4. In Fig. 9-37, three uniform thin rods, each of length $L = 24 \text{ cm}$, form an inverted U. The vertical rods each have a mass of 14 g; the horizontal rod has a mass of 42 g. What are (a) the x coordinate and (b) the y coordinate of the system’s center of mass?

![Fig. 9-37 Problem 4](image1)

5. What are (a) the x coordinate and (b) the y coordinate of the center of mass for the uniform plate shown in Fig. 9-38 if $L = 5.0 \text{ cm}$.

![Fig. 9-38 Problem 5](image2)

13. A shell is shot with an initial velocity $\vec{v}_0$ of 20 m/s, at an angle of $\theta_0 = 60^\circ$ with the horizontal. At the top of the trajectory, the shell explodes into two fragments of equal mass (Fig. 9-42). One fragment, whose speed immediately after the explosion is zero, falls vertically. How far from the gun does the other fragment land, assuming that the terrain is level and that air drag is negligible?
17. In Fig. 9-45a, a 4.5 kg dog stands on an 18 kg flatboat at distance \( D = 6.1 \) m from the shore. It walks 2.4 m along the boat toward shore and then stops. Assume no friction between the boat and the water, find how far the dog is then from the shore. \((\text{Hint: See Fig. 9-45b.})\)

27. A force in the negative direction of an \( x \) axis is applied for 27 ms to a 0.40 kg ball initially moving at 24 m/s in the positive direction of the axis. The force varies in magnitude, and the impulse has magnitude 32.4 N \( \cdot \) s. What are the ball’s (a) speed and (b) direction of travel just after the force is applied? What are (c) the average magnitude of the force and (d) the direction of the impulse on the ball?

37. A soccer player kicks a soccer ball of mass 0.45 kg that is initially at rest. The foot of the player is in contact with the ball for 3.0 \( \times \) 10\(^{-3}\) s, and the force of the kick is given by \( F(t) = [(6.0 \times 10^5)t - (2.0 \times 10^9)t^2] \) N for \( 0 \leq t \leq 3.0 \times 10^{-3} \) s, where \( t \) is in seconds. Find the magnitudes of (a) the impulse on the ball due to the kick, (b) the average force on the ball from the player’s foot during the period of contact, (c) the maximum force on the ball from the player’s foot during the period of contact, and (d) the ball’s velocity immediately after it loses contact with the player’s foot.

45. A 20.0 kg body is moving through space in the positive direction of \( x \) axis with a speed of 100 m/s when, due to an internal explosion, it breaks into three parts. One part, with a mass of 10.0 kg, moves away from the point of explosion with a speed of 100 m/s, in the positive \( y \) direction. A second part, with a mass of 4.00 kg, moves in negative \( x \) direction, with a speed of 500 m/s. (a) In unit-vector notation, what is the velocity of the third part? (b) How much energy is released in the explosion? Ignore effects due to the gravitational force.

50. A 5.20 g bullet moving at 700 m/s strikes a 700 g wooden block at rest on a frictionless surface. The bullet emerges, traveling in the same direction with its speed reduced to 450 m/s. (a) What is the resulting speed of the block? (b) What is the speed of the bullet-block center of mass?

51. In Fig. 9-58a, a 3.50 g bullet is fired horizontally at two blocks at rest on a frictionless table. The bullet passes through block 1 (mass 1.20 kg) and embeds itself in block 2 (mass 1.80 kg). The blocks end up with speeds \( v_1 = 0.630 \) m/s and \( v_2 = 1.40 \) m/s (Fig. 9-58b). Neglecting the material removed from block 1 by the bullet, find the speed of the bullet as it (a) leaves and (b) enters block 1.

---

**Fig. 9-58  Problem 51**
58. In Fig. 9-62, block 2 (mass 1.0 kg) is at rest on a frictionless surface and touching the end of an unstretched spring of spring constant 230 N/m. The other end of the spring is fixed to a wall. Block 1 (mass 2.0 kg), traveling at speed $v_1 = 4.0 \text{ m/s}$, collides with block 2, and the two blocks stick together. When the blocks momentarily stop, by what distance is the spring compressed?

![Fig. 9-62 Problem 58](image1.png)

59. In Fig. 9-63, Block 2 (mass 5.0 kg) is moving rightward at 10 m/s and block 2 (mass 5.0 kg) is moving rightward at 3.0 m/s. The surface is frictionless, and a spring with a spring constant of 1120 N/m is fixed to block 2. When the blocks collide, the compression of the spring is maximum at the instant the blocks have the same velocity. Find the maximum compression.

![Fig. 9-63 Problem 59](image2.png)

64. A steel ball of mass 0.600 kg is fastened to a cord that is 70.0 cm long and fixed at the far end. The ball is then released when the cord is horizontal (Fig. 9-65). At the bottom of its path, the ball strikes a 2.80 kg steel block initially at rest on a frictionless surface. The collision is elastic. Find (a) the speed of the ball and (b) the speed of the block, both just after collision.

![Fig. 9-65 Problem 64](image3.png)

65. A body of mass 2.0 kg makes an elastic collision with another body at rest and continues to move in the original direction but with one-fourth of its original speed. (a) What is the mass of the other body? (b) What is the speed of the two-body center of mass if the initial speed of the 2.0 kg body was 4.0 m/s?

68. In Fig. 9-67, block 1 of mass $m_1$ slides from rest along a frictionless ramp from height $h = 3.00 \text{ m}$ and then collides with stationary block 2, which has mass $m_2 = 2.00 m_1$. After collision, block 2 slides into a region where the coefficient of kinetic friction $\mu_k$ is 0.450 and comes to a stop in distance $d$ within that region. What is the value of distance $d$ if the collision is (a) elastic and (b) completely inelastic?

![Fig. 9-67 Problem 68](image4.png)
70. In Fig. 9-69, puck 1 of mass \( m_1 = 0.25 \text{ kg} \) is sent sliding across a frictionless lab bench, to undergo a one-dimension elastic collision with stationary puck 2. Puck 2 then slides off the bench and lands a distance \( d \) from the base of the bench. Puck 1 rebounds from the collision and slides off the opposite edge of the bench, landing a distance \( 2d \) from the base of the bench. What is the mass of puck 2? (Hint: Be careful with signs)

![Fig. 90-69 Problem 70](image)

72. Ball \( B \), moving in the positive direction of an \( x \) axis at speed \( v \), collides with stationary ball \( A \) at the origin. \( A \) and \( B \) have different masses. After the collision, \( B \) moves in the negative direction of the \( y \) axis at speed \( v/2 \). (a) In what direction does \( A \) move? (b) Show that the speed of \( A \) cannot be determined from the given information.

73. After a completely inelastic collision, two objects of the same mass and same initial speed move away together at half their initial speed. Find the angle between the initial velocities of the objects.

74. Two 2.0 kg bodies, \( A \) and \( B \), collide. The velocities before the collision are \( \vec{v}_A = (15\hat{i} + 30\hat{j}) \text{ m/s} \) and \( \vec{v}_B = (-10\hat{i} + 5.0\hat{j}) \text{ m/s} \). After the collision, \( \vec{v}_A = (-5.0\hat{i} + 20\hat{j}) \text{ m/s} \). What are (a) the final velocity of \( B \) and (b) the change in the total kinetic energy (including sign)?

75. A projectile proton with a speed of 500 m/s collides elastically with a target proton initially at rest. The two protons then move along perpendicular paths, with the projectile path of \( 60^\circ \) from the original direction. After the collision, what are the speeds of (a) the target proton and (b) the projectile proton?

78. Consider a racket that is in deep space and at rest relative to an inertial reference frame. What must be the rocket’s engine is to be fired for a certain interval. What must be the rocket’s mass ratio (ratio of initial to final mass) over that interval if the rocket’s original speed relative to the inertial frame is to be equal to (a) the exhaust speed (speed of the exhaust products relative to the rocket) and (b) 2.0 times the exhaust speed?

79. A rocket that is in deep space and initially at rest relative to an inertial reference frame has a mass of \( 2.55 \times 10^5 \text{ kg} \), of which \( 1.81 \times 10^5 \text{ kg} \) is fuel. The rocket engine is then fired for 250 s while fuel is consumed at the rate of 480 kg/s. The speed of the exhaust products relative to the rocket is 3.27 km/s. (a) What is the rocket’s thrust? After the 250 s firing, what are (b) the mass and (c) the speed of the rocket?
93. A railroad freight car of mass $3.18 \times 10^4 \text{ kg}$ collides with a stationary caboose car. They couple together, and 27.0% of the initial kinetic energy is transferred to thermal energy, sound, vibrations, and so on. Find the mass of the caboose.

95. In the arrangement of Fig.9-21, billiard ball 1 moving at a speed of $2.2 \text{ m/s}$ undergoes a glancing collision with identical billiard ball 2 that is at rest. After the collision, ball 2 moves at speed $1.1 \text{ m/s}$, at an angle of $\theta = 60^\circ$. What are (a) the magnitude and (b) the direction of the velocity of ball 1 after the collision? (c) Do the given data suggest the collision is elastic or inelastic?

101. In Fig. 9-78, a 3.2 kg box of running shoes slides on a horizontal frictionless table and collides with a 2.0 kg box of ballet slippers initially at rest on the edge of the table, at height $h = 0.40 \text{ m}$. The speed of the 3.2 kg box is 3.0 m/s just before the collision. If the two boxes stick together because of packing tape on their sides, what is their kinetic energy just before they strike the floor?

103. In Fig. 9-80, block 1 of mass $m_1 = 6.6 \text{ kg}$ is rest on a long frictionless table that is up against a wall. Block 2 of mass $m_2$ is placed between block 1 and the wall and sent sliding to the left, toward block 1, with constant speed $v_{2i}$. Find the value of $m_2$ for which both blocks move with the same velocity after block 2 has collided once with block 2 and once with the wall. Assume all collisions are elastic (the collision with the wall does not change speed block 2).
4) (a) 12 cm (b) – 4.8 cm
5) (a) – 0.45 cm (b) – 2.0 cm
13) 53.1 m
17) 4.2 m

27) (a) 57 m/s (b) –x direction (c) \( F_{avg} = 1.20 \times 10^3 \text{ N} \) (d) –x direction

37) (a) 9.0 N\cdot s (b) 3.0 \times 10^3 \text{ N} (c) 4.5 \times 10^3 \text{ N} (d) 20 m/s

45) (a) \( \vec{v}_j = (6.67 \times 10^2 \text{ m/s})\hat{i} - (1.67 \times 10^2 \text{ m/s})\hat{j} \) (b) 1.87 \times 10^6 \text{ J}

50) (a) 1.86 m/s (b) 5.16 m/s
51) (a) 721 m/s (b) 937 m/s
58) 0.31 m
59) 0.33 m
64) (a) 2.39 m/s (b) 1.30 m/s
65) (a) 1.2 kg (b) 2.5 m/s
68) (a) 2.96 m (b) 0.741 m
70) 1.3 kg
72) (a) \( \phi = 27^\circ \)
73) 120°

74) (a) \( 10\hat{i} + 15\hat{j} \text{ m/s} \) (b) \( \Delta K = -5.0 \times 10^2 \text{ J} \)

75) (a) 433 m/s (b) 250 m/s
78) (a) \( e^1 \) (b) \( e^2 \)
79) (a) 1.57 \times 10^6 \text{ N} (b) 1.35 \times 10^5 \text{ kg} (c) 2.08 \times 10^3 \text{ m/s}
93) 1.18 \times 10^4 \text{ kg}

95) (a) 1.9 m/s (b) \( \theta_1 = 30^\circ \), measured clockwise from the +x-axis
101) 29 J
103) 2.2 kg