AP Physics C: Mechanics
Unit 4 Practice Exercises

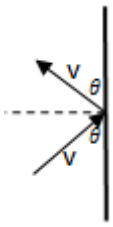
Directions: Show the steps required to arrive at the answer (if applicable). Use g = 9.80 m/s^2 and neglect air resistance unless otherwise stated. Work out the problems on separate page.

4.1 – Momentum & Impulse

1. A bouncy ball is thrown at a wall The force, F, exerted on the ball by the wall is given as a function of time by $F(t) = 300t - 3000t^2$. The ball is in contact with the wall for a total of .10 s. What is the magnitude of the change of momentum of the ball?

2. The momentem p of a moving object as a function of time t is given by the expression $p(t) = kt^3$. Derive a function for the force causing this motion.

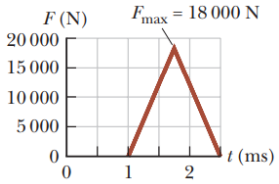
3. Tennis star and motivational speaker Matsuoka Shuzo hits a tennis ball at a wall. It hits the wall making an angle with the horizontal. It rebounds in the opposite direction as shown with the same angle with the horizontal.



a) What is the direction of the impulse of the wall on the ball?
b) What is the magnitude of the impulse of the wall on the ball?

4. A 2.4-kg ball falling vertically hits the floor with a speed of 2.5 m/s and rebounds with a speed of 1.5 m/s. What is the magnitude of the impulse exerted on the ball by the floor?

5. The force acting on a 4.0-kg object is shown. The velocity is +20.0 m/s at t = 0.



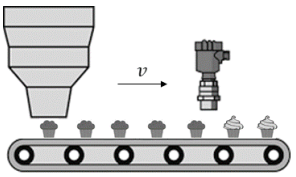
a) What is the impulse on the object?
b) What is the velocity at t = 2.0 ms?

6. A force of magnitude $F(t) = At + Bt^3$ and directed to the right is applied to an object of mass M starting at time t =0 to time t = T.

a) What is the impulse?
b) If the object is initially at rest, what is its velocity at T?
c) What is the average force during the time interval?

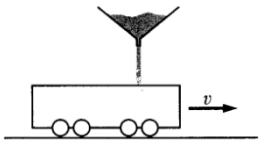
7. A garden hose is held by a gardener. The hose is originally full of motionless water. What additional force is necessary to hold the nozzle stationary after the water flow is turned on if the discharge rate is 0.800 kg/s with a speed of 22.0 m/s?

8. Cupcakes are put on a conveyer belt to add frosting. At time t, the belt is moving at cupcakes at a speed of 8 m/s, but the belt is slowing down at a rate of 0.10 m/s^2 as frosting is added to the cupcakes at a rate of 0.30 kg/s. At this instant, the total mass of the cupcakes on the conveyer belt is 12.0 kg. What is magnitude of the instantaneous force exerted on the conveyer belt at time t?



9. A rocket has a total mass (fuel plus rocket) of M. The rocket is in deep space at rest at position x = 0 and t = 0 when it starts putting out exhaust at a speed of v_e and at rate of mass loss of σ kg/s.
a) Derive an expression for the velocity of the rocket as a function of time.
b) Derive an expression for the acceleration of the rocket as a function of time.

10.An open-top railroad car (initially empty and of mass M_o) rolls with negligible friction along a straight horizontal track and passes under the spout of a sand conveyor. When the car is under the conveyor, sand is dispensed from the conveyor in a narrow stream at a steady rate $\frac{\Delta M}{\Delta t} = k$ and falls vertically from an average height h above the floor of the railroad car. The car has initial speed v_o and sand is filling it from t=0 to t=T.



a) Determine the mass M of the car plus the sand that it catches as a function of time t for 0 < t < T. and sand is filling it from time t = 0 to t = T.

b) Determine the speed v of the car as a function of time t for 0 < t < T.

c) i. Determine the initial kinetic energy ii. Determine the final kinetic energy K

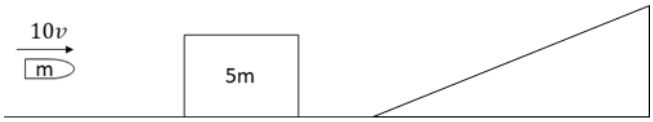
iii. Is kinetic energy conserved? Explain why or why not.

<u>4.2 – Inelastic Collisions</u>

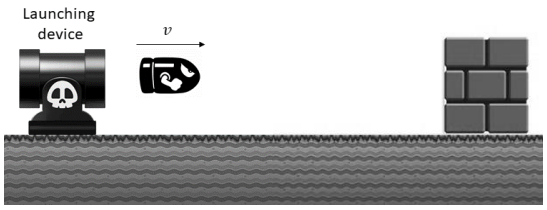
1. A boat travels down a river with kinetic energy of K. As it passes under a bridge, a package is dropped on the boat. If the package has the same mass as the boat, what percent of the boat's kinetic energy is lost after the package is dropped on it?

2. Oddjob is standing on a frozen lake. He throws his steel-lined hate with a velocity of 30 m/s at 30^o above the horizontal towards James Bond. If Oddjob's mass is 60 kg and his hat is 5 kg, what is his horizontal recoil velocity.

3. A bullet of mass m is shot at a speed of $10v$ to the right as shown. The bullet passes through a block of mass $5m$, which is initially at rest. The bullet passes through the block. After the bullet passes completely through the block, the bullet's velocity has dropped to $5v$. What is the maximum height the block travels up the incline?



4. A bullet of mass m is fired horizontally from a launching device, exiting with speed v. Assume the original direction of the bullet is the positive direction.



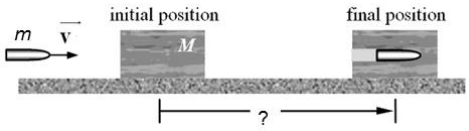
a) The projectile is fired horizontally into a block that is clamped to the ground. The bullet travels a distance of D into the block before coming to rest in the block. Determine an expression for the average force on the bullet from the block.

b) Now the bullet and block are used again, but the block is not clamped to the ground and free to move.

i. Will the magnitude of the distance, that the block travels into the block before stopping be greater than, less than, or equal to D? Justify your answer qualitatively.

ii. The block/bullet system slides on the ground with a total force on the bullet/block combo given by $F = -kv^2$, where k is some constant. Determine an expression for the velocity of the bullet/block system. Take the time when the bullet/block system start moving together as one mass at time t = 0.

5. A bullet of mass m is fired at speed v into a wooden block of mass M. The bullet instantaneously comes to rest in the block. The block with the embedded bullet slides along a horizontal surface with a coefficient of kinetic friction, μ.



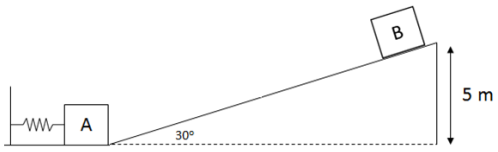
a) Determine an expression for the speed of the block after the bullet is embedded in it.

b) Determine an expression for how far the bullet will slide along the surface after the bullet is embedded in it. Show all work to justify you answer.

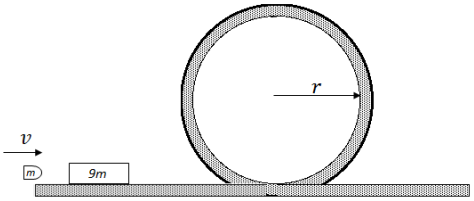
c) Momentum of the bullet/block combo is not conserved as it slides across the ground. Why?

d) If the bullet were to pass through the block instead of becoming embedded in the block, would the block slide further or less than it did with the bullet embedded? Justify your answer.

6. Two blocks of identical mass m = 1.0 kg are set up as shown. Block A is compressed against a distance of .10 cm from rest an ideal spring of elastic constant k = 100 N/m. Block A is released from rest after being compressed. Block B is released from rest at a height of 5 m. The two blocks collide perfectly inelastically halfway up the incline (the release of each block is time accordingly for this to occur). Calculate the velocity (direction and speed) of the combined blocks after they collide.

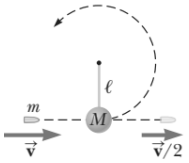


7. A bullet of mass m travels with speed v towards a block of mass $9m$ as shown (not to scale). The bullet becomes embedded in the block, which slides on a frictionless track that includes a vertical loop of radius r.



a) Determine an expression for the velocity of the bullet/block combo after the collision.
b) Determine an expression for the bullet block combo at the top of the loop.
c) After going through the loop, the bullet reaches the bottom of the loop, but is still in circular motion. Determine an expression for the normal force between the block and track at the bottom of the loop.
c) Suppose for this problem, m = 1.0 kg and r = 2.5 m. Calculate the minimum speed, v, the bullet would have so that the block/bullet combo would go through the loop.

8. A bullet of mass m and speed v passes completely through a pendulum bob of mass M. The bullet emerges with a speed of $v/2$. The pendulum bob is suspended by a rod of length l. What is the minimum value of v such that the pendulum bob will barely swing through a complete vertical circle?

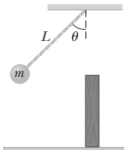


9. An object of mass 4.0 kg moving with an initial velocity of 8.00$\hat{\imath}$ m/s collides and sticks to an object of mass 8.0 kg moving with initial velocity of -4.00$\hat{\jmath}$. Find the final velocity of the composite object.

10. The mass of a rocket and its fuel is 2200 kg. The rocket is traveling upward at 85 m/s. The rocket's side engine discharge 90 kg of fuel at 1200 m/s perpendicular to the rocket's original motion. What is the velocity (speed and direction) of the rocket after ejecting the fuel?

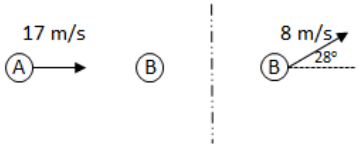
<u>4.3 – Elastic Collisions</u>

1. A ball is suspended by a string that is tied to a fixed point above a wooden block standing on end. The ball is pulled back as shown and released. In trial A, the ball rebounds elastically. In trial B the ball to stick to the block. In which trial is the ball more likely to knock the block over?



2. Ball A travels 5.0 m/s to the right when it collides with identical Ball B moving 9.0 m/s to the left. Find the velocity of each ball after the collision.

3. A tennis ball moves at 17 m/s towards an identical ball that is initially at rest as shown. The ball that was stationary moves at 8 m/s and makes an angle of 28° above the horizontal. What is the resulting magnitude and direction of the ball that was originally moving at 17 m/s?



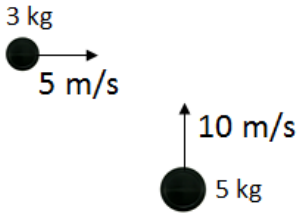
4. A kg block moves at 10 m/s towards a 4 kg block that is initially at rest. Friction is negligible. The blocks collide and bounce off each other in an elastic collision. The 4 kg is tied to a 3 m string which is fixed to a ceiling.

a) Find the velocity of the 4 kg mass after the collision.
b) Find the maximum angle that the string holding the 4 kg block makes with the vertical.

5. A 6.0 kg block is traveling on a frictionless surface when it collides *perfectly inelastically* with a 3.0 kg block. The two blocks move off as a one 9 kg mass and collide *elastically* with a 2 kg block.

a) Find the velocity of the combined 9 kg block.
b) Find the velocity of the 9 kg after it collides elastically with the 2 kg block.
c) The 2 kg block hits a spring after the elastic collision. The spring is non-linear and has a spring force that varies with distance from equilibrium, x, given by $= -5x - \frac{2}{x^2}$. Calculate the maximum distance the spring is compressed.

6. Two pucks collide on frictionless ice as shown on the right. Before the collision, a 3 kg puck moves at 5 m/s to the east. It collides with a 5 kg puck that was moving at 10 m/s due north. After the collision, the 5 kg puck moves at a speed of 4 m/s in a direction 60° north of east (60° above the horizontal).

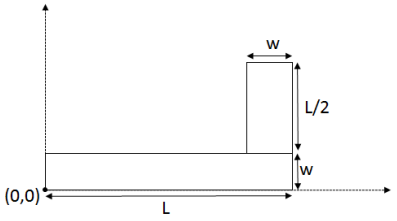


a) Calculate the speed and direction of the 3kg puck after the collision.
b) Was the collision inelastic or elastic? Justify your answer.

<u>4.4 – Center of Mass</u>

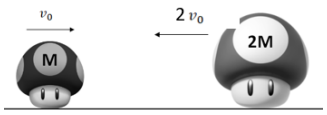
1. Two identical blocks with mass 5.0 kg each are connected to the opposite ends of a compressed spring. The blocks initially slide together on a frictionless surface with a velocity 2 m/s to the right. The spring is then released by remote control. At some instant later, the left block is moving to the left at 1 m/s, and the other block is moving to the right. What is the speed of the center of mass of the system at that instant?

2. Consider the object shown. Both blocks have identical mass. The lower left is the origin.

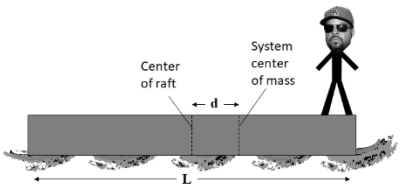


a) What is the x-coordinate of the center of the center of mass of the object?
b) What is the x-coordinate of the center of the center of mass of the object?

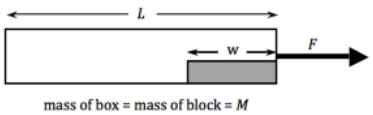
3. A mushroom of mass M moves to the right, the positive direction, with a speed of v_0 as shown. Meanwhile, a mushroom of mass 2M moves to the left with a speed of with a speed of $2v_0$. What is the velocity of the center of the mass of two mushroom system at this instant?



4. O'Shea Jackson is standing at one end of a uniform raft of length L that is floating motionless in the water. Today was not such a good day. The center of mass of the O'Shea Jackson-raft system is a distance d from the center of the raft as shown. O'Shea Jackson walks to the other end of the raft. How far does the raft move relative to the water?



5. A block of width w is located inside of the right side of a box of length L. The block and box are of equal mass, M, and are initially at rest. The surface between the block and the box is frictionless. An external force F is applied to the box that accelerates while the block slides until it strikes the left end of the box. During that time period, what distance will the block/box system's center of mass have moved?



6. A rod of length 0.4 m has linear density (mass per length) given by $\lambda = 60 + 20x$ where x is the distance from one end
a) What is the mass of the rod?
b) How far from the x=0 (the left end) is the center of mass?