Momentum Problems

Momentum of a Single Object

1 What is the momentum of a 3000 kg truck traveling at 25 m/s?

2 A 1500 kg ferryboat has a momentum of 25000 kg·m/s. What is the speed of the ferryboat?

3 A car travels at a constant speed of 24 m/s and has a momentum of 28800 kg·m/s. What is the mass of the car?

4 An 8 kg bowling ball rolls at a constant speed of 3 m/s. What is the momentum of the ball?

5 A bicyclist travels at a constant speed of 7 m/s. What is the total mass of the bicycle and the boy, when the total momentum is 490 kg·m/s?

6 When a 45 kg cannon ball leaves a barrel it has a momentum of 14000 kg·m/s. What is the speed of the ball at the end of the barrel?

7 A 45 kg woman runs at a speed of 5.6 m/s. What is her momentum?

8 A certain bowling ball rolls at a constant speed of 5 m/s. If the momentum of the ball is 42.5 kg·m/s, what is its mass?

9 What is the speed of a 0.25 kg arrow with a momentum of 8 kg·m/s?

10 A 1500 kg car travels 400 m in 12 s. What is its momentum?

11 An electron has a mass of 9.1×10^{-31} kg. What is its momentum if it is travelling at a speed of 3.5×10^{6} m/s?

12 A 3 kg stone is dropped from a height of 4 m. What is its momentum as it strikes the ground?

Change of Momentum and Impulse

13 *A 1200 kg car accelerates from 13 m/s to 17 m/s. Find the change in momentum of the car.

14 *A small object with a momentum of 6 kg·m/s to the west approaches head-on a large object at rest. The small object bounces straight back with a momentum of 5 kg·m/s. What is the change in the momentum of the small object? What is the impulse exerted on the small ball? What is the impulse exerted on the large object?

15 *A 0.03 kg golf ball is hit off the tee at a speed of 34 m/s. The golf club was in contact with the ball for 0.003 s. What is the average force on ball by the golf club?

16 *A toy rocket achieves a velocity of 55 m/s after 3 s, when fired straight up. If the average force exerted by the engine is 28 N, what is the toy's mass?

17 *A 15000 kg air jet accelerates from rest to 45 m/s before it takes off. What is the change in momentum of the jet?

18 *A 0.025 kg piece of clay is thrown into a wall and has a speed of 9 m/s before it strikes the wall. Find the change in momentum of the clay and the impulse exerted on the clay if it does not bounce from the wall.

19 *A small bouncy ball with a momentum of 8 kg·m/s to the left approaches head-on a large door at rest. The ball bounces straight back with a momentum of 6 kg·m/s. What is the change in the momentum of the ball? What is the impulse exerted on the ball? What is the impulse exerted on the door?

20 *A 0.07 kg tennis ball leaves a racket with a speed of 56 m/s. If the ball is in contact with the racket for 0.04 s, what is the average force on the ball by the racket?

21 *A 0.145 kg baseball reaches a speed of 36 m/s when a bat strikes. If the average force of 500 N was applied on the ball by the bat, what is the impact time?

22 *A 0.17 kg hockey puck slows down from 54 m/s to 35 m/s when it slides on horizontal ice surface. Find the change in momentum of the puck?

23 *A 0.01 kg bullet is fired at 250 m/s into a wooden block that is fixed. The bullet emerges from the block with a speed of 120 m/s. What is the change in momentum of the bullet?

24 *A 0.05 kg tennis ball moves at a speed of 10 m/s and is struck by a racket causing it to rebound in the opposite direction at a speed 16 m/s. What is the change in momentum of the ball? What is the impulse exerted on the ball? What is the impulse exerted on the racket?

25 *A 0.25 kg beach ball rolling at a speed of 7 m/s collides with a heavy exercise ball at rest. The beach ball bounces straight back with a speed of 4 m/s. That is the change in momentum of the beach ball? What is the impulse exerted on the beach ball? What is the impulse exerted on the exercise ball?

26 *A 0.16 kg hockey puck is moving on an icy horizontal surface with a speed of 5 m/s. A player strikes the puck by a hockey stick, after the impact the puck moves in opposite direction with a speed of 9 m/s. If the puck was in contact with the stick for 0.005 s, what is the average force on the puck by the stick?

27 *A constant force of 12 N acts for 5 s on a 5 kg object. What is the change in object's velocity?

28 *A small object with a mass of 1 kg moves in a circular path with a constant speed of 5 m/s. What is the change in momentum during ½ of period; one period?

Momentum of a System of Objects

29 Determine the momentum of a system that consists of two objects. One object, m_1, has a mass of 6 kg and a velocity of 13 m/s towards the east and a second object, m_2, has a mass of 14 kg and a velocity of 7 m/s in that same direction.

30 Determine the momentum of a system that consists of two objects. One object, m_1, has a mass of 6 kg and a velocity of 13 m/s in the direction of the positive x-axis and a second object, m_2, has a mass of 14 kg and a velocity 7 m/s in the direction of the negative x-axis.

31 Determine the momentum of a system that consists of three objects. One object, m_1, has a mass of 7 kg and a velocity 23 m/s towards the north, a second object, m_2, has a mass of 9 kg and a velocity 7 m/s towards the north and the third object, m_3 has a mass of 5 kg and a velocity of 42 m/s towards the south.

32 Determine the momentum of a system of the two objects. One object, m_1, has a mass of 35 kg and a velocity of 3.7 m/s towards the east and the second object, m_2, has a mass of 57 kg and a velocity of 4.3 m/s towards the west.

33 Determine the momentum of a system of the two objects. One object, m_1, has a mass of 35 kg and a velocity of 3.7 m/s towards the north and the second object, m_2, has a mass of 57 kg and a velocity of 4.3 m/s towards the south.

34 Determine the momentum of a system that consists of three objects. One object, m_1, has a mass of 12 kg and a velocity 120 m/s towards the east, a second object, m_2, has a mass of 25 kg and a velocity 18 m/s towards the west and the third object, m_3 has a mass of 1 kg and a velocity of 350 m/s towards the east.

Conservation of Momentum, Perfectly Inelastic Collisions and Explosions

35 *A 13,500 kg railroad freight car travels on a level track at a speed of 4.5 m/s. It collides and couples with a 25,000 kg second car, initially at rest and with brakes released. What is the speed of the two cars after collision?

36 *A 40 kg girl skates at 3.5 m/s on ice toward her 65 kg friend who is standing still, with open arms. As they collide and hold each other, what is the speed of the couple?

37 *A 50 kg boy jumps off the front of a 1.5 kg skateboard moving forward. Find the skateboard's velocity immediately after the boy jumps, assuming that the skateboard's initial velocity is 3.5 m/s and the boy's velocity when jumping off the front is 5 m/s.

38 *A 0.01 kg bullet has a speed of 700 m/s before it strikes a 0.95 kg wooden block that is stationary on a horizontal frictionless surface and remains inside of it. What is the speed of the block after the bullet becomes embedded in it?

39 *A cannon ball with a mass of 100 kg flies in horizontal direction with a speed of 600 m/s and strikes a railroad freight car filled with sand and initially at rest. The total mass of the car and sand is 25,600 kg. Find the speed of the car after the ball becomes embedded it the sand.

40 *A 0.01 kg bullet is fired at a 0.5 kg block initially at rest. The bullet, moving with an initial speed of 400 m/s, emerges from the block with a speed of 300 m/s. What is the speed of the block after the collision?

41 *A 50 kg boy jumps off the back of a 1.5 kg skateboard moving forward. Find the skateboard's velocity immediately after the boy jumps, assuming that the skateboard's initial velocity is 3.5 m/s and the boy's velocity when jumping off the back is 5 m/s.

42 *Two football players with mass 85 kg and 110 kg run directly toward each other with speeds 4 m/s and 7 m/s respectively. If they grab each other as they collide, what is the combined speed of the players just after the collision?

43 *An air track car with a mass of 0.55 kg and velocity of 5.8 m/s to the right collides and couples with a 0.45 kg car moving to the left with a velocity of 3.9 m/s. What is the combined velocity of the cars just after the collision?

44 *An air track car with a mass of 0.25 kg and velocity of 3.4 m/s to the right collides and couples with a 0.45 kg car moving to the left with a velocity of 3.9 m/s. What is the combined velocity of the cars just after the collision?

45 *A 15000 kg railroad car travels on a horizontal track with a constant speed of 12 m/s. A 6000 kg load is dropped onto the car. What will be the car's speed?

46 *A 55 kg skater at rest on a frictionless rink throws a 3 kg ball, giving the ball a velocity of 8 m/s. What is the velocity of the skater immediately after?

47 *A 0.015 kg bullet is fired at a 1.5 kg block initially at rest. The bullet, moving with an initial speed of 500 m/s, emerges from the block with a speed of 400 m/s. What is the speed of the block after the collision?

48 *A 40 kg surfer jumps off the front of a 20 kg surfboard moving forward. Find the surfboard's velocity immediately after the girl jumps, assuming that the surfboard's initial velocity is 8 m/s and the girl's velocity when jumping off the front is 3 m/s.

49 *A 40 kg surfer jumps off the back of a 20 kg surfboard moving forward. Find the surfboard's velocity immediately after the girl jumps, assuming that the surfboard's initial velocity is 8 m/s and the girl's velocity when jumping off the back is 3 m/s.

Elastic Collisions (No Masses Given)

50 *Two objects have an elastic collision. Before the collision they approach one another with a velocity of 45 m/s. With what velocity will they be separating after the collision?

51 *Two objects, m_1 and m_2, have an elastic collision. The initial velocity of m_1 is +8.0 m/s and of m_2 is -4.0 m/s. After the collision, the velocity of m_1 is +5.0m/s. What is the velocity of m_2?

52 *Two objects, m_1 and m_2, have an elastic collision. The initial velocity of m_1 is -12.0 m/s and of m_2 is + 8.0 m/s. After the collision, the velocity of m_1 is + 9.0m/s. What is the velocity of m_2?

53 *Two objects with identical masses, m_1 and m_2, have an elastic collision. The initial velocity of m_1 is +20 m/s and of m_2 is +9.0 m/s. After the collision, what will be the velocity of m_1?

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55 *Two objects have an elastic collision. The mass of m_1 is much greater than that of m_2, so that the velocity of m_1 is barely affected by the collision. The initial velocity of m_1 is +10 m/s and m_2 is initially at rest. After the collision, what will be the velocity of m_2?

56 *Two objects have an elastic collision. The mass of m_1 is much greater than that of m_2, so that the velocity of m_1 is barely affected by the collision. The initial velocity of m_2 is +10 m/s and m_1 is initially at rest. After the collision, what will be the velocity of m_2?

57 *A bat has a nearly elastic collision with a baseball. The velocity of the bat is barely affected by the collision. The initial velocity of the bat is 10 mph and that of the baseball is 30 mph. What is the speed of the ball leaving the bat?

58 *Two objects have an elastic collision. Before the collision they approach one another with a velocity of 18 m/s. With what velocity will they be separating after the collision?

59 *Two objects, m_1 and m_2, have an elastic collision. The initial velocity of m_1 is +6.0 m/s and of m_2 is +4.0 m/s. After the collision, the velocity of m_1 is +5.0m/s. What is the velocity of m_2?

60 *Two objects, m_1 and m_2, have an elastic collision. The initial velocity of m_1 is -5.0 m/s and of m_2 is +8.0 m/s. After the collision, the velocity of m_1 is +7.0m/s. What is the velocity of m_2?

61 *Two objects with identical masses, m_1 and m_2, have an elastic collision. The initial velocity of m_1 is -9.0 m/s and of m_2 is -3.0 m/s. After the collision, what will be the velocity of m_1?

62 *Two objects with identical masses, m_1 and m_2, have an elastic collision. The initial velocity of m_1 is -9.0 m/s and of m_2 is -3.0 m/s. After the collision, what will be the velocity of m_2?

63 *Two objects have an elastic collision. The mass of m_1 is much greater than that of m_2, so that the velocity of m_1 is barely affected by the collision. The initial velocity of m_1 is +20 m/s and m_2 is initially at rest. After the collision, what will be the velocity of m_2?

64 *Two objects have an elastic collision. The mass of m_1 is much greater than that of m_2, so that the velocity of m_1 is barely affected by the collision. The initial velocity of m_2 is +20 m/s and m_1 is initially at rest. After the collision, what will be the velocity of m_2?

65 *A bat has a nearly elastic collision with a baseball. The velocity of the bat is barely affected by the collision. The initial velocity of the bat is 25 mph and that of the baseball is 80 mph. What is the speed of the ball leaving the bat?

Elastic Collisions (Masses Given)

66 *A ball of mass 0.34 kg moving with a speed of 2.7 m/s to the right collides head on with a 0.24 kg ball at rest. If the collision is elastic, what is the speed and direction of each ball after the collision?

67 *An ice puck of mass 0.54 kg moving with a speed of 5m/s to the right collides with a 0.28 kg piece of ice moving with a speed of 4.2 m/s to the right. If the collision is elastic, what is the speed and direction of each ball after the collision?

68 *An air track car with a mass of 0.75 kg and velocity of 8.5 m/s to the right collides elastically with a 0.65 kg car moving to the left with a velocity of 7.2 m/s. If the collision is elastic, what is the speed and direction of each ball after the collision?

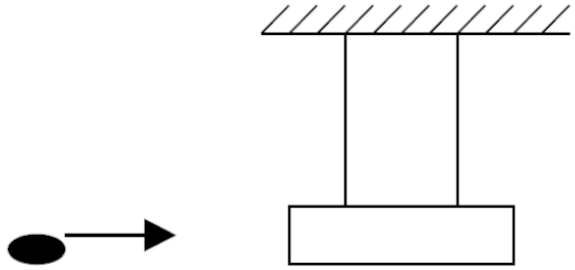
69 *An air track car with a mass of 0.85 kg and velocity of 3.4 m/s to the right collides elastically with a 0.95 kg car moving to the left with a velocity of 4.9 m/s. If the collision is elastic, what is the speed and direction of each ball after the collision?

70 *A ball of mass 6.5 kg moving with a speed of 15 m/s to the right collides head-on with a 3.5 kg ball which is at rest. If the collision is elastic, what is the speed and direction of each ball after the collision?

71 *An ice puck of mass 7.5 kg moving with a speed of 18 m/s to the right collides with a 2.5 kg piece of ice moving with a speed of 4.2 m/s to the right. If the collision is elastic, what is the speed and direction of each mass after the collision?

General Problems

72. The diagram above shows a ballistic pendulum. A 10 g bullet is fired into the suspended 2 kg block of wood and remains embedded inside it (a perfectly inelastic collision). After the impact of the bullet, the block swings up to a maximum height h. If the initial speed of the bullet was 35 m/s:



a. What was the momentum of the bullet before the collision?

b. What was the kinetic energy of the bullet before the collision?

c. *What was the velocity of the bullet-block system just after the collision?

d. *What was the total kinetic energy of the bullet-block system after the collision?

e. *What is the maximum possible potential energy of the bullet-block system when it reaches its maximum height?

f. *What is the maximum possible height of the bullet-block system?

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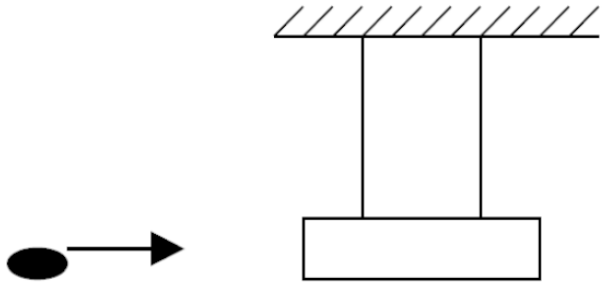

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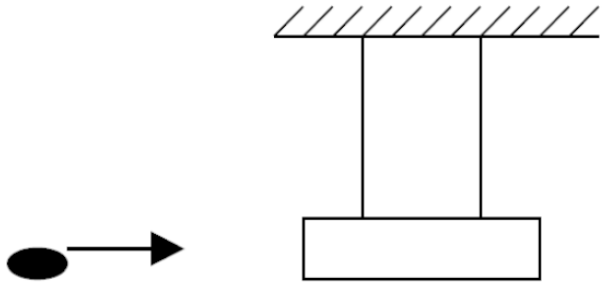

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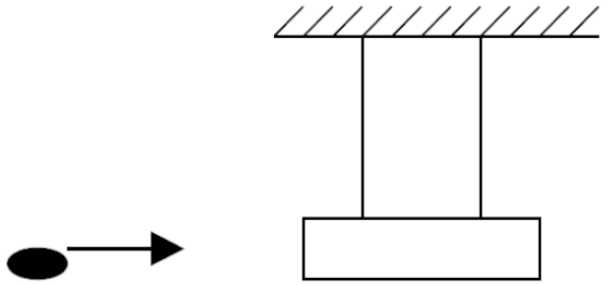

c. *What was the velocity of the bullet-block system just after the collision?

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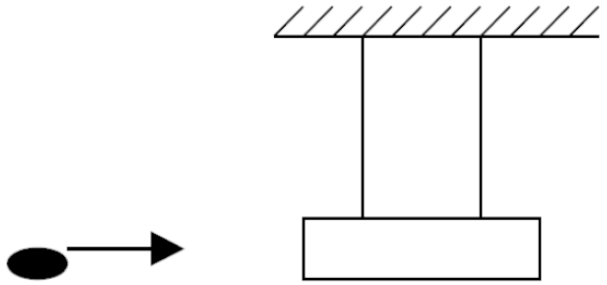

d. *What was the total kinetic energy of the bullet-block system after the collision?

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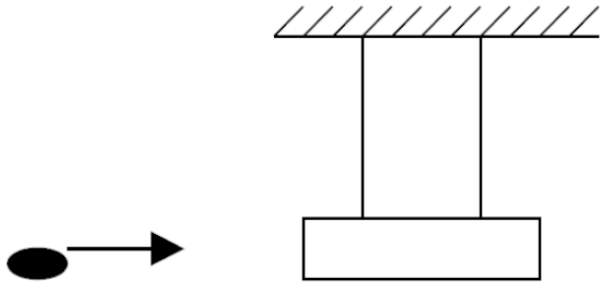

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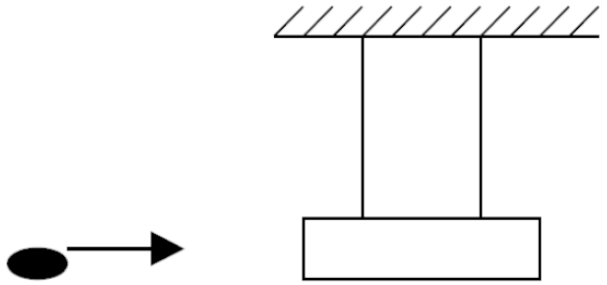

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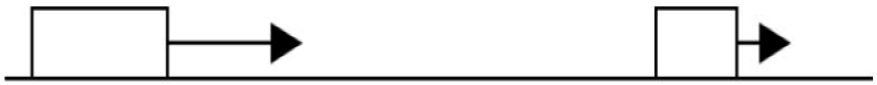


73. Two objects, A and B, with masses of 3.2 kg and 1.8 kg, move on a frictionless horizontal surface. Object A moves to the right at a constant speed of 5.1 m/s while object B moves to the right at a constant speed 1.4 m/s. They collide and stick together (a perfectly inelastic collision).

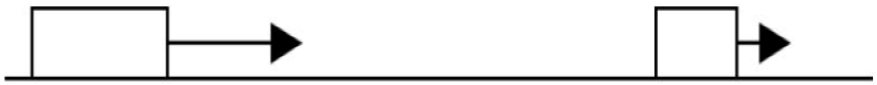
a. Determine the total momentum of the system (both objects) before the collision

b. Determine the total kinetic energy of the system before the collision

c. *Find the speed of the two objects after the collision

d. *Find the total kinetic energy of the system after the collision.

e. *Is the kinetic energy of the system conserved? Explain.



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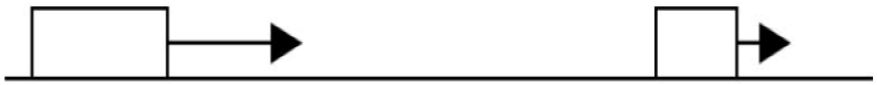

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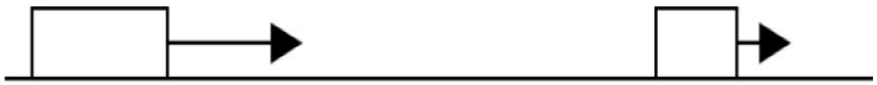

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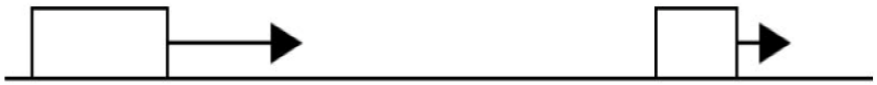

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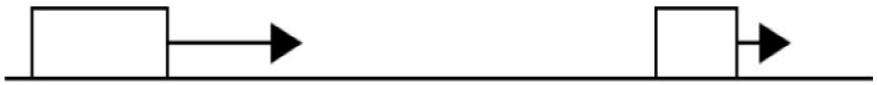

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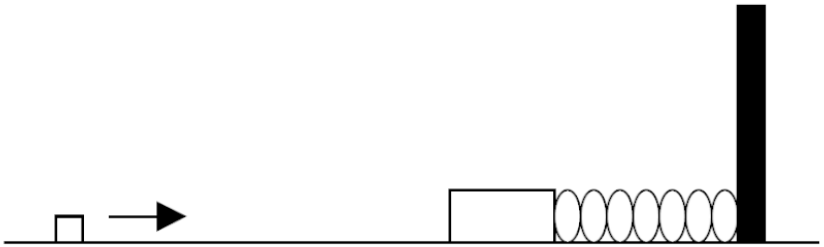


74. A small cube, with a mass of 25 g, slides along a frictionless horizontal surface at a constant speed of 18 m/s until it collides with, and sticks to, a large wooden 3.5 kg block. The large block is attached to the left end of a spring with a spring constant of 100 N/m as shown above.

a. What is the momentum of the cube before the collision?

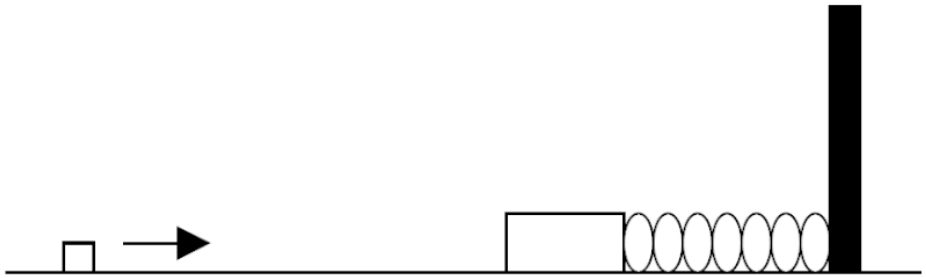
b. What is the kinetic energy of the cube before the collision?

c. *Find the speed of the combined cube and block system just after the collision.

d. *Find the kinetic energy of the cube-block system just after the collision.

e. *What is the maximum potential energy that can be stored in the spring due to this collision?

f. *How far will the cube-block system move before it stops?



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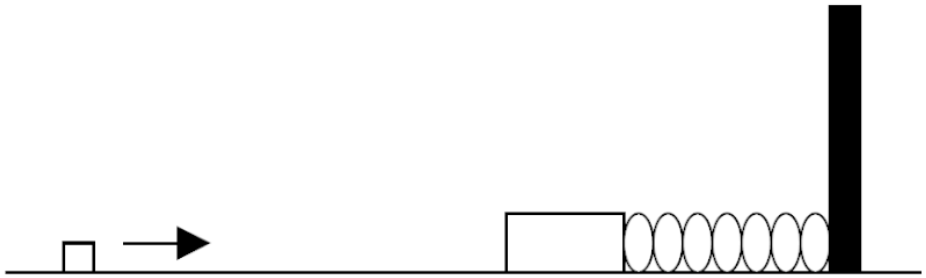

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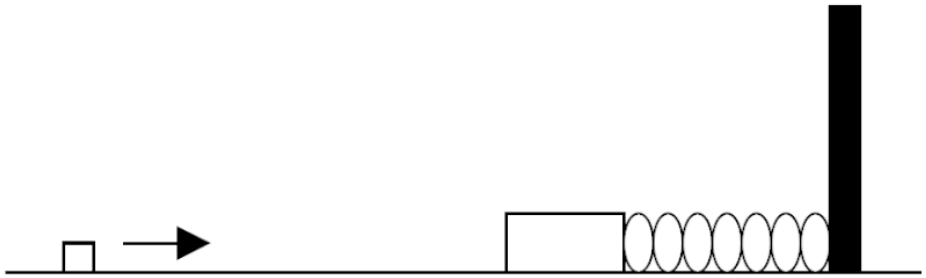

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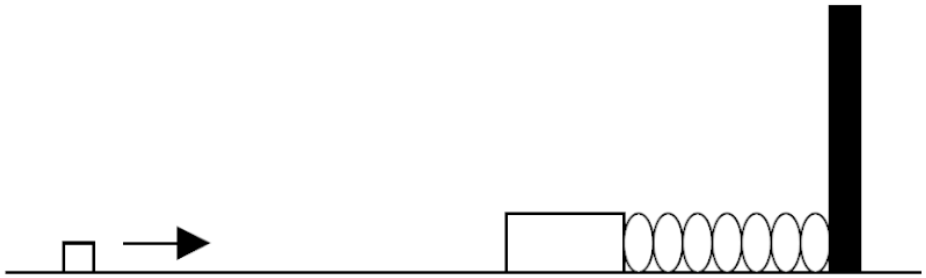
c. *Find the speed of the combined cube and block system just after the collision.



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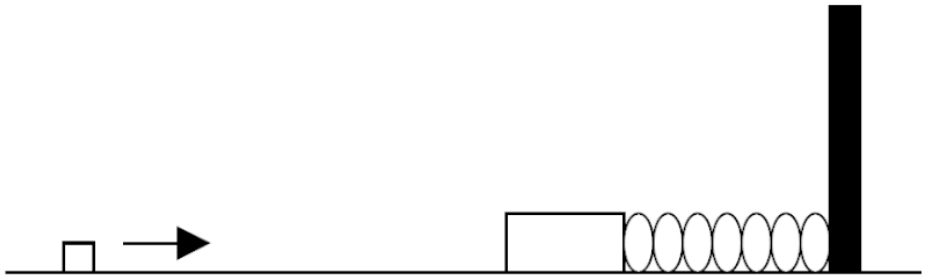
d. *Find the kinetic energy of the cube-block system just after the collision.



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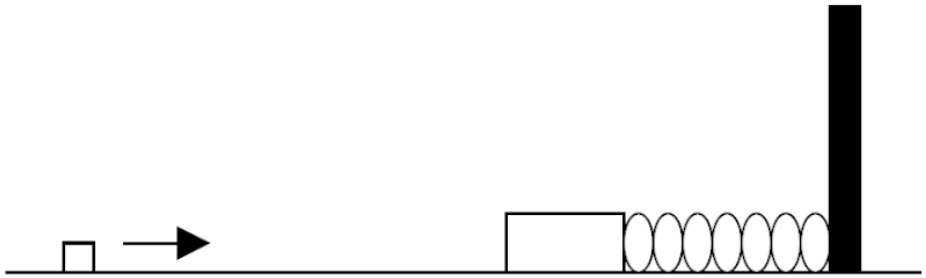
e. *What is the maximum potential energy that can be stored in the spring due to this collision?



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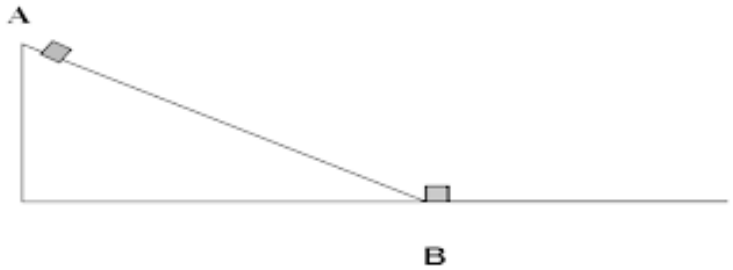
f. *How far will the cube-block system move before it stops?



75. A track consists of a frictionless incline plane, which is a height of 0.5 m, and a rough horizontal section with a coefficient of kinetic friction 0.02. Block A, whose mass is 1.5 kg, is released from the top of the incline plane, slides down and collides instantaneously and inelastically with identical block B at the lowest point. The two blocks move to the right through the rough section of the track until they stop.

a. Determine the initial potential energy of block

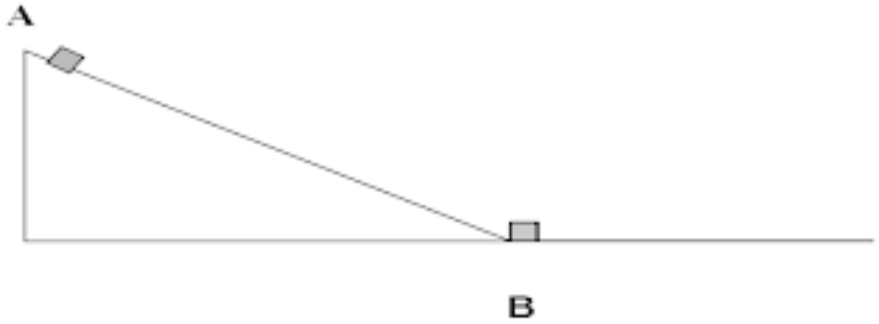
b. Determine the kinetic energy of block A at the lowest point, just before the collision.

c. *Find the speed of the two blocks just after the collision.

d. *Find the kinetic energy of the two blocks just after the collision.

e. *How far will the two blocks travel on the rough section of the track?

f. *How much work will the friction force do during this time?



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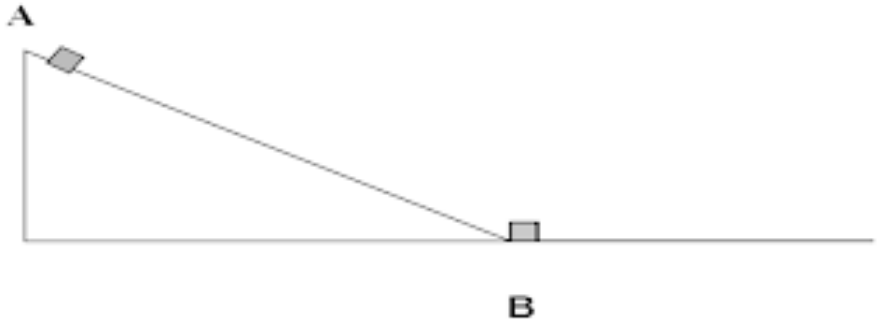

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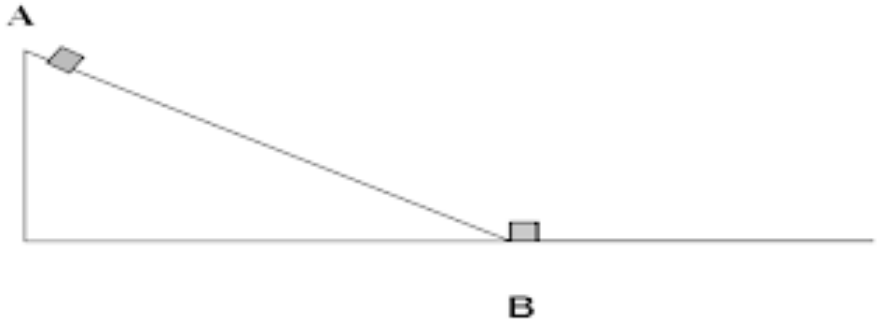
b. Determine the kinetic energy of block A at the lowest point, just before the collision.



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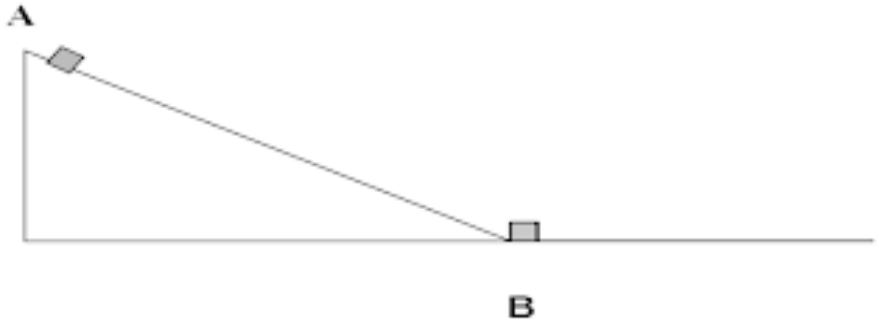
c. *Find the speed of the two blocks just after the collision.



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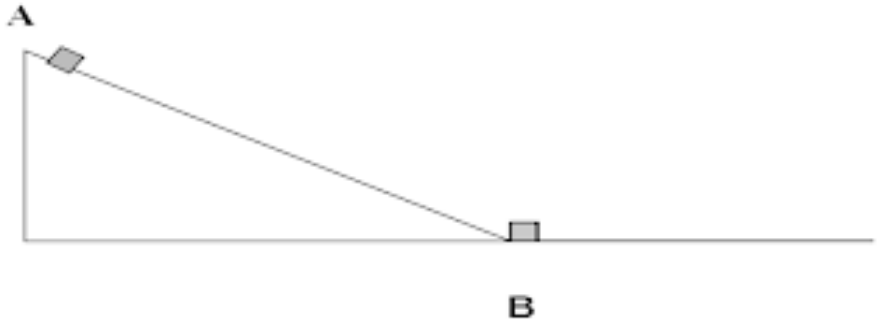
d. *Find the kinetic energy of the two blocks just after the collision.



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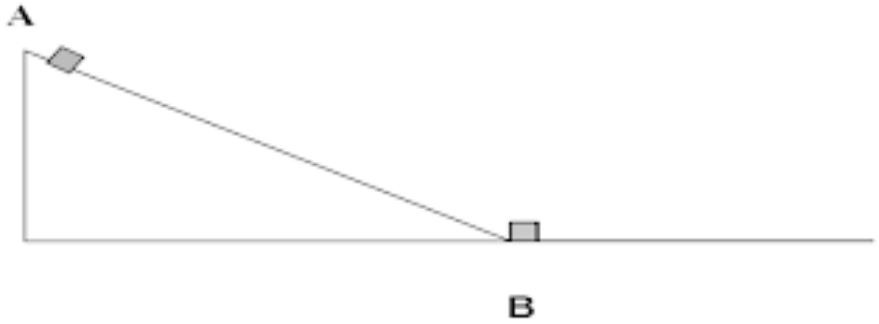
e. *How far will the two blocks travel on the rough section of the track?



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f. *How much work will the friction force do during this time?

76. A bullet of mass 0.01 kg is moving horizontally with a speed of 100 m/s when it hits a block of mass 2 kg that is at rest on a horizontal surface with a coefficient of friction of 0.4. After the collision the bullet becomes embedded in the block.

a. What is the net momentum of the bullet-block system before the collision?

b. What is the net momentum of the bullet-block system after the collision?

c. *What is the speed of the bullet-block system after the collision?

d. *Find the total energy of the bullet-block system before the collision?

e. *Find the total energy of the bullet-block system after the collision?

f. *Is the total energy conserved during the collision?

g. *Find the maximum traveled distance of the bullet-block after the collision?

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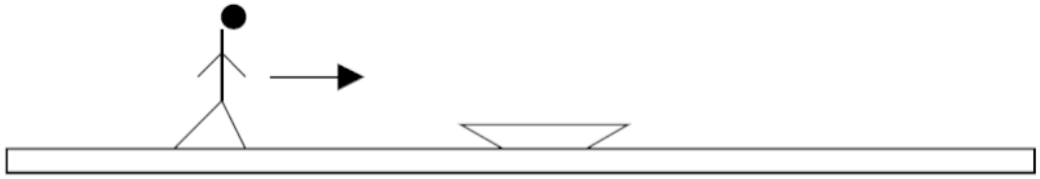


77. A 35 kg child moving at 5 m/s jumps onto a 40 kg sled that is initially at rest on a horizontal ice surface with the coefficient of friction of 0.02.

a. Determine the total momentum of the child-sled system before the child jumps onto the sled.

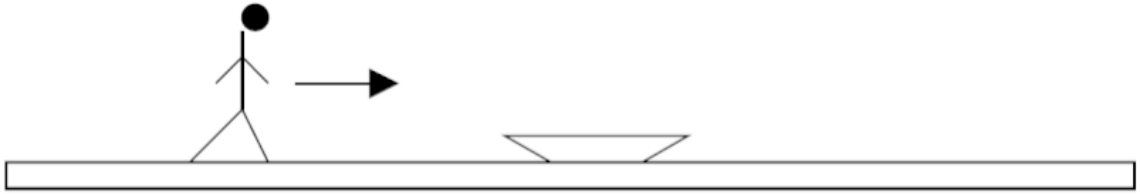
b. Determine the total momentum of the child-sled system after the child jumps onto the sled.

c. *Determine the velocity of the child-sled system after the child jumps onto the sled.

d. *Determine the total energy of the child-sled system before the child jumps onto the sled.

e. *Determine the total energy of the child-sled system after the child jumps onto the sled.

f. *Determine the maximum horizontal distance that child-sled can go after the child jumps onto the sled?



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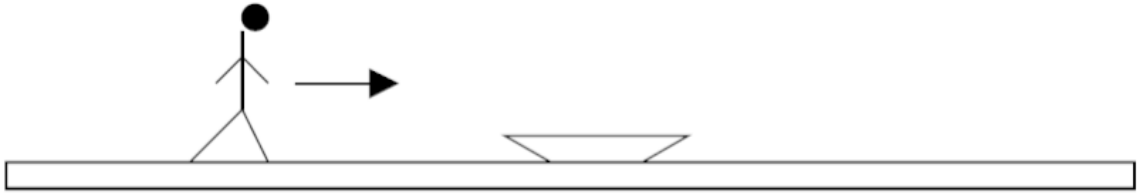

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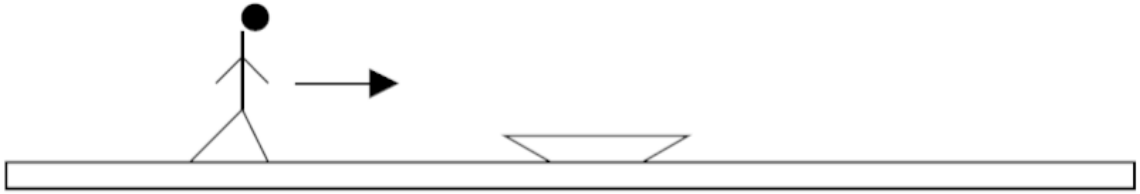
b. Determine the total momentum of the child-sled system after the child jumps onto the sled.



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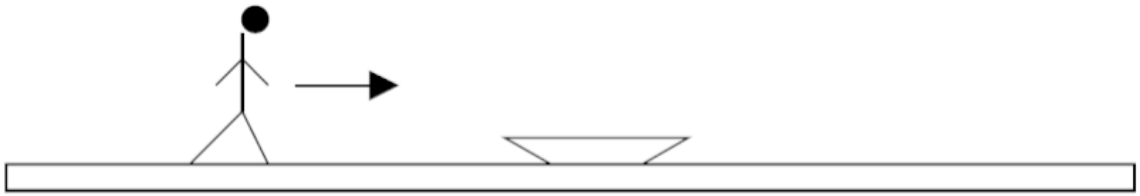

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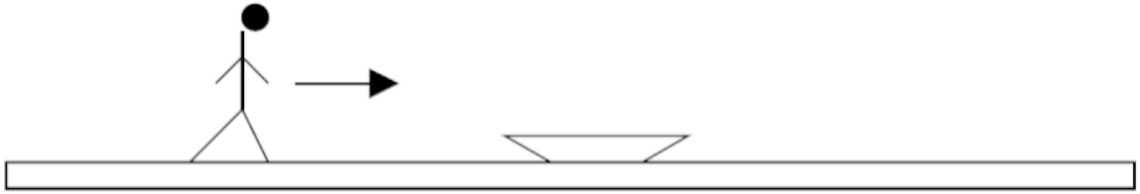

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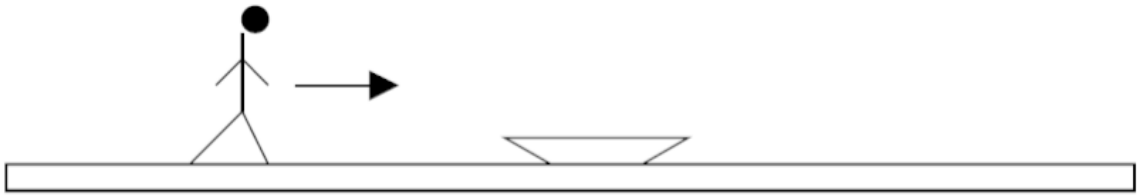

77. A 35 kg child moving at 5 m/s jumps onto a 40 kg sled that is initially at rest on a horizontal ice surface with the coefficient of friction of 0.02.

f. *Determine the maximum horizontal distance that child-sled can go after the child jumps onto the sled?

78. A 10 g piece of sticky clay moving horizontally with a speed of 12 m/s strikes a pendulum bob and sticks to the bob. The pendulum bob has a mass of 50 g and it is suspended from a 0.7 m string.

a. Find the momentum of the clay before the collision.

b. *Find the momentum of the clay-bob system after the collision.

c. *Find the velocity of the clay-bob system after the collision.

d. *Find the kinetic energy of the clay-bob system after the collision.

e. *Find the maximum height of the clay-bob system that they deflect after the collision.

f. *What velocity should the clay have before the collision in order for the clay-bob system to complete one circle?

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b. *Find the momentum of the clay-bob system after the collision.

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79. As shown above, a 0.35 kg cart is moving on a horizontal, frictionless track with a speed of 5 m/s when it hits and sticks to a 1.6 kg cart initially at rest on the track. The 1.6 kg cart is connected to one end of a massless spring with a spring constant 80 N/m.

a. Determine the momentum of the 0.35 kg cart before the collision.

b. Determine the kinetic energy of the 0.35 kg cart before the collision.

c. Determine the momentum of the carts after the collision.

d. *Determine the kinetic energy of the carts after the collision.

e. *Is the kinetic energy conserved during the collision? Explain you reasoning.

f. *Determine the maximum displacement of the spring after the collision.

79. As shown above, a 0.35 kg cart is moving on a horizontal, frictionless track with a speed of 5 m/s when it hits and sticks to a 1.6 kg cart initially at rest on the track. The 1.6 kg cart is connected to one end of a massless spring with a spring constant 80 N/m.

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c. Determine the momentum of the carts after the collision.

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f. *Determine the maximum displacement of the spring after the collision.