NON-HARMONIC OSCILLATIONS

I. A charged particle in outer space

Consider a charged particle (charge $-q$, mass m) held near a large, positively charged sheet. The sheet is in outer space, where there is neither air nor gravity. It has a very small hole in it through which the particle can pass. The particle is released from rest at a distance x_0 from the sheet.

A. Setting up the problem:

1. Sketch this situation, and clearly label a coordinate axis.

2. Write the equation of motion for the particle. Recall that the electric force $\mathbf{F}_E = q\mathbf{E}$, and that the electric field of a charged sheet does not depend on distance.

3. With your group, discuss the particle's expected motion. Use free-body diagrams if appropriate.

B. How is the motion of this particle different from the motion of a particle with a Hooke's Law restoring force?

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II. A charged particle and a charged sheet

Suppose we move the charged sheet to Earth and hold it horizontally. The particle is released from rest at a distance x_0 above the sheet. There is still no air resistance.

A. Setting up the problem:

1. Sketch this situation, and clearly label a coordinate axis.

2. Write the equation of motion for the particle.

3. How does the motion of the Earthly particle differ from the motion of the particle in outer space? Use free-body diagrams if appropriate.

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B. With your answers to part A in mind, solve:

1. Write a separable equation for velocity and position, and then separate the equation. (*Hint:* If you haven't already, try breaking the motion of the particle into two parts.)

2. Discuss with your group the limits of integration. Explain your reasoning for choosing the limits you do. Which of the limits are constants, and which are variables?

3. Find $v(x)$. Keep in mind which quantities are positive and which are negative.

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C. Make sense of your answer by thinking about the position of the particle below the sheet. What is the maximum position of the particle below the sheet of charge?

1. Consider several limits to this situation:

   a. What is the maximum position below the sheet when the force due to the charged sheet gets large (in an experiment, you could do this by increasing the charge density)?

   b. What is the velocity below the sheet when the force due to the charged sheet becomes equal to the weight force?

   c. What is the velocity below the sheet when the charge on the sheet becomes zero?

2. Are your answers consistent with your description in question II.A.3? Resolve any inconsistencies.

D. Is it appropriate to call your solution "velocity as a function of position?" If so, why? If not, what would be a more appropriate label?

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