

## Exam Three Momentum Concept Questions

### Isolated Systems

**4.** A car accelerates from rest. In doing so the absolute value of the car's momentum changes by a certain amount and that of the Earth changes by:

1. a larger amount.
2. the same amount .
3. a smaller amount.
4. The answer depends on the interaction between the two.

*Answer:* 2. Momentum is equal to the force times the time over which it acts. The forces exerted on the car by Earth and those exerted on Earth by the car are equal and opposite, and the times during which these forces are exerted are equal.

**6.** Suppose the entire population of the world gathers in one spot and, at the sounding of a prearranged signal, everyone jumps up. While all the people are in the air, does Earth gain momentum in the opposite direction?

1. No; the inertial mass of Earth is so large that the planet's change in motion is imperceptible.
2. Yes; because of its much larger inertial mass, however, the change in momentum of Earth is much less than that of all the jumping people.
3. Yes; Earth recoils, like a rifle firing a bullet, with a change in momentum equal to and opposite that of the people.
4. It depends.

*Answer:* 3. If we consider Earth to be an isolated system (during the short time interval that the people jump up, this approximation is appropriate), then momentum must be conserved. So the momentum of Earth must be equal to and opposite that of the jumping people. Because of Earth's large inertial mass, however, there is no perceptible motion.

**7.** Suppose the entire population of the world gathers in one spot and, at the sound of a prearranged signal, everyone jumps up. About a second later, 5 billion people land back on the ground. After the people have landed, Earth's momentum is

1. the same as what it was before the people jumped.

2. different from what it was before the people jumped.

*Answer:* 1. It's impossible to change the momentum of an isolated system from inside the system.

Collisions:

**8.** Suppose rain falls vertically into an open cart rolling along a straight horizontal track with negligible friction. As a result of the accumulating water, the momentum of the cart

1. momentum of the cart increases, and the kinetic energy of the cart increases.
2. momentum of the cart increases, and the kinetic energy of the cart does not change
3. momentum of the cart increases, and the kinetic energy of the cart does decreases
4. momentum of the cart does not change ,and the kinetic energy of the cart increases.
5. momentum of the cart does not change , and the kinetic energy of the cart does not change
6. momentum of the cart does not change , and the kinetic energy of the cart decreases
7. momentum of the cart decreases, and the kinetic energy of the cart increases.
8. momentum of the cart does decreases, and the kinetic energy of the cart does not change
9. momentum of the cart decreases, and the kinetic energy of the cart decreases

*Answer:* 6. The water, because it falls vertically, does not change the cart's horizontal momentum. The mass of the cart increases, however, and so its speed decreases. Therefore its kinetic energy decreases as well.

**10.** Consider these situations: (i) a ball moving at speed  $v$  is brought to rest; (ii) the same ball is projected from rest so that it moves at speed  $v$ ; (iii) the same ball moving at speed  $v$  is brought to rest and then projected backward to its original speed. In which case(s) does the ball undergo the largest change in momentum?

1. (i)
2. (i) and (ii)
3. (i), (ii), and (iii)

4. (i)
5. (ii) and (iii)
6. (iii)

*Answer:* 6. Let's say the ball has inertial mass  $m$  and velocity  $v$ . The decrease in momentum in case (i) is  $0 - mv = -mv$  (final momentum minus initial momentum). In case (ii), we find  $mv - 0 = +mv$ . In case (iii), we have  $m(-v) - mv = -2mv$  because the ball's velocity is now in the opposite direction. So the magnitude of the change is greatest in the third case.

**11.** Consider two carts, of masses  $m$  and  $2m$ , at rest on an air track. If you push first one cart for 3 s and then the other for the same length of time, exerting equal force on each, the momentum of the light cart is

1. four times
2. twice
3. equal to
4. one-half
5. one-quarter

the momentum of the heavy cart.

*Answer:* 3. Momentum is equal to force times time. Because the forces on the carts are equal, as are the times over which the forces act, the final momenta of the two carts are equal.

**12.** Consider two carts, of masses  $m$  and  $2m$ , at rest on an air track. If you push first one cart for 3 s and then the other for the same length of time, exerting equal force on each, the kinetic energy of the light cart is

1. larger than
2. equal to
3. smaller than

the kinetic energy of the heavy car.

*Answer:* 1. Because the momenta of the two carts are equal, the velocity of the light cart must be twice that of the heavy cart. Thus, the kinetic energy of the light cart is twice the kinetic energy of the heavy one.

**13.** Suppose a ping-pong ball and a bowling ball are rolling toward you. Both have the same momentum, and you exert the same force to stop each. How do the time intervals to stop them compare?

1. It takes less time to stop the ping-pong ball.
2. Both take the same time.
3. It takes more time to stop the ping-pong ball.

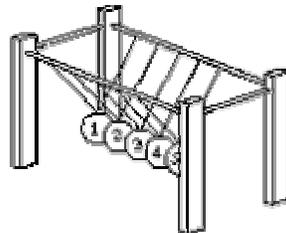
*Answer:* 2. Because force equals the time rate of change of momentum, the two balls lose momentum at the same rate. If both balls initially have the same momentum, it takes the same amount of time to stop them.

**14.** Suppose a ping-pong ball and a bowling ball are rolling toward you. Both have the same momentum, and you exert the same force to stop each. How do the distances needed to stop them compare?

1. It takes a shorter distance to stop the ping-pong ball.
2. Both take the same distance.
3. It takes a longer distance to stop the ping-pong ball.

*Answer:* 3. Because the momenta of the two balls are equal, the ball with the larger velocity has the larger kinetic energy. Being that the ping-pong ball has a smaller inertial mass, it must therefore have the larger kinetic energy. This means more work must be done on the ping-pong ball than on the bowling ball. Because work is the product of force and displacement, the distance to stop the ping-pong ball is greater.

**15.** If ball 1 in the arrangement shown here is pulled back and then let go, ball 5 bounces forward. If balls 1 and 2 are pulled back and released, balls 4 and 5 bounce forward, and so on. The number of balls bouncing on each side is equal because



1. of conservation of momentum.
2. the collisions are all elastic.
3. neither of the above

*Answer:* 2. There are many different final states that conserve momentum, but this is the only one that also conserves kinetic energy. Since conservation of kinetic energy is the same thing as saying "the collisions are elastic," choice 2 is correct.

**16.** A cart moving at speed  $v$  collides with an identical stationary cart on an air track, and the two stick together after the collision. What is their velocity after colliding?

1.  $v$
2.  $0.5 v$
3. zero

4.  $-0.5v$
5.  $-v$
6. need more information

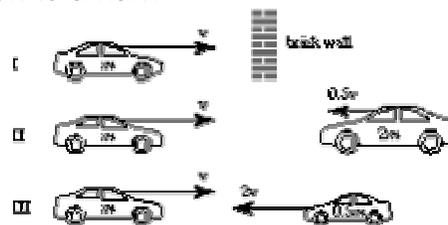
*Answer:* 2. Because total momentum must be conserved, we have  $mv = 2mu$ , which gives a final velocity  $u = 0.5v$ .

**17.** A person attempts to knock down a large wooden bowling pin by throwing a ball at it. The person has two balls of equal size and mass, one made of rubber and the other of putty. The rubber ball bounces back, while the ball of putty sticks to the pin. Which ball is most likely to topple the bowling pin?

1. the rubber ball
2. the ball of putty
3. makes no difference
4. need more information

*Answer:* 1. Because momentum is conserved in these interactions, more momentum is transferred to the bowling pin from the rubber ball than from the putty ball. Hence, the rubber ball is more likely to knock the pin over.

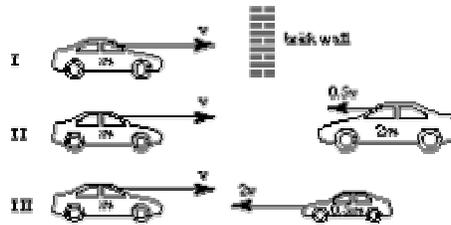
**19.** If all three collisions in the figure shown here are totally inelastic, which bring(s) the car on the left to a halt?



1. I
2. II
3. III
4. I, II
5. I, III
6. II, III
7. all three

*Answer:* 7. Momentum conservation tells us that all three collisions bring the left-hand car to a halt.

**20.** If all three collisions in the figure shown are totally inelastic, which cause(s) the most damage?



1. I
2. II
3. III
4. I, II
5. I, III
6. II, III
7. all three

*Answer:* 3. The right car in III loses more kinetic energy in the collision than the right car in II or the wall (which has zero kinetic energy) in I. Since any amount of kinetic energy lost goes into deforming the cars, the most damage occurs in III.

**21.** A golf ball is fired at a bowling ball initially at rest and bounces back elastically. Compared to the bowling ball, the golf ball after the collision has

1. more momentum but less kinetic energy.
2. more momentum and more kinetic energy.
3. less momentum and less kinetic energy.
4. less momentum but more kinetic energy.
5. none of the above

*Answer:* 4. The golf ball bounces back at nearly its incident speed, whereas the bowling ball hardly budge. Thus the change in momentum of the golf ball is nearly  $-2mv$ , and the bowling ball must gain momentum  $+2mv$  to conserve momentum. However, since the mass of the bowling ball is much larger than that of the golf ball, the bowling ball's velocity and hence its kinetic energy are much smaller than those of the golf ball.

~~**22.** A golf ball is fired at a bowling ball initially at rest and sticks to it. Compared to the bowling ball, the golf ball after the collision has~~

- ~~1. more momentum but less kinetic energy.~~
- ~~2. more momentum and more kinetic energy.~~
- ~~3. less momentum and less kinetic energy.~~
- ~~4. less momentum but more kinetic energy.~~
- ~~5. none of the above~~