Physics 12
Momentum Test Solutions

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

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

   a. True
   b. False

   Solution
   True. Momentum is conserved in all 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. work
   b. momentum
   c. impulse
   d. kinetic energy

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

6. **Problem**
Consider two balls of equal mass moving at different speeds. Ball 1 has double the momentum of ball 2. How does the kinetic energy of ball 1, KE_1, compare to the kinetic energy of ball 2, KE_2?

   a. $KE_1 = KE_2$
   b. $KE_1 = \sqrt{2}KE_2$
   c. $KE_1 = 2KE_2$
   d. $KE_1 = 4KE_2$

   Solution
   Kinetic energy is proportional to momentum squared.

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

   So when momentum is doubled, the kinetic energy must quadruple.

$$KE_1 = 4KE_2$$

7. **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).

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. Linear momentum 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
   Linear momentum is conserved during any type of collision.

10. **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.

11. **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.

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

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

Solution
Linear momentum is conserved in all collisions.

13. **Problem**
A ball of mass 830 g, moving horizontally with speed 19 m/s strikes a wall and rebounds at 18 m/s. What is the magnitude of the change in momentum of the ball?

a. 13.9 kg m/s
b. 25.3 kg m/s
c. 30.7 kg m/s
d. 30 700 kg m/s

Solution
The change in momentum is

$$\Delta p = m\Delta v = 30.7\,\mathrm{kg\,m/s}$$

14. **Problem**
A machine gun, of mass 11 kg, fires bullets of mass 20 g, with a muzzle speed of 698 m/s, at the rate of 925 rounds per minute. What is the average force exerted on the machine gun mount?

a. 215 N
b. 130 N
c. 215000 N
d. 12900 N

Solution
The impulse is equal to the change in momentum

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

Solving for F

$$F = \frac{m\Delta v}{\Delta t} = (0.02\,\mathrm{kg})(698\,\mathrm{m/s})(925\,\mathrm{rpm})(1/(60\,\mathrm{s/min})) = 215\,\mathrm{N}$$

15. **Problem**
A ball of mass 11 g is dropped from a height of 6 m. Its momentum just before it strikes the ground is

a. 66 kg m/s
b. 0.09 kg m/s
c. 0.12 kg m/s
d. 0.07 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

$$p = mv = m\sqrt{2gh} = (0.011\,\text{kg})\sqrt{2(9.8\,\text{m/s}^2)(6\,\text{m})} = 0.12\,\text{kg m/s}$$

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

a. $(2/15)v$
b. $(2/13)v$
c. $(13/15)v$
d. $(13/2)v$

Solution
Conservation of momentum

$$mv = \left(m + \frac{2}{13}m\right)v'$$

Solve for v'

$$v' = \left(\frac{m}{m + (2/13)m}\right)v = \left(\frac{13}{2+13}\right)v$$

17. **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

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

18. **Problem**
Object 1 and Object 2 have the same momentum. The ratio of Object 1's mass to Object 2's mass is $m_1/m_2 = 4/9$. What is the ratio of Object 1's kinetic energy to Object 2's kinetic energy, KE_1/KE_2?

a. $4/9$
b. $81/16$
c. $9/4$
d. $16/81$

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

$$\frac{m_1v_1^2/2}{m_2v_2^2/2} = \frac{m_1}{m_2}\left(\frac{v_1}{v_2}\right)^2 = \frac{m_1}{m_2}\left(\frac{m_2}{m_1}\right)^2 = \frac{m_2}{m_1} = \frac{9}{4}$$

19. **Problem**
A bullet (70 g) is fired into the wooden block (9.00 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 65 cm. What was the initial speed of the bullet?

a. 600 m/s
b. 462 m/s
c. 651 m/s
d. 865 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

$$v_1 = \frac{m + M}{m}\sqrt{2gh} = \frac{0.07 + 9}{0.07}\sqrt{2(9.8\,\mathrm{m/s^2})(0.65\,\mathrm{m})} = 462\,\mathrm{m/s}$$

20. **Problem**
A car of mass 1310 kg, traveling with a velocity 35 km/h, strikes a parked truck of mass 11790 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. $1/81$
b. $1/9$
c. $1/10$
d. $9/10$

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

$$m_1 v_1 = (m_1 + m_2)v'$$

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

$$\Delta KE/KE = \frac{m_1 v_1^2/2 - (m_1 + m_2)v'^2/2}{m_1 v_1^2/2} = \frac{m_2}{m_1 + m_2} = \frac{m_2/m_1}{1 + m_2/m_1}$$

When $m_2/m_1 = 9$, this simplifies to

$$\frac{9}{10}$$