Topics

1. Impulse
2. Momentum
   a. Collisions
      i. Elastic
      ii. Inelastic
   b. Conservation of momentum
   c. Conservation of Kinetic Energy

Equations

\[ V = \frac{2pr}{T} \]
\[ F = ma \]
\[ W = F \cos \theta \]
\[ PE = mgh \]
\[ KE = \frac{1}{2} mv^2 \]
\[ E = PE + KE \]
\[ P = \frac{W}{t} \]
\[ P = Fv \]
\[ \Delta p = F \Delta t \]
\[ F = -kx \]
\[ PE = \frac{1}{2} kx^2 \]
\[ p = mv \]

Multiple Choice Questions

1. In the diagram below, a block of mass \( M \) initially at rest on a frictionless horizontal surface is struck by a bullet of mass \( m \) moving with horizontal velocity \( v \).

![Diagram of a block and a bullet] What is the velocity of the bullet-block system after the bullet embeds itself in the block?

\[ (1) \left( \frac{M + v}{M} \right)_m \]
\[ (2) \left( \frac{m + M}{m} \right)_v \]
\[ (3) \left( \frac{m + v}{M} \right)_m \]
\[ (4) \left( \frac{m}{m + M} \right)_v \]

2. A 3.0 kg steel block is at rest on a frictionless horizontal surface. A 1.0 kg lump of clay is propelled horizontally at 6.0 m/s toward the block as shown in the diagram below.

![Diagram of clay and steel block collision] Upon collision, the clay and steel block stick together and move to the right with a speed of

\[ (1) 1.5 \text{ m/s} \]
\[ (2) 2.0 \text{ /s} \]
\[ (3) 3.0 \text{ m/s} \]
\[ (4) 6.0 \text{ m/s} \]
3. Which two quantities can be expressed using the same units?
   (1) energy and force
   (2) impulse and force
   (3) momentum and energy
   (4) impulse and momentum

4. A 60 kg rollerskater exerts a 10 N force on a 30 kg rollerskater for 0.20 seconds. What is the magnitude of the impulse applied to the 30 kg rollerskater?
   (1) 50 Ns
   (2) 12 Ns
   (3) 2.0 Ns
   (4) 6.0 Ns

5. In which of the following systems are both momentum and kinetic energy conserved?
   (1) An elastic collision
   (2) A partially elastic collision
   (3) A totally inelastic collision

6. What is the kinetic energy and momentum, respectively, of a 2.0 kg ball that is skidding at 5.0 m/s on a frictionless surface?
   (1) 25. kg m/s and 10. kg m^2/s^2
   (2) 10. kg m^2/s^2 and 25. kg m/s
   (3) 25. kg m^2/s^2 and 10. kg m/s
   (4) 10. kg m/s and 25. kg m^2/s^2

7. Which object has the greatest momentum?
   (1) a 0.001 kg bumblebee traveling at 2 m/s
   (2) a 0.1 kg baseball traveling at 20 m/s
   (3) a 5 kg bowling ball traveling at 3 m/s
   (4) a 10. kg sled at rest

8. What is the speed of a 1.0 x 10^3 kg car that has a momentum of 2.0 x 10^4 kg m/s east?
   (1) 5.0 x 10^-2 m/s
   (2) 2.0 x 10^1 m/s
   (3) 1.0 x 10^4 m/s
   (4) 2.0 x 10^7 m/s

9. If the speed of a car is doubled, the kinetic energy of the car is
   (1) doubled
   (2) halfed
   (3) quadrupled
   (4) quartered

10. For a constant impulse, there is a _______ relationship between force and the time the force is applied.
    (1) direct
    (2) inverse
    (3) concave
    (4) convex
Short Answer Questions  (Show all work)

11. (10 pts) Briefly explain how a spacecraft can use the law of conservation of momentum to change directions by firing its rockets in outer space?

12. (10 pts) Give an example of a situation where a collision can conserve momentum but not kinetic energy? Does this example violate the Law of conservation of energy? Explain your response.
Problems with calculations – show all appropriate work and circle your final answer

13. (10 pts) A 9500 kg boxcar traveling at 16 m/s strikes a second car at rest. The two stick together and move off with a speed of 6.0 m/s. What is the mass of the second car?

14. (10 pts) A golf ball of mass 0.045 kg is hit off the tee at a speed of 45 m/s. The golf club was in contact with the ball for \(5.0 \times 10^{-3}\) s.

(a) Find the impulse imparted to the golf ball.

(b) Find the average force exerted on the ball by the golf club.
15. (15 pts) A 0.50 kg pool ball with an initial velocity of 3.0 m/s strikes a second 1.0 kg pool ball, with an initial velocity of -2.0 m/s. If the collision is head-on and completely elastic, what are the final velocities of both pool balls after collision, assuming a frictionless surface?

16. (10 pts) Calculate the recoil velocity of a 6.0 kg rifle that shoots a 50. g bullet at a speed of 120 m/s?

17. (10 pts) An eagle (m₁ = 4.3 kg) moving with a speed of 7.8 m/s is on a collision course with a second eagle (m₂ = 5.6 kg) moving with a speed of 10.2 m/s in the opposite direction. After the collision the two eagles hold onto one another. In what direction and with what speed are they moving after the collision? Draw a picture to support your answer.
Answers

1. 4
2. 1
3. 4
4. 3
5. 1
6. 3
7. 3
8. 2
9. 3
10. 2

11. Fire the rocket perpendicular to the direction the rocket is going. Initially the momentum of the rocket perpendicular (y) to its initial direction (x) is zero. As the gases are expelled in one direction, the rocket must change direction with a component opposite to the direction of the gases and of equal but opposite magnitude to the momentum of the gases coming out of the rocket.

12. Elastic collisions conserve both momentum and kinetic energy. Two billiards balls colliding is a great example. In a frictionless system the kinetic energy is conserved. In the real world situation kinetic energy is lost to friction and other forms of energy such as sound.

13. \((9500 \, \text{kg})(16 \, \text{m/s}) = (9500 + x \, \text{kg})(6.0 \, \text{m/s})\)
   a. \(x = 16000 \, \text{kg}\)

14. 
   a. \(\Delta p = (0.045 \, \text{kg})(45 \, \text{m/s}) - 0 = 2.0 \, \text{kg m/s}\)
   b. \(\Delta p = F\Delta t, 2.0 \, \text{kg m/s} = F(0.0050 \, \text{s}), F = 405 \, \text{kg m/s}^2\)

15. After solving the simultaneous equations for conservation of momentum and kinetic energy, you get two possible solutions from the quadratic equation specifically \(x = +3.0\) or \(-3.7 \, \text{m/s}\). Interestingly enough the +3.0 m/s solution is the same velocity that the 0.5 kg pool ball had before collision and is not a reasonable answer. Therefore, the answer must be -3.7 m/s. Plug this result back into one of the equations and solve for the velocity of the second pool ball.

   The answer for after the collision is that the 0.5 kg pool ball will have a velocity of -3.7 m/s and the 1.0 kg pool ball will have a +1.3 m/s velocity.

16. 1.0 m/s
17. -2.4 m/s