NATIONAL MUSEUM OF THE UNITED STATES AIR FORCE™

Gyrocopter Drop: Describing Rotary Motion

Students will work in teams to understand rotary motion and its components by dropping different gyrocopters from varying heights.

LESSON PLAN

Learning Objectives:

The students will:
- Conduct experiments on angular displacement
- Conduct experiments on rotation time
- Calculate angular velocity value by using equations
- Perform unit conversions
- Apply the "right-hand" rule of angular velocity
- Determine if height variations affect angular velocities achieved

Purpose:

This class is designed to give students the opportunity to practice, observe, and analyze rotational motion with the use of gyrocopters. Students will learn how to calculate and convert different measurement equations while monitoring the height and time of the gyrocopters being released. Students will calculate the average angular velocities for each gyrocopter tested as it falls by collecting the appropriate data of angular displacement and time of rotation and will express their calculated angular velocities in the following units: Revolutions per second, revolutions per minute, and radians per second. Students will, lastly, apply the "right-hand rule" of angular velocity to determine the direction of the axis of rotation and will explore how changes in the release height affects the average angular velocity calculations.

Introduction:

There are various types of motion such as linear, free-fall, projectile, circular and rotary. Though each is distinctively different, all can be described in terms of displacement, velocity and acceleration. When it comes to rotary motion, it is described in terms of angular displacement, angular velocity and angular acceleration. Angular displacement is the angle about the axis of rotation through which the object turns and can be expressed in the units of revolutions, degrees or radians. Angular velocity is defined as the time rate change in angular displacement. Angular acceleration is the constant rate in change of angular velocity. Even though the equations for each type of motion are specific, the basic means of description remains the same.

Grade Level: 9 – 12

Ohio Learning Standards/Science (2018)
Expectations for Learning
Nature of Science

High School Physical Science:
PS.FM.1: Motion
PS.FM.2: Forces
PS.FM.3: Dynamics

High School Physics:
P.M.2: Problem Solving
P.M.3: Projectile Motion
P.F.1: Newton's laws
P.F.2: Gravitational force
P.F.5: Air Resistance and drag
P.F.6: Forces in two dimensions

Ohio Learning Standards/Mathematics (2017)
Number and Quantity Standards
(+) N.VM.1: Recognize vector quantities
(+) N.VM.3: Solve problems: velocity & vectors
(+) N.VM.5: Multiply a vector by a scalar

Algebra
A.CED.4: Rearrange formulas
A.REI.1: Explain solution process
A.REI.2: Solve rational & radical equations

Materials Required:

- 3 Gyrocopters made with different materials: construction or typing paper, poster board, etc.
- Pencil and paper
- Meter sticks or metric tape measure
- Calculators
- Stopwatches

Procedure:

A. Warm-up

1. Review briefly the equation for calculating angular velocity

$$\overline{W} = \varnothing_1 - \varnothing_2 / t1 - t2 = \Delta\varnothing / \Delta t$$

2. Review unit conversion factors between revolutions, degrees, and radians

3. Develop three gyrocopters made of three ***different*** materials but of the same size

4. Review the job of each member of the team. Timer, Recorder/Observer, Launcher

B. Activity I

1. Choose a construction material from those provided

2. Construct three gyrocopters from the three ***different*** materials using the master pattern sheet

- Cut on the solid black lines.
- Fold on the dotted line at "A" so the fold does not cover the name.
- Fold on the dotted line at "B" so the fold does not cover the name.
- Fold on the dotted line at "C" so the fold does not cover the name.
- Fold on the dotted line at "D" so the fold does not cover the name, and fold on the dotted line at "E" so the fold covers the name.
- Bring the two "wings" up so they are perpendicular to the ABC section

C. Activity II

1. Teams select their own release height for the gyrocopters, and record it in meters on the Flight Data Log. The same release height will be used for all flight trials

2. The Launcher releases the gyrocopter from the selected height and counts the number of revolutions or spins the gyrocopter undergoes as it "falls" to the floor. This is the angular displacement. The timer records the total time of the gyrocopter's descent from the moment it is released until it touches the floor. The Recorder/Observer notes the direction of spin

3. Record all data in the Flight Data Log

4. Test each gyrocopter three times at this height and record all data

5. Noting the direction of spin for each gyrocopter, apply the "right-hand" rule to determine the direction of the angular velocity

6. Calculate and record the magnitude of the average angular velocity for each of the three gyrocopters

7. Perform unit conversions from revolutions/second to revolutions/minute and radians/second

8. Vary the release height for the gyrocopters at least twice, repeating steps 2 – 7 with each variation. Be sure to record the height chosen

D. Wrap-up

1. Analyze all recorded observations, collected data, and calculations

2. Discuss and compare results with other lab groups

3. Write a conclusion based on the analysis of your results. Within your conclusion, compare and contrast calculated average angular accelerations for each gyrocopter. Formulate possible explanations for how differences in construction material affect rates of rotation

4. Formulate possible explanations for how differences in release height affect rates of rotation

Assessment/Evaluation:

Students will be evaluated on the collection and organization of data, calculation performances, and conclusion responses.

Resources:

Rotary Motion:
https://www.sciencedirect.com/topics/engineering/rotary-motion

Angular displacement, angular velocity and angular acceleration:
https://www.grc.nasa.gov/WWW/K-12/airplane/angdva.html

"Right Hand" Rule:
https://web.ua.es/docivis/magnet/righthand_rule.html#:~:text=The%20right%2Dhand%20rule%20imposes,the%20index%20finger%20represents%20b.

Torque:
https://www.khanacademy.org/science/physics/torque-angular-momentum/torque-tutorial/a/torque

Rotational Inertia
https://www.khanacademy.org/science/physics/torque-angular-momentum/torque-tutorial/a/rotational-inertia

Gyrocopters:
https://www.exploratorium.edu/science_explorer/roto-copter.html

Gyrocopters – Describing Rotary Motion

Name _____

Launch Height (m) _____

Gyrocopter	Modification /Description	Number of Revolutions (Angular Displacement) (sec)	Direction of Spin	Descent Time (sec)	Direction of Angular Velocity	Average Angular Velocity		
						Rev/ sec	Rev/ min	Rad/ sec
1								
2								
3								

Launch Height (m) _____

Gyrocopter	Modification /Description	Number of Revolutions (Angular Displacement) (sec)	Direction of Spin	Descent Time (sec)	Direction of Angular Velocity	Average Angular Velocity		
						Rev/ sec	Rev/ min	Rad/ sec
1								
2								
3								

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GYROCOPTER PATTERN Cut on solid lines, fold on dotted lines