

U-grad or M-Eng or PhD? & 4730 or 5730?

Your name:

Cornell
ME 470/5730

Prelim 2

November 19, 2013

No calculators, books or notes allowed.

3 Problems, 90 minutes (+ up to 90 minutes extra if you want it)

How to get the highest score?

Please do these things:

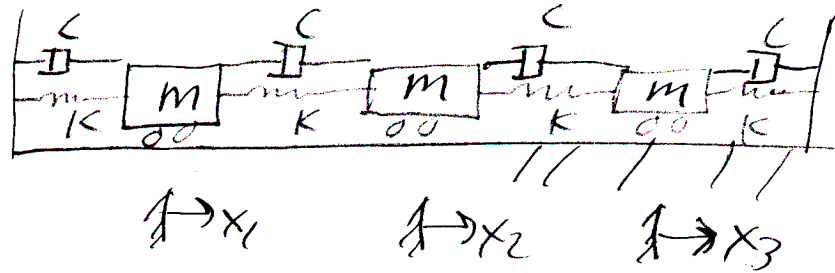
- Draw **Free body diagrams** whenever force, moment, linear momentum, or angular momentum balance are used.
- Use correct **vector notation**.
- A+ Be (I) neat, (II) clear and (III) well organized.
- TIDILY REDUCE and box in your answers (Don't leave simplifyable algebraic expressions).
- >> Make appropriate Matlab code clear and correct.
You can use shortcut notation like " $T_7 = 2\pi$ " instead of, say, " $T(7) = 2*\pi$ ";".
Small syntax errors will have small penalties.
- ↗ Clearly **define** any needed dimensions (ℓ, h, d, \dots), coordinates ($x, y, r, \theta \dots$), variables (v, m, t, \dots), base vectors ($\hat{i}, \hat{j}, \hat{e}_r, \hat{e}_\theta, \hat{\lambda}, \hat{n} \dots$) and signs (\pm) with sketches, equations or words.
- **Justify** your results so a grader can distinguish an informed answer from a guess.
- ➡ If a problem seems *poorly defined*, clearly state any reasonable assumptions (that do not oversimplify the problem).
- ≈ Work for **partial credit** (from 60–100%, depending on the problem)
 - Put your answer is in terms of well defined variables even if you have not substituted in the numerical values.
 - Reduce the problem to a clearly defined set of equations to solve.
 - Provide Matlab code which would generate the desired answer (and explain the nature of the output).
- **Extra sheets.** The last page is blank for your use. Ask for more extra paper if you need it. Put your name on each extra sheet, fold it in, and refer to back pages or extra sheets on the page of the relevant problem.

Problem 4: ____/25

Problem 5: ____/25

Problem 6: ____/25

4) Three equal masses m are held apart between two walls by four equal linear springs k and four equal linear dashpots c .



a) Assume $m = 1$, $k = 2$ and $c = 0.01$ in some consistent unit system. Use initial conditions

$$\vec{x}(0) = \begin{bmatrix} 1 \\ 2 \\ 3 \end{bmatrix} \quad \text{and} \quad \dot{\vec{x}}(0) = \vec{v}(0) = \begin{bmatrix} 4 \\ 5 \\ 6 \end{bmatrix}.$$

Write Matlab commands that would find $x_1(t = 10)$. You may *not* use numerical integration (e.g., *no* Euler's method, *no* ODE45, etc).

- b) Can the general motion (that is, the solution for an arbitrary initial condition) of this system be found as the sum of solutions each of which is a 'mode' behaving as an independent damped oscillator? If so, describe precisely how to find these modes. If not, explain why not.
- c) Assume a force $F = 3 \sin(2t)$ is applied to just mass 1. In steady state, approximately what are the amplitudes of vibration of the three masses? No detailed arithmetic is desired, rather say something like 'mass 7 moves much more than mass 8 and much less than mass 4', with appropriate substitutions for 7, 8, 4 the words 'much more' and 'much less'. Use words to justify your answer.

5) Three equal point masses m move in 2D and are attracted to each other by inverse square gravity $F_{ij} = Gm_i m_j / r_{ij}^2$. There are no other forces. One possible motion is that they all travel in circles about the origin, each with the same constant $\dot{\theta} = \omega$, with the three masses on the vertices of a (rotating) equilateral triangle with sides $= \ell$. Find the rate of rotation ω in terms of G, m and ℓ .

6) A uniform stick with mass m and length ℓ hangs from a stationary hinge at one end. Gravity g acts. The angle of the stick from vertically down is $\theta(t)$, measured CCW.

- a)** Find $\ddot{\theta}$ in terms of some or all of m, g, ℓ, θ and $\dot{\theta}$ as many different ways as you can. If you have well-defined equations from which $\ddot{\theta}$ could be found, you need not do the algebra.
- b)** Find, using any single method of your choice, the force acting on the hinge in terms of some or all of $m, g, \ell, \theta, \dot{\theta}$ and any unit vectors you clearly define (your choice of unit vectors).

