

Flashlights

Introductory Question

- A flashlight may use a lightbulb or an LED. If you reverse the 2 batteries in a working flashlight and they again make good contact inside, will the flashlight still work?
- A. Lightbulb : Yes, LED: Yes
 - B. Lightbulb : Yes, LED: No
 - C. Lightbulb : No, LED: Yes
 - D. Lightbulb : No, LED: No

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

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What Lightbulbs Do

- Lightbulbs 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

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Clicker Question

- In a flashlight, power is transferred from batteries to lightbulb. Why can't the power go the other way, from lightbulb to batteries?
 - A. Power can only flow forward in the flashlight
 - B. The lightbulb consumes the electric charges, too
 - C. Disordered energy can't become ordered energy
 - D. Current is actually negatively charged electrons

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Question 2

- How does power flow from batteries to bulbs?

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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

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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

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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.

power provided = current · 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 associated gradient.
- Current loses voltage in the filament
 - and the filament thus consumes electric power.

power consumed = current · voltage drop

Clicker Question

- If you move the bulb from a 2 D-cell flashlight to a 4 D-cell flashlight and turn that flashlight on, the bulb will
 - A. burn out almost instantly.
 - B. glow normally for a much longer time.
 - C. glow normally for a much shorter time.
 - D. glow normally for about the same time.

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.

Introductory Question (revisited)

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- A. Lightbulb: Yes, LED: Yes
 B. Lightbulb : Yes, LED: No
 C. Lightbulb : No, LED: Yes
 D. Lightbulb : No, LED: No

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:

voltage drop = resistance · 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)

Clicker Question

- If you move the bulb from a 2 AA-cell flashlight to a 2 D-cell flashlight and turn that flashlight on, the bulb will
 - A. burn out almost instantly.
 - B. glow normally for a much longer time.
 - C. glow normally for a much shorter time.
 - D. glow normally for about the same time.

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 lowers the current’s voltage