NAME UCID

1. Answer all three questions. Maximum mark is 18.
2. For multiple-choice questions, indicate the correct answer. There may be more than one correct answer, in which case indicate all correct answers.
3. Show your work as much as possible, within time and space constraints.
4. Only this one sheet of paper will be collected and graded

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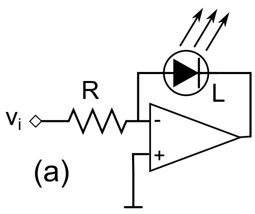
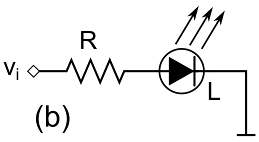
1. Consider the two circuits below. LED L, resistor R and input voltage v_i are identical. Will (a) produce more light, (b) produce more light, or will both produce the same amount of light? **Why?** *(3 marks)*

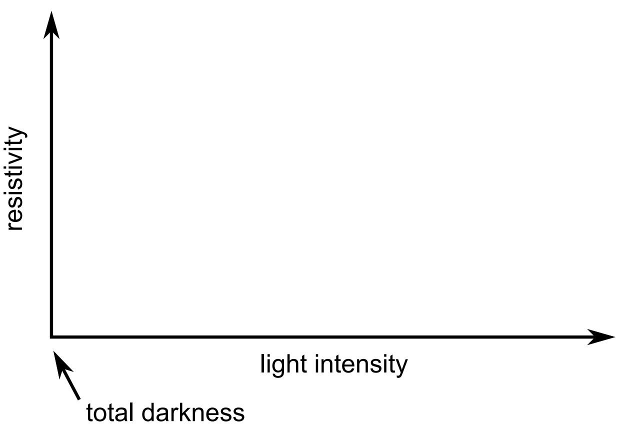


(a)



(b)

2. Consider an intrinsic semiconductor where the electron and hole mobilities are equal. It is irradiated with light with photon energy equal to the material bandgap. Assume that the carrier generation rate is linearly proportional to light intensity. Draw a rough sketch of the resistivity of the material against increasing intensity of light on the axes below. **Explain your trace.** *(3 marks)*



$$
\begin{aligned}
n &= \frac{N_D - N_A}{2} + \sqrt{\left(\frac{N_D - N_A}{2}\right)^2 + n_i^2} \\
&= N_D - N_A \text{ if } N_D - N_A > 10n_i \\
p &= \frac{N_A - N_D}{2} + \sqrt{\left(\frac{N_A - N_D}{2}\right)^2 + n_i^2} \\
&= N_A - N_D \text{ if } N_A - N_D > 10n_i \\
n &= N_C e^{-(E_C - E_F)/kT} \\
p &= N_V e^{-(E_F - E_V)/kT} \\
np &= n_i^2 \text{ at equilibrium} \\
n &= n_0 + n' \\
p &= p_0 + p' \\
dn'/dt &= dp'/dt = -n'/\tau = -p'/\tau \\
f(E) &= \frac{1}{1 + e^{(E - E_F)/kT}} \\
E_p &= hc/\lambda \\
J_{\text{drift}} &= q(n\mu_n + p\mu_p)E \\
J_{\text{diffusion}} &= qD_n\frac{dn}{dx} - qD_p\frac{dp}{dx} \\
D &= \frac{kT}{q}\mu
\end{aligned}
$$

Universal

$$
\begin{aligned}
k &= 1.38 \times 10^{-23} \text{ J/K} \\
q &= 1.60 \times 10^{-19} \text{ C} \\
kT &= 26 \text{ meV at 300K} \\
kT/q &= 26 \text{ mV at 300K}
\end{aligned}
$$

Silicon@300K

$$
\begin{aligned}
N_C &= 2.8 \times 10^{19}/\text{cm}^3 \\
N_V &= 1.0 \times 10^{19}/\text{cm}^3 \\
n_i &= 1.0 \times 10^{10}/\text{cm}^3 \\
E_g &= 1.1\ eV \\
\mu_n &= 1400 \text{ cm}^2/\text{Vs} \\
\mu_p &= 470 \text{ cm}^2/\text{Vs}
\end{aligned}
$$

Germanium@300K

$$
\begin{aligned}
N_C &= 1.0 \times 10^{19}/\text{cm}^3 \\
N_V &= 6.0 \times 10^{18}/\text{cm}^3 \\
n_i &= 2.0 \times 10^{13}/\text{cm}^3 \\
E_g &= 0.67\ eV \\
\mu_n &= 3900 \text{ cm}^2/\text{Vs} \\
\mu_p &= 1900 \text{ cm}^2/\text{Vs}
\end{aligned}
$$

4. Consider a semiconductor doped with donors varying with x as $N_D(x) = \frac{N_{D0}}{1+x}$ with $N_{D0} >> n_i$. Use appropriate symbols for any material constants you want to use for this question. *(12 marks)*
(a) Find the location where the electron and hole diffusion currents are equal.
(b) At the above location, indicate the direction (if any) of the movement of **electrons by drift**, and **holes by diffusion**. Answer as +x, -x, or no movement for both carriers and explain your answer.
(c) Show that the electric field in the semiconductor is $\frac{v_T}{1+x}$ where v_T is the thermal voltage.
(d) Draw the energy band diagram of the material.