—Print your netID on the top of every side of every sheet—
—Print clearly (for computer text recognition)—

Net ID (don't include'@cornell.edu')

Your name:

Cornell
ME 2030

No calculators, books or notes allowed.

Final Exam

May 15, 2019
5 Problems, 150 minutes (+ no over time)

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 $\boxed{\text{box in}}$ 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 ($\hat{\imath}, \hat{\jmath}, \hat{e}_r, \hat{e}_\theta, \hat{\lambda}, \hat{n} \ldots$) 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). If you are referred here during the exam it means that answering your question would be telling you something you are being tested on.
- ≈ Work for **partial credit** (from 50% –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 you. Ask for more if you need it. Put your name on each sheet, and fold it in. Refer to extra pages (We have to find them on a computer scan.)

Problem 13:	/30
Problem 14:	/30
Problem 15:	/30
Problem 16:	/30
Problem 17:	/30

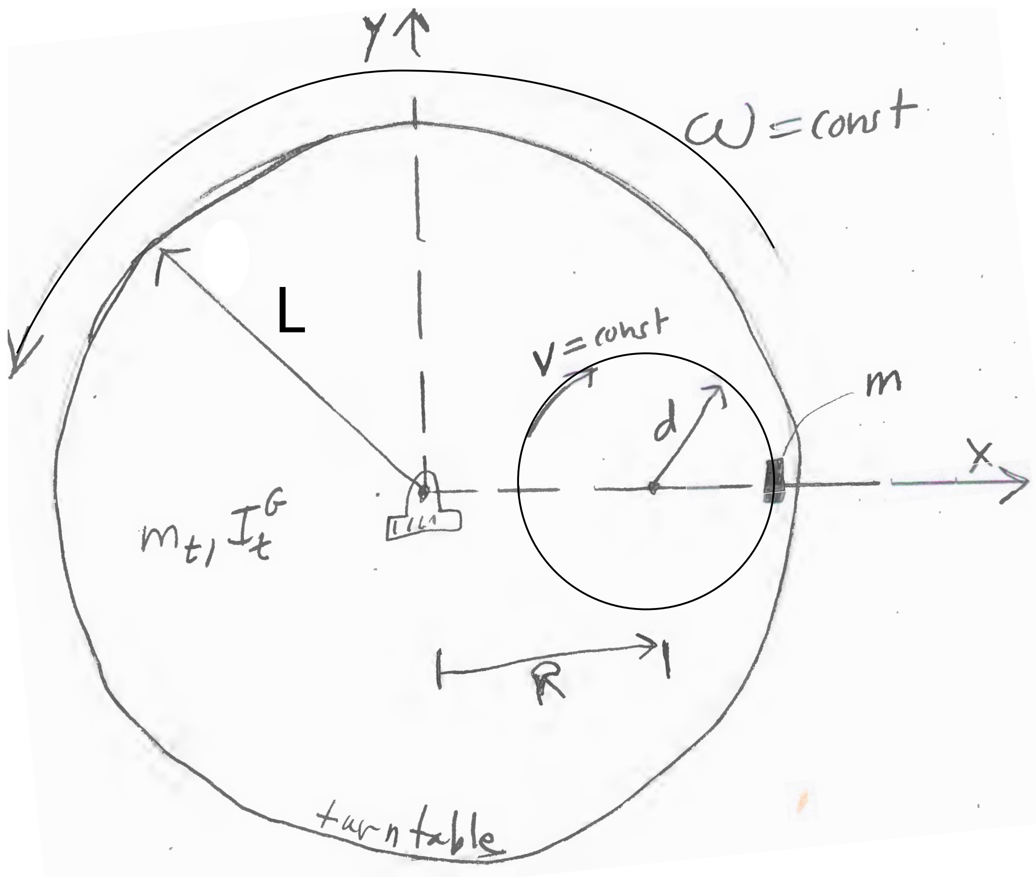
13) Bug on a turntable 2D. Ignore gravity. A motor (not shown) turns a shaft welded to a large turntable at its center (motor and shaft not shown). It turns at constant CCW rate ω. The turntable has radius L, mass m_t, and moment of inertia I_t^G A bug with mass m runs in circles on the turntable with constant linear speed (distance per time), relative to the turntable, of v. The marked clockwise track the bug runs on has radius d and has center a distance R from the center of the big turntable. At the instant of interest the bug is at the position shown on the x axis of the fixed frame. $\hat{\imath}$ and $\hat{\jmath}$ are aligned with the x and y of the fixed frame.

a) **Velocity.** At that instant, what is the velocity of the bug in the Newtonian frame? Answer in terms of some or all of the quantities given above.

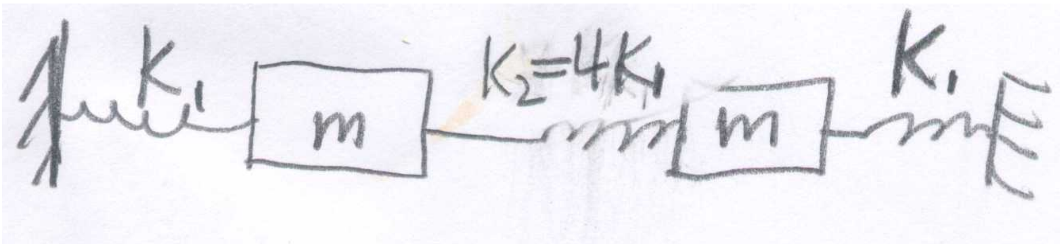
b) **Acceleration.** Same as above, but for acceleration.

c) **Force.** Same as above, but for the force (a vector) and moment on the turntable from the shaft.

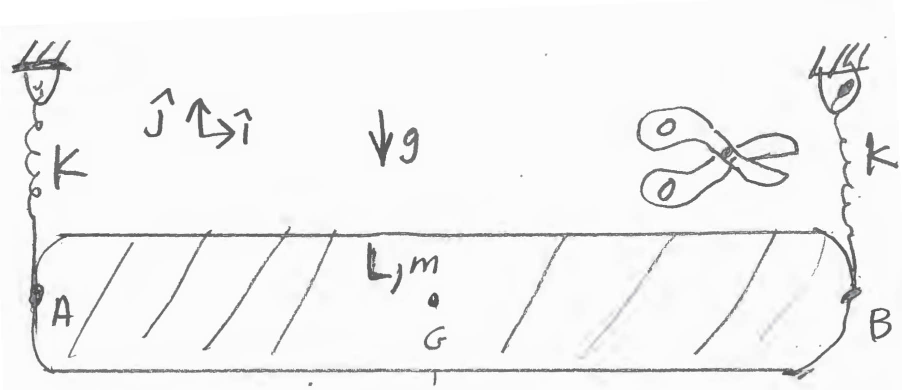
Hint: you can check your answer for velocity by seeing the answer in the special case that $v = \omega(d + R)$



14) Two masses. 1D. No gravity. g. x_1 and x_2 are the deflections of the two blocks relative to the equilibrium position. The middle spring is 4 times as stiff as the side springs. Find any non-zero solution of the equations of motion. That is, find any $f_1(k_1, m, t)$ and $f_2(k_1, m, t)$ so that $x_1 = f_1$ and $x_2 = f_2$ satisfy the governing differential equations. At least one of the two functions has to be non-zero.



15) Bar hung by springs. 2D. There is gravity g. The uniform narrow bar, with length L and mass m is hung by two equal springs k and is in equilibrium. Then the right spring is cut. Immediately after the cut is made, what is the acceleration $\vec{\boldsymbol{a}}_A$ of point A? Answer in terms of some or all of m, L, k, g, $\hat{\boldsymbol{\imath}}$ and $\hat{\boldsymbol{\jmath}}$. Note: $I^G = mL^2/12$



16) Car braking. 2D. There is gravity g. The car is screeching to stop on level ground. All wheels are braked and locked and skidding with friction coefficient μ. Assume all of the wheels stay on the ground. The mass of car = m. Moment of inertia about CoM is I^G. Distance between front and back wheels is $2d$. The center of mass is halfway between the front and back (*i.e.,* d forwards from the rear wheels), and at height h from the ground. In terms of some or all of these variables, find the vertical component of the ground force on the rear wheels.

17) Stick swings. 2D, there is gravity g. A massless stick with length $2d$ hangs a distance d below a fixed hole, suspended by two strings, both with length $\sqrt{2} \cdot d$ and tied to the hole and the stick. The strings stay taut. Attached to the ends of the stick are two point masses m. You want to understand the swinging motion. Find the differential equation(s) of motion. That is, define an appropriate variable θ and find $\ddot{\theta}$ in terms of some or all of g, d and m. In the position shown, $\theta = 0$.