1) A 2 gm bullet is fired into the center of a 130 gm wooden block from point blank range as shown in the figure. The bullet lodges in the block and together they rise to h=80 cm as indicated by the dashed outline of the block.

a) What is the speed of the bullet just before it enters the block? (3 pts)

![Diagram of a block with an arrow indicating the bullet's velocity.]

b) If the bullet were fired into the edge of the block, as shown below, would the block rise as high? YES or NO. Please explain your answer. (1 pt)

![Diagram of a block with an arrow indicating the bullet's velocity.]

2) Think fast! You've just driven around a curve in a narrow, one way street at 25 MPH when you notice a car identical to yours coming at you at 25 MPH. You have only two options: hitting the other car head on or swerving into a massive concrete wall, also head on. In the split second before the impact, in order to minimize the damage to you, you decide to:

1) Hit the other car.
2) Hit the wall.
3) Hit either one -- it makes no difference.
4) Consult your physics notes.

Question from Eric Mazur (1 pt)

(CONTINUED ON OTHER SIDE)

Rewrite and sign the honor pledge: “I pledge my honor that I have not violated the Honor Code during this examination.”

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3) Grandma Moses is moving in her wheelchair on an icy parking lot with speed $V_G = 1.5 \text{ m/s}$. Her grandson runs up to her with a velocity $V_B = 3 \text{ m/s}$ perpendicular to his Grandma’s motion. He jumps into her lap. The mass of the grandma is $M_G = 70 \text{ kg}$ and the mass of the boy is $M_B = 35 \text{ kg}$. Neglect friction.

a) What is the final velocity vector of the wheelchair? (2 pts)

b) Find the force vector that the boy experienced assuming it was constant and lasted for 0.1 seconds. (3 pts)
1) A 2 gm bullet is fired into the center of a 130 gm wooden block (which is at rest) and sticks in it as indicated in the figure. The bullet’s velocity is 250 m/s just before it enters the block. How high does the block/bullet combination rise? (3 pts)

2) Suppose the entire population of the world gathered in one spot. On a prearranged signal, they all jump up. While they are in the air, does Earth gain momentum in the opposite direction? (please circle the correct answer, 1 pt)
A) No, only the Sun and Moon can affect the motion of the Earth.
B) No, the Earth has too much mass.
C) No, the gravitation attraction between the people and the Earth prevents the Earth from gaining momentum.
D) Yes, but the gain in momentum is smaller than the net momentum of the people because of the Earth’s gravitational attraction.
E) Yes, the Earth recoils with a momentum opposite to that of the people.

(CONTINUED ON OTHER SIDE)

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3) A steel ball of mass \(M = 15\) kg is shot at an angle of 60 degrees above the horizon with an initial velocity of 150 m/s. Just at its maximum height, it explodes and breaks into two pieces. One piece of mass \(m_1 = 12\) kg stops and falls vertically to the ground.

A) What is the velocity, \(V\), of the second piece (\(m_2\)) immediately after the break up? (2 pts)

B) What is the energy released in the explosion? (give the least possible figure, 2 pts)

C) Which of the two pieces will be the first to reach the ground? (2 pts)
After an exhausting day ice fishing, a man is too tired to walk from his hole in the lake to the shore. He sits on a sled on the ice (it is frictionless), pulls out a machine gun (don’t leave home without one) and fires 100 bullets, horizontally, all in the same direction.

1. [1 point] If the mass of a single bullet is 12.5 g (0.0125 kg) and its velocity is 800 m/s, what is the momentum of a single bullet?

2. [2 points] If the total mass of the man, the sled, and the machine gun is 100 kg, what is his velocity after firing 100 bullets? (You may neglect the mass lost in the gun due to the release of bullets.)

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The man slides along for a while and then suddenly collides with a 400 kg moose, which was standing still on the ice. After the collision, the moose slides away at angle $\theta = 30^\circ$, as shown in the diagram, while the man (still on his sled, carrying his machine gun) ends up traveling at a $90^\circ$ angle to his original path.

3. [2 points] What is the magnitude of the final velocity of the moose?

4. [3 points] What is the final velocity of the man?

5. [2 points] Was the collision elastic? (Justify your answer quantitatively.)
1. The figure shows two balls hanging from the ceiling. The first ball has mass \( m \), and the second ball has mass \( 2m \). The first ball is raised a distance \( h = 0.35 \) m and then released with an initial speed of \( 5.0 \) m/s as indicated in the figure. Show all work for all parts for full credit.

(a) (2 pts) What is the speed of the first ball just before it hits the second ball?

(b) (3 pts) If the two balls collide head-on in a totally elastic collision, what will be the speed of the first ball immediately after the collision?

(c) (2 pts) If instead the two balls collide head-on and stick together afterwards, what will be their final speed immediately after the collision?
2. Hail falls straight down onto the sidewalk with speed 13.0 m/s and rebounds straight up with speed 12.5 m/s.

(a) (1 pts) If a single hailstone has mass 0.010 kg, what impulse must the sidewalk deliver to it?

(b) (2 pts) If hail falls at a mass rate of \( m/\delta t = 0.150 \) kg/s, what is the average force the hail applies to the sidewalk?

Rewrite and sign the Honor Pledge: *I pledge my honor that I have not violated the Honor Code during this examination.*

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Problem 1 Two 20 kg sleds are standing at rest on a frozen lake close to each other. A 3 kg cat jumps from one sled to the other. The cat’s speed relative to the ice is 10 m/s. In the following ignore any friction between the sleds and the ice!

(a) [2 point] What is the speed of the first sled after the cat jumped off?

(b) [2 point] What is the speed of the second sled after the cat arrived there?

(c) [1 point] What is the velocity of the center of mass (of the 2 sleds and the cat) after the cat arrived on the second sled?

Continued on the other side....
(d)[5 points] The cat is still sitting on the second sled when the sled collides head-on with a third sled which is at rest on the ice. The mass of the third sled is 20 kg. What is the velocity of the third sled after the elastic collision? If you do not trust your result for the velocity of the second sled that you derived in part (b), use \( v_2 = 2 \text{ m/s} \).

Rewrite and sign the honor pledge: “I pledge my honor that I have not violated the Honor Code during this examination.”

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1.) A 100 kg man is training his 40 kg son to be a hockey goalkeeper. They are standing 5 m apart on an icy surface (no friction) when the man whacks a 5 kg puck (initially at rest) with an impulse of 150 N \cdot s toward his son.

a.) Considering the man+boy+puck system, what happens to the center of mass after the puck is hit? Does it move toward the boy, toward the man, or remain stationary? Explain your answer. [1 pt]

b.) What is the speed of the puck right after the man hits it? [2 pts]

c.) Find the speed of the boy after he catches the puck (and doesn’t drop it). [2 pts]
2.) A pendulum bob of mass $M = 1$ kg is suspended from a rigid rod of length $L = 10$ cm and negligible mass. A bullet with mass $m = 8$ g travelling at 300 m/s passes through the bob and emerges with speed $v < 300$ m/s. (Throughout this problem, ignore the fact that the bob has a hole in it after the bullet passes through!)

a.) Assuming that the bob has enough energy to just barely swing through a complete circle, find the initial speed of the bob just after the bullet exits. (Hint: assume $v = 0$ for the bob when it’s at the top of the loop.) [2 pts]

b.) What is the final speed of the bullet? (Assume $v_{\text{bob}} = 1$ m/s if you could not solve a.) [2 pts]

c.) Is this collision elastic? Justify your answer quantitatively. [1 pt]

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