Classical Mechanics (PHYS 350): Toy Week

Fall 2005 v2.0

Extra: Impress your friends! Confound your relatives! Toy Week has arrived at last!

We will apply our new methods of classical mechanics to a set of toys. We'll do our best to understand the Gryo-ring, rattleback, a "super bounce," a symmetric sleeping top, the Tippy Top, the Big Coin, Diabolical Cylinders, and more!

Toys:

Choose one toy to investigate in detail. Develop an explanation of the physics involved in the dynamic behavior of the system. After you have done some initial work please come by so we can talk about your presentation. Write up your results and provide a copy for everyone in the seminar. Just ask me for a copier code.

There is a high degree of variability in these projects; some are quite hard, some quite easy. All are open-ended to one degree or another. Having done most (but not all!) of these projects I'm happy to give you an indication of the difficulty and time commitment involved in the projects.

Oh, and the bonuses are just that. Do one and pick up some more points!

Enjoy!

- **Foucault Pendulum** Install a Foucault pendulum in the Atrium! In this project you will construct "version 1.0" of the pendulum. The possibilities are open: careful suspension mechanisms, magnetic drivers, elliptic motion damping, ... I encourage you to explore these but the minimum is to construct a working pendulum and test whether the Science Building in fact rotates with Earth by comparing theory with experiment.
- **Sleeping Top** When we set a top spinning in a stable configuration, the axis of rotation remains upright. After a little while, it slows down and "nods off," i.e. the axis tips over a bit. This is the case of the sleeping top. Investigate this motion for a symmetric top. Find the condition for stable motion. Show why this condition changes as the top spins down and make a plot of the effective potential for a variety of cases.
- **A Cylinder and a Sphere: The story** Do 7.3 in T & M as a warm-up showing that

  $$\omega = \sqrt{\frac{5g}{7(R-r)}}.$$

  Now, assume that both the cylinder and the sphere move. Set up the Lagrangian and find the frequency of small oscillations. Experimentally test your result for ω using the demonstration.
- **Skipping Stones** Folks who live by a body of water have a great opportunity for amusement - skipping stones. Flat stones are given spin and plenty of forward momentum. If aimed correctly, the stone bounces off the surface of the water a remarkable number of times... Model the physics of this activity [Reference: L. Bocquet *Am. J. Phys* **71** (2003) 150].
- **Tippy Top** A Tippy Top has the odd behavior that, once spinning, it leans over and "hops" onto its stem. Explain this behavior qualitatively. Where does the energy come from to raise the center of mass? For a more extensive investigation, find the equations of motion (Euler's equations). Numerically integrate these equations to show the effect of the torque before the stem hits the floor. [References: R. Cohen *Am. J. Phys.* 45 (1977) 12; *Am. J. Phys.* **70** (2002) 815; several pages of text (see me for these).]
- **Big Coin** A coin initially set spinning on its edge will begin to precess (wobble) as its spins decreases. With further loss of energy the coin will "lie down" with an increase in precession rate while the turning rate decreases. Explain this curious of a spinning coin in detail. Assume

that the coin does not slip. [Hints: See diagram; show that the rolling condition is $\omega_3 = 0$; show that the precession of the line of the nodes increases as $1/\sqrt{\sin\theta}$; show that the rotation rate around the vertical decreases as $(\sin\theta)^{3/2}$.]

- **Gyro-Ring** Explain how this toy works. The more detail the better ... not much is known about this one.
- **Rattleback** A very simple toy with very surprising behavior: rotated one way it merrily rotates until friction slows it to rest. Rotated the other, it protests by rocking back and forth and then rotating the other way! Explain this curious behavior in detail. References: Jearl Walker *American Scientist* vol? (date?) page 172; Hermann Bondi *Proc. R. Soc. Lond. A* **405** (1986) 265. I've got copies.
- **Bonus: 1 pt.** "Eileen's Ice Tea" You may have noticed, as Eileen did some years ago, that when you slide a pitcher of tea (or other beverage) to a friend across a table, the pitcher exhibits rather erratic behavior. Try it. Explain what you see and show your calculations.
- **Bonus: 1 pt.** "The no-flip flip" Take a quarter to Jim Schreve. Ask him to demonstrate and watch in amazement. He can flip a coin with out flipping it? Wait! How does it work?
- **Bonus: 2 pts.** "The stability of a bicycle wheel" Find the condition under which a rolling bicycle wheel (or coin, your preference) is stable under small oscillations. Include a numerical result for the minimum speed of the wheel or coin.
- **Bonus: 1 pt.** "Rotating levitation" In a demo often done in first year physics, a rotating bicycle wheel is held on one side of the axle. The wheel oddly enough does not fall, but instead rotates! Explain why. Include a quantitative prediction for the angular speed of rotation. Compare this to the demo.

Review:

I strongly recommend that you also use this week for review. Concentrate on the methods of Lagrangian and Hamiltonian mechanics and the applications. These include nonlinear dynamics, rotational motion, physics in non-inertial reference frames, central potential motion, and oscillations. I would start with problems, referring back to the text, class notes, or solutions when you need a reminder.