AP Physics C Name: _____

Unit 4: Momentum Test

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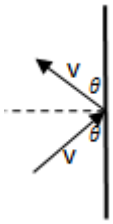
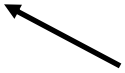
**Part 1**: Multiple Choice - Choose the answers that best answers the questions below. If an exact answer is not present, chose the closest available answer. (4 points each)

1. Wah! Waluigi, a noted tennis player, hits tennis ball right at the 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?

A) 0.5 $kg\frac{m}{s}$ B) 2.0 $kg\frac{m}{s}$ C) 15 $kg\frac{m}{s}$ D) 5.0 $kg\frac{m}{s}$ E) 10 $kg\frac{m}{s}$

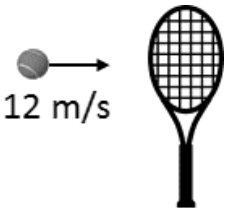
2. Waluigi hits a tennis ball at a wall. It hits the wall making an angle with the horizontal. It rebounds in the opposite direction as shown with the same angle with the horizontal. Which of the following best represents the impulse vector of the wall on the ball?




A)  B)  C) 

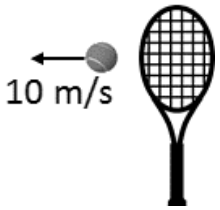
D)  E) 

(3-4) A 50 g tennis ball approaches Waluigi's tennis racket with a speed of 12 m/s as shown. The ball rebounds with a speed of 10 m/s. Waluigi's racket exerts an average force of 20 N on the tennis ball while in contact with the ball.




3. How long are the ball and racket in contact?

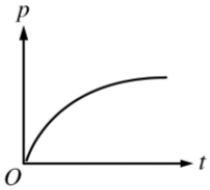
A) .055 s B) .550 s C) 5.0 s D) .005 s E) .020 s

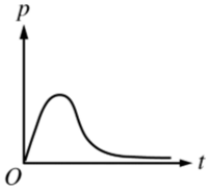


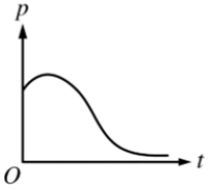

4. How does the magnitude of the average force exerted by the ball on the racket compare to the magnitude of the average force exerted by the racket on the ball?

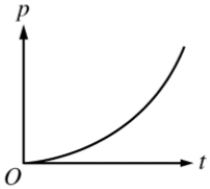
A) It is less. B) It is greater. C) It is equal. D) It is zero.
E) It cannot be determined without knowing the recoil speed of the racket.

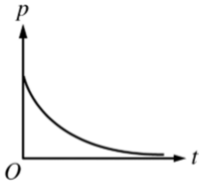
5. Whahaha! Waluigi drops a tennis ball from a great height. The ball accelerates due to gravity, but it is also affected by drag. Which of the following graphs shows the momentum of the object as a function of time?

A) 

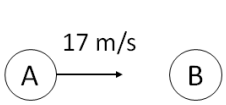
B) 

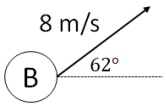
C) 

D) 

E) 

6. Waluigi throws a tennis ball 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. Which of the following describes the magnitude and direction of the ball that was originally moving at 17 m/s?



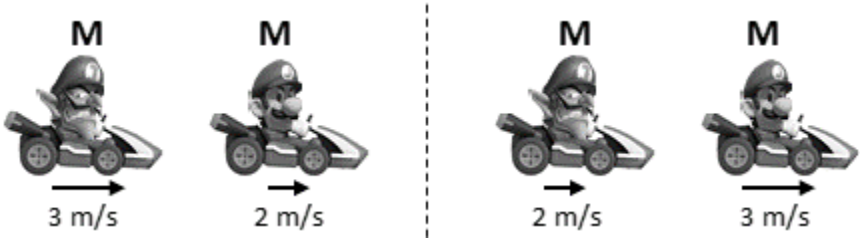

A) 15 m/s, 62° below the horizontal
B) 18.8 m/s, 62° below the horizontal
C) 18.8 m/s, 28° above the horizontal
D) 15 m/s, 28° below the horizontal
E) 15 m/s, 90° below the horizontal

7. Just when you though there couldn't possibly be more questions about tennis, two tennis balls, A, and B, of the same mass, but of composed different material, are dropped by Waluigi from the same height above the floor. After colliding with the floor, ball A bounces higher than ball B bounces. Which of the following quantities must be large for ball A than for ball B?

A) The impulse exerted by the floor.
B) The amount of time in contact with the floor.
C) The momentum just before colliding with the floor.
D) The average force exerted by the floor.
E) The kinetic energy just before colliding with the floor.


8. A person of mass M is running at a speed of $v$ and jumps onto a stationary sled of equal mass M on a frozen lake as shown. What percent of the person's kinetic energy is lost as a result of jumping on the sled?

A) 0% B) 50% C) 25% D) 67% E) 75%

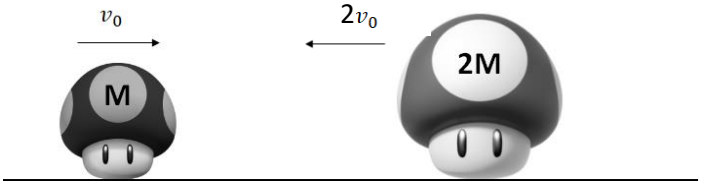



9. A go-kart of mass M collides with an identical go-kart of mass M as shown. The trailing go-kart is going at 3 m/s before the collision and the leading go-kart is going at 2 m/s in the same direction. After the two go-karts collide and separate, the leading go-kart now is going at 3 m/s and the trailing go-kart goes at 2 m/s in the same direction. Which of the following is true of the collision?

A) It is elastic because momentum is conserved.
B) It is elastic because kinetic energy is conserved.
C) It is inelastic because momentum is not conserved.
D) It is inelastic because kinetic energy is not conserved.
E) More information is need to determine whether the collision is elastic or inelastic.

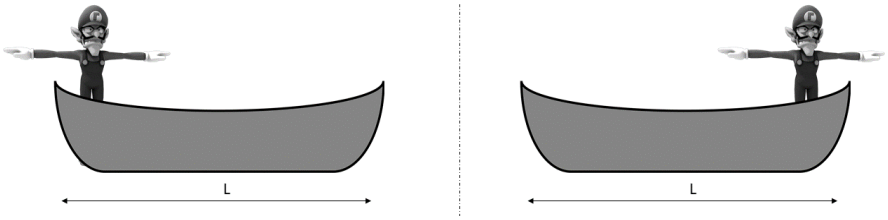

10. Waluigi shoots a bullet bill of mass $m$ at a speed of $10v$ to the right as shown. The bullet passes through a block of mass $5m$, which is initially at rest. The bullet passes through the block. After the bullet passes completely through the block, the bullet's velocity has dropped to $5v$. What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

A) $\frac{v^2}{2g}$ B) $\frac{9v^2}{2g}$ C) $\frac{25v^2}{2g}$ D) 0 E) $\frac{50v^2}{3g}$




11. 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?

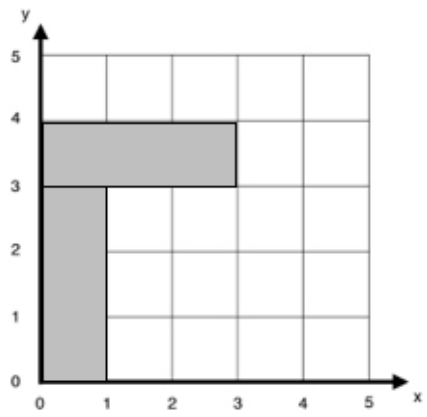
A) $-3v_0$ B) $-v_0$ C) $-4v_0/3$ D) $-2v_0/3$ E) $-v_0/3$



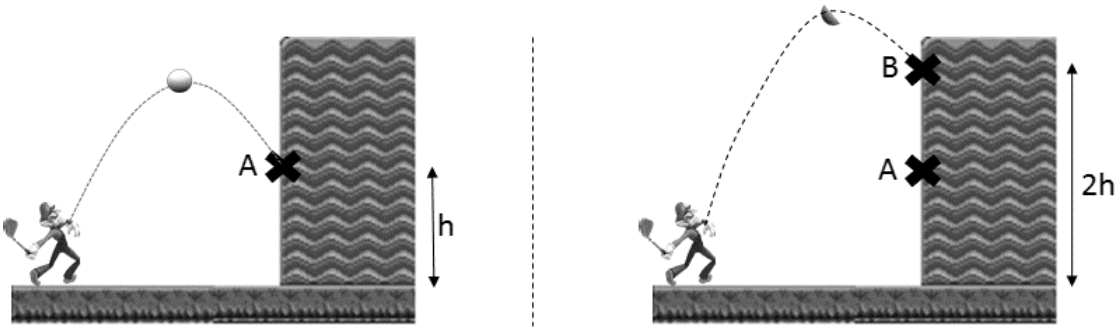

12. A fisherman stands at the back of a perfectly symmetrical boat of length *L*. The boat is at rest in the middle of a perfectly still and peaceful lake, and the fisherman has a mass $^1/_4$ that of the boat. If the fisherman walks to the front of the boat, by how much is the boat displaced?

A) L/10 B) L/5 C) L/4 D) L/8 E) 2L/5

13. A Waluigi logo consisting of two equal 2D rectangular masses is placed on a coordinate system as shown. What is the location of the center of mass of the Waluigi logo?

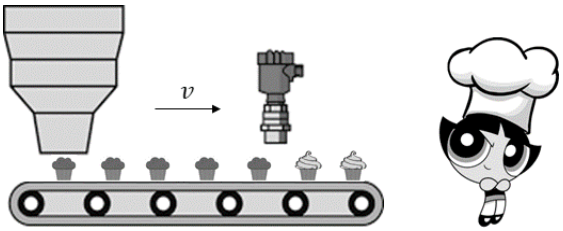



A) (1.0, 2.5)
B) (1.0, 2.75)
C) (1.25, 2.5)
D) (1.5, 2.5)
E) (1.75, 2.75)




14. Waluigi launches a golf-ball at cliff twice. In both cases the ball is hit the exact same way. The first time the ball is hit, the ball hits the cliff at point A, which is a height of h above the ground. The second time the ball is hit (with the same launch angle and launch speed), the ball explodes into two pieces of equal mass in the air right after being hit. One piece lands at point B, a height of 2h above the ground. At what height, y, does the other piece hit the cliff?

A) At ground level, $y = 0$.
B) Between the ground and point A, $0 < y < h$.
C) At point A, $y = h$.
D) Between points A and B, $h < y < 2h$.
E) At point B, $y = 2h$.

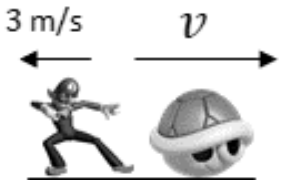



15. Chef Terra puts cupcakes on a conveyer belt to add frosting. At time t, the belt is moving at cupcakes at a speed of 8 m/s, but the belt is slowing down at a rate of 0.10 m/s$^2$ as frosting is added to the cupcakes at a rate of 0.30 kg/s. At this instant, the total mass of the cupcakes on the conveyer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

A) 2.8 N  B) 6.0 N  C) 3.6 N  D) 2.4 N  E) 1.2 N

Part 2: Free Response. **You must show all steps** required to arrive at the correct answer for the problem below, including any diagrams. **All answers must be given with correct units.** (14 points each)

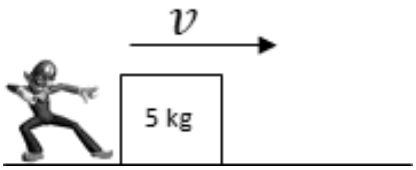
16. Waluigi pushes a giant Koopa shell while standing on an icy surface. Waluigi has mass 72 kg and the rock has a rock of 8 kg. Waluigi recoils off the shell with a velocity of 3 m/s as shown.




a) What direction is the impulse the shell exerts on Waluigi?

b) What is the velocity of the shell after being pushed?

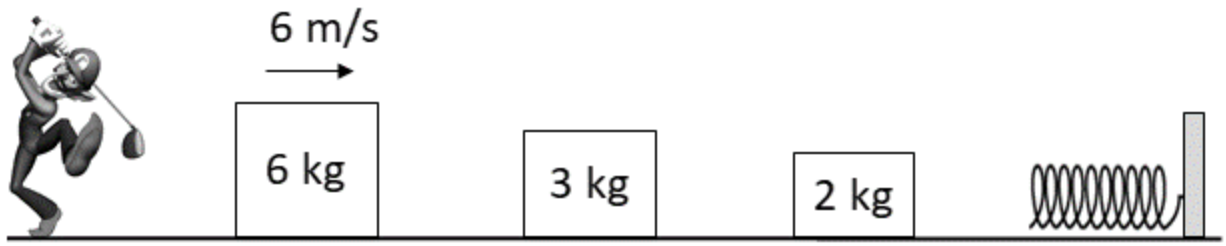
c) Waluigi wants to conduct an experiment to determine the speed kinetic coefficient of friction between the ice and a 5.0 kg block. To measure this, he varies the speed, $v$, he gives the block measures how far the block slides, $D$.




| **v (m/s)** | 3 | 5 | 8 | 10 | 13 |
|---|---|---|---|---|---|
| **D (m)** | 7 | 18 | 45 | 73 | 114 |

i. Write an expression for a straight line relationship that relates $v$ and $D$ in such a way that the slope of the line can be used to calculate the value of $\mu$, the coefficient of friction between the bullet/block bomb and the icy surface.

ii. Using your equation from ii., calculate the value of the coefficient of friction between the block and ice.

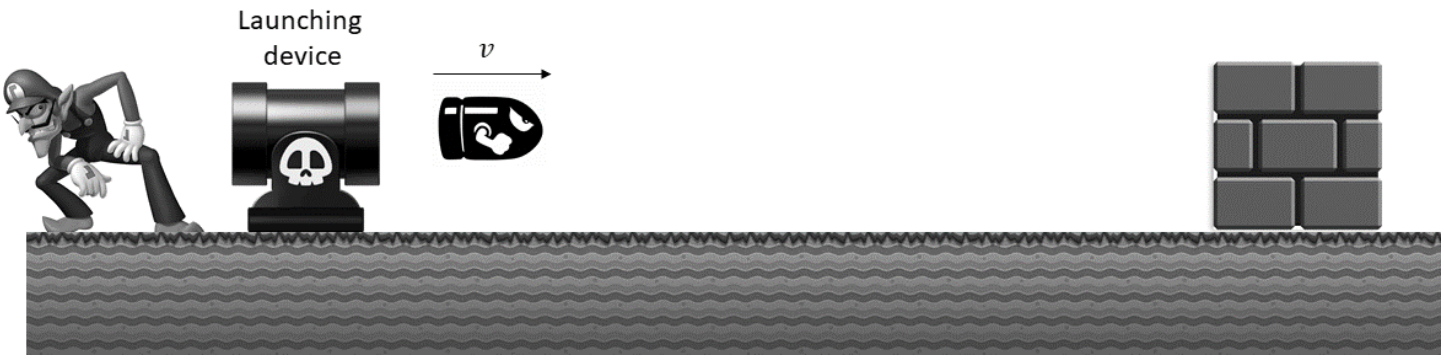



17. A 6.0 kg block is traveling on a frictionless surface when it collides *perfectly inelastically* with a 3.0 kg block. The two blocks move off as a one 9 kg mass and collide *elastically* with a 2 kg block.

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.




18. 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 to that it cannot move. 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.

**Bonus:** A block of mass m slides at velocity $v_o$ across a horizontal frictionless surface toward a large curved movable ramp of mass 3m as shown in Figure 1. The ramp, initially at rest, also can move without friction and has a smooth circular frictionless face up which the block can easily slide. When the block slides up the ramp, it momentarily reaches a maximum height as shown in Figure II and then slides back down the frictionless face to the horizontal surface as shown in Figure III.

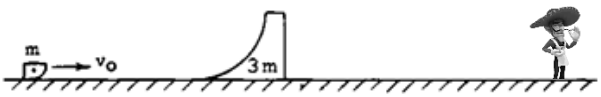


Figure I

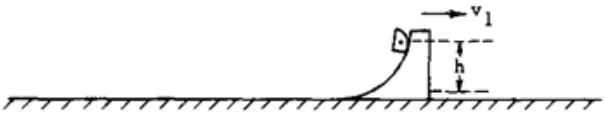


Figure II

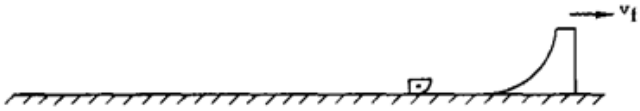


Figure III

B1. To what maximum height h does the center of mass of the block rise above its original height? (1 points)

B2. Determine the final speed $v_f$ of the ramp and the final speed v' of the block after the block returns to the level surface. State whether the block is moving to the right or to the left. (2 points)