Propellers, Forces and Energy

Students will work in teams to measure and calculate the distance, velocity, kinetic energy, and time of flight using a balsa wood glider that is propelled using energy stored in the potential energy of a rubber band.

LESSON PLAN

Lesson Objectives

The students will:
- Construct a model airplane out of balsa wood
- Measure distances and time of flight
- Calculate the average velocity for each trial
- Calculate the average distance for each trial
- Graph the average distance traveled versus the number of turns of the propeller
- Interpret data to make inferences about the relationship of energy and work

Goal
In this lesson, students will construct and fly a model airplane, record measurements and observations, and create inferences of relationships of distance, rate, time, energy and work.

Background
Airplane engines push fast moving air out behind the plane (either by propeller or jet) causing the plane to move forward. The propeller provides the thrust (forward force) to move the plane horizontally. In the balsa wood model, potential energy is stored in the twisted rubber band which drives the propeller. When the rubber band untwists, energy is converted from potential energy into mechanical kinetic energy, and work is done in turning the propeller. The propeller provides the thrust, which pushes the airplane forward according to Newton's Third Law of Motion.

As the plane moves forward through the air, lift generated by the wings allows the airplane to fly. The lift force is weakest at take-off and landing since the magnitude of lift is lower at lower speeds. Changing the geometry of the wings by using ailerons or flaps alters the surface area of the wing, a quantity that is directly proportional to generated lift (greater surface area=greater lift, if velocity is the same).

Grade Level: 7-8

Ohio Learning Standards/Science (2018)
Expectation of Learning
Nature of Science

Physical Science

7.PS.4 Conservation of Energy
8.PS.2 Forces and Motion

Ohio Learning Standards/Mathematics (2017)

7.RP.1 Compute Unit Rates
7.RP.2 Recognize Proportionality
7.EE.4 Use Variables in the Real World
8.EE.5 Graph Proportional Relationships
8.F.3 Interpret Linear Functions
8.F.4 Construct Linear Relationships
8.F.5 Describe Linear Relationships Graphically

Materials Required:
- Balsa Wood Airplane kit
- Scissors
- Glue
- Rubber Band
- Pin
- Measuring Tape
- Stopwatch

Activity Summary

Students will work in teams to build model airplanes of balsa wood and observe the results when the number of propeller rotations is altered. The distance traveled by the model and the total duration (time) of flight will be used to calculate the average velocity and distance. Students will graph the average distance traveled versus the number of propeller rotations, interpret the data to discover relationships between the amount of potential energy (in the propeller) and the amount of work done (length of flight), and identify the types of energy and forces that relate to airplane flight.

SAFETY INSTRUCTIONS

Do **NOT** fly model planes directly at another person. Use caution when flying the models. Create a single direction flight zone. Have all students stand behind the "takeoff" line. Give an "all clear" signal when it is time to fly the planes, and do not allow students to cross the "takeoff" line to retrieve airplanes that have already landed until a "retrieve all planes" signal has been given.

Part I: Warm Up Activity

1. Review the four fundamental forces acting on an airplane – lift, weight, thrust, and drag – and the direction in which they act.
2. Review lift, which occurs when a moving flow of gas is turned by a solid object. The flow is turned in one direction, and the lift is generated in the opposite direction, according to Newton's 3rd law. Because air is a gas and the molecules are free to move about, any solid object can detect a flow. For an aircraft wing, both the upper and lower wing contribute to the flow turning. Neglecting either the top or bottom wing leads to an incorrect theory of lift.
3. Review the Coanda Effect and Bernoulli's Principle.
4. Review Newton's Third Law of action and reaction.
5. Introduce thrust and the function of the propeller.
6. Review the jobs for each team. These are:
    a. Pilot – the student that will be winding the plane and releasing the plane for each flight
    b. Recorder – the student that will be writing down the data for the group
    c. Timer – the student that will be timing the flight time of the aircraft
    d. Measurer – the student that will be measuring the distance travelled by the aircraft

Part II: Test Flight

1. Depending on the model of aircraft, assemble according to manufacturer instructions.
2. The first trial that will be performed is a test run to ensure the plane will fly straight, and the plane does not bank or turn excessively to the right or to the left.
3. Rotate the propeller clockwise 50 times (full revolutions), then hold the propeller still.
4. Hold the plane level, and await the "All clear"
5. When the "All Clear" signal is given, students will release their planes. As a group, monitor if the plane flies in a straight line. The student with the timer responsibility will time the flight using a stopwatch. The recorder will write down the time reported by the timer.
6. When the "retrieve all planes" signal has been given, the measurer will use the measuring tape to measure the horizontal distance from the point of release to the point of landing. The recorder will write down the distance the measurer reports.
7. If the plane failed to fly in a straight line, then modifications can be made according to the teacher's discretion. Only correct severe flight problems. On some balsa gliders, the wings can be moved forward

or back and side to side. Use sticky notes to make modifications to ailerons and elevators.

Part III: Take Flight!

1. Rotate the propeller clockwise 25 time (full revolutions), and hold it there.
2. Hold the plane level.
3. When the "all clear" signal is given, the team will observe the plane's flight path, ensuring it is flying in a straight path. The timer will record the flight time using the stopwatch.
4. When the "retrieve all planes" signal has been given, the measurer will use the measuring tape to measure the horizontal distance from the point of release to the point of landing. The recorder will record the data.
5. Repeat the procedure two more times for a total of three trials at this number of rotations.
6. Repeat the trial flights with the propeller rotated clockwise 50 times, 75 times, 100 times, and 150 times. Record all data in the Flight Data log on the following page.

Part IV: Wrap-Up

- Calculate the average distance travelled and the average time of flight for the identical trials.
- Calculate the average velocity by dividing the average distance by the average time of flight.
- Create a graph that relates the number of turns (on the x axis) to the average distance traveled (on the y axis).
- Write a lab report which includes the following sections:
    - Introduction: Specifies the purpose of the experiment, a hypothesis, and briefly indicate how the experiment will be conducted.
    - Method: Write directions as if someone needed to repeat the experiment, and only had your steps.
    - Data and Observations: Report observations and the flight data sheet.
    - Evaluation: In complete sentences, answer or address the following:
        - Average distance travelled for each number of turns
        - Average of flight for each number of turns
        - Average velocity for 25, 50, 75, 100 and 150 trials
        - Estimate a relationship for number of turns to the average distance. Is it linear? Is it quadratic? Using Microsoft Excel, fit a function to the data,
        - Estimate a relationship for number of turns to the average velocity. Is it linear? Is it quadratic? Using Microsoft Excel, fit a function to the data.
        - (+) Calculate the average kinetic energy for each set of trials. Estimate a relationship between the numbers of turns to the kinetic energy. Use a spreadsheet to fit a function to the data.
    - Conclusion: Summarize the experiment, observations and lessons learned. Did your hypothesis hold true? If you could change something to make this experiment, what would you change?

References:

Lift: https://www.grc.nasa.gov/www/k-12/airplane/lift1.html
Thrust: https://www.grc.nasa.gov/www/k-12/airplane/propth.html
Propeller Design: https://www.nationalmuseum.af.mil/Visit/Museum-Exhibits/Fact-Sheets/Display/Article/196934/test-propellers/

Name____________________

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Flight Log Data Sheet

Test Flight Portion

Number of Propeller Rotations	Description of Flight (Straight, to the left, etc.)	Distance (m)	Time (s)	Necessary modifications
50				

Experiment Portion

Number of Propeller Rotations	Distance (m)	Time (s)	Average Distance (m)	Average Time (m)
25				
50				
75				
100				
150				