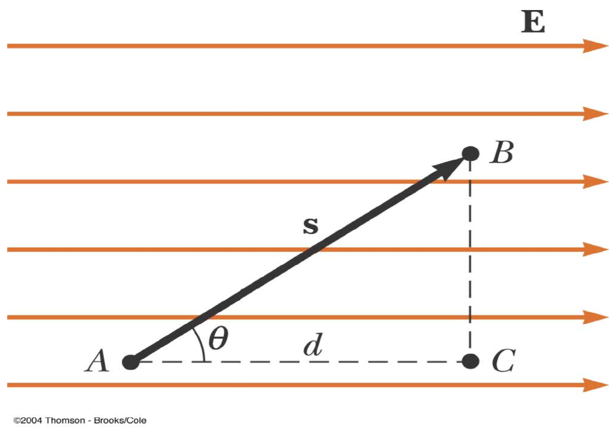
Chapter 25

Electrical Potential

25.1 Potential Difference and Electric Potential



Let's place a positive test charge in a uniform electric field
What's the work done moving the charge from A to B?

dW= F *dl* cosθ

However, the total work done is given by*:*

$$W = \int_A^B Fdl\cos_\theta$$

Since F=Eq one can rewrite W as:

$$W = \int_A^B qEdl\cos_\theta$$

But work is the negative of change in potential energy,

$$\Delta U = U_f - U_i = -\int_A^B qEdl\cos_\theta = -\int_A^B q\vec{E}.d\vec{l}$$

This means that the potential energy is changed by an amount of $-q\,\vec{E}.d\vec{l}$

Electric potential is defined as potential energy per unit charge:

$$V = \frac{\Delta U}{q} = -\int_A^B \vec{E}.d\vec{l}$$

Electric potential is a scalar characteristic of an electric field, independent of any charges that may be placed in the field.

Because electric potential is a measure of potential energy per unit charge, the SI unit of both electric potential and potential difference is joules per coulomb, which is defined as a volt (V):

$$1\,V \equiv 1\,\mathrm{J/C}$$

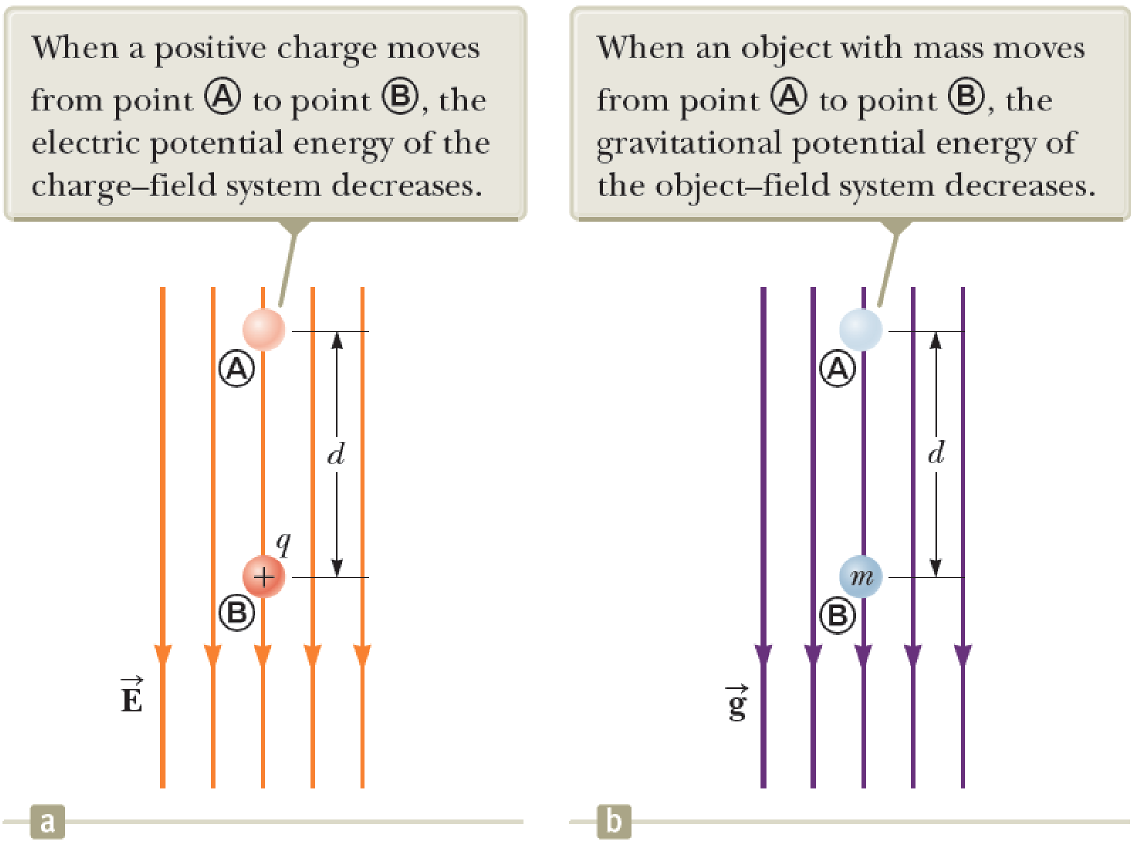
25.2 Potential difference in Uniform electric field

Often what one is interested in is the *difference* in potential between two particular points. In words, potential difference is the ratio of the work you have to do to move a charge from A to B, divided by the magnitude of that charge

$$\Delta V_{AB} = -\int_A^B E dl \cos_\theta = V_B - V_A$$

$$\Delta V_{AB} = -E\int_A^B dl \cos_0 = -Ed$$

Often the potential difference is taken with respect to ground potential (recall mgh for gravitational potential energy)
This expression rearranged gives work required to move a charge:
$W=V_{AB}q$

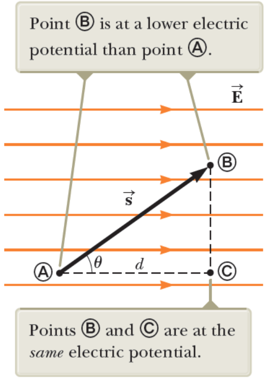


Electric potential is a scalar characteristic of an electric field, independent of the charges that may be placed in the field. However, when we speak of potential energy, we are referring to the charge–field system.

Just as with potential energy, only *differences* in electric potential are meaningful. To avoid having to work with potential differences, however, we often take the value of the electric potential to be zero at some convenient point in an electric field. This is what we do here: arbitrarily establish the electric potential to be zero at a point that is infinitely remote from the charges producing the field. Having made this choice, we can state that the **electric potential at an arbitrary point in an electric field equals the work required per unit charge to bring a positive test charge from infinity to that point.**

If we take the point A at infinity, one can write the electric potential at any point B as:

$$V_B - 0 = -\int_{\infty}^{B} Edl\cos_{\theta} = V_B$$



Prove that $V_B=V_C$.

Example 25.2 Motion of a Proton in a Uniform Electric Field AM

A proton is released from rest at point Ⓐ 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 magnitude $d = 0.50$ m to point Ⓑ in the direction of $\vec{E}$. Find the speed of the proton after completing the displacement.

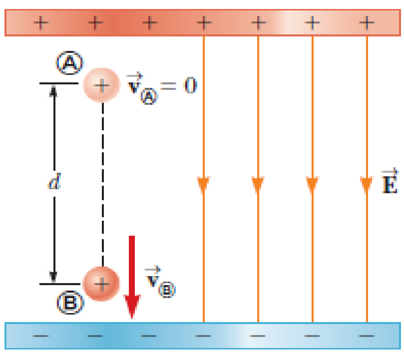


Figure 25.6 (Example 25.2) A proton accelerates from Ⓐ to Ⓑ in the direction of the electric field.