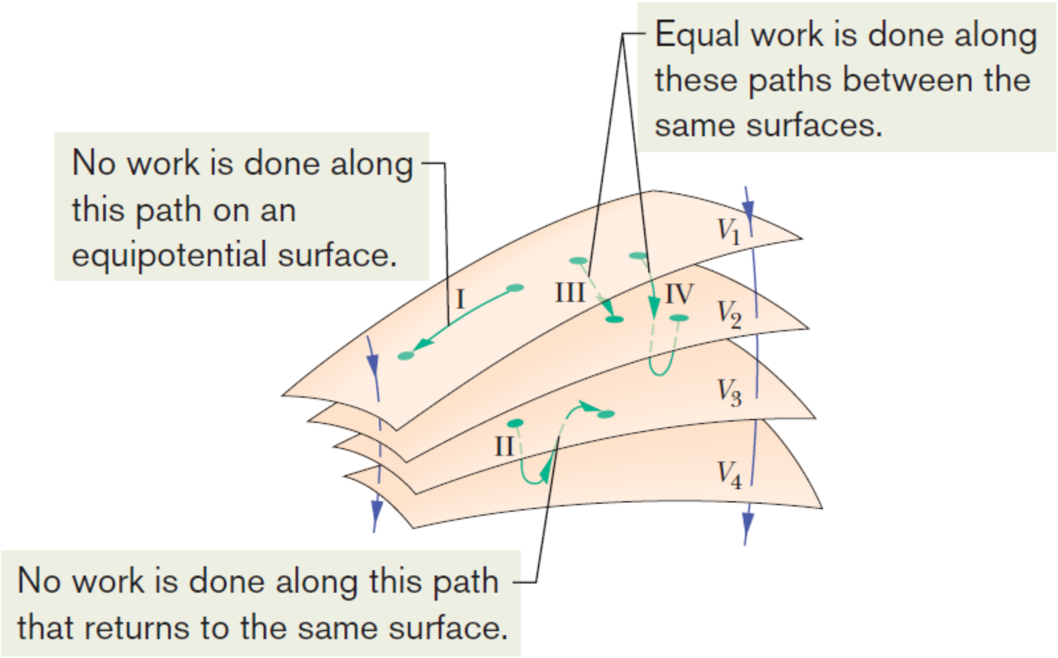
Change in system potential energy: $\Delta U = q\Delta V = q(V_f - V_i)$

Electron-volts. In atomic and subatomic physics, energy measures in the SI unit of joules often require awkward powers of ten. A more convenient (but non-SI unit) is the e*lectron-volt* (eV)

$$1\ eV = 1.602 \times 10^{-19} J$$

Equipotential Surfaces

An **equipotential surface is** an imaginary surface or a real, physical surface where no net work *W* is done on a charged particle by an electric field when the particle moves between two points *i* and *f* on the same equipotential surface



Calculating potential from field

$$dW = \vec{F} \cdot d\vec{s}. \qquad (24\text{-}15)$$

For the situation of Fig. 24-6, $\vec{F} = q_0\vec{E}$ and Eq. 24-15 becomes

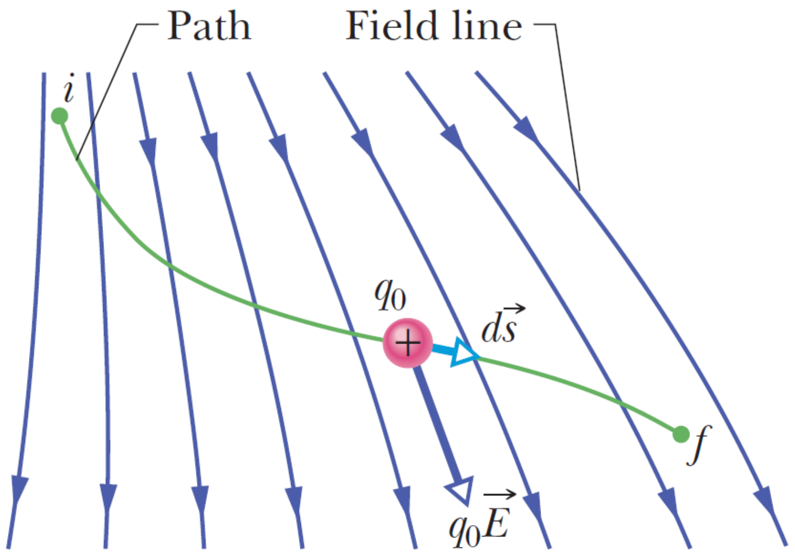
$$dW = q_0\vec{E} \cdot d\vec{s}. \qquad (24\text{-}16)$$

To find the total work W done on the particle by the field as the particle moves from point i to point f, we sum—via integration—the differential works done on the charge as it moves through all the displacements $d\vec{s}$ along the path:

$$W = q_0 \int_i^f \vec{E} \cdot d\vec{s}.$$

If we substitute the total work W from Eq. 24-17 into Eq. 24-6, we find

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



$$\boxed{V = E\Delta x}$$

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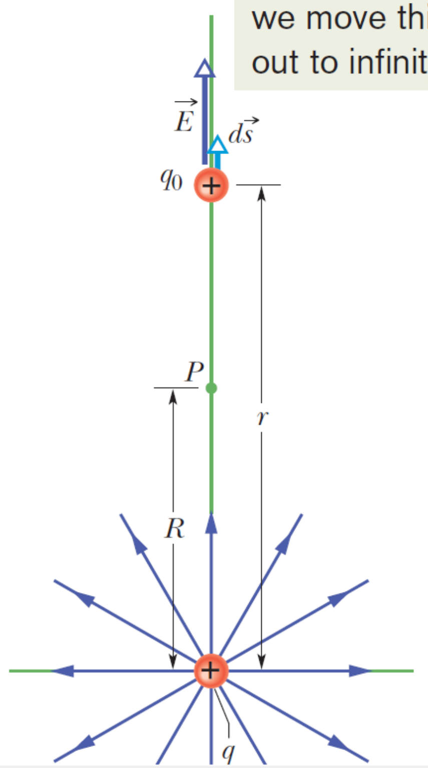
Potential Due to a Charged Particle



$$V_f - V_i = -\int_R^\infty E\,dr. \qquad (24\text{-}23)$$

Next, we set $V_f = 0$ (at ∞) and $V_i = V$ (at R). Then, for the magnitude of the electric field at the site of the test charge, we substitute from Eq. 22-3:

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}. \qquad (24\text{-}24)$$

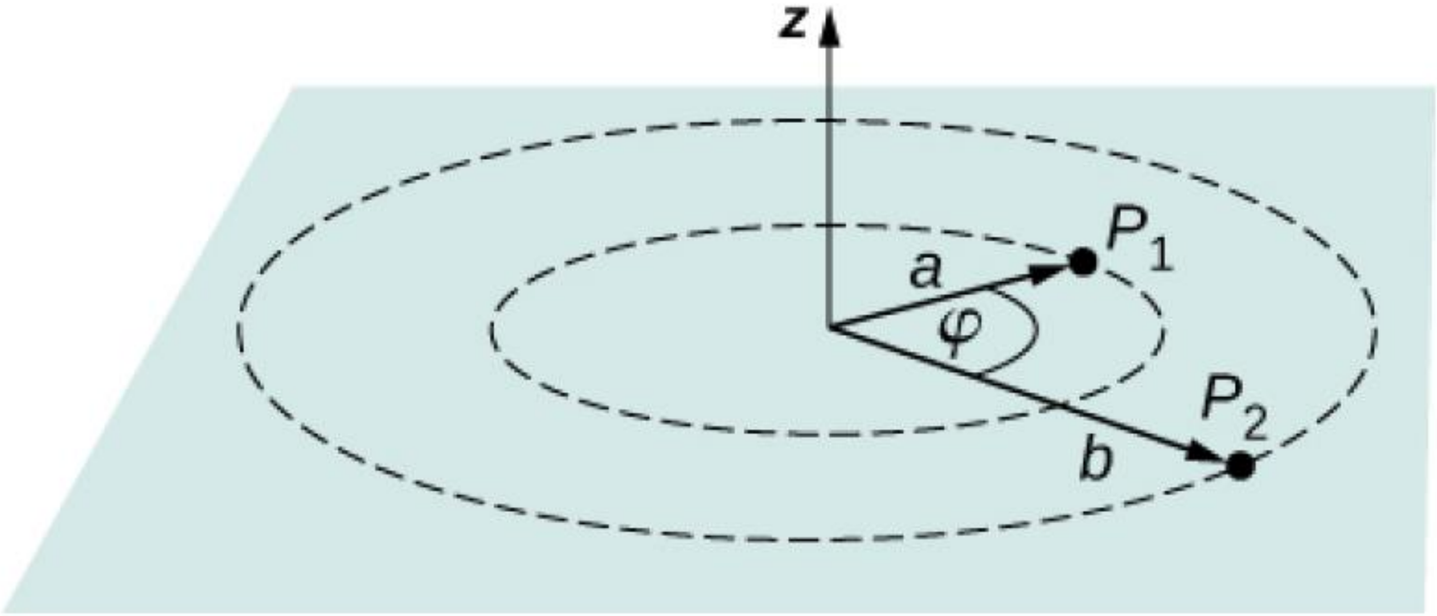
With these changes, Eq. 24-23 then gives us

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

$$= -\frac{1}{4\pi\varepsilon_0}\frac{q}{R}. \qquad (24\text{-}25)$$

$$\boxed{V = \frac{1}{4\pi\epsilon_0}\frac{q}{r}}$$

Potential at points of finite distances



$$\Delta V = -\int_a^b \frac{kq}{r^2} dr = kq\left[\frac{1}{a} - \frac{1}{b}\right]$$

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Potential Due to a Group of Charged Particles

We can find the net electric potential at a point due to a group of charged particles with the help of the superposition principle

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

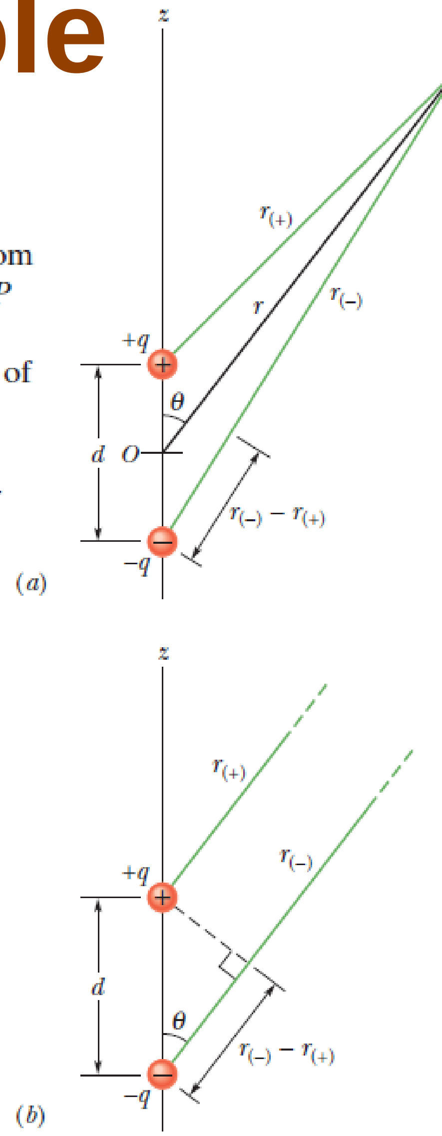
The sum in this equation is an *algebraic sum,* not a vector sum. It is a lot easier to sum several scalar quantities than to sum several vector quantities

Potential Due to an electric dipole

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

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

Figure 24-13 (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 $r_{(-)}$.



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

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

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