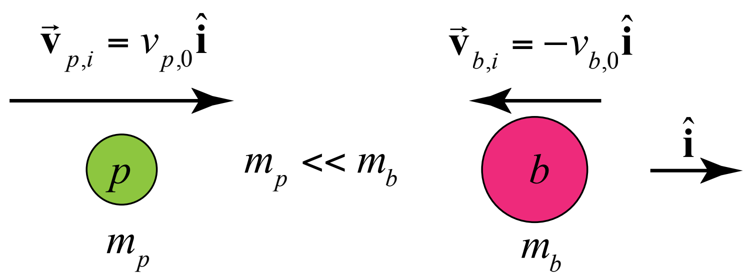
# Problem Set 9

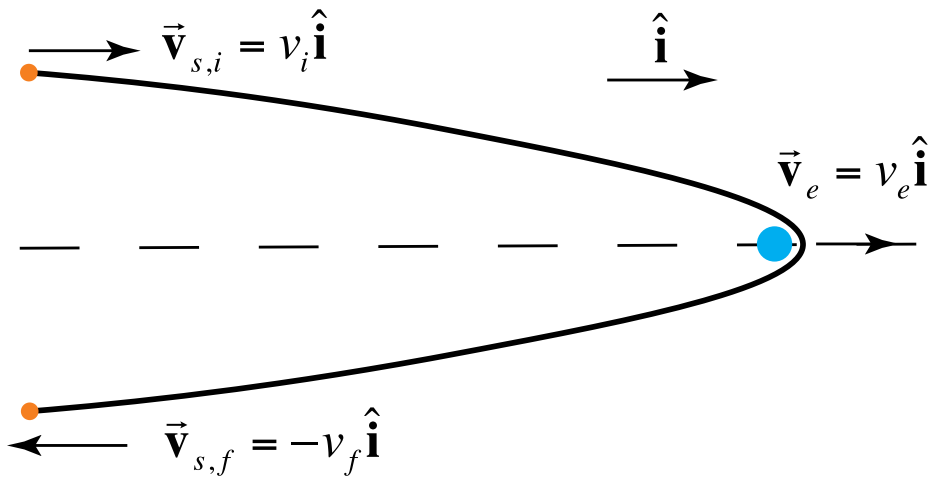
1. **Ping-Pong Ball and Bowling Ball Collision**

A ping-pong ball and a bowling ball collide elastically on a frictionless surface. The magnitude of the initial velocity of the ping-pong ball is $v_{p,0}$ and the direction of the velocity is in the positive $x$-direction. The magnitude of the initial velocity of the bowling ball is $v_{b,0}$ and the direction of the velocity is in the negative $x$-direction. You may assume that the mass of the bowling ball is much greater than the mass of the ping-pong ball.




After the collision, what is the component of the velocity of the ping-pong ball in the $x$ direction? (pay attention to signs). Express your answer in some or all of the following variables: $v_{p0}$ and $v_{b0}$.

2. **Satellite Fly-By** A satellite (with mass negligible compared to that of the Earth) is making a fly-by of the Earth on a hyperbolic orbit. Let the velocity of the Earth be $\vec{v}_e = v_e\hat{i}$. The satellite originally approaches from the negative $x$-direction, goes around the earth, and then flies off in the same direction it came from. Far from the Earth, the magnitude of the satellite's $x$-component of velocity is $v_i$ when approaching and $v_f$ when receding.

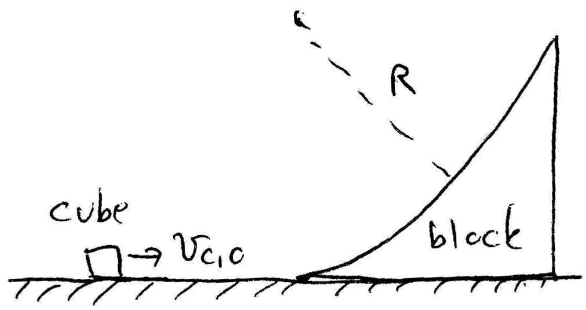



For the case where $\vec{v}_i = 4v_e\hat{i}$, what is the final speed $v_f$ of the satellite in terms of the speed of the earth $v_e$?

3. **Block Sliding up Curved Surface**

A block of mass $m_b$ sits at rest on a frictionless table; the block has a circular surface of radius $R$ as shown in the figure. A small cube of mass $m_c < m_b$ and speed $v_{c,0}$ is incident upon the block; the cube moves without friction on the table and the block.

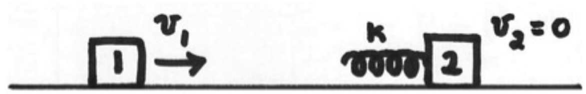
**Notice that in this problem, the block does move since it is not fixed to the table**




(a) What is the maximum height $h$ above the table that is reached by the cube? Assume $v_{c,0}$ is small enough so that $h < R$. Express your answer using some or all of the following variables: $v_{c,0}$, $g$, $m_b$ and $m_c$.

(b) After the cube reaches the maximum height, it slides back down the wedge. After the two separate again, what is the speed (magnitude of the velocity) of each? Express your answer using some or all of the following variables: $v_{c,0}$, $g$, $m_b$ and $m_c$.

4. **Spring Blocks Motion**

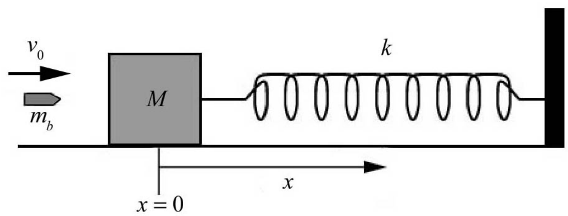


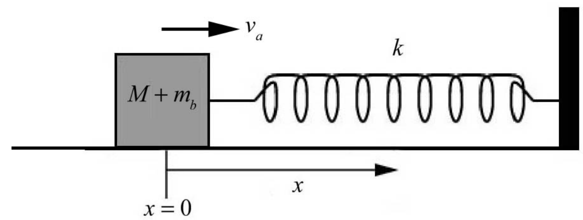

Block 1 of mass $m_1$ is moving with speed $v_1$ to the right on a horizontal frictionless table as shown in the figure above. The block collides with the free end of a spring-block system of $m_2$ that is initially at rest. The collision is one-dimensional. The spring has spring constant $k$.

What is the maximum compression of the spring? Express your answer using some or all of the following: k, $m_1$, $m_2$ and $v_1$.

5. **Bullet-Spring Collision**

A massless spring with spring constant $k$ is attached at one end of a block of mass $M$ that is resting on a frictionless horizontal table. The other end of the spring is fixed to a wall. A bullet of mass $m_b$ is fired into the block from the left with a speed $v_0$ and comes to rest in the block (assume that this happens instantaneously).



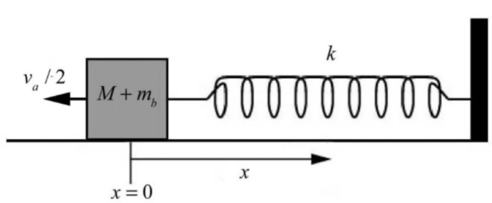




(a) How fast is the block moving immediately after the bullet comes to rest with respect to the block? Express you answer in terms of some or all of the following: $M$, $m_b$, and $v_0$.

(b) The block is at $x = 0$ when the bullet hits the block and the block starts moving. How far has the block travelled when it first comes to rest after this? Express you answer in terms of some or all of the following: $M$, $m_b$, $k$ and $v_0$.

(c) Immediately after the bullet comes to rest with respect to the block, what is the ratio of the kinetic energy of the bullet-block to the original kinetic energy of the bullet? Express you answer in terms of some or all of the following: $M$, $m_b$ and $v_0$.

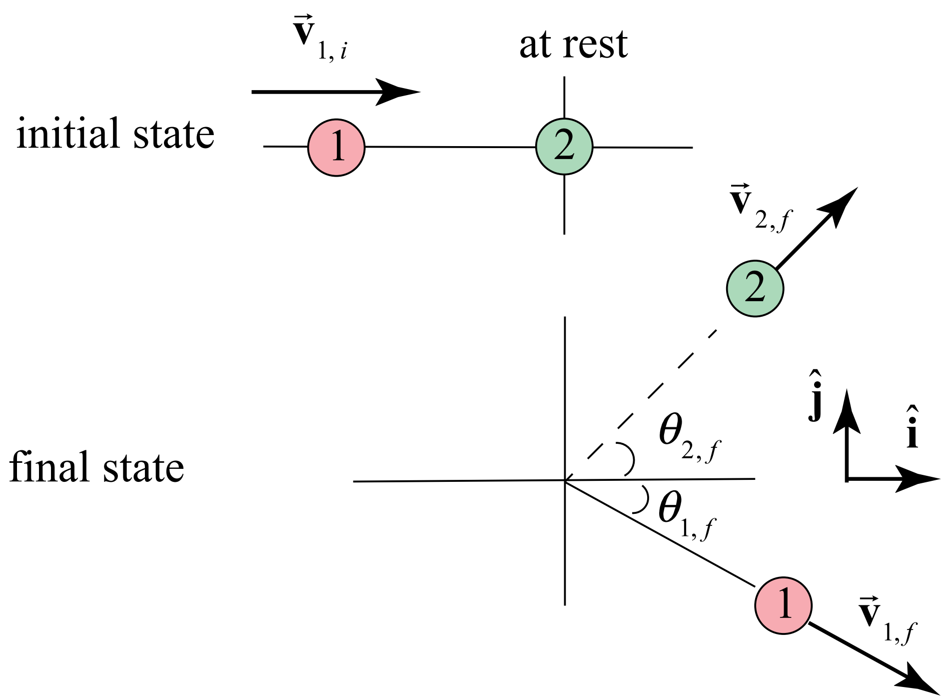
(d) Now suppose that instead of sliding on a frictionless table, the coefficient of kinetic friction between the block and the table is $\mu_k$. Suppose that when the block first returned to the position $x = 0$, the speed of the block was found to be one half the speed immediately after the collision that you found in part a.




What is the total distance that the block traveled before returning to $x = 0$? Express you answer in terms of some or all of the following: $M$, $m_b$ and $v_0$, $\mu_k$, and $g$.

6. **Elastic 2D Collision**

   Particle 1 of mass $m_1 = m$ is initially moving in the positive $x$-direction with a speed $v_{1,i}$ and collides elastically with Particle 2 of mass $m_2 = 2m$, which is initially at rest. After the collision Particle 1 moves with an unknown speed $v_{1,f}$, at an unknown angle $\theta_{1,f}$ with respect to the positive $x$-direction and particle 2 moves with an unknown speed $v_{2,f}$, at an angle $\theta_{2,f} = 45°$ with respect to the positive $x$-direction (notice the convention of measuring the angles shown below).




   Find $\tan\theta_{1,f}$ (your answer should reduce to a simple numerical value)