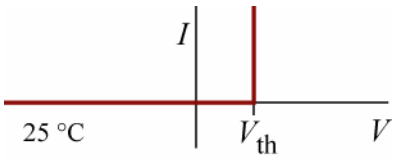
Midterm Exam, Spring 2005

ECSE-6961, Light-emitting diodes and solid-state lighting

Note: (***i***) Put your name on paper, show your work, underline results, and always show units.
(***ii***) Textbook, manuscript, excerpts, and calculators are allowed.

1. Consider a light-emitting diode, biased at 3.5 V, emitting 10^{16} photons per second having a wavelength of 650 nm when injected with 10^{17} electrons per second.
   (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? (Assume that the equivalent circuit of the device is an ideal diode with a series resistance)
   (g) What is the power that is consumed in the series resistance?
   (h) What is the total power converted to heat in the device?
   (i) Explain the difference between the last two questions.

2. Assume a constant voltage power supply of 5 V driving a diode with a threshold voltage of $V_{th} = 2.5$ V, a forward voltage of $V_f = V_{th} = 2.5$ V at 25 °C (see sketch below), and a temperature coefficient of the forward voltage of – 2.5 mV/K.
   (a) Design a simple circuit using the 5 V power supply, that gives an injection current of 20 mA.
   (b) Show the "load line" of your circuit. Give the values of all axes intercepts.
   (c) What is the forward current when the device is heated to 100 °C?
   (d) Describe how you would change the circuit elements in your circuit to automatically obtain a 20 % increase in the current when the device is heated from 25 °C to 100 °C while keeping the current at 20 mA for room-temperature operation. Give the values of all circuit elements.
   (e) Why would it be desirable to increase the drive current as the temperature increases?



3. Discuss the advantages of double heterostructure design over homojunction design.

4. Choose one LED structure where current spreading /current crowding is an issue. Discuss how the materials parameters (doping and mobilities) and structural parameters (e.g. thickness of layers) affect current spreading.

5. Choose and discuss two schemes that afford high light-extraction efficiency.