Unit 21 *Homework Problems*

Learning Goals:

F.21 Draw the electric field lines given a set of equipotential surfaces or vice versa.

21-1) According to the universal law of gravitation the gravitational force on a small object at the surface of the Earth is proportional to the product of the object's mass and the mass of the Earth and inversely proportional to the square of the distance between the object and the center of the Earth. It is a well-established fact that Newton's Second Law holds and also that within the limits of experimental uncertainty all objects with mass that are tossed or dropped in a laboratory located on the surface of the Earth experience the same constant vertical acceleration of $\vec{a}_{ff} = -9.8\ \mathrm{m/s^2}\ \hat{y}$.

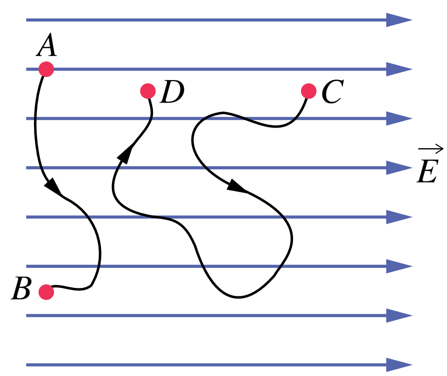
(a) If the Earth's gravitational force on a mass depends on the distance between it and the center of the Earth why doesn't the magnitude of the acceleration of an object dropped from the ceiling of a laboratory increase as the object gets closer and closer to the floor of the laboratory?

(b) If the Earth's gravitational force on an object is proportional to its mass, why isn't the acceleration of an object that is twice the mass double that of the original mass? **Hint**: Examine the consequences of Newton's Second Law!

21-2) Estimate the magnitude of the gravitational force between a 60-kg woman and an 80-kg man standing 4.0 m apart. What if they are practically touching ($\approx$ 0.2 m between their centers)?

21-3) Calculate the effective magnitude of g, the local gravitational constant (*i.e.*, the gravitational field), at (*a*) 3200 m, and (*b*) 3200 km, above the Earth's surface (sea level).

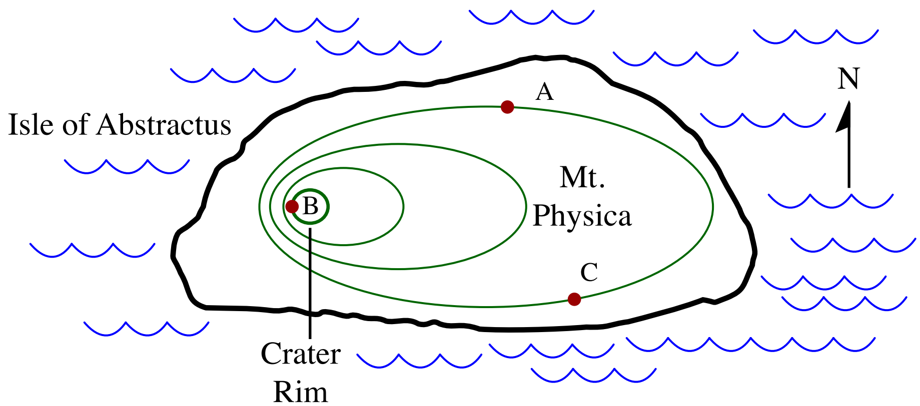
21-4) Consider a charge $q = -3.0\mu$C that moves along one of the paths shown in the diagram to the right. This charge is moving in the presence of a uniform electric field of magnitude E = 200 N/C.

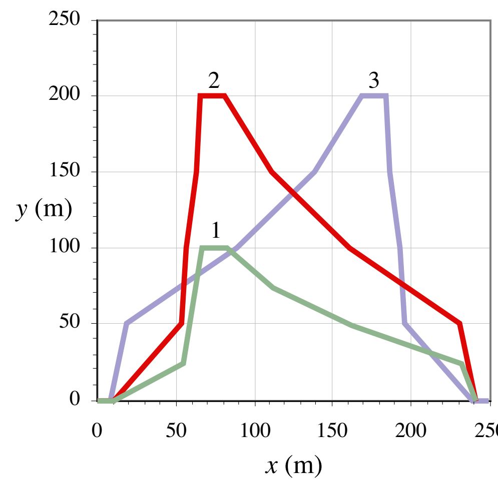


(a) What is the total work done by the electric field on the charge in going from A to B if the distance between A and B is 0.62 m?

(b) What is the total work done by the electric field on the charge in going from C to D if the distance between C and D is 0.58 m?

21-5) In an obscure location in the South Pacific, an explorer in a small sail boat claims to have discovered a tiny volcanic island she calls the Isle of Abstractus. The volcano is shiny and seems to be made of obsidian, which is a glass like substance. The map she made has 50-meter contour lines. The rim of the volcano crater happens to be one of the contour lines and the explorer estimates that the island is 250 m long from west to east and 100 meters wide from North to South.





(a) Suppose you are sitting in a boat in the water in the middle of the south side of the island. Which graph best represents the profile of the island (including its volcano)? 1, 2 or 3?

(b) How high above sea level is the rim of the volcano crater?

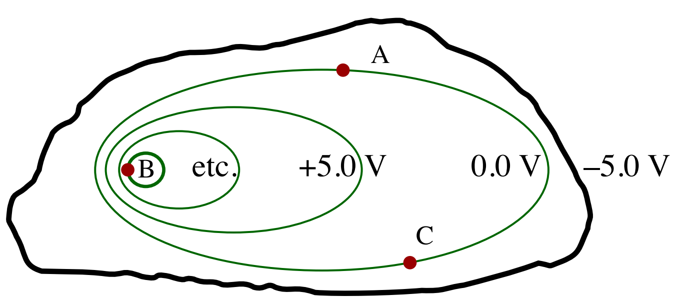
(c) How much work does the gravitational force do on our explorer if she moves following a direct path A→B, if her mass is 55 kg?

(d) How much work does the gravitational force do on our explorer in going from A→C if she follows a direct path from A→B and then a direct path from B→C?

(e) Where is the steepest slope on the mountain (*i.e.*, is it at point A, B, or C? Does it point to the N, W, S, or E)?

(f) Which direction (N, W, S, or E) is a ball most likely to roll in if it is released from the rim at point B but doesn't fall into the crater?

21-6) In an obscure region inside of an electrical device there is a non-uniform electric field. The diagram that follows show equipotential lines every +5.0 volts. The potential at the outer rim of the region (which is shown as a darker line) is fixed at –5.0 volts. The region is 25 cm long from left to right and 10 cm wide from top to bottom.



(a) What is the electrical potential at point B?

(b) What is the potential difference between point B and the region boundary?

(c) If a unit test charge of 1.0 μC is moved along a direct path from point A to point B, how much work is done by the electrical force on the charge?

(d) How much work is done by the electrical force on the charge if it is forced to move from A→C by following a direct path from A→B and then a direct path from B→C?

(e) Where is the part of the region that has the greatest value of electric field (*i.e.*, is it at point A, B, or C? Does it point right, left, up, or down in the diagram)? **Hint**: You may want to consider the analogy with problem 21-5.

(f) Which direction (up, down, right or left) is a positive test charge released from rest at point B most likely to move?

21-7) The work done by an external force to move a –8.0 μC charge from point *a* to point *b* is 25.0×10^{-4} J. If the charge was started from rest and had 5.2×10^{-4} J of kinetic energy when it reached point *b*, what must be the potential difference between *a* and *b*? Which point is at the higher potential, *a* or *b*?

21-8) An electron is released from rest 65.0 cm from a fixed point charge with $Q = -0.125$ μC. How fast will the electron be moving when it is very far away?

21-9) In Activity 21.11 you mapped out the equipotential lines for one or two different electrode configurations: 2 small circular electrodes and/or the two bar-like electrodes. Now imagine we combine these electrodes and take one small circular electrode and place it opposite of one bar-like electrode as shown in the figure below. You should consider both electrodes to be conductors. Make a drawing of this configuration that is slightly larger (for clarity). Draw the electrodes with a black pen. Then sketch electric field lines (with a red pen). Indicate the direction of the electric field! In the same diagram sketch also the equipotential lines (with a green pen).