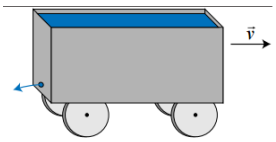
AP Physics 1
Unit 4 Practice Exercises

Directions: Show the steps required to arrive at the answer. Work out the problems on separate page.

4.1 – Momentum

1. Give 3 ways in which momentum is different from kinetic energy.

2. A cart full of water travels horizontally on a frictionless track with initial velocity v. As shown in the diagram, in the back wall of the cart there is a small opening near the bottom of the wall that allows water to stream out.



a) What happens to the velocity of the cart over time?
b) What happens to the cart's kinetic energy over time?
c) How would your answers change if the hole was plugged and water was poured into the cart?

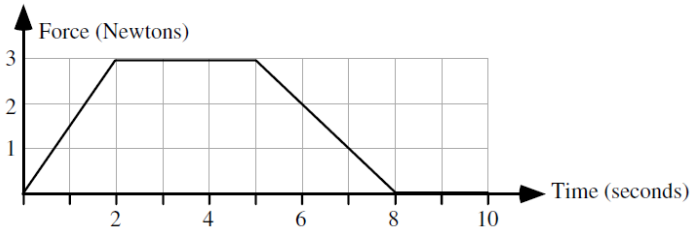
3. A bomb is initially at rest on a flat surface when it explodes, sending pieces of itself in various directs. Explain how momentum is conserved in this situation.

4. Explain how a car air-bag protects a passenger during a car crash in terms of the force exerted on them?

5. An object falls off a building's roof. Why is momentum not conserved in the system?

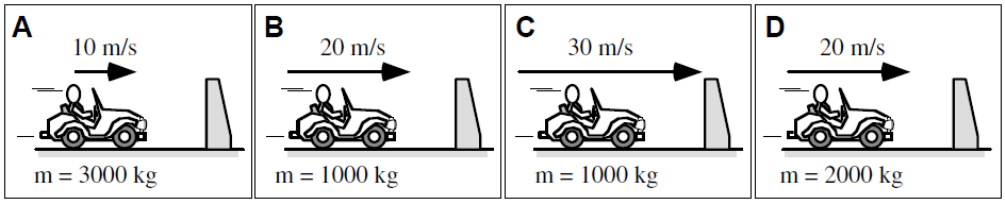
6. If momentum can only be changed by an external force, how can a car's brakes change the car's momentum?

7. A 10-kg box, initially at rest, moves along a frictionless horizontal surface. A horizontal force to the right is applied to the box. The magnitude of the force changes as a function of time as shown.



a) Rank the impulse applied to the box by this force during each 2-second interval indicated below.
A. 0 to 2 s B. 2 to 4 s C. 4 to 6 s D. 6 to 8 s E. 8 to 10 s
Explain your reasoning.
b) What is the velocity of the box after 5 seconds? 10 seconds?

8. Cars moving along horizontal roads are about to be stopped when they hit a protective barrier. All of the cars are the same size and shape, but they are moving different speeds and have different masses. The barriers are all identical and exert the same constant force.



Rank the time that it takes to stop the cars as the barriers apply the same constant force. Explain your reasoning.

9. A rocket engine provides 7400 N of thrust for 6.2 s.
a) What impulse is imparted to the rocket?
b) What is the change in momentum of the rocket?

10. A pitcher supplies a constant force on a baseball whose mass is .14 kg. The pitcher's hand is in contact with the ball over a distance of 1.5 m. The ball's speed as it is released is 40 m/s.

a) What force acted on the ball?
b) What was the change in momentum of the ball?
c) How long did the force act on the ball?

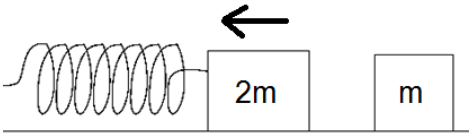
12. Two skaters on a frictionless surface, initially at rest, push on each other for 1.5 s with a force of 60 N. The skaters move in opposite directions as a result. The mass of one skater is 50 kg and other is 60 kg.

a) What is the final speed of the 50 kg skater?
b) What is the final speed of the 60 kg skater?
c) Over what distance did the 60 N force act on the 50 kg skater?

12. A truck of mass 900 kg traveling 20 m/s east makes a head on collision with a car of mass 500 kg traveling 50 m/s, west. The vehicles lock together after the collision.

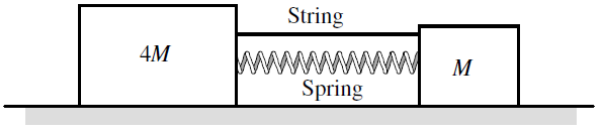
a) How fast are the 2 locked together cars moving after the collision?
b) In which direction do the locked together vehicles move?

13. A block of mass $2m$ is pushed against a spring of elastic constant K until the spring is compressed a distance of X. The spring is then released and the block slides along the frictionless surface until collides with the smaller block of mass m. If the 2 blocks stick together, find the final velocity of the 2 block system.



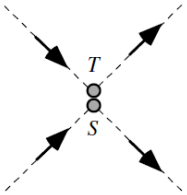
4.2 – Collisions

1. Two boxes are tied together by a string and are sitting at rest on a frictionless surface. Between the two boxes is a massless compressed spring. The string tying the two boxes together is cut and the spring expands, pushing the boxes apart. The box on the left has four times the mass of the box on the right.



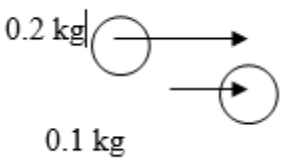
a) After the string is cut and the boxes lose contact with the spring, will the magnitude of the momentum of the box on the left be *greater than*, *less than*, or *equal to* the magnitude of the momentum of the box on the right? Explain your reasoning.
b) At the instant (after the string is cut) that the boxes lose contact with the spring, will the speed of the box on the left be *greater than*, *less than*, or *equal to* the speed of the box on the right? Explain your reasoning.

2. Two identical steel balls, *S* and *T*, are shown at the instant that they collide. The paths and velocities of the two balls before and after the collision are indicated by the dashed lines and arrows. The speeds of the balls are the same before and after the collision.



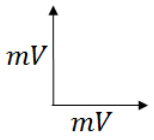
a) What is the direction of the change in momentum for ball *T*?
b) What is the direction of the change in momentum for ball *T*?

3. Two objects of mass 0.2 kg and 0.1 kg, respectively, move parallel to the x-axis, as shown. The 0.2 kg object overtakes and collides with the 0.1 kg object. Immediately after the collision, the y-component of the velocity of the 0.2 kg object is 1 m/s upward. What is the y-component of the velocity of the 0.1 kg object immediately after the collision?



4. A cart traveling on a track with velocity v collides and sticks to an identical cart on the track, initially at rest. What is the maximum percentage of the cart's initial kinetic energy maintained as kinetic energy in the system?

5. A stationary object explodes, breaking into three pieces of masses *m*, *m*, and *3m*. The two pieces of mass *m* move off at right angles to each other with the same magnitude of momentum mV, as shown in the diagram. What are the magnitude and direction of the velocity of the piece having mass *3m*?



6. A 4.00 kg ball traveling east at 10.0 m/s collides with a 6.00 kg ball traveling west at 2.00 m/s. The 4.00 kg ball moves east at 4.00 m/s after the collision.
a) Find the velocity of the 6.00 kg ball after the collision.
b) How much kinetic energy was lost in the collision?

7. A cart with mass 2m has a velocity v before it strikes another cart of mass 3m at rest. If the collision is perfectly inelastic, find the velocity of the 2 cart system after the collision.

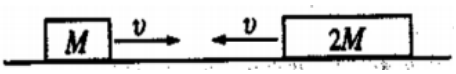
8. A 65.0 kg ice skater moving to the right on frictionless ice with a velocity of 2.50 m/s throws a 0.150 kg snowball to the right with a velocity of 32.0 m/s relative to the ground.
a) What is the velocity of the ice skater after throwing the snowball?
b) A second skater initially at rest with a mass of 60.0 kg catches the snowball. What is the velocity of the second skater after catching the snowball in a perfectly inelastic collisions?

9. What is the recoil velocity of a 4.0 kg rifle that shoots a .050 kg paintball at a speed of 280 m/s?

10. A 1200 kg car traveling north on an icy road at 40 m/s collides with a 3200 kg truck traveling east at 30 m/s. The two vehicles lock together and slide in the icy intersection. What is the magnitude and direction of speed of the velocity the wreck moves after the collision?

11. A .085 kg bullet strikes a 5.000 kg block of wood. The bullet becomes embedded in the block, which slides horizontally for 6.0 m before coming to rest. If $\mu_{sliding}$ is .30 then what was the original speed of the bullet?

12. The two blocks of masses M and 2M shown above initially travel at the same speed v but in opposite directions. They collide and stick together. How much mechanical energy is lost to other forms of energy during the collision?

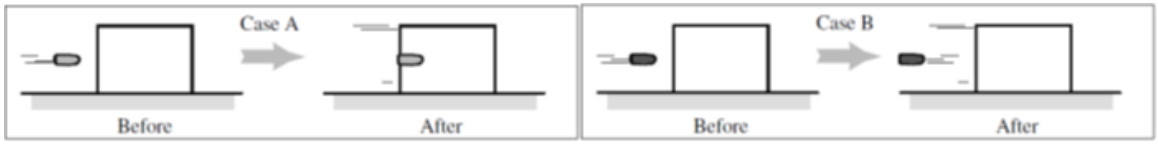


13. A block of mass M is initially at rest on a frictionless floor. The block, attached to a massless spring with spring constant k, is initially at its equilibrium position. An arrow with mass m and velocity v is shot into the block. The arrow sticks in the block. What is the maximum compression of the spring?

14. A sled of mass *m* is coasting on the icy surface of a frozen river. While it is passing under a bridge, a package of equal mass *m* is dropped straight down and lands on the sled. The sled continues moving. How does the kinetic energy of the sled + load compare with the original kinetic energy of the sled?

15. A boy of mass m and a girl of mass 2m are initially at rest at the center of a frozen pond. They push each other so that she slides to the left at speed v across the frictionless ice surface and he slides to the right. What is the total work done by the children?

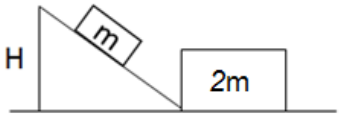
16. In Case A, a metal bullet penetrates a wooden block. In Case B, a rubber bullet with the same initial speed and mass bounces off an identical wooden block.



a) Will the speed of the wooden block after the collision be greater in Case A, greater in Case B, or the same in both cases? Explain your reasoning.

b) In Case B, will the speed of the bullet after the collision be greater than, less than, or the same as the speed of the bullet just before the collision? Explain your reasoning.

*17. A block of mass m slides down a frictionless incline and strikes a bigger block of mass $2m$. The larger block slides on the horizontal surface with a coefficient of friction μ. The smaller block is released from rest at the top of the incline and reaches a speed of $3v$. After the collision, the larger block moves right with a velocity $2v$.

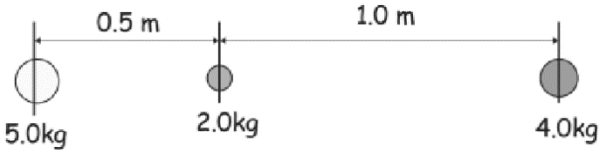


a) Derive an expression for H, the height of the incline in terms of m, and v.
b) Is the collision elastic or inelastic? Justify you answer.
c) Derive an expression for the distance the large block travels before coming to rest.
d) Derive an expression for the maximum height up the incline the smaller block travels.

4.3 – Center of Mass

1. Estimate where the approximate center of mass of Palm Beach County is located. Justify your answer.

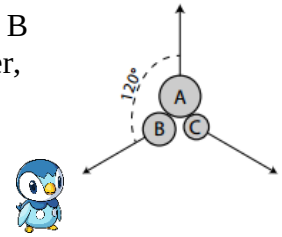
2. Find the center of mass of the system shown on the right.



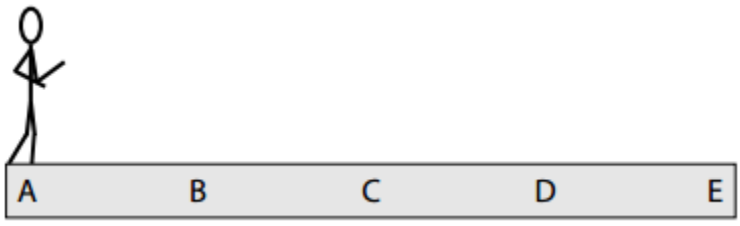
3. A car of mass $2m$ moves with velocity v east when it collides with a car of mass m and velocity $-2v$ west.
a) Find the velocity of the center of mass of the 2 car system before the collision.
b) How will the velocity of the center of mass of the system change after the collision? Justify your answer qualitatively.
c) What role does center of mass play in conservation of momentum?

4. A fisherman in a small fishing boat at rest in a lake hooks a giant log floating in the lake 30 meters away. The fisherman reels the log in. During this process, the boat moves 12 meters in the direction of the log. If the mass of the boat and fisherman is 400 kg, what is the mass of the log?

5. Three penguins are arranged in the center of a patch of frictionless ice floating across the ocean with a velocity of 2 m/s west. The mass of penguin A is 38 kg, the mass of penguin B is 30 kg, and the mass of penguin C is 23 kg. At time t=0, the penguins push off each other, each with a force of 20 N, such that they all slide away from the center of the floating ice patch at an angle of 120° from each other as shown in the diagram at right. Describe the motion of the center of mass of the three-penguin system at time t=3s



6. An 60 kg student stands on the left end of a 180-kg log which is floating in the water (which you may treat as a frictionless surface). The student and the log are both initially at rest.



a) Which point is the approximate center of mass of the student-log system?
b) The student walks to the far end of the log at a constant speed of 2 m/s. As the student walks to the right, describe the motion of the log. Provide quantitative values wherever possible.
c) What is the velocity of the center of mass of the student-log system while the student is walking?