Summary

Use the work-energy relations to understand/ estimate

1) the work done by thrust force for cruising or acceleration;

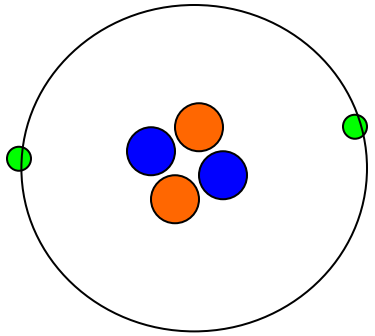
2) Estimate fuel economy of a car /air plane;

3) Understand the advantage of flying high.

Introduction to electricity and electric circuits

electric charges, conductors and insulators

Example: He-Atom



- 2 protons, positively charged: + 2e
- 2 neutrons, no charge
- 2 electrons, negative charge: - 2e
- elementary charge, **e = 1.6 x 10^{-19} C**
- **Atoms are neutral**, unless electrons are removed (or added): Ionization requires energy.
- Protons and neutrons consists of 3 quarks each.

Properties of Electric Charge

- Charges are due to **elementary particles**: Protons carry (+ e), electrons carry (- e).
- Charge is **quantized**: $Q = n \cdot e$ with $n = \pm 1, \pm 2, \pm 3, \ldots$ and $e = 1.602 \times 10^{-19}$ C
- Charge is **conserved**.
- **Atoms are neutral** in their 'normal' state.
- All **objects are uncharged** (electrically neutral) in their normal state.
- Charged objects exert a force onto each other: **like charges repel** each other, **unlike charges attract** each other.

Solid Conductors (Metals)

- Transport electric charges well.
- Freely moving **conduction electrons** and bound electrons that remain at the location of the nucleus of each atom.
- Atoms (**nucleus + bound electrons) remain in place** and form a crystal lattice (chemical bonds).
- Positive charges (ions) can only move in a liquid or a gas.
- Electric current: Net motion of charges (free electrons in a metal).

Demos

- Pie plates on Van De Graaff generator.

Insulators

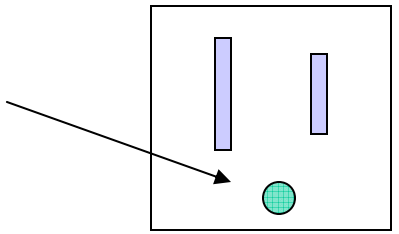
- **Insulators** (plastic, glass, pure water): All **electrons are tightly bound** and cannot move.
- No conduction electrons (or only very few): **no transport of charge**, i.e. electric currents.
- You can charge an insulator: Rubbing a glass rod with a silk cloth.
- The rubbing action removes electrons locally from the glass surface.
- The positive charge remains there because other electrons cannot move there to replace the missing electrons.

Conductors and Insulators

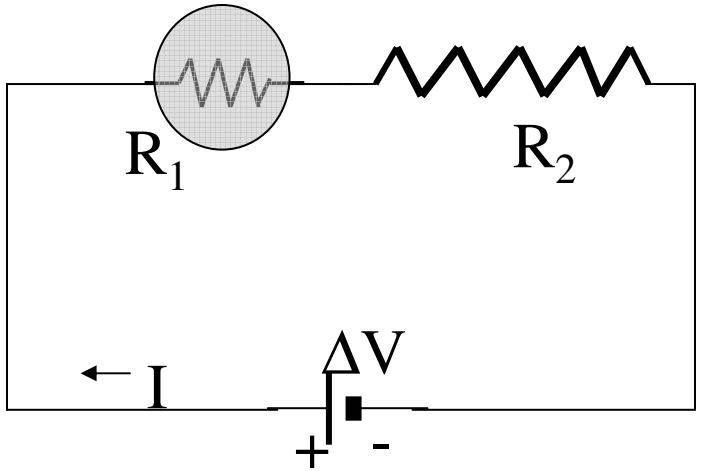
- Excess charge on a conductor is distributed so that the net electrostatic force on each charge is zero (**electrostatic equilibrium**). Only surface charges.
- Excess charge on an insulator remains at the spot where it was deposited.
- The same element or material may be conducting or insulating, depending on its crystal structure. Carbon is an example for this: at room temperature, graphite is a good conductor while diamond is an insulator.

Grounding

- Connecting a charged conductor to Earth: Extra charges are neutralized by Earth.
- Earth = infinite sink (or supply) of charges.
- In practice, connection to your water lines or heat pipes makes a good ground connection, as long as these pipes are made of metal.
- Your wall plugs also provide an Earth-ground lead (the small circular plug).



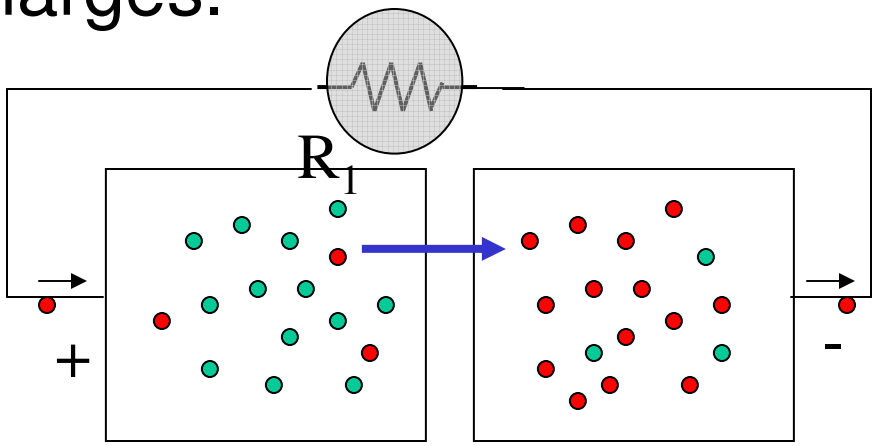
Electric Circuits



- Power source maintaining a potential difference.
- Consumer (load resistance).
- Conducting wire to connect the potential difference and form a circuit.
- Only when the circuit is closed, power source drives electrons around the circuit (electric current).
- The potential energy stored inside the battery is transformed into kinetic energy of the electrons.

The Electric Battery

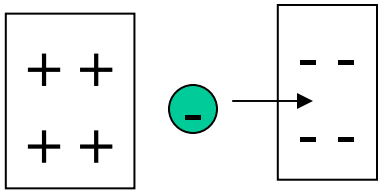
- Contains a large amount of electric potential energy due to the separation of positive and negative charges.



- Acts as the source and the drain for the electrons in the circuit (‘charge pump’).
- Once an electron arrives at the positive terminal, another electron is produced at the negative terminal: An electrochemical reaction maintains a constant potential difference (‘voltage’ or emf ε) until the battery is dead.

Electric Potential Energy

- Electric potential energy stored inside a battery due to the separation of many charges: Charging the battery.
- Assume that the battery has already more positive charges in one chamber, and more negative charges in the other.
- Must do work to move another electron from the positive side to the negative side against the Coulomb force.



- The net work to separate positive and negative charges is stored as electric potential energy.

$$W = \Delta U = U_+ - U_- = F_e\, d$$