Lesson 23: Introduction to Solar Energy and Photo Cells

ET 332a

Dc Motors, Generators and Energy Conversion Devices

Learning Objectives

After this presentation you will be able to:

- Identify the solar spectrum
- Determine the angle that captures the maximum solar energy
- Explain the atomic difference between conductor, insulators, and semiconductors
- Explain physics behind the photoelectric effect
- Compute the open circuit voltage and short circuit current of a photocell

Solar Energy and Photocells

Solar Spectrum

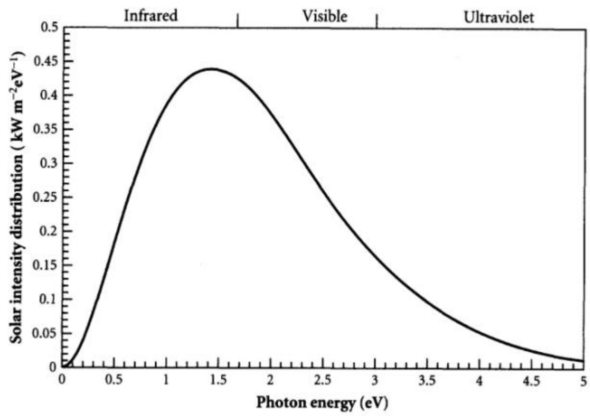


Fig. 6.1 Black-body spectrum at $T = 5800$ K. The total intensity is normalized to that of the AM1.5 solar spectrum of 1 kW m^{-2}.

AM0 =1.36 kW/m^2
Incident on Atmosphere

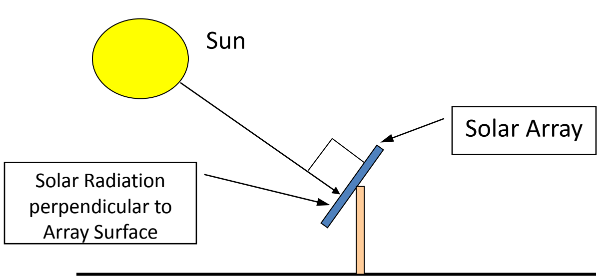
AM1.5-1.0 kW/m^2
Passing through Atmosphere

Incident to 48^0angle to vertical

Includes absorption of water vapor, $C0_2$, methane.

Solar Energy Conversion

Direct Radiation depends on season, location, cloudiness. Yearly average 30% Average Intensity (W/m^2) 10% in lower Canada to 50% in tropics



Defuse Radiation unfocusable. Long wavelengths scatter more color sky blue.

Solar Intensity

Example: Direct sunlight with an average intensity of 450 W/m[2] is incident perpendicularly to a solar cell. The cell has an area of 0.15 m[2]. Calculate to total incident energy on the cell for one day in kWh. What is the percentage energy reduction if the sunlight falls on the cell at 35 degrees from perpendicular?

$I := 450 \cdot W \cdot m^{-2}$ Incident solar energy

$A := 0.15 \cdot m^2$ Solar cell area

$P := I \cdot A$ $P = 67.5\,W$

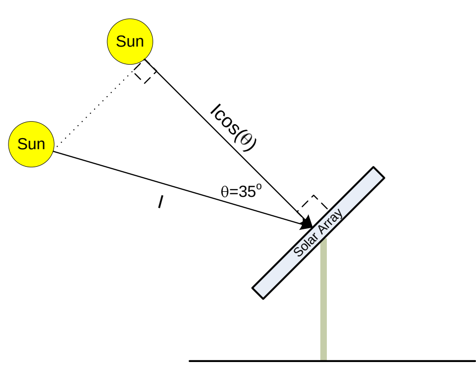
Power multiplied by time gives energy

$t := 24 \cdot hr$

$E := P \cdot t$ $E = 1620\,W \cdot hr$

$E \cdot \frac{1 \cdot kWh}{1000 \cdot W \cdot hr} = 1.62\,kWh$ Convert to Kilowatt-hours

Solar Intensity



Example: cont.

$\theta := 35 \cdot deg$

$P_{30} := I \cdot \cos(\theta) \cdot A$ $P_{30} = 55.3\,W$

Power multiplied by time gives energy

$t := 24 \cdot hr$

$E_{30} := P_{30} \cdot t$ $E_{30} = 1327\,W \cdot hr$

$E_{30} \cdot \frac{1 \cdot kWh}{1000 \cdot W \cdot hr} = 1.3\,kWh$ Convert to Kilowatt-hours

$\%Reduction := \left(\frac{E - E_{30}}{E}\right)$ $\%Reduction = 18.1\%$

Conductors, Insulators and Semiconductors

Conductors – Free electrons in atomic structure
Valence electrons form current when electric potential applied.
Examples: copper, silver

Insulators – No free electrons in valence band
Examples: glass, plastics.

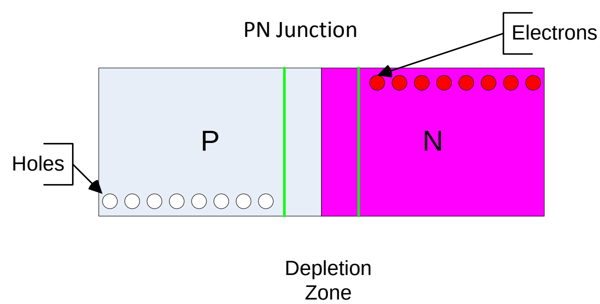
Semiconductors – Valence electrons exist
Bonded to other atoms
Bonds broken by external energy like heat or light
Examples: Silicon, Germanium

Semiconductors

Doped Semiconductors – Impurities added to increase conductance

P-type semiconductor - excess holes (absent electrons)
N-type semiconductor – excess electrons

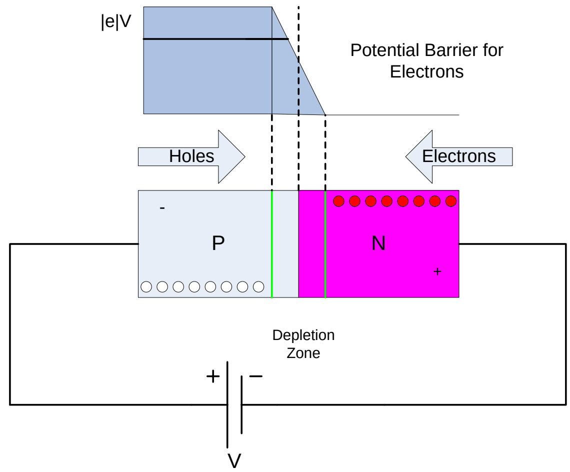
Charge drift forms Depletion Zone



Forward Biased PN Junction

V lowers potential barrier for electrons upsets balance

I flows



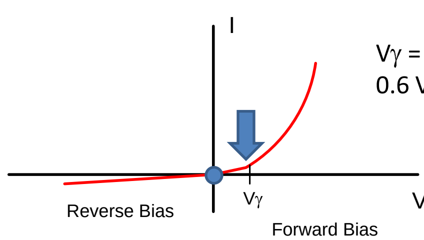
Forward Bias

I = Holes +Electrons

PN Junction-Diode Operation

PN Junction Characteristic

Junction conducts when forward biased



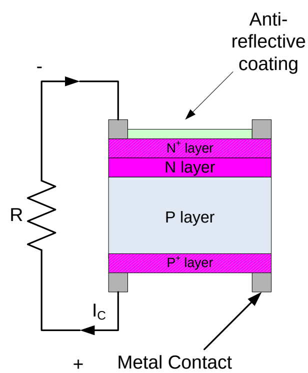
Vγ = cut-in voltage
0.6 V for silicon

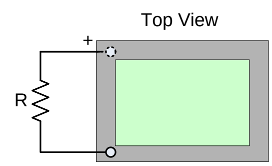
$$I = I_s(e^{V/V_T} - 1)$$

V_T = Voltage-equivalent of Temperature = 0.026 V at room temperature
I_s = saturation current depends on junction area and doping

Photoelectric Effect

Light striking a PN junction creates currents. Photons must have sufficient energy increase electron energy and create Electron/hole pairs





Photon E >1.1 eV

$$I_C = I_L - I_s\left(e^{\frac{I_C R}{V_T}} - 1\right) = I_L - I_s\left(e^{\frac{V}{V_T}} - 1\right)$$

I_C = cell current
I_L = reverse current

Open Circuit Voltage/Short Circuit Current

Open circuit means R=∞ and I_C=0, so open circuit voltage is

$$V_{OC} = V_T \ln\left(1 + \frac{I_L}{I_s}\right) \approx V_T \ln\left(\frac{I_L}{I_s}\right)$$

V_T = 0.026 V at room temperature
I_s = saturation current
I_L = reverse current

Cell power output given by

$$P_C = I_C V = I_C^2 R$$

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END LESSON 23