Power Adapters

Introductory Question

- If you install a pocket radio's batteries backward, it won't work because its

A. speaker will move the wrong direction.
B. parts can only conduct current one way.
C. batteries will absorb power and recharge.

Observations about Power Adapters

- They obtain power from AC electrical outlets
- They provide DC power to electronic devices
- They somehow fix the AC versus DC problem
- They come in various voltages and other ratings

5 Questions about Power Adapters

- Why isn't a power adapter simply a transformer?
- Why can electrons move in metals not insulators?
- How does charge move in a semiconductor?
- How does a diode carry current only one way?
- How does a capacitor store electric charges?

Question 1

- Why isn't a power adapter simply a transformer?

Power Adapter Components (part 1)

- A basic power adapter completes three steps
  - to convert household AC power
  - into low-voltage DC power.
  - A transformer performs only one of those steps.
- Step 1: household AC to low-voltage AC
  - Performed by a step-down transformer
  - Household AC flows into the primary coil
  - Low-voltage AC flow out of the secondary coil

Power Adapter Components (part 2)

- Step 2: low-voltage AC to low-voltage pulsed DC
  - Performed 1 to 4 diodes: one-way devices for current
  - Low-voltage AC flows into the system of diodes
  - The diodes switch the current so that it always flows out through one wire and returns through the other
  - Because the AC reversals cause the voltage to pulse,
  - low-voltage pulsed DC flows out of the diodes

Power Adapter Components (part 3)

- Step 3: low-voltage pulsed DC to low-voltage DC
  - Performed by a capacitor: a charge storage device
  - Low-voltage pulsed DC flows into the capacitor
  - Capacitor stores charge when voltage is increasing
  - Capacitor releases charge when voltage is decreasing
  - The capacitor smoothes out the voltage pulses
  - Low-voltage DC flows out of the capacitor

Question 2

- Why can electrons move in metals not insulators?

Metals, Insulators, and Diodes

- Three different electrical behaviors:
  - Metals can carry current in any direction
  - Insulators can't carry current
  - Diode carry current only in one direction
- To understand a diode,
  - we need to understanding metals and insulators
  - so we must take a peek at quantum physics.

Quantum Physics (Part 1)

- Classical physics (pre-1900) thought that
  - everything in nature is a particle or a wave
  - electrons, atoms, and billiard balls are particles
  - light and sound are waves
- Modern physics (post-1900) recognizes that
  - everything in nature is both particle and wave
  - things are most wave-like as they move unobserved
  - things are most particle-like when they interact

Quantum Physics (Part 2)

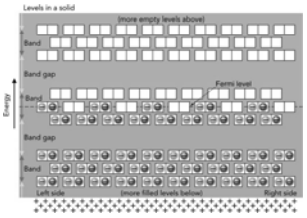
- Example 1: light
  - travels as waves (electromagnetic waves)
  - is emitted and absorbed as particles (photons)
- Example 2: electrons
  - are emitted and detected as particles (electrons)
  - travel as waves (matter waves)
  - reside in atoms and solids as standing waves

Electrons in Solids (Part 1)

- In a solid, each electron is a standing wave
  - Similar to the vibration of a string or a drumhead
  - Only certain standing waves fit properly in the solid
  - Each allowed standing wave is called a "level"
  - An electron's level determines its energy
- At most two electrons can occupy a single level
  - A consequence of the Pauli exclusion principle
  - and the electron's two possible spins: up and down

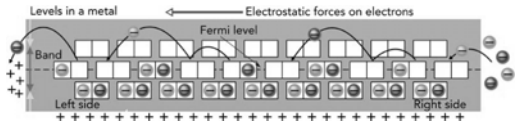
Electrons in Solids (Part 2)

- Electrons settle into a solid's lowest-energy levels
- Fermi level is between last filled and first unfilled
- The levels in a solid are not uniformly distributed in energy: they clump together in "bands" that are separated by "band gaps"



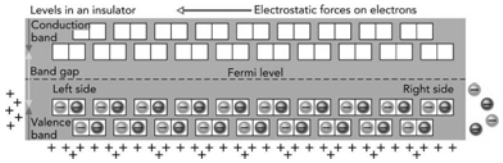
Metals

- In a metal,
  - the Fermi level has empty levels just above it
  - Like patrons in a partly filled theatre, electrons can move in response to electric fields
  - Currents can flow through a metal in any direction



Insulators

- In an insulator,
  - The Fermi level has no empty levels nearby
  - Like patrons in a full theatre, electrons can't move in response to electric fields
  - Current can't flow through an insulator

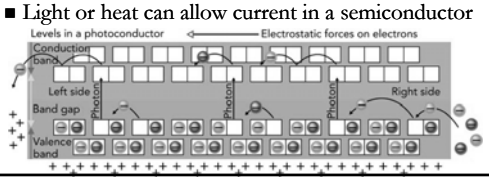


Question 3

- How does charge move in a semiconductor?

Semiconductors

- Pure semiconductors are "poor insulators"
  - A narrow band gap separates the full "valence" band below from the empty "conduction" band above
  - Like patrons in a full theatre with a low empty balcony, electrons can hop to the balcony and move
  - Light or heat can allow current in a semiconductor



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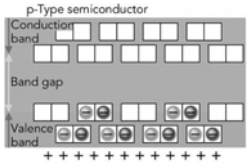
p-Type Semiconductor

- Adding impurity atoms to a semiconductor
  - changes the number of electrons it contains
  - alters the filling of its valence and conduction bands
- Impurities that reduce the number of electrons
  - leave some of the valence levels empty
  - and current can flow via those valence levels.
- p-type semiconductor



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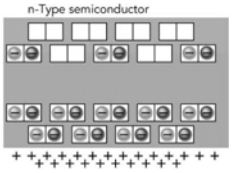
n-Type Semiconductor

- Impurities that increase the number of electrons
  - fill some of the conduction levels
  - and current can flow via those conduction levels.
- n-type semiconductor



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Question 4

- How does a diode carry current only one way?

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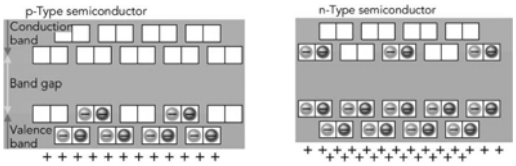
pn-Junction (before contact)

- Before p-type semiconductor meets n-type,
  - each material can conduct electricity
  - and each material is electrically neutral everywhere.



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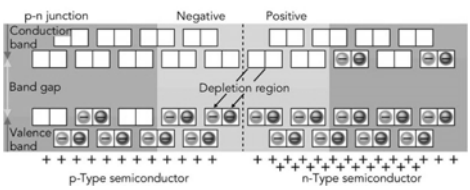
pn-Junction (after contact)

- After p-type semiconductor meets n-type,
  - electrons migrate from the n-type to the p-type
  - an insulating depletion region appears at junction
  - and that depletion region is electrically polarized.



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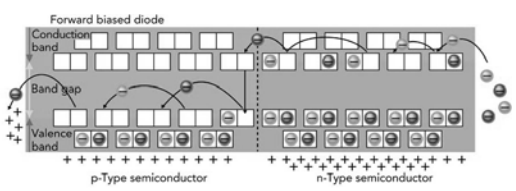
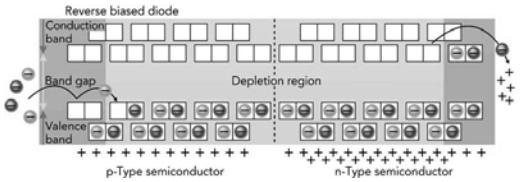
Forward Conduction

- When electrons are added to the n-type end and removed from the p-type end,
  - the depletion region shrinks
  - and the diode conducts current.



Reverse Conduction

- When electrons are added to the p-type end and removed from the n-type end,
  - the depletion region grows
  - and the diode does not conduct current.



Question 5

- How does a capacitor store electric charges?

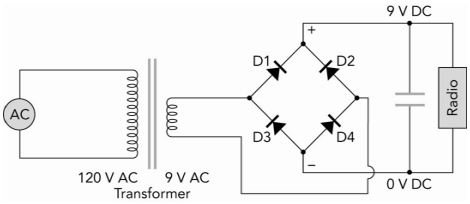
Capacitors

- A capacitor consists of
  - two conducting plates
  - an insulator that separates those plates.
- The capacitor can
  - accumulate equal but opposite charges on its plates
  - develop a voltage difference between its plates
  - store electrostatic potential energy
- Charge and voltage difference are proportional:

charge on positive plate = voltage difference · capacitance

Complete Power Adapter

- A transformer provides low-voltage AC,
- diodes convert that AC to pulsed DC,
- and a capacitor smoothes out the pulses.



Introductory Question (revisited)

- If you install a pocket radio's batteries backward, it won't work because its

A. speaker will move the wrong direction.
B. parts can only conduct current one way.
C. batteries will absorb power and recharge.

Summary about Power Adapters

- Use transformers to obtain low-voltage AC
- Use diodes to obtain low-voltage pulsed DC
- Use a capacitor to obtain low-voltage DC
- Semiconductor diodes make them practical