These exercises are meant to help you practice the concepts from lecture. Only the exercises with starred numbers (e.g., #1) are mandatory. You will submit the mandatory exercises in your groups. The other exercises are optional; I will give you some extra credit if you submit them. As always, feel free to ask me if you have any questions.

*1. Set up and run the sample problem for PMWIN. Follow the instructions in chapter 2 of *Processing Modflow* at least up to and including step 4. For this problem you will be most concerned with the volume of water out of the region (Table 2.2).

   a. The model requires you to specify several parameters. Run the model with the parameters given in chapter 2, and then re-run by doubling in turn the effective porosity, the horizontal hydraulic conductivity, the vertical hydraulic conductivity, the difference in head between the west and east boundaries, and the recharge rate. When you change one parameter, be sure to return the others to their original values. Make a table of the total volume out for each of these runs.

   b. Try to explain how doubling each of the parameters affects the total volume out.

   c. Make a list of at least three questions you have about the model, the parameters, the results, etc. These questions can be either about the physics of the groundwater movement or the details of the model.

*2. Fig. 3.1 of Fetter’s book gives the porosity for a cubic packing of uniform spheres to be 47.65% and a rhombohedral packing of uniform spheres to be 25.95%. Verify these values. Notice that these are the maximum and minimum values of porosity for sediment with spherical grains of uniform diameter.

*3. Explain why one would expect the porosity of glacial till to be low.

4. Porosity depends on the representative elemental volume (REV) in which the volume of voids is computed. The REV size for the medium is given by the location yielding the largest REV size. For the infinite two-dimensional medium below, plot the porosity as a function of area of squares centered on the points P and Q. (Tip: Consider averaging areas of 1, 4, 9, 16, 25, 36, 49, … squares.) Which point would you use to determine the size of the REA (representative elemental are) and what is that size?
5. In our discussion of hydraulic conductivity, we said that \( K \) depends on the sediment diameter \( d \), the density \( \rho \) and dynamic viscosity \( \mu \) of the fluid, and the acceleration of gravity \( g \). Use dimensional analysis and other reasoning to obtain the hydraulic conductivity to within a multiplicative constant.

6. Explain why the hydraulic conductivity increases when the fluid density increases.

7. Design a constant-head permeameter for sand so that Darcy’s law will be valid. In other words, recommend a maximum value for the hydraulic head (as a multiple of the sample length) such that laminar flow occurs. Compare your recommendation to Fetter’s.

8. The analysis of the falling-head permeameter in my version of Fetter’s book contains this intermediate step:

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K = -\frac{A_t L}{A_c} \frac{dh}{dt}
\]

Explain in convincing terms why this cannot possibly be correct.

9. What is the flow per unit width for the aquifer example in class if \( L = 500 \) m, \( b = 10 \) m, \( K = 10^{-5} \) m/s, \( h_0 = 2 \) m, and \( h_L = 1 \) m. Is Darcy’s law valid for this case?