

# Flashlights

## Observations about Flashlights

- You turn them on and off with switches
- Brighter flashlights usually have more batteries
- Flashlights grow dimmer as their batteries age
- Sometimes smacking a flashlight brightens it

## 6 Questions about Flashlights

- Why do flashlights need batteries and bulbs?
- How does power flow from batteries to bulbs?
- How does a flashlight's switch turn it on or off?
- How can a battery be recharged?
- Why does a short-circuited flashlight get hot?
- What distinguishes different-voltage lightbulbs?

## Question 1

- Why do flashlights need batteries and bulbs?

## What Batteries Do

- Batteries provide flashlights with electric power
- A battery "pumps" charges from  $-$  to  $+$ 
  - Decreases the battery's chemical potential energy
  - Increases the charges' electrostatic potential energy
- Those charges undergo a rise in voltage:
  - 1.5 volts in a typical alkaline cell,
  - 3.0 volts or more in a lithium cell,
  - and of even more in a chain of cells.
- In a two-cell alkaline flashlight, the rise is 3.0 V

## What Lightbulbs Do

- Bulbs turn electric power into light power
- A bulb lets charges flow through its filament,
  - Decreases the charges' electrostatic potential energy
  - Produces thermal energy, including light.
- Those charges undergo a drop in voltage
  - while passing through the bulb's tungsten filament
  - because thin tungsten wire is a poor conductor.
- In a two-cell alkaline flashlight, the drop is 3.0 V

## Question 2

- How does power flow from batteries to bulbs?

## Electric Power

- Electric power is the rate of energy transfer,
  - the electric energy transferred per unit of time,
  - and is measured in watts (i.e., joules/second).
- Batteries provide electric power
- Lightbulbs consume electric power

## Electric Current

- Electric current is the rate of charge transfer,
  - the electric charge passing a point per unit of time,
  - and is measured in amperes (i.e., coulombs/second).
- Batteries provide power to electric currents
- Lightbulbs extract power from electric currents

## Electric Current in a Flashlight

- In a flashlight,
  - an electric current carries power
  - from batteries (the energy source)
  - through a wire (the outgoing current path)
  - to a lightbulb filament (the energy destination),
  - and the current then returns through another wire
  - to the battery for reuse.

## How a Battery Works

- A battery uses its chemicals to pump current
  - from its negative terminal to its positive terminal.
- Current gains voltage in the battery
  - and the battery thus provides electric power.
$$\text{power provided} = \text{current} \cdot \text{voltage rise}$$

## How a Lightbulb Filament Works

- Normal electrical conductors are imperfect,
  - so electric currents don't coast through them;
  - electric fields are required to keep currents moving.
- For a current to flow through a filament,
  - the filament must have an electric field in it
  - caused by a voltage drop and an associate gradient.
- Current loses voltage in the filament
  - and the filament thus consumes electric power.
$$\text{power consumed} = \text{current} \cdot \text{voltage drop}$$

### Question 3

- How does a flashlight's switch turn it on or off?

### Circuits and Flashlights

- Steady current requires a circuit or loop path
  - because charge mustn't accumulate anywhere
  - and a closed conducting loop avoids accumulation.
- In a flashlight, the electric circuit is
  - closed (complete) when you turn the switch on
  - open (incomplete) when you turn the switch off

### Question 4

- How can a battery be recharged?

### Recharging a Battery (Part 1)

- While a battery discharges:
  - Current flows forward, from – end to + end.
  - Current experiences a voltage rise
  - Charges' electrostatic potential energy increases
  - Battery's chemical potential energy decreases

### Recharging a Battery (Part 2)

- While a battery recharges:
  - Current flows backward, from + end to – end.
  - Current experiences a voltage drop
  - Charges' electrostatic potential energy decreases
  - Battery's chemical potential energy increases

### The Direction of Current

- Current is defined as the flow of positive charge
  - but negative charges (electrons) carry most currents.
- It's difficult to distinguish between:
  - Negative charges flowing to the right
  - Positive charges flowing to the left.
- We pretend that current is flow of + charges,
  - although it's really – charges flowing the other way.

## Effects of Current Direction

- Batteries typically establish the current direction
- Current direction doesn't affect
  - wires, heating elements, or lightbulb filaments,
- Current direction is critically important to
  - electronic components such as transistors and LEDs
  - and some electromagnetic devices such as motors.

## Question 5

- Why does a short-circuited flashlight get hot?

## Short Circuits

- If a conducting path bridges the filament,
  - current bypasses the filament
  - and the circuit is abbreviated or "short."
- There is no appropriate energy destination,
  - so energy loss and heating occurs in the wires.
- Such a short circuit is a recipe for fires!

## Question 6

- What distinguishes different-voltage lightbulbs?

## Ohm's Law

- Currents experience voltage drops while passing through wires, filaments, and other conductors.
- In ordinary electrical conductors, the voltage drop is proportional to the current:
  - $\text{voltage drop} = \text{resistance} \cdot \text{current}$
  - where resistance is a characteristic of the conductor.
- That relationship is known as Ohm's law.

## Resistance and Filaments

- The smaller a filament's resistance,
  - the more current it carries for a given voltage drop
  - the more electrical power it consumes
- To avoid overheating, filaments in higher-voltage flashlights must have
  - larger resistances (to limit power consumption)
  - or larger surfaces (to dissipate more thermal power)

## **Summary about Flashlights**

- Current carries power from batteries to bulb
- The switch controls the flashlight's circuit
- Current flows only when the circuit is closed
- The batteries raise the current's voltage
- The lightbulb lower the current's voltage