Physics 322 Problem Set #0
(A Review of Classical Mechanics)

Due Friday, January 16 at 4:00 pm

NOTES REGARDING PROBLEM SETS:

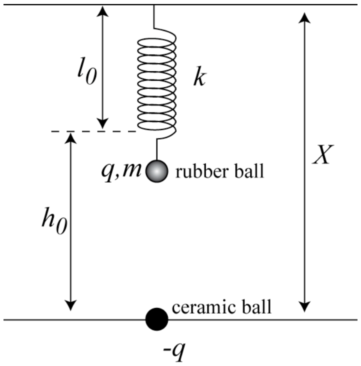
- **Full credit on problem sets will only be given to students who clearly show me not only their mathematical approach to the answer, but clearly state their reasoning. I expect a minimum of a few sentences in each problem explaining your thinking in addition to any math.**
- **Always cite the sources of any equations you use.**
- You may work together in groups on the problem sets. **However, the work you present must be your own.** You will get little out of the problem sets if you just copy someone else's solutions. To avoid the appearance of plagiarism, I would also strongly suggest you state clearly who, if anyone, you worked with on your homework.

ASSUMED READING: Before starting this homework, you should read Harris' *Review of Classical Physics* (posted on the class website, *http://phys322.cabanela.com/*) concentrating on the sections on Conserved Quantities (pages 1-6) and Wave Behavior (pages 22-30) and possibly have your own Physics 201/202 textbook handy before attempting them.

1. When is it inappropriate to use the following expression for the difference in potential energy between two locations

$$U_2 - U_1 = -\int_1^2 \vec{\mathbf{F}} \cdot \mathrm{d}\vec{\ell}$$

(equation 3 from the *Review of Classical Physics* handout)? Specifically, are there any forces for which this expression doesn't work? *Explain* how you arrived at your conclusion. **HINT:** Consider what should happen when the initial and final position are the same.



2. The spring hangs from a ceiling distance X above the floor. The spring has a "relaxed" length of l_0, so that the bottom of the spring would be a height h_0, when the rubber ball is not attached, You can assume that the gravitational attraction between the two charged balls is negligible and the electrical attraction between them is NOT strong enough to overcome the spring's upward pull, so the rubber ball doesn't touch the ceramic ball on the floor. Show that the change in potential energy of the rubber ball as it changes from height h_1 to height h_2 above the floor is $U_2 - U_1 = \frac{1}{2}k\left(\left[h_0 - h_2\right]^2 - \left[h_0 - h_1\right]^2\right) + \frac{q^2}{4\pi\varepsilon_0}\left[\frac{1}{h_1} - \frac{1}{h_2}\right]$. **HINT:** Since potential energy is a scalar, you can compute the potential energy change for the two force separately, then sum them to get the total change in potential energy.

3. In experimental particle physics, the momentum and mass of a particle are often more measurable than its velocity. **Derive** an expression for the kinetic energy of a particle in terms of only its momentum, *p*, and its mass, *m*.

4. The 1-D classical wave equation describing the waves that can propagate in a string with mass per unit length μ and tension τ is
$$\mu \frac{\partial^2 y(x,t)}{\partial t^2} = \tau \frac{\partial^2 y(x,t)}{\partial x^2}$$
$$\frac{\partial^2 y(x,t)}{\partial t^2} = \frac{\tau}{\mu} \frac{\partial^2 y(x,t)}{\partial x^2}$$
as derived on pages 22-23 of Harris' *Review of Classical Physics*.
   a. Explain, in words, what physical principles were used and what assumptions were made in deriving the wave equation. Put another way, in what situations is this wave equation valid.
   b. As suggested in the text (but poorly presented), you should consider a solution to this equation of form $y(x,t) = f(u) = f(x \pm vt)$ where *v* is the velocity of the wave down the string. Notice the way I wrote this, we can treat this as a function of a single variable, *u=x±vt.* Compute $\frac{\partial^2 y(x,t)}{\partial t^2}$ and $\frac{\partial^2 y(x,t)}{\partial x^2}$ in terms of $\frac{\partial^2 f}{\partial u^2}$ and use the results to show that the velocity of the wave must be $v = \sqrt{\frac{\tau}{\mu}}$ if *f(x±vt)* is a valid solution to the wave equation. Notice this means the wave equation can be generalized to the form:
$$\frac{\partial^2 y(x,t)}{\partial t^2} = v^2 \frac{\partial^2 y(x,t)}{\partial x^2}.$$
Hint: You'll need to extensively use the chain rule such as $\frac{\partial^2 f}{\partial t^2} = \frac{\partial}{\partial t}\left(\frac{\partial f}{\partial t}\right)$ and $\frac{\partial f}{\partial x} = \frac{\partial u}{\partial x}\frac{\partial f}{\partial u}$. Also note this is not exactly the way Harris attacks the derivation in his writeup.
   c. Verify that if we have two solutions (let's call them functions *f* and *g*) to the wave equation:
$$\frac{\partial^2 y(x,t)}{\partial t^2} = v^2 \frac{\partial^2 y(x,t)}{\partial x^2}$$
then a superposition of the two waves, *Af*+*Bg* (where *A* and *B* are constants), is also a solution to the wave equation. **Hint:** If you are doing more than a few lines of mathematics, you are on the wrong path.