

Tutorial 4

Exercise 1: Foundational Exercise

A monocrystalline silicon solar cell is tested under standard AM1.5 conditions: ($P_{in} = 1000W/m^2$). The cell area is $156cm^2$. Testing yields: $I_{SC} = 6.24A$, $V_{OC} = 0.61V$, $I_{mp} = 5.85A$ (Current at Maximum Power Point), $V_{mp} = 0.52V$ (Voltage at Maximum Power Point), Calculate:

1. The Maximum Power (P_{max}).
2. The Fill Factor (FF).
3. The Efficiency (η).

Exercise 2: Complex Synthesis Problem

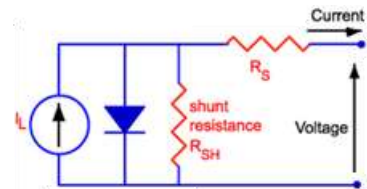
We can observe that while the sunlight is intense, the high heat is causing the cells to underperform. A cell has an ideal V_{OC} of $0.70V$ at $25^\circ C$ (STC). However, the desert operating temperature is $65^\circ C$. The V_{OC} temperature coefficient is $-0.3\%/^\circ C$. Simultaneously, a thin layer of dust has accumulated, providing a Shunt Resistance (R_{Sh}) path that reduces the Fill Factor by an additional 10% . Analyze the following:

1. Thermal Degradation: Calculate the new V_{OC} at operating temperature.
2. Circuit Interaction: Explain using the Equivalent Circuit model how the dust (R_{Sh}) and the temperature-induced V_{OC} drop combine to shift the "knee" of the I-V curve.
3. Optimization: Propose one material change (e.g., choosing a different bandgap) and one structural change to mitigate these specific losses.

Exercise 3: The "Real-World" Shunt & Series Loss

A silicon solar cell is modeled using the Equivalent Circuit (Single Diode Model).

You are given the following parameters: Photo-generated Current $I_L = 4.0A$; Series Resistance $R_S = 0.05\Omega$; Shunt Resistance $R_{shunt} = 10.0\Omega$; Operating Voltage $V = 0.45V$



Assuming the diode current I_D is negligible at this specific voltage point, calculate the Output Current I_{output} delivered to the load.

Exercise 4: Determining Dark Saturation Current (I_0)

To understand the I-V Characteristic curve, you need to find the "Dark Saturation Current," which dictates how much voltage the cell can generate. Short-Circuit Current $I_{SC} = 3.5A$; Open-Circuit Voltage $V_{OC} = 0.60V$; Thermal Voltage $V_t = 0.026V$ at $300K$; Ideality Factor $n = 1.0$. Calculate the Dark Saturation Current I_0

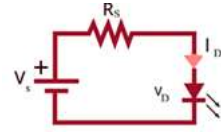
Exercise 5: LED Wavelength and Material

This problem focuses on the relationship between the semiconductor material's band gap energy and the color (wavelength) of light emitted by an LED. The key physical relationship is the Planck-Einstein relation, where the energy of the emitted photon equals the band gap energy (E_g). A material engineer is designing an LED using gallium nitride (GaN), which has

a typical band gap energy (E_g) of approximately 3.4 eV. What is the expected wavelength of the emitted light, and what color does this correspond to in the visible spectrum?

Exercise 6: LED Circuit Design (Current Limiting)

LEDs are current-sensitive devices, meaning a small change in voltage can cause a large change in current, potentially damaging the device. A series current-limiting resistor (R_S) is crucial for safe operation. An engineer wants to power a red LED from a 9V DC power supply. The red LED has a typical forward voltage $V_D = 2.1V$ and should operate with a forward current $I_F = 20mA$ for optimal brightness and lifespan. Calculate the required value for the series resistor (R_S).



Exercise 7: LED Luminous Efficacy Calculation

Luminous efficacy is a measure of how efficiently a light source produces visible light, essentially converting electrical power into light output. A modern high-power LED lamp is rated to produce a total luminous flux of 1500 lumens while consuming 12 watts of electrical power. Calculate the luminous efficacy of this LED lamp in lumens per watt (lm/W).

Exercise 8. Emission Wavelength Calculation

A laser diode is fabricated using a semiconductor material with a bandgap energy $E_g = 1.43eV$. Calculate the wavelength λ of the light it emits and determine which part of the electromagnetic spectrum it belongs to

Exercise 9. Threshold, Output Power and Power Conversion Efficiency (PCE)

A laser diode has a threshold current $I_{th} = 25mA$ and a slope efficiency $\eta_{slope} = 0.5mW/mA$.

1. Calculate the optical output power P_o if the operating current is increased to 60 mA.
2. If the diode operates at 2.0 V when the current is 60 mA, find its Power Conversion Efficiency (also known as Wall-Plug Efficiency).

Exercise 10: Complex Multi-Part Problem: Thermal Effects and Internal Losses

An InGaAsP Edge-Emitting Laser (EEL) designed for telecommunications has a threshold current $I_{th} = 30mA$ at an ambient temperature of $25^{\circ}C$. The device has an internal differential quantum efficiency $\eta_{slope} = 85\%$ and an internal loss coefficient $\alpha_s = 15\text{ cm}^{-1}$. The cavity length $L = 500\text{ }\mu m$, and the end facets have a reflectivity $R = 0.32$.

1. Calculate the slope efficiency (η_{slope}) in W/A and the optical output power (P_o) when the operating current (I) is 100 mA.
2. High-power operation causes the junction temperature T_j to rise, increasing the threshold current. If the laser's characteristic temperature $T_0 = 60K$ is and the thermal resistance $R_{th} = 60\text{ K/W}$, estimate the new threshold current $I_{th,new}$ when the total electrical input power is 0.2 W.