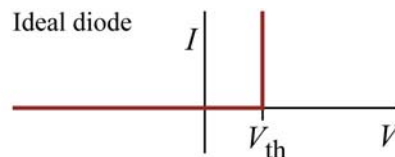
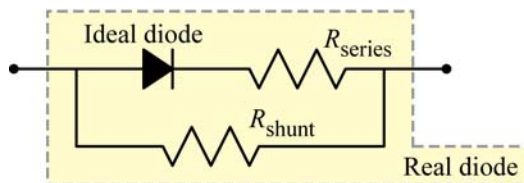


Midterm Exam, Spring 2007
ECSE-6961, Light-emitting diodes and solid-state lighting

Note: Put your name on paper. Show your work. Underline results. Always show units. All materials are allowed (books, manuscripts, excerpts, calculators, etc.). Use ball-point pen, no pencil.

1. Consider a light-emitting diode, through which a constant electrical current is flows for a time of 10 s so that the total electrical charge flowing through the diode is 1 C. A photon counter counts 10^{17} photons being emitted from the LED per second. The LED emits at a wavelength of 650 nm and has a forward voltage of 1.91 V.
 - (a) What is the external quantum efficiency of the device?
 - (b) What is the injection current of the device?
 - (c) What is the electrical input power of the device?
 - (d) What is the optical output power of the device?
 - (e) What is the power efficiency of the device?
 - (f) What is the series resistance of the device?
 - (g) What is the total power converted to heat in the device?
 - (h) What is the internal quantum efficiency of the device assuming that the light-extraction efficiency is 100%?
 - (i) What is the energy consumed, after the 1 C charge has flow through the device?

2. A 460 nm blue LED is tested in a manufacturing environment by measuring the $V_{f1} = 4.5$ V and $V_{f2} = 2.0$ V, measured at 100 mA and 1 μ A, respectively. Assume that the device can be modeled by the equivalent circuit shown below. Also assume that the “ideal diode” shown in the circuit has a negligibly small reverse saturation current.
 - (a) What is V_{th} of the “ideal diode”?
 - (b) What is the series resistance of the device?
 - (c) What is the shunt resistance of the device?
 - (d) What would be the value of V_{f1} if the series resistance would be zero?
 - (e) What would be the value of V_{f2} if the shunt resistance would be infinitely high?
 - (f) Consider the choice between 4 diodes with relative V_{f1} and V_{f2} values of: $(V_{f1}, V_{f2}) = (\text{high, high})_{\text{for Diode 1}}, (\text{high, low})_{\text{for Diode 2}}, (\text{low, high})_{\text{for Diode 3}}, \text{ and } (\text{low, low})_{\text{for Diode 4}}$. Which of the diodes is the best and why?



3. The temperature dependence of the optical output power of an LED can be described in terms of a characteristic temperature T_1 . A red-emitting diode has $T_1 = 200$ K and it emits an optical power of 100 mW at 300 K.
 - (a) Give the formula describing the temperature dependence of the output power of the LED.
 - (b) What is the physical meaning of T_1 ?
 - (c) What is the optical output power at 400 K and 500 K?
 - (d) What is the main physical cause of the temperature dependence of the output power?
 - (e) How could the inherent temperature dependence of the device be decreased?
 - (f) Assume that the temperature dependence of the device could be decreased. Would T_1 then increase or decrease?
 - (g) Show a circuit that can compensate for the temperature dependence of the LED optical emission power, so that the LED emits a power that is independent of temperature.
 - (h) Explain the circuit.