K/U Knowledge/Understanding T/I Thinking/Investigation C Communication A Application

For each question, select the best answer from the four alternatives.

1. Which of the following has the greatest magnitude of momentum? (5.1) K/U T/I
   (a) a 60 kg skier travelling at 80 km/h
   (b) a jumbo jet with a mass of 408 233 kg taxiing on the runway at 3 km/h
   (c) a 1 kg object ejected from an airplane with a speed of 960 km/h relative to the ground
   (d) a proton with a mass of 1.67×10^{-27} kg travelling at 99.995 % of the speed of light (3.0×10^8 m/s)
2. Suppose two billiard balls, A and B, with the same mass undergo a head-on elastic collision. Ball A was initially stationary. Which of the following outcomes is possible following the collision? (5.2) K/U
   (a) One ball is moving and one is stationary.
   (b) Both balls are moving.
   (c) Both balls are stationary.
   (d) All of the above outcomes are possible.
3. Which of the following uses conservation of momentum to move? (5.2) K/U T/I
   (a) a rocket being launched out of Earth's atmosphere
   (b) a squid taking in water and expelling it in one direction
   (c) a balloon deflating and flying around the room
   (d) all of the above
4. A cannon with a mass of 346 kg shoots a 12 kg cannonball at a speed of 126 m/s. At what speed does the machine recoil? (5.2) K/U T/I
   (a) 2.2 m/s
   (b) 4.4 m/s
   (c) 8.7 m/s
   (d) 1.5×10^2 m/s
5. Which of the following collisions can be treated as most elastic? (5.3) K/U T/I A
   (a) A chef throws a piece of spaghetti against the wall to test whether it is done.
   (b) In a game of marbles, the shooter marble strikes two smaller marbles.
   (c) An egg rolls off the counter and hits the kitchen floor.
   (d) A meteorite strikes the Moon and creates a crater.
6. In a perfectly elastic collision, a small marble collides with a stationary marble three times its mass. What percentage of the small marble's kinetic energy is transferred to the stationary marble after the collision? (5.4) K/U
   (a) 25 %
   (b) 50 %
   (c) 75 %
   (d) 100 %
7. An asteroid moves through deep space and suddenly breaks into two pieces of equal mass. The two pieces fly off at a right angle to each other. What can you conclude? (5.5) K/U
   (a) The pieces have equal final speed.
   (b) The pieces both travel at 45° to the original direction of the asteroid.
   (c) The pieces have equal kinetic energy.
   (d) All of the above are true.

Indicate whether each statement is true or false. If you think the statement is false, rewrite it to make it true.

8. Momentum is a scalar quantity. (5.1) K/U
9. When a collision occurs between two objects, the vector sum of the momenta changes. (5.1) K/U
10. All collisions conserve momentum and can be distinguished on the basis of whether they also conserve kinetic energy. (5.2) K/U
11. During a hockey game, a stationary goalie stops a puck. If we know his kinetic energy after the save, we can determine the initial kinetic energy of the puck. (5.2) K/U T/I
12. When two bodies travelling toward each other at the same speed collide, the resultant velocity of each body is different. (5.2) K/U
13. In reality, collisions between heavy objects can only be approximately elastic. (5.3) K/U
14. A curling stone hits a wall at a right angle and rebounds with a final speed that is nearly equal to its initial speed. Its final path will almost be the mirror image of its initial path. (5.5) K/U T/I A

Go to Nelson Science for an online self-quiz.
WEB LINK

K/U Knowledge/Understanding T/I Thinking/Investigation C Communication A Application

Knowledge

For each question, select the best answer from the four alternatives.

1. Suppose object A has greater momentum than object B. Which of the following can you conclude? (5.1) K/U
   (a) Object A has a greater mass than object B.
   (b) Object A has a greater velocity than object B.
   (c) Object A has greater kinetic energy than object B.
   (d) None of the above is necessarily true.
2. A 61 kg gymnast falls vertically from a jump onto a trampoline. Her speed as she hits the trampoline is 5.2 m/s, and she comes to a stop in 0.20 s. What is the average magnitude of the force exerted on the gymnast by the trampoline? (5.1) K/U
   (a) 6.1 N
   (b) 305 N
   (c) 610 N
   (d) 1600 N
3. A ball with a mass of 0.5 kg, initially at rest, is struck with a bat and acquires a velocity of 4.0 m/s. What is the magnitude of the change in momentum of the ball? (5.2) K/U
   (a) 0.5 kg·m/s
   (b) 2.0 kg·m/s
   (c) 2.5 kg·m/s
   (d) 10.0 kg·m/s
4. Two tennis balls undergo a head-on elastic collision. Under which of these initial conditions is it impossible for both balls to be moving in the same direction after the collision? (5.4) K/U T/I
   (a) The lighter ball is stationary and the heavier ball is in motion.
   (b) The two balls have the same mass and are initially moving in the same direction, and they collide because the faster-moving ball overtakes the slower-moving one.
   (c) The two balls have the same mass and only one is moving.
   (d) none of the above

Indicate whether each statement is true or false. If you think the statement is false, rewrite it to make it true.

5. You can determine the average force exerted on an object during a collision if you know only the object's momentum before and after the collision. (5.1) K/U
6. When an acorn falls and hits the ground, Earth's response is imperceptible. (5.2) K/U A
7. In an inelastic collision only momentum is conserved. (5.3) K/U
8. When two objects undergo a perfectly elastic head-on collision, each object will always have a final velocity equal to the initial velocity of the other object. (5.4) K/U T/I
9. A head-on collision is a collision in which the initial and the final velocities of colliding masses lie in the same line. (5.4) K/U
10. In glancing collisions in two dimensions, momentum is no longer conserved. (5.5) K/U
11. Scientists can detect neutrinos using conservation of momentum. (5.7) K/U

Understanding

12. Verify, using the definition of momentum, that the units for momentum are the same as those for force multiplied by time. (5.1) K/U
13. Two friends in a hurry to go picnicking decide to stand outside a window, holding a cloth to catch a watermelon tossed out the window by a third friend. Explain why a stretchy cloth is less likely to tear than an inflexible cloth when the watermelon hits it. (5.1) K/U T/I A
14. Two construction workers use different hammers to pound in nails. Both swing their hammers with the same speed, and the duration of both hammers' collisions with the nails is equal. However, one worker seems to achieve more force than the other. Offer a possible explanation. (5.1) K/U T/I A
15. A 57 g tennis ball approaches a player horizontally at a speed of 6.0 m/s. The player hits the ball with a racquet in a collision that lasts 4.0 ms. To return the ball with a horizontal speed of 7.0 m/s, how much average force must the player apply? (5.1) K/U A
16. A car with a mass of 1100 kg is travelling at a speed of 33 m/s. Determine the magnitude of the total momentum. (5.1) T/I
17. When a meteor enters Earth's atmosphere, it slows down. Explain why this does not violate conservation of momentum. (5.2) K/U T/I A

18. In each of the following situations, explain why conservation of momentum appears to fail. These are not isolated systems. (5.2) K/U A
    (a) On a stretch of gravel, two race cars collide and come to a stop.
    (b) In a flowing river, a stick repeatedly bumps the shore.
    (c) A bus slows down, picks up a passenger, and speeds back up again.
19. A cup is sliding over a frictionless table while a waiter pours water into it from above. Describe what will happen to the cup's speed. (5.2) K/U T/I A
20. A bobsled team rides a sled across a horizontal runway of ice. Describe what happens to the sled's speed as the sledders jump off the sled. (5.2) K/U T/I A
21. Two tennis balls of equal mass are moving in directions opposite to each other. The tennis balls are travelling with equal speed when they collide head-on. You can assume that this collision is perfectly elastic. Describe in your own words what happens after the tennis balls collide. (5.2) T/I C A
22. Using conservation of momentum, explain whether the following situation is possible: Two objects collide head-on with equal and opposite velocities. When they rebound, the velocity of each object is doubled. (5.2) T/I
23. Two soccer players collide head-on and are stopped. If the mass of one player is 1.2 times the mass of the other player, what can you conclude about their initial speeds? (5.3) K/U
24. Classify the following collisions as elastic, inelastic, or perfectly inelastic. (5.3) K/U T/I A
    (a) A child throws a lump of modelling clay against a refrigerator. It rebounds, but a part of it sticks.
    (b) Two electrons collide in a cyclotron.
    (c) A ball is thrown into jelly.
    (d) Two marbles bounce off each other after colliding.
25. The data in **Table 1** represent the given information for a head-on elastic collision in one dimension. Determine the final velocities for each row. (5.4) T/I

Table 1

(a)	$m_1 = 25$ kg	$v_1 = 6.0$ m/s [E]	$m_2 = 15$ kg	$v_2 = 0$ m/s
(b)	$m_1 = 12$ kg	$v_1 = 8.0$ m/s [E]	$m_2 = 22$ kg	$v_2 = 2.0$ m/s [E]
(c)	$m_1 = 150$ kg	$v_1 = 2.0$ m/s [N]	$m_2 = 240$ kg	$v_2 = 3.0$ m/s [S]

26. Hockey player 1 is travelling at a velocity of 12 m/s [N] and hockey player 2 is travelling at a velocity of 18 m/s [S] when they collide head-on. After colliding, the hockey players hang on to each other and slide along the ice with a velocity of 4.0 m/s [S]. If hockey player 1 weighs 120 kg, calculate how much hockey player 2 weighs. (5.4) K/U T/I
27. In a demonstration in physics class, a 1.2 kg dynamics cart starts from rest at the top of a ramp. The ramp is 2.4 m above the ground. The cart then rolls down to the bottom of the ramp, where it collides with a stationary 1.4 kg dynamics cart. Assume that an elastic head-on collision occurs. Calculate the speed of each cart just after the collision. (5.4) T/I
28. A 1.2 kg cart slides eastward down a frictionless ramp from a height of 1.8 m and then onto a horizontal surface where it has a head-on elastic collision with a stationary 2.0 kg cart cushioned by an ideal Hooke's law spring. The maximum compression of the spring during the collision is 2.0 cm. (5.4) T/I
    (a) Determine the spring constant.
    (b) Calculate the velocity of each cart just after the collision.
    (c) After the collision, the 1.2 kg cart rebounds up the ramp. Determine the maximum height reached by the cart.
29. Two people on inner tubes collide head-on on a frictionless surface of ice. The first inner tube and its rider have a total mass of 81 kg, and the second inner tube with rider has a total mass of 93 kg. The final velocities of the two inner tubes, including the riders, are 1.7 m/s [N] and 1.1 m/s [S], respectively. (5.4) T/I A
    (a) Determine the initial velocities of the inner tubes.
    (b) Determine the total kinetic energy of the inner tubes and riders.
    (c) Determine the total momentum of the inner tubes and riders.
30. A sailboat with a mass of 240 kg glides at a speed of 4.3 m/s on frictionless ice, runs aground on mud, and comes to a stop after 3 s. Determine the average force of friction exerted by the mud on the boat. (5.1) K/U A
31. Two balls of different masses and equal speeds undergo a head-on elastic collision. If the balls are moving in opposite directions after the collision, how can you determine from the outcome of the collision which object has a greater mass? (5.4) K/U

32. A curling stone travelling at 5.0 m/s collides with a stationary stone of the same mass. Following the collision, the two stones travel at angles of 17° and 38° in opposite directions with respect to the initial motion of the first stone. (5.5) K/U T/I C
   (a) Draw a diagram of the stones' motion.
   (b) Calculate the speed of each stone after the collision.
33. During a spacewalk, three astronauts wearing jetpacks approach each other at equal speeds along lines equally spaced by an angle of 120° (**Figure 1**). As the astronauts approach each other, they take each other's hands. If the astronauts come to rest after colliding, what conclusion can you draw? (5.5) T/I

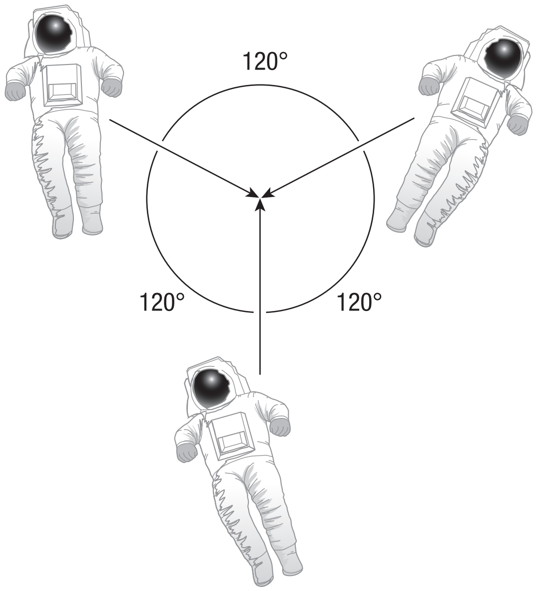

Figure 1

Analysis and Application

34. (a) If two objects with non-zero mass and non-zero velocity have equal momentum and equal kinetic energy, what can you conclude about their velocities?
   (b) Can you draw any conclusion about their masses? Explain your answer. (5.1) K/U T/I A
35. Draw three different graphs of force applied to an object over a time interval so that in each graph, the impulse is the same. (5.1) K/U T/I C
36. For each of the following collisions, calculate the force exerted on the object. (5.1) K/U T/I C A
   (a) A baseball with a mass of 0.152 kg hits a cement wall. Immediately before the collision, the baseball is travelling horizontally at 35 m/s. The collision lasts 1.6 ms. Immediately after the collision, the baseball is travelling horizontally away from the wall at 29 m/s.
   (b) A squash ball with a mass of 0.125 kg collides horizontally with a cement wall at a speed of 25 m/s. The collision lasts for 0.25 s. Immediately after the collision, the squash ball travels horizontally away from the wall at 23 m/s.
   (c) In a forensics test, a metal projectile with a mass of 0.06 kg collides horizontally with a cement wall at a speed of 340 m/s. The collision lasts 0.1 ms. Immediately after the collision, the projectile travels horizontally away from the wall at 3 m/s.
37. Ball 1 of mass 0.1 kg makes an elastic head-on collision with ball 2 of unknown mass that is initially at rest. If ball 1 rebounds at one-third of its original speed, determine the mass of ball 2. (5.1) K/U C A
38. At the circus, a human cannon is used to convert the potential energy of the performer to kinetic energy (**Figure 2**). To achieve maximum height, the organizers are debating whether to use a lighter performer with higher speed, or a heavier performer with less speed. Explain which they should choose. (5.1) K/U T/I C

Figure 2

39. Suppose a watermelon with a mass of 2.0 kg undergoes a head-on elastic collision on a frictionless counter with a grapefruit with a mass of 0.8 kg. If the total kinetic energy of the system is 10.5 J and the total momentum is 7.5 kg·m/s, determine the possible initial and final velocities for the watermelon and the grapefruit. (5.4) K/U A

40. A team of four 63 kg bobsledders push their sled, which has a mass of 210 kg when empty. They start to push their sled over a flat frictionless surface at an initial speed of 3.0 m/s. One by one, at intervals of 2.0 s, each bobsledder sprints forward at a speed of 2.0 m/s faster than the sled's current speed and then jumps in. (5.2) K/U T/I A
    (a) Determine the sled's final speed once all of the sledders are in.
    (b) Determine the sled's final momentum once all of the sledders are in.

41. A force acts on a 2.4 kg object with the magnitude shown in **Figure 3** as a function of time. (5.1) K/U C A

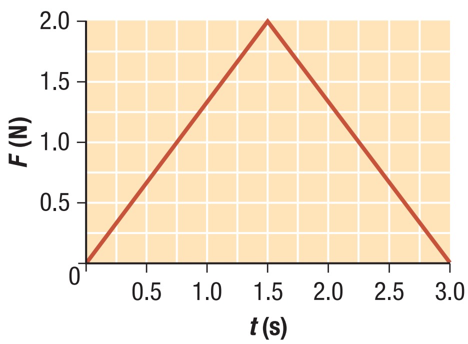

Figure 3

    (a) Determine the impulse imparted by the force on the object.
    (b) Determine the final velocity of the object if it had an initial velocity of 14 m/s in the negative direction.

42. A frog leaps at a constant horizontal speed from a lily pad to an adjacent lily pad. The lily pads have the same mass and are initially stationary on a frictionless surface. When the frog has completed the leap, both lily pads are moving. (5.2) K/U T/I
    (a) What are the directions of the lily pads' motion?
    (b) Which lily pad has a higher speed? Explain why.

43. A rocket in deep space with an initial velocity of 12 km/s [forward] sheds its rear stages, which represent two-thirds of its mass. The rear stages travel with a velocity of 10.0 km/s [backward]. The remaining rocket continues in the initial direction of motion. Calculate the rocket's velocity after shedding the rear stages. (5.2) K/U T/I A

44. Two 0.3 kg gliders collide elastically on a frictionless track. Prior to the collision, their total kinetic energy is 0.52 J and their total momentum is 0.12 kg·m/s [left] along the track. Calculate the final velocities of the gliders. (5.2) K/U T/I A

45. A boy is at rest on a sheet of flat frictionless ice. He throws a snowball of mass 0.02 kg at a speed of 18 m/s in a horizontal direction. If his mass is 75 kg, how fast will the recoil make him drift on the ice? (5.2) K/U A

46. (a) In Question 45, what is the total kinetic energy
        (i) before the boy throws the snowball?
        (ii) after the boy throws the snowball?
    (b) Why are your answers in (a) different?
    (c) Where did the difference in kinetic energy come from? (5.3) T/I A

47. Suppose a circus selects a performer of mass 78 kg to be shot from the human cannon with a kinetic energy of 1.2×10^5 J. On his way out of the cannon, the performer holds his arm ahead of him to punch a stationary beach ball of mass 40.0 g balanced on a post. The beach ball flies out in the direction of the performer's motion, and the performer's speed is reduced by 0.1 m/s. (5.3) K/U T/I A
    (a) What is the speed of the beach ball after the collision?
    (b) If the collision of the performer's fist with the beach ball lasts for 5 ms, how much average force did he exert on the ball?
    (c) What is the performer's final speed?
    (d) Could you have answered (a) and (b) without determining the performer's final speed? Explain.

48. On a frictionless sheet of ice, an 810 kg adult moose skids toward a stationary baby moose at a speed of 5.2 m/s, and they collide and continue together in the same direction. The final velocity of the adult moose and baby moose system is 4.85 m/s. Determine the mass of the baby moose. (5.3) K/U A

49. A block of ice of mass 50.0 g slides along a frictionless, frozen lake at a speed of 0.30 m/s. It collides with a 100.0 g block of ice that is sliding in the same direction at 0.25 m/s (**Figure 4**). The two blocks stick together. (5.3) K/U A
   (a) How fast are the two blocks moving after the collision?
   (b) How much kinetic energy is lost?

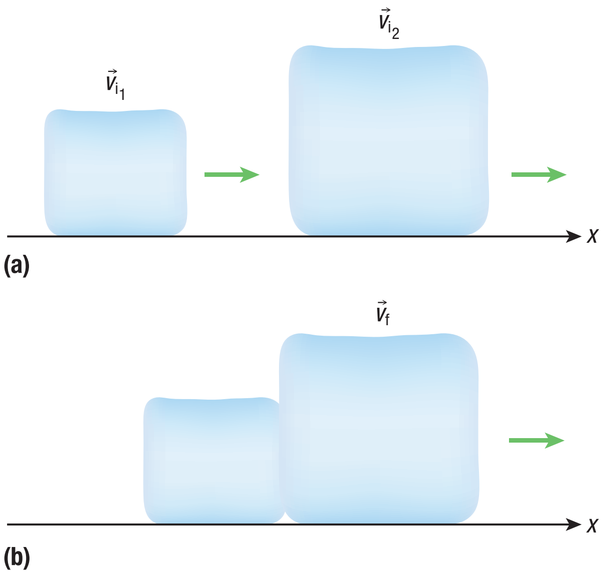

Figure 4

50. Using your answer from Question 48, suppose that the adult moose again approaches at 5.2 m/s. This time, after the two collide, the baby moose's final velocity is 8.0 m/s in the direction of the adult moose's original motion. What is the adult moose's final velocity? (5.4) K/U A
51. Two equal-mass hockey pucks undergo a glancing collision. Puck 1 is initially at rest and is struck by puck 2 travelling at a velocity of 13 m/s [E]. Puck 1 travels at an angle of [E 18° N] after the collision. Puck 2 travels at an angle of [E 4° S]. Determine the final velocity of each puck. (5.5) K/U A
52. In a 1500 kg car, 1.3 m of its front section is designed to crumple in an accident, protecting the driver and passengers. Suppose the car is travelling at 32 m/s and comes to a stop while uniformly slowing down over 1.3 m. (5.6) T/I A
   (a) What is the duration of the collision?
   (b) What is the average force exerted on the car?

Evaluation

53. Give two examples of collisions in open systems. For each example, define the open system and explain how to expand an open system to be closed. (5.1) T/I C A
54. Consider a perfectly elastic head-on collision between two objects of equal mass m. (5.2) T/I C A
   (a) Use algebraic reasoning to prove that conservation of kinetic energy can be expressed as $v_1^2 + v_2^2 = C$, where C is a constant and v_1 and v_2 represent the speeds of the objects at any time other than the instant of the collision.
   (b) Similarly, show that conservation of momentum can be expressed as $v_1 + v_2 = C'$, where C' is another constant.
   (c) Graph these two equations on the same set of axes for v_1 versus v_2.
   (d) At how many points do the graphs intersect? What do the intersections represent?
55. Suppose that a bowling ball collides elastically with a row of stationary bowling balls all of the same mass. All the bowling balls are confined to move only along the gutter beside the lane in a bowling alley. Prove that after the collision only one ball can be in motion. Use the laws of conservation of momentum and conservation of energy (kinetic energy) to support your answer. (5.2) T/I C A
56. Two objects undergo an elastic head-on collision in one dimension, with one object initially at rest and the other moving at 12 m/s [E]. Make a prediction for each scenario below, explaining your reasoning. Then calculate the velocity of each object after the collision for each situation. (5.4) K/U T/I A
   (a) The moving object is twice the mass of the stationary object.
   (b) The stationary object is twice the mass of the moving object.
   (c) The moving object is 106 times the mass of the stationary object.
   (d) The stationary object is 106 times the mass of the moving object.
57. Suppose that two objects undergo a perfectly elastic collision. The first object, with an initial velocity of v_i, is much more massive than the second object, which is initially at rest. (5.4) T/I C
   (a) Predict what the final velocities will be after the collision.
   (b) Use the final velocity equations to determine the approximate final velocities of both masses.
   (c) Compare these results with your predictions.

Reflect on Your Learning

58. What did you find most surprising in this chapter, and what did you find most interesting? T/I C

59. (a) Do you feel that you could explain momentum to a fellow student who has not taken physics? Discuss your answer with a classmate.
 (b) Does anything about momentum and conservation of momentum still confuse you? T/I C

Research

WEB LINK

60. Research Newton's cradle, which was named after Sir Isaac Newton. Explore how the device works and observe what factors are being conserved. T/I C A

61. A Galilean cannon demonstrates the conservation of momentum. Research the Galilean cannon. In a short oral presentation, describe how you could use a basketball and a tennis ball to demonstrate the principle behind this device. T/I C A

62. While landing on the ground, skydivers and paratroopers always keep their knees bent (**Figure 5**). Research and write a report on how the various laws of conservation work in this case. If possible, speak with a professional in this field and highlight the safety measures that skydivers and paratroopers should take while landing. T/I C A

Figure 5

63. Research the standard spacing and height of 10-pin bowling pins and the standard radius of bowling balls. Discuss in a one-page report how the game would be easier or more difficult if these standards were changed. Would it be possible to knock down all the pins with one shot? At what point would it become inevitable? T/I C A

64. Research the length of crumple zones in cars. How should the length of the crumple zone vary with the mass of the car? Research what parameters are varied in crash tests and what information is contained in crash test ratings. Write up your findings in a short report. K/U T/I C A

65. Principles of momentum play a part in the safe demolition of buildings. As modern buildings become larger and taller and urban areas become more densely populated, methods of safe building demolition must improve. Research methods of building demolition and how the methods have evolved. Prepare a multimedia report that includes video examples of demolition techniques. Include your thoughts on practical ways to improve demolition technology. K/U T/I C A

66. Use the concept of momentum to explain how child car seats help protect children riding in motor vehicles. Describe some ways that the design of standard child car seats or the materials used in them might be improved. K/U T/I C A

67. Research the history of crash test dummies and summarize the impact their use has had on motor vehicle safety research. Why are crash test dummies used? What impact have innovations in crash test dummy design and use had on traffic accident injuries? K/U T/I C A

68. In the Unit Task on page 270, you may choose to design a Rube Goldberg machine. Research Rube Goldberg machines and write a short summary of your findings. Include the following information in your summary: T/I C A
 (a) What was Rube Goldberg's educational background and career pathway? Did his education and the jobs he held have an impact on his designs?
 (b) Describe two of Rube Goldberg's designs and identify any physics principles at work.
 (c) Discuss how Rube Goldberg's machines have had an impact on society.