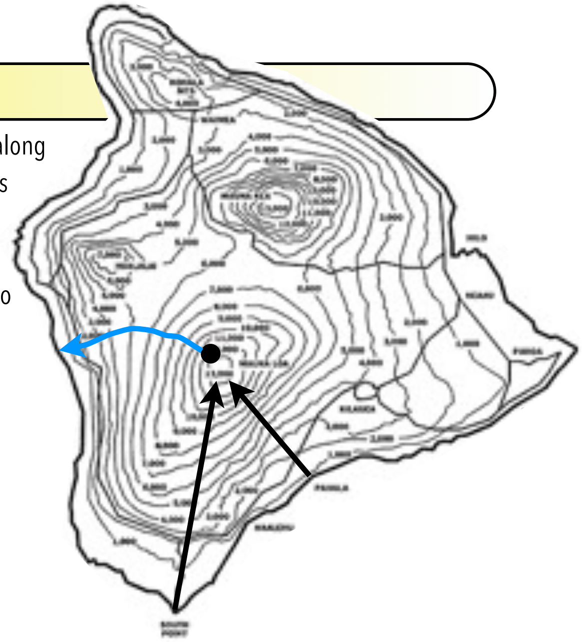
Electrical Mapping



Every looked at a map and seen very thin, wiggly lines that often have a number printed along their path? They aren't roads or rivers, they're called contour lines, and they show places with equal heights.

At right is a map of the main island of Hawaii. These contour lines show elevations every 1000 feet (sorry!) above sea level. There are two arrows showing a trip from the ocean to the top of the volcano, Mauna Loa.

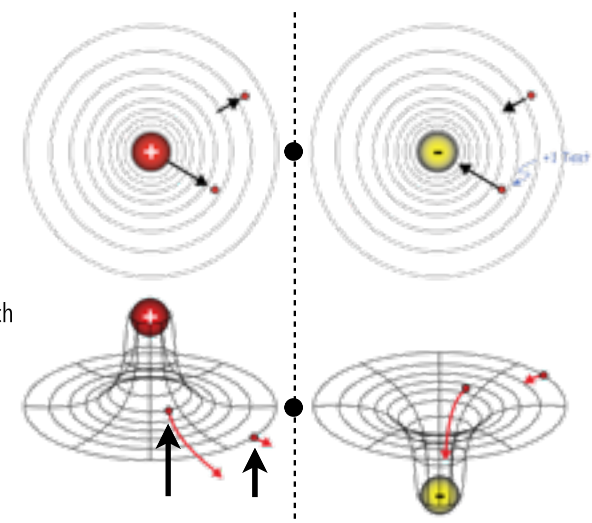
1) Which trip would be a more difficult climb–the one from South Point or the one from Pahala? How does the map tell you this?

Pahala–it is steeper in a few more areas
The closer the lines, the steeper the climb

2) Which part of the island probably has the flattest coastal farmlands?
NORTH SOUTH EAST WEST

3) Imagine Mr. S. puts a giant spherical boulder where the large circle is near the top of Mauna Loa. Draw in its path until it reaches the ocean. Will it travel in a straight line? YES NO
What can you say about the direction of the boulder's path and that of the the contour (equal potential energy) lines?

The bolder will always travel downhill and will always be moving perpendicular to a contour line when it passes from one height level to the next.



Here is an image of equipotential lines around two opposite charges. The smaller dots are test charges, and the arrows are showing the direction of the force on those test charges. We can think of a drawing like this as being an overhead view of positively charged hills and negatively charged valleys. The image below that is a view of how we can imagine the positive charge as like a hill and the negative charge as being like a valley. The lines are called equipotential lines because they show places of not only equal potential energy (as in the Hawaii example) but also lines of equal voltages (potentials).

4) If Mr. S. places a small, positive test charge at the point shown by the black circle, in which direction will it move? LEFT RIGHT UP DOWN NOT AT ALL

5) What is the potential energy of an electron placed at the position of the black dot? 0 J

6) What is the voltage at the position of the black dot? 0 V

7) Why didn't I specify the charge at that location for the last question?

Voltage (potential) depends only on the charges creating a field (and therefore a potential energy difference) in an area, and not on any test charge at a given location.

8) If each equipotential line is 1 Volt apart, what is the potential difference between the positions of the two test charges shown near the large positive charge? (Remember: In Physics, any change is always the final minus the initial!)

+6 V +5 V +1 V 0 V -1 V -5 V -6 V

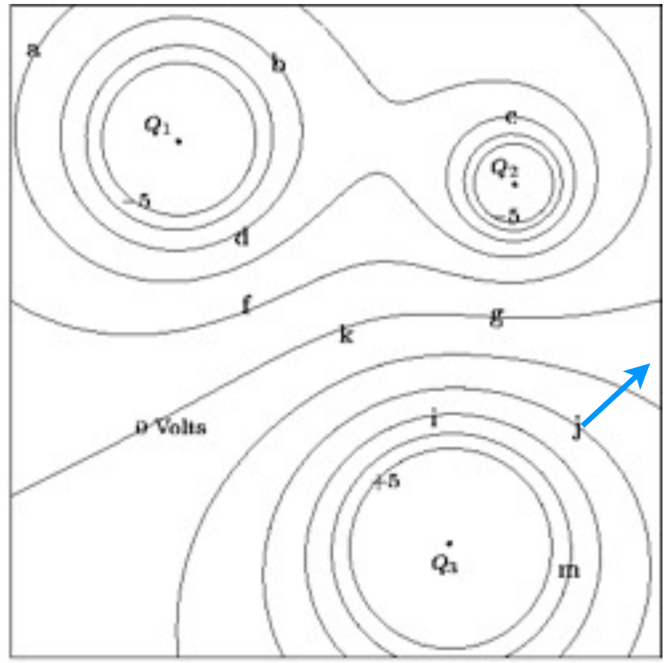
9) How much work would it take to move an electron from the left position to the right position shown by the arrows? (Don't answer in Joules!)

The electron is moving toward the negative charge, so positive work will have to be done to push it where it doesn't want to go. The potential difference is still 5V, so the work needed will be + 5 eV. (Remember: $E_{PE} = qV$)

10) What would be the energy change for a proton moving from the left position to the right position shown by the arrows? Is it a loss or gain?

A proton has the same charge as an electron, but this time it's moving in the direction it wants to go so it's losing energy. The potential difference is 5V, so the energy change will be – 5 eV. It's a loss

Here's an equipotential plot for three charges. The +5, 0 and –5 Volt potential lines are labeled, and the potential difference from one line to the next is 1 V.



11) What's the potential difference between points ***b*** and ***c*** (kinda' looks like an ***e***)?

0 V

12) Which charges are POSITIVE? Q1 Q2 **(Q3)** NONE

13) Which charges are NEGATIVE? **(Q1)** **(Q2)** Q3 NONE

14) What's the electrical potential energy change between points ***g*** and ***k***?

0 J

15) How much work would be required to move an electron from point ***m*** to ***d***?

+ 7 eV (positive work because it's an electron moving toward a negative charge)

16) Which direction does the electric field point at point ***g***?

(UP) DOWN LEFT RIGHT THERE IS NONE

17) Which charge has the greatest magnitude?

Q1 Q2 **(Q3)** ALL THE SAME

HINT: The largest charge will have lines that look closest to those for a single point charge (the others won't affect it much).

18) Would an electron move from ***d*** to ***f*** or from ***f*** to ***d*** on its own?

From ***d*** to ***f*** (away from the negative charge)

19) At point ***j***, draw in the electric field's direction. What is its magnitude due only to charge Q3, which is 5μC in size and 2.1 cm from point ***j***?

$\boldsymbol{E} = kQ/d^2 = 9{\cdot}10^9(5{\cdot}10^{-6})/(0.021)^2 = 1.02{\cdot}10^8$ N/C (or V/m)

20) If Q3 is 5μC in size, and you know the voltage at point ***d***, why can't you calculate the distance from Q3 to ***d***?

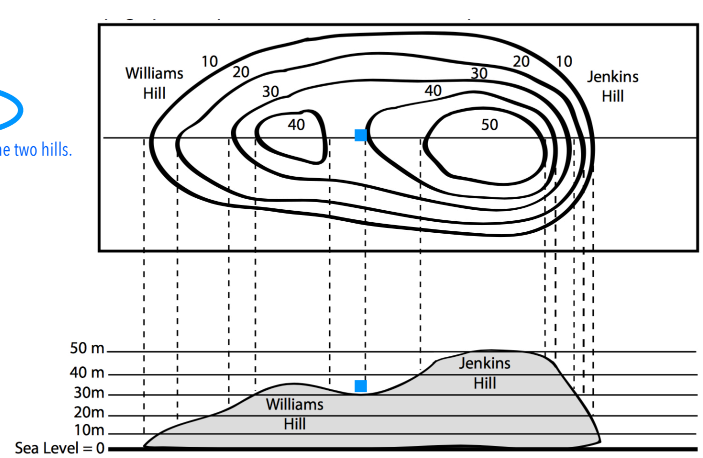
The electric field is not constant due to their being three charges.

Below is a contour map for Jenkins Hill and Williams Hill. If this was an equipotential plot for two charges instead of an elevation map for two hills…

21) Which "hill" would be positively charged? WILLIAMS JENKINS **(BOTH)** NEITHER

22) Is there a position where a positive test charge would be in equilibrium between the two "hills?"

(YES) NO [If so, mark it with a small ■]



23) If you put a small positive test charge at the top of "Williams Hill," which way would it move? LEFT RIGHT IT WOULDN'T **(CAN'T TELL)**

It's more probable that it would move to the left, but it could move to the right and be in equilibrium between the two hills.

24) If you put an electron at the top of "Williams Hill," which way would it move? LEFT RIGHT **(IT WOULDN'T)** CAN'T TELL

It's already at its highest potential–being at the top of a "positive hill."

25) Which "hill" would have an electron moving the fastest at its peak if the electron were released from the 0 V level?

WILLIAMS **(JENKINS)** SAME CAN'T TELL

It's gone through the greatest potential energy change, which will become kinetic energy.