University of Maryland
Department of Physics

Physics 374 — **Dr. E. F. Redish**

Fall 2004 — **Exam 1** — **11. October, 2004**

Instructions:

Do not open this examination until the proctor tells you to begin.

1. When the proctor tells you to begin, **write your full name and section number at the top of every page.** This is essential since this exam booklet will be separated for grading.
2. Do your work for each problem on the page for that problem. You might find it convenient to either do your scratch work on the back of the page before starting to write out your answer or to continue your answer on the back. **If part of your answer is on the back, be sure to check the box on the bottom of the page so the grader knows to look on the back!**
3. On all the problems your answers will be evaluated at least in part on how you got them. If explanations are requested, more than half the credit of the problem will be given for the explanation. LITTLE OR NO CREDIT MAY BE EARNED FOR ANSWERS THAT DO NOT SHOW HOW YOU GOT THEM. Partial credit will be granted for correct steps shown, even if the final answer is wrong.
4. Write clearly and logically so we can understand what you are doing and can give you as much partial credit as you deserve. We cannot give credit for what you are thinking — only for what you show on your paper.
5. All estimations should be done to the appropriate number of significant figures.
6. At the end of the exam, write and sign the honor pledge in the space below: "I pledge on my honor that I have not given or received any unauthorized assistance on this examination."

#1:	#2:	#3:	#4:	#5:	Total

!!! Good Luck !!!

1. (30 points) When studying the orbits of an object of mass m around a planet of mass M it is useful to create an "effective radial potential" that is only a function of the raidus and has the form

$$U_{eff}(r) = -\frac{GmM}{r} + \frac{L^2}{2mr^2}$$

where L is the object's orbital angular momentum.

With a little algebra and dimensional analysis (don't do it) we can write this in the more convenient form

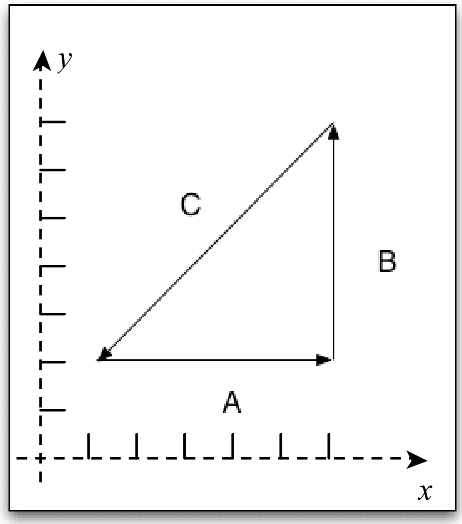
$$U_{eff} = \varepsilon\left[-\left(\frac{\sigma}{r}\right) + \frac{1}{2}\left(\frac{\sigma}{r}\right)^2\right]$$

(a) Sketch what the curve of $U_{eff}(r)$ looks like as a function of r identifying the salient points (maxima or minima, crossings of 0) by giving an expression for them in terms of the constants σ and ε.

(b) Expand $U_{eff}(r)$ in a power series about the location of its minimum value, r_0, to second order. Sketch the same figure you drew in (a) but this time add onto it a sketch of the second order power series approximation you have generated.

(c) Identify the "effective spring constant", k, that would give an approximation for $U_{eff}(r)$ in the neighborhood of its minimum, $U_{eff}(r) \approx U_0 + \frac{1}{2}k(r - r_0)^2$

2. (25 points) You are pulling a block along a table following the path shown in the figure at the right (top view). The block has a mass *m* and the coefficient of kinetic friction between the block and the table is μ. An x-y coordinate system is shown. Each tic mark represents 10 cm.



(a) Calculate the work done on the block by friction along each leg of the triangle. Be sure to show how you got the result starting from the definition of work. (15 pts)

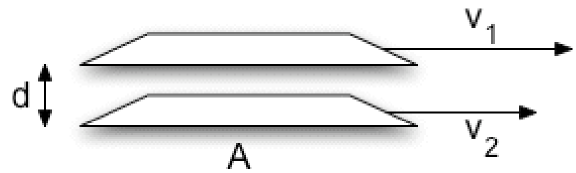
(b) If the block starts from rest and ends at rest, how much work did you do on the block? Explain. (10 pts)

3. (15 points) An unrestrained child is playing on the front seat of a car that is traveling in a residential neighborhood. A small dog runs across the road and the driver applies the brakes, stopping the car quickly and missing the dog. Estimate the speed with which the child strikes the dashboard, presuming that the car stops before the child does so. Compare this speed with that of the world-record 100 m dash, which is run in about 10s. *Be sure to clearly state your assumptions and how you came to the numbers you estimated, since grading on this problem will be mostly based on your reasoning, not on your answer.*

4. (10 points) In this class we have introduced the idea of a "complex number." Explain what a complex number is mathematically. To what extent it is useful physically? Give an example.

5. (20 points) When we were considering the kind of resistance a fluid can exert on an object moving in it, we considered the force linear in velocity, the viscous force. In fluid flow, the viscosity is a kind of internal friction.

If we consider two neighboring sheets of fluid (don't worry too much about how to define this precisely) moving with different velocities as in the figure at the right, then each sheet will exert a force on the other of magnitude



$$F = \eta A \frac{\Delta v}{d}$$

where A is the area of the sheets, Δv the difference between their velocities, and d the distance between them. The constant η is known as the viscosity.

If you have a fluid of density ρ flowing through a pipe of diameter D, you can create a natural velocity for the system from ρ, D, and η. Find it using dimensional analysis.