Unit 7 Torque and Rotational Motion

Content Area: **Science**
Course(s): **AP Physics 1**
Time Period: **March**
Length: **15 Blocks**
Status: **Published**

Enduring Understandings

- 3.A: All forces share certain common characteristics when considered by observers in inertial reference frames.
- 3.F: A force exerted on an object can cause a torque on that object.
- 4.D: A net torque exerted on a system by other objects or systems will change the angular momentum of the system.
- 5.E: The angular momentum of a system is conserved.
- The acceleration of the center of mass of a system is related to the net force exerted on the system, where a = SUM F/m.

Essential Questions

- How does a system at rotational equilibrium compare to a system in translational equilibrium?
- How does the choice of system and rotation point affect the forces that can cause a torque on an object or a system?
- How can balanced forces cause rotation?
- Why does it matter where the door handle is placed?
- Why are long wrenches more effective?
- How can an external net torque change the angular momentum of a system?
- Why is a rotating bicycle wheel more stable than a stationary one?
- How does the conservation of angular momentum govern interactions between objects and systems?
- Why do planets move faster when they travel closer to the sun?

- How can the particle model be extended to a rigid-body model of an object?
- How are the rotational quantities (angular position, velocity, and acceleration) related to linear quantities?
- What does it mean for angular momentum to be conserved?
- What are the conditions necessary for two people with significant differences in mass to balance on a seesaw?
- What are the conditions necessary for static equilibrium?
- In what ways are rotational motion and linear motion related?
- What are the relationships among angular momentum, angular velocity, angular acceleration, rotational inertia, and torque?

Vocabulary

- Angular Position
- Arc Length
- Radian
- Angular displacement
- Angular Velocity
- Angular Speed
- Rigid body
- Translational Motion
- Rotational Motion
- Combination Motion
- Angular Acceleration
- Tangential Acceleration
- Radial Line
- Moment Arm
- Torque
- Center of mass
- Rotational kinematics
- Rotational dynamics
- Rotational inertia/Moment of Inertia
- Rotational kinetic energy
- Angular momentum
- Conservation of angular momentum
- Rolling Constraint

Skills

Enduring Understanding	Topic	
3.A	7.1 Rotational Kinematics	• 1.5 The student can re-express key elements • 2.1 The student can justify the selection of a • 2.2 The student can apply mathematical rout
3.F	7.2 Torque and Angular Acceleration	• 1.4 The student can use representations and • 2.1 The student can justify the selection of a • 2.2 The student can apply mathematical rout • 2.3 The student can estimate quantities that • 4.1 The student can justify the selection of tl • 4.2 The student can design a plan for collect • 5.1 The student can analyze data to identify • 5.3 The student can evaluate the evidence pr • 6.4 The student can make claims and predict • 7.2 The student can connect concepts in and
4.D	7.3 Angular Momentum and Torque	• 1.2 The student can describe representations • 1.4 The student can use representations and • 2.2 The student can apply mathematical rout • 3.2 The student can refine scientific questior • 4.1 The student can justify the selection of tl

		• 4.2 The student can design a plan for collect • 5.1 The student can analyze data to identify • 5.3 The student can evaluate the evidence pr
5.E	7.4 Conservation of Angular Momentum	• 2.1 The student can justify the selection of a • 2.2 The student can apply mathematical rout • 6.4 The student can make claims and predict • 7.2 The student can connect concepts in and

- Learning Objective (3.F.1.1): The student is able to use representations of the relationship between force and torque.
- Learning Objective (3.F.1.2): The student is able to compare the torques on an object caused by various forces.
- Learning Objective (3.F.1.3): The student is able to estimate the torque on an object caused by various forces in comparison to other situations.
- Learning Objective (3.F.1.4): The student is able to design an experiment and analyze data testing a question about torques in a balanced rigid system.
- Learning Objective (3.F.1.5): The student is able to calculate torques on a two-dimensional system in static equilibrium, by examining a representation or model (such as a diagram or physical construction).
- Learning Objective (3.F.2.1): The student is able to make predictions about the change in the angular velocity about an axis for an object when forces exerted on the object cause a torque about that axis.
- Learning Objective (3.F.2.2): The student is able to plan data collection and analysis strategies designed to test the relationship between a torque exerted on an object and the change in angular velocity of that object about an axis.
- Learning Objective (3.F.3.1): 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.
- Learning Objective (3.F.3.2): 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 (3.F.3.3): 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.
- Learning Objective (4.A.1.1): The student is able to use representations of the center of mass of an isolated two-object system to analyze the motion of the system qualitatively and semi-quantitatively.
- Learning Objective (4.D.1.1): 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 (4.D.1.2): 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.
- Learning Objective (4.D.2.1): 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 (4.D.2.2): 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.

- Learning Objective (4.D.3.1): 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 (4.D.3.2): 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.
- Learning Objective (5.E.1.1): 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.
- Learning Objective (5.E.1.2): 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 (5.E.2.1): 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.

Standards

AP: Physics 1 (2021 - 2022)

Big Idea 3: The interactions of an object with other objects can be described by forces

- Enduring Understanding 3.A: All forces share certain common characteristics when considered by observers in inertial reference frames.
  - Learning Objective (3.A.1.1): Express the motion of an object using narrative, mathematical, and graphical representations. [See Science Practices 1.5, 2.1, and 2.2]

- Enduring Understanding 3.F: A force exerted on an object can cause a torque on that object.
  - Learning Objective (3.F.1.1): The student is able to use representations of the relationship between force and torque. [See Science Practice 1.4]
  - Learning Objective (3.F.1.2): The student is able to compare the torques on an object caused by various forces. [See Science Practice 1.4]
  - Learning Objective (3.F.1.3): The student is able to estimate the torque on an object caused by various forces in comparison to other situations. [See Science Practice 2.3]
  - Learning Objective (3.F.1.4): The student is able to design an experiment and analyze data testing a question about torques in a balanced rigid system. [See Science Practices 4.1, 4.2, and 5.1]
  - Learning Objective (3.F.1.5): The student is able to calculate torques on a two-dimensional system in static equilibrium, by examining a representation or model (such as a diagram or physical construction). [See Science Practices 1.4 and 2.2]
  - Learning Objective (3.F.2.1): The student is able to make predictions about the change in the angular velocity about an axis for an object when forces exerted on the object cause a torque about that axis. [See Science Practice 6.4]
  - Learning Objective (3.F.2.2): The student is able to plan data-collection and analysis strategies designed to test the relationship between a torque exerted on an object and the change in angular velocity of that object about an axis. [See Science Practices 4.1, 4.2, and 5.1]
  - Learning Objective (3.F.3.1): 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. [See Science Practices 6.4 and 7.2]
  - Learning Objective (3.F.3.2): 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. [See Science Practice 2.1]

- Learning Objective (3.F.3.3): 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. [See Science Practices 4.1, 4.2, 5.1, and 5.3]

Big Idea 4: Interactions between systems can result in changes in those systems

- Enduring Understanding 4.D: A net torque exerted on a system by other objects or systems will change the angular momentum of the system.
  - Learning Objective (4.D.1.1): 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. [See Science Practices 1.2 and 1.4]
  - Learning Objective (4.D.1.2): 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. [See Science Practices 3.2, 4.1, 4.2, 5.1, and 5.3]
  - Learning Objective (4.D.2.1): 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. [See Science Practices 1.2 and 1.4]
  - Learning Objective (4.D.2.2): 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. [See Science Practice 4.2]
  - Learning Objective (4.D.3.1): 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. [See Science Practice 2.2]
  - Learning Objective (4.D.3.2): 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. [See Science Practices 4.1 and 4.2]

Big Idea 5: Changes that occur as a result of interactions are constrained by conservation laws

- Enduring Understanding 5.E: The angular momentum of a system is conserved.
  - Learning Objective (5.E.1.1): 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. [See Science Practices 6.4 and 7.2]
  - Learning Objective (5.E.1.2): 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. [See Science Practices 2.1 and 2.2]
  - Learning Objective (5.E.2.1): 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 use qualitative reasoning with compound objects perform calculations with a fixed set of extended objects and point masses. [See Science Practice 2.2]

The Standards above were taken from the 2014-2015 curriculum. The left over ones are not in the College Board for Unit 7.

AP: Physics 1 (2014 -15)
AP: AP

Enduring Understanding 4.A: The acceleration of the center of mass of a system is related to the net force exerted on the system, where $a = \Sigma F/m$

Learning Objective (4.A.1.1): The student is able to use representations of the center of mass of an isolated two-object system to analyze the motion of the system qualitatively and semiquantitatively. [See Science Practices 1.2, 1.4, 2.3, and 6.4]

Resources