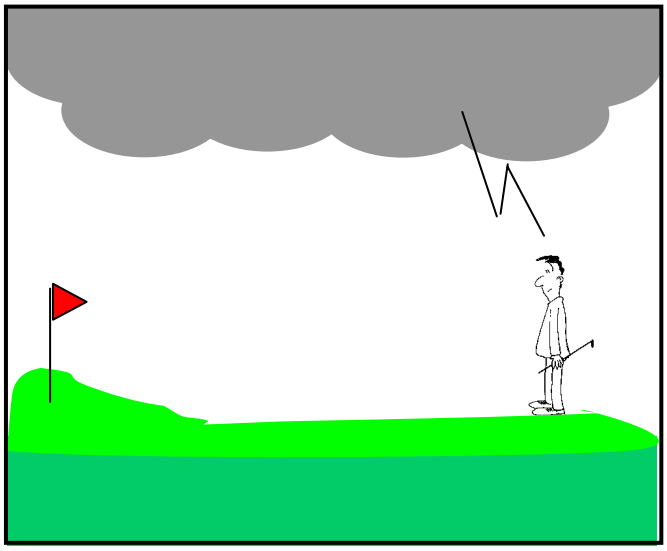
Workshop Tutorials for Biological and Environmental Physics

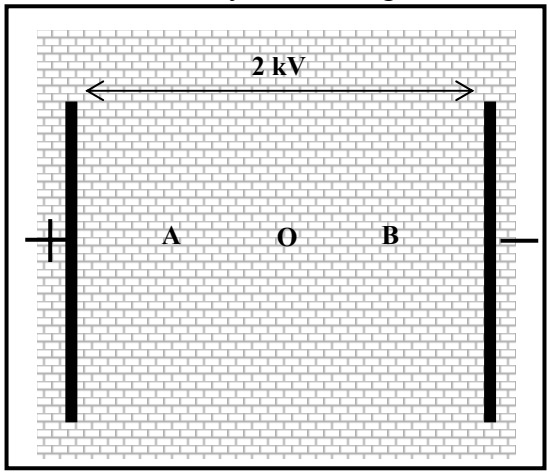
ER4B: **Electric Potential**

A. Qualitative Questions:



1. Brent and his brother Bert are playing golf on a Sunday afternoon.
It gradually clouds over until there is a thick layer of cloud above them, and they hear the threatening rumble of a thunder storm. Brent tells Bert that the potential difference between the cloud layer overhead and the ground is probably around a gigavolt (10^9 V), and that he's going back to the club house for a drink. Bert decides to finish the hole that he's on first.
a. Draw field lines and equipotential lines for Bert and his surroundings.
b. What is the potential difference between Bert's feet and his head?
c. Is this different from the potential difference between the ground at his feet and the air at the level of his head, if he wasn't standing there?
d. What is the electric potential of Bert's head? Explain your answer.
e. Why is it a bad idea to play golf in a storm?
f. Even when it is fine weather there is an electric field of around 100 $V.m^{-1}$, yet we don't get electrocuted just walking around or playing golf in the sunshine. Why not?

2. Many factories use dust precipitators in their chimneys to remove airborne pollutants. In one such precipitator a pair of plates is placed in the square chimney with a potential difference of 2 kV between them. The large electric field causes molecules to be ionized. Free electrons and ions can then attach to dust particles making them charged. Suppose that a dust particle in the chimney has a charge of +1*e*.



a. Draw field lines and lines of equipotential for the arrangement shown.
b. If the dust particle starts from rest at point O, half way between the plates, will it move towards point A or B?
c. Will the system gain or lose electric potential energy? Where does this change in energy come from?
d. Repeat parts **b** and **c** for a particle with a charge of –2*e*. Will the change in electric potential energy be greater, less than or the same for this particle for a given distance traveled?
e. Rank the electric potential at points A, B and O.
f. What do you think the difference between electric potential and electric potential energy is?

B. Activity Questions:

1. Equipotentials

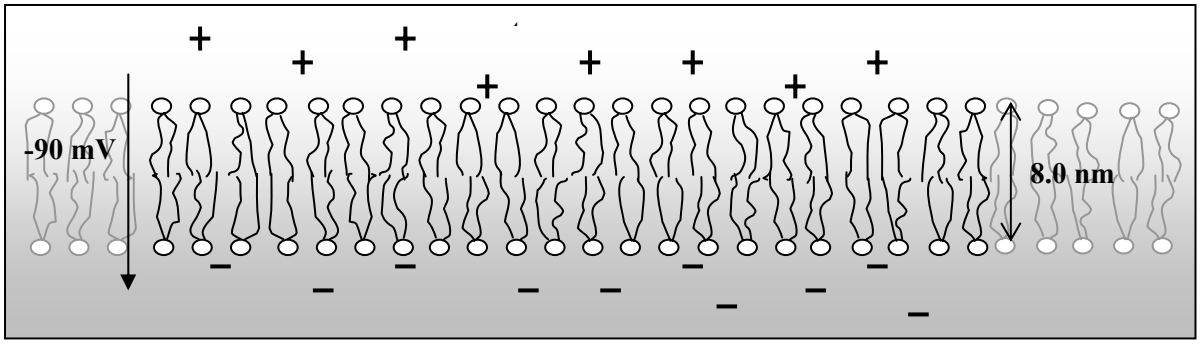
Use the probe to mark out equipotential lines for the arrangements of charge as shown.
What does the density of equipotential lines tell you?

2. Measuring voltages

Use the voltmeter to measure the potential differences across the terminals of the various batteries.
Use the voltmeter to measure the potential difference between two points on the wire.
Now measure the potential difference between one end of the resistor and the other.
Explain why they are different.
Voltmeters are always connected in parallel with the device you are measuring the voltage across.
Why is this the case?

C. Quantitative Questions:

1. Cell membranes are made up of a double layer of fats, about 8.0 nm thick, as shown below.
Inside the cell there is an excess of negative ions, mostly Cl^-, and outside there is an excess of positive ions, mostly Na^+. The cell maintains a potential difference of around –90 mV across the cell membrane.



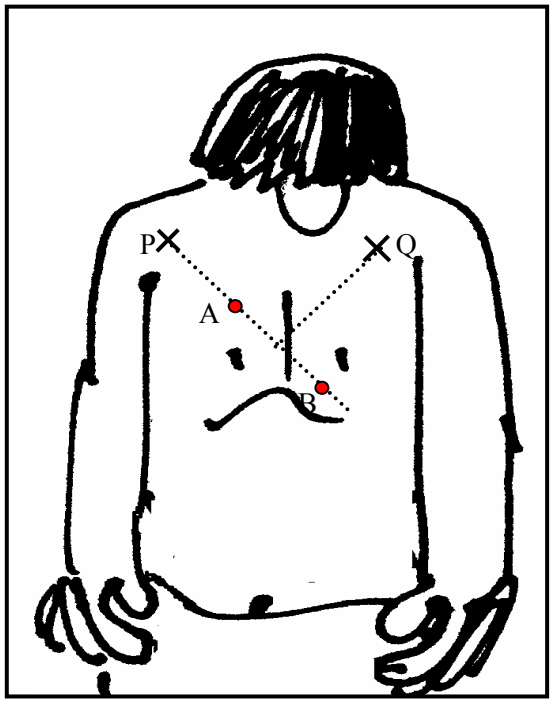
a. Assuming the electric field is uniform, what is the magnitude of the electric field across the membrane?

The membrane potential is maintained by biochemical pumps which move ions into and out of the cell. Moving positive ions against an electrical potential gradient requires energy, and up to 20% of the body's resting energy usage may be used in maintaining this movement.

b. A particular pump transports 3 Na^+ ions out of the cell at the same time as it transports 2 K^+ ions into the cell. What minimum energy must this process use?

2. Electrocardiograms (ECGs) record electric potential differences between points on the chest due to the electrical activity of the heart. The heart behaves at some moments like a dipole as shown.

The charges are 6 cm apart, point P is at an electrode 6.0 cm from charge A and point Q is at an electrode 9.0 cm from a point half way between the charges as shown. The charge at point A is $+ 2.0 \times 10^{-14}$ C, and that at point B is -1.5×10^{-14} C



a. Draw lines of equipotential for this arrangement.
b. What is the potential at point P due to charge A?
c. What is the potential at point P due to charge B?
d. What is the potential at point P?
e. What is the potential difference between points P and Q?