Physics 7B

DLM 5 Overview

Unit 4: Angular Momentum and Torque

Model/Approach: Angular Momentum Conservation Model

Act-4.2.6 Wrap-up of linear momentum: FNTs 1 – 6 from DLM-4 **(~70 min)**

Learning Goals:

- Get more practice with both qualitative and analysis of inelastic collisions in both 1-D & 2-D
- Get more practice working with vector components of momentum and related quantities
- Develop a deeper understanding of the independence of motion in perpendicular directions
- Get more practice applying the impulse = Δmomentum relation

Act-4.3.1 Introduction to Angular Momentum and Torque **(~70 min)**

Learning Goals:

- Become comfortable with the constructs of angular velocity and angular momentum (including their vector nature) as they apply to spinning a bike wheel.
- Become comfortable with the constructs of torque and angular impulse (including their vector nature) as they apply to spinning a bike wheel.
- Develop understanding of the dependence of torque on how a force is applied
- Get practice using the right-hand rule to determine directions of $\boldsymbol{\omega}$, $\boldsymbol{\tau}$, ang**J**, Δ**L**, and **L**

Announcements

- Be sure to check the Physics 7B webpage periodically for new information and material, various announcements, and all office hours

Activity 4.2.6

Wrap-up of Linear Momentum

A) FNTs 1-3 from DLM-4

Phenomenon: Inelastic collisions in both one and two dimensions.

1) **In your group** compare your individually created momentum charts for FNT 1 and 2. Note that you do not need to complete the entire chart to simply find the final velocity. That is, you don't need to find the change in momentum of each asteroid separately. However, finding the individual changes is a good opportunity to hone your skills with momentum conservation.

   Note: You may find it useful to choose an x-y coordinate system and fill in the chart for FNT-2 with x and y components.

2) **On the board,** put up a complete momentum charts (with equations worked through to numerical values) for both the linear collision in FNT 1 and the right-angle collision in FNT 2.

3) Compare your answers to FNT-3, come to a consensus and put your responses on the board.

4) Many body problem: Three asteroids collide and stick together; diagram a possible momentum chart.

Whole Class Discussion

B) FNTs 4-6 from DLM-4

Phenomenon: Horizontally thrown and dropped balls

1) **In your group** compare your individually created momentum charts for FNT 4 and 5. It is simplest to put one header row, with labels p_i, Δp, and p_f, and then start a new row in your chart for each time step.

2) Put your charts for FNT 4 & 5 on the board.

3) Discuss and be prepared to share with the class the question: "Describe in words how the motion changes in the two directions. Compare your diagrams from part 4.c & 5. Are the paths you constructed still the same?" and the question in FNT 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."

4) Come to a consensus on the questions in FNT 6b and 6c and be prepared to share them with the whole class.

Whole Class Discussion

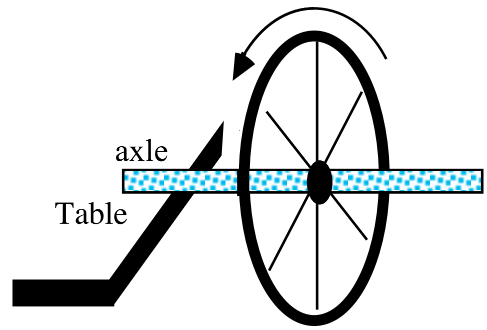
Practice quiz: spend no more than 5 minutes as a WC explaining to your DL instructor how to complete a momentum chart and the answers to this former FNT.

C) Two hockey goalies on ice skates block speeding pucks. Their ice skates point in the direction they move, so we can model them as on a frictionless surface. Goalie A catches the puck in her glove, while goalie B lets it bounce off of his stomach and return (with a slower speed) in the direction it came from. Both goalies have the same mass and were initially stationary, and both pucks have the same mass and were initially moving at the same speed.

(a) Explain which goalie exerts the greater impulse on the puck.
(b) Explain which goalie has the greater impulse exerted on him/her by the puck.
(c) After blocking the puck, which goalie will be moving the fastest? Use impulse to explain why.

Activity 4.3.1

Angular Velocity, Momentum and Torque with a Bike Wheel



<u>Phenomenon</u>: Change of Angular momentum of a stationary wheel clamped to a table. All of these questions and activities center around the "bike" wheel with an axle clamped to the table.

<u>Reference</u>: You will need to be constantly referring to your Course Notes on Angular Momentum Conservation in this activity. Make sure you have these notes out in front of you.

A. Rotation with constant speed.

Spin the wheels at your table so that they are rotating with a constant speed.

1) Describe in everyday English words precisely what **ω** is and what **L** is. Which can you observe?

2) Draw the wheel and axle and show the *vectors* **ω** and **L** on your drawings.

3) Does **ω** change over time? Why or why not?

B. Speeding up the rotation of the wheel and slowing it down:

Carefully observe how a member of your group uses her/his hand to increase the angular velocity of the wheel and then to decrease the angular velocity of the wheel. You should note precisely what the hand is doing to make the wheel (i) speed up and (ii) slow down.

1) Describe in everyday English words precisely what the hand did to make the wheel speed up and to slow down.

2) Use the information on pages 29 to 32 of the Notes as needed to describe what the hand did to the wheel in each case using the technical language of torque, angular impulse, and change in angular momentum.

3) For the case of the wheel speeding up, draw a set of sketches showing the vectors **ω, τ**, ang**J**, Δ**L,** and $\mathbf{L_i}$ **&** $\mathbf{L_f}$. Draw an "initial" wheel showing $\mathbf{L_i}$ and $\boldsymbol{\omega}_i$, a "change" wheel showing **τ**, ang**J** and Δ**L**, and a "final" wheel showing $\mathbf{L_f}$ and $\boldsymbol{\omega}_f$. Repeat for the wheel slowing down.

4) Put your two descriptions and vectors from (1) (2), and (3) on the board. Be prepared to explain to the whole class. Make a simple angular momentum chart.

Whole Class Discussion

(Turn page over and complete activity.)

C. Creating the torque with your finger. Each group member must do this!

Start the wheel turning by using one finger pushing hard against a spoke near the outer rim of the wheel and observe and feel how an initially stationary wheel responds. Observe how this compares to pushing hard very close to the central hub to start the wheel turning. Also, try to stop the wheel by placing your finger at either of the previous locations. Which location is it easier to stop the wheel? (If you are having trouble noticing a distinction use one finger to push open the DL door near the hinge versus near the door handle.)

1) Describe in everyday English words precisely what was different about how you pushed and how the wheel responded in each case (pushing near the rim and pushing near the hub).

2) Use the information on pages 29 to 32 of the Notes as needed to explain the differences using technical language that you previously described in (1) using everyday language. Make a simple drawing to illustrate your technical description and to show explicitly the difference between the two cases of pushing near the rim and near the hub.

3) Summarize on the board what torque is, what it depends on, and what it does.

Whole Class Discussion

4) Now you will determine the difference between net Torque, net Force, angular Impulse, and Impulse.

When you are pushing on the spoke of the wheel as in (B) is there a net Force acting on the wheel? Is there a net Torque? To answer, do the following:

a) You should already know how to answer the net force question by examining the change in the linear momentum of the wheel. The wheel's linear momentum is zero before you push on it. Does its linear momentum change when you push on it? In other words, does the wheel fly up into the air, or drop to the floor, or fly across the room in any way? What does your answer imply about the net force, $\Sigma\mathbf{F}$, on the wheel when you are pushing on it? Draw a properly scaled force diagram for the wheel when you are pushing on it.

b) Now draw a simple picture of the wheel and transfer the forces from your force diagram onto this picture of the wheel. Place the forces on your picture *at the points where they are actually acting*. We call this an **extended force diagram**.

c) Determine the direction of $\Sigma\boldsymbol{\tau}$ from the vectors drawn in (2) on the extended force diagram. Are your values for $\Sigma\mathbf{F}$ and $\Sigma\boldsymbol{\tau}$ consistent with what you observed for $\Delta\mathbf{p}$ and $\Delta\mathbf{L}$?

d) When you are not pushing on the wheel is there a net Torque or net Force? Why does the wheel continuing rotating?

Whole Class Discussion

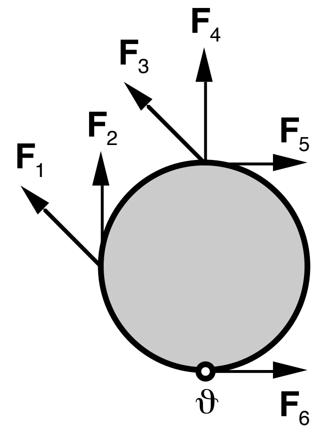
Physics 7B **Exit Handout** **DLM 05**

FNTs

Read through the Course Notes on the Angular Momentum Model, pages 26 – 37. Work hard on seeing the analogies between linear momentum phenomena and angular momentum phenomena.

1) "Torque" can be best described as which of the following? Give an example of both a force and a torque and explain why in a couple of sentences.

I. Rotational force. II. Rotational velocity.
III. Rotational energy. IV. Rotational power.
V. All of the above.

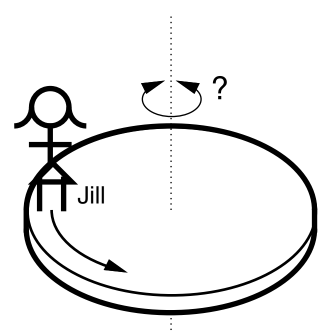


2) Circle *all* of the forces shown acting on a disk of radius *r* (shown to right) which exert a non-zero torque about point ϑ. Cross out *all* forces which exert a zero torque about point ϑ. (This is a top view of the disk, as seen from above.) If you are having trouble, draw these on a piece of paper and holding it at the pivot point, actually apply the force by pulling and see what happens. For each of forces that exert a non-zero torque, make a drawing showing the moment-arm, **r**, the force, **F**, and the tangential component of the force, $\mathbf{F}_{tangential}$.

3) For each of the forces in (2) that exerts a non-zero torque about point ϑ, use the right-hand-rule to state whether the torque points out of the plane of the drawing or into the plane of the drawing.

4) Could the torques exerted by F_3 and F_5 in (2) be balanced? Note that these two forces do not have the same magnitude. Explain, taking into account everything that determines the torque, including its direction.

5) Jill is atop a stationary merry-go-round, which is a disk free to spin around a vertical, frictionless axis. Jill is herself initially stationary. If Jill begins to walk in the counterclockwise direction on the surface of the merry-go-round, what will the merry-go-round do? Use an appropriate diagram (energy-system, momentum, or angular momentum) to explain what will happen. Develop an algebraic expression that expresses your answer.



merry-go-round disk

6) A figure skater increases the rate at which he is spinning by pulling in both of his arms and one of his legs. Assume that doing this decreases his rotational inertia, I, by 40%.

(a) Make an angular momentum chart to clarify what is happening with angular momentum. What is happening?
(b) Explain, using your result from (a), how it is that he can increase his rate of spinning.
(c) By what factor does the skater's rotational speed increase?
(d) Find the percentage change in the skater's kinetic energy. Is it an increase, a decrease, or no change? If there is a change, where does this energy come from or go to?