Roller Coasters: Theory, Design, and Properties
Short Term 2005
Basic Physics: In-Class Problems

Notation

Determine if the following are vectors or scalars

1. $\vec{r}$

2. l

3. $\mathbf{t}$

4. $(\langle 3, 2\rangle \cdot \hat{i})\ \hat{i}$

Forces

5. Let $\vec{F}_1 = \langle 2, 4 \rangle$ and $\vec{F}_2 = \langle 4, -5 \rangle$.
   a) Find $\vec{F}_{total}$.

   b) Find F_{total}.

   c) Assume this force is in Newtons, and that it acts on a mass of 2 kg. Find the acceleration vector.

   d) What is the magnitude of the acceleration in the direction $\langle 1, 2 \rangle$?

6. We found the magnitude of the force of gravity in the normal direction of a negative sine curve to be

$$\frac{mg}{\sqrt{1 + \cos^2 s}}.$$

   For what values of s is this force maximal? When is it minimal? Sketch $-\sin s$ to see if this make sense. Remember, we are looking at the normal (perpendicular) direction.

Energy

7. Consider two objects, a 2 kg box and a 2 kg sphere.
   a) What is the translational kinetic energy of the box if it is moving along a frictionless surface at 5 m/s?

   b) What is the translational kinetic energy of the sphere if it is rolling along a rough surface at 5 m/s?

   c) What is the rotational kinetic energy of the sphere? (It is rolling on a rough surface. $I = \frac{2}{5}mr^2$, and $\omega = v/r$.)

   d) Now consider the box and the ball traveling up a frictionless ramp. Which will climb higher?

   e) Now consider the box and the ball traveling up a rough ramp. Which will climb higher?

   f) Now consider the box traveling up a frictionless surface, and the ball travelling up a rough ramp. Which will climb higher?

8. Imagine a point mass rests at the top of a parabola. If given a little push (that is, suppose it starts moving, but set initial speed to 0) how fast is it moving when it reaches the point {2,-4}? (Assume distance is in meters, and $g = 9.8$ m/s^2.)

9. We measure a point mass (with mass 10 kg) at the point (1,-1) traveling with a speed of 5 m/s to the left ("northwest") climbing up our usual parabola.
   a) What is the kinetic energy of the particle at the point (1,-1)?

   b) Define $h = 0$ when $y = 0$. What is the potential energy of the particle? ($g = 9.8$ m/s^2)

   c) What is the total mechanical energy of the particle?

   d) Will the particle make it over the hill? (Hint: Assume it is at the top, and find its speed)

   e) We can describe the points on a parabola by the following position vector:

$$\langle s, -s^2 \rangle$$

   Once again, s will vary with position on the parabola. What is the potential energy of the particle in terms of this s?

   f) Assuming an ideal track with no energy lost to friction, use the work-energy equation to determine the speed of the particle as a function of s.

   g) If the speed at the point (1,-1) was 4 m/s, how would this change the situation?