

## Flashlights

### Question:

If you remove the 2 batteries from a working flashlight and reinstall them backward so that they make good contact inside, will the flashlight still work?

### Observations About Flashlights

- They turn on and off with a switch
- More batteries usually means brighter
- The orientation of multiple batteries matters
- Flashlights dim as batteries age
- Sometimes smacking a flashlight brightens it

### A Battery

- Battery “pumps” charge from – end to + end
  - Chemical potential energy is consumed
  - Electrostatic potential energy is produced
- Current undergoes a rise in voltage
  - Alkaline cell: 1.5 volt rise
  - Lead-acid cell: 2.0 volt rise
  - Lithium cell: 3.0 volt rise
- Chain of cells produces larger voltage rise

### A Light Bulb

- Structure
  - Contains a protected tungsten filament
  - Filament conducts electricity, but poorly
- Filament barely lets charge flow through it
  - Electrostatic potential energy is consumed
  - Thermal energy is produced
- Current undergoes a drop in voltage
  - Two-cell alkaline flashlight: 3.0 volt drop

### A Simple Circuit

- A battery – the energy source
- A wire – the outgoing current path
- A light bulb – the energy destination (the load)
- A wire – the return current path

## Circuits 1

- Steady current requires a circuit path (a loop)
  - Charge mustn't accumulate anywhere
  - A closed conducting loop avoids accumulation
- Steady current flow requires energy
  - Currents lose energy (and voltage) in conductors
  - Missing energy becomes thermal energy
  - Lost energy must be replaced

## Circuits 2

- A circuit can transport energy
  - Current obtains energy from a battery
  - Current delivers energy to a light bulb
  - Current starts the trip over again

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## Recharging a Battery

- Forward (discharging) current flow
  - Battery “pumps” charge from – end to + end
  - Current undergoes voltage rise
  - Battery’s chemical potential energy is consumed
- Reverse (recharging) current flow
  - Circuit “pushes” charge from + end to – end
  - Current undergoes voltage drop
  - Battery’s chemical potential energy is replenished

## Positive Charge

- Current points in the direction of *positive* flow
- Flow is really *negative* charges (electrons)
- It's hard to distinguish between:
  - negative charge flowing to the right
  - positive charge flowing to the left
- We pretend that current is flow of + charges
- It's really – charges flowing the other way

## Short Circuits

- If a conducting path bridges the load
  - Current bypasses the load
  - Circuit is abbreviated or “short”
- No appropriate energy destination (load)
- Energy loss and heating occurs in the wires
- A recipe for fires!

## Power

- Power is energy per unit of time
- Power is measured in joules/second or watts
- Batteries are power sources
- Loads are power consumers

## Battery Power

- Current: units of charge pumped per second
- Voltage rise: energy given per unit of charge

$$\text{current} \cdot \text{voltage rise} = \text{power produced}$$

## Load Power

- Current is units of charge passed per second
- Voltage drop: energy taken per unit of charge

$$\text{current} \cdot \text{voltage drop} = \text{power received}$$