Unit 4: Circular Motion
UNIT PLAN

Advanced Physics
Unit 4: Circular Motion
Suggested Duration: 12 Days

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UNIT NARRATIVE

This unit begins with a hands-on activity for students to observe and describe the velocity of an object in uniform circular motion as changing, even though magnitude remains constant, to help them deduce that there must be a force acting on an object in circular motion according to Newton's Laws. Students will be asked to sketch vectors representing the instantaneous velocity, acceleration and net force acting on an object throughout thi unit. Next students will move to a 2-day lesson where students will use a virtual simulation of horizontal circular motion to perform 3 different experiments to describe the force that creates circular motion, centripetal force, and discover the variable relationships that define the centripetal force (day 2-3). Then students will practice identifying the centripetal force in circular motion scenarios by identifying the force that always points toward the center of the circular motion (day 3). This lesson helps address a common misconception, that centripetal force is a new type of force, which is incorrect because centripetal force is just a name given to any of the forces that we have already explored when it is creating circular motion.

Next students will practice making quantitative predictions about circular motion scenarios (day 5) using the variable relationships that define centripetal force. Now students will experimentally determine the maximum safe velocity for a car making a circular turn using a virtual simulation and how the maximum safe velocity changes based on changes to the scenario (day 6-7). During this virtual lab students will confirm that the centripetal force is once of the forces we have already explored in this course, Friction, and experimentally describe variable relationships for these types of scenarios. At the end of this lesson the teacher should facilitate a Think Aloud to explain the variable relationships discovered in this lab using the Second Law equation describing this scenario and highlighting each variable relationship that affects the maximum velocity.

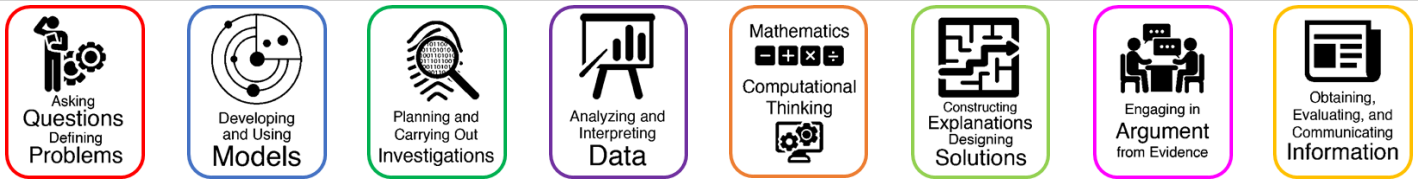
The next lesson is intended to address another significant misconception about circular motion, the common observation that objects in circular motion are pushed/thrown toward the outside of the circular path, or the existence of centrifugal force (day 8). Students will watch a video of a circular motion carnival where riders are held stationary against the wall without their feet touching ground and attempt to explain how this is possible by creating FBD and justification using physics principles. Then they will model and explain a simple scenario (with same phenomenon) about how loose objects inside a car move when making a horizontal circular turn to help understand the puzzling behavior of riders on the carnival ride.

Finally, students will explore a vertical circular motion scenario with lab activity where they whirl a cup of water to determine the minimum speed required to keep all the water inside the cup (day 9-10). Vertical circular motion is the most complex scenario explored in this unit because there are two forces acting on the object to create the centripetal force (force of gravity and tension/normal force). Students will create FBD and Second Law Equations for the vertical circular motion (only at the top and bottom positions of the circular path, to simplify the math) to discover how the tension/normal force must change at different positions in the circular path and have the opportunity to observe this phenomenon by focusing on the force of tension in the string as they whirl their cup of water.

NOTE: ***There is not a mandatory unit exam for this unit because of the unit ending just before the Semester Exam. All topics in this unit may be assessed on the semester exam.***

Focus on Disciplinary Literacy

In science, disciplinary literacy is synonymous with the science and engineering practices. The SEPs are the context through which all science concepts should be taught. In the lessons, you will find the Science and Engineering practices icons when the SEPs are being explicitly used by students.



UNPACKED CONTENT STANDARDS

Texas TEKS Physics Standards

Standard ID	Standard Description
C.5.D	describe and analyze acceleration in uniform circular and ~~horizontal projectile~~ motion in two dimensions using equations;
C.5.H	describe and calculate, using scientific notation, how the magnitude of force between two objects depends on their masses and the distance between their centers, and predict the effects on objects in linear and orbiting systems using Newton's law of universal gravitation.

College Board AP Physics Standards

Note – Standards in red will not be covered in this unit.

Topic #	Topic	LO #	Learning Objective	EO #	Essential Knowledge
2.9	**Circular Motion**	2.9.A	Describe the motion of an object traveling in a circular path.	2.9.A.1	Centripetal acceleration is the component of an object's acceleration directed toward the center of the object's circular path. i. The magnitude of centripetal acceleration for an object moving in a circular path is the ratio of the object's tangential speed squared to the radius of the circular path. **Relevant equation --> $a_c = \frac{v^2}{r}$** ii. Centripetal acceleration is directed toward the center of an object's circular path.
				2.9.A.2	Centripetal acceleration can result from a single force, more than one force, or components of forces exerted on an object in circular motion. i. At the top of a vertical, circular loop, an object requires a minimum speed to maintain circular motion. At this point, and with this minimum speed, the gravitational force is the only force that causes the centripetal acceleration. **Derived equation--> $v = \sqrt{gr}$** ii. Components of the static friction force and the normal force can contribute to the net force producing centripetal acceleration of an object traveling in a circle on a banked surface. iii. A component of tension contributes to the net force producing centripetal acceleration experienced by a conical pendulum.
				2.9.A.3	Tangential acceleration is the rate at which an object's speed changes and is directed tangent to the object's circular path.
				2.9.A.4	The net acceleration of an object moving in a circle is the vector sum of the centripetal acceleration and tangential acceleration.

				2.9.A.5	The revolution of an object traveling in a circular path at a constant speed (uniform circular motion) can be described using period and frequency. i. The time to complete one full circular path is defined as period T. ii. The rate at which an object is completing revolutions is defined as frequency, f. **Relevant equation--> $T = \frac{1}{f}$** iii. For an object traveling at a constant speed in a circular path, the period is given by the **Derived equation --> $T = \frac{2\pi r}{v}$**
		2.9.B	Describe circular orbits using Kepler's third law.	2.9.B.1	For a satellite in circular orbit around a central body, the satellite's centripetal acceleration is caused only by gravitational attraction. The period and radius of the circular orbit are related to the mass of the central body. **Derived equation --> $T^2 = \frac{4\pi^2}{GM} R^3$**

UNDERSTANDINGS AND QUESTIONS

Important big ideas and processes for the unit.

Key Understandings

- Uniform circular motion has constant speed but still accelerates because the direction of the velocity is constantly changing. The instantaneous velocity is ALWAYS in the direction tangent to the circular path.
- The instantaneous velocity of an object in uniform circular motion is ALWAYS in the direction tangent to the circular path.
- The acceleration and net force on an object in uniform circular motion will ALWAYs be directed toward the center of the circular path.
- Centripetal force is not a new type of force. It is a label for any force that creates circular motion and is one of the common forces already explored in this course (tension, friction, normal force, force of gravity).
- The amount of centripetal force required for circular motion is defined by the speed, radius and mass of the object.
- A car making a turn can be analyzed as about one quarter of a circular path. The centripetal force is provided by the friction between the car tires and the road.
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Key Questions

- How do we describe the speed and velocity of an object moving in a circular path?
- How can we predict if a car will make a safe (circular) turn while driving a car?
- What variables affect the required centripetal force?

VERTICAL STANDARDS

This section details the **progression** of key student expectations/standards** in the courses **before** and **after** this course. This will help you understand what **prior knowledge skills to build upon** and guide you in knowing what **skills you are preparing your students** for in the subsequent course.

5th Grade Science	6/7 Grade Hybrid Science	8th Grade Science
3-5(7) Force, motion, and energy. The student knows the nature of forces and the patterns of their interactions. The student is expected to: • 5(7)(A) investigate and explain how equal and unequal forces acting on an object cause patterns of motion and transfer of energy; and • 5(7)(B) design a simple experimental investigation that tests the effect of force on an object in a system such as a car on a ramp or a balloon rocket on a string.	**6(7) Force, motion, and energy. The student knows the nature of forces and their role in systems that experience stability or change. The student is expected to:** • 6(7)(A) identify and explain how forces act on objects, including gravity, friction, magnetism, applied forces, and normal forces, using real-world applications; • 6(7)(B) calculate the net force on an object in a horizontal or vertical direction using diagrams and determine if the forces are balanced or unbalanced; and • 6(7)(C) identify simultaneous force pairs that are equal in magnitude and opposite in direction that result from the interactions between objects using Newton's Third Law of Motion. **7(7) Force, motion, and energy. The student describes the cause-and-effect relationship between force and motion. The student is expected to:** • 7(7)(D) analyze the effect of balanced and unbalanced forces on the state of motion of an object using Newton's First Law of Motion.	**8(7) Force, motion, and energy. The student understands the relationship between force and motion within systems. The student is expected to:** • 8(7)(A) calculate and analyze how the acceleration of an object is dependent upon the net force acting on the object and the mass of the object using Newton's Second Law of Motion; and • 8(7)(B) investigate and describe how Newton's three laws of motion act simultaneously within systems such as in vehicle restraints, sports activities, amusement park rides, Earth's tectonic activities, and rocket launches.

VOCABULARY GLOSSARY

Domain-specific words and definitions for this unit.

Key Content Vocabulary
Uniform Circular Motion – the motion of a body traversing a circular path at constant speed. **Tangential Velocity –** the component of motion along the edge of a circle measured at any arbitrary instant. Tangential velocity describes the motion of an object along the edge of this circle whose direction at any given point on the circle is always along the tangent to that point. **Centripetal -** proceeding or acting in a direction toward a center or axis **Centripetal Acceleration –** the acceleration of an object following circular motion. It is always directed toward the center of the curved path and is perpendicular to the instantaneous (tangential) velocity of the object. **Centripetal Force –** a force that makes a body follow a circular path. It is always directed toward the center of the curved path and is perpendicular to the instantaneous (tangential) velocity of the object. *This is not a new force but is a label for a force in a scenario that is creating circular motion and can be any of the typical forces that are covered in this course including Tension, Friction, Force of Gravity and Normal Force.* **Centrifugal Effect (Force) -** the apparent push that is felt/observed on a person/object moving in a curved path that acts outwardly away from the center of circular motion or rotation. THIS IS NOT A REAL FORCE!

Related Vocabulary					
Constant velocity Constant speed acceleration Free body diagram (FBD)	Inertia Newton's First Law (Inertia) Newton's Second Law Newton's Third Law	Inertia Newton's First Law (Inertia) Newton's Second Law Newton's Third Law			