Physics 7B

DLM 4 Overview

Unit 4: Momentum and Force

Model/Approach: Momentum Conservation Model

Act-4.2.4 Momentum and Change in Momentum in Two and Three Dimensions II (~70 min)
FNTs 1 – 6 from DLM-3

Learning Goals:

- Get practice identifying momentum and change in momentum in two and three dimensions
- Get practice identifying impulse from the net force in multiples spatial dimensions
- Get practice representing impulse, momentum, and change in momentum as vectors using scaled-arrows in momentum charts.
- Get practice defining and analyzing phenomena that occur in more than one dimension using momentum charts to facilitate using the Momentum Conservation Model

Act-4.2.5 The Importance of Δt in Collisions (~70 min)
Tablecloth activity and FNTs 7-10 from DLM-3

Learning Goals:

- Get practice defining and analyzing phenomena using ***momentum charts*** to facilitate using the Momentum Conservation Model
- Develop an intuitive understanding of how Δt affects net Impulse, J, and net force $\boldsymbol{\Sigma F}$ in collisions and the tablecloth trick.
- Get practice making meaningful estimates of Δt and $\boldsymbol{\Sigma F}$ in automobile crashes.

Announcements

- **Reading Assignment** - Finish reading Unit 4.
- Be sure to use the Physics 7B webpage periodically for new information and material and practice problems.

DLM-4 Exit Handout

FNTs

1. Two asteroids collide head-on and stick together. Before the collision, asteroid A (mass 1,000 kg) moved at 100 m/s, and asteroid B (mass 2,000 kg) moved at 80 m/s in the opposite direction.

Use momentum conservation (make a complete Momentum Chart) to find the velocity of the asteroids after the collision.

2. Two asteroids identical to those in FNT 1 collide at right angles and stick together; i.e, their initial velocities were perpendicular to each other.

Use momentum conservation (make a complete Momentum Chart) to find the velocity (magnitude and direction with-respect-to the velocity asteroid A had before the collision) of the asteroids after the collision.

3. Determine the fractional decrease in total kinetic energy of the two asteroids in the previous **two** FNTs when they collide. If the average specific heat of the material composing the asteroids is assumed to be that of ice (2.05 kJ/kg·C°), by how much does the temperature of the asteroids rise as a result of the collision in each case?

4. Throw an object (like a ball) horizontally and observe its motion. You are now going to analyze this motion using conservation of momentum.

Consider the motion of the ball just after it has left your hand moving in a horizontal direction.

a. Draw a force diagram for the ball. What direction is the net force?

b. Complete the first two rows in the given momentum chart. The $\mathbf{p}_i$ of each successive step will be the $\mathbf{p}_f$ from the previous step. What direction is **Δp?**

c. Add three more rows to the Momentum Charts (just show the three vectors $\mathbf{p}_i$, **Δp**, and $\mathbf{p}_f$). Assume the same time interval for each change such that **Δp** will be 1/5 the length of the initial momentum, $\mathbf{p}_i$

d. Why does **Δp** stay constant for each step?

e. After you have carefully constructed a series of final momenta, use them, and what you know about the relationship of the direction of momentum to the path of an object to construct a path of the ball.

Open System	$\mathbf{p}_i$	Δp	$\mathbf{p}_f$
Ball Δt₁	→		↘
Ball Δt₂	↘		

5. Repeat what you did in FNT 4, but this time do two separate momentum charts for the horizontal and the vertical components of the motion. Describe in words how the motion changes in the two directions. Compare your diagrams from part e between 4 & 5. Are the paths you constructed still the same?

6. a. Wrap up what you have done in questions 4 and 5 by explaining, in as few words as possible, why the ball moves in this path.

b. For *any* object to be moving in a curved path what is necessary about the relationships $\mathbf{p}_i$, **Δp**, $\mathbf{p}_f$, and **ΣF**?

c. If **Δp** were always perpendicular to $\mathbf{p}_i$ and $\mathbf{p}_f$ what type of path would this be?

Momentum and Change in Momentum In Two and Three Dimensions II

1) FNT 1, DLM 3: heavy ball swung in a horizontal circle; string breaks

a) **On the board,** draw a physical picture of the situation. Make sure to include from 10˚ before the string breaks until the after the string breaks.

b) Make a momentum chart for this phenomenon taking the initial point to be about 10˚ before the string breaks and the final point to be immediately before the string breaks.

c) **On the board,** make a second momentum chart for this phenomenon taking the initial point to be immediately after the string breaks and the final point to be after the ball has gone a short distance.

d) Use your charts to explain the path of the heavy ball both before and after the string breaks.

2) FNT 2, DLM 3: puck moving in a straight line receives a kick at right angles

a) **On the board,** make a momentum chart for this phenomenon taking the initial point to be just before the kick and the final point to be just after the kick.

b) **On the board,** make a second momentum chart for this phenomenon taking the initial point to be the same point as the final point in (2a) and the final point to be after the puck has traveled some distance.

c) Use your momentum charts to explain the path of the puck.

d) Considering your work above in (2a) what is the predominant effect of the kick?

3) FNT 3, DLM 3: puck moving in a straight line receives a kick at right angles

On the board, use the appropriate momentum chart from (2) to justify your answer to FNT 3.

4) FNT 4, DLM 3: puck moving in a straight line receives a kick at right angles

On the board, use the appropriate momentum chart from (2) to make a scaled force diagram to answer FNT 4.

5) FNT 5, DLM 3: ball dropped and bounces

On the board, make a momentum chart (include a force diagram) that helps make sense of this situation and helps you to answer the question in FNT 5.

The Importance of Δt in Collisions

Phenomenon: These FNTs and the next activity–pulling a tablecloth out from under the dishes–illustrate how the *time duration* of an impulse relates to the net force and $\Delta \mathbf{p}$.

A) FNTs 6, 7, and 8, DLM 3: Automobile crash

1) **In your group** decide on two specific scenarios (FNT 8) and use these scenarios below (in parts 2, 3, and 4) to answer all of the other questions in this set of FNTs.
2) **On the board,** put up complete momentum charts (with force diagrams and equations worked through to numerical values) for the car and for the person in each of the two scenarios you have chosen. Describe the scenario above each of the momentum charts for the person.
3) Use your momentum charts to explain why the net force acting on the person will not be the same in both scenarios.
4) For each of the scenarios that you described in (FNT #8), you will estimate the magnitude of the average force that would have been acting on you to bring you to a stop.
   i) You will have to determine the time during which the impulse acts for the different scenarios. To do this you must first decide the initial and final momentum for the cases you are describing and over what distance does the impulse act.
   ii) Now you need to calculate the time of the impulse, using your knowledge of how distance and time are related. If you assume that you slow down at a constant rate, then your average speed during this time is one-half your initial speed.
   iii) Make an estimation of the average force for the two situations. If your answers differ for the situations explain what factor is causes this difference?
5) If you know the initial and the final momentum, then you know the impulse. In each of your scenarios did you have the same or a different impulse? What then is the effect of changing Δt (with the given constraints in the case of this automobile crash)?

Whole class sharing

B) The Tablecloth Trick

<u>Phenomena:</u> If a tablecloth (large piece of paper) is pulled quickly enough from out under the objects sitting on it, those objects barely move. However, if the tablecloth is pulled more slowly, all objects get dumped on the floor.

Try the trick:

Use a mass or another object and a fairly large piece of paper. Try pulling at different rates, so that the (1) mass moves a lot (but does not fall off the table) and (2) moves very little. Each time you try this, make sure that the mass is actually sliding on the paper.

Your job:

1) Begin your description by focusing on one object. What are the initial and final states of interest in this phenomenon? How does varying the pull on the tablecloth change the final state?

Quick Whole Class Sharing

Express the friction force, which is the <u>horizontal</u> component of the force the paper exerts on the object, $F_{ll\ paper\ on\ object}$, as a constant (coefficient of friction, μ) times the object's weight, mg. (Note that the coefficient will depend on the surfaces of the two materials in contact, but for reasonably smooth surfaces like paper and metal, it generally has a value in the range of 0.5 to 1.0. The important point for the analysis here is that *the friction force is only proportional to the weight of the object*, mg) and <u>not</u> the speed of the pull.

2) Draw two force diagrams for the *same* object: one diagram when it is pulled quickly and the second when it is pulled slowly. Make sure all forces are appropriately labeled. Does how fast you pull the tablecloth affect the net force acting on the object? (Hint: identify exactly what things are exerting forces on your object).

3) In your small group make a complete momentum chart (including force diagram) for ***one of the objects*** on your table (various masses and assorted other objects, such as keys, small bottles, etc) that is sitting on a piece of paper, which is pulled out from under it. The **initial tim**e is before the pull and the **final time** is immediately after the paper is no longer under the object.

4) Develop an explanation of this phenomenon using the momentum charts you have prepared. (Recall that a "faster" pull means a smaller "Δt" for the same Δp).

<u>Extra question:</u> Try pulling multiple objects; do all the objects appear to move about the same distance for a given pull? How can you explain this?

5) If you know the initial and the final momentum, then you know the impulse. In each of your scenarios did you have the same or a different impulse? So what is the effect of changing Δt (with the given constraints in the case of the table cloth trick)? How does this differ from your response in question 5) for the car crash? Which parameters are variable and which are constrained between these scenarios?

Be ready to illustrate and give your explanation to the whole class.
Whole Class Sharing