Fall 2014 – Physics 325 Midterm Exam #1
Thursday Oct 2, 11:00 am – 12:30 pm

This is a closed book exam. No use of calculators or any other electronic devices is allowed. Work the problems only in your answer booklets only. The exam questions will *not* be collected at the end, so **anything you write on these question pages will NOT be graded**

You have **90 minutes** to work the problems.

At the beginning of the exam:
1) Write your **name** and **netid** on your answer booklet(s).
2) Turn your **cell phone off**.
3) Put away all calculators, phones, computers, notes, and books.

During the exam:
1) **Show your work** and/or reasoning. **Answers with no work or explanation get no points.** But ...
2) **Don't write long essays** explaining your reasoning. We only need to see enough work to confirm that you understand what you're doing and are **not just guessing**. Also a good **annotated sketch** is often the best explanation of all!
3) **All question parts on this exam are independent**: you can get full points on any part even if your answers to all the other parts are incorrect. Therefore you should **attempt all the question parts!** If you get stuck, move on to the next one and come back later. The worst thing you can do is stall on one question and not get to others whose solution may be very simple.
4) Partial credit will be given for incorrect answers if the work is understandable and some of it is correct. IMPORTANT: If you think you've made a mistake but can't find it, **explain what you think is wrong** ➔ you may well get partial credit for noticing your error!
5) It is fine to leave answers as **radicals or irreducible fractions** (e.g. $10\sqrt{3}$ or 5/7).
6) Specify the **units** for all numerical answers.

Remember: There are many **Math Tables** provided ➔ do **Use Them!**

When you're done with the exam:
Turn in your **answer booklet**. (You can keep the exam questions).

Academic Integrity:

The giving of assistance to or receiving of assistance from another person, or the use of unauthorized materials during University Examinations can be grounds for disciplinary action, up to and including expulsion from the University.

Please be aware that prior to or during an examination, the instructional staff may wish to rearrange the student seating. Such action does not mean that anyone is suspected of inappropriate behavior.

You must derive any result that is not on the formula sheet.
You may of course use from memory any formulae from a previous class, e.g. 211, 225.

You may use without proof these Moments of Inertia:

- **Thin rod** of uniform mass m and length d rotating around its **center**: $I = md^2/12$
- **Thin rod** of uniform mass m and length d rotating around its **end**: $I = md^2/3$

In both of the above cases, the axis of rotation $\hat{\omega}$ is perpendicular to the rod.

Problem 1 : Skydiving Cow

An adventurous spherical cow of mass m enjoys skydiving. She steps out of a plane and falls under the influence of uniform gravity, g, and a quadratic air resistance force, $\vec{F} = -cv^2\,\hat{v}$, where c is a constant.

What is the terminal velocity achieved by the cow before she opens her parachute?

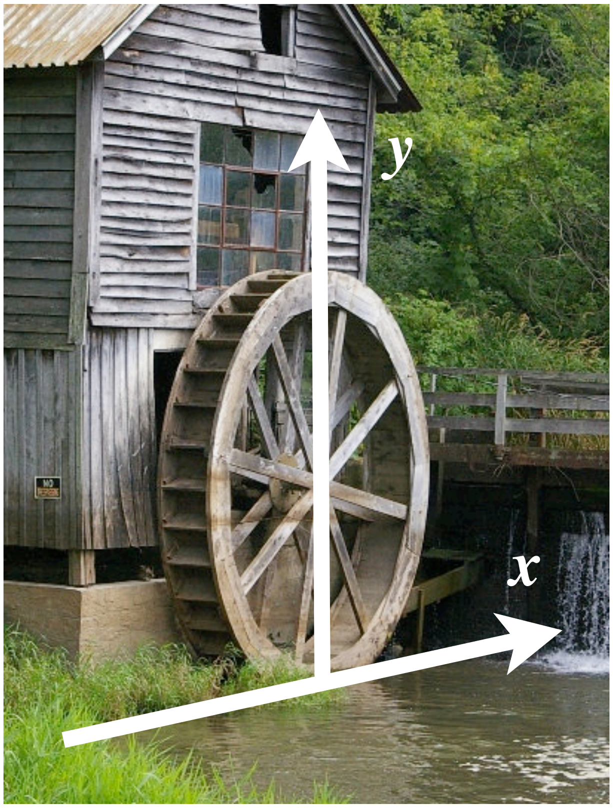
Problem 2 : Water Wheel

A water wheel has radius b and a total mass M that is distributed uniformly on its circumference. (The wheel's radial spokes are massless so you can treat the wheel as a thin circular ring.) Let the y-axis point upwards and the x-axis point horizontally. The wheel is placed in this xy-plane, and its center is connected to a fixed, frictionless axis that runs parallel to the z axis. The wheel is positioned so that only its **lowest point** is in contact with a running stream, whose water flows at a constant speed u in the $-x$ direction.

The stream exerts a force

$$\vec{F} = -k(u + v_x)\hat{x}$$

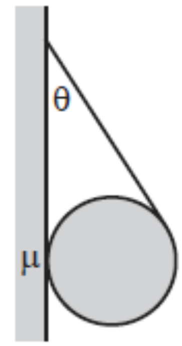
on the **lowest point** of the wheel, where v_x is the x-component of that lowest point's velocity relative to the ground (not the water).



(a) At time $t = 0$, the clamps preventing the wheel from rotating are released. Calculate the wheel's rotational speed ω as a function of time for $t \geq 0$.

(b) Check your result in the limiting cases $t = 0$ and $t \to \infty$, and explain why the ω values you find make sense. If they *don't* make sense, you will still get full points for this part if you can explain what $\omega(t=0)$ and $\omega(t=\infty)$ *should* be.

Problem 3 : A Ball and a Wall



As shown in the figure, a spherical ball is is held against a vertical wall by a string (the thin line). The string is secured to the wall at its top end, while the string's lower end is attached to the ball so that it is tangential to the ball's surface. If the angle between the string and the wall is θ, what is the minimum coefficient of static friction, μ, between the ball and the wall that will prevent the ball from slipping?

Problem 4 : This Should be Quick

At a given instant in time, a particle of mass m has position $\vec{r}$, velocity $\vec{v}$, and acceleration $\vec{a}$.
Calculate $\dot{T}$, the rate of change of the particle's kinetic energy at this moment in time. Express your answer entirely in terms of the quantities m, $\vec{r}$, $\vec{v}$, and/or $\vec{a}$ (*not* their derivatives, just quantities from that list).

Problem 5 : Incoming!

A rocket is launched from rest straight downwards toward its target on earth. (This rocket is a *missile*, not a spaceship!) The rocket's known specifications are its exhaust speed v_{ex}, its initial mass m_0, the fraction λ of the initial mass that is fuel, and the rate $\dot{m} = -k$ at which the fuel is ejected (where k is a positive constant). Uniform gravity g is also present and helps to accelerate the missile. The helicopter from which the missile is launched is positioned so that the missile hits its target at the exact moment when all of its fuel (λm_0) is gone.

Calculate the rocket's velocity when it hits its target. Hint: The integral you have to do is a simple one that doesn't require any integral table. If you encounter a difficult-looking integral, stare at it for a second → there is a (simple) algebraic manipulation you might have missed that will greatly simplify the integrand.

Problem 6 : A Falling Stick Clips a Table

A thin rod of uniform mass M and length d is held at rest so that it is horizontal to the floor (but above it). Both ends of the stick are released at the same time, and the stick starts to fall downward in uniform gravity g. At time $t = 0$, the stick's CM has reached speed v_0 ... then one of its ends collides briefly with the edge of a table. Oops! The table imparts an **upward impulse** $F\,\Delta t$ to the end of the stick, where $F\,\Delta t$ equals **half of the stick's total momentum at the instant of collision** ($t = 0$). The stick continues to fall … and when it hits the floor, it has amazingly completed exactly **half a rotation**, so that both ends strike the floor simultaneously.

Calculate the time at which the stick hits the floor in terms of the given values M, d, v_0, and/or g.