Topic 10: Electric Potential

Source: *Conceptual Physics* textbook, CPO textbook, CP lab book and CPO lab book

Types of Materials: Textbooks, lab books, demonstrations, worksheets, video and websites, good stories

Leading to: After mechanics concepts and electric force ideas have been studied, electric potential topics prepare the student to be ready to understand the workings of circuits. Constructing circuits and doing experiments reinforces the theory of electric forces and electric potential. Devices used in circuits and how they work can be introduced such as capacitors, transistors, resistors, batteries, etc.

Links to Physics: As stated above, the electric potential topic allows for circuit work and how different circuits can enhance our lives. While doing circuits, discussion of the conservation of energy should be connected to circuit study. Energy in and energy out should be compared. Power in and power out should be calculated and compared. Electron motion in wires like the skin effect will make the connection to what has been previously studied. Drift speed and reasons for the slow progress of the electron is also good for tying in previous topics.

Links to Chemistry: As in physics, chemistry uses circuits and the understanding of these circuits is possible with the understanding of electric forces and electric potential. In electrochemistry, oxidation, reduction, half-cells, voltaic cells, salt bridges and batteries (dry cells and fuel cells) are all dependent on electric potential.

Links to Biology: The electric potential across a membrane is important and in molecular biology, the formation of ATP and the detailed workings of photosynthesis and cellular respiration require a familiarity with electric potential. Redox reactions in photosynthesis and cell respiration also require this background. Membrane potential and its influence on the function of nerve impulses and kidney function also require a working knowledge of electric potential.

Materials:

(a) Hewitt*

(b) Hsu*

(c) My Lab/Activity
Electric Potential*

(d) Worksheet
Electric Potential Worksheet*

(e) Demonstrations
Potential Difference and Equipotential

(f) Websites and Videos
1. The Ohm Zone Lab Sim (Shockwave)
2. Powerhouse Lab Sim (Shockwave)
3. PhET Circuit Sims (Java)
4. www.library.advanced.org/10796/ch12/ch12.htm
(This site compares the gravitational force field to the electric force field and their derivations. This site is mainly for the teacher.)

(g) Good Stories
1. Alessandro Giuseppe Antonio Anastasio Volta (1745-1827)
2. Michael Faraday – The Fading of a Genius
3. Michael Faraday – The Early Years

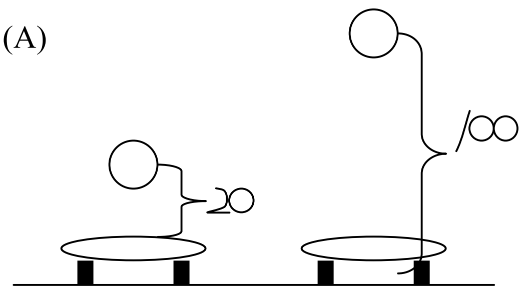
Topic 10: Electric Potential Demonstration

Demonstration of Potential Difference and Equipotential

Showing potential energy difference for the earth's gravitational field can be shown visually. Showing electrical potential (energy) difference is harder to visually show and understand. I like to use the gravity analogy to establish the electrical potential difference concept.

So, first:

(A)



(a) Drop an object (ex: baseball) from rest from 20 cm above a pie tin on spacers. Observe.
(b) Reposition the pie tin and spacers to a different location and again drop the ball from 20 cm. Observe.
(c) Drop the same ball onto pie tin 2, but from 100 cm above pie tin 2 and observe.

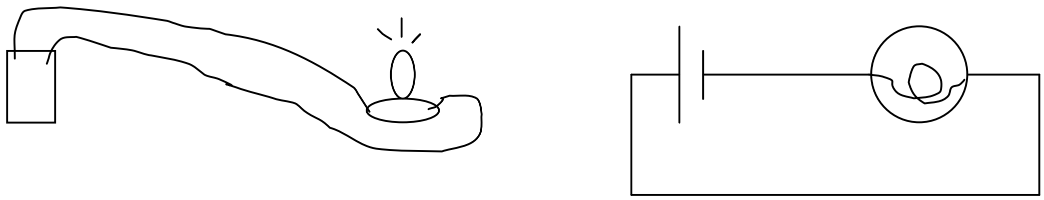
The noise from the two drops at 20 cm will look and sound about the same. The look and sound from 100 cm will be more violent and noisy since the system has five times more energy!

The GPE difference is GPE = mg Δ h = mg (100 cm – 20 cm) = mg (80 cm). This represents the potential difference in both trials and what is observed is the increased violence and sound at impact. This PD is given to the ball-earth system by the gravitational force field as the force of gravity acts through the displacement.

The two trials at 20 cm drop are the same potential difference since Δ h = 20 cm in both cases. The release points for the two 20 cm trials are "equipotential," or at the same starting energy.

(B) The Electrical Analogy for Potential Difference (Electrical):

Connect a DC 6V battery to a 6V bulb. Observe. Touch the bulb. Observe.



The bulb gives off light (energy) and heat (HOT), which is also energy. This energy of light and heat at the bulb comes from the battery's "electric force field" that drives the charge (electrons) through the bulb.

Since potential difference is measured in volts, use a DC voltmeter to measure the battery voltage (potential energy gain) while in operation and the bulb's voltage (potential energy drop; voltage drop).

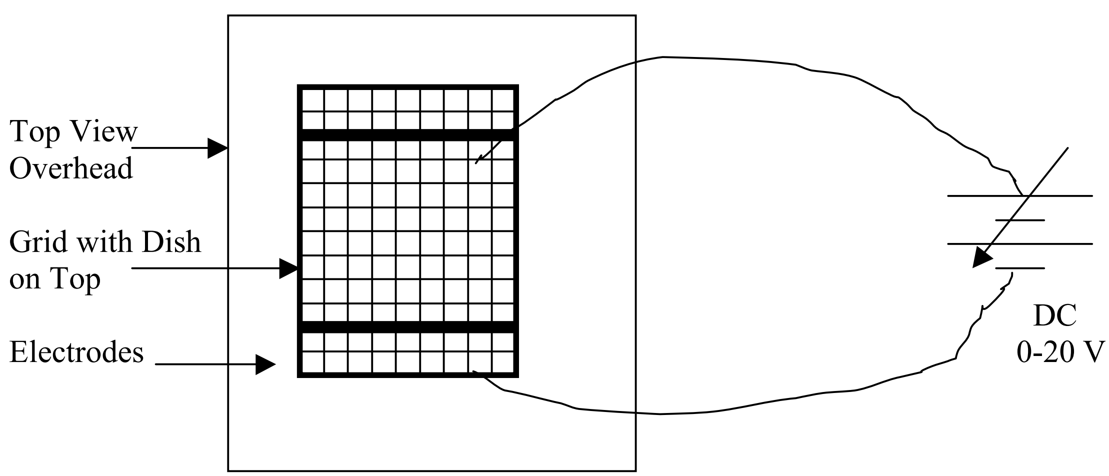
Since voltage is a measure of the ENERGY per CHARGE, $\frac{\text{(ENERGY)}}{\text{(CHARGE)}}$,

the energy delivered to the circuit by the charges matches the energy used by the circuit (voltage gain equals voltage drop) around the circuit. This is just the conservation of energy.

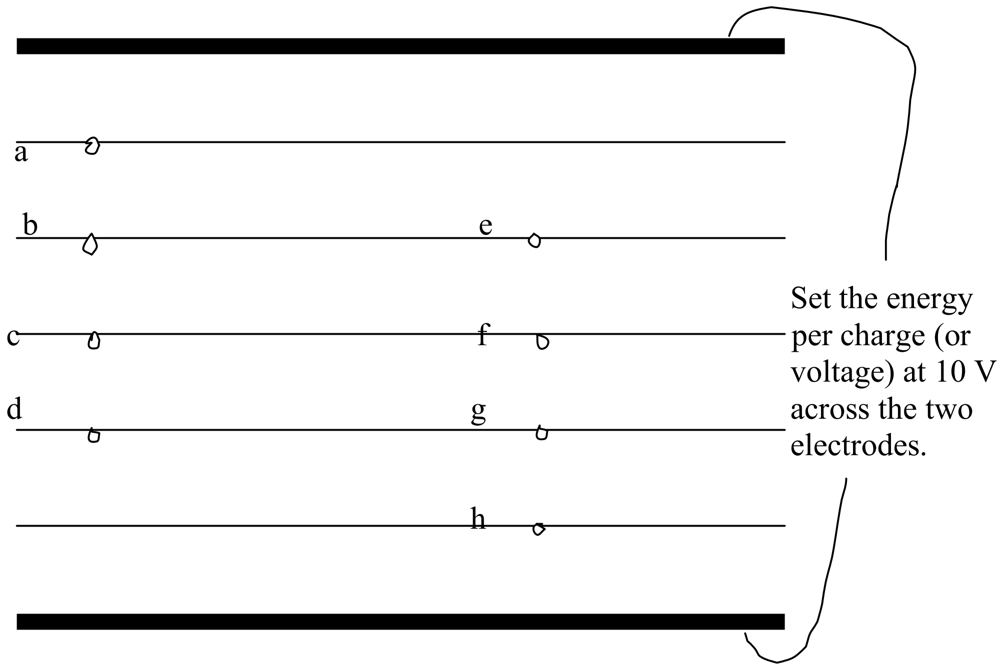
(C) Showing "Equipotential and Potential Difference"

DEMO

1. Obtain a clear glass rectangular dish about 15 cm by 30 cm. A cooking dish would work or buy a ready-made dish with a grid from a science supply house.
2. Obtain a clear plastic sheet with a grid. Place the grid on an overhead projector and the dish on the grid.
3. Obtain two metal strips about 4 cm x 10 cm (electrodes) and vertically secure them parallel to each other at opposite ends of the dish.
4. Pour about 1 cm of salt water in the dish to cover the lower part of the electrodes.
5. Connect a variable DC power supply (0-20 V) to the electrodes in the dish using leads. See sketch.



6. Enlarged grid/electrodes with reference points:



7. Use a DC voltmeter to measure the "electrical potential difference (PD)" with the two voltmeter probes at the following pair of points:

(a)

a and c: PD = ______________________________

b and d: PD = ______________________________

e and g: PD = ______________________________

f and h: PD = ______________________________

Now do:

(b)

a and f: PD = ______________________________

e and d: PD = ______________________________

a and h: PD = ______________________________

Now do:

(c)

b and e: PD = ______________________________

c and f: PD = ______________________________

d and g: PD = ______________________________

Results:

Since all the “change in positions, displacements” for all of (a) and (b) are TWO SPACES, the electrical potential energy difference (PD) IS THE SAME!

However, in (c), the two points chosen for each trial are at the same energy so the ENERGY/CHARGE or potential difference (voltage) is equal to ZERO!

For (c), the chosen pairs are at the same energy, thus, EQUIPOTENTIAL.

Alessandro Giuseppe Antonio Anastasio Volta (1745-1827)

On November 3, 1776, while on summer holiday on Lake Maggiore, his boat went alongside the reeds. Volta began to poke the muddy bottom of the lake with a stick and saw lots of gassy bubbles rise to the surface and burst. He collected some of this gas and discovered that it was inflammable. He called it "inflammable air from marshlands." Today the gas is known as methane.

In Volta's time electricity and chemistry were considered very closely related. The possibility of sparking off an explosive mixture of gas led Volta to construct an interesting gadget later called Volta's Pistol. This was a glass container made in the shape of a pistol that would contain an inflammable gas, which was ignited by an electrical spark. This contraption was surprisingly effective firing a lead ball and denting wood at a distance of five meters.

In that same year Volta had the idea of using a long metal wire, insulated from the ground by wooden boards, for conveying an electrical signal. Volta had imagined an electrical signal, generated from a Leyden jar, passing through the wire, into a nearby stream and traveling down stream to a nearby village and igniting an inflammable gas in the Volta Pistol. The concept of the telegraph had been born.

Volta's Pistol continued to be used in determining the relative percentage of oxygen in inflammable airs by the force they generated when exploded.

In 1801 Napoleon Boneparte invited Alessandro to Paris to confer upon him the title of Count and proclaim him a senator of Italy.

Michael Faraday – The Fading of a Genius

In the 1830's, after several years of very concentrated work, Michael's health let him down suddenly and dramatically. He began to suffer giddy spells and even more frighteningly, complete lapses of memory. Eventually, although reluctantly, he listened to his doctors and took a complete nine-month break in Switzerland. On his return he did no more work at all for four years and then only began to research again at a very slow pace.

Then from 1845 onwards, Faraday's health recovered almost miraculously and another seventeen years of brilliant research emerged from his laboratory, although his memory was never again as good. He wrote himself copious notes to make sure he could remember what he was doing, making it possible for him to continue as a respected and successful scientist. However, his memory, which had given him trouble for years, increasingly, let him down. He could remember the past but not the present. He dare not work in the same areas of research as other people because he could not remember what they had done and feared he might again appear to steal ideas.

"My memory wearies me greatly in working; for I cannot remember from day to day the conclusions I came to. I do not remember the order of things or even the facts themselves."

From his retirement in 1865, Faraday deteriorated rapidly. Toward the end of his life he was rarely lucid and unable to do anything for himself, spending most of his time sitting in a chair staring vacantly into space. Finally, on August 25, 1867, Faraday died, still sitting quietly in his chair.

Michael Faraday – The Early Years

As a child, Michael Faraday's formal education was cut short by a series of dramatic events. Unfortunately for young Michael, the educational philosophy of the day was "Spare the whip, spoil the child." This combined with a speech impediment that prevented him from pronouncing his R's, lead to a traumatic experience, which Michael would never forget. Ongoing friction between the schoolmaster and young Michael finally came to a head. One morning the schoolmaster beat the child so severely that he could not move off the classroom floor. Enraged at seeing this, Michael's older brother Robert (Wobert as Michael called him) leapt from his desk, flew out of the school and raced home. About an hour later Robert reappeared at the school with the boy's mother. As they entered the classroom, young Michael was still lying on the floor. Mrs. Faraday became furious. She picked up the boy and marched out of the school with Robert trailing behind while lashing out at the schoolmaster. Michael Faraday had left the public education system forever. For the rest of his life, Michael Faraday was a self-taught man.

Internet Sources