Physics 308: Advanced Classical Mechanics  
Bryn Mawr College, Fall 2011  
Problem Set 3

Distributed: Thursday, September 15, 2011.  
Due: Thursday, September 22, 2011 by the start of class.

Reading

For Tuesday, please read Sections 5.1 – 5.3 in Taylor. For Thursday, read Sections 5.4 – 5.6.

I encourage you to spend time thinking (not writing) about which fundamental principles are at play (e.g. conservation of energy or momentum or both and/or others?). As always, I encourage you to work collaboratively on these problems (with the exception of the problem labeled “INDIVIDUAL PROBLEM,” which must be completed by you alone).

Problems

1. **Bye-bye Snowball:** You throw a snowball against a wall. Where does its momentum go? Show mathematically that the change in the kinetic energy of the Earth is negligible compared to the kinetic energy lost by the snowball. Where does the snowball’s kinetic energy go?

2. **Up, Up and Away:**

   (a) Find the escape velocity for a particle on a spherical planet of radius $R$ and mass $M$. What is the numerical value for the Earth? (The escape velocity is the velocity above which a particle can escape to $r = \infty$.)

   (b) Approximately how small must a spherical planet be in order for a human to be able to jump off? Assume a density roughly equal to that of the Earth. You can also assume that the jumping speed on this hypothetical planet is the same as that on the Earth. If you’re not sure what a typical initial velocity is when someone jumps, assume that a “good” jump takes a person 1 meter off the ground and then calculate what the person’s initial velocity was.

3. **Leaving the Sphere:** A small mass rests on top of a fixed frictionless sphere. The mass is given a tiny kick and slides downward. Let $\theta$ be the angle describing the location of the mass on the sphere ($\theta = 0$ at the top and increasing clockwise). For what value of $\theta$ does the mass lose contact with the sphere?

4. **INDIVIDUAL PROBLEM – Roller Coaster:** A roller coaster starts at rest and coasts down a frictionless track. It encounters a vertical loop of radius $R$. How much higher than the top of the loop must the car start if it is to remain in contact with the track at all times?
5. **Down, then Around on a Cone:** A fixed hollow frictionless cone is positioned with its tip pointing down. A particle is released from rest on the inside surface. After it has slid part way down to the tip, it bounces elastically off a platform. The platform is positioned at a 45° angle along the surface of the cone, so the particle ends up being deflected horizontally along the cone’s surface (in other words, into the page in the following figure). If the resulting motion of the particle is a horizontal circle around the cone, what is the ratio of the initial height of the particle to the height of the platform?