PH 223 Week 4

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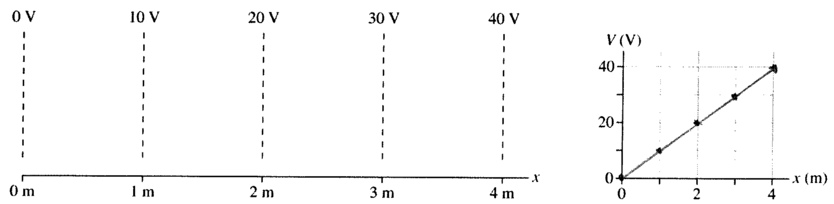
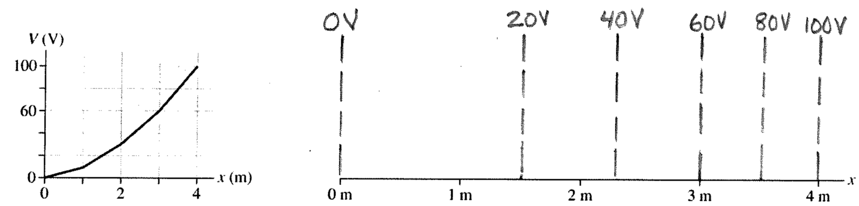
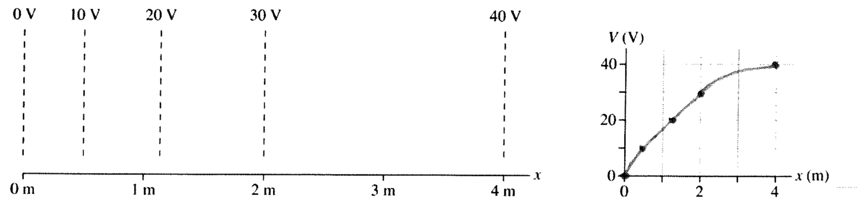
These problems are borrowed/adapted from Chapter 25 of the *Student Workbook* for *Physics for Scientists and Engineers.*

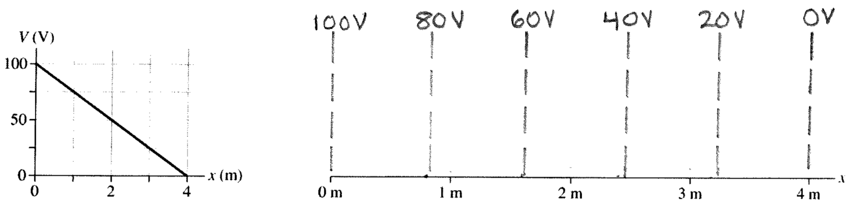
Activity 1

On the left, you will either be given a contour map or a V-versus-x graph. If you are given a contour map, draw a graph of V-versus-x on the provided axes. Your graph should be a straight line or a smooth curve. If you are given a graph, assume the potential varies with x but not with y and draw a contour map of the electric potential. Space your equipotential lines every 20 volts and label them.

a.


b.


c.


d.


Students will not have seen this material in lecture yet, so do warn them that this is a preview. However, the task should not be difficult.

Activity 2

An inflatable metal balloon of radius R is charged to a potential of 1000 V. After all wires and batteries are disconnected, the balloon is inflated to a new radius $2R$.

> Students may fixate on the wire and batteries, even though they are not part of the problem. You may wish to warn them that these elements are simply a narrative device to explain how the balloon got charged, and do not have any bearing on the problem.

(a) Does the potential of the balloon change as it is inflated? If so, by what factor? If not, why not?

Yes. The potential decreases by a factor of 2. Once the wires are disconnected, the charge Q on the balloon is constant. For a symmetric sphere of charge, Gauss' law tells us that the electric field outside is the same as that of a point charge Q at the center of the sphere. At the surface of the balloon at its initial radius, it has potential

$$V_1 = \frac{1}{4\pi\epsilon_0}\frac{Q}{R}.$$

Once we inflate it, the new potential at the surface is

$$V_2 = \frac{1}{4\pi\epsilon_0}\frac{Q}{2R}.$$

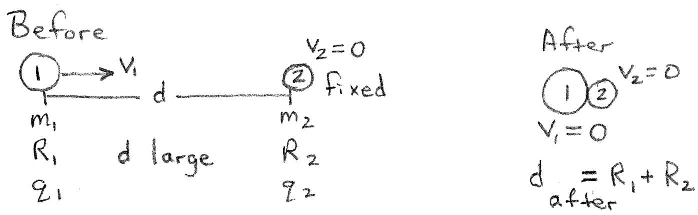
(b) Does the potential at a point at distance $r = 4R$ change as the balloon is inflated? If so, by what factor? If not, why not?

No. As was remarked before, the potential outside of the sphere is the same as that of a point charge Q located at the center of the sphere. The distance $r = 4R$ remains outside of the balloon as it is inflated, and Q is unchanged.

Activity 3

A small charged sphere of radius R_1, mass m_1, and positive charge q_1 is shot head on with speed v_1 from a long distance away toward a second small sphere having radius R_2, mass m_2, and positive charge q_2. The second sphere is held in a fixed location and cannot move. The spheres repel each other, so sphere 1 will slow as it approaches sphere 2. If v_1 is small, sphere 1 will reach a closest point, reverse direction, and be pushed away by sphere 2. If v_1 is large, sphere 1 will crash into sphere 2. For what speed v_1 does sphere 1 just barely touch sphere 2 as it reverses direction?

(a) Begin by drawing a before and after pictorial representation. Initially, the spheres are far apart, and sphere 1 is heading toward sphere 2 with speed v_1. The problem ends with the spheres touching. What is the speed of sphere 1 at this instant? How far apart are the centers of the spheres at this instant? Label the before and after pictures with complete information—all in symbolic form.



(b)We can treat this as an energy conservation problem, but first we have to identify the "moving charge" q and the "source charge" that creates the potential.

The moving charge is q_1, and the source charge is q_2.

(c) We're told the charges start "a long distance away" from each other. Based on that statement, what value can you assign to V_i, the potential of the source charge at the initial position of the moving charge? Explain.

The initial potential $V_i \approx 0$ V, since $V = \frac{1}{4\pi\epsilon_0}\frac{q_2}{d}$, and d is very large.

(d) Now write an expression in terms of the symbols defined above (and any constants that are needed) for the initial energy $K_i + qV_i$.

$$K_i + qV_i = \frac{1}{2}m_1v_1^2 + 0$$

(e) Referring to information on your visual overview, write an expression for the final energy.

$$K_f + qV_f = 0 + \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{R_1 + R_2}$$

(f) Energy is conserved, so finish the problem by solving for v_1.

Since energy is conserved,

$$\frac{1}{2}m_1v_1^2 = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{R_1 + R_2}.$$

Rearranging, we find

$$v_1 = \left[\frac{q_1q_2}{2\pi\epsilon_0 m_1(R_1 + R_2)}\right]^{1/2}.$$