Tutorial Homework:

Electric potential   **Name**_____
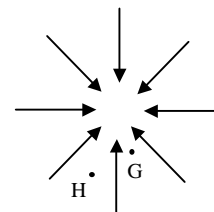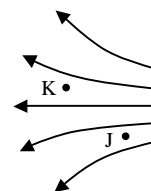
I. How does field strength relate to potential?

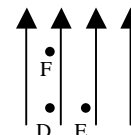A. This diagram shows the gravitational field around a planet.

    1. At which point, G or H, would a rock have more gravitational potential energy? Explain.

    2. At which point, G or H, does the rock feel a stronger gravitational field and hence a stronger force? Explain.

    3. How can you tell *just from the field lines* where the field is stronger? In other words, how could you answer question 2 without already knowing what you know about gravity near a planet?

B. This next diagram shows an electric field. We're not going to tell you anything about the charges that produce this field. So, you'll need to reason entirely from the field.

    1. Which point, J or K, has a higher electric potential? Explain.

    2. At which point, J or K, is the electric field stronger? Explain.
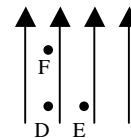
C. Here's another electric field.

    1. At which of the three labeled points is the electric potential highest? Second highest? Lowest? Be sure to indicate any ties, and explain your reasoning.

    2. At which of the three labeled points is the electric field strongest? Second strongest? Weakest? Be sure to indicate any ties, and explain your reasoning.

D. Now for the punch line. Is there a fixed relation between the field strength and the electric potential? In other words, is there a general rule such as "the field is stronger where the potential is higher," or "the field is stronger where the potential is lower," that holds in all situations? If so, what's the rule? Explain.

II. Energy changes along different paths

A. In the electric field re-drawn here, a positively-charged bead is carried from point F to point E, along one of these two paths:

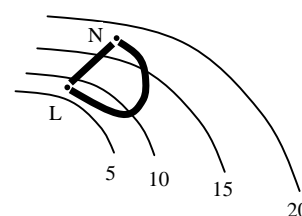> *Path 1:* Directly from F to E along an angled straight line.

> *Path 2:* F to D along a vertical straight line, then D to E along a horizontal line.

1. Along which path, if either, is more work needed to push the bead from F to E? Explain.

2. Suppose the bead is pushed from D to E. Is the work done on the bead positive, negative, or zero? Explain. Hint: The work done on the bead is the energy given to the bead by exerting a force through a distance. This work can be less than the energy expended by the pusher, if some of the energy she burns isn't "productive" (in the sense that pushing against a wall burns calories but isn't productive).

3. Answering question 1 above, a student says

   The work is the same along both paths, for this reason: Along path 2, you fight the field head on (from F to D), which means your force is directly against the field; but that force acts over a short distance. Along path 1 you fight the field at an angle, not head-on, which means you're exerting a smaller force along the direction of motion; but you do so over a longer distance. This compensation between distance and force-against-the-field makes the work come out the same in both cases.

   In what ways do you agree and/or disagree with the student?

B. In this diagram, the thin lines are equipotential lines, labeled in volts. The thick lines represent hollow plastic tubes through which a charged bead could slide frictionlessly from point L to point N or vice versa.
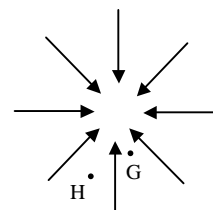
1. A positive bead is put into the straight tube at L. Does it naturally move to point N, or must it be pushed through the tube to reach N? Explain.

2. Two identical beads (same charge, same mass) are released from rest into the straight and curvy tube, respectively, at point N. Which bead (if either) reaches point L with more speed? Explain.

3. A student points out, correctly, that the bead in the straight tube has a higher acceleration, on average, than the bead in the curvy tube. (We'll see why below.) Reconcile this observation with your answer to the previous question.

C. On p. 2, parts A and B illustrate that **in an electrostatic field, an object's change in potential energy going from one point to another does not depend on which path the object takes between the two points**. But those questions actually focused on work and on speed, not on potential energy! Explain why parts A and B nonetheless illustrate the boldfaced principle.
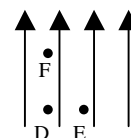
III. Relating field to equipotential lines

A. Again consider this field; but now let's say it's the electric field produced by a negatively charged sphere, rather then the gravitational field generated by a planet. Recall that an equipotential line consists of points that all have the same potential. So, when a charge moves along an equipotential line, it neither gains nor loses potential energy.

1. Draw the equipotential line through point G, making sure it contains all points on the page that have the same potential as G. Explain your reasoning.

2. Draw the equipotential line through point H.
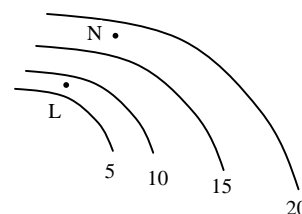
B. Again consider this uniform electric field.

1. Draw the equipotential line through point F, and explain your reasoning.

2. Now draw the equipotential line through point D.

C. Let's look for patterns in the two sets of equipotential lines you just drew.

1. In these examples of simple electric fields, what is the angle between the field lines and the corresponding equipotential lines?

2. The answer you just gave applies to *all* electrostatic fields. Explain why. Hint: What would happen to the energy of a charge that moves along a path that has a component in the direction of the field?

D. Finally, re-consider this equipotential map.

1. At which point, L or N is the electric field stronger? What rule did you just use to figure it out?

2. Explain why that rule is true.

3. Draw arrows at L and N showing the electric field at those points. Explain your reasoning.