Academic Year 2021-22

Tutorial #05

PH100: Mechanics and Thermodynamics

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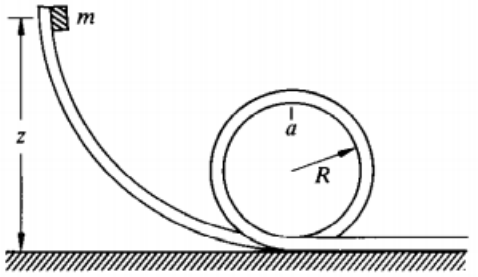
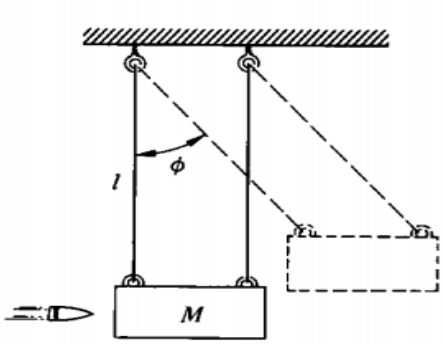
1. A small block of mass *m* starts from rest and slides along a frictionless loop-the-loop as shown in the figure. What should be the initial height *z*, so that *m* pushes against the top of the track (at a) with a force equal to its weight?



2. A simple way to measure the speed of a bullet is with a ballistic pendulum. As illustrated, this consists of a wooden block of mass *M* into which the bullet is shot. The block is suspended from cables of length *l*, and the impact of the bullet causes it to swing through a maximum angle Φ, as shown. The initial speed of the bullet is *v*, and its mass is *m*.
   a. How fast is the block moving immediately after the bullet comes to rest? (Assume that this happens quickly.)
   b. Show how to find the velocity of the bullet by measuring *m*, *M*, *l*, and Φ.



3. Mass *m* whirls on a frictionless table, held to circular motion by a string which passes through a hole in the table. The string is slowly pulled through the hole so that the radius of the circle changes from l_1 to l_2. Show that the work done in pulling the string equals the increase in kinetic energy of the mass.

4. A simple and very violent chemical reaction is $H + H \longrightarrow H_2 + 5\ eV.$

However, when hydrogen atoms collide in free space they simply bounce apart! The reason is that it is impossible to satisfy the laws of conservation of momentum and conservation of energy in a simple two body collision which releases energy. Can you prove this?
You might start by writing the statements of conservation of momentum and energy.

5. A commonly used potential energy function to describe the interaction between two atoms is the Lennard-Jones potential:

$$U = \epsilon \left[\left(\frac{r_0}{r} \right)^{12} - 2 \left(\frac{r_0}{r} \right)^{6} \right].$$

   a. Show that the radius at the potential minimum is r_0, and that the depth of the potential well is \epsilon.

   b. Find the frequency of small oscillations about equilibrium for 2 identical atoms of mass *m* bound to each other by the Lennard-Jones interaction.

6. A particle of mass *m* moves in one dimension along the positive x axis. It is acted on by a constant force directed toward the origin with magnitude *B*, and an inverse square law repulsive force with magnitude A/x^2.
   a. Find the potential energy function *U(x)*.
   b. Sketch the energy diagram for the system when the maximum kinetic energy is $K_0 = (1/2)\, m\, v_0^2$.
   c. Find the equilibrium position, x_0.
   d. What is the frequency of small oscillations about x_0?