Conservation of Momentum Problems

Do your work on a separate sheet of paper or notebook. For each problem,

- ***<u>draw clearly labeled diagrams</u> showing the masses and velocities for each object <u>before and after</u> the collision.***
- ***Define the system you are analyzing and justify why conservation of momentum of the system can be used.***

Don't forget about <u>directions</u> – momentum, velocity and impulse are VECTORS.

1. In a railroad yard, a train is being assembled. An empty boxcar, coasting at 3 m/s along a frictionless track, strikes a loaded car that is stationary, and the cars couple together. Each of the boxcars has a mass of 9000 kg when empty, and the loaded car contains 55,000 kg of lumber.
   a. Write the momentum conservation equation for the system in terms of variables (*m,v).*
   b. Find the speed of the coupled boxcars.
   c. Calculate and compare the total kinetic energy of the system before and after the collision. Use this comparison to determine the type of collision (elastic, inelastic, or explosion).

2. An 80 kg astronaut is on a spacewalk away from the shuttle when his tether line breaks. Starting at rest (relative to the shuttle) he throws the 9.5 kg oxygen tank away from him with a velocity of -2.0 m/s so that he recoils in the opposite direction, towards the shuttle.
   a. Write the momentum conservation equation for the system in terms of variables (*m,v).*
   b. Find the speed with which the astronaut moves towards the shuttle.
   c. Determine the impulse exerted on the oxygen tank by the astronaut.
   d. Determine the impulse exerted on the astronaut by the oxygen tank.
   e. Calculate and compare the total kinetic energy before and after the event. Use this comparison to determine the type of collision (elastic, inelastic, or explosion).
   f. Determine the maximum distance the astronaut can be from the shuttle when the line breaks and still return within 60.0 s (the amount of time he can hold his breath).

3. A 50 kg cart is moving across a frictionless floor at 2.0 m/s. A 70 kg boy, riding in the cart, jumps off so that he hits the floor with zero velocity.
   a. Write the momentum conservation equation for the system in terms of variables (*m,v).*
   b. What was the velocity of the cart after the boy jumped?
   c. How large an impulse did the boy give to the cart?
   d. Calculate and compare the total kinetic energy before and after the event. Use this comparison to determine the type of collision (elastic, inelastic, or explosion).

4. Two children with masses of 50 kg and 70 kg are at rest on frictionless in-line skates. The larger child pushes the smaller so that the smaller child rolls away at a speed of 10 m/s.
   a. Write the momentum conservation equation of the system in terms of variables (*m,v).*
   b. Calculate the velocity of the larger child.
   c. Calculate the impulse that each child imparts to the other.
   d. Calculate and compare the kinetic energy before and after the event. Use this comparison to determine the type of collision (elastic, inelastic, or explosion).

5. A 0.8 kg apple is balanced on a circus performer's head 1.9 m above the ground. An archer shoots a 50 g arrow at the apple with a speed of 45 m/s. The arrow passes through the apple and emerges with a speed of 12 m/s.
   a. Write the momentum conservation equation of the system in terms of variables (*m,v).*
   b. Find the velocity of the apple right immediately after the arrow emerges.
   c. What is the impulse exerted on the apple by the arrow?
   d. Calculate and compare the total kinetic energy before and after the event. Use this comparison to determine the type of collision (elastic, inelastic, or explosion).
   e. When the apple hits the ground, how far behind the clown is it? Neglect friction when the apple is atop the clown's head.

6. An object, which has a mass of 6.0 kg, is moving to the right with a velocity of 8.0 m/s when it collides with a second mass of 12.0 kg which is initially at rest. After the collision, the 12.0 kg mass moves off to the right with a new velocity of 5.33 m/s. Neglect friction.
   a. Write the momentum conservation equation of the system in terms of variables (*m,v).*
   b. Determine the velocity of the 6.0 kg object after the collision
   c. Is the collision elastic? How do you know? Support your answer with evidence.

7. An object of mass m_1=2.0 kg, moving with a velocity of v_1=12.0 m/s collides head-on with a stationary object whose mass is m_2=6.0 kg. The collision is <u>elastic.</u> What are the velocities of the two objects after the collision? Neglect friction. (Note: there are two unknowns here. Elastic collision means that you have 2 conservation equations to use: conservation of momentum and conservation of mechanical energy. You can also use conservation of momentum along with another equation involving relative velocities; finish and look at the geogebra simulation to find this third relationship)

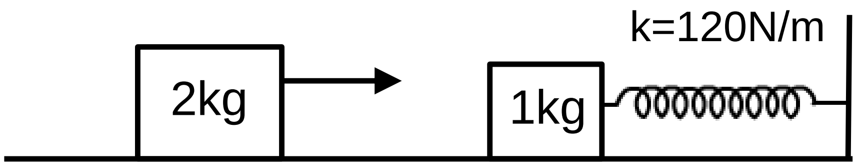
8. A particle of mass 4.0 kg, initially moving horizontally with a velocity of 2.0 m/s collides <u>elastically</u> with a particle of mass 6.0 kg. initially moving with a velocity of -4.0 m/s. What are the velocities of the two particles after the collision? There is no friction or air resistance

9. A 25 g bullet traveling horizontally at 140 m/s is fired into 2.0 kg block, initially at rest on a level surface with a coefficient of kinetic friction of 0.28. The bullet gets imbedded in the block. The momentum transferred to the block causes it to slide along the surface.
   <u>Note:</u> There are 2 parts to this problem: collision (before to immediately after) followed by the sliding of the block. It is important that you draw 3 diagrams here: before collision, immediately after collision, and the sliding with constant acceleration along surface.
   a) Determine the velocity of the block-bullet combination immediately after the bullet collides with the block (before it starts to slide).
   b) Determine how far the bullet and the block slide along the surface before coming to rest.
   c) How much energy was lost as the bullet was lodged in the block?
   d) The collision of the bullet with the block took place over 0.0022s. Determine the average net force exerted on the bullet.

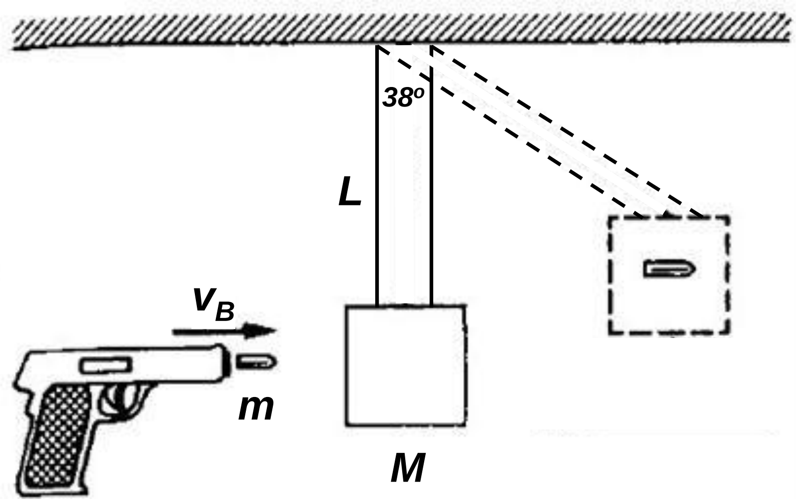
10. A 1.20-kg skateboard is coasting along the pavement at a speed of 5.00 m/s when a 0.800-kg cat drops from a tree vertically downward onto the skateboard. What is the speed of the skateboard-cat combination? (Remember that momentum is a vector and that conservation of momentum is a vector equation that is applied *separately* in x- and y- directions)

11. A 65.0-kg person throws a 0.045 0-kg snowball forward with a ground speed of 30.0 m/s. A second person, with a mass of 60.0 kg, catches the snowball. Both people are on skates. The first person is initially moving forward with a speed of 2.50 m/s, and the second person is initially at rest. What are the velocities of the two people after the snowball is exchanged? Disregard the friction between the skates and the ice.

12. A 2.00 kg block is sliding at 15.0 m/s to the right. It collides with and sticks to a 1.00 kg block attached to a spring connected to a wall as shown. The horizontal surface is frictionless. The spring has a spring constant of 120 N/m. Note: There are 2 parts to this problem: collision (before to immediately after) followed by blocks compressing spring.
   a) Determine the velocity of the double block combination immediately after the collision.
   b) What will be the maximum distance the spring is compressed?



13. A rifle, which has a mass of 5.50 kg, fires a bullet, which has a mass of ***m***=65.0grams, at a ballistic pendulum. The ballistic pendulum consists of a block of wood, which has a mass ***M*** = 5.00 kg, attached to two strings of length ***L***=1.25m. When the block is struck by the bullet, the block swings backward until the angle between the ballistics pendulum and the vertical reaches a maximum angle of 38°. Note: There are 2 parts to this problem: collision (before to immediately after) followed by the swinging of the pendulum.



a) Determine the maximum gravitational potential energy of the ballistic pendulum-Earth system when it reaches its maximum angle
b) Determine the velocity of the block of wood+bullet immediately after being struck
c) Determine the velocity of the bullet, v_B, immediately before colliding with the block of wood.
d) How much work was done on the bullet as it got stopped by the block of wood (in other words, how much energy was lost in the collision?)
e) Determine the recoil velocity of the rifle.
f) How much energy was released when the bullet was fired (in other words, how much energy was gained in explosion?)

Answers

1a) $m_1v_1=(m_1 + m_2)v'$ b) $v'=0.37$m/s c) $K_{before}=40{,}500$J, $K_{after}=4997$J, inelastic

2a) $0 = -m_Tv_T'+m_Av_A'$ b) $v_A'=0.24$m/s c) -19N s d) +19 N s e) $K_{before}=0$J, $K_{after}=22.5$J, explosion f) 14.4m

3a) $(m_B+m_C)v = m_Cv_C'$ b) $v_C'=4.8$m/s c) $I_C=140$N s d) $K_{before}=240$J, $K_{after}=576$J, explosion

4a) $0 = -m_1v_1' + m_2v_2'$ b) $v_1'=-7.14$m/s c) $I_1=-500$ N s; $I_2=-I_1$ d) $K_{before}=0$J, $K_{after}=4280$J, explosion

5a) $m_1v_1 = m_1v_1' + m_2v_2'$ b) $v_2'=2.06$m/s c) 1.65 N s d) $K_{before}=50.6$J, $K_{after}=5.72$J, inelastic e) 1.28m

6a) $m_1v_1 = m_1 v_1'+m_2 v_2'$ b) $v_2'=2.66$ m/s left c) Yes elastic $K_{before}= K_{after} =192$J

7) $v_1'=-6$m/s, $v_2'=6$m/s **8**) $v_1'=-5.2$m/s, $v_2'=0.8$m/s **9**a) 1.73 m/s b) 0.55m c) $\Delta K=-242$J d) -1571N

10) 3 m/s **11**) 2.48 and 0.0225 m/s **12**a) 10 m/s b) 1.58m

13a) 13.2 J b) 2.30 m/s c) 179 m/s d) 1030J e) 2.11 m/s f) 1050J