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? Momentum is conserved when two objects collide and stick together.

   a. True
   b. False

   Solution
   True. Momentum is conserved in all collisions.

2. **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.

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 in both elastic and inelastic collisions.

   a. True
   b. False

   Solution
   True. Momentum is conserved in all collisions.

5. **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

$$KE = \frac{p^2}{2m}$$

6. **Problem**
   The area under a force-time graph represents
   a. work
   b. momentum
   c. kinetic energy
   d. impulse

   Solution
   The area under a force-time graph represents impulse.

7. **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.

8. **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.

9. **Problem**
   Two objects collide and stick together. Kinetic energy is
   a. conserved only if there is no friction.
   b. definitely not conserved.
   c. conserved only if the collision is elastic.
   d. definitely 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.

10. **Problem**
    Two objects collide and bounce apart. Linear momentum is

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

    Solution
    Linear momentum is conserved in all collisions.

11. **Problem**
    Two objects collide and bounce apart. Kinetic energy is

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

    Solution
    Kinetic energy is conserved only if the collision is elastic.

12. **Problem**
    A very heavy ball rolling with speed v collides with a very light 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 change. Using conservation of momentum, we can see that

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

    If $m_2 \ll m_1$, then $m_1/(m_1 + m_2) \approx 1$.

13. **Problem**
    A ball of mass m rolls with speed v towards another ball of mass $(2/3)m$ at rest. If the collision is completely inelastic, what is the speed of the combined mass after the collision?

    a. $(3/5)v$
    b. $(2/5)v$
    c. $(2/3)v$
    d. $(3/2)v$

    Solution
    Conservation of momentum

$$mv = \left(m + \frac{2}{3}m\right) v'$$

Solve for v'

$$v' = \left(\frac{m}{m + (2/3)m}\right) v = \left(\frac{3}{2+3}\right) v$$

14. **Problem**
A ball of mass 626 g, moving horizontally with speed 30 m/s strikes a wall and rebounds at 29 m/s. What is the magnitude of the change in momentum of the ball?

   a. 36.9 kg m/s
   b. 5.7 kg m/s
   c. 36 900 kg m/s
   d. 0.63 kg m/s

   Solution
   The change in momentum is

$$\Delta p = m\Delta v = 36.9\,\mathrm{kg\,m/s}$$

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 960 N. If the hose delivers 22 kg / s, what is the velocity of water needed, assuming that the water doesn't bounce back?

   a. 44 m/s
   b. 31 m/s
   c. 58 m/s
   d. 25 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,

$$v_i = F\left(\frac{\Delta t}{m}\right) = (960\text{ N})/(22\text{ kg / s}) = 44\text{ m/s}$$

16. **Problem**
A 116 g baseball is thrown towards a batter at 10 m/s. The batter hits the ball back along the same path, and at the same speed. If the bat was in contact with the ball for 1.5 ms, the average force exerted by the bat was

   a. 1550 N
   b. 1.55 N
   c. 773 N
   d. 1.16×10^6 N

Solution
The impulse is equal to the change in momentum

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

Solving for F

$$F = \frac{m\Delta v}{\Delta t} = \frac{(0.116\,\mathrm{kg})(10\,\mathrm{m/s} - -10\,\mathrm{m/s})}{0.0015\,\mathrm{s}} = 1550\,\mathrm{N}$$

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

   a. $2/3$
   b. $4/9$
   c. $3/2$
   d. $9/4$

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

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

18. **Problem**
A proton at rest is struck head-on by an alpha particle (which consists of 2 protons and 2 neutrons) moving at speed v. If the collision is completely elastic, what speed will the alpha particle have after the collision? Assume that the neutron's mass is equal to the proton's mass.

   a. $(5/3)v$
   b. $(3/5)v$
   c. $(1/4)v$
   d. $(1/5)v$

Solution
The general solution for an elastic collision in 1D is

$$v_1' = \frac{(m_1 - m_2)v_1 + 2m_2v_2}{m_1 + m_2}$$

When $m_1 = 4m_2$, $v_1 = v$, and $v_2 = 0$, this simplifies to

$$v_1' = (3/5)v$$

19. **Problem**
A skater of mass 93 kg skates at speed 2 m/s towards another skater of mass 44 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. 0.77 m/s
   b. 1.36 m/s
   c. 1.85 m/s
   d. 0.99 m/s

   Solution
   Conservation of momentum gives

$$v' = \left(\frac{m_1}{m_1 + m_2}\right) v_1 = \left(\frac{93}{93 + 44}\right) (2 \text{ m/s}) = 1.36 \text{ m/s}$$

20. **Problem**
A bullet (14 g) is fired into the wooden block (1.00 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 72 cm. What was the initial speed of the bullet?

   a. 456 m/s
   b. 239 m/s
   c. 140 m/s
   d. 272 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

$$v_1 = \frac{m + M}{m}\sqrt{2gh} = \frac{0.014 + 1}{0.014}\sqrt{2(9.8\,\mathrm{m/s^2})(0.72\,\mathrm{m})} = 272\,\mathrm{m/s}$$