Electric Potential

Work and Energy for Charges

Electrostatics

I. Charge and Force
- concepts and definition
- Coulomb's Law

II. Electric Fields
- effect on charge
- production by charge

III. Potential
- **relation to work, energy, field**
- association with charge

	The student will be able to:	HW:
1	Relate electrical phenomena to the motion and position of the fundamental charge found on electrons and protons and recognize the coulomb as the SI unit of charge and *e* as the elementary quantum of charge.	1 – 5
2	State and apply Coulomb's Law to solve problems relating force, charge, and distance.	6 – 13
3	Define and apply the concept of an electric field and sketch field lines for a given distribution of charge and solve for the electric field strength at any point relative to a collection of point charges.	14 – 22
4	Define electric potential and potential difference and the volt and solve problems relating electric potential to charge, work or energy, electric field strength and distance.	23 – 32
5	Define and calculate potential and isolines for common charge distributions and solve related problems.	33 – 38

Work and Energy for Charges

Work must be done by an external force in order to separate opposite charges.

Opposite charges that have been separated represent **potential energy** because of the attractive force between such charges. (There is the potential for work to be done by the electric force as the separation decreases.)

Work and Energy for Charges

Likewise work must be done in order to *decrease* the separation of *like* charges.

Like charges that have been pushed together represent potential energy because of the *repulsive* force. (There is the potential for work to be done by the electric force as the separation *increases*.)

Electric Potential

$$\Delta V = \frac{W}{q}$$

OR

$$\Delta V = \frac{\Delta U_E}{q}$$

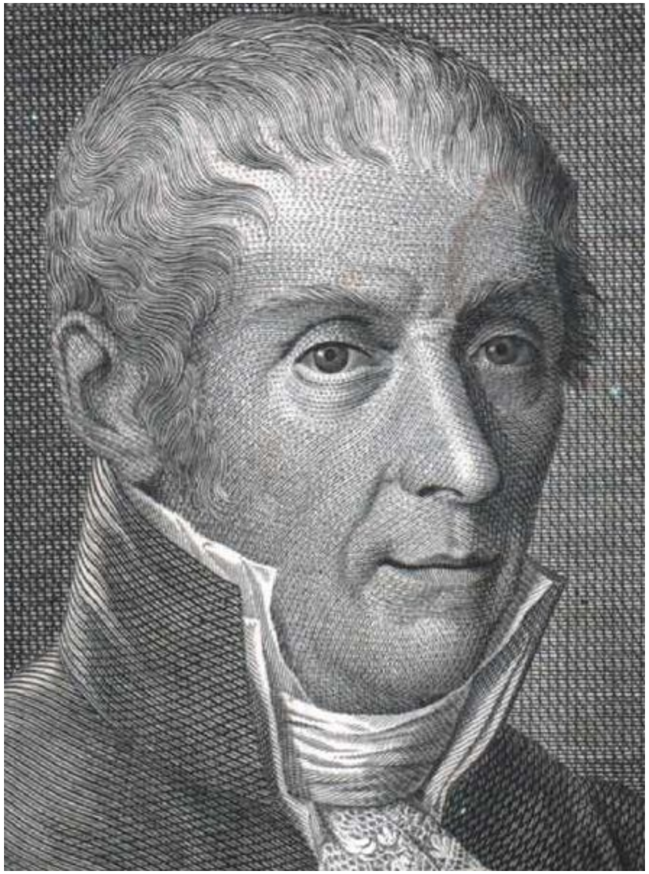
where: ΔV = electric potential difference
W = work done to move charge q between two positions
ΔU_E = change in potential energy as charge q moves between two positions

Units of Electric Potential

- The SI unit for electric potential is the **volt**.
- One volt is equal to one joule of work or energy per every one coulomb of charge:

$$1\ \text{V} = 1\ \text{J/C}$$

- Other names for electric potential: voltage, potential difference, potential, electromotive force (or emf).

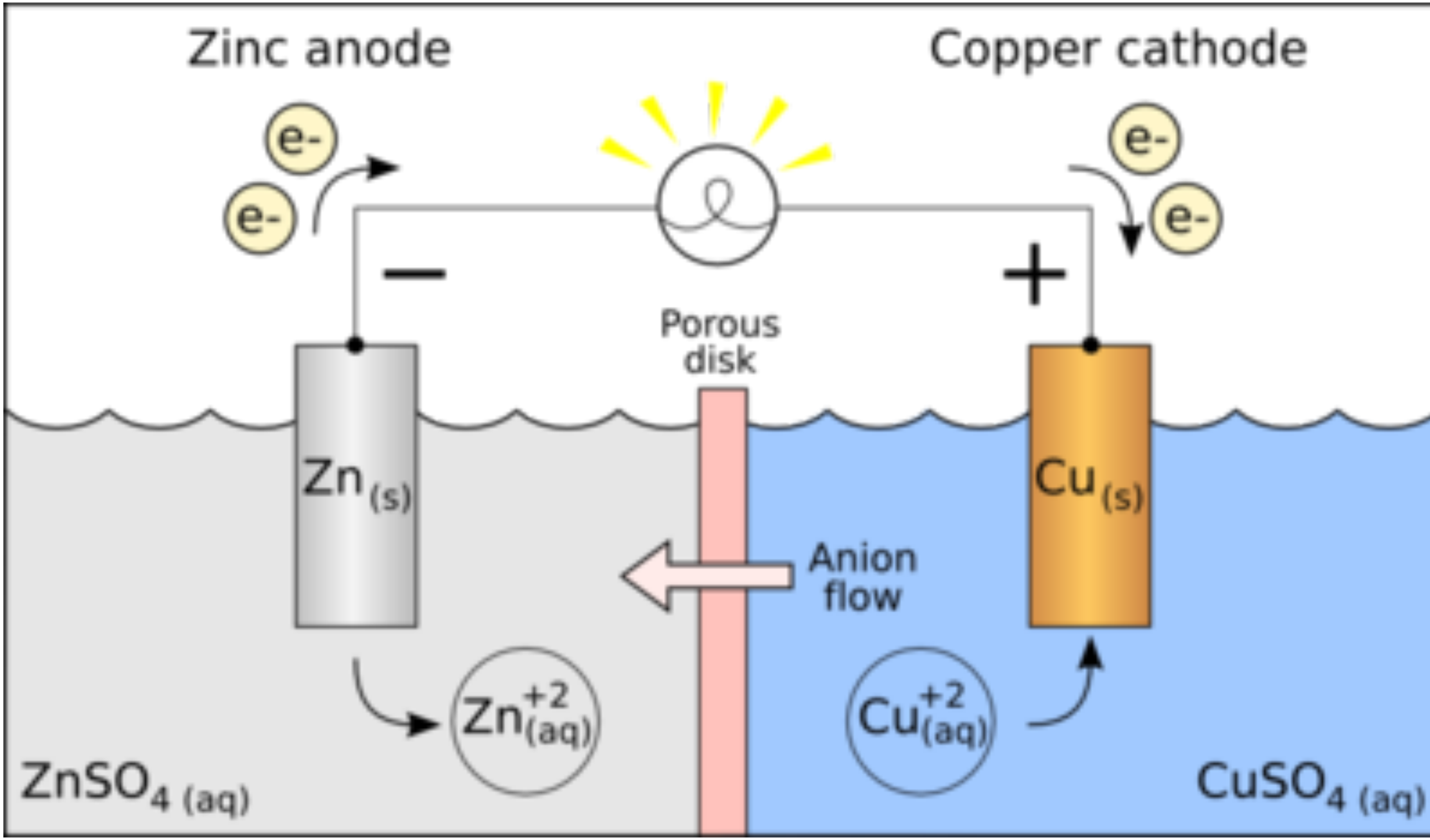


Alessandro Volta invented the first battery around 1800.

a “voltaic pile”

Sources of Electric Potential

- Voltaic cells – *i.e.* "batteries" – chemical energy is converted to electric energy
- Electric Generator – mechanical work results in electric energy
- Solar cells – *i.e.* photovoltaic cells – light energy is converted to electric energy
- Van de Graaff – mechanical work results in electric energy
- There are others…

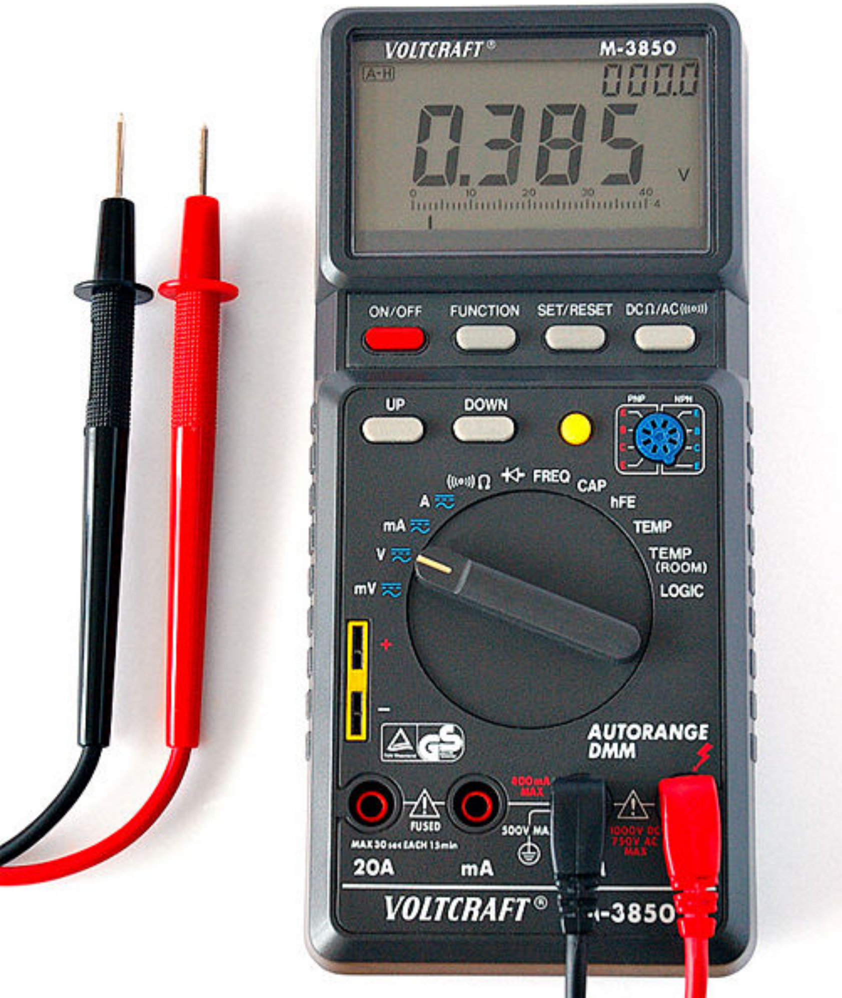


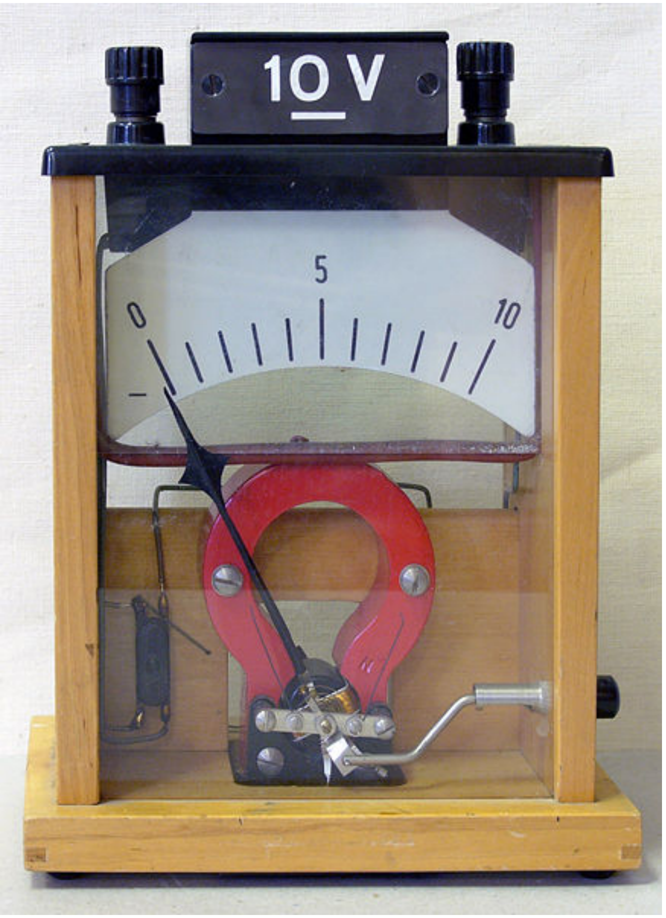
source: Wikipedia, Ohiostandard

Voltage of a cell is a measure of the work done per charge by the chemical reaction, which also indicates the energy per charge available to power a device.

Measuring Electric Potential

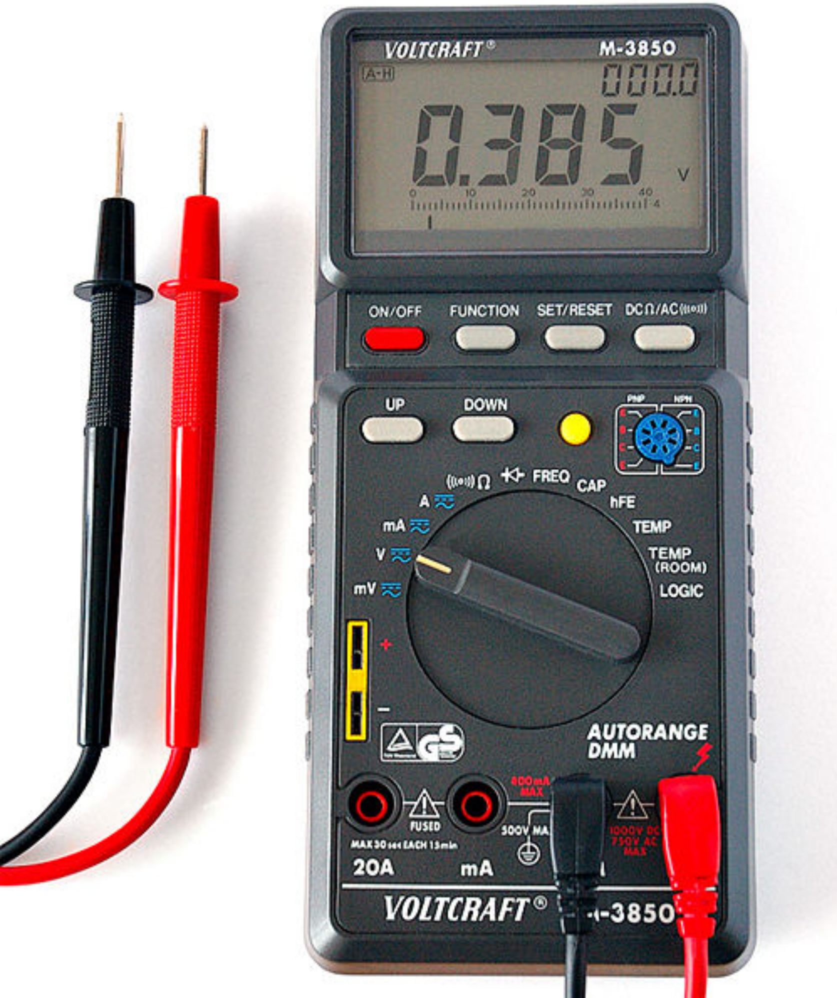
Digital Multimeter

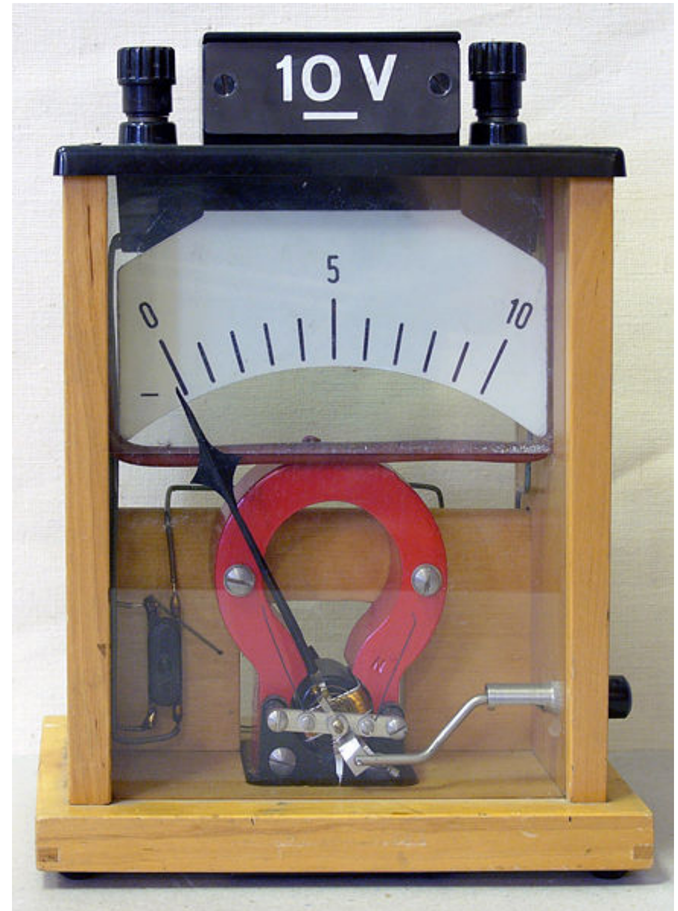




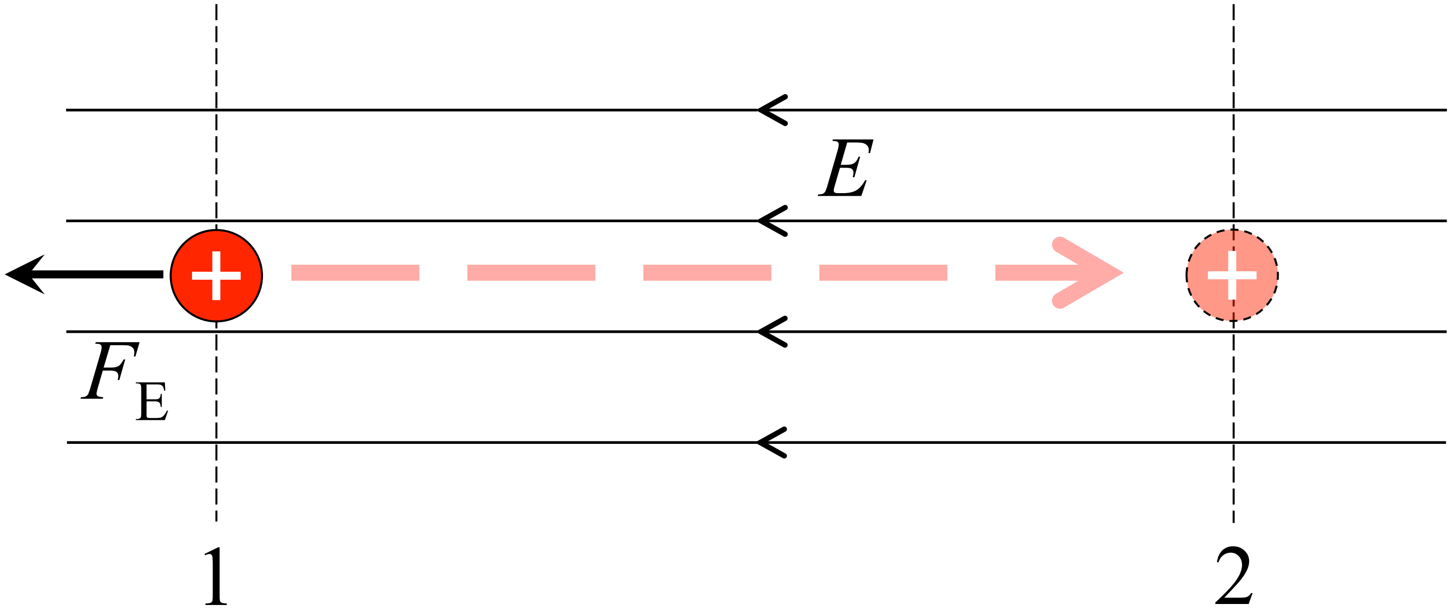
Analog Voltmeter

Either device can indicate the potential difference between the two probes or leads.



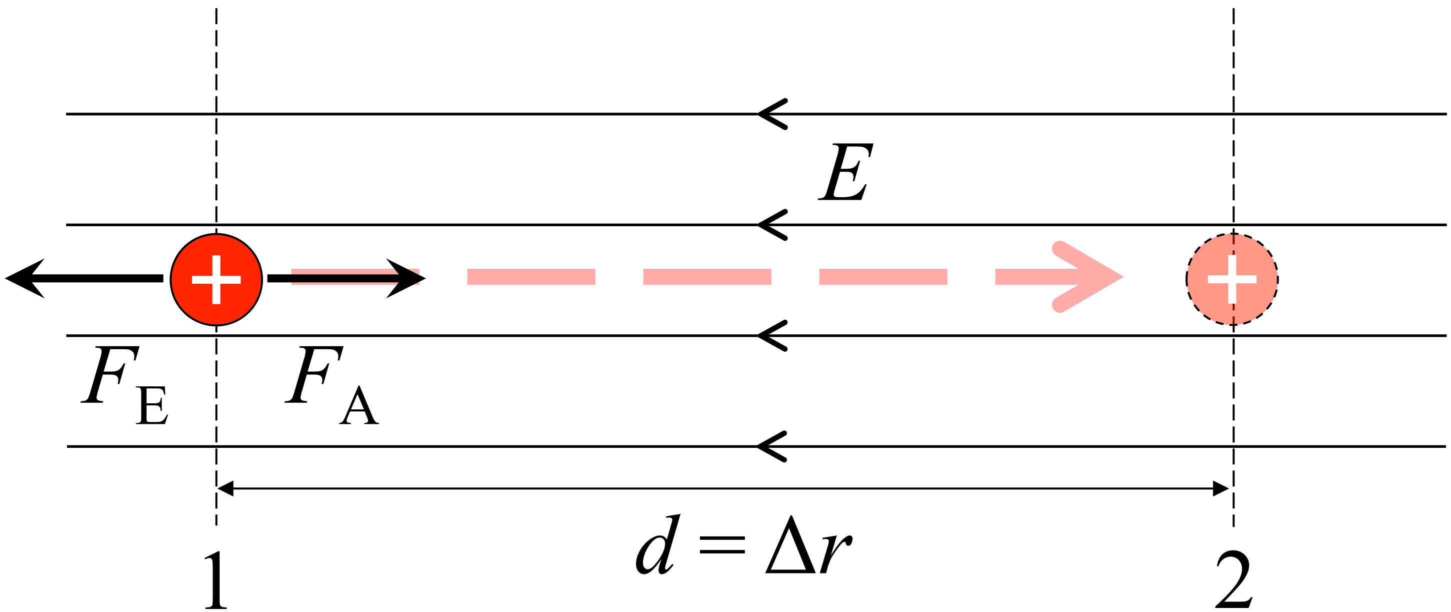


Electric Potential vs. Electric Field



By how much does the electric potential change when the object moves from 1 to 2?
Hint: potential is work or energy per charge!

Electric Potential vs. Electric Field



$$W = Fd$$

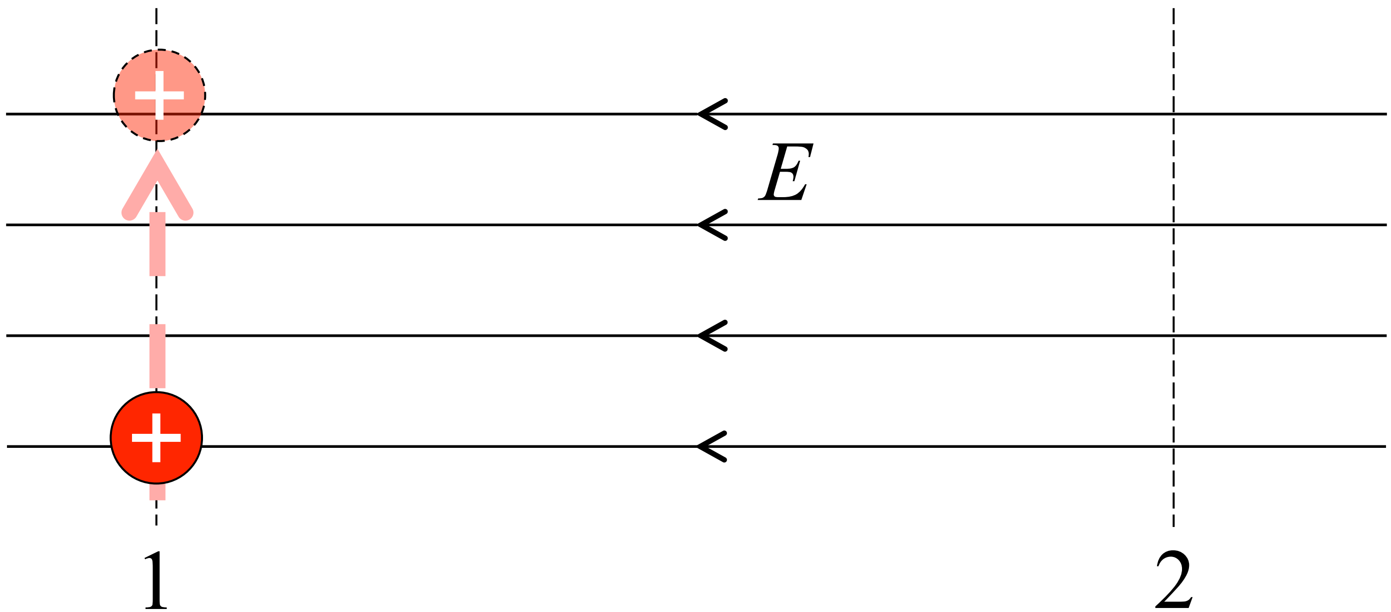
$$\frac{W}{q} = \frac{Fd}{q} = \frac{F}{q}d$$

$$\Delta V = E \cdot \Delta r$$

The potential increases by amount ΔV moving from line 1 to line 2.

(regardless of the value of q!)

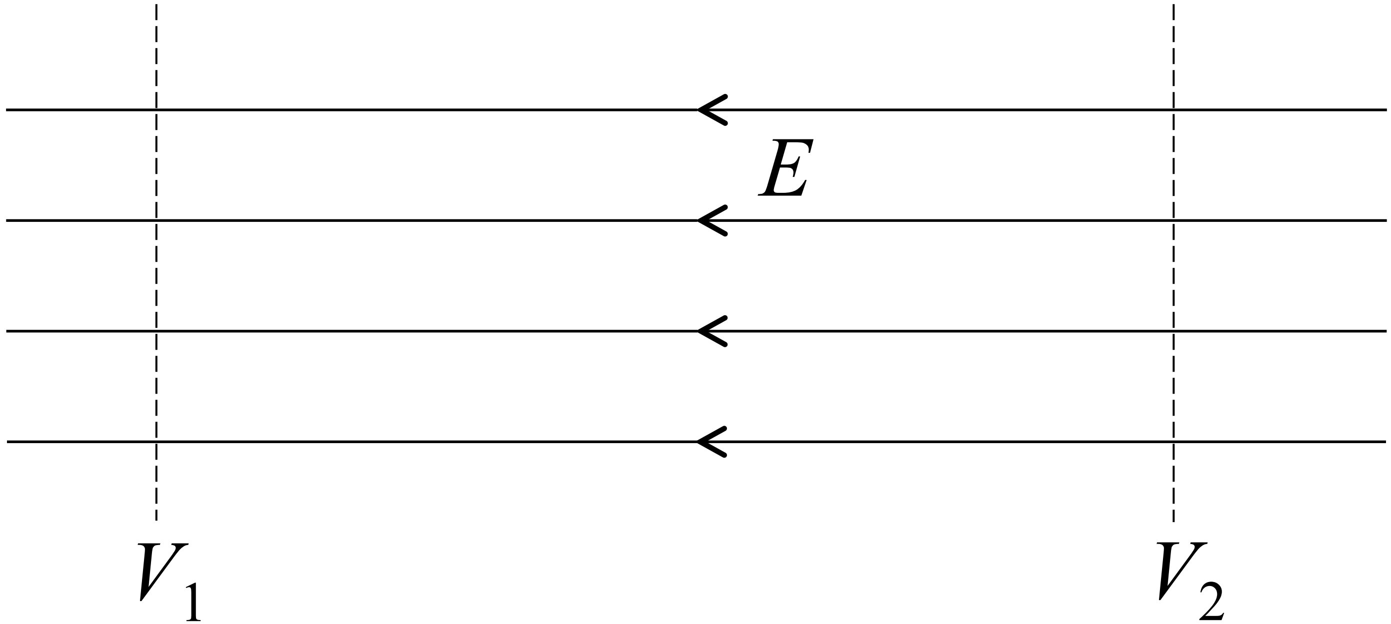
Electric Potential vs. Electric Field



How much does electric potential change if the object moves *along* the line 1?

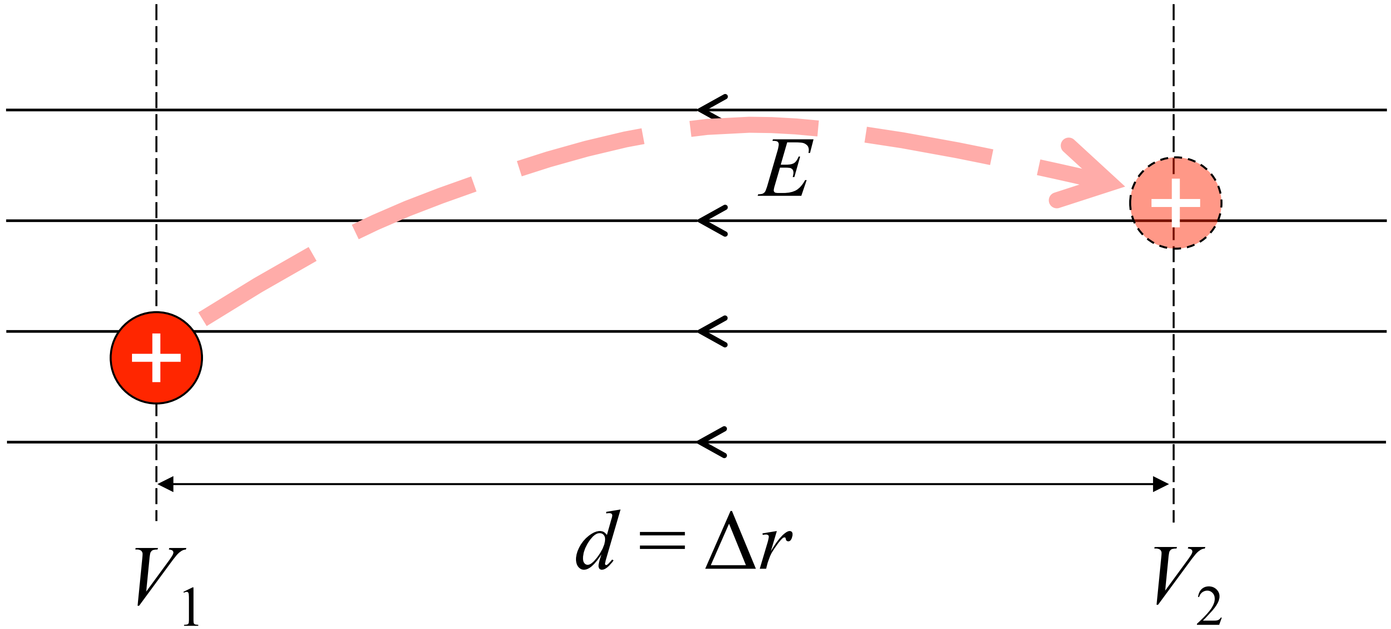
The potential does not change at all moving along the line 1 or any line perpendicular to the electric field because there is no work done by the electric force and no change in potential energy!

Electric Potential vs. Electric Field



The perpendicular lines 1 and 2 represent certain "levels of energy" and are called isolines of potential or simply equipotential lines. At any point along such a line there is a certain potential.

Electric Potential vs. Electric Field



How much does electric potential change if the object moves as shown?

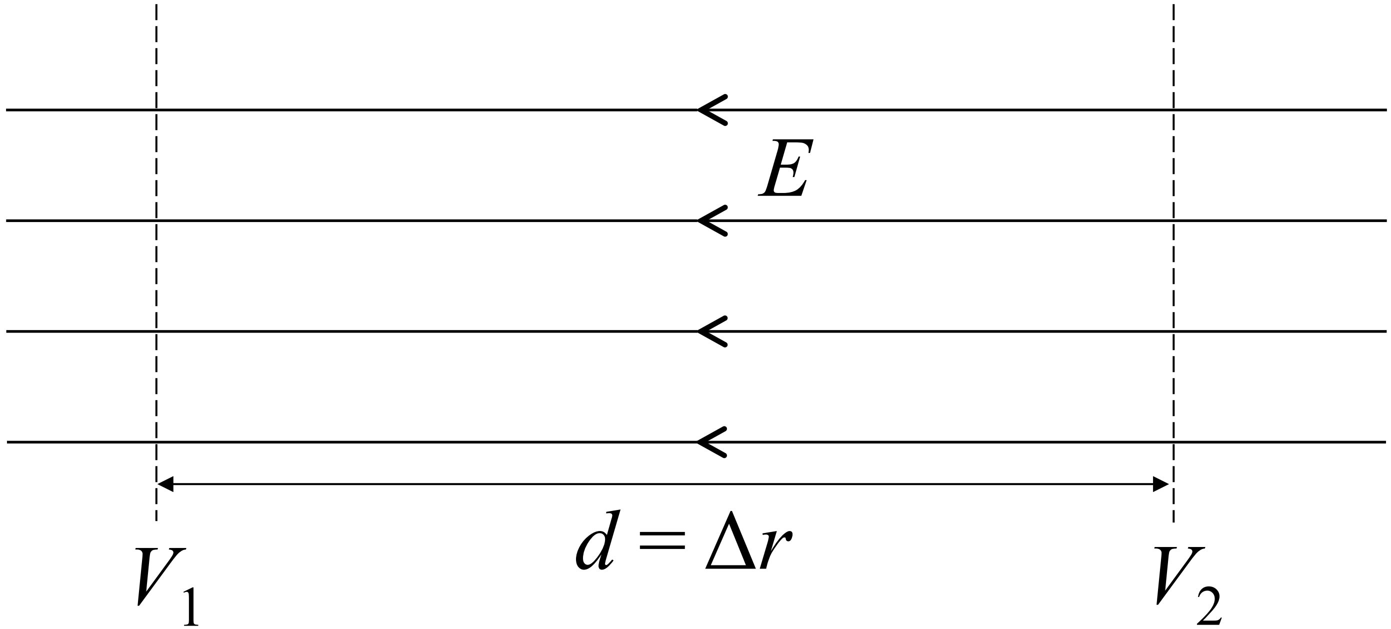
$$\Delta V = E \cdot \Delta r$$

$$V_2 - V_1 = E \cdot \Delta r$$

$$V_2 = V_1 + E \cdot \Delta r$$

The potential V_2 is greater than V_1 by amount $E\Delta r$.

Electric Potential vs. Electric Field



The equipotentials V_2 and V_2 and the difference ΔV are related to the field as shown regardless of whether there is a charge moving in the region!

$$\Delta V = E \cdot \Delta r$$

$$V_2 - V_1 = E \cdot \Delta r$$

Electric Potential vs. Electric Field

$$|\Delta V| = |E \cdot \Delta r|$$

OR

$$|E| = \left|\frac{\Delta V}{\Delta r}\right|$$

where: ΔV = electric potential difference
Δr = separation *along* field lines
E = electric field strength

note: E is assumed constant over the span Δr.