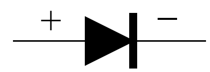
Diodes

- Schematic symbol:



- Signal diodes, power diodes

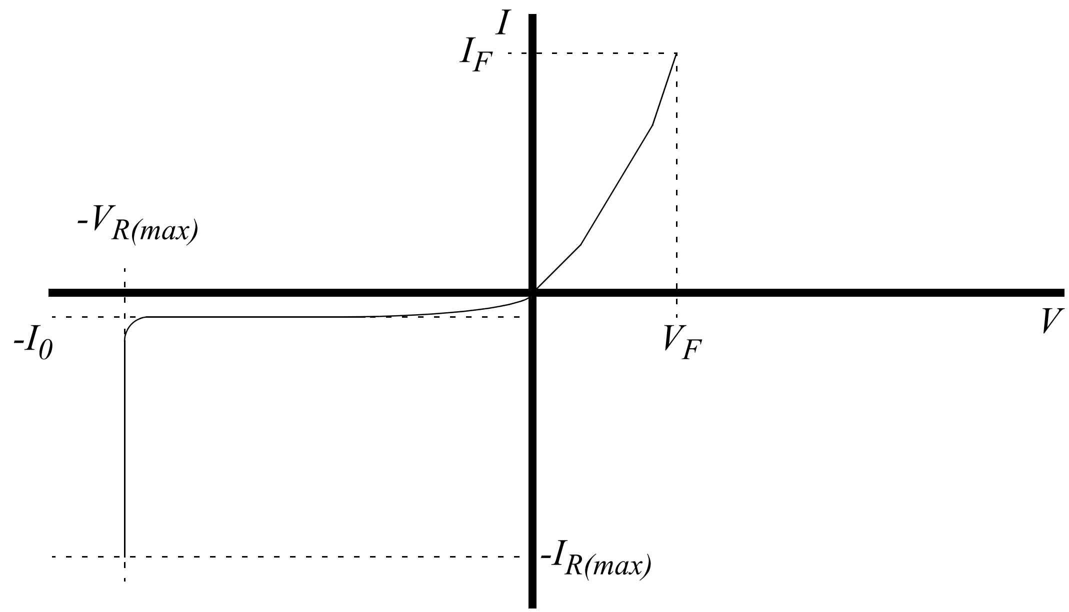
  $V_{R(\max)}$: Maximum reverse voltage

  $I_{R(\max)}$: Maximum reverse current

  V_F: Typical forward voltage drop

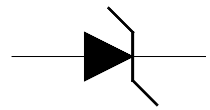
  Maximum power dissipated

  Capacitance

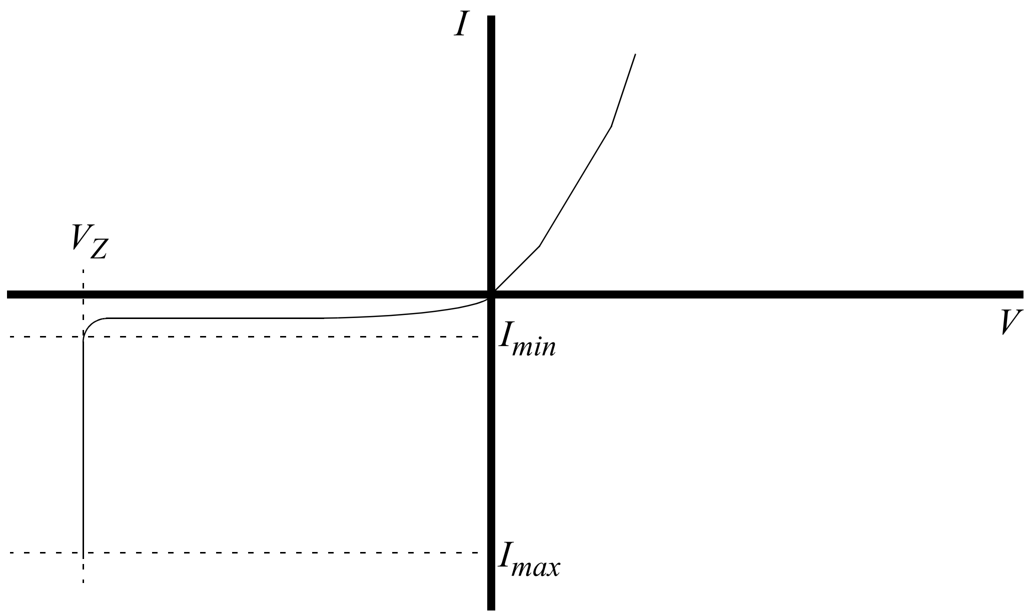


Zener Diode

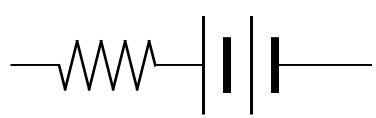
- Schematic symbol:



- Zener diodes have well defined reverse breakdown voltages and they are designed to run there.
- Voltage change is very small (1%) over a wide range of operating current.

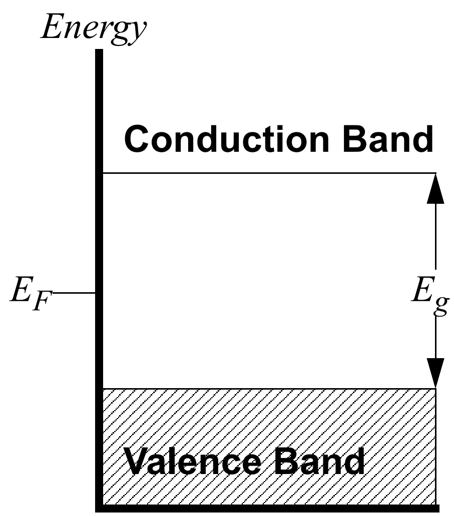


- Equivalent circuit: battery and a resistor.



Photoconduction

- Electrons can be excited from a valence band to a conduction band by photons.



E_g = 1.09 eV in Silicon (Si)

E_g = 0.72 eV in Germanium (Ge)

- The minimum energy of a photon needed to excite an electron across the gap is equal to the energy of the gap. the frequency of that photon is given by

$$E_g = h\nu = hc/\lambda$$

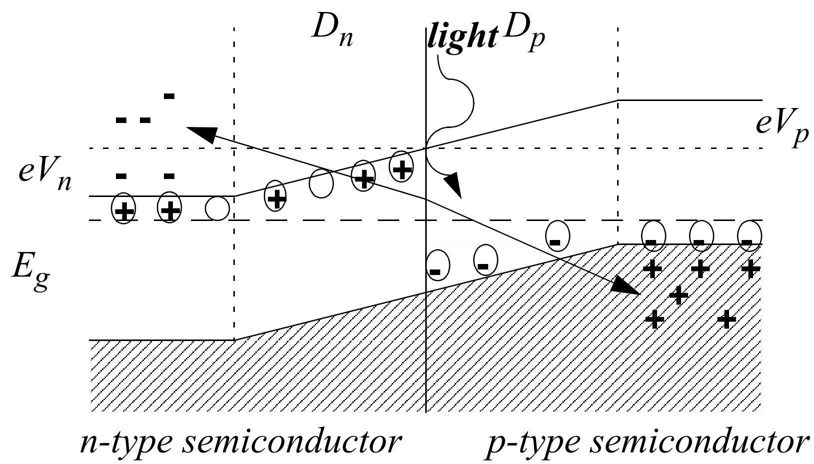
In Si: $\lambda = hc/E_g$ = (1.24 μm-eV)/(1.09 eV) = 1140 nm

In Ge: λ = (1.24 μm-eV)/(0.72 eV) = 1720 nm

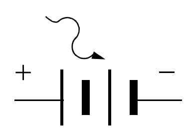
- These wavelengths are in the near-infrared. Visible light is more energetic (350 to 700 nm).

Photovoltaic Diode

- Light falling on a p-n junction can create electrons and holes



- Electrons move to the n-type material, holes to the p-type material.
- The electrons and holes create a potential between the two sides of the junction. This appears as a reverse current I_L.
- A photocell acts like a battery.



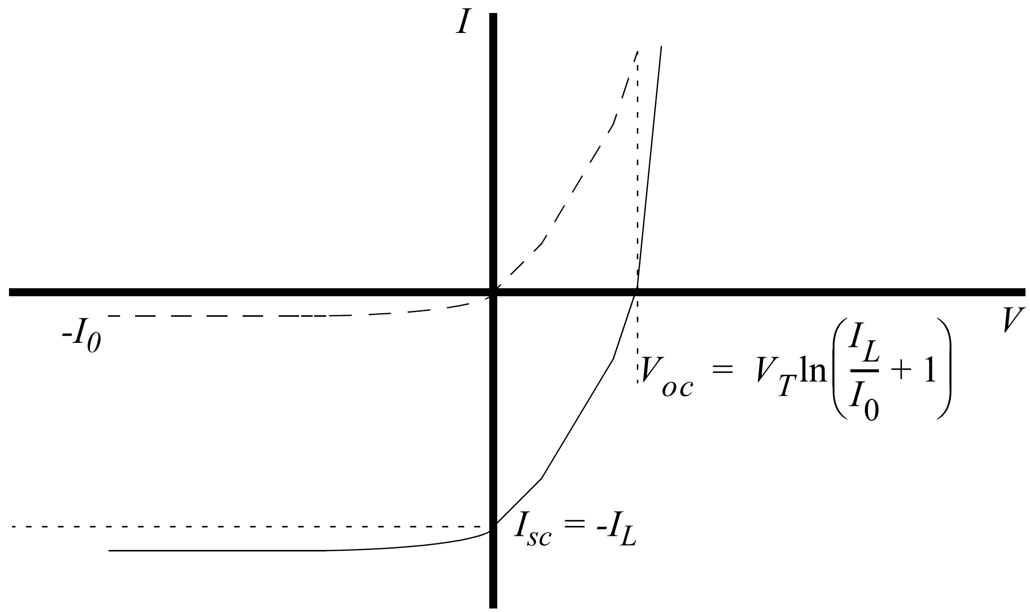
- Solar cells connect multiple photocells in series to get the desired output voltage, and in parallel to get the needed current.
- At 10 % efficiency a solar battery can deliver 100 W/m^2. Averaged over a real day with real weather reduces this.

Photocurrent

- The total current for the photovoltaic diode is

$$I = I_0(e^{V/V_T} - 1) - I_L$$

Graphically

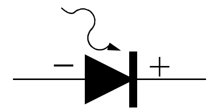


- The equivalent voltage is typically 0.6 V for silicon.
- V_D = 0.5 - 0.6 V "diode drop"
- The theoretical maximum voltage is equal to gap voltage V_g, but the real voltage is determined by the current.

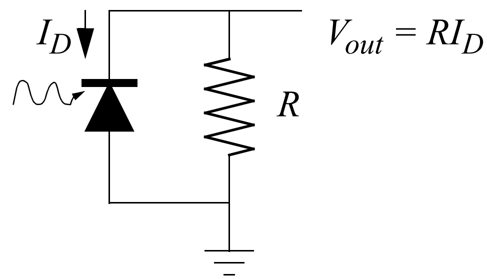
Photodiode

Photodiode as a Light Meter

- Photodiode schematic symbol.



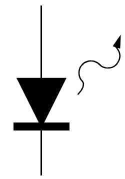
- A resistor converts the current to a voltage



- Typical currents are 1 μA/μW incident light.

Light Emitting Diode (LED)

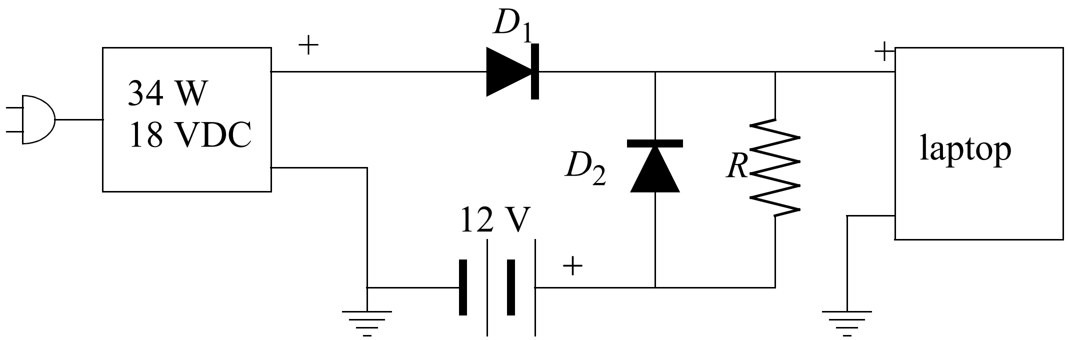
- Forward biased diode, loses energy as light as well as heat.
- Schematic symbol



- An ohmmeter can be used to check the polarity
- Voltage requirements: turn on at 1.7 V (1.5 V - 2.5 V).
- Current requirements: 1 mA is dim, 10-20 mA is bright.

Diode Gates

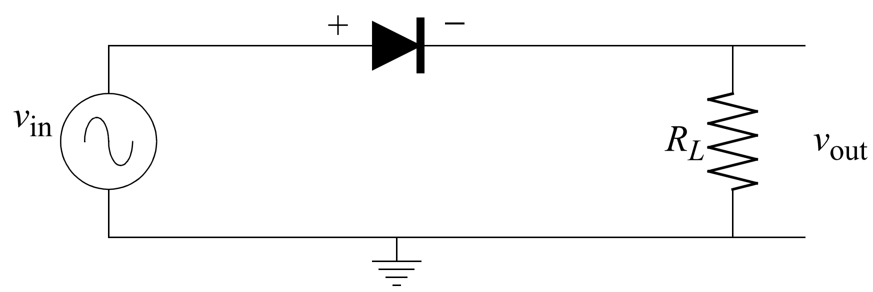
- Diodes can be used to select the higher of two voltages
- Example: battery backup for a laptop



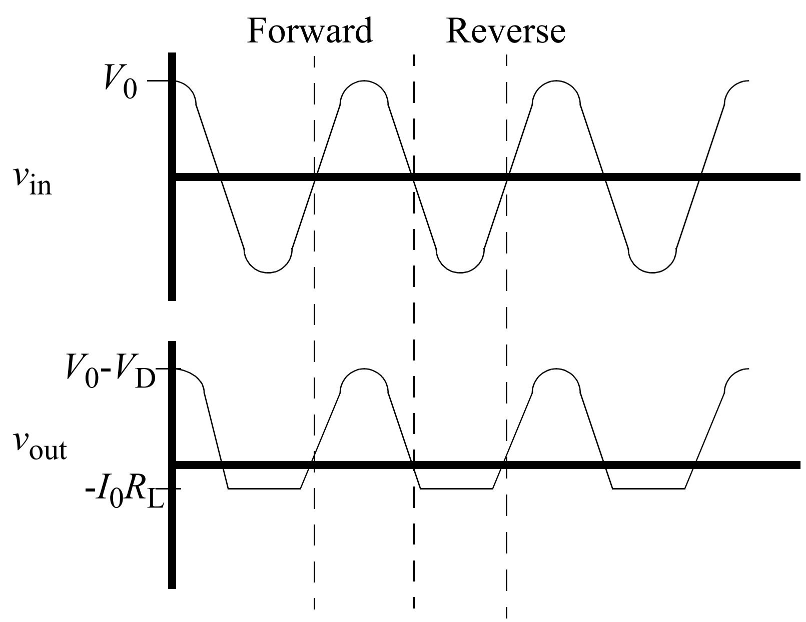
- If the power cord is plugged in, current flows through D_1 and the input voltage to the laptop is 17.4 V. D_2 doesn't conduct since 17.4 V is greater than 12 V.
- If the power cord is unplugged, there is no current through D_1 so D_2 conducts and there is 11.4 V to the laptop.
- The resistor R will have a current in it if the power cord is plugged in. The current is (17.4 V - 12 V)/R. If it takes 10 mA of current to charge the 12 V battery, then R = 5.4 V/10 mA = 540 Ω.

Half-wave Rectifier

- Single diode, AC signal

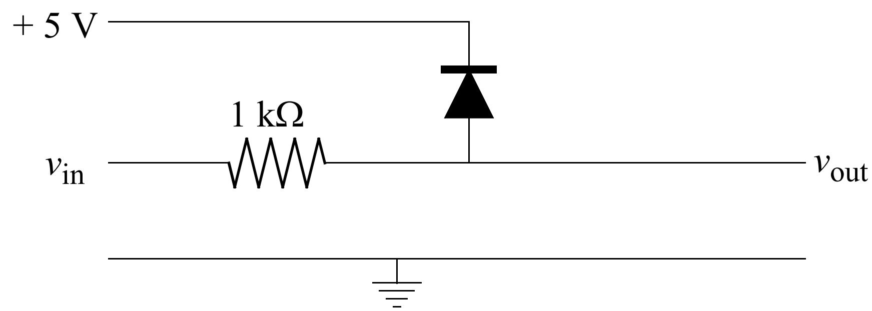


- Forward biased the signal passes, reverse biased the signal is blocked



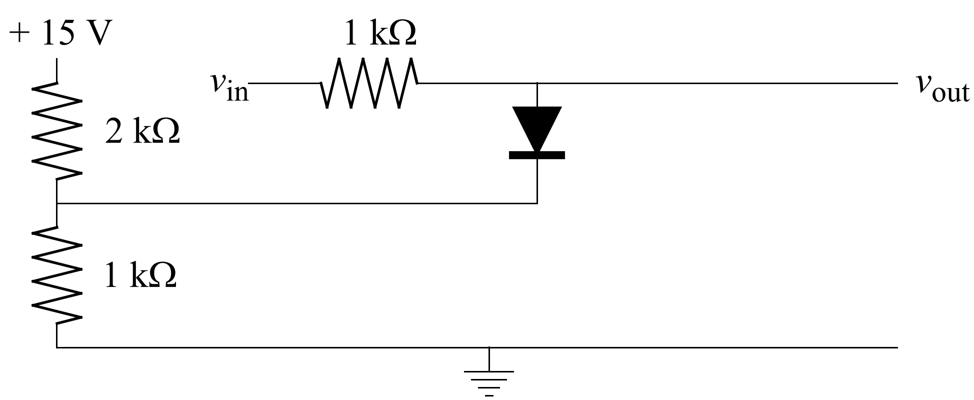
Diode Clamp

- Cutoff current at voltages other than ground



If $v_{in} > 5.6$ V, $v_{out} = 5.6$ V.

- The reference voltage can be set with a voltage divider



- The voltage divider has a Thevenin equivalent circuit of 5 V and 670 Ω.
- The input resistor then forms a divider with the 670 Ω and not all the current goes through the diode. Use $R_{input} >> R_{divider}$.