Firefly Wind Wheel-Blade Pitch Investigation Lesson Plan – Grades 6-8

Objective: Build a small "firefly" using a generator, LED light, and simple craft materials to learn how wind turbines convert moving air into electrical energy.

Time: 30-120 mins

Grades: 6th-8th

NGSS Alignment: NGSS Performance Expectations (Grades 6–8)

- **MS-PS3-3**: Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer. *(Your Firefly wind wheel tests designs that maximize energy transfer from wind → motion → electricity.)*
- **MS-PS3-5**: Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object. *(Students argue that more wind energy = faster spin = brighter LED.)*
- **MS-ETS1-2**: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. *(Comparing flat vs. tilted blades with brightness data.)*
- **MS-ETS1-3**: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution. *(Students test blade pitches and decide which is most effective.)*

Disciplinary Core Ideas (DCI)

- PS3.A – Definitions of Energy: Motion energy is dependent on mass and speed.
- PS3.B – Conservation of Energy and Energy Transfer: Energy can be transferred from one object to another through electric currents or mechanical means.
- ETS1.A – Defining and Delimiting Engineering Problems:
  Criteria and constraints must be considered to develop successful solutions.
- ETS1.B – Developing Possible Solutions: Testing different designs allows the identification of characteristics that improve performance.

Crosscutting Concepts (CCC)

- Cause and Effect – Changes in blade pitch cause observable differences in spin speed and LED brightness.
- Energy and Matter – Energy from wind is transformed into mechanical motion, then into electrical energy, lighting the LED.
- Structure and Function – The shape and tilt of blades affect how well they capture wind energy.

Science and Engineering Practices (SEP)

- Planning and Carrying Out Investigations – Measure and test blade pitch angles systematically.
- Analyzing and Interpreting Data – Record pitch, LED brightness, and spin speed in a data table.
- Constructing Explanations and Designing Solutions – Use evidence to explain why a certain pitch performed best.
- Engaging in Argument from Evidence – Justify your chosen design using collected data and science principles.

Overview:
The Firefly Wind Wheel activity introduces students to the concepts of wind energy, mechanical energy, and electrical energy. Students build a small wind turbine that captures kinetic energy from moving air, converts it into mechanical rotation, and then into electrical energy that can power a small LED or other low-power device. This hands-on activity blends **engineering design** and **physical science**. Students experiment with blade pitch, shape, and number to see how these variables affect energy output.

Background:

Wind Energy Basics

- Wind is moving air caused by uneven heating of Earth's surface by the sun.
- Wind turbines harness the **kinetic energy** of wind.
- The moving air pushes against turbine blades, causing them to rotate.

Energy Transformations

- **Kinetic Energy (Wind) → Mechanical Energy (Spinning Blades)**
    - The blades act like airplane wings, using *lift* and *drag* to rotate.
    - Blade pitch (angle) affects how efficiently they capture wind energy.
- **Mechanical Energy → Electrical Energy**
    - The spinning shaft turns a small generator.
    - Magnets spinning past copper coils create an electric current through **electromagnetic induction**.

Energy Transformations

- **Too flat (0° pitch)** – blades don't catch much wind, producing little rotation.
- **Too steep (>30° pitch)** – blades push too much against the wind, slowing rotation.
- **Optimal pitch (10–20°)** – balances lift and drag for efficient spinning.

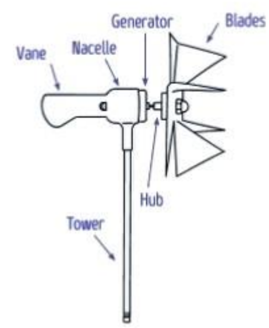
The Generator

- In the Firefly, a small DC motor acts as a generator.
- When the shaft spins, magnets inside pass by wire coils, producing an electric current that lights the LED.
- This demonstrates **Faraday's Law of Induction** – changing a magnetic field induces an electric current in a conductor.
    - *References:*
        - *NEED Project – Wind Energy Curriculum*
        - *Vernier – Blade Design: Pitch Lab*
        - *ATSE – Wind Energy Teacher Guide*
        - *WindWise Education – Blade Design and Pitch*

Learning Objectives (I CAN STATEMENTS):

- **I can** explain how the pitch (tilt) of turbine blades changes how much wind energy is captured.
- **I can** measure blade pitch angles accurately using a protractor.
- **I can** collect and record data about LED brightness and spin speed for different blade pitches.
- **I can** identify cause-and-effect relationships between blade pitch and energy output.
- **I can** use data and scientific reasoning to explain why a specific blade pitch design worked best.
- **I can** apply the engineering design process to improve a wind turbine's performance.

🧰 Materials (per student or group)



- Firefly kits can be checked out for 20 students (in groups of 3-4)
- Nacelle
  - Small DC generator (already in the nacelle)
  - LED light (already in the nacelle)
- Screw Hub
- Acorn Hex Nut
- Pencil
- Classroom Material to Share
  - Blade Material-Card Stock, index cards, colored paper etc
    - Premade cardstock printouts
- Ruler or small protractor (digital or plastic)
- Small sticky notes or tape to mark pitch angles (optional)
- Scissors
- Markers-optional
- 2 Box Fans

Middle School CER Lesson Plan – Firefly Wind Wheel

Phenomenon: (5 min)

Teacher Action:

- Turn on the fan and place the Firefly Wind Wheel in front of it so the LED lights up.
- Keep the pitch at an effective angle so the light is bright.
- Ask:
  1. *"What's making the light turn on?"*
  2. *"What might happen if I change the tilt of the blades?"*

Key Vocabulary: (5–7 min)

Teacher Tip: Write each term on the board with a student-friendly definition. Hold or point to the part on the Firefly as you explain.

- **Wind turbine:** machine that turns wind energy into electricity

- **Blade:** the part that catches the wind and spins
- **Pitch:** the tilt angle of the blade
- **Generator:** device inside the Firefly that turns spinning into electricity
- **LED:** light-emitting diode, uses small amounts of electricity to light up
- **Electricity:** energy that powers lights, machines, and electronics

The Challenge: (3 min)

Teacher Script:

Your job is to figure out what blade pitch will make your Firefly light up the brightest. We'll be changing the tilt angle of the blades, measuring the angle, and recording the LED brightness in a data table. Then you'll use your data to make a claim and explain why it worked.

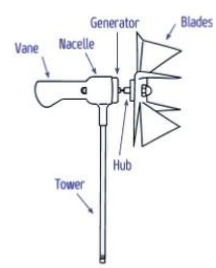
Measuring Blade Pitch: (Demonstration – 5 min)

Teacher Directions:

1. **Show baseline pitch** — Start with blades tilted just slightly forward (~10–15°).
2. **Explain how to measure:**
   - Place a ruler or protractor along the blade's edge.
   - Compare blade angle to a flat 0° reference.
   - Record angle in the data table (estimate to nearest 5°).
3. **Demonstrate changing pitch:** Bend blade tips more forward or backward and re-measure.
4. **Stress one-variable testing:** Only change the pitch; keep fan distance and speed the same.

5. Engineering Design Process (40 min)

Teacher Guidance:



- Organize students into groups of 2–4.
- Distribute Firefly kits building with the templates or making their own
- Generators and LEDs will be already in the nacelles
- Pencils go into the bottom of the nacelle for students to hold on to while their turbine turns.
- Show students what they will need to do with the templates or paper to make blades
  - Let students be creative but remember what they are testing.
- Have students cut and fold blades, then mount on the hub.
- Explain and model how to add the blades to the hub.
  - Students will need to need to take off the acorn hex nut to add their blades
  - Add blades by pushing the point of the screw hub through the blades or using a hole punch to make a hole in the middle of their paper
  - Screw the acorn hex nut over the top to hold the blades in place.
  - Remind them they can spin their blades manually to make sure their LED lights up.
- Instruct them to start with a **baseline pitch (control)** and test it.

- After first test, direct them to **increase** pitch (more tilt) and test again.
- Final test: **reduce** pitch (less tilt) from baseline.
- Between tests, ensure they **measure pitch angle** and record LED brightness.

Example Data Table:

Trial	Pitch Angle (°)	LED Brightness (Low, Med, High)	Spin Speed (Slow, Med, Fast)	Notes
1	15°	Medium	Medium	Baseline
2	30°	High	Fast	Brighter LED
3	5°	Low	Slow	Barely lit

Facilitating the CER Writing (10–15 min):

Teacher Prompt:

- *Claim:* Which blade pitch worked best?
- *Evidence:* Point to your best trial in your data table. What did you see?
- *Reasoning:* Why did that pitch work best? Think about how blades catch wind and how the generator works.

Teacher Support:

- Remind students: More effective pitch means blades "catch" more wind, spin faster, and turn the generator more times per second, making more electricity for the LED.
- Walk around and ask probing questions to push reasoning beyond "because it spun faster."

Wrap-Up Discussion (5–7 min)

- Invite a few groups to share their claim and evidence.
- Compare pitch angles that worked best across the class.
- Discuss real-world connection: How do engineers decide blade pitch for real wind turbines?

(See Student Data Worksheet)

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