Physics 20 Problem Set 10

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due at the Final - Tuesday, December 7, 8am

Course Announcements: Please return your midterm for checking when you turn in this problem set, or bring your midterm to class or the final. The reading for this problem set is KK Chap. 4, pp. 152-173, and RHK4 Chapters 7 and 8. We will follow RHK4 in lecture.

Object	Speed (mph)	Mass (kg)	Kin. En. (Joules)	Gal. Gas.	Tons TNT	Fat Men
Car	65	1.8×10^3				
767 Plane	500	1.8×10^5				
Freight Train	55	9.1×10^6				

Table 1: Problem 1.

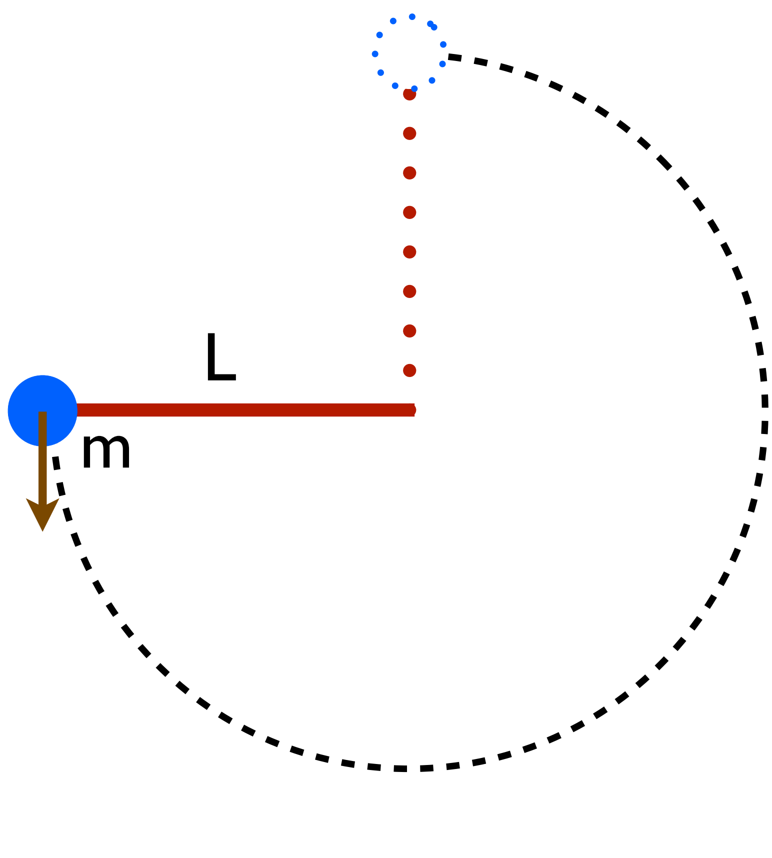

Figure 1: Problem 2.

1. Calculate the kinetic energies in Joules of the moving objects in Table 1. Then convert these numbers for the last three columns: one gallon of gasoline releases 1.3×10^8 Joules, one Ton of TNT releases 4.2×10^9 Joules, and one ‘Fat Man’ atomic bomb releases 9×10^{13} Joules.

(a) Concerning the 767 plane: the energy in a full *fuel* tank of a 767 corresponds to 1000 Tons of TNT. How does that compare to the kinetic energy of the 767? In the horrible collision of a 767 with the World Trade Center on 9/11/2001, which source of energy was greater, kinetic energy of the plane, or energy available in the fuel? What fraction of a Fat Man bomb was released by the fuel?

(b) Trains are stopped by brakes applied to the wheels. The best braking strategy involves no skidding of wheels on the tracks, and the resulting coefficient of friction is about $\mu = 1/4$. In what distance could the train in Table 1 be brought to rest? If skidding commences, $\mu = 1/40$.... in that case, what is the distance the train goes before being brought to rest? (There is right now a movie, *Unstoppable*, in theaters about stopping a runaway train).

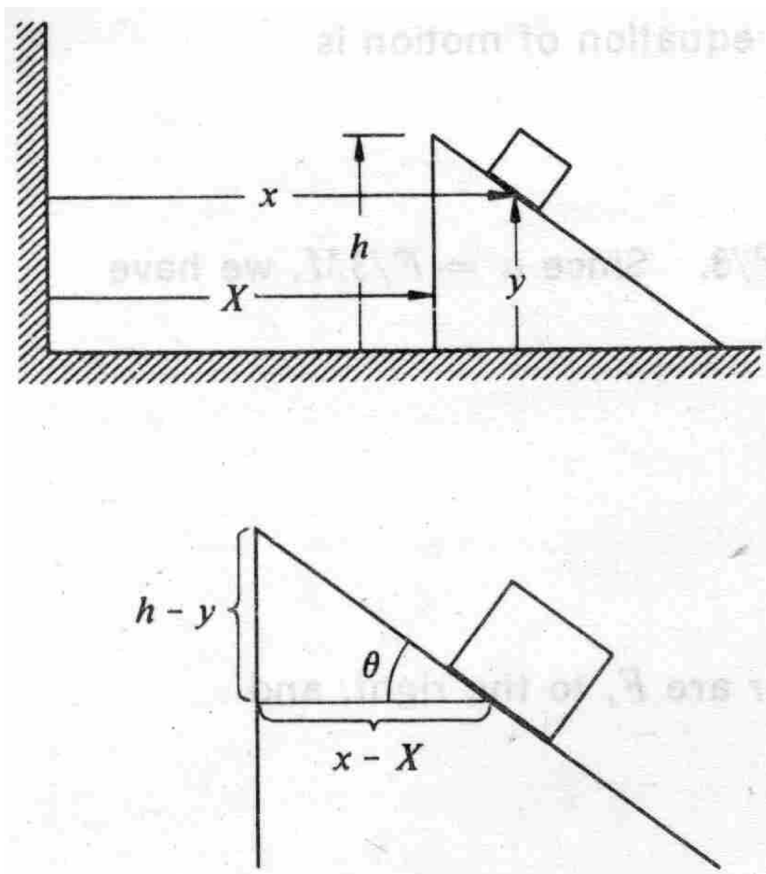

Figure 2: Problem 4.

2. The force exerted on an object is $F(x) = F_0(x/x_0 - 1)$, where F_0 and x_0 are constants. Find the work done in moving the object from $x = 0$ to $x = 3x_0$

   (a) by plotting $F(x)$ and using geometry to find the area under the curve

   (b) by evaluating the integral analytically. (RHK4 7.13)

3. A ball of mass m is attached to the end of a massless rod of length L. The other end of the rod pivots so that the ball moves in a vertical circle. The rod is pulled aside to a horizontal position and given a downward push as shown in Fig. 1 so that the rod swings down and then up, finally just reaching the vertically upward position. What initial speed was imparted to the ball?

4. Let's look at the 'Wedge and Block' problem from Page 74 of the KK from an energy perspective. The figure and variables are shown in Fig 2.

   (a) As a warm-up, imagine dropping a mass straight downward from a height of h. Show, using energy, that the y-component of the velocity, $\dot{y}$, satisfies the equation: $\dot{y}^2 = g \times 2(h - y)$, where y is the vertical coordinate.

   (b) Assemble the 3 equations for the wedge and block problem, which involve $\dot{y}$, y, $\dot{x}$, and $\dot{X}$:

      i. From the constraint that the small block (mass m) stays on the incline of the wedge (mass M).

      ii. From conservation of momentum in the horizontal.

      iii. From conservation of energy (don't forget $\dot{y}$).

   (c) Solve those three equations for $\dot{y}$ in the same form as reasoned out in Part (a), and deduce $\ddot{y}$.

   (d) In the limit $m/M \to 0$, what do you get for $\ddot{y}$?
