University of Maryland
Department of Physics

Physics 374 **Dr. E. F. Redish**

Fall 2004 **Exam 2** **3. December, 2004**

Instructions:

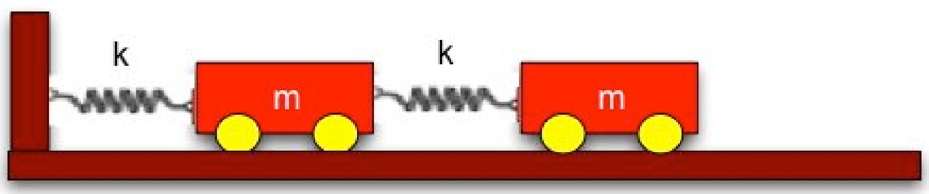
Do not open this examination until the proctor tells you to begin.

1. When the proctor tells you to begin, **write your full name 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. (25 points) Two identical wheeled carts of mass m are connected to a wall and each other as shown in the figure below. The two springs have spring constants k and a rest length l_0.



(a) Choose a convenient coordinate system for describing the positions of the carts and write the equations of motion for the carts. Be sure to specify your coordinate system. (7 pts.)

(b) Do you have some way to check that these equations are right?
Describe one check you made. (3 pts.)

(c) Find the frequencies of oscillation of the possible normal modes of the system. (10 pts)

(d) Our "standard normal modes" $\frac{1}{\sqrt{2}}\begin{pmatrix}1\\1\end{pmatrix}$ and $\frac{1}{\sqrt{2}}\begin{pmatrix}1\\-1\end{pmatrix}$ that we have found for many systems are not normal modes of this system. Explain why not. (You don't have to find the actual modes.) (5 pts.)

2. (20 points) A two mass system where each mass can be displaced in one dimension is described as a linear space spanned by the basis vectors $\vec{f}_1 = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$ and $\vec{f}_2 = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$. Suppose the normal modes of the system are found to be described by the orthonormal set of vectors $\vec{e}_1 = \begin{pmatrix} \alpha \\ \beta \end{pmatrix}$ and $\vec{e}_2 = \begin{pmatrix} \gamma \\ \delta \end{pmatrix}$ where α, β, γ, δ could be complex.

(a) If we choose to describe these 4 vectors as Dirac states, $|f_i\rangle$, i = 1,2 and $|e_i\rangle$, i = 1,2, find the 8 inner products $\langle e_i | f_j \rangle$ and $\langle f_i | e_j \rangle$. (8 pts)

(b) What is the matrix (in the f-basis) that represents the sum $\sum_{i=1}^{2} |e_i\rangle\langle e_i|$. (5 pts)

(c) A vector is represented in the f-basis by the sum $|A\rangle = \sum_{i=1}^{2} A_i |f_i\rangle$. This same vector is represented in the e-bases by $|A\rangle = \sum_{i=1}^{2} A'_i |e_i\rangle$. Find the A'_i in terms of the A_j. (7 pts)

3. (15 points) From your knowledge of other students estimate the total number of hours that University of Maryland undergraduates spend playing video games in one semester. *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*

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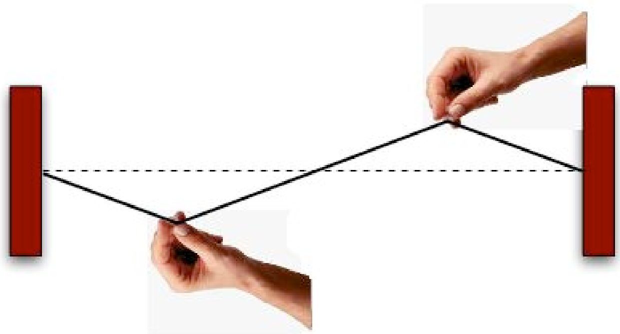
4. (10 points) In our discussions of the Fourier series we have introduced the Dirac delta function, $\delta(x-x')$. Defining this symbol carefully by its properties and explain both what it is good for and why it is somewhat peculiar when thought of as a function.

5. (30 points) A guitar string is “plucked” by holding it at the 1/3 and 2/3 points and pulling in opposite directions as shown in the figure at the right.



In order to figure out what the string will sound like when it is plucked in this fashion, we need to know which of the normal modes of the string are present in the subsequent motion.

(a) If the string has a length L, a tension T, and a mass M, identify the normal modes of the string and the frequencies associated with those modes. (10 pts.)

(b) Identify which modes will be present. If any will be absent, explain why. (5 pts.)

(c) How would you find how much of each mode is present in the motion? Don’t do the calculation, but create an expression that, given the values of the parameters L, T, and M, a computer programmer who knows knothing about the physics could produce the answers. (10 pts.)

(d) Write an expression that will yield the shape of the string, $y(x,t)$, at any time. (5 pts.)