

# Workshop Tutorials for Introductory Physics

## EI3: Electric Potential

### A. Review of Basic Ideas:

Use the following words to fill in the blanks:

towards, ground, electric, difference, conservation, changes, kinetic,  $kq/r$ , gravitational, volt, charge

#### **Electric potential and potential energy**

When a negative charge is placed near a positive charge and released it will be accelerated \_\_\_\_\_ the positive charge. As it accelerates its kinetic energy increases as it moves faster and faster. Where does this energy come from? We know from \_\_\_\_\_ of energy that when an object gains kinetic energy it must lose some other sort of energy. In this case the charge has \_\_\_\_\_ potential energy which is converted to \_\_\_\_\_ energy. In the same way a ball held above the ground and released accelerates towards the ground as its \_\_\_\_\_ potential energy is converted to kinetic energy.

In the case of gravitational potential energy we define the zero of gravitational energy to be when an object is on the \_\_\_\_\_. This is an arbitrary but convenient convention. For charges, we usually define the zero of electric potential energy to be when the charges are infinitely far apart. As with gravitational potential it is really only the \_\_\_\_\_ in potential energy that are important, hence we usually talk about potential energy difference. The change in electric potential energy,  $\Delta U$ , as a charge is moved in a uniform electric field is the electric force,  $F_e$ , acting on the \_\_\_\_\_,  $q$ , times the distance,  $d$ , over which it acts,  $\Delta U = F_e \cdot d$ . We know that the electric force is the charge times the electric field,  $F_E = qE$ , so the change in potential energy is  $\Delta U = qE \cdot d$ . The change in potential energy is proportional to the charge,  $q$ . The change in potential energy per unit charge is called the potential \_\_\_\_\_,  $\Delta V = \Delta U/q = E \cdot d$ . The unit for energy is the joule, J, so the unit for potential difference is the joule divided by the coulomb, J/C which is also called the \_\_\_\_\_, V, in honour of Alessandro Volta who constructed the first battery in 1800. Potential differences are often referred to as voltages.

Using the convention that electric potential energy is zero at a point infinitely far away from other charges, we can define the potential due to a point charge at a distance  $r$  from that charge as  $V =$  \_\_\_\_\_ where  $k$  is the Coulomb constant,  $8.99 \times 10^9 \text{ N}\cdot\text{m}^2\cdot\text{C}^{-2}$ .

### B. Activity Questions:

#### **1. Equipotentials**

Use the probes to find lines which have the same potentials all the way along them.

These are called equipotential lines.

How can you use these equipotential lines to draw field lines?

#### **2. Batteries I**

Examine the different batteries.

What does a battery do? Explain how energy is stored in a battery.

#### **3. Measuring voltages**

Use the voltmeter to measure the potential differences across the terminals of the various batteries.

Use the voltmeter to measure the potential difference between two points on the wire.

Now measure the potential difference between one end of the resistor and the other.

Explain why they are different.

Voltmeters are always connected in parallel with the device you are measuring the voltage across.

Why is this the case?

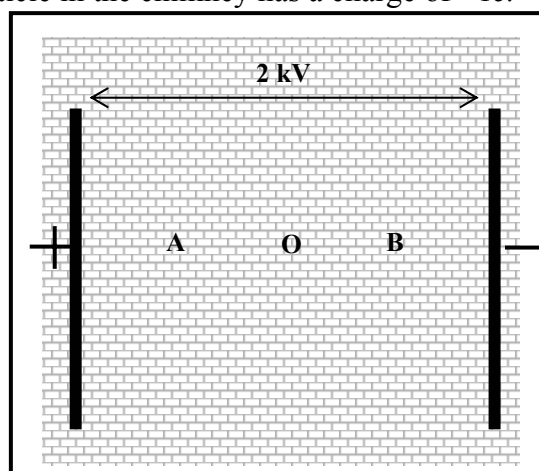
### C. Qualitative Questions:

1. When we talk about gravity we usually talk about gravitational potential energy, and not gravitational potential. In electrostatics we do the opposite – we usually talk about electric potential rather than electric potential energy.

- What is the difference between electric potential and electric potential energy?
- Why is the electric potential energy of a pair of like charges positive and the electric potential energy of a pair of unlike charges negative?
- Is the gravitational potential energy of a pair of massive bodies such as the Earth and the moon positive or negative?

2. Many factories use dust precipitators in their chimneys to remove airborne pollutants. In one such precipitator a pair of plates is placed in the square chimney with a potential difference of 2 kV between them. The large electric field causes molecules to be ionized. Free electrons and ions can then attach to dust particles making them charged. Suppose that a dust particle in the chimney has a charge of  $+1e$ .

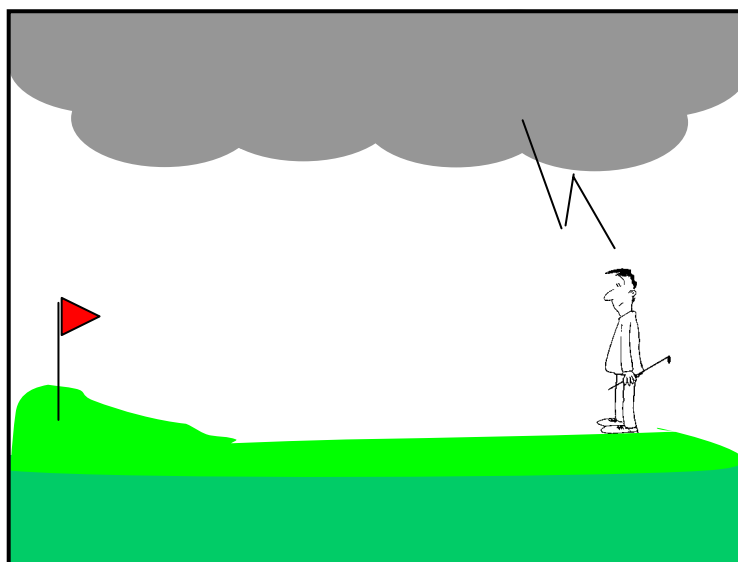
- Draw field lines and lines of equipotential for the arrangement shown.
- If the dust particle starts from rest at point O, half way between the plates, will it move towards point A or B?
- Will the system gain or lose electric potential energy? Where does this change in energy come from?
- Repeat parts **b** and **c** for a particle with a charge of  $-2e$ . Will the change in electric potential energy be greater, less than or the same for this particle for a given distance traveled?
- Rank the electric potential at points A, B and O.



### D. Quantitative Question:

Brent and his brother Bert are playing golf on a Sunday afternoon.

It gradually clouds over until there is a thick layer of cloud above him, and they hear the threatening rumble of a thunder storm. Brent tells Bert that the potential difference between the cloud layer 500 m overhead and the ground (at 0 V) is probably around a gigavolt ( $10^9$  V), and that he's going back to the club house for a drink. Bert decides to finish the hole that he's on first.



- Estimate the magnitude of the electric field that Bert is standing in. (Treat the ground and clouds as parallel charged sheets.)
- Draw a diagram showing field lines and equipotential lines for Bert.
- Bert is 180 cm tall. If Bert were not there what would be the potential difference between the ground and a point 180 cm above ground?
- When Bert is standing there what is the potential difference between the hair on his head and his feet?
- What is the electric potential of his head? Explain your answer.
- Why is it a bad idea to play golf in a storm? Refer to your diagram to help explain your answer.