Physics 12
Momentum Test Solutions

	a.	b.	c.	d.
1.	☐	☒ X		
2.	☒ X	☐		
3.	☐	☒ X		
4.	☒ X	☐		
5.	☒ X	☐	☐	☐
6.	☐	☐	☒ X	☐
7.	☒ X	☐	☐	☐
8.	☒ X	☐	☐	☐
9.	☒ X	☐	☐	☐
10.	☐	☐	☐	☒ X
11.	☐	☒ X	☐	☐
12.	☒ X	☐	☐	☐
13.	☐	☐	☐	☒ X
14.	☐	☐	☐	☒ X
15.	☐	☐	☒ X	☐
16.	☐	☐	☐	☒ X
17.	☐	☐	☒ X	☐
18.	☒ X	☐	☐	☐
19.	☐	☐	☒ X	☐
20.	☐	☐	☐	☒ X

1. **Problem**
   True or false? Kinetic energy is conserved in all collisions.

   a. True
   b. False

   Solution
   False. Kinetic energy is only conserved in elastic collisions.

2. **Problem**
   True or false? Momentum is conserved in both elastic and inelastic collisions.

   a. True
   b. False

   Solution
   True. Momentum is conserved in all collisions.

3. **Problem**
   True or false? Kinetic energy is conserved when two objects collide and stick together.

   a. True
   b. False

   Solution
   False. Kinetic energy is not conserved during an inelastic collision.

4. **Problem**
   True or false? Momentum is conserved when two objects collide and stick together.

   a. True
   b. False

   Solution
   True. Momentum is conserved in all collisions.

5. **Problem**
   In a game of pool, the white cue ball hits the #2 ball and stops, while the #2 ball moves away with the same velocity as the cue ball had originally. Both balls have the same mass. The type of collision is

   a. elastic
   b. inelastic
   c. completely inelastic
   d. any of the above, depending on the mass of the balls

   Solution
   The collision described conserves kinetic energy. Therefore, it is an elastic collision.

6. **Problem**
A very light object moving to the right collides with a very heavy object at rest. After the collision, the heavy object moves to the right with a small speed, and the light object moves to the left. Which object experienced the greater magnitude of impulse during the collision?

   a. The heavy object.
   b. The light object.
   c. Both objects experienced the same magnitude of impulse.
   d. Cannot be determined from the information given.

   Solution
   Both objects experienced the same force (Newton's Third Law of Motion) for the same amount of time. Therefore, they both experienced the same magnitude of impulse.

7. **Problem**
Two equal mass balls, one red and one blue, are dropped from the same height, and bounce off the floor. The red ball bounces higher than the blue ball. Which ball is subjected to the greater magnitude of impulse during its collision with the floor?

   a. The red ball.
   b. It depends on the elasticity of the collisions.
   c. Both balls were subjected to the same impulse.
   d. The blue ball.

   Solution
   Both balls hit the floor with the same speed, but the red one rebounds with a greater speed (since it goes higher). Therefore, the red ball had the greater change in momentum and must have experienced the greater impulse.

8. **Problem**
An object of mass m is moving with momentum p. Which of the following represents its kinetic energy?

   a. $p^2/(2m)$
   b. $mp^2/2$
   c. mp
   d. $mp/2$

   Solution
   Momentum is
   $$p = mv$$
   While kinetic energy is
   $$KE = \frac{1}{2}mv^2$$
   So in terms of momentum, kinetic energy is
   $$KE = \frac{p^2}{2m}$$

9. **Problem**
   Two balls of equal mass roll straight toward each other with the same speed v and collide head on. If the collision is completely inelastic, then the speed of the combined mass after the collision is

   a. 0
   b. $v/2$
   c. v
   d. $2v$

   Solution
   The total momentum before is zero and must remain zero after the collision.

10. **Problem**
    Two objects collide and stick together. Kinetic energy is

    a. definitely conserved.
    b. conserved only if the collision is elastic.
    c. conserved only if there is no friction.
    d. definitely not conserved.

    Solution
    Kinetic energy is conserved only if the collision is elastic. However, if the two objects stick together, then the collision is definitely inelastic. Therefore, kinetic energy is definitely not conserved.

11. **Problem**
    Two objects collide and stick together. Linear momentum is

    a. definitely not conserved.
    b. definitely conserved.
    c. conserved only if the collision is elastic.
    d. conserved only if there is no friction.

    Solution
    Linear momentum is conserved during any type of collision.

12. **Problem**
    A very light ball rolling with speed v collides with a very heavy ball at rest. If the collision is completely inelastic, then the speed of the combined mass after the collision is approximately

    a. 0
    b. $v/2$
    c. v
    d. $2v$

    Solution
    The very light ball will have very little effect on the very heavy ball and so the combined mass will hardly move. Using conservation of momentum, we can see that

    $$v' = \left(\frac{m_1}{m_1 + m_2}\right) v_1$$

    If $m_2 \gg m_1$, then $m_1/(m_1 + m_2) \approx 0$.

13. **Problem**
A ball of mass m rolls with speed v towards another ball of mass $(2/1)m$ at rest. If the collision is completely inelastic, what is the speed of the combined mass after the collision?

    a. $(2/1)v$
    b. $(1/2)v$
    c. $(2/3)v$
    d. $(1/3)v$

    Solution
    Conservation of momentum

$$mv = \left(m + \frac{2}{1}m\right)v'$$

Solve for v'

$$v' = \left(\frac{m}{m + (2/1)m}\right)v = \left(\frac{1}{2+1}\right)v$$

14. **Problem**
A ball of mass 99 g is dropped from a height of 4 m. Its momentum just before it strikes the ground is

    a. 880 kg m/s
    b. 400 kg m/s
    c. 870 kg m/s
    d. 0.88 kg m/s

    Solution
    The velocity of the ball just before hitting the ground can be calculated using conservation of mechanical energy

$$\frac{1}{2}mv^2 = mgh$$
$$v = \sqrt{2gh}$$

The momentum is the product of mass and velocity

$$p = mv = m\sqrt{2gh} = (0.099\,\mathrm{kg})\sqrt{2(9.8\,\mathrm{m/s^2})(4\,\mathrm{m})} = 0.88\,\mathrm{kg\,m/s}$$

15. **Problem**
A fire hose is turned on the door of a burning building in order to knock it down. This requires a force of 1052 N. If the hose delivers 33 kg / s, what is the velocity of water needed, assuming that the water doesn't bounce back?

    a. 40 m/s
    b. 17 m/s
    c. 32 m/s
    d. 56 m/s

    Solution
    The impulse is related to the momentum by

$$F\Delta t = m\Delta v$$

Since the water does not bounce back, $v_f = 0$ and $\Delta v = -v_i$, where v_i is the velocity of the water needed to knock down the door. Therefore,

$$v_i = F\left(\frac{\Delta t}{m}\right) = (1052\text{ N})/(33\text{ kg / s}) = 32\text{ m/s}$$

16. **Problem**
A machine gun, of mass 12 kg, fires bullets of mass 38 g, with a muzzle speed of 1130 m/s, at the rate of 978 rounds per minute. What is the average force exerted on the machine gun mount?

   a. 700000 N
   b. 576000 N
   c. 42000 N
   d. 700 N

Solution
The impulse is equal to the change in momentum

$$F\Delta t = m\Delta v$$

Solving for F

$$F = \frac{m\Delta v}{\Delta t} = (0.038\,\text{kg})(1130\,\text{m/s})(978\,\text{rpm})(1/(60\,\text{s/min})) = 700\,\text{N}$$

17. **Problem**
Object 1 and Object 2 have the same momentum. The ratio of Object 1's mass to Object 2's mass is $m_1/m_2 = 3/4$. What is the ratio of Object 1's kinetic energy to Object 2's kinetic energy, KE_1/KE_2?

   a. $16/9$
   b. $9/16$
   c. $4/3$
   d. $3/4$

Solution
Object 1 and 2 have the same momentum so $m_1v_1 = m_2v_2$ or

$$\frac{m_1}{m_2} = \frac{v_2}{v_1}$$

The ratio of their kinetic energy is

$$\frac{m_1v_1^2/2}{m_2v_2^2/2} = \frac{m_1}{m_2}\left(\frac{v_1}{v_2}\right)^2 = \frac{m_1}{m_2}\left(\frac{m_2}{m_1}\right)^2 = \frac{m_2}{m_1} = \frac{4}{3}$$

18. **Problem**
A bullet (16 g) is fired into the wooden block (8.00 kg) of a ballistic pendulum. As a result, the bullet is lodged into the block, and the centre of mass of the pendulum-projectile system swings up to a maximum height of 62 cm. What was the initial speed of the bullet?

    a. 1750 m/s
    b. 3390 m/s
    c. 2450 m/s
    d. 2800 m/s

    Solution
Conservation of momentum for the initial inelastic collision gives

$$mv_1 = (m+M)v'$$

The maximum pendulum swing height can be calculated using conservation of energy during the swing.

$$v' = \sqrt{2gh}$$

The speed of the bullet can be found by combining the two equations

$$v_1 = \frac{m+M}{m}\sqrt{2gh} = \frac{0.016+8}{0.016}\sqrt{2(9.8\,\mathrm{m/s^2})(0.62\,\mathrm{m})} = 1750\,\mathrm{m/s}$$

19. **Problem**
A car of mass 1353 kg, traveling with a velocity 71 km/h, strikes a parked truck of mass 4059 kg head-on. The bumpers lock together in this completely inelastic collision. What fraction of the initial kinetic energy is lost in the collision?

    a. $1/4$
    b. $1/9$
    c. $3/4$
    d. $1/3$

    Solution
Consevation of momentum for an inelastic collision in 1D with $v_2 = 0$

$$m_1v_1 = (m_1+m_2)v'$$

The fraction of kinetic energy lost is $\Delta KE/KE$

$$\Delta KE/KE = \frac{m_1v_1^2/2 - (m_1+m_2)v'^2/2}{m_1v_1^2/2} = \frac{m_2}{m_1+m_2} = \frac{m_2/m_1}{1+m_2/m_1}$$

When $m_2/m_1 = 3$, this simplifies to

$$\frac{3}{4}$$

20. **Problem**
A skater of mass 32 kg skates at speed 19 m/s towards another skater of mass 90 kg who is standing still with open arms. If the skaters hold on to each other after they collide, with what speed do they both move off together?

   a. 6.49 m/s
   b. 4.46 m/s
   c. 2.55 m/s
   d. 4.98 m/s

   Solution
   Conservation of momentum gives

$$v' = \left(\frac{m_1}{m_1 + m_2}\right) v_1 = \left(\frac{32}{32 + 90}\right) (19 \text{ m/s}) = 4.98 \text{ m/s}$$