Physics 12
Momentum Test Solutions

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

1. **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.

2. **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.

3. **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.

4. **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.

5. **Problem**
   The area under a force-time graph represents

   a. kinetic energy
   b. momentum
   c. work
   d. impulse

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

6. **Problem**
A small car collides with a large truck in a head-on collision. Which of the following statements concerning the magnitude of the average collision force is correct?

   a. The truck experiences the greater average force.
   b. The car experiences the greater average force.
   c. The car and the truck experience the same average force.
   d. Cannot be determined because the masses and velocities are not given.

   Solution
   Both objects experienced the same force (Newton's Third Law of Motion).

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

   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**
A very heavy ball rolling with speed v collides with a very light ball at rest. If the collision is elastic, then the light ball's speed after the collision is approximately

   a. $v/2$
   b. v
   c. $2v$
   d. $3v$

   Solution
   Conservation of momentum and kinetic energy with $v_2 = 0$ gives the velocity of the light ball after the collision

$$v_2{}' = \left(\frac{2m_1}{m_1 + m_2}\right) v_1$$

   When $m_1 \gg m_2$, the factor $2m_1/(m_1 + m_2)$ is approximately 2, which means that the light ball has about twice the velocity of the heavy ball.

10. **Problem**
A very light ball rolling with speed v collides with a very heavy ball at rest. If the collision is elastic, then the light ball's speed after the collision is approximately

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

   Solution
   Conservation of momentum and kinetic energy with $v_2 = 0$ gives the velocity of the light ball after the collision

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

   When $m_1 \ll m_2$, the factor $(m_1 - m_2)/(m_1 + m_2)$ is approximately -1, which means that the ball bounces back with the same velocity v.

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

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

   Solution
   Linear momentum is conserved in all collisions.

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

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

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

13. **Problem**
A ball of mass 48 g is dropped from a height of 5 m. Its momentum just before it strikes the ground is

a. 480 kg m/s
b. 0.48 kg m/s
c. 180 kg m/s
d. 390 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

$$p = mv = m\sqrt{2gh} = (0.048\,\text{kg})\sqrt{2(9.8\,\text{m/s}^2)(5\,\text{m})} = 0.48\,\text{kg m/s}$$

14. **Problem**
A fire hose is turned on the door of a burning building in order to knock it down. This requires a force of 1330 N. If the hose delivers 15 kg / s, what is the velocity of water needed, assuming that the water doesn't bounce back?

a. 74 m/s
b. 170 m/s
c. 110 m/s
d. 89 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,

$$v_i = F\left(\frac{\Delta t}{m}\right) = (1330\ \text{N})/(15\ \text{kg / s}) = 89\ \text{m/s}$$

15. **Problem**
A ball of mass m rolls with speed v towards another ball of mass $(1/17)m$ at rest. If the collision is completely inelastic, what is the speed of the combined mass after the collision?

a. $(17/18)v$
b. $(1/18)v$
c. $(17/1)v$
d. $(1/17)v$

Solution
Conservation of momentum

$$mv = \left(m + \frac{1}{17}m\right)v'$$

Solve for v'

$$v' = \left(\frac{m}{m + (1/17)m}\right)v = \left(\frac{17}{1+17}\right)v$$

16. **Problem**
A ball of mass 440 g, moving horizontally with speed 15 m/s strikes a wall and rebounds at 12 m/s. What is the magnitude of the change in momentum of the ball?

a. 11 900 kg m/s
b. 3.6 kg m/s
c. 9.98 kg m/s
d. 11.9 kg m/s

Solution
The change in momentum is

$$\Delta p = m\Delta v = 11.9\,\mathrm{kg\,m/s}$$

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

a. $1/2$
b. $1/4$
c. $2/1$
d. $4/1$

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

$$\frac{m_1v_1^2/2}{m_2v_2^2/2} = \frac{m_1}{m_2}\left(\frac{v_1}{v_2}\right)^2 = \frac{m_1}{m_2}\left(\frac{m_2}{m_1}\right)^2 = \frac{m_2}{m_1} = \frac{2}{1}$$

18. **Problem**
A skater of mass 82 kg skates at speed 2 m/s towards another skater of mass 43 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. 0.83 m/s
b. 1.17 m/s
c. 1.31 m/s
d. 1.01 m/s

Solution
Conservation of momentum gives

$$v' = \left(\frac{m_1}{m_1 + m_2}\right) v_1 = \left(\frac{82}{82 + 43}\right) (2 \text{ m/s}) = 1.31 \text{ m/s}$$

19. **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

$$v_1' = \frac{(m_1 - m_2)v_1 + 2m_2 v_2}{m_1 + m_2}$$

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

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

20. **Problem**
A bullet (17 g) is fired into the wooden block (7.00 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 61 cm. What was the initial speed of the bullet?

a. 1880 m/s
b. 2650 m/s
c. 1430 m/s
d. 850 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

$$v_1 = \frac{m+M}{m}\sqrt{2gh} = \frac{0.017+7}{0.017}\sqrt{2(9.8\,\mathrm{m/s^2})(0.61\,\mathrm{m})} = 1430\,\mathrm{m/s}$$