

Unit 4: Momentum and Force**Model/Approach: Galilean Space-Time Model****CG 4.1 Using Vectors to represent Force, Velocity, and Other Vector Quantities****Act-4.1.3 Net Force** (includes DLM01 FNT's)**(~70 min)**

Learning Goals:

- Get practice identifying the net Force in various situations
- Get more practice working with vectors; adding/subtracting using the tail-to-head method
- Get more practice working with components and using components to determine net force
- Get practice using sine and cosine to determine components

Model/Approach: Momentum Conservation Model**CG 4.2 Momentum and Impulse****Act-4.2.1 Momentum and Change in Momentum in One Dimension****(~70 min)**

Learning Goals:

- Get practice identifying momentum and change in momentum in simple 1-D collisions
- Get practice identifying impulse
- Get practice representing impulse, momentum, and change in momentum as vectors using the scaled-arrow representation
- Get practice defining and analyzing collisions/interactions, representing conservation of momentum using both the scaled-arrow and vector-equation representations

Announcements

- **Buy your Physics 7B Course Notes** at the **Memorial Union Bookstore**. At the bookstore, you will also need to buy the clicker for the lecture problems/activities; keep your receipt and rebate coupon, and then send for your rebate on the clicker.
- The first **quiz** will be in lecture 2. The quiz will cover all material from the *activities and FNTs* of the first 2 DLs (Discussion/Labs).
- Be sure to check the Physics 7B webpage periodically for new information and material. The FNTs will be available at this site as well as various announcements and all office hours

Net Force: Force Diagrams

A) DLM 1 FNTs

In Your Small Group

- 1) Compare your responses to FNTs (1)-(7) with other members of your small group. For FNT 2 also determine the length of $\Sigma \mathbf{F}$, $\Delta \mathbf{p}$, & $-\Delta \mathbf{p}$.
- 2) Come to a consensus on an appropriate response to each FNT and be able to make convincing reasons why you know for sure your response is appropriate. Each person in your group should be prepared to do this for any of the FNTs.

Whole Class Sharing

B) Phenomenon: You are going to pull on a metal ring with three ropes attached. A spring is attached to each rope to determine the tension in the rope.

1) Helpful hints:

Before you start make sure each scale is set to zero by twisting the knob.

Work together as a group. This takes multiple hands:

Persons 1 and 2 will change their pull direction and magnitude

Person 3 should always pull in the same direction and always read 30N

Attach the ropes with the scales white side up to **read values in Newtons**

Scenario 1: As shown in the upper picture to the right, have person 1 and person 2 pull directly opposite to person 3 with enough force to make the yellow spring scale for the third person read 30N. Record the values on all three scales.

Scenario 2: Persons 1 and 2 each change the direction they are pulling until their ropes make an angle of about **130° with respect to person 3**, as shown in the lower picture to the right. Record the readings of all scales.

To get the angles to be 130°, trace the ring on a sheet of paper and make a vertical line pointing down from it, then use the plastic protractor to mark the 130° angles from the vertical line. Now you can line up the ropes along the lines you drew and then note the force scale readings.

- a) Use the paper with the angles to graphically add the appropriately scaled force vectors (arrows) as accurately as possible. Also show the components.
- b) Make two properly labeled and scaled force diagrams on the board (one for *each* scenario above). See Course Notes, pages 8-9, for labeling conventions.
- c) On the board off to the side of each force diagram, reproduce the vector addition from (a). What is the net force in this case? Why does this make sense?

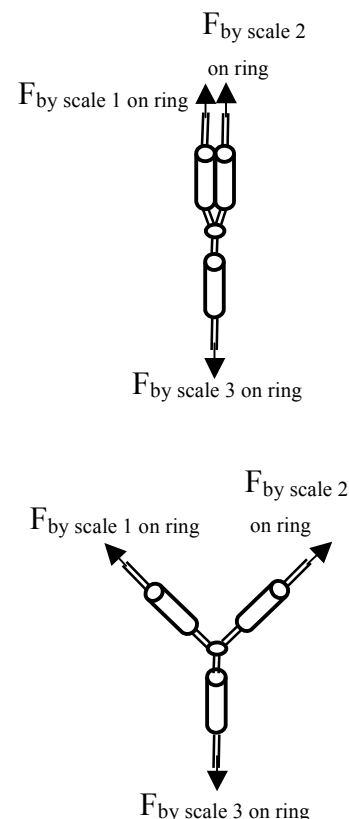
Quick Whole Class Sharing

- d) Use trigonometry (sine and cosine, as appropriate) to find the magnitude of the *components* (x and y) of the two forces, $F_{1 \text{ on ring}}$ and $F_{2 \text{ on ring}}$.
 - i) What is the relation between the components of these two forces and those of the third force?
 - ii) Develop an explanation for this relationship in your small group and be ready to share.
 - iii) Explain why the scale readings changed when the two people pulling parallel separated.

Whole Class Sharing

- 2) You are again going to pull on the metal ring with the three ropes. Start at the same 130° angles as before. With person 3 still reading 30N, have persons 1 and 2 pull with a significantly greater force and your angle apart should widen. Draw a force diagram and repeat the three parts of 1d) above.
- 3) Could two people pull their ropes all the way to 180° apart with the third person still pulling at 30N? Include a force diagram in your response.

Whole Class Sharing



Momentum and Change in Momentum In Two and Three Dimensions

Phenomenon: Impulses and changes in momentum in more than one-dimension.

A) The essential elements of the Momentum Conservation Model: (See page 23-25 of the Course Notes)

Meaning of Impulse

$$\text{Net Impulse}_{\text{ext}} = \Sigma F_{\text{avg ext}} \Delta t = \int \Sigma F_{\text{ext}}(t) dt$$

$$\Delta \mathbf{p}_{\text{system}} = \mathbf{p}_{f \text{ sys}} - \mathbf{p}_{i \text{ sys}} = \text{Net Impulse}_{\text{ext}}$$

Statement of Conservation of Linear Momentum

$$\Delta \mathbf{p}_{\text{system}} = \mathbf{p}_{f \text{ sys}} - \mathbf{p}_{i \text{ sys}} = \mathbf{0} \quad \text{or} \quad (\text{Net Impulse}_{\text{ext}} = 0 \text{ or } \Sigma F_{\text{ext}} = 0)$$

1. In your small group, describe an example of an impulse. Identify two ways you can change this impulse. For instance, how could you make the impulse greater? Describe both a) a system that involves one object and b) a system that involves two interacting objects. Explain what $\Delta \mathbf{p}_{\text{sys}}$ is for each of your physical systems. Put this on the board.
2. In your small group, develop a statement in your own words of what **conservation of momentum** means for your two systems in (1).

B) Representation of Conservation of Momentum with Vectors (See page 25 of Course Notes)

Just as an *energy-system diagram* is useful in helping us work through conservation of energy questions/problems, a *momentum chart* is useful for questions/problems using conservation of momentum. The momentum chart, like an energy-system diagram, helps us keep track of what we know about the interaction, and also helps us see what we do not know.

All momentum charts are to be filled in with scaled arrows representing momentum vectors.

Typically used for collisions/interactions involving two or more objects (also useful for vector components).

Conserved System	\mathbf{p}_i	+	$\Delta \mathbf{p}$	=	\mathbf{p}_f
Object 1					
Object 2					
Total System			0		

For total system: $\Delta \mathbf{p} = 0$

For each object: $\mathbf{p}_i + \Delta \mathbf{p} = \mathbf{p}_f$

*Typically used when the phenomenon involves a **net impulse** acting on the system (also useful for vector components).*

Net Impulse System	\mathbf{p}_i	+	$\Delta \mathbf{p}$	=	\mathbf{p}_f
Total System					

For total system: $\Delta \mathbf{p} = \text{Net Impulse}_{\text{ext}}$

$$\mathbf{p}_i + \Delta \mathbf{p} = \mathbf{p}_f$$

(Show the force diagram here that determines $\Sigma F \Delta t = \text{Net Impulse}_{\text{ext}}$)

Can also write expressions for each momentum vector, such as $\mathbf{p} = m\mathbf{v}$, in additional equations related to the chart.

- 1) On your boards, complete momentum charts for both of your examples from part A.
- 2) Each row and each column is a separate vector equation. Check that every row equation and every column equation is added correctly and is consistent.
- 3) Which column is significant for momentum conservation?
- 4) Determine what parts of the momentum charts are analogous to energy system diagrams. List the analogous parts on the board. In what fundamental way do these diagrams differ?

Momentum and Change in Momentum in One Dimension I

C) Phenomenon - collisions of one cart with another object:

You are going to observe, talk about in your group, and analyze simple collisions in one-dimension using aluminum carts that slide on a long track. **PLEASE be gentle** with the carts and track. Thank you.

Make sure everyone in your group fully understands the ideas behind each question or part in these activities before going on to the next part.

- 1) Arrange a collision so a cart so it sticks to the bumper. Observe the collision several times. Analyze the collision using the Momentum Conservation Model.
 - a) Use vectors to represent the various momenta. Draw on the board a momentum chart. Each column should have appropriately scaled and labeled vectors for either the momentum or the impulse that acted during the collision.
 - b) Write a vector equation for the momentum, off to the side of your chart, with appropriate subscripts on the symbols, to express what you observed during this collision.
 - c) Describe in words what physically happened and how conservation of momentum applies in this situation. Draw a force diagram for the cart for the time when its momentum was changing. Put your diagrams, equation, and word statement on the board, but leave enough space so you can write the responses to (2) for comparison.
- 2) Arrange a collision so a cart bounces off the bumper. Observe the collision several times. Analyze the collision using the Momentum Conservation Model. Do (a), (b) and (c) as in (1)
- 3) When total kinetic energy is conserved in a collision, we call it an *elastic collision*. If it is not conserved, we call it an *inelastic collision*. Classify the two collisions above as elastic or inelastic.
- 4) Does an inelastic collision violate conservation of energy? If not, which other energy systems could the kinetic energy have gone to?
- 5) Is momentum conserved in the inelastic case and the elastic case? Where in your momentum chart is this shown?

FNTs

- 1) Rework the parts of Activities 4.2.1 you are not sure of. Bring your questions to the next DL meeting.
- 2) For each part of this problem suppose that an initial state consists of two of the carts (each with the same mass, m) that you used in this DL. In the initial state, these two carts are moving **toward each other** with the same initial speed, v_i , along the track. These carts collide and the result is some final state. The three parts of this question are concerned with three different final states.
 - (a) Assume that the carts hit each other and stop so that the final state of the system has both carts just sitting still (not moving). Draw a momentum chart for this situation. Is the total kinetic energy before the collision equal to the total kinetic energy after the collision? If not, what energy system might have increased?
 - (b) Assume that the carts bounce off each other so that the final state of the system has each cart moving oppositely to its initial motion but with the **same speed**. Draw a momentum chart for this situation. Is the total kinetic energy before the collision equal to the total kinetic energy after the collision? If not, what energy system might have increased?
 - (c) As in (b) assume that the carts bounce off each other but now assume that the final speed is smaller than the initial speed (but not zero). Can both momentum and kinetic energy be conserved with these smaller speeds?
 - (d) In general, is there any way to conserve both momentum and kinetic energy in this collision if the final speeds are not the same as the initial speeds? Explain.
 - (e) Is the collision in (b) elastic or inelastic? What about the collision in (c)? Explain how you know.
- 3) A rocket works by expelling gas at a high velocity out of the back of the rocket. We are going to treat the rocket as being far away from any gravitational objects.
 - (a) Draw a momentum chart for the rocket expelling gas in space.
 - (b) Use your chart to explain why the rocket accelerates.
 - (c) Does the rocket have to keep expelling gas to stay at a constant speed? Explain.
- 4) Victoria is standing on a boat, during a perfectly calm day. Then Victoria walks from one end of the boat to the other. Draw a momentum chart for this situation. Does the boat move, and if so which way?
- 5). Note: This is a *continuation* of FNT 5 from DLM 1.
Two force vectors (\mathbf{F}_1 and \mathbf{F}_2 , as shown at right) act on a 2 kg object that has an initial velocity \mathbf{v}_i of 3 m/s in the $+x$ direction.
 - (c) Use the xy components of the force you found in (a) to determine the xy components of impulse that would act on the 2 kg object if the forces were applied for a time interval of 0.50 s. Always include units with your answers.
 - (d) Find separately, for each component, the change in velocity of the 2 kg object, due to the impulse from (c).
 - (e) Find the magnitude of the velocity of the object after the impulse as acted and the direction the velocity makes with the positive x -axis.

