General Physics 1–Honors (PHYS 101H): Problem Set 5

Chris Monahan
Department of Physics, William & Mary

Overview

The written Problem Sets will help you gain experience with how to present your solutions to university-level physics problems. This will be necessary for your midterm and final exams, as well as future courses thoughout your undergraduate career. Present your solutions legibly and as logically as you can. What this means in practice is the following:

1. Write down what quantities you know.
2. Write down the relevant equations.
3. When carrying out manipulations or substituting values into equations, try to write each equality on separate lines. For example:

$$\begin{aligned} x(t_0) &= \frac{1}{2}at_0^2 + v_0t_0 + x_0 \\ &= \frac{1}{2}\cdot 9.8 \cdot 1.0^2 + 1.5 \cdot 1.0 + 0.7 \\ &= \boxed{7.1\,\mathrm{m}}. \end{aligned}$$

4. Circle or underline your final answers to identify them clearly (see the equation above).

I will post solutions that will also provide one possible model for how to present solutions.

Some hints:

1. Only substitute values at the end of your calculation and try to carry out all manipulations symbolically.
2. Double check the order of magnitude of your answer.
3. Double check the units of your answer.
4. Double check the number of significant figures of your answer (do not give more significant figures than the question provides for physical quantities).

This Problem Set, in particular, will provide practice in applying conservation of momentum in one dimension and calculating the centre of mass for three different objects.

This Problem Set is worth 50 points; there are three questions in this Problem Set.

Instructions

Read these instructions carefully. You must submit your Problem Set as a **single PDF** file (it is best to use an app like Adobe Scan to make your solutions legible), with the file name `lastname_hwXX.pdf` (replace `lastname` with your last name and `XX` with the problem set number). If you do not submit your Problem Set according to these instructions, you will be deducted five points.

Question 1 **15pts**

You sit on a crate on frictionless ice. You are happy. The combined mass of you and the crate is m.

(a) You are now given a block of mass m to hold. Since you don't like this block, you throw it away, with relative horizontal speed v_0. What is your resulting speed (assuming you are still sitting on the crate)?

(b) The person that gave you the block is disappointed that you threw their block away, so when you come to rest (still on the ice), they give you another block of mass m. This time you dislike it so much you break it in half, then throw away the first half, wait a moment and then throw away the second half. What is your resulting speed? Assume that you throw each piece horizontally and the relative speed each time is v_0.

(c) You are starting to exasperate the person that gave you the blocks, but they persist and give you another block of mass m. You don't understand why. At this point, you are so mad that you break the block into n pieces of equal mass and throw each one away individually (again at relative speed v_0). Find your resulting speed after you have thrown all pieces away (your result should take the form $f(n)v_0$, where $f(n)$ is the function you are trying to determine).

Question 2 **15pts**

A hose shoots a stream of water vertically, with an initial speed of v_0 and mass flow rate of R (measured in kg/s).

(a) What is the maximum height that the water will reach?

A horizontal board is now placed a very small distance above the hose and released.

(b) Find the mass of the board that is necessary for the board to hover at this height. Assume that the water bounces of the board essentially sideways.

(c) If you halve the mass of the board (by breaking it in half, for example), how high above the hose should you place the board so that it hovers in place?

The stream of water is now replaced by a stream of marbles that strike the original board elastically. Assume that the marbles arrive at the board almost continuously (with the same mass rate, R, as the water) and do not interfere with each other once they bounce off the board.

(d) Find the mass of the board that is necessary for the board to hover at a very small height.

Question 3 **20pts**

Find the center of mass of the following objects:

(a) A cuboid of uniform mass density, ρ, with height H and a square base of side length a. For your calculation, assume that the cuboid is oriented such that the height is defined to be in the z direction and that the origin is defined at one corner of the cuboid.

(b) A cuboid of nonuniform mass density, $\rho(x, y, z) = mz^2$, with height H and a square base of side length a. Here m is a constant. For your calculation, assume that the cuboid is oriented such that the height is defined to be in the z direction and that the origin is defined at one corner of the cuboid.

(c) A pyramid of nonuniform mass density, $\rho(x, y, z) = mz^2$, with a square base of side length a and four triangular faces that are equilateral triangles. Here m is a constant. For your calculation, assume that the pyramid is oriented such that the height is defined to be in the z direction and the origin lies directly below the point of the pyramid.