CHAPTER 6 MOMENTUM AND CONSERVATION OF MOMENTUM

This chapter introduces the notion of a conservation law. In the physical world almost everything we can measure is changing with the passage of time as the result of various physical processes. It is logical, then, to focus a great deal of attention upon those quantities which do NOT change as a result of a physical process. Such quantities which do not change are said to be CONSERVED, and a law of physics which says that a specific quantity is conserved is logically called a conservation law.

Quantities which otherwise might be of little interest assume paramount importance in physics if their values do not change (i.e. if they are conserved) during various processes. One such quantity is MOMENTUM. This chapter defines momentum and explains the significance of the momentum conservation law when two or more bodies "interact". In following chapters, we will use the concept of a conservation law to introduce another important concept - ENERGY.

Chapter 6 PERFORMANCE OBJECTIVES

Upon completion of this chapter, you should:

1. be able to define impulse and momentum and state the primary metric units of each.

2. be able to recognize that ~~an impulse~~ A FORCE causes a change in momentum. AND THAT THE AMOUNT OF THE CHANGE EQUALS THE IMPULSE.

3. be able to recognize that in a two-body interaction, the change in momentum of one object equals the negative change in momentum of the other.

4. be able to apply the principle of conservation of momentum involving the interaction of two or more masses - in both one and two dimensional collisions.

5. be able to recognize that analyzing momentum from a center of mass point of view can simplify the analysis.

6. given a description of a force, be able to state the reaction force.

1. Read: Section 6-1 Impulse page 109
   Section 6-2 Momentum page 111

   a. What symbol is used to represent: Impulse?_____ Momentum?_____

   b. Define mathematically: Impulse __________ Momentum __________

   c. Is impulse a vector quantity? ___ Momentum? ___ Explain.

   d. What are the units of: Impulse? ___________ Momentum? __________

   e. What does unit analysis say about letting impulse equal momentum?

   f. Have you seen $F\Delta t = m\Delta v$ before? Where?

   g. Can $m\Delta v = \Delta (mv)$? A proof is needed.

   h. Thus impulse equals ____________________________________.

   i. How would one determine the impulse given to an object if the force varies over the time interval Δt?

   j. What can one say about two objects that have the same momentum?

2. Problems: page 110: #1 #2 #3 #4
   page 113: #6 #7 #8

3. A skier with a velocity of 10 m/sec stops in 1.5 sec. Calculate:

   a. the acceleration.

   b. the force needed to stop if the skier has a mass of 75 kg.

   c. the impulse given to the skier.

4. Does the momentum of a 2-ton car going North at 30 km/hr equal the momentum of a 1-ton car going West at 60 km/hr? Is it possible to compare the momenta if one was going North and the other South?

5. Find the change in momentum of a 1500 kg car when it changes in velocity from 20 m/sec North to 20 m/sec West.

6. Complete the quiz sheet covering Sections 1 and 2 which is enclosed in this packet. Have it evaluated when completed.

7. Experiment: THE CART AND THE BOOK (Laboratory procedure enclosed.)

   a. A proper laboratory report is to be presented to your instructor. All data must be presented in table form.

   b. Write out answers to the questions in the last four paragraphs. Then have instructor evaluate your report.

8. Experiment: COLLISION IN TWO DIMENSIONS (Lab procedure enclosed.)

   a. A proper laboratory write-up is due.

   b. Be sure to express the mass of the steel ball as a function of the mass of the glass marble. Having done this, ask for permission to measure the mass of each using an electronic balance.

   c. mass (steel) = ________ mass (glass) EXPERIMENTAL

   d. mass of steel ball _______: mass of glass marble _______ (MEASURED)

   e. mass (steel) = ________ mass (glass) ACTUAL

   f. Percent Error ________

9. Read: Section 6-3 Changes in Momentum When Two Bodies Interact p-113
   Section 6-4 The Law of Conservation of Momentum page 118

10. Problems: page 117: #9 #10
    page 121: #11 #12 #13
    page 128: #20 #21 #22

11. Complete and then have evaluated the 7-problem quiz for Sections 3 and 4 which is enclosed.

12. Problems: page 129: #25

    A copy of Figure C, page 129 is included in this packet which may aid you as you solve the problem.

13. Read: Section 6-5 Rockets page 121
    Section 6-6 The Center of Mass page 122
    Section 6-7 The Center of Mass Frame of Reference page 124

14. Ask to see demonstration of Center of Mass.

15. Problems: page 126: #16 #17

16. Ask for collision ball apparatus. What explanation can you give for the behavior of the spheres?

17. Complete Written Exercise about a U.N. Exposition. Then have it evaluated.

Thought for the chapter.

Give a knave 2.54 centimeters and he will take 1.6093 kilometers.

ANSWERS Chapter 6

1. (a) $\vec{I}$, $\vec{p}$ (b) $\vec{I} = \vec{F}\Delta t$, $\vec{p} = m\vec{v}$ (c) yes, yes, both vector & scalar
   (d) N-sec, kg-m/sec (e) units are equivalent, might be
   (f) another form of Newton's Law
   (g) $m\Delta v = m(\vec{v}_f - \vec{v}_i) = m\vec{v}_f - m\vec{v}_i = \vec{p}_f - \vec{p}_i = \Delta p = \Delta(mv)$
   (h) the change in momentum
   (j) it takes the same impulse to stop both objects

2. (1) (a) four (b) the bounce
   (2) 1.5 N-sec
   (3) 32.0 N-sec
   (4) (a) 24 N-sec (b) 2.0 sec
   (6) 500 N (In which direction?)
   (7) (a) −120 N-sec (b) −30 N (Direction?) (c) 100 kg m/s, −20 kg m/s
   (8) zero

3. (a) − 6.7 m/sec^2 (b) −500 N (c) −750 N-sec

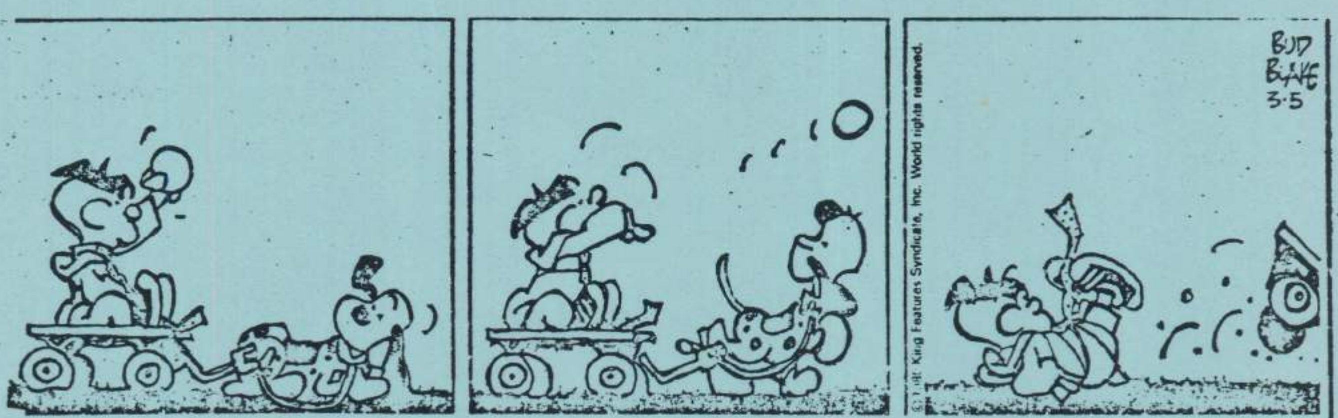
4. no, one is the negative of the other

5. 4.24×10^4 kg m/sec West 45° South

10. (9) (10) (11) S.A.B.
    (12) 2/5
    (13) 0.60 m/sec
    (20) (a) no change (b) 6.0 m/sec (c) −6.0 m/sec
    (21) (a) 0.52 (b) 1.9 (c) equal but opposite (d) −0.52
    (22) (a) 7×10^{-27} kg (b) no (c) cannot be computed

12. (25) (a) (b) S.A.B. (c) 0.429 (d) S.A.B. (e) 86.3 grams

15. (16) (a) straight line (b) yes
    (17) (a) v/2 (b) S.A.B.



Chapter 6 QUIZ Section 1 & 2

1. A force of 5 Newtons acts on a body for a total of 5 seconds. (a) What is the magnitude of the impulse? (b) What is the momentum change of the body? (c) If the body was initially at rest, and has a mass of 2 kg, what is the final speed?

a. ____________ b. ____________ c. ____________

2. A golf ball of mass 100 grams is struck by a club. After the impact the ball moves off with a speed of 100 m/sec. If the ball and club were in contact for 5×10^{-3} sec, what was the average force on the ball?

____

3. Two forces act on a 5 kg mass which is initially at rest. First the body is subjected to a 20 Newton force for 3 seconds which acts in a northward direction. One second after the first force is applied the body is subjected to a force of 30 Newtons which acts in an eastward direction for two seconds. (a) What is the northward component of the impulse? (b) What is the eastward component of the impulse? (c) What is the final momentum of the body? (d) If the eastward force had been applied initially at the same instant as the northward force, instead of a second later, what would be the final momentum of the body?

a. ____________

b. ____________

c. ____________

d. ____________

4. A 2 kg ball moving with an initial speed of 3 m/sec to the right is acted upon by a constant force F to the left for a period of 6 seconds. After the interaction, the ball is moving to the left with a speed of 6 m/sec. What is the magnitude of F ?

____

5. A body is subjected to a varying force which increases linearly with time from zero to 10 Newtons in 0.1 sec, remains constant at 10 Newtons for 1 second, and then decreases linearly to zero in 0.2 sec. (a) What is the total impulse? (b) If the body has a mass of 2.3 kg, and was initially at rest, what is its final speed?

a. ____________

b. ____________

Erian

Chapter 6 QUIZ Sections 1 and 2

1. A force of 5 Newtons acts on a body of mass 2.0 kg for a total of 5 seconds.
   a. What is the magnitude of the impulse?
   b. What is the momentum change of the body?
   c. What is the final speed of the object if it started from rest?

$F = 5\,N$, $m = 2\,Kg$, $t = 5\,sec$

a) $I = F\Delta t = 5\,N \times 5\,sec$; $I = 25\,N\cdot sec$

b. $\Delta p = I$; $\Delta p = 25\,Kg\frac{m}{s}$

(c) $\Delta p = m(V_f - V_i)$; $V_f = \frac{\Delta p}{m} = \frac{25\,Kg\frac{m}{s}}{2\,Kg} = $ $V_f = 12.5\,\frac{m}{s}$

2. A golf ball of mass 45 grams is struck by a club. After the impact the ball moves off with a speed of 100 m/sec. If the ball and club were in contact for 5×10^{-3} seconds, what was the average force on the ball?

$M = 45\,g$, $t = 5\times10^{-3}\,sec$, $V_f = 100\,\frac{m}{s}$

$F\Delta t = m(V_f - V_i)$

$F = \frac{45\,g \times 100\,m/s}{5\times10^{-3}\,sec} \times \frac{1\,Kg}{1000\,g} = 900\,N = F$

3. Two forces act on a 5-kg mass which is initially at rest. The body is subjected to a 20-N force for 3 sec which acts in a northward direction. One second after the first force is applied the body is subjected to a force of 30-N which acts in an eastward direction for two seconds.
   a. What is the northward component of the impulse?
   b. What is the eastward component of the impulse?
   c. What is the final momentum of the body.
   d. If the eastward force had been applied initially at the same instant as the northward force, instead of a second later, what would be the final momentum of the body?

$m = 5\,Kg$, $F_1 = 20\,N \uparrow$, $F_2 = 30\,N \rightarrow$, $t_1 = 3\,sec$, $t_2 = 2\,sec$

a. 60 N·sec

b. 60 N·sec

c. $84.9\,Kg\frac{m}{s}$ ↗

d. SAME

4. A 2-kg ball moving with an initial speed of 3 m/sec to the right is acted on by a constant force F to the left for a period of 6 seconds. After the interaction, the ball is moving to the left with a speed of 6 m/sec. What is the magnitude of the force?

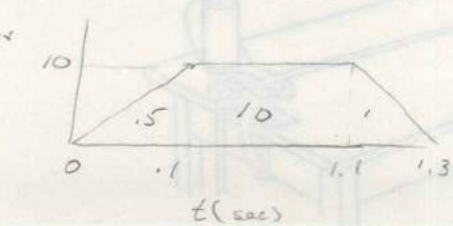
$m = 2\,Kg$, $V_i = 3\,\frac{m}{s} \rightarrow$, $F = ?$, $t = 6\,sec$, $V_f = 6\,\frac{m}{s} \leftarrow$

$F\Delta t = m(V_f - V_i)$; $F = \frac{m(V_f - V_i)}{\Delta t} = 2\,Kg \times \frac{-6\frac{m}{s} - 3\frac{m}{s}}{6\,sec} = F = 3\,N$

5. A body (mass = 2.3 Kg) is subjected to a varying force which increases linearly with time form zero to 10-N in 0.1 seconds, remaining constant at 10-N for 1 second, and then decreasing linearly to zero in 0.2 sec.
   a. What is the total impulse?
   b. What is the final speed of the body given that it started from rest?

a. = $I = 11.5\,N\cdot sec$

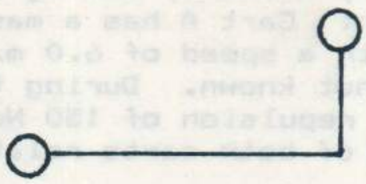
b. = $V_f = 5\,\frac{m}{sec}$



$I = \Delta p = m(V_f - V_i)$

$V_f = \frac{I}{m} = \frac{11.5\,Kg\cdot\frac{m}{s}}{2.3\,Kg}$

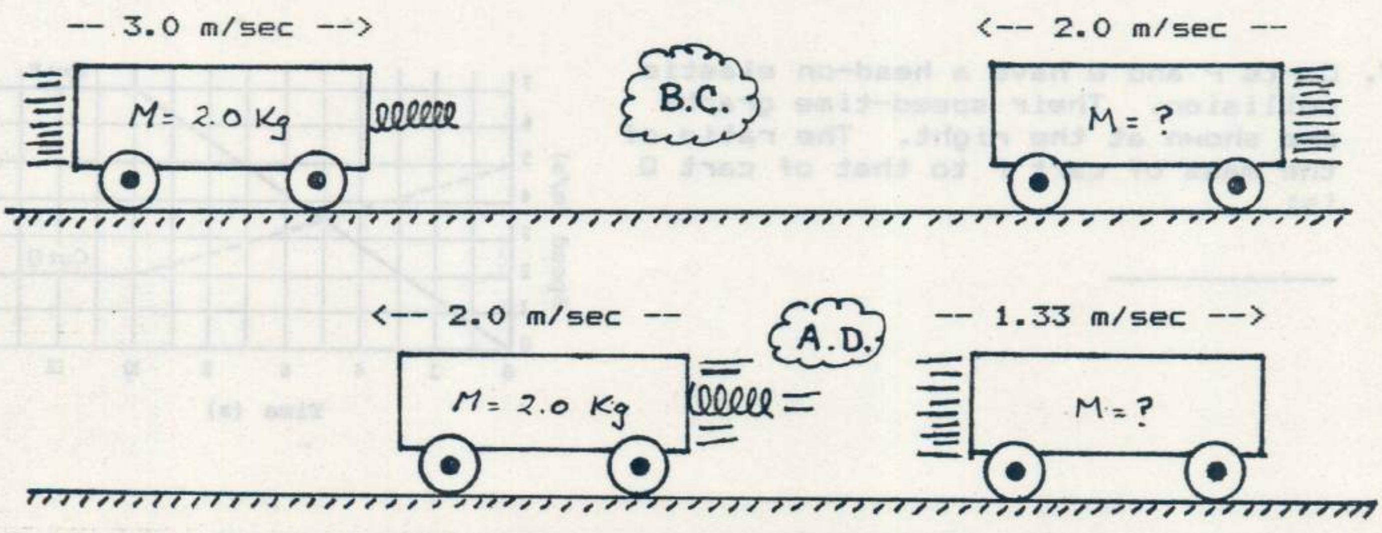
1. Three identical masses are close together and at rest on a horizontal frictionless table, when an explosion drives them apart. The sketch to the right (top view) taken a moment later shows two of the masses. Where is the third?



2. In the above problem, where would the third mass be if its mass were twice as large as the other two.

3. A 2.0-kg mass (A) collides with a second mass (B) of 3.0-kg which are moving as shown. Find the velocity of the carts after the collision. Assume the collision is perfectly inelastic (i.e. carts stick together upon collision).

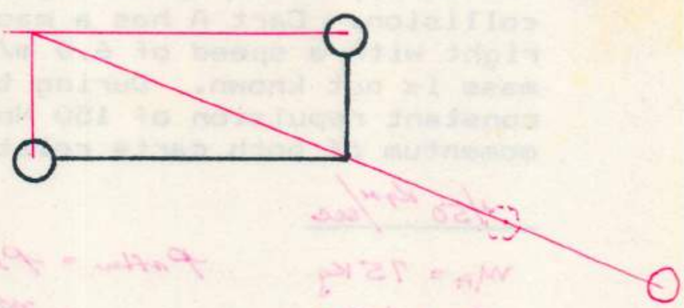
4. Find the mass of the cart on the right that would under go collision shown below. Assume the collision is perfectly elastic.



Chapter 6 Quiz Sections 3 & 4

Correct

1. Three identical masses are close together and at rest on a horizontal frictionless table, when an explosion drives them apart. The sketch to the right (top view) taken a moment later shows two of the masses. Where is the third?

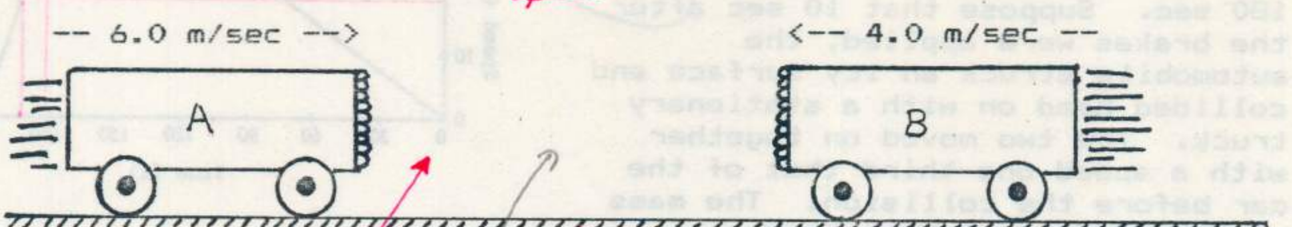


2. In the above problem, where would the third mass be if its mass were twice as large as the other two.

$\frac{1}{2}$ as far

3. A 2.0-kg mass (A) collides with a second mass (B) of 3.0-kg which are moving as shown. Find the velocity of the carts after the collision. Assume the collision is perfectly inelastic (i.e. carts stick together upon collision).

$v_f = 0$



$m_1 = 2.0\,Kg$, $m_2 = 3.0\,Kg$, $v_i = 6.0\frac{m}{s}\rightarrow$, $v_f = 4.0\frac{m}{s}\leftarrow$, $v_{after} = ?$

$\frac{m_1 v_1 + m_2 v_2}{m_1 + m_2} = (m_1 + m_2) v_f$

$\frac{2.0Kg \cdot 6.0\frac{m}{s} - 3.0Kg \cdot -4\frac{m}{s}}{2.0\,Kg + 3.0\,Kg}$

$\frac{12\,Kg\frac{m}{s} - 12\frac{Kgm}{s}}{5\,Kg} = 0$

$m_1 = 2.0\,Kg$, $m_2 = ?$, $v_1 = 3.0\frac{m}{s}$, $v_2 = -2\frac{m}{s}$, $v_1' = -2\frac{m}{s}$, $v_2' = 1.33\frac{m}{s}$

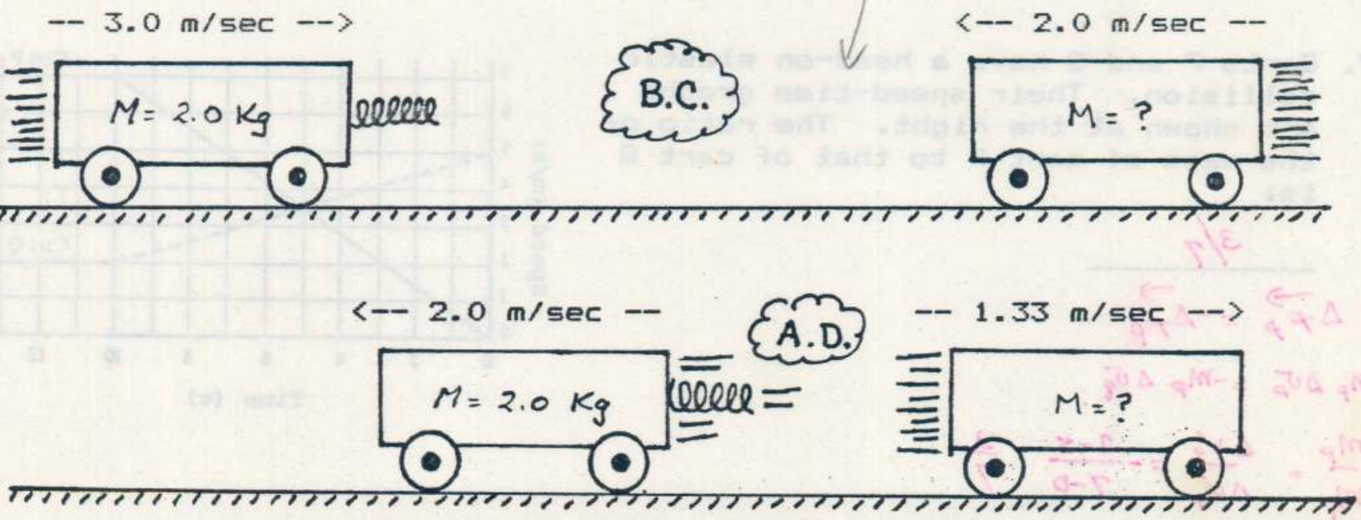
$m_1 v_1 + m_2 v_2 = m_1 v_1' + m_2 v_2'$

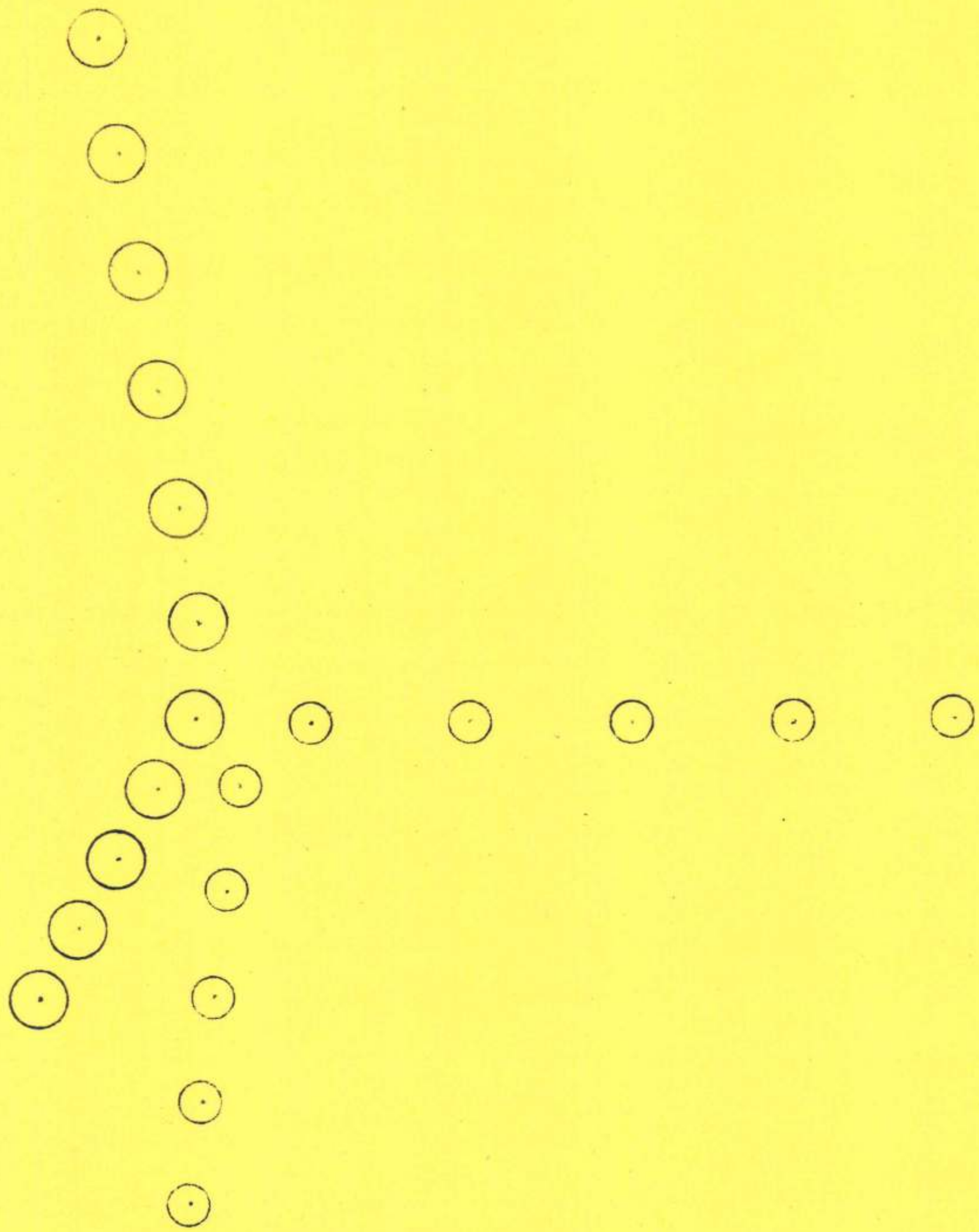
$m_1 v_1 - m_1 v_1' = m_2 v_2' - m_2 v_2$

$\frac{m_1(v_1 - v_1')}{v_2' - v_2} = m_2$

$\frac{2.0Kg(3.0\frac{m}{s} + 2\frac{m}{s})}{1.33 + 2\frac{m}{s}} = \frac{2.0\,Kg \cdot 5}{3.33} = 3\,Kg$

4. Find the mass of the cart on the right that would under go collision shown below. Assume the collision is perfectly elastic.





Some Questions About Momentum

1. Discuss the advisability of attempting to jump from a rowboat to a dock that seems just within jumping distance.

2. In terms of impulse and momentum, why are padded dashboards safer in automobiles?

3. In terms of impulse and momentum, why are nylon ropes, which stretch considerably under stress, favored by mountain climbers?

4. The apple that is said to have dropped on the head of Isaac Newton may have weighed about 1 newton. The force of impact, however, would have been considerably greater than 1 newton. Why?

5. Why does a judo expert slap the mat when she has been thrown to the floor?

6. A fully dressed person is at rest in the middle of a pond on perfectly frictionless ice and must get to shore. How is this accomplished?

7. Why is it difficult for a fire-fighter to hold a hose that ejects large amounts of high speed water?

8. Would you care to fire a gun that has a bullet ten times the mass of the gun? Explain.

9. When traveling in your car at highway speed the momentum of a bug is suddenly changed in momentum as it splatters into your windshield. Compared to the momentum change of the bug, how does the momentum of the car change?

10. Would a head-on collision between two cars be more damaging to the occupants if the cars stick together or if the cars rebound upon impact?

11. Suppose you throw a ball against a wall and catch it on the rebound. How many impulses are applied to the ball? Why is the impulse against the wall greatest?

12. If an astronaut on a "space walk" fires a rifle, what kind of motion will he experience?

13. If the polar ice caps melted, how would this affect the length of the day?

14. Why when you strike a normal brick does it hurt more that when you strike a rubber brick?

15. Why does a long-jumper build up all the speed he can get before his jump, whereas a high-jumper runs fairly slowly?

16. Why is follow-through more important when hitting a softball than when hitting a baseball.

17. In 1854 an Englishman, J. Howard long-jumped 29 ft, 7 in with the help of two 5-lb weights. It took another 114 years before Bob Beamon broke the 29 ft mark without the aid of weights. How did the Englishman do it?

The Cart and the Book

What happens when a book is dropped on a moving cart as the cart passes beneath the book? Load a cart with one book and push it firmly across the table. Have your partner hold another book and drop it onto the cart as it passes beneath his or her hand (Figure 1). Practice this several times until you have found the right initial velocity to give a sufficient velocity after the collision. Your partner will also need practice in dropping the book so that it lands firmly and squarely on the loaded cart. It is only necessary to hold the book a few centimeters above the loaded cart. Make sure the book has no horizontal motion when it is dropped.

Hook the cart to the timer tape and make a run. From the timer tape, first locate the region where the book was dropped. Next measure the distance between each tick before and after the interaction to determine the constant speed just before and after the book was dropped. From this and the masses of the loaded cart and book, compute the momentum of the system of loaded cart and book before and after the collision. Also compute the change in momentum of the loaded cart and the horizontal change in momentum of the dropped book. Is momentum conserved in this interaction? Note...Let the units of momentum be grams-cm/tick.

What is the horizontal impulse applied to the falling book? Try to estimate the length of time of the interaction by examining the tape. Can you make a rough estimate of the horizontal force applied to the falling book? How does this compare with the force the book applied to the cart?

What happened to the vertical momentum of the book? Would it make any difference if the book were dropped from different heights as long as you didn't break the cart or the table?

What would happen if, instead of dropping the book on the cart, you suspended a funnel full of sand above the table and let the sand run into a box on the cart as it passes beneath the funnel? What would happen to the velocity of the cart if, instead of letting the sand run into the cart, you let the sand run out of it?

Make a couple more runs with different numbers of books on the cart and make the same measurements and calculations as before.

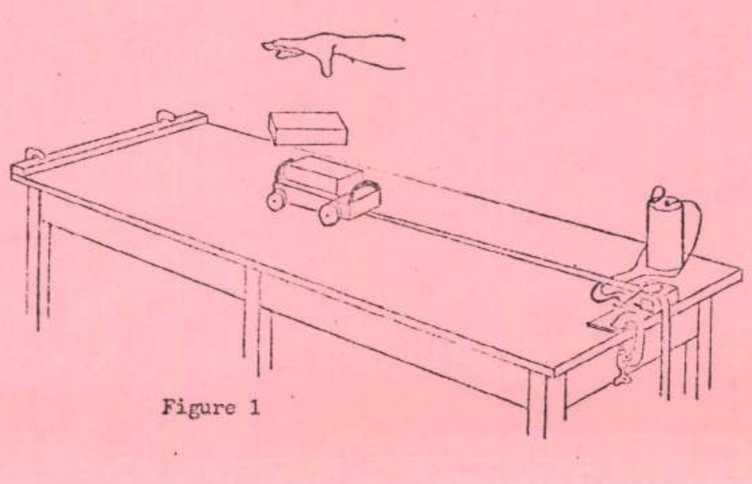


Figure 1

Collision in Two-Dimensions

WHAT YOU NEED TO KNOW

If an object is part of a system of constant mass on which no external forces can act, the object is said to be in a closed system. What happens inside the system does not affect anything outside the system, nor does anything outside the system affect the objects in the system. In a previous experiment you observed that a moving object has momentum 'p' (plural momenta), which is defined as the product of its mass 'm' and its velocity 'v'; that is, $p = mv$. Since velocity is a vector quantity (having both magnitude and direction), momentum is also a vector quantity. Physicists have learned that the total momentum of all the objects in a closed system is constant. The statement is known as the law of conservation of momentum. It is one of the most powerful principles of physics.

Consider two objects in a closed system, one stationary and the other moving toward it. If the objects collide and rebound, then the moving object may slow down, stop, or reverse its direction, and the stationary object may be set in motion. The extent of these changes in the motions depends upon the masses of the two objects and the original velocity of the moving object. According to the law of conservation of momentum, the combined momenta of the two objects after collision must equal the momentum of the moving object before collision. Thus, the momentum gained by the stationary object must be equal to the momentum lost by the moving object.

STRATEGY

You will allow a steel sphere to roll down an incline. The sphere gathers momentum as it rolls. You will measure its momentum at the bottom of the incline. The steel sphere is rolled down the incline additional times and allowed to collide with a stationary sphere, positioned at the bottom of the incline, first head on and then at various angles. Momentum is transferred from the incident steel sphere to the target steel sphere.

By measuring the momentum of each sphere after collision and comparing the total momentum before and after collision, you will determine whether momentum is conserved.

Finally, you will allow the steel sphere to roll down the incline and strike a glass sphere. Using the conservation of momentum principle, you will find the mass of the steel sphere as a function of the mass of the glass sphere. When the calculations are completed, you will be allowed to measure the mass of both the glass and steel spheres.

GETTING STARTED

Set up the equipment as in Figure 1. Place the incident sphere as high on the track as possible and use this position as the starting point for all parts of the experiment. The bottom of the track must be absolutely horizontal so that, upon leaving the track, the sphere will have only horizontal velocity. Position the set-screw so that the distance between it and the edge of the track is 1.5 diameters of the sphere shown in Figure 2. Adjust the height of the set screw so that the incident steel sphere just clears the screw.

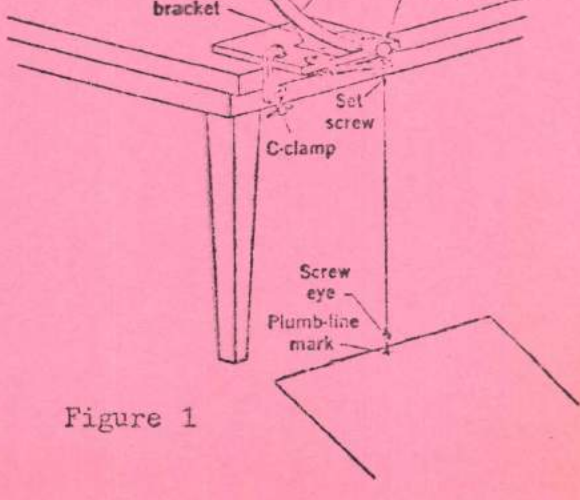


Figure 1

To find the point of impact of the sphere with the floor, make a record on paper as follows. Tape a sheet of large paper to the floor as shown in Figure 1. The sheet must not move until the experiment is finished. Carbon paper can be placed face down over the sheet whenever you wish to record a collision.

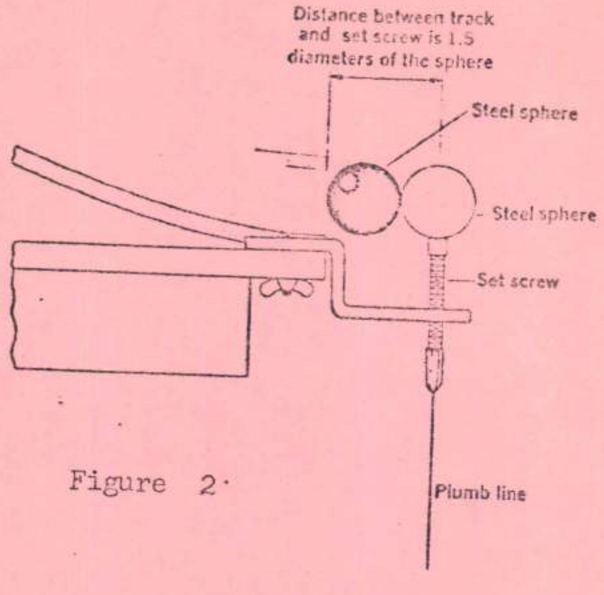


Figure 2·

As the steel sphere rolls down the ramp it collides with a second sphere and both fall to the floor where their distances from the point of collision are measured. Since both the incident and target sphere fall the same vertical distance, they both reach the floor in the same time. Thus the horizontal distance the ball travels during the time of fall will depend only upon the horizontal velocity of the spheres. This horizontal distance will be the distance from the point on the floor directly below the ball when the collision occurs and the point where the sphere lands.

When equal masses are used, the horizontal distance traveled by each sphere represents the momentum of that sphere.

$$\vec{p}_h = m \cdot \vec{v}_h = \frac{m \cdot \Delta \vec{d}_h}{\Delta t}$$

$\vec{p}_h \propto \vec{d}_h$ because both mass and Δt are constant

DOING THE EXPERIMENT

A. Momentum Before the Collision

On the paper locate the position of the screw-eye. One student allows the steel sphere to roll down the track onto the paper. "Do not push the sphere." A second student catches the sphere after the first bounce. Once the position of the sphere strikes the paper is known, carbon paper can be placed face down and several runs made. Make sure the sphere always starts from the same starting spot. Draw a circle around the group of landing points. Draw a line from the plumb-line mark to a spot on the circle which you consider to be the average. Measure and record this distance which represents the initial momentum of the steel sphere.

B. Momentum After Collision

Place a second steel sphere on the set-screw. Permit the steel sphere to roll down the track from the same starting point used in part A. After collision, the target sphere should strike the paper on a line drawn between the point below the screw-eye and the average landing point determined in part A. If not, adjust the set-screw until it does. The incident sphere should strike the set-screw bracket and bounce off. Thus the position it strikes the paper is of no value. Make several runs and record the landing positions. Remove the carbon paper, circle the group of landing points, measure and record the average distance that the target sphere moved after collision. Compare this distance to the distance found in part A. What can you conclude about the conservation of momentum when two equal masses collide head-on?

Now adjust the position of the set-screw so that the incident sphere will collide with the target sphere at an angle (see Figure 3). Mark the point on the paper directly below the new position of the set-screw. With a steel ball balanced on the set-screw, try several collisions, releasing the incident ball from the same point as before. To change the point of collision for a different run, turn the arm supporting the target ball through a small angle. Remember to mark the new position of the target sphere whenever its position is changed.

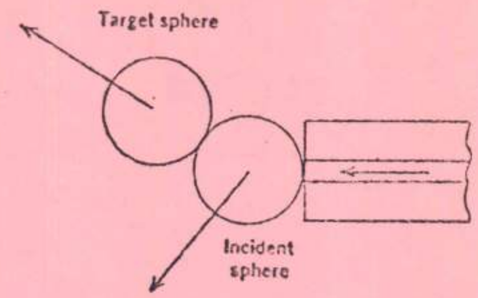


Figure 3 A glancing collision

For each different angle collision, draw a vector from the position of the plumb bob to the point where the target sphere hit the paper. Draw a second vector from the position of the incident sphere when it collided with the target sphere and the point where it strikes the paper. The position of the target sphere at the instant of impact can be determined with the help of Figure 4.

Add the two displacement vectors representing momentum graphically on the paper, placing the tail of the vector of the target ball at the head of the vector of the incident ball.

How does the vector sum of the two final momenta compare with the initial momentum of the incident ball? Is momentum conserved in these interactions? How does the arithmetic sum of the two magnitudes of the momenta after the collision compare with the magnitude of initial momentum of the incident ball?

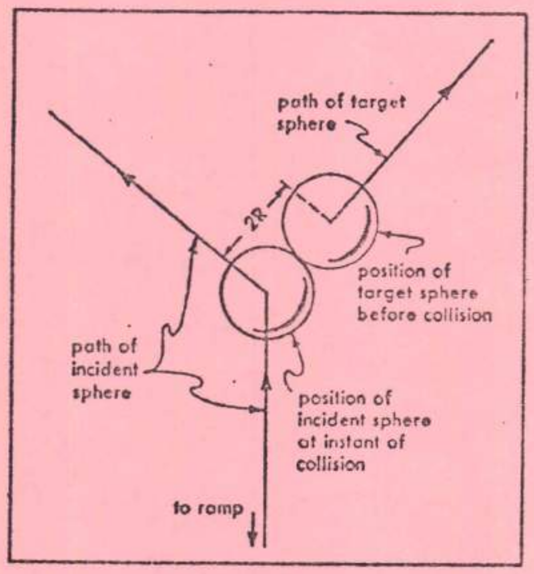
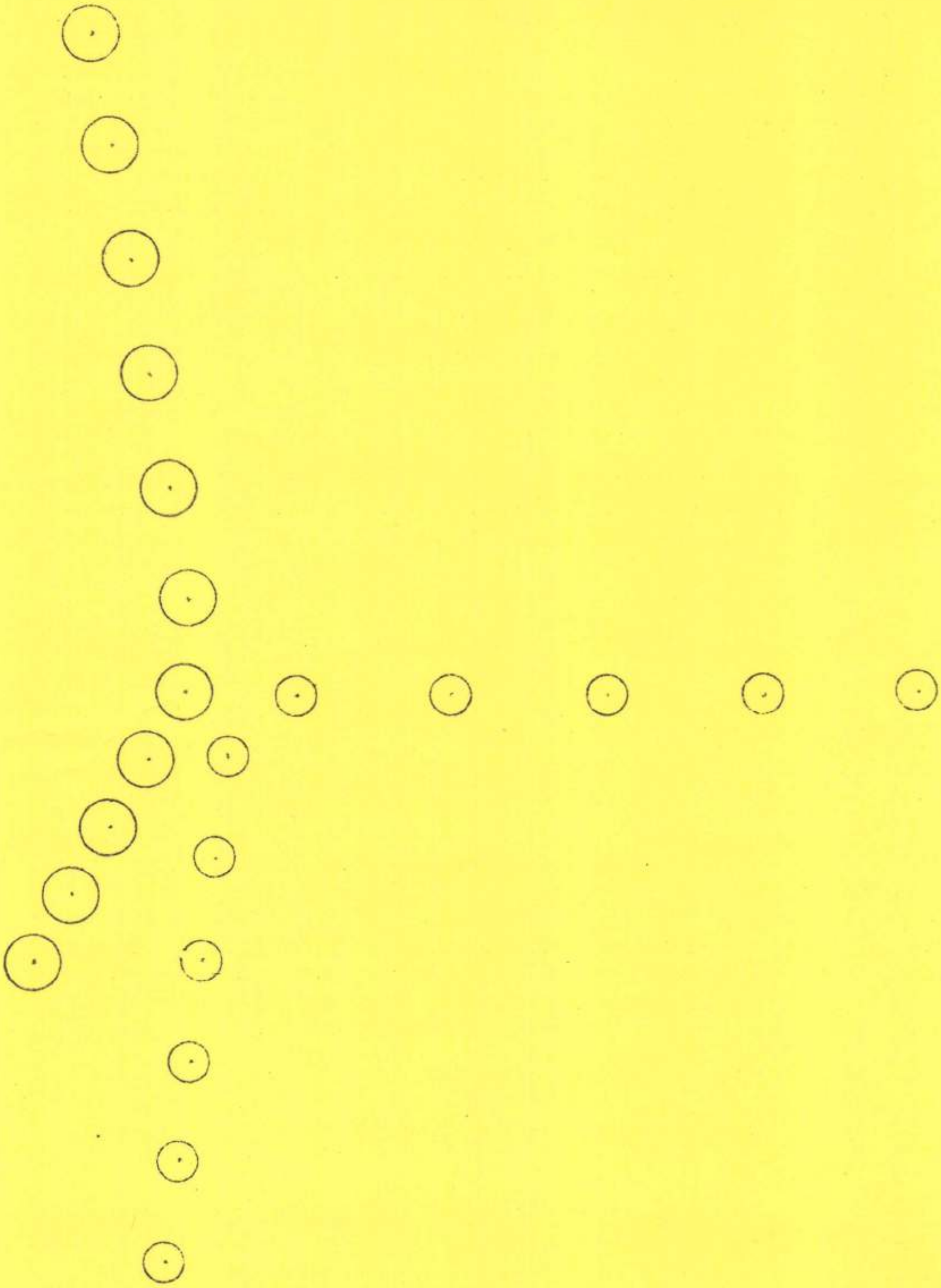


Figure 4

Repeat the experiment using two spheres, one steel and one glass of the same size. Which one should be used as the incident sphere? How does the vector sum of the displacements vectors of the two spheres after collision compare to the initial displacement vector of the sphere before the collision.

Since the masses are not the same, how can the displacement vectors be converted to represent momentum vectors? Once done, determine the mass of the steel sphere as a function of the glass sphere. Report your findings to your instructor. Then you will be allowed to measure the masses of the two spheres on an electronic balance.



AMPAD EFFICIENCY® LINE NO. 6636

	1	2	3	4	5	6	7	8	9	10	11	12	13
	(Kg)	(M/sec)	Kg M/sec	Kg M/sec	Kg	M/sec	M/sec	p_f					
	m_i	v_i	p_i	Δp	m_f	Δv	V_f	p_f	Δp	$p_{75\,Kg}$	$p_{60\,Kg}$		
	1490	300	447,000	1875	1415	1.325	301.325	426,375	20,625	20,625		75 Kg x 275 M/sec	
	1415	301.325	426,375	1800	1355	1.328	302.654	410,095	16,280		16,280	60 Kg x 271.33	
	1355	302.654	410,095	1750	1305	1.341	303.994	396,713	13,382			13,382	50 x 267.65

	$\vec{p}$		m	v
p_f	396,713	=	1305	x 303.994
p_{EQUD}	20,625		75	275
$p_{ENGLISH}$	16,280		60	271.33
$p_{Chinese}$	13,382		50	267.65
p_{TOTAL}	447,000			

$\Delta d = \Delta v\, t$

3.994 M/sec

x 1 hr = 1.44×10^4 M

x 1 day = 3.45×10^5 M

x 1 yr = 1.26×10^8 M

OBJECTIVES: Ch. 22 PSSC Physics
"Momentum and the Conservation of Momentum"

You must be able to:

( ) 1. a) Define "impulse" and offer an example of this concept.
b) Define "momentum" and offer a number example of this concept.

( ) 2. a) With a given amount of impulse, be able to compute the change in momentum that a body will acquire and also its change in velocity.
b) With a given amount of momentum change desired, be able to compute the impulse that will do this.

( ) 3. Collision problem: A car of say, 1000 kg mass, moving at 30 m/sec strikes a motionless car of say, 1500 kg mass. Be able to compute the speed and direction of the combined wreckage. Assume a direct hit.

( ) 4. Problem of the specific type of #17 (collision)

( ) 5. a) State, in "plain English", or your own words, the law of Conservation of Momentum.
b) State the above as an equation.
c) Illustrate this concept with a sketch and with number example.

( ) 6. Starting with Newton's law, F= ma, derive (showing all steps) the Impulse-Momentum Equation.

( ) 7. Problem of the specific type of #24.
(Hint: changes in velocity are expressed as $\overrightarrow{\Delta V} = \overrightarrow{V_2} - \overrightarrow{V_1}$

( ) 8. Problem of the specific type of #26.

( ) 9. a) State Newton's law (action-reaction) in your own words.
b) State the above as an equation.
c) Show, by steps that the Conservation of Momentum equation may be transformed into the above.
d) Offer a word or story ~~of~~ example of this concept.

_______ OBJECTIVES of 9 for _____%. Each item counts 11%

MOMENTUM TEST CHAPTER 6 -1- NAME KEY

1.		(B)	(C)	(D)	(E)	10.	(A)	(B)	(C)		(E)	19.	(A)	(B)		(D)	(E)
2.	(A)	(B)		(D)	(E)	11.	(A)	(B)	(C)		(E)	20.	(A)	(B)	(C)	(D)	
3.	(A)		(C)	(D)	(E)	12.	(A)	(B)		(D)	(E)	21.	(A)	(B)		(D)	(E)
4.	(A)	(B)		(D)	(E)	13.	(A)	(B)	(C)	(D)		22.	(A)		(C)	(D)	(E)
5.	(A)	(B)		(D)	(E)	14.	(A)		(C)	(D)	(E)	23.		(B)	(C)	(D)	(E)
6.		(B)	(C)	(D)	(E)	15.	(A)		(C)	(D)	(E)	24.	(A)	(B)	(C)	(D)	
7.	(A)	(B)		(D)	(E)	16.	(A)	(B)		(D)	(E)	25.	(A)	(B)		(D)	(E)
8.	(A)	(B)		(D)	(E)	17.	(A)		(C)	(D)	(E)	26.	(A)		(C)	(D)	(E)
9.	(A)		(C)	(D)	(E)	18.	(A)	(B)		(D)	(E)						

1. A 4 kg body has been accelerated by a constant force of 12 N from 15 m/sec to 24 m/sec.
   a. What impulse was given to the body?
   b. How long was the force acting?

a. $36 \frac{kg\,m}{sec}$ b. 3 sec

$m = 4kg$ $F = 12N$ $I = \Delta p = m(v_f - v_i)$ $I = F\Delta t$

$v_i = 15\frac{m}{s}$ $4kg(24\frac{m}{s} - 15\frac{m}{s})$ $\Delta t = \frac{I}{F} = \frac{36\ kg\,m/sec}{12\ kg\,m/sec^2}$

$v_f = 24\frac{m}{s}$ $4kg\ 9\frac{m}{s}$

2. A proton (mass 1.87×10^{-27} kg) with a speed of 1.0×10^{7} m/s collides with a motionless helium nucleus. The proton bounces back with a speed of 6.0×10^{6} m/sec. The helium nucleus moves forward with a speed of 4.0×10^{6} m/sec after the bombardment. Compute the mass of the helium nucleus.

7.48×10^{-27} kg

$p_B = p_A$

$p_p = p_p' + p_H$

PROTON HE

$p_H = p_p - p_p'$

$m = 1.87 \times 10^{-27}$ kg $m = ?$ $m_H v_H = m_p(v_p - v_p')$

$v_i = 1.0 \times 10^7$ m/s $v_i = 0$ $\frac{m_p(v_p - v_p')}{v_H}$

$v_f = -6.0 \times 10^6 \frac{m}{s}$ $v_f = 4.0 \times 10^6 \frac{m}{s}$ $= \frac{1.87 \times 10^{-27} kg\,(1.0 \times 10^7 \frac{m}{s} + 6.0 \times 10^6 \frac{m}{s})}{4.0 \times 10^6\ m/s}$

3. A stationary refrigerator car with mass 28,000 kg is rammed by a loaded gondola car with mass 32,000 kg. Before impact, the gondola car was going 2.0 m/sec. If they lock together, what is the new velocity?

a. $1.07 \frac{m}{s}$

$p_g = (m_g + m_R)v$

REF GOND

$v = \frac{m_g v_g}{m_g + m_R} = \frac{3.2 \times 10^4 kg \times 2\frac{m}{s}}{(2.8 + 3.2) \times 10^4 kg}$

$m = 2.8 \times 10^4$ kg $m = 3.2 \times 10^4$ kg 6.0

$v_i = 0$ $v_i = 2.0$ m/s

$v_f =$

4. A railroad freight car with a mass of 52,000 kg is rolling along a level track at 0.30 m/s (0.7 mi/hr). A rope trails behind it. A reasonable estimate of the largest force you could apply to stop the car by pulling on the rope is 250 N.
   a. How long would it take you to bring the car to rest?
   b. Ten meters from the point where you start pulling, another car is standing. Will there be a crash? Show proof that supports your answer.

a. 62.4 sec

b. NO

$d = ?$ $d = \frac{1}{2}t(v_f + v_i)$

$v_i = .3$ m/s

$v_f = 0$ $\frac{1}{2} \times 62.4s \times .3\frac{m}{s}$

a

$t = 62.4$

$d = 9.36$ M

$m = 5.2 \times 10^4$ kg $F = 250N$

$v_i = 0.30 \frac{m}{s}$ $t = ?$

$v_f = 0$

$F\Delta t = m\Delta v$

$t = \frac{m v_i}{F} = \frac{5.2 \times 10^4 kg \times 0.30 \frac{m}{s}}{250 N}$

8. A heavy truck and a small car both roll down a hill. If friction is negligible, at the bottom of the hill the heavy truck will have the greater
   a. velocity
   b. acceleration
   c. momentum
   d. all of these
   e. none of these

9. When a ball player catches a ball, he moves his hand backward in the direction of the ball's motion as he catches it. This reduces the force of impact on his hand principally because
   a. the resultant velocity of impact is lessened
   b. the time of impact is increased
   c. the momentum of impact is reduced
   d. "riding with the punch," so to speak, always results in a lessening of the force of impact
   e. none of the above

10. Most often a greater stopping force is required to stop a moving truck than a moving automobile traveling at the same speed. But considerably more stopping force may be required to stop the smaller car depending on
   a. a prolonged impulse
   b. its mass
   c. its momentum compared to the momentum of the truck
   d. a shorter stopping time
   e. whether or not internal forces contribute to a stopping impulse

11. The velocity of a bullet will be equal and opposite to the velocity of the recoiling gun
   a. because momentum is conserved
   b. because velocity is conserved in this case
   c. because both momentum and velocity are conserved in all cases
   d. if the weight of the bullet equals the weight of the rifle
   e. none of these

12. Padded dashboards in cars are safer than nonpadded ones because they
   a. are softer
   b. lessen impulse due to their "give"
   c. extend the time during which the momentum of an occupant is reduced
   d. all of these
   e. none of these

13. The force of impact of an apple that falls on your head depends upon the
   a. weight of the apple
   b. speed of the apple
   c. time during impact
   d. whether or not the apple bounces
   e. all of these

14. When you jump from an elevated position you usually bend your knees upon meeting the ground and thereby extend the time your momentum is reduced by about 10 times that of a stiff-legged landing. In this way the average forces your body experiences are reduced
   a. less than 10 times
   b. about 10 times
   c. more than 10 times
   d. none of the above
   e. all of the above

15. Momentum is imparted to the ground when an apple falls upon it. The momentum is
   a. negligible compared to the momentum of the apple
   b. greater than that of the apple if the apple bounces
   c. equal and opposite to the momentum of the apple just before impact
   d. none of these
   e. all of these

16. According to the impulse-momentum equation Ft = change in (mv), a person will suffer less injury falling on a wooden floor which "gives" than on a more rigid cement floor. The "F" in the above equation stands for the force exerted on the
   a. person
   b. floor
   c. either of these
   d. neither of these

17. If all of the people, animals, trains and trucks all over the world began to walk or run towards the east, then the
   a. earth would spin faster
   b. the earth would spin slower
   c. the spin would not be affected, even in the most minute way
   d. all of the above
   e. none of the above

18. Our recoil is noticeable if we throw a heavy ball while standing on roller skates. If we instead go through the motions of throwing the ball but hold onto it, our recoil will be
   a. smaller but still noticeable
   b. as if we threw the ball
   c. a net zero
   d. all of the above
   e. none of the above

19. A heavy truck and a small car rolling down a hill at the same speed are forced to a stop. Compared to the force that halts the small car, the force to bring the heavy truck to rest
   a. must be greater
   b. must be the same
   c. may be smaller

20. When a 1-newton apple falls to the ground, it strikes with an impact force of about
   a. 1 N   b. 2 N
   c. 4 N   d. 9.8 N
   e. not enough information to say

 NAME Error

21. A karate expert executes a swift blow and severs a cement block with her bare hand. It is interesting to note that the
    a. impulse on both the block and her hand have the same magnitude
    b. force on both the block and her hand have the same momentum magnitude
    c. both of these
    d. none of these

22. A chunk of putty moving with 1 unit of momentum strikes a heavy bowling ball that is initially at rest and free to move. After the putty sticks to the ball, both are set in motion with a combined momentum that must be
    a. less than 1 unit
    b. 1 unit
    c. more than 1 unit
    d. not enough information is given to say

23. A 1-kg chunk of putty moving at 1 m/sec collides with and sticks to a 5-kg bowling ball that is initially at rest and free to move. The bowling ball with the putty sticking to it is set in motion with a momentum of
    a. 1 kg-m/sec
    b. 5 kg-m/sec
    c. 1/6 kg-m/sec
    d. 6 kg-m/sec
    e. not enough information to say

24. A 1-kg chunk of putty collides with and sticks to a 5-kg bowling ball that is initially at rest and free to move. The bowling ball with its putty is then set in motion with a speed of
    a. 1 m/sec
    b. 5 m/sec
    c. 1/6 m/sec
    d. 1/5 m/sec
    e. not enough information to say

25. You're driving down the highway and a bug spatters into your windshield. Which undergoes the greater change in momentum?
    a. the bug
    b. your car
    c. both the same
    d. none of the above
    e. not enough information to say

26. Suppose an astronaut in outer space wishes to play a solitary "throw-bounce-and catch" game by tossing a ball against a very massive and perfectly elastic concrete wall. If the ball is as massive as the astronaut
    a. she will catch only one bounce, but never a second
    b. she will never catch the first bounce
    c. her time between catches will decrease as the game progresses
    d. her time between catches will increase as the game progresses

Chapter 6 WRITTEN EXERCISE

In connection with a United Nations sponsored expedition to the moon, a group of four men (100-kg Russian, 80-kg American, 60-kg Englishman, and a 50-kg Chinese) in a big 1200-kg capsule blast off from the moon on the return trip to the earth. A problem arose when it was discovered that they did not possess sufficiently high enough velocity to reach earth before their oxygen gave out. The velocity of the capsule, men, equipment, etc. is 300 m/sec.

Note...The mass of the capsule given is the mass remaining after blast off from the moon and does not include the mass of the men.

1. The American thought for a while and decided that if 75-kg of equipment was thrown out in pieces behind them at a velocity of 25 m/sec this would increase their forward velocity.
   a. What additional momentum did it add to the capsule?
   b. What was their new velocity?
   c. Account for all momentum as this is a closed system and none is lost.

   a. ______________

   b. ______________

   c. ______________________________

2. After a short period it became increasingly apparent that sufficient weight had not been ejected out the rear of the capsule. Not willing to sacrifice valuable equipment containing their moon trip's information, the Englishman ran courageously out the rear door of the capsule at 30 m/sec shouting "God save the Queen!"
   a. What additional momentum did he impart to the capsule?
   b. What was their new velocity?
   c. Account for all momentum.

   a. ______________

   b. ______________

   c. ______________________________

3. Time passed slowly but it became apparent to the Russian that the capsule could bring its cargo back safely if it could gain a very small additional velocity. Remembering what the Englishman did, he went to the back of the capsule and opened the door. Then with a tremendous effort which realized a velocity of 35 m/sec, he shouted "Long live Lenin" as he threw the Chinese out.

   a. What additional momentum did this add to the space ship?
   b. What was the capsule's final velocity?
   c. What is the capsule's and remaining contents final momentum?

   a. ______________

   b. ______________

   c. ______________

Chapter 6 WRITTEN EXERCISE

In connection with a United Nations sponsored expedition to the moon, a group of four men (100-kg Russian, 80-kg American, 60-kg Englishman, and a 50-kg Chinese) in a big 1200-kg capsule blast off from the moon on the return trip to the earth. A problem arose when it was discovered that they did not possess sufficiently high enough velocity to reach earth before their oxygen gave out. The velocity of the capsule, men, equipment, etc. is 300 m/sec.

Note...The mass of the capsule given is the mass remaining after blast off from the moon and does not include the mass of the men.

1. The American thought for a while and decided that if 75-kg of equipment was thrown out in pieces behind them at a velocity of 25 m/sec this would increase their forward velocity. — relative to capsule
   a. What additional momentum did it add to the capsule?
   b. What was their new velocity?
   c. Account for all momentum as this is a closed system and none is lost.

   a. 1875 Kg M/sec
   b. 301.325 M/sec
   c. 426,375 Kg M/sec (capsule) + 20,625 Kg M/sec (equipment)

2. After a short period it became increasingly apparent that sufficient weight had not been ejected out the rear of the capsule. Not willing to sacrifice valuable equipment containing their moon trip's information, the Englishman ran courageously out the rear door of the capsule at 30 m/sec shouting "God save the Queen!"
   a. What additional momentum did he impart to the capsule?
   b. What was their new velocity?
   c. Account for all momentum.

   a. 1800 Kg M/sec
   b. 302.654 M/sec
   c. 410,095 Kg M/sec + 16,280 Kg M/sec (Englishman)

3. Time passed slowly but it became apparent to the Russian that the capsule could bring its cargo back safely if it could gain a very small additional velocity. Remembering what the Englishman did, he went to the back of the capsule and opened the door. Then with a tremendous effort which realized a velocity of 35 m/sec, he shouted "Long live Lenin" as he threw the Chinese out.
   a. What additional momentum did this add to the space ship?
   b. What was the capsule's final velocity?
   c. What is the capsule's and remaining contents final momentum?
   d. Where is the remaining momentum?

   a. 1750 Kg M/sec
   b. 303.994 M/sec
   c. 396,713 Kg M/sec + 13,382 Kg M/sec (Chinese)
   d. ______

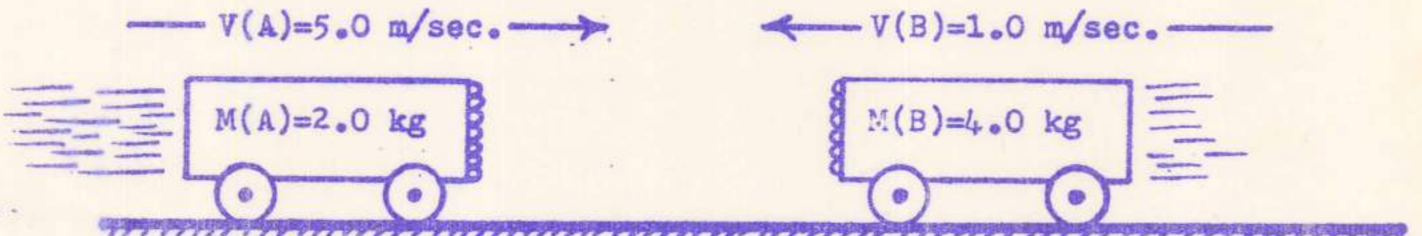
PSSC PHYSICS QUIZ #______ NAME Jim Nelson - Not Used.

MOMENTUM (CH. 14) DATE ______
(need ruler)

1. A 10-gram bullet is fired with a muzzle speed of 10,000 meter/second from a freely suspended (like a pendulum) gun of 2 kilograms. What is the recoil speed of the gun? (1 pt.)

2. On the drawing you are given find the following:* Assume that drawing is to scale. (Note: You don't need to give directions of vector if you draw and label them carefully; however, you do need to give numerical values for a, b, c below.) (4 pts.)
   A) change of velocity of object A
   B) change of momentum of object A
   C) mass of object B (given mass of A) mass of A = 2.0kg
   D) show motion of center of mass of system on diagram from beginning to end.

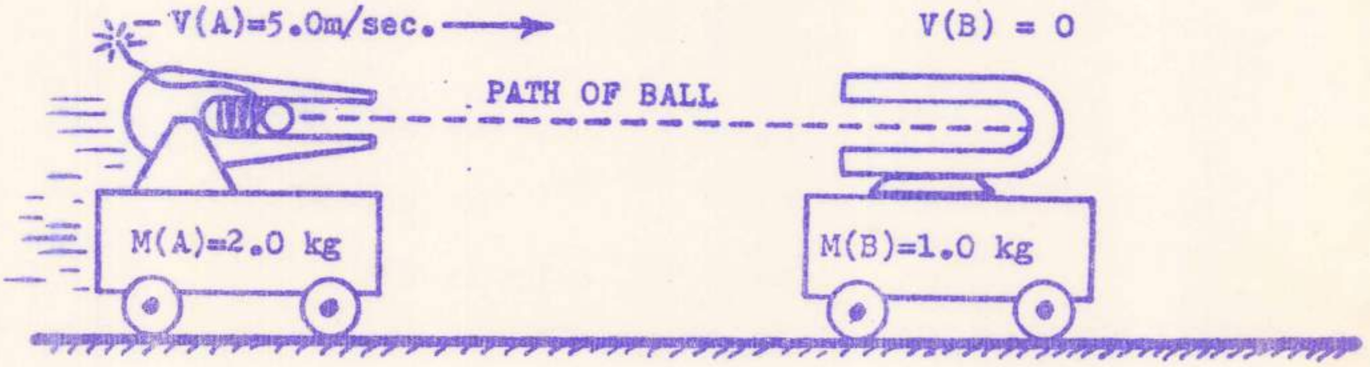
3. Two carts are moving as shown below:



If the collision is perfectly inelastic (i.e. carts stick together upon collision), what will be the velocity of the carts after they collide? (2 pts.)

Use

4. Carts A & B roll without friction on a straight level track. Initially cart A moves to the right with velocity 5 meters/second, while B is at rest. A ball of mass 0.5 kg. is fired from the spring gun on A into a trap on B, where it sticks. The masses of A and B (without ball) are 2 kg. and 1 kg. respectively. If the velocity of A is 2 meters/second toward the right after the ball is fired, what is the velocity of B after the ball is trapped? (show work clearly) (3 pts.)



*SEE PAGES 14 & 15

from the desk of

Dick Heckathorn

"Things Go Better With Science"

CART & THE BOOK

1. HOW DID YOU FIND OUT IF MOMENTUM WAS CONSERVED?
   - TOTAL BEFORE = TOTAL AFTER
   - CHANGE IN CART = "-" CHANGE IN BOOK

WHAT WAS HORIZ. IMPULSE APPLIED TO BOOK?

- $I = \Delta p$

ESTIMATE TIME OF INTERACTION

- # TICKS = ______
- T OF TIMER = ______

DETERMINE HORIZONTAL FORCE ON BOOK

$F = I/t = \Delta p/t$

DETERMINE HORIZ. FORCE ON CART + (BOOKS)

WHAT HAPPENED TO VERTICAL MOMENTUM OF CART?

WHAT IF CHANGED HEIGHT OF DROP?

WHAT IF USED SAND? RUN INTO CART?

WHAT IF LET SAND RUN OUT?

from the desk of

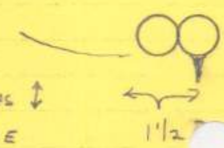
Dick Heckathorn

"Things Go Better With Science"

IS MOMENTUM CONSERVED?

1 ROLL BALL DOWN RAMP
(Represents p_i)

2. HEAD ON : STEEL → STEEL
SET SCREW : 1.5 D away ↔
: SO INCIDENT SPHERE CLEARS ↕
: SO TARGET SPHERE ON LINE
FROM PLUM BOB → FIRST HIT



- compare $d_R(2)$ to $d_R(1)$

3. AT Angle : STEEL - STEEL

4. AT Angle : GLASS - GLASS