1. A moving car has momentum. If it moves twice as fast, its momentum is \_\_\_\_\_\_ as much.

2. Two cars, one twice as heavy as the other, move down a hill at the same speed. Compared to the lighter car, the momentum of the heavier car is \_\_\_\_\_ as much.

3. When someone shoots a gun, the recoil momentum of the gun that “kicks” is (more, less, or the same) as the momentum of the bullet it fires?

4. If a man firmly holds a gun when fired, then the momentum of the bullet is equal to the recoil momentum of the (gun alone, gun-man system, or the man alone)?

5. Suppose you are traveling in a bus at highway speed on a nice summer day and the momentum of an unlucky bug is suddenly changed as it splatters onto the front window.

a. Compared to the force that acts on the bug, how much force acts on the bus? (more, less, or the same)

b. The time of impact is the same for both the bug and the bus. Compared to the impulse on the bug, this means the impulse on the bus is more, the same, or less?

c. How does the change in momentum of the bus, compare to the change of momentum of the bug (more, the same, or less)?

d. Which undergoes the greater acceleration? (bus, bug, or both)

e. Which therefore, suffers the greater damage? (bus, bug, or both)

6. John whizzes around the rink and is suddenly confronted with his son, Stephen, at rest directly in his path. Rather than knock him over, he picks him up and continues in motion without braking.

a. Is this an elastic or inelastic collision?

b. How do the momentum of the system before collision compare with the momentum of the system after collision.

c. Complete the before-collision data in the table below.

BEFORE COLLISION

|  |  |
| --- | --- |
| John’s mass | 80 kg |
| John’s speed | 3 m/s |
| John’s momentum |  |
| Stephen’s mass | 42 kg |
| Stephen’s speed | 0 m/s |
| Stephen’s momentum |  |
| Total momentum |  |

d. After collision, does John’s speed increase or decrease?

e. After collision, does Stephen’s speed increase or decrease?

f. After collision, what is the total mass of John + Stephen?

g. After collision, what is the total momentum of John + Stephen?

h. Use the conservation of momentum law to find the speed of John and Stephen together after collision. (Show your work).

7. Bernie, whose mass is 70.0 kg, leaves a ski jump with a velocity of 21.0 m/s. What is Bernie’s momentum as he leaves the ski jump?

8. Ethel is sitting on a park bench feeding the pigeons when a child’s ball rolls toward her across the grass. Ethel returns the ball to the child by hitting it with her 2.0 kg pocketbook with a speed of 20 m/s. If the impact lasts for 0.4s, with what force does Ethel hit the ball?

9. When Reggie stepped up to the plate and hit a 0.150 kg fast ball traveling at 36.0 m/s, the impact caused the ball to leave his bat with a velocity of 45.0 m/s in the opposite direction. If the impact lasted for 0.002 s, what force did Reggie exert on the baseball?



10. Astronaut Pam Melroy, history’s third woman space shuttle pilot, flew the space shuttle Discovery to the International Space Station to complete construction in October of 2000. To undock from the space station Pilot Melroy released hooks holding the two spacecraft together and the 68,000 kg shuttle pushed away from the space station with the aid of four large springs.

1. If the 73,000 kg space station moved back at a speed of 0.50 m/s, how fast and in what direction did the space shuttle move?

 b. What was the relative speed of the two spacecraft as they separated?

**ANSWERS**

1. A moving car has momentum. If it moves twice as fast, its momentum is \_\_\_\_\_\_ as much.

*Since the car’s mass does not change, the only variable is velocity.*

*mv (before) 🡪 m2v (after) … momentum is twice as much.*

2. Two cars, one twice as heavy as the other, move down a hill at the same speed. Compared to the lighter car, the momentum of the heavier car is \_\_\_\_\_ as much.

*Since the two car’s velocities are the same, the only variable is mass.*

*mv vs. 2mv … momentum is twice as much.*

3. When someone shoots a gun, the recoil momentum of the gun that “kicks” is (more, less, or the same) as the momentum of the bullet it fires?

*The speed and acceleration of the bullet are much greater than the gun. However, the gun’s mass is much greater than the bullet. According to the conservation of momentum, the bullet’s momentum (when fired) must be matched by the gun’s recoil momentum.*

4. If a man firmly holds a gun when fired, then the momentum of the bullet is equal to the recoil momentum of the (gun alone, gun-man system, or the man alone)?

*According to the conservation of momentum, the bullet’s momentum (when fired) must be matched by the gun-man system’s recoil momentum. The gun-man system represents the mass x velocity of recoil that equals the mass x velocity of the bullet fired.*

5. Suppose you are traveling in a bus at highway speed on a nice summer day and the momentum of an unlucky bug is suddenly changed as it splatters onto the front window.

a. Compared to the force that acts on the bug, how much force acts on the bus? (more, less, or the same)

*The bus’ mass and speed (mv) are much greater than the bug. However, according to Newton’s 3rd law, the action of the bug equals the reaction and the same is true for the bus. The force of impact on each (bus and bug) are the same, but in opposite directions.*

b. The time of impact is the same for both the bug and the bus. Compared to the impulse on the bug, this means the impulse on the bus is more, the same, or less?

*Impulse is ft = ∆mv. Both the time and the force of impact are the same, therefore, the impulse (change in momentum) is the same for both the bus and the bug. The key is the change in momentum for the bus and bug are the same.*

c. How does the change in momentum of the bus, compare to the change of momentum of the bug (more, the same, or less)?

*Impulse is ft = ∆mv. Although the momentum of the bus is very large compared to the momentum of the bug, the CHANGE in momentum of the bus is the same as that for the bug.*

d. Which undergoes the greater acceleration? (bus, bug, or both)

*Since the action/reaction force of the bus & bug are the same, the acceleration (actually the deceleration) for the bug is much greater than the bus. Impulse (ft = ∆mv) is derived from f = ma. Since the bug’s mass is tiny compared to the bus’, the bug’s deceleration will be much greater than the bus’.*

e. Which therefore, suffers the greater damage? (bus, bug, or both)

*Surely, the bug suffers more damage because of its composition and mass. The bus’ momentum is far greater than the bug’s, although the change in momentum due to the collision/impact is the same.*



6. John whizzes around the rink and is suddenly confronted with his son, Stephen, at rest directly in his path. Rather than knock him over, he picks him up and continues in motion without braking.

a. Is this an elastic or inelastic collision?

*Since John and Stephen combine (and do not bounce off each other), this is an inelastic collision.*

b. How do the momentum of the system before collision compare with the momentum of the system after collision.

*John and his son are two parts of the same system. Since we assume that no outside forces act on the system, the momentum of the system before the collision equals the momentum of the system after collision.*

c. Complete the before-collision data in the table below.

BEFORE COLLISION

|  |  |
| --- | --- |
| John’s mass | 80 kg |
| John’s speed | 3 m/s |
| John’s momentum | *240 kg m/s* |
| Stephen’s mass | 42 kg |
| Stephen’s speed | 0 m/s |
| Stephen’s momentum | *0 kg m/s* |
| Total momentum | *240 kg m/s* |

d. After collision, does John’s speed increase or decrease?

*John and Stephen now become one “unit” so the mass is larger than before the collision. Therefore, the velocity after collision must be less to conserve momentum.*

e. After collision, does Stephen’s speed increase or decrease?

*Stephen was at rest before collision (velocity = 0 m/s). Therefore, after the inelastic collision, he is moving with John so his speed increases.*

f. After collision, what is the total mass of John + Stephen?

*John’s and Stephen’s masses would combine after collision.*

*80 kg + 42 kg = 122 kg.*

g. After collision, what is the total momentum of John + Stephen?

*The momentum after the inelastic collision equals the momentum before the collision according to the conservation of momentum. 240 kg m/s.*

h. Use the conservation of momentum law to find the speed of John and Stephen together after collision. (Show your work).

*p (after) = m x v (after)*

*p (before) = p (after) v = p / m. 240 kg m/s / 122 kg = 2 m/s*



7. Bernie, whose mass is 70.0 kg, leaves a ski jump with a velocity of 21.0 m/s. What is Bernie’s momentum as he leaves the ski jump?

*p = m x v = 70.0 kg x 21.0 m/s = 1470 kg m/s*

8. Ethel is sitting on a park bench feeding the pigeons when a child’s ball rolls toward her across the grass. Ethel returns the ball to the child by hitting it with her 2.0 kg pocketbook with a speed of 20 m/s. If the impact lasts for 0.4s, with what force does Ethel hit the ball?

*Impulse is ft = ∆mv. f (0.4 s) = (2.0 kg)(20 m/s) = 100 N*

9. When Reggie stepped up to the plate and hit a 0.150 kg fast ball traveling at 36.0 m/s, the impact caused the ball to leave his bat with a velocity of 45.0 m/s in the opposite direction. If the impact lasted for 0.002 s, what force did Reggie exert on the baseball?

*mv (before) = (0.150 kg)(36.0 m/s) = 5.40 kg m/s*

*mv (after) = (0.150 kg)(45.0 m/s) = -6.75 kg m/s … opposite direction*

*Impulse is ft = ∆mv. f (0.002 s) = change in momentum (before – after)*

*f (0.002 s) = (5.40 kg m/s – (-6.7g kg m/s))*

*f (0.002 s) = (12.15 kg m/s) = 6075 N*

10. Astronaut Pam Melroy, history’s third woman space shuttle pilot, flew the space shuttle Discovery to the International Space Station to complete construction in October of 2000. To undock from the space station Pilot Melroy released hooks holding the two spacecraft together and the 68,000 kg shuttle pushed away from the space station with the aid of four large springs.

a. If the 73,000 kg space station moved back at a speed of 0.50 m/s, how fast and in what direction did the space shuttle move?

*mv (before) = mv (after) or m1v1 = m2v2 They moved in opposite directions.*

*(73,000 kg)(0.5 m/s) = (68,000 kg) V V = 0.54 m/s*

 b. What was the relative speed of the two spacecraft as they separated?

*Since the shuttle and the space station moved in opposite directions, the velocities must be added together for the relative speed. (0.50 m/s + 0.54 m/s) = 1.04 m/s*





Total relative speed = 1.04 m/s

0.50 m/s

0.54 m/s