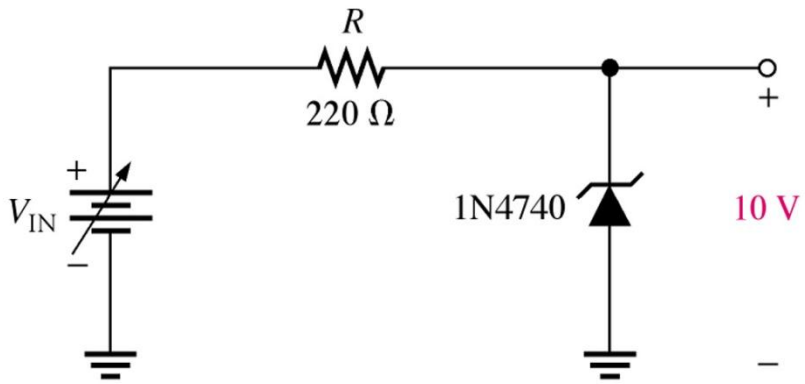
Diodes and Optoelectronic Devices

Introduction

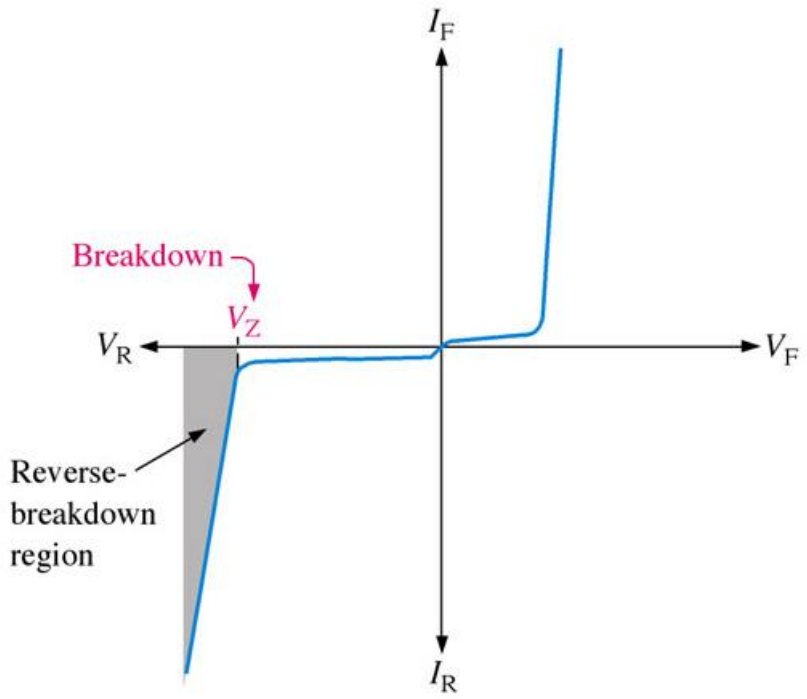
The basic function of zener diode is to maintain a specific voltage across its terminals within given limits of line or load change. Typically it is used for providing a stable reference voltage for use in power supplies and other equipment.



This particular zener circuit will work to maintain 10 V across the load.

Zener Diodes

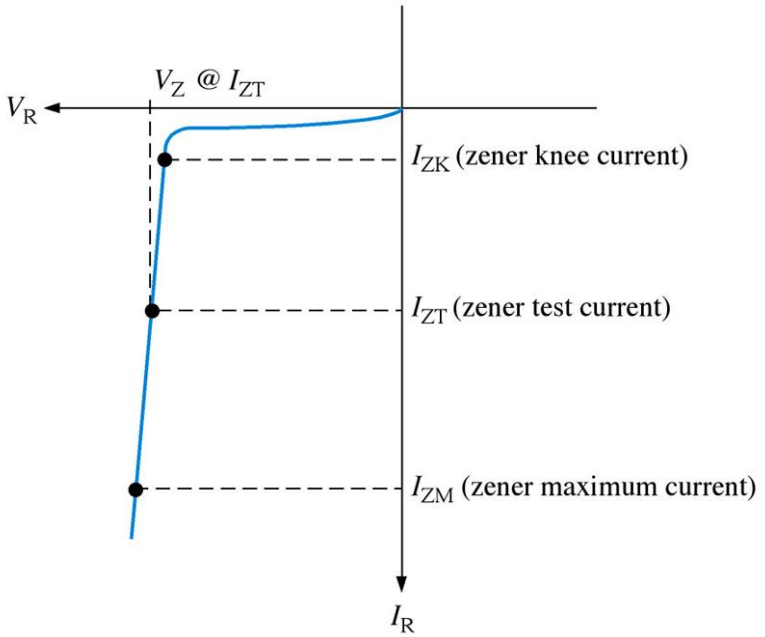
A zener diode is much like a normal diode, the exception being is that it is placed in the circuit in reverse bias and operates in reverse breakdown. This typical characteristic curve illustrates the operating range for a zener. Note that its forward characteristics are just like a normal diode.



(b) The normal operating region for a zener diode is shaded.

Zener Diodes

The zener diode's breakdown characteristics are determined by the doping process. Low voltage zeners less than 5V operate in the zener breakdown range. Those designed to operate more than 5 V operate mostly in avalanche breakdown range. Zeners are available with voltage breakdowns of 1.8 V to 200 V.



Zz=

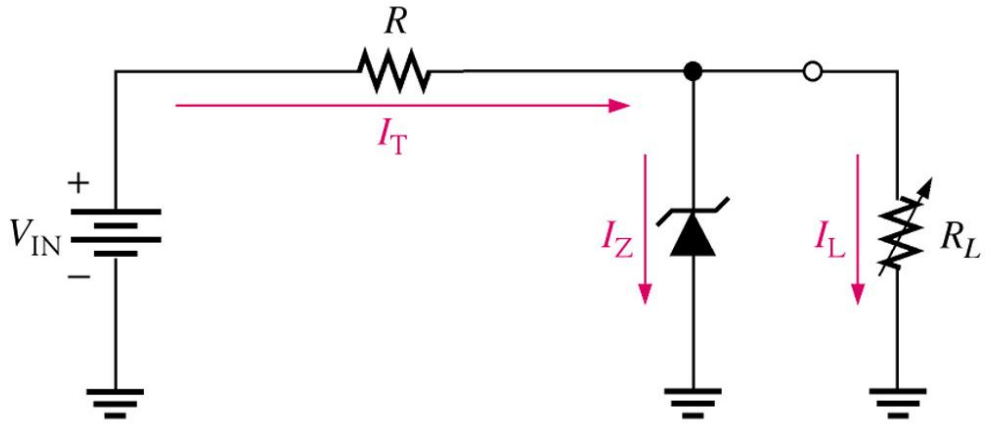
$$\Delta Vz / \Delta Iz$$

This curve illustrates the minimum and maximum ranges of current operation that the zener can effectively maintain its voltage.

Zener Diode Applications

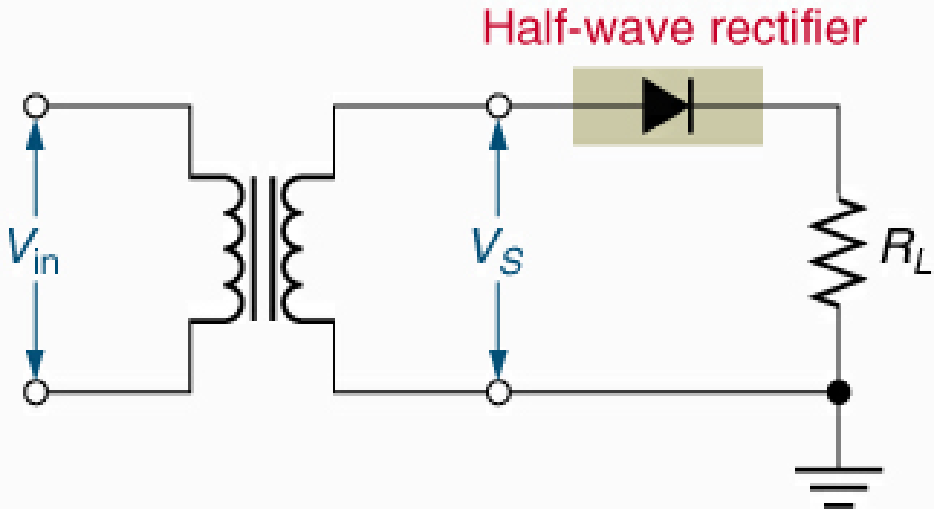
Regulation

In this simple illustration of zener regulation circuit, the zener diode will "adjust" its impedance based on varying input voltages and loads (R_L) to be able to maintain its designated zener voltage. Zener current will increase or decrease directly with voltage input changes. The zener current will increase or decrease inversely with varying loads. Again, the zener has a finite range of operation.

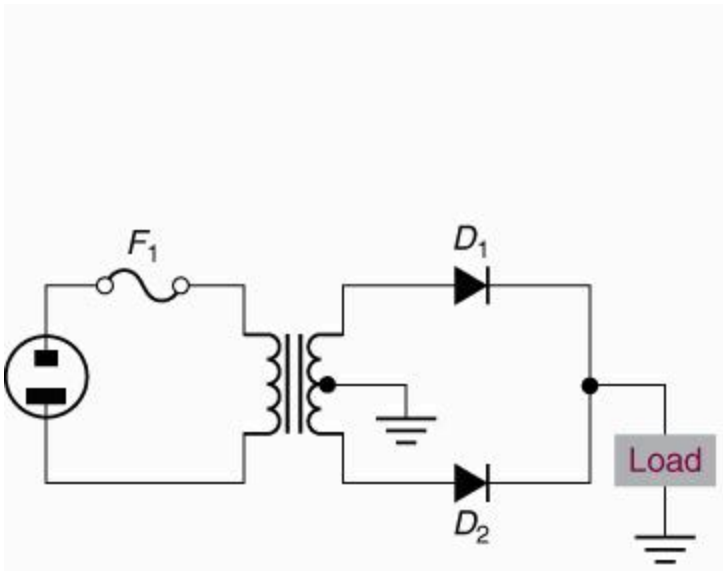


Rectifier Diode

- Half-wave rectifier – A diode placed in series between a transformer (or ac line input) and its load.

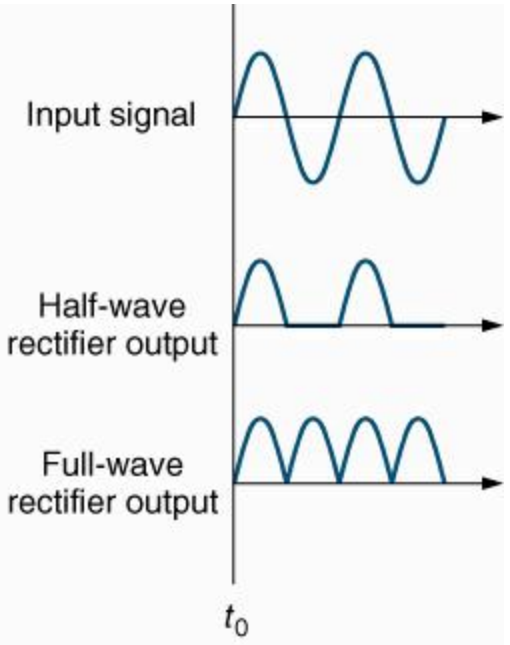


Full-wave Rectifier Diode



A full-wave rectifier

(a)

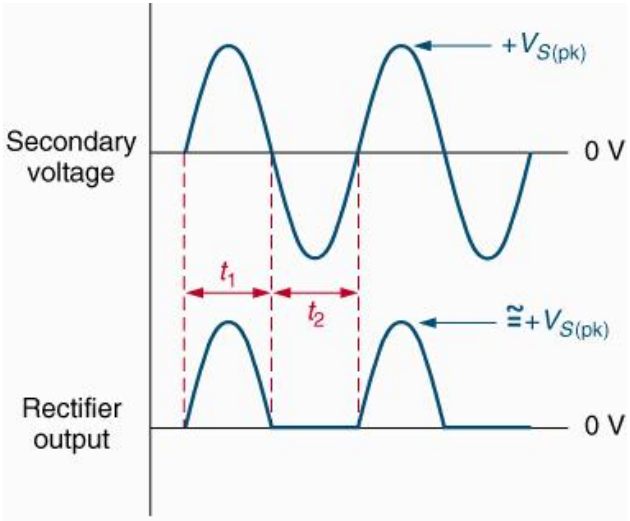


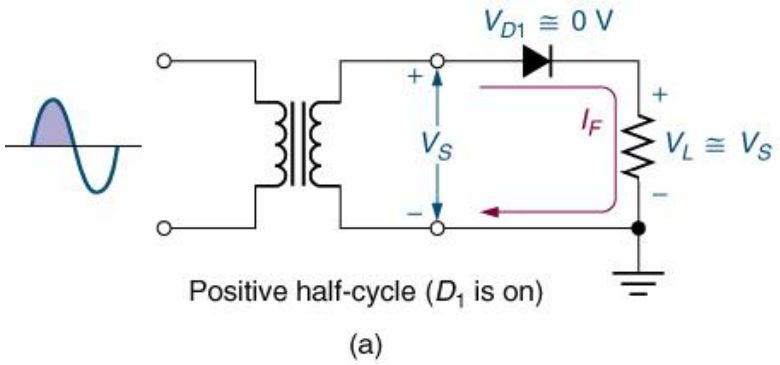
Typical rectifier waveforms

(b)

Positive Half-wave Rectifiers

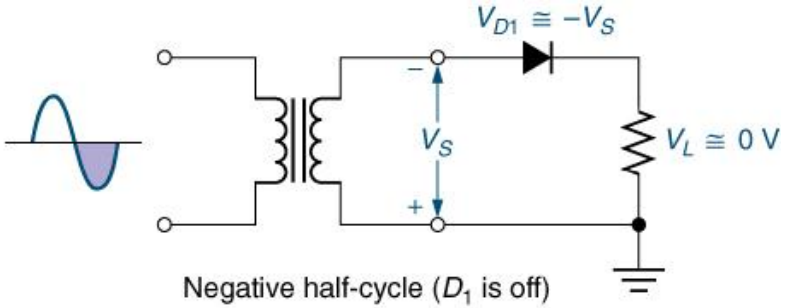
This circuit converts an ac input to a series of positive pulses.





Positive half-cycle (D_1 is on)

(a)

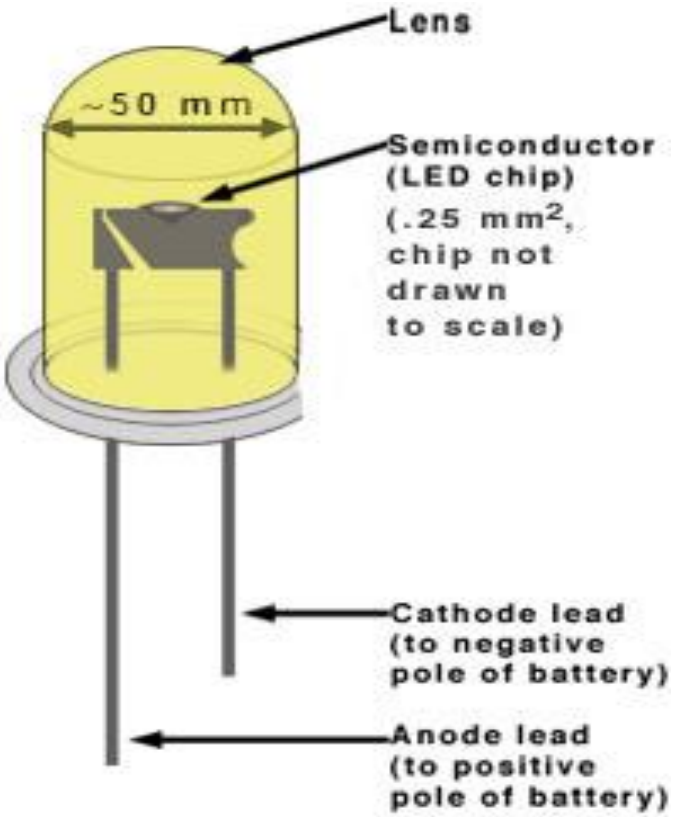


Negative half-cycle (D_1 is off)

(b)

LIGHT EMITTING DIODE (L E D)

Getting to know LED



Advantages of Light Emitting Diodes (LEDs)

Longevity:

The light emitting element in a diode is a small conductor chip rather than a filament which greatly extends the diode's life in comparison to an incandescent bulb (10 000 hours life time compared to ~1000 hours for incandescence light bulb)

Efficiency:

Diodes emit almost no heat and run at very low amperes.

Greater Light Intensity:

Since each diode emits its own light

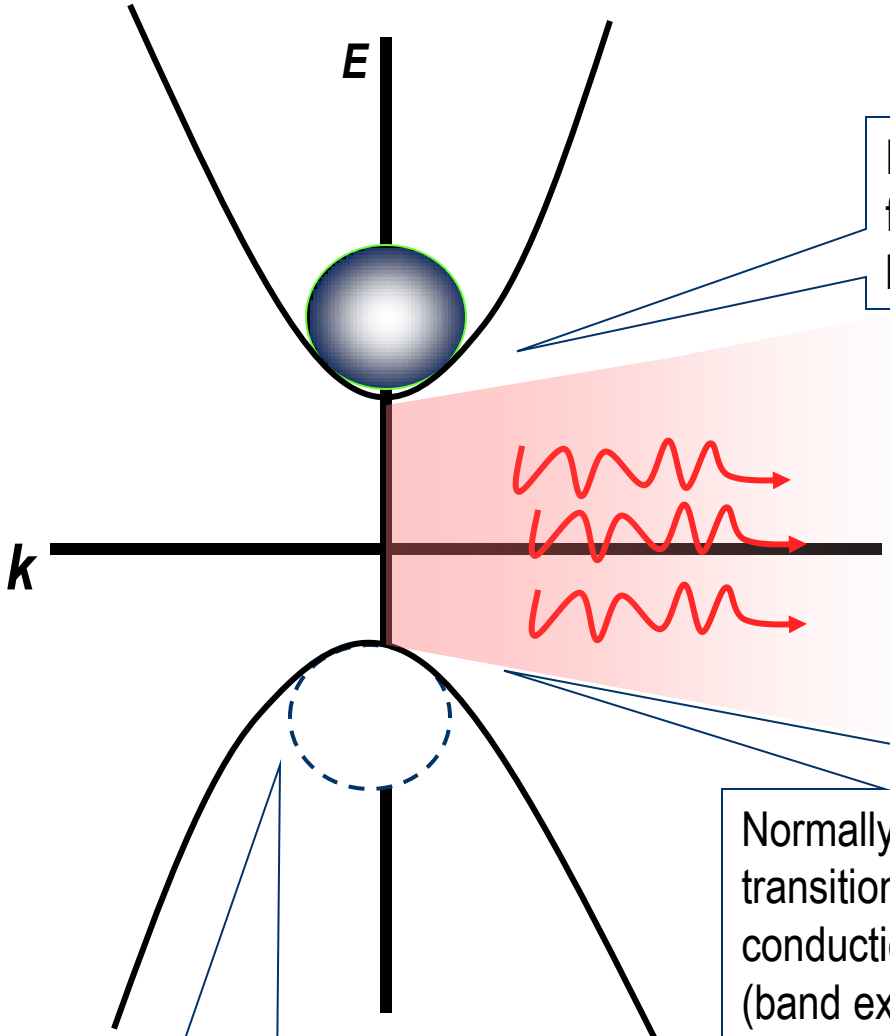
Cost:

Not too bad

Robustness:

Solid state component, not as fragile as incandescence light bulb

Excitation



Electron (excited by the biased forward voltage) is in the conduction band

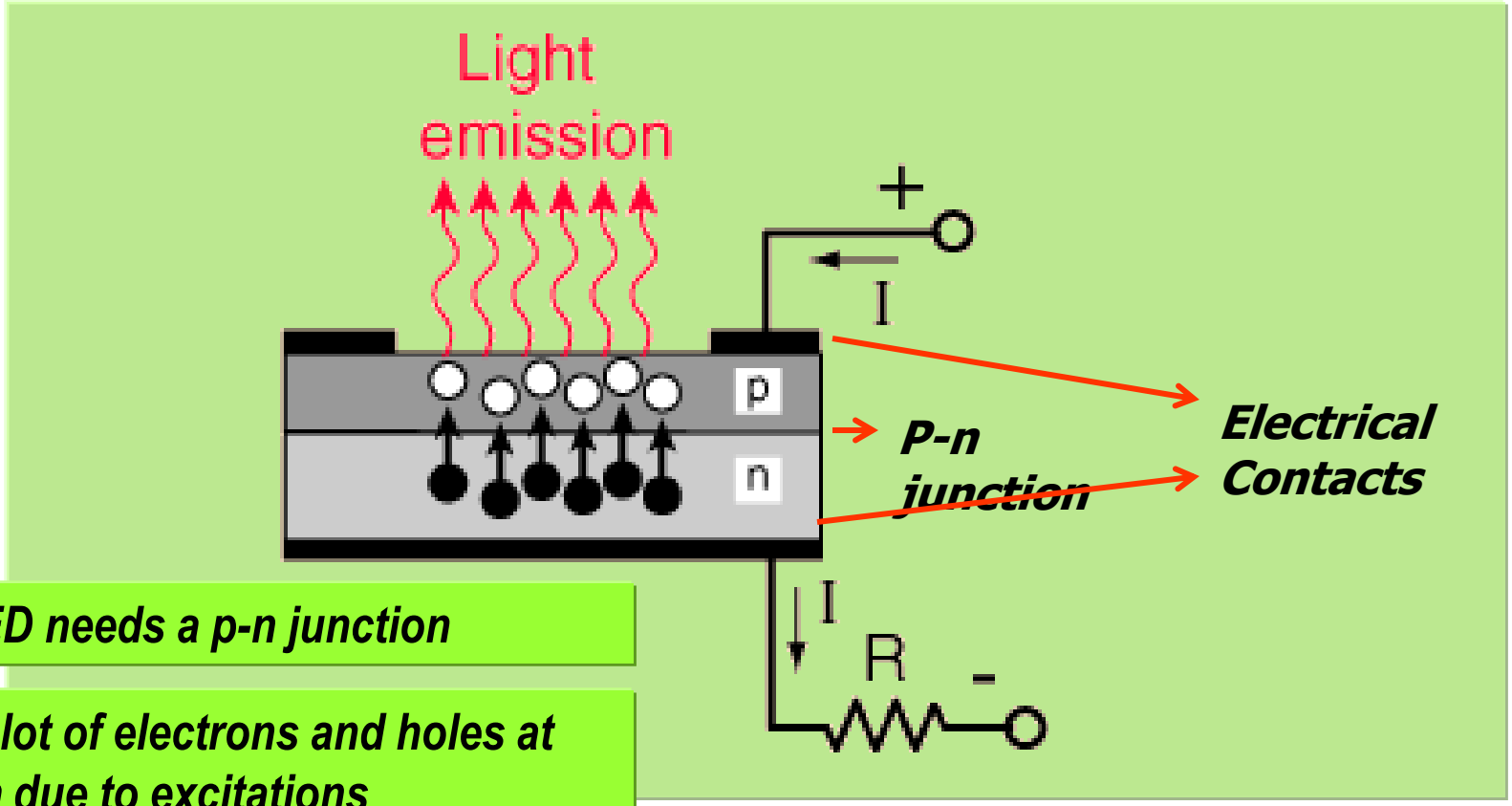
Hole is in valance band

Normally the recombination takes place between transition of electrons between the bottom of the conduction band and the top of the valance band (band exterma).

The emission of light is therefore;

$hc/\lambda = E_c - E_v = E_g$(only direct band gap allows radiative transition)

How does it work?



A typical LED needs a p-n junction

There are a lot of electrons and holes at the junction due to excitations

Electrons from n need to be injected to p to promote recombination

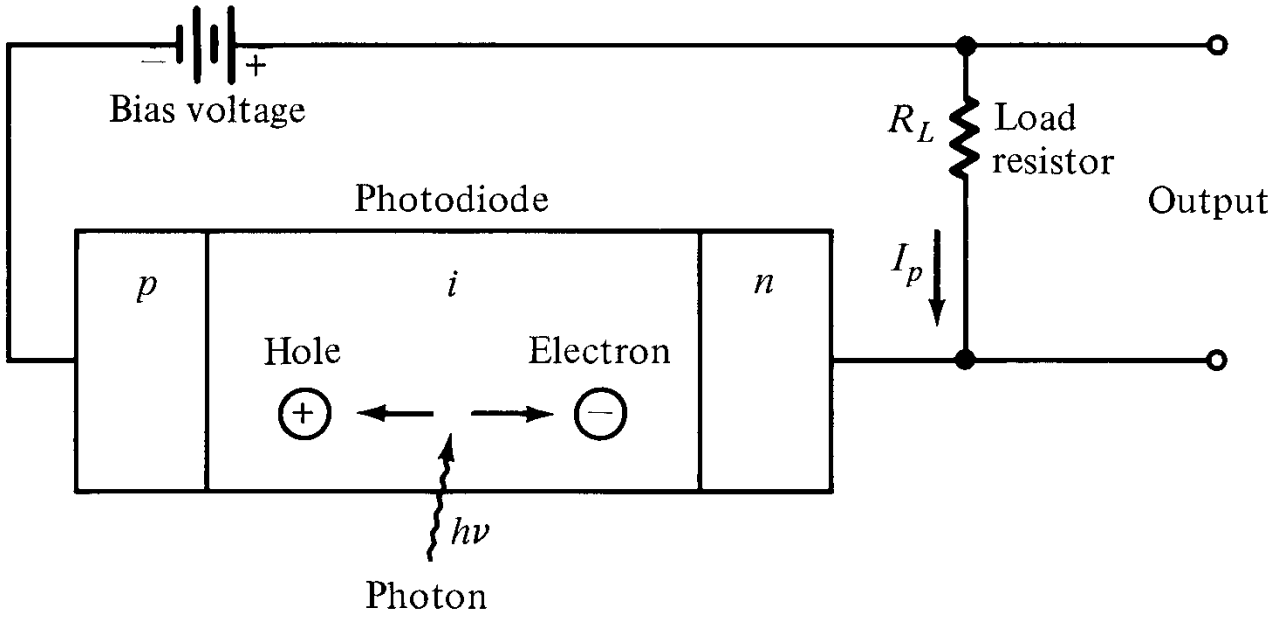
Junction is biased to produce even more e-h and to inject electrons from n to p for recombination to happen

Recombination produces light!!

Photodiodes

- Due to above requirements, only *photodiodes* are used as photo detectors in optical communication systems
- Positive-Intrinsic-Negative (*pin*) photodiode
  - No internal gain
- Avalanche Photo Diode (*APD*)
  - An internal gain of *M* due to self multiplication
- Photodiodes are *reverse biased* for normal operation

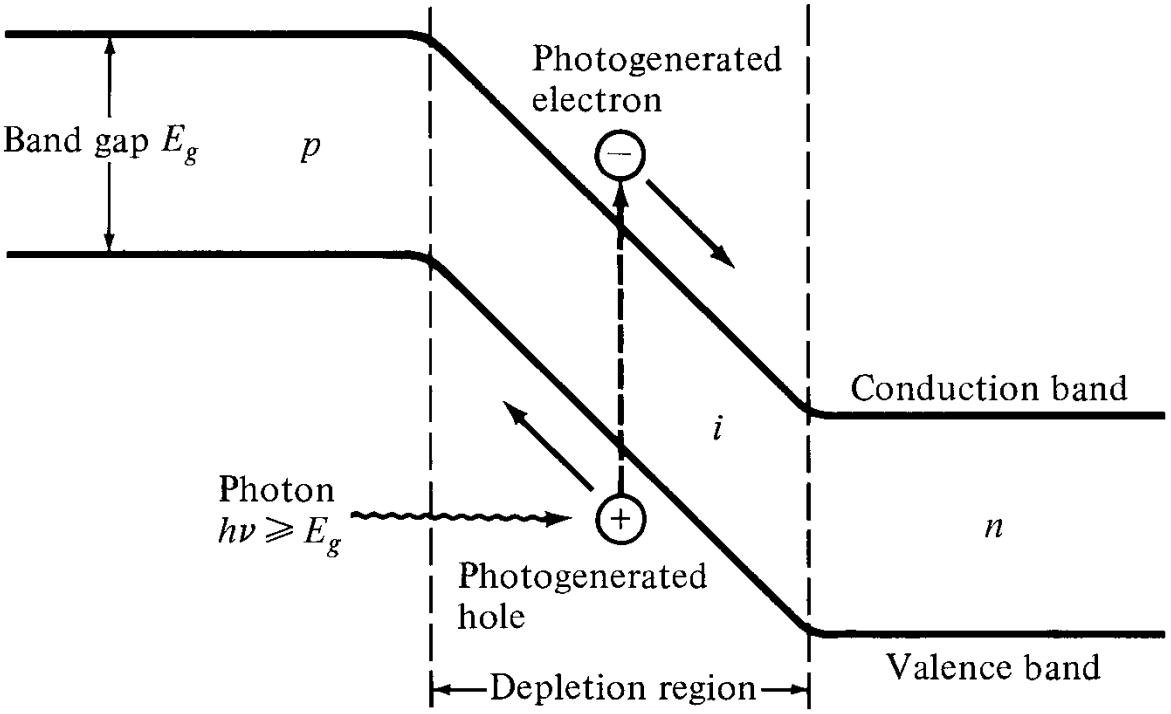
Basic *pin* photodiode circuit



- Incident photons trigger a *photocurrent* I_p in the external circuitry

Photocurrent ∝ Incident Optical Power

pin energy-band diagram



$$\lambda_c = \frac{hc}{E_g}$$

Cut off wavelength depends on the bandgap energy

Working of APD:-

A photon is absorbed in the depletion region, creating a free electron and a free hole. The large electrical forces cause these charges to accelerate, gaining kinetic energy. When fast charges collide with neutral atoms, they create additional electron-hole pairs by using part of their kinetic energy to raise electrons across the energy bandgap. One accelerating charge can generate several secondary charges. The secondary charges can themselves accelerate and create even more electron-hole pairs; this is the process of avalanche multiplication.

APPLICATIONS OF PHOTODETECTORS :-

1. P-N photodiodes are used in similar applications to other photodetectors, such as photoconductors, charge-coupled devices, and photomultiplier tubes.
2. Photodiodes are used in consumer electronics devices such as compact disc players, smoke detectors, and the receivers for remote controls in VCRs and televisions.
3. In other consumer items such as camera light meters, clock radios (the ones that dim the display when it's dark) and street lights, photoconductors are often used rather than photodiodes, although in principle either could be used.
4. Photodiodes are often used for accurate measurement of light intensity in science and industry. They generally have a better, more linear response than photoconductors.

Introduction

Solar cell: Solar cell is a photovoltaic device that converts the light energy into electrical energy based on the principles of photovoltaic effect

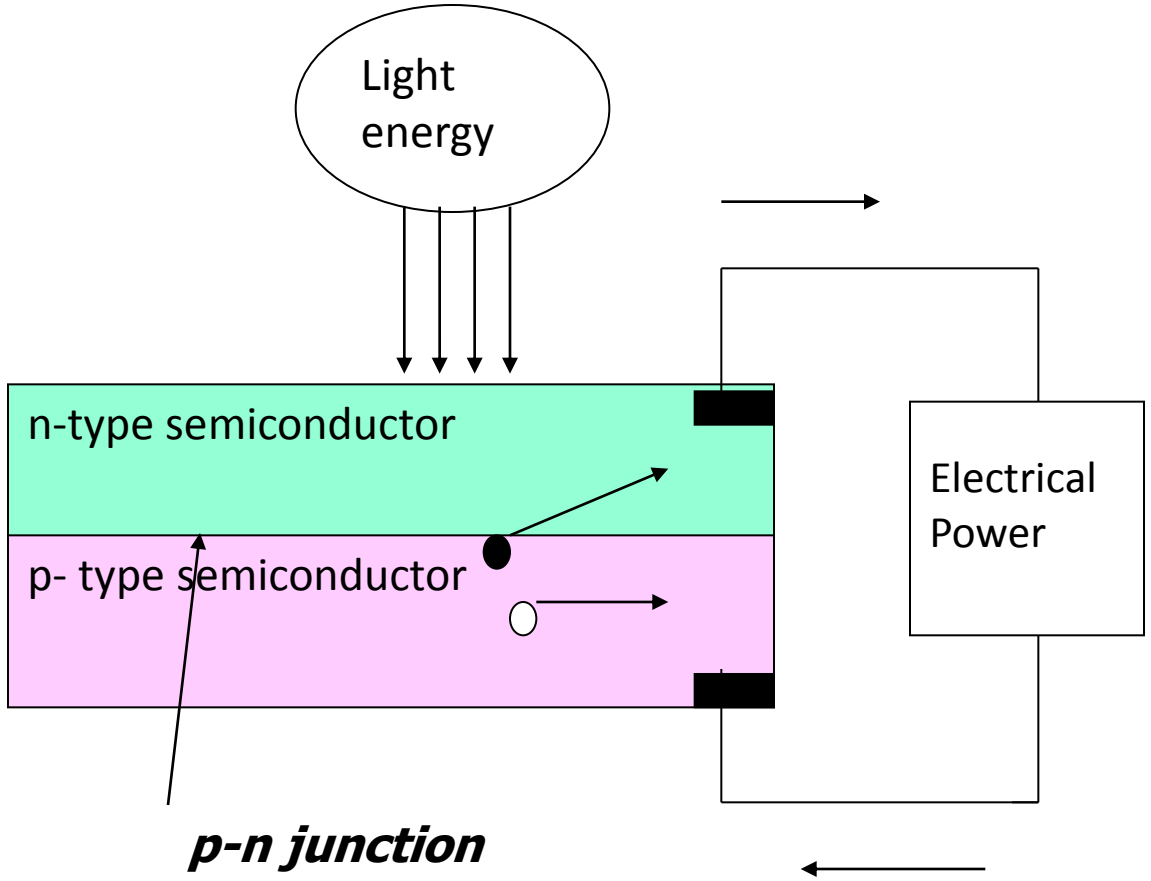
Albert Einstein was awarded the 1921 Nobel Prize in physics for his research on the photoelectric effect—a phenomenon central to the generation of electricity through solar cells.

In the early stages, the solar cell was developed only with 4 to 6 % efficiency(because of inadequate materials and problems in focusing the solar radiations). But, after 1989, the solar cells with more than 50% efficiency was developed.

Photovoltaic effect

Definition:

The generation of voltage across the PN junction in a semiconductor due to the absorption of light radiation is called photovoltaic effect. The Devices based on this effect is called photovoltaic device.

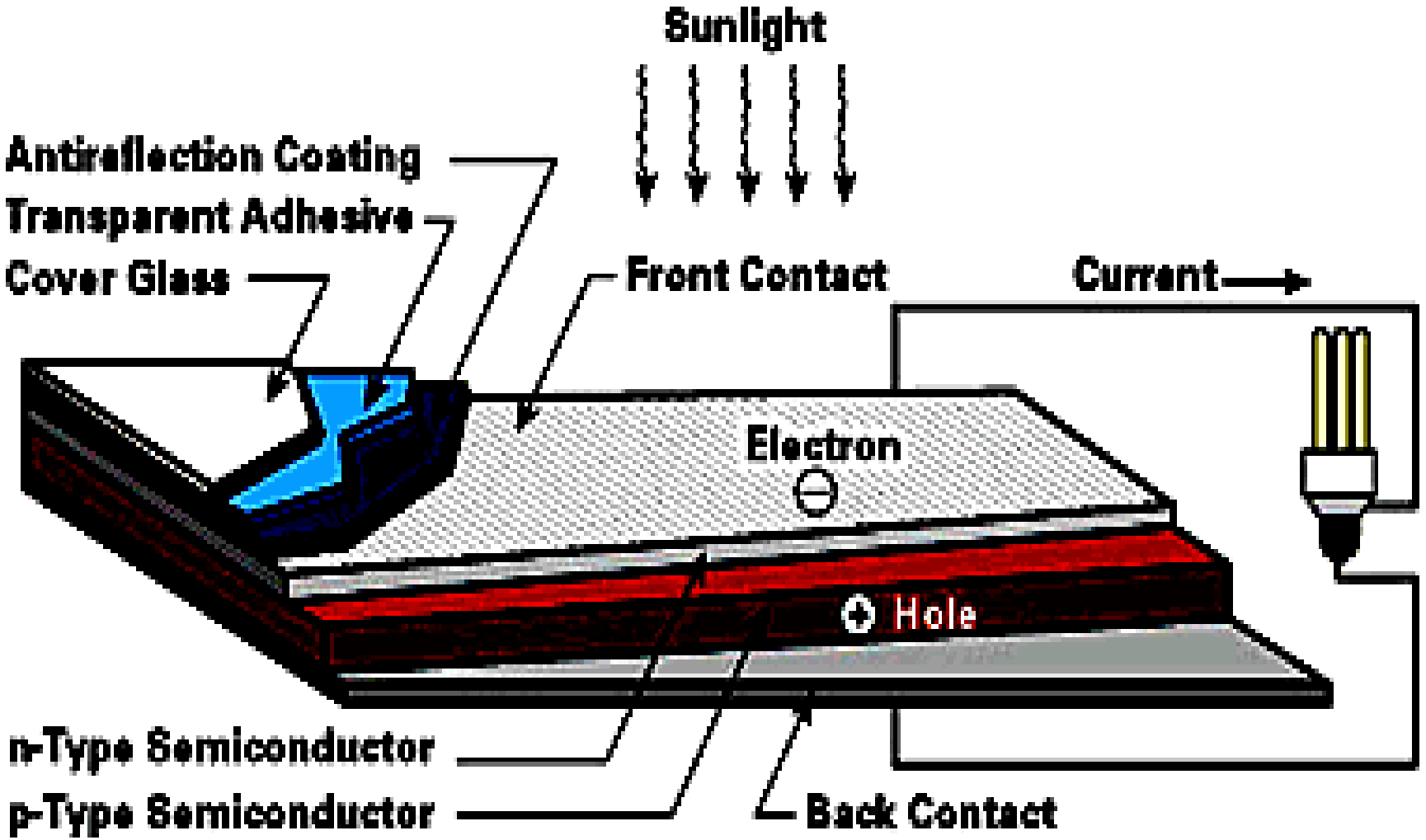


Principle, construction and working of Solar cell

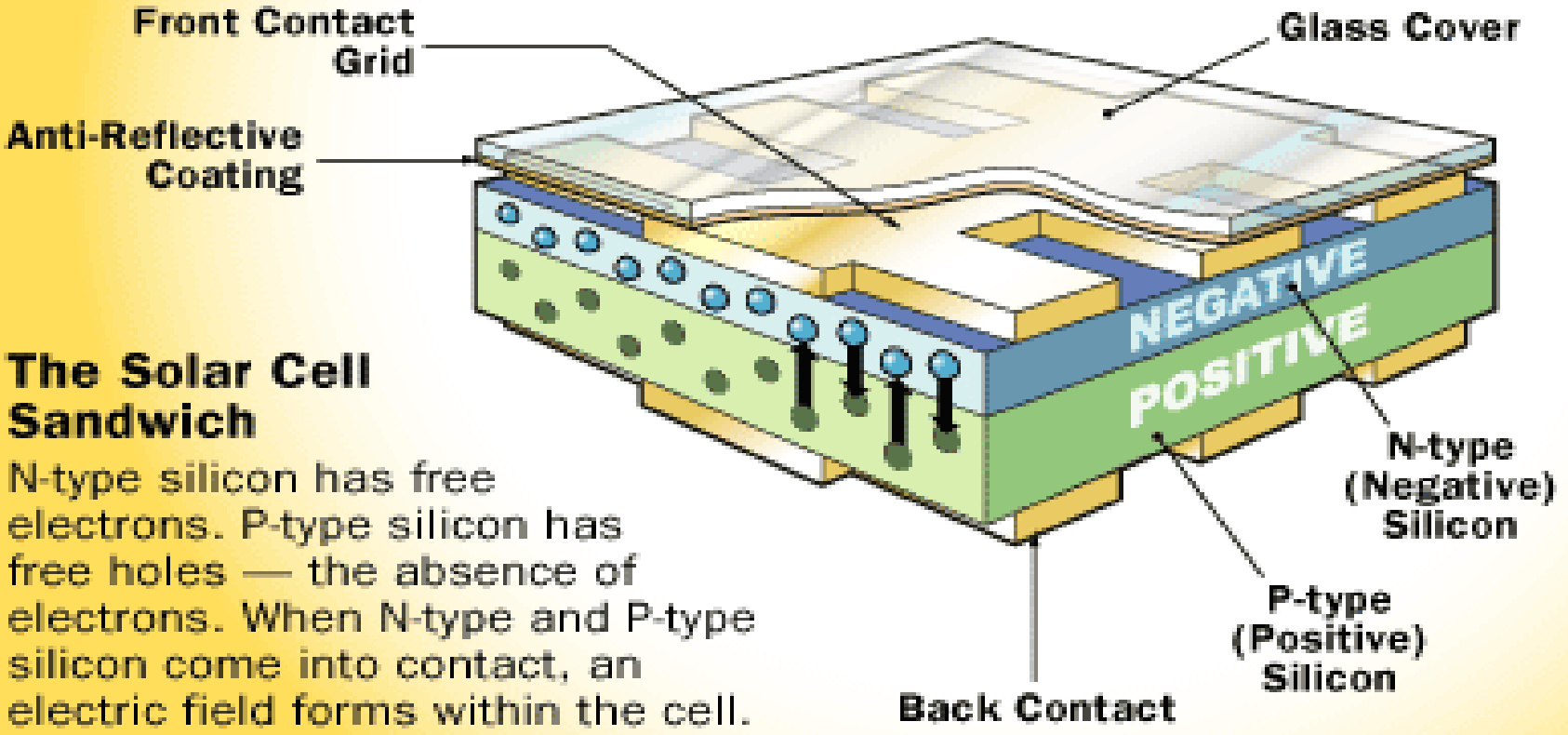
Principle: *The solar cells are based on the principles of photovoltaic effect.The photovoltaic effect is the photogeneration of charge carriers in a light absorbing materials as a result of absorption of light radiation.*

Construction

- *Solar cell (crystalline Silicon) consists of a n-type semiconductor (emitter) layer and p-type semiconductor layer (base). The two layers are sandwiched and hence there is formation of p-n junction.*
- *The surface is coated with anti-refection coating to avoid the loss of incident light energy due to reflection*


Sunlight
Antireflection Coating
Transparent Adhesive
Cover Glass
Front Contact
Current
Electron
Hole
n-Type Semiconductor
p-Type Semiconductor
Back Contact

How Solar Cells Work



The Solar Cell Sandwich

N-type silicon has free electrons. P-type silicon has free holes — the absence of electrons. When N-type and P-type silicon come into contact, an electric field forms within the cell.

- ***A proper metal contacts are made on the n-type and p-type side of the semiconductor for electrical connection***

Working:

- ***When a solar panel exposed to sunlight , the light energies are absorbed by a semiconduction materials.***
- ***Due to this absorded enrgy, the electrons are libereted and produce the external DC current.***
- ***The DC current is converted into 240-volt AC current using an inverter for different applications.***

Advantage, disadvantage and application of Solar cell

Advantage

1. *It is clean and non-polluting*
2. *It is a renewable energy*
3. *Solar cells do not produce noise and they are totally silent.*
4. *They require very little maintenance*
5. *They are long lasting sources of energy which can be used almost anywhere*
6. *They have long life time*
7. *There are no fuel costs or fuel supply problems*

Disadvantage

1. ***Solar power can be obtained in night time***
2. ***Soalr cells (or) solar panels are very expensive***
3. ***Energy has not be stored in batteries***
4. ***Air pollution and whether can affect the production of electricity***
5. ***They need large are of land to produce more efficient power supply***