Hall Effect Notes:

1) Note: the original board for the hall effect has been replaced by a new board, which has different circuit wiring. We are still waiting to get an updated lab manual. In the mean time the new board can be used based on the information in the advertising flier, which is posted to the blackboard web page.
2) (Note, this only applies to the old boards, since the new boards have a built in current source) The Hall Effect apparatus can be damaged by running too much current through it. Pay careful attention to the voltage and current settings in the lab manual. When you are running a forward-biased current through the sample, you can use the current-limiting circuit that is on the board. This should prevent any problems. However, if you want to explore the effect of running reverse-biased current you can't use the current-limiting circuit. You can try this if you want, BUT you must be aware of everything you do. A mistake in the voltage settings will destroy the delicate germanium sample.
3) Some useful introductory reading for the Hall Effect is in Giancoli, section 25-8 on the microscopic view of electric current, section 27-8 on the Hall effect and sections 41-6, 41-7 and 41-8, on band theory and conductivity in solids. A slightly more advanced treatment is given in Melissinos and Napolitano, sections 2.1 – 2.4. A detailed discussion of band theory and conduction can be found (from the physics perspective) in Ashcroft and Mermin, chapters 1-3 and (from the electrical engineering perspective) in Sze, chapter 2. The book by Sze can be hard to find in the library since it is required for EE students, so, if you need this, talk to me and I can put my own copy on reserve in the library.
4) In addition to the standard things that the lab report tells you to do, here are a few others:
    a. See if you can measure the Hall Effect in the copper sample. This requires much more accurate voltage readings, however.
    b. Look at the deviations from the simple theory of the Hall voltage. The theory presented in the lab manual treats the most important effect (the thermal excitation of carriers into the conduction band), but there are also secondary effects, in particular the change in the mean free path of carriers with temperature. See if you can analyze your data in a way so as to bring out these secondary effects.
5) The sign of the Hall voltage changes from plus to minus for the p-doped germanium as the temperature is increased. The reason for this is a little subtle, so it is worth explaining. As the temperature increases the type of conduction goes from extrinsic carriers (e.g. dopant generated holes) to intrinsic carriers (e.g. thermally generated holes and electrons). At high enough temperature, it no longer matters which type of semiconductor you started with (p or n) since there are approximately equal numbers of holes and electrons, and there are much more of these thermal carriers than the original extrinsic carriers. You might expect, in this case, that there would be no Hall voltage since a) there would be a different sign Hall voltage for the holes and for the electrons and b) these are of equal number (the thermal excitation of each electron leaves behind a hole). However, the mobility of electrons and holes are not the same. Electrons actually move

through the crystal lattice more easily than holes do. As a result you can think of the semiconductor as consisting of two resistances in parallel. One "resistor" corresponds to the electrons and one "resistor" corresponds to the holes. As with any parallel resistor circuit the current will divide itself unequally if the resistances are not of the same value, and as a result, the current of holes will be less than the current of electrons. Similarly, the Hall voltage generated by electrons will be larger than the Hall voltage generated by holes. Thus, at high enough temperature, all semiconductors appear to be "n" type. Consequently, for p-type Germanium, one would expect the sign of the Hall coefficient to change at high temperature.

References

1. Douglass C. Giancoli, *Physics for Scientists and Engineers*. (Prentice Hall, Upper Saddle River, NJ, 2000).

2. S. M. Sze, *Semiconductor Devices: Physics and Technology*, Second ed. (John Wiley and Sons, New York, 2002).

3. Neil W. Ashcroft and N. David Mermin, *Solid State Physics*. (Hold Saunders, Philadelphia, 1976).