Question 1 (10 points)
A bullet with mass $m$ and a velocity of $v$ in the vertical direction is shot into the center of a wooden block of mass $M$ as shown in figure. The bullet punches through the wooden block and leaves it with a velocity of $v/2$. Find:

a. The velocity of the wooden block just after the bullet leaves the block.
b. How high the wooden block rises

c. The energy lost during the collision.
d. The maximum height the bullet reaches (no air friction)

![Diagram of bullet and wooden block](image)

Question 2 (10 points)

(a) A ball, $B_2$, with (very small) mass $m_2$ sits on top of another ball, $B_1$, with (very large) mass $m_1$. The bottom of $B_1$ is at a height $h$ above the ground, and the bottom of $B_2$ is at a height $h + d$ above the ground. The balls are dropped. To what height does the top ball bounce? (Assume $m_1$ is much heavier than $m_2$. Assume that the balls bounce elastically.)

(b) The balls are dropped again. This time the balls bounce elastically. After $n$ bounces, calculate the height $h_n$ above the ground.

![Diagram of balls](image)

2. (a) 2. (b)
(b) \( n \) balls, \( B_1, \ldots, B_n \), having masses \( m_1, m_2, \ldots, m_n \) (with \( m_1 >> m_2 >> \cdots >> m_n \)), sit in a vertical stack. The bottom of \( B_1 \) is at a height \( h \) above the ground, and the bottom of \( B_n \) is at a height \( h + l \) above the ground. The balls are dropped. In terms of \( n \), to what height does the top ball bounce?

**Question 3 (10 points)**

The two balls, \( m_2 \) and \( m_3 \), on the right of figure are slightly separated and initially are at rest; the left ball, \( m_1 \), is incident on \( m_2 \) with speed \( v_0 \). Assuming head-on elastic collisions and no friction:
(a) Find speeds of \( m_1 \) and \( m_2 \) just after the first collision.
(b) Assuming that \( m_1 = m_2 = m \) and \( m_3 \leq m \), show that there are two collisions and find all final velocities.
(c) Assuming that \( m_1 = m_2 = m \) and \( m_3 > m \), show that there are three collisions and find all final velocities (6 points).

**Question 4 (10 points)**

A particle is shot with an initial speed of \( v_i \) on a horizontal surface toward a semi-circular track of radius \( R \). The initial speed is adjusted such that the particle barely avoids falling down at the topmost part of the semi-circular track. There is no friction.

a) Show that the initial speed must be \( v_i = \left( \frac{5gR}{\pi^3} \right) \), if the particle barely avoids falling down at the very top of the semi-circular track.
b) At the topmost part of the semicircle, the velocity of the ball is momentarily horizontal. How far from the edge of the semicircle does it fall (see figure below)?