Classical Mechanics (PHYS 350): Week "10"

Fall 2011 v1.0

We'll finish up discussion our initial discussion of physics in non-inertial frames on Monday. Beginning Wednesday we will start on the study of the dynamics of "rigid bodies" - modeling the motion of masses with real spatial extent - things like tennis rackets. Although they retain their shape, the motion will prove quite interesting and intricate. It is also a source of much of the fun of the upcoming physics toys.

The dynamics of rigid bodies culminates our work on center of mass, relative motion, and dynamics in non-inertial frames. Using elements from the past three weeks we will investigate the dynamics of rotating and translating arbitrarily-shaped objects. Key new pieces of formalism are the **inertia tensor, principal axes, Eulerian angles, and Euler's equations**. We will finish up the discussion of dynamics before Thanksgiving break.

We also have a talk next week: "We have a talk next Monday afternoon (November 7th) by Jeff Melton, class of 1991. Jeff graduated from Hamilton with a degree in physics and went on to do graduate work in engineering and then to teach at the University of New Hampshire. His seminar will be about his work in environmental engineering," from Ann's email. Please plan on attending if you can.

Reading:

Chapter 11 T & M pack a lot in this chapter. I encourage you to read carefully and slowly. We'll take 2 weeks to discuss the material in class.

Problems:

These problems are due Wednesday November 9 at 5 PM.

(1) Read page 101 on the generation of hurricanes from "The Perfect Storm" by Sebastian Junger (On reserve at Burke, QC945.J66 1997) and correct the passage. Ooops! An important effect was omitted from the description. What did he leave out? As his editor, how would you suggest he change this section?

(2) A ladybug crawls with constant speed in a circular path of radius b on a turntable rotating with uniform angular velocity ω. The circular path is concentric with the center of the turntable. Of the mass of the bug is m and the coefficient of static friction is μ_s, how fast, relative to the turntable, can the bug crawl without slipping if it goes
  (a) in the direction of rotation and
  (b) opposite the direction of rotation?

(3) Suppose that after Hurricane Irene the northward flowing Oriskany river had a width of $b = 9.5$ m as it flowed under the College St. bridge. Suppose further that it moved at $v = 2.7$ m/s. The Coriolis effect causes one side of the river to be higher than the other side.
  (a) On which side was the river deeper?
  (b) Show that the difference in heights is

$$\frac{2bv\omega}{g}\sin\lambda$$

  where v is the water speed, λ is the latitude, and ω is the earth's angular speed. Please neglect the earth's motion around the sun.
  (c) What is the numerical value of this height difference?
  (d) What would the situation be in the southern hemisphere for a similar southerly flowing river?

(4) As we did in class, consider a puck on the (frictionless) air table, rotating counterclockwise with constant angular speed ω.
  (a) Find the equations of the motion in the non-in frame.
  (b) By using the same technique as in the solution to a critically damped oscillator, find the general solution to the equations of motion.
  (c) At $t = 0$ you push the puck at $(x'_o, 0)$ giving it velocity $(\dot{x}'_o, \dot{y}'_o)$, show that

$$\begin{aligned} x'(t) &= (x'_o + \dot{x}'_o t)\cos(\omega t) + (\dot{y}'_o + \omega x'_o)t\sin(\omega t) \\ y'(t) &= -(x'_o + \dot{x}'_o t)\sin(\omega t) + (\dot{y}'_o + \omega x'_o)t\cos(\omega t) \end{aligned} \tag{1}$$

(5) 10-15 The Lagrangian and Hamiltonian for uniform rotation
(6) Find a Lagrangian for the Foucault pendulum. Assume that the usual small angle approximation for a pendulum holds.
(7) 10-22 A curious bit of old industry. There are shot towers still standing in Baltimore and Philly.