Your TA, Section # and Section time:

Your name:

Cornell
ME 2030, Dynamics

Final Exam

May 15, 2014

No calculators, books or notes allowed.

5 Problems, 150 minutes (+ no overtime, Cornell rules)

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 simplifiable algebraic expressions).
- >> : Make appropriate `Matlab code` clear and correct.
  You can use shortcut notation like "$T_7 = 18$" instead of, say, "`T(7) = 18`".
  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 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 13: ____ /25

Problem 14: ____ /25

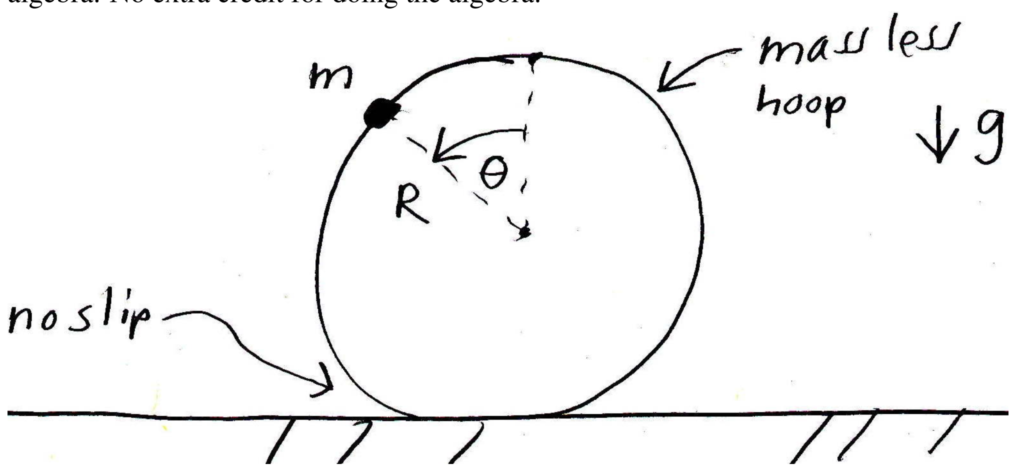
Problem 15: ____ /25

Problem 16: ____ /25

Problem 17: ____ /25

13) 2D. A round rigid hoop with radius R has negligible mass. A point mass m is glued to the hoop. The hoop rolls without slip on a horizontal surface. Given $\theta, \dot{\theta}, m, g$ and R find $\ddot{\theta}$.

Full credit for reducing the problem to a totally clear math problem (one that a skilled person could solve without understanding the problem or looking at any pictures). That is, you should set up the problem correctly while making clear that you could do all of the algebra required (e.g., show all of the planned substitutions and show the results of any needed dot and cross products between base vectors). That is, there is no point in doing any lengthy algebra. No extra credit for doing the algebra.



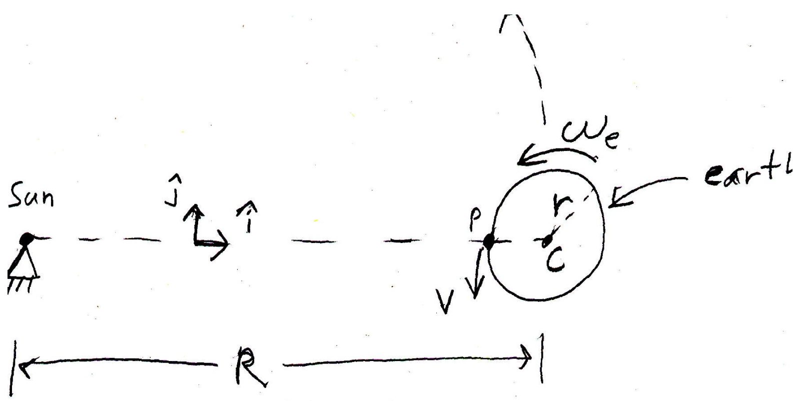
14) 2D. The earth goes around the sun. A plane goes around the earth.

- The earth goes around the sun in a counter-clockwise circular orbit with radius R once per unit time T (that is, if you were to substitute numbers, which you should *not* do, $T = 1$ year).
- The angular velocity of the earth is $\omega_e = \omega_{e/\mathcal{F}}$ relative to the fixed distance Newtonian-reference-frame stars (That is, $\omega_e > 2\pi/\text{day}$ by a little bit).
- The earth radius is r.
- A plane is going counterclockwise around the earth with constant speed v_p relative to the earth (v_p is the so-called "ground speed" of the plane).
- At the time of interest everything is lined up like in the picture below (with the plane at P on the line from the sun to the center of the earth).
- Answer all questions in terms of some or all of R, r, T, ω_e, v_p, $\hat{\boldsymbol{\imath}}$ and $\hat{\boldsymbol{\jmath}}$.

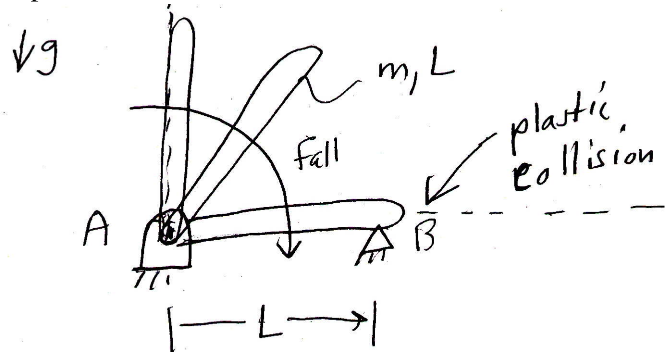
a) What is the position of the plane $\vec{\boldsymbol{r}}_p$?

b) What is the velocity of the plane $\vec{\boldsymbol{v}}_p$?

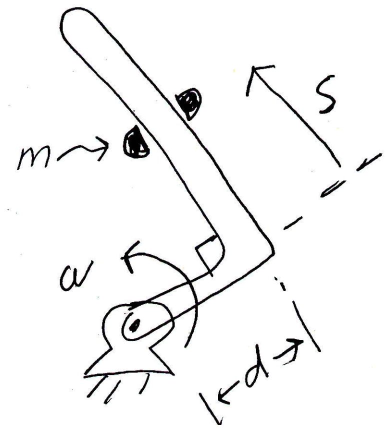
c) What is the acceleration of the plane $\vec{\boldsymbol{a}}_p$?



15) 2D. A uniform rigid stick with length L and mass m is balanced upright. It is hinged at A. It is then given a tiny push (big enough to cause a fall, but small enough so that the kinetic energy just after the push is negligible) and eventually falls to the right. It has a plastic collision at B, assume the impulse at B is vertical. What is the impulse at B? Answer in terms of some or all of m, ℓ and g.



16) 2D. No gravity. A rigid L-shaped rod rotates at constant angular speed ω. A point mass m slides on the rod with no friction. Given that $s(0) = 0$ and $\dot{s}(0) = v_0$ find $s(t)$. Your answer can contain some or all of t, v_0, m, d and ω.



17) 1D. No gravity. Spring-mass-dashpot system. The width of the two masses is negligible. At $t = 0$ the masses have given positions x_{10}, x_{20} and speeds to the right v_{10}, v_{20}. Assume any non-zero values, in consistent units, for the parameters $x_{10}, x_{20}, v_{10}, v_{20}, k, \ell_0, c1, c_2$ and t_{end}. Using ODE45, write Matlab code to plot the position of mass one for the interval $0 \le t \le t_{end}$.