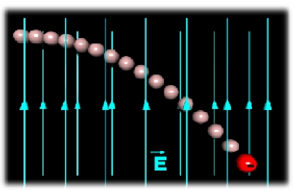
SPH4U
UNIVERSITY PHYSICS

ELECTRIC, GRAVITATIONAL, & ... FIELDS
☞ Electric Potential Energy
(P.346-349)

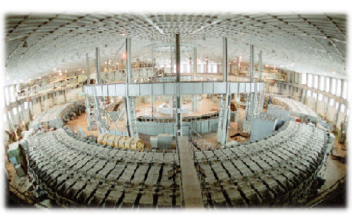
Electric Fields

From the definition of an electric field as a force acting on a charge, it follows that, for a given uniform electric field, charge, and particle mass, the particle undergoes a uniform acceleration (since the force is constant). This ability of an electric field to accelerate charged particles with known conditions has proven useful to physicists and engineers.



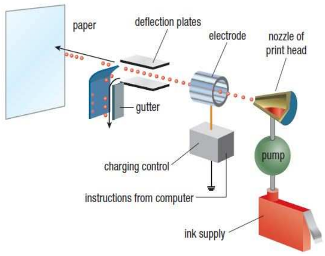
Electric Fields & Particle Acceleration

For example, particle accelerators are used to accelerate particles to speeds near the speed of light. They are also used in a large variety of other applications including particle therapy for oncological purposes.



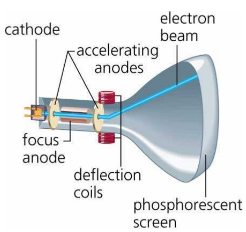
Electric Fields & Particle Acceleration

Particle acceleration is also important in some everyday devices as well. For example, ink droplets from the print head of an inkjet printer are either charged or uncharged. The uncharged droplets move to the paper undeflected, forming the letters. Charged droplets are deflected into the gutter, leaving those parts of the paper blank.



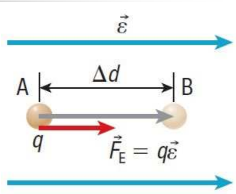
Electric Fields & Particle Acceleration

Another application of particle acceleration is old television sets and computer monitors which have cathode-ray tubes. These tubes accelerate electrons toward a phosphor screen. Variations in the deflection of the accelerated electrons determine the brightness and colour of the screen.



Work & Electric Fields

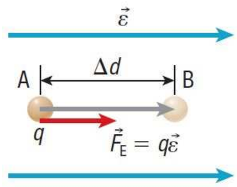
Recall that in a region of space where the electric field ε is constant, ε has the same magnitude and direction at all points. A point charge q in this region experiences an electric force $F_E = q\varepsilon$ that is parallel to ε.



Work & Electric Fields

Suppose this charge moves a certain distance Δd, starting at point A and ending at point B. If we assume the displacement is parallel to the electric force, then the work done by the electric force on the charge is:

$W = F_E \Delta d$

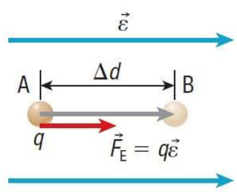


NOTE!

The electric force does work on the charge and is independent of the path it takes from A to B.

Work & Electric Potential Energy

*We can now define the **electric potential energy**, E_E, which is the energy stored in the system that can do work W on a positively charged particle. From your studies you know that the change in the potential energy associated with this type of force is equal to -W (i.e. the electric field has lost energy doing work on the particle to accelerate it).*



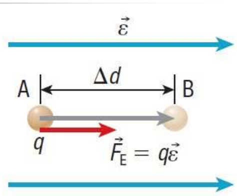
ELECTRIC POTENTIAL ENERGY (E_E)

- the energy stored in a system due to a charge in an electric field

Work & Electric Potential Energy

So, if the electric force does an amount of work W on a charged particle, the change in the electric potential energy is:

$\Delta E_E = -W$
$\Delta E_E = -F_E \Delta d$
$\Delta E_E = -q\varepsilon\Delta d$



NOTE!

The change in the potential energy depends on the starting and ending locations but not on the path taken.

Electric Potential Energy Difference

ELECTRIC POTENTIAL ENERGY DIFFERENCE

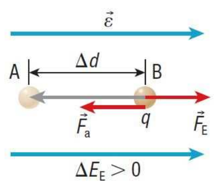
$$\Delta E_E = -q\varepsilon\Delta d$$

where ΔE_E is the change in the potential energy of the field (J)
q is the charge on the object (C)
ε is the electric field intensity (N/C)
d is the displacement of the object (m)

NOTE!
Electric potential energy is stored or lost through the potential effect of the electric field on an electric charge.

Electric Potential Energy Difference

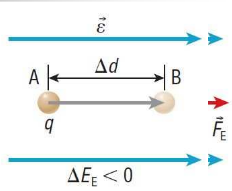
For example, if a positive charge q is moved from B to A, against the electric field, by an external force F_a then the work done by the electric field on the particle is negative. In other words, a positive amount of energy is stored in the system, composed of the charge q and the electric field (i.e. $\Delta E_E > 0$).



NOTE!
This energy loss could appear as an decrease in the kinetic energy of the particle.

Electric Potential Energy Difference

And as the charge moves from A back to B, the process is reversed. Energy stored in the electric field and particle system is taken out of the system. Now the electric field does a positive amount of work on the particle and the change in the electric potential energy is negative (i.e. $\Delta E_E < 0$).



NOTE!
This energy gain could appear as an increase in the kinetic energy of the particle.

Electric Potential Energy

PRACTICE

1. A charged particle moves in a uniform electric field.
   (a) For a proton ($q = +1.6 \times 10^{-19}$ C), calculate change in electric potential energy (ΔE_E) when the magnitude of the electric field is 250 N/C[E], the starting position is 2.4 m from the origin, and the final position is 3.9 m from the origin.

   (a) $\Delta E_E = -6.0 \times 10^{-17}$ J
   In this case the system loses energy to the proton and the proton speeds up (i.e. $\Delta E_k = -\Delta E_E$).

Electric Potential Energy

PRACTICE

1. A charged particle moves in a uniform electric field.
   (b) Calculate the change in the electric potential energy for an electron ($q = -1.6 \times 10^{-19}$ C) in the same field and with the same displacement.

   (b) $\Delta E_E = +6.0 \times 10^{-17}$ J
   In this case the system gains energy from the electron and the electron slows down (i.e. $\Delta E_k = -\Delta E_E$).

Electric Potential Energy

PRACTICE

2. Using the law of conservation of energy, calculate the final speed of the proton ($m = 1.67 \times 10^{-27}$ kg) in part (a) of question 1 for the given displacement. Assume that the proton starts from rest.

   Hint: $\Delta E_E + \Delta E_K = 0$ or $-q\varepsilon\Delta d + \frac{1}{2}m(v_f^2 - v_i^2) = 0$
   $v_f = 2.7 \times 10^5$ m/s

Electric Potential Energy

PRACTICE

3. Determine the initial speed of the electron ($m = 9.11 \times 10^{-31}$ kg) in part (b) of question 1, assuming it has come to rest after the same displacement.

Hint: $\Delta E_E + \Delta E_K = 0$ or $-q\varepsilon\Delta d + ½m(v_f^2 - v_i^2) = 0$

$v_i = 1.1 \times 10^7$ m/s

✔ Check Your Learning

TEXTBOOK

P.349 Q.1-3