



DEVIL PHYSICS
THE BADDEST CLASS ON CAMPUS

AP PHYSICS

LSN 8-8: ANGULAR MOMENTUM AND ITS CONSERVATION

Questions From Reading
Activity?

Big Idea(s):

- The interactions of an object with other objects can be described by forces.
- Interactions between systems can result in changes in those systems.
- Changes that occur as a result of interactions are constrained by ***conservation laws***.

Enduring Understanding(s):

- A force exerted on an object can cause a torque on that object.
- ***A net torque exerted on a system by other objects or systems will change the angular momentum of the system.***

Enduring Understanding(s):

- Certain quantities are conserved, in the sense that the changes of those quantities in a given system are always equal to the transfer of that quantity to or from the system by all possible interactions with other systems.
- ***The angular momentum of a system is conserved.***

Essential Knowledge(s):

- ***A torque exerted on an object can change the angular momentum of an object.***
 - ***Angular momentum is a vector quantity, with its direction determined by a right-hand rule.***
 - ***The magnitude of angular momentum of a point object about an axis can be calculated by multiplying the perpendicular distance from the axis of rotation to the line of motion by the magnitude of linear momentum.***
 - ***The magnitude of angular momentum of an extended object can also be found by multiplying the rotational inertia by the angular velocity.***
 - ***The change in angular momentum of an object is given by the product of the average torque and the time the torque is exerted.***

Essential Knowledge(s):

- Torque, angular velocity, angular acceleration, and **angular momentum are vectors** and can be characterized as **positive or negative** depending upon whether they give rise to or correspond to **counterclockwise or clockwise** rotation with respect to an axis.
- The **change in angular momentum is given by the product of the average torque and the time interval during which the torque is exerted.**

Essential Knowledge(s):

- The angular momentum of a system may change due to interactions with other objects or systems.
 - The **angular momentum** of a system with respect to an axis of rotation is the **sum of the angular momenta**, with respect to that axis, of the objects that make up the system.
 - The **angular momentum** of an object about a fixed axis can be found by **multiplying the momentum of the particle by the perpendicular distance from the axis to the line of motion of the object**.
 - Alternatively, the **angular momentum** of a system can be found from the **product of the system's rotational inertia and its angular velocity**.

Essential Knowledge(s):

- For all systems under all circumstances, energy, charge, linear momentum, and ***angular momentum are conserved***. For an isolated or a closed system, conserved quantities are constant. An open system is one that exchanges any conserved quantity with its surroundings.
- ***If the net external torque exerted on the system is zero, the angular momentum of the system does not change.***

Essential Knowledge(s):

- The angular momentum of a system is determined by the locations and velocities of the objects that make up the system.
- The rotational inertia of an object or system depends upon the distribution of mass within the object or system.

Essential Knowledge(s):

- Changes in the radius of a system or in the distribution of mass within the system result in changes in the system's rotational inertia, and hence in its angular velocity and linear speed for a given angular momentum.
- Examples should include elliptical orbits in an Earth-satellite system. Mathematical expressions for the moments of inertia will be provided where needed. Students will not be expected to know the parallel axis theorem.

Learning Objective(s):

- The student is able to ***predict the behavior of rotational collision situations*** by the same processes that are used to analyze linear collision situations using an analogy between impulse and change of linear momentum and angular impulse and change of angular momentum.
- In an unfamiliar context or using representations beyond equations, ***the student is able to justify the selection of a mathematical routine to solve for the change in angular momentum of an object caused by torques exerted on the object.***

Learning Objective(s):

- The student is able to ***plan data collection*** and analysis strategies designed to test the relationship between torques exerted on an object and the change in angular momentum of that object.
- The student is able to ***describe a representation and use it to analyze a situation*** in which several forces exerted on a rotating system of rigidly connected objects change the angular velocity and angular momentum of the system.

Learning Objective(s):

- The student is able to plan data collection strategies designed to establish that torque, angular velocity, angular acceleration, and angular momentum can be predicted accurately when the variables are treated as being clockwise or counterclockwise with respect to a well-defined axis of rotation, and refine the research question based on the examination of data.
- The student is able to describe a model of a rotational system and use that model to analyze a situation in which angular momentum changes due to interaction with other objects or systems.

Learning Objective(s):

- The student is able to plan a data collection and analysis strategy to determine the change in angular momentum of a system and relate it to interactions with other objects and systems.
- The student is able to **use appropriate mathematical routines** to calculate values for initial or final angular momentum, or change in angular momentum of a system, or average torque or time during which the torque is exerted in analyzing a situation involving torque and angular momentum.

Learning Objective(s):

- The student is able to plan a data collection strategy designed to test the relationship between the change in angular momentum of a system and the product of the average torque applied to the system and the time interval during which the torque is exerted.
- The student is able to define open and closed systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations.

Learning Objective(s):

- The student is able to ***make qualitative predictions*** about the angular momentum of a system for a situation in which there is no net external torque.
- The student is able to ***make calculations of quantities*** related to the angular momentum of a system when the net external torque on the system is zero.

Learning Objective(s):

- The student is able to ***describe or calculate the angular momentum and rotational inertia of a system in terms of the locations and velocities of objects that make up the system.*** Students are expected to do qualitative reasoning with compound objects. Students are expected to do calculations with a fixed set of extended objects and point masses.

ANGULAR MOMENTUM

Angular Momentum

Angular Momentum

Angular Momentum

- Linear momentum

$$p = mv$$

- Angular momentum (L)

- I = moment of inertia
- ω = angular velocity

$$L = I\omega$$

- Units

$$\frac{kg \cdot m^2}{s}$$

Angular Momentum

- Newton's Second Law
 - In terms of linear momentum

$$\Sigma F = ma$$

$$\Sigma F = \frac{\Delta p}{\Delta t}$$

Angular Momentum

- Newton's Second Law
 - In terms of angular momentum and re-written in terms of torque
 - $\Sigma\tau$ = net torque acting to rotate the object
 - ΔL = change in angular momentum
 - Δt = time interval

$$L = I\omega$$

$$\Sigma\tau = I\alpha$$

$$\alpha = \frac{\Delta\omega}{\Delta t}$$

$$\Sigma\tau = \frac{I\omega}{t}$$

$$\Sigma\tau = \frac{\Delta L}{\Delta t}$$

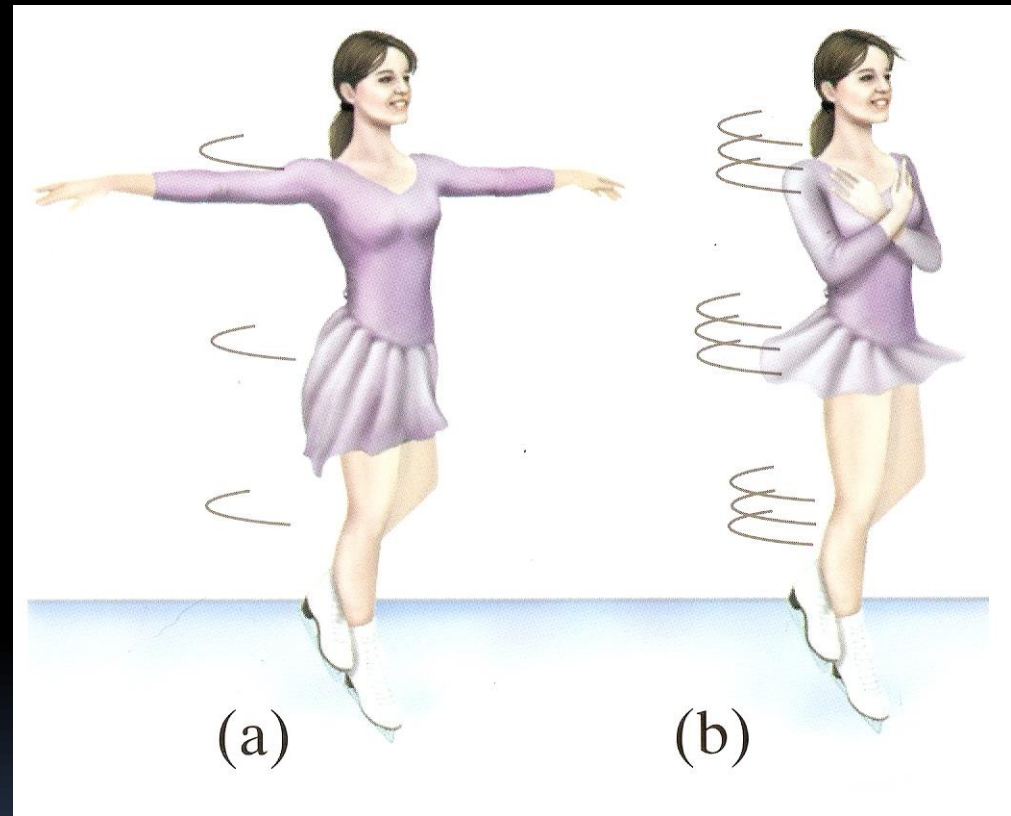
Conservation of Angular Momentum

- The total angular momentum of a rotating object remains constant if the net torque acting on it is zero

$$I\omega = I_0\omega_0 = \text{const}$$

Conservation of Angular Momentum

- What happens when a spinning figure skater extends and retracts her arms?



$$I\omega = I_0\omega_0$$

$$I = mr^2$$

Conservation of Angular Momentum

- *Why does a 2 ½ in the pike position have a higher degree of difficulty than the same dive in the tuck position?*

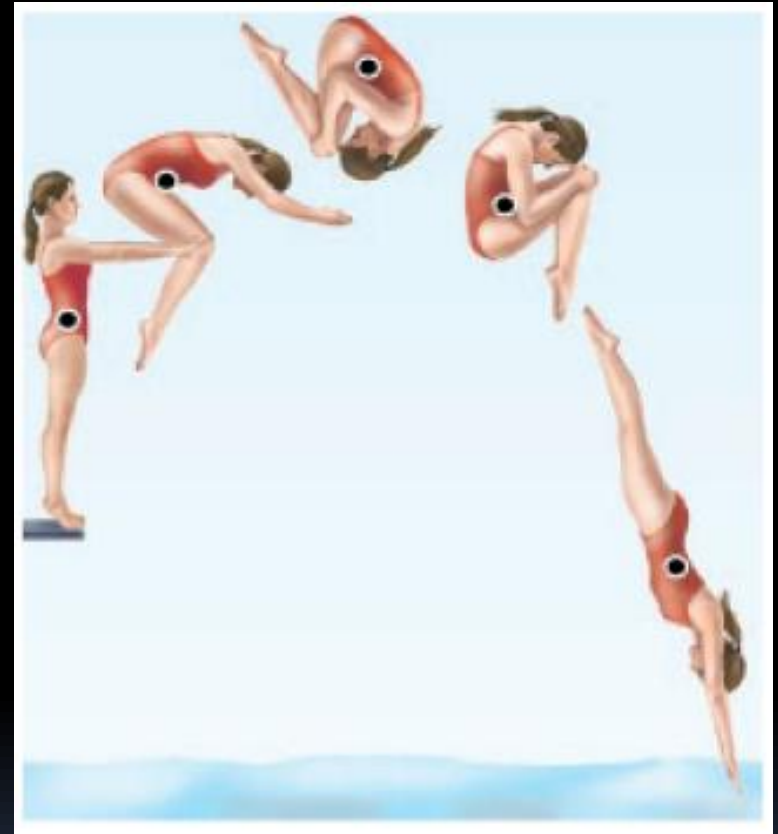


$$I\omega = I_0\omega_0$$

$$I = mr^2$$

Conservation of Angular Momentum

- *For angular momentum to be conserved,*
 - a) Net torque must be 0*
 - b) Net force must be 0*
 - c) Both a and b*
 - d) Neither a nor b*
 - e) It depends*

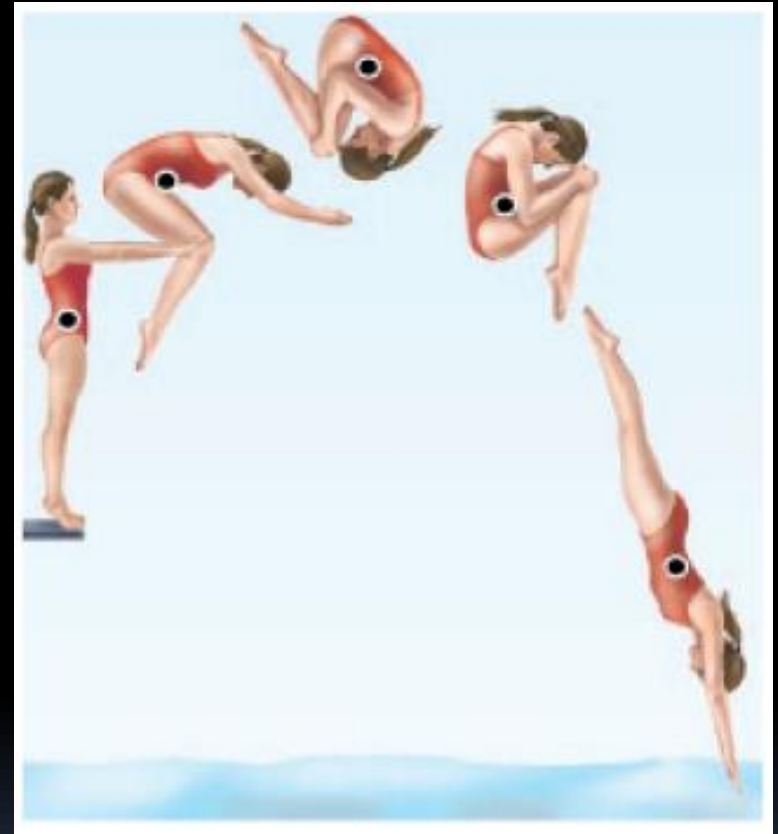


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Summary Video: The Mechanical Universe-Angular Momentum

**TRY HW PROBLEM #62 ON A
WHITEBOARD**

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Enduring Understanding(s):

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Big Idea(s):

- The interactions of an object with other objects can be described by forces.
- Interactions between systems can result in changes in those systems.
- Changes that occur as a result of interactions are constrained by conservation laws.



QUESTIONS?



Homework

51-64

Rotational Kinetic Energy - Example Problem

