HW7

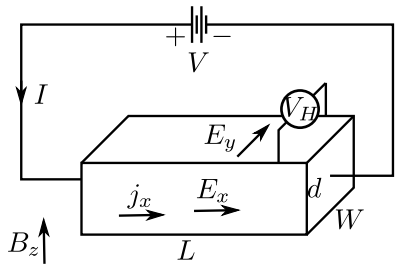
MTLE-6120: Spring 2018

Due: Apr 2, 2018

1. **Semiconductor hall probe**

   We want to design a sensitive microscopic magnetic field sensor using the Hall effect in an n-type semiconductor. Assume that we work with a doping level $N_d \gg n_i$ (so that hole contributions are negligible), and in the rectangular geometry shown below.

   Further, assume that we need 1 μm spatial resolution, so that we set $L = W = 1$ μm. We also need to operate using a voltage source with $V = 1$ V. The parameters we need to design are the thickness d and the doping level N_d. Assume for simplicity that the electron mobility is $\mu_e = 1000$ cm^2/(Vs), independent of N_d.



   (a) Express the sensitivity of measured Hall voltage to magnetic field, $\mathrm{d}V_H/\mathrm{d}B$ in terms of the device geometry, voltage and mobility. Do not substitute any values yet.

   (b) How does the sensitivity depend on the undetermined design parameters N_d and d? Which material properties most affect this sensitivity?

   (c) What is the condition on $N_d \cdot d$ such that the power dissipated in the semiconductor is less than 1 mW? Substitute values and express result in cm^{-2} units.

   (d) These Hall probes are intended to be used in an array to map magnetic fields, and should ideally all exhibit the same electrical characteristics. One issue is that if there are N dopants on average per device, statictical fluctuations produce variations on the order of $\sqrt{N}$. What is the condition on $N_d \cdot d$ such that the variability of electrical characteristics is less than 1%? Substitute values and express result in cm^{-2} units.

   (e) Set $N_d \cdot d$ to be the geometric mean of the minimum and maximum values determined in the previous two parts. Calculate the sensitivity $\mathrm{d}V_H/\mathrm{d}B$ of the Hall voltage to magnetic field in V/T units.

2. **Kasap 7.20: Capacitor design**