Please write your net ID and name on the top of every side of every page, now.

—Please print clearly (for computer text recognition)—

U-grad or M-Eng or PhD? & 4730 or 5730? **Your netID (xyz*lmn*) & name:**

Cornell ME 4730/5730

Prelim 1

Thursday October 8, 2020, 7:30-9 PM$^+$

No calculators, books or notes allowed.

3 Problems, 90 minutes (+ 90 minutes extra time)

How to get the highest score?

Please do these things:

Scans. Start each problem on a clean sheet.
Put ***your name, *net ID, *problem number** and ***page number** on the top of every side of every sheet.
At the end:
—Scan your exam, including both sides of this sheet,& check it for completeness and quality;
—Filename should be netID-first-last.pdf (*e.g.,* alr3-Andy-Ruina.pdf);
—Subject: "Prelim 1";
—email it to: ruina@cornell.edu;
—Check that it has been received before leaving the exam;

- 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 $\boxed{\text{box in}}$ your answers (Don't leave simplifyable algebraic expressions).

>> Make appropriate `Matlab code` clear and correct.
You can use shortcut notation like "$\phi_7 = 2\pi$" instead of, say, "`phi(7) = 2*pi;`".
Small syntax errors will have small penalties.

Clearly **define** any needed dimensions ($\ell, h, d, \ldots$), coordinates ($x, y, r, \theta \ldots$), variables ($v, m, t, \ldots$), base vectors ($\hat{\boldsymbol{\imath}}, \hat{\boldsymbol{\jmath}}, \hat{\boldsymbol{e}}_r, \hat{\boldsymbol{e}}_\theta, \hat{\boldsymbol{\lambda}}, \hat{\boldsymbol{n}} \ldots$) and signs ($\pm$) with sketches, equations or words.

Justify your results so a grader can distinguish an informed answer from a guess. If you quote a fact that a grader might doubt your understaning of, explain it. Especially if it is not commonly used.

If a problem seems *poorly defined*, clearly state any reasonable assumptions (that do not oversimplify the problem).

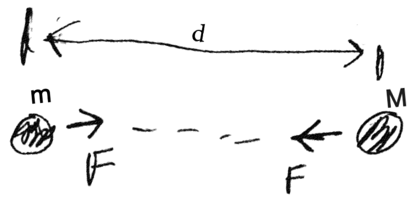
≈ Work for **partial credit** (from 60 – 100%, depending on the problem)

- 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 (unless specifically precluded).

Extra sheets. Ask for more extra paper if you need it. Put your name, net ID, problem number and page number on each extra sheet, label it clearly place it in order with it's associated problem.

All problems are 2D.

1) Circular motion. 2D. Two particles with (possibly different) masses m and M are in circular motion in which, because of the gravity force and the appropriate initial conditions, the distance between them remains a constant d. The only forces on them are their mutual gravitational attractions due to the usual (*e.g.,* earth and moon) inverse-square attraction, with the gravitational constant 'big' G. In terms of some or all of G, m, M and d, what is the angular momentum of the system (about any point that you choose and clearly define)? [No need for a giant formula, your answer can be in terms of intermediate quantities that are defined in terms of G, m, M and d.]



2) Particle with four forces on it. 2D. A particle m is connected to the origin with a (1) linear spring (k, ℓ_0) and (2) a linear dashpot c. Also, (3) gravity g acts in the $-y$ direction. Finally, (4) there is also a drag force opposing the direction of motion, with magnitude dv^2, where d is a drag constant. Assume that MATLAB code has been written where, at the time of interest, all of the following quantities have already been defined, or found:

`m, g, k, ell_o, c, d`, and
`r = [x,y]'`, and `v = [v_x,v_y]'`.

Write MATLAB code, the last line of which should be

`a = ________________`,

where `a` is a two component vector giving the x and y components of the acceleration. Short and clear lines of code are far preferred to long lines of code. Comments need not follow MATLAB notation (*i.e.,* circles and arrows are ok). Informal notation is ok (*e.g.,* ℓ_0 and v_x instead of `ell_0` and `v_x`).

3) Koenig's theorem 2D. Start with a reasonable definition of the kinetic energy E_{K} of a system of particles.

a. Show that E_{K} can be written as a sum of two terms, one concerning the motion of the center of mass, $E_{\mathrm{K}G}$, and one concerning motion relative to the center of mass, $E_{\mathrm{K}/G}$.

b. Show how $E_{\mathrm{K}/G}$ simplifies if you assume that all of the particles are part of a single rigid object.