

EduTrend Contents

W4C · SCIENCE & ENGINEERING · HIGH SCHOOL

Wind Power Lab

Design, test and optimise turbine blades

Ages 15–18	Level: Advanced	2 × 60 minutes	Teams of 3	Activity 05

Inside: activity at a glance · step-by-step session plan · facilitator notes · 3 student worksheets · assessment checklist

ACTIVITY 05 · AT A GLANCE

Wind Power Lab

Students build a small wind turbine from card blades, a hub and a DC motor used as a generator. Using a desk fan as a steady wind source, they measure the voltage across a fixed resistor, calculate electrical power and optimise one blade variable such as pitch angle or number of blades. The session ends with an efficiency discussion and a short engineering report.

Learning outcomes

By the end of the session students can:

- describe the energy transfers from moving air to electrical power in a load;
- calculate electrical power using $P = V^2/R$ and handle units correctly;
- design a controlled test of one blade variable with repeat measurements;
- evaluate the results, including sources of uncertainty and the limits set by the Betz limit.

KEY WORDS

kinetic energy · generator · voltage · resistance · power · pitch angle · efficiency · Betz limit · uncertainty

CURRICULUM LINKS

Physics: energy transfers, electricity and power. Design & technology: iterative design and testing. Maths: formulae and graphs. Energy conversion devices (NGSS HS-PS3-3); engineering design (NGSS HS-ETS1).

1	2	3	4	5	6
DEFINE	**BUILD**	**CALIBRATE**	**MEASURE**	**CALCULATE**	**OPTIMISE**
Set the brief	Hub, blades, generator	Fix fan and distance	Voltage across R	Power $P = V^2/R$	Change one variable

Materials (per team)

- Small DC hobby motor (3–6 V) mounted on a clamp stand
- Hub: cork or thick bottle cap that fits tightly on the motor shaft
- Card for blades, wooden skewers or lolly sticks, hot glue (adult use) or strong tape
- Protractor, ruler, scissors
- Digital multimeter and crocodile leads
- Fixed resistor, for example 100 ohms
- Desk fan with a guard; tape measure
- Worksheets 1, 2 and 3

Before the session

- Check each motor produces a reading when the shaft is spun by hand.
- Mark the fan position and a fixed distance (for example 50 cm) on each bench.
- Pre-cut hub slots or drill small holes so blades can be set at different angles.
- Build and test one turbine yourself to find a sensible voltage range.

SAFETY

Keep fingers clear of spinning blades and switch the fan off before adjusting. Wear eye protection and clamp turbines firmly. Adults handle hot glue.

ACTIVITY 05 · SESSION PLAN

Step by step

Session 1 covers the brief, build and first measurements. Session 2 covers the controlled optimisation test, analysis and report.

Time	What happens	Say or ask
S1 0–10 min Brief	Show a photo of a large wind turbine and a hand-spun hobby motor lighting an LED. Set the brief: maximise electrical power from a fixed wind source.	*"Where does the energy come from, and where does it go?"*
S1 10–40 min Build	Teams build a hub with 3 blades at 20° pitch, fit it to the motor and connect the resistor and multimeter.	*"Why do we measure across a resistor rather than just the motor?"*
S1 40–60 min First test	Teams set the fan at the marked distance, wait for steady rotation and record voltage. They calculate power and agree on the variable to optimise.	*"How long should you wait before reading? Why?"*
S2 0–30 min Optimise	Teams test one variable (pitch angle 10°, 20°, 30°, 40°, or 2, 3, 4 and 6 blades), taking three readings for each setting.	*"What must stay the same so only one thing changes?"*
S2 30–45 min Analyse	Teams calculate mean power, plot a graph and identify the best setting.	*"Is the peak clear, or could it lie between two of your settings?"*
S2 45–60 min Report	Teams complete Worksheet 3 and present their best design, results and one improvement.	*"How close could any turbine get to taking all the energy from the wind?"*

CHALLENGE CARD (print or copy onto the board)

Design turbine blades that deliver the most electrical power to a 100-ohm resistor from a fixed desk fan at a fixed distance. Support your final design with repeat measurements, a graph and an evaluation.

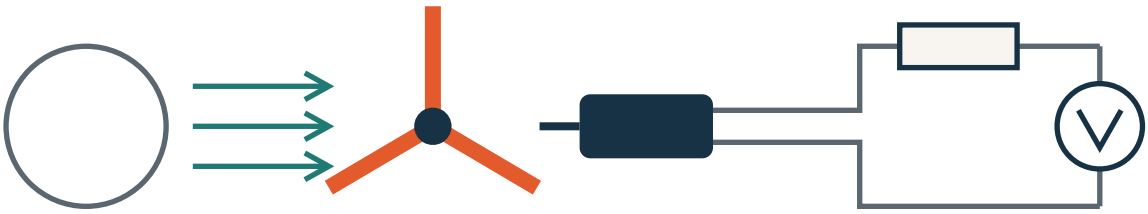
ACTIVITY 05 · FACILITATOR NOTES

The science in brief



Photo: Jacob McGowin / Unsplash

Moving air carries kinetic energy. The power in the wind passing through the rotor area A is P = ½ × air density × A × v^3, where v is the wind speed. Because of the v^3 term, doubling the wind speed gives eight times the power, which is why the fan distance must stay fixed. The blades turn some of this energy into rotation, and the motor, working as a generator, converts rotation into electrical energy.



Fan: moving air (kinetic energy) *Blades and generator: rotation to electricity* *Resistor R with voltmeter V across it: P = V^2/R*

No turbine can capture all of the wind's energy, because the air must keep moving to get out of the way. The theoretical maximum, the Betz limit, is about 59% of the power in the wind. Real turbines lose more energy to drag, friction and generator losses. Blade pitch matters because the blade must meet the oncoming air at an angle that produces a strong turning force without stalling.

Common ideas to listen for

- "More blades always give more power." Extra blades add drag and can disturb each other's airflow; the best number depends on the design.
- "A higher voltage reading is the same as more power." Power depends on voltage and the load; compare P = V^2/R with the same resistor.
- "The turbine makes energy." It transfers energy from the moving air; efficiency is always below 100%.

Adapting the activity

Support

Provide a ready-made hub with slots at fixed angles and a results table with the power column already set up in mW.

Stretch

Measure the wind speed with an anemometer, calculate the power in the wind for your rotor area and estimate the efficiency of your turbine. Compare it with the Betz limit and suggest reasons for the difference.

WORKSHEET 1

Design specification

Name: _____ Class: _____ Date: _____

Agree your design and test plan before building.

Specification

Item	Our choice
Number of blades	
Blade length (cm)	
Starting pitch angle (°)	
Fan setting and distance	
Load resistor R (ohms)	
Variable we will optimise	

Blade sketch

Show blade shape, dimensions and how the pitch angle is set on the hub.

Prediction and reasoning

WORKSHEET 2

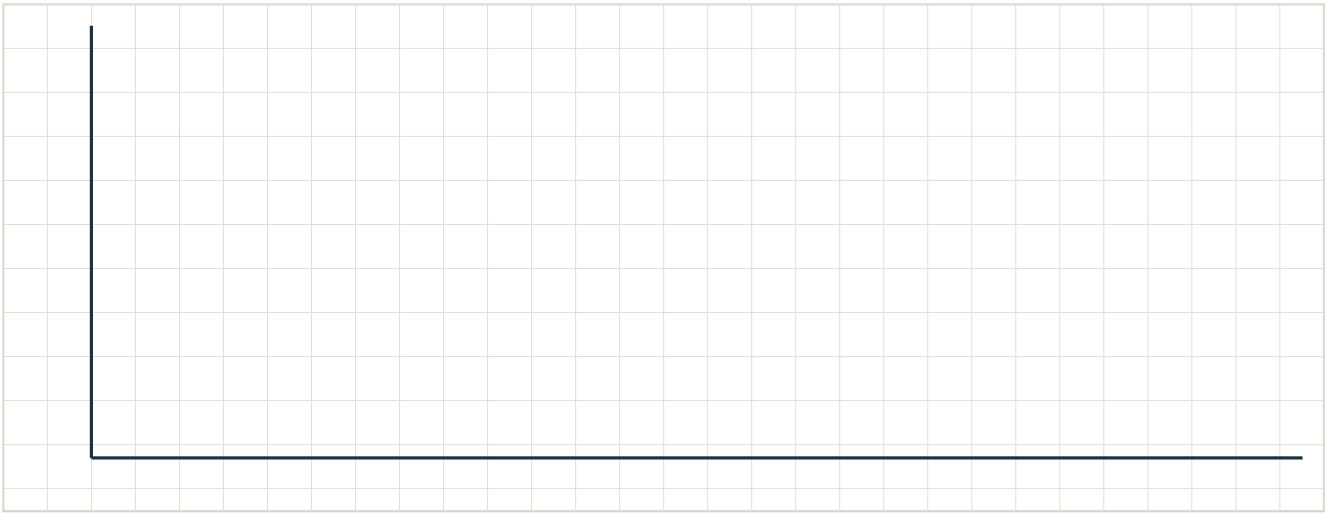
Measurements and analysis

Wait for steady rotation before each reading. Power $P = V^2/R$. Give power in milliwatts (mW).

Results

Setting	V1 (V)	V2 (V)	V3 (V)	Mean V (V)	P (mW)

Graph



y-axis: power (mW)

x-axis: setting (pitch angle or number of blades)

WORKSHEET 3

Engineering report

Write concisely, as you would for a design review.

Result

State your best setting and the power it produced, with units.

Evaluation

Identify two sources of uncertainty or error and explain their effect on your results.

Efficiency and limits

Explain why your turbine cannot convert all the wind's energy into electrical energy, referring to the Betz limit and other losses.

Next iteration

Describe one design change you would test next and how you would test it.

FOR THE TEACHER

Assessment checklist

Use during the session. One sheet covers up to eight students; copy as needed.

Student	Explains energy transfers	Measures and calculates power	Evaluates design and uncertainty

Suggested codes: W = working towards · E = expected · G = greater depth

ABOUT THIS ACTIVITY

Wind Power Lab is a sample activity from the EduTrend Contents W4C Science & Engineering programme (high school, level: advanced). Every activity in the programme follows the same format: a practical challenge, a clear session plan, facilitator notes and ready-to-print worksheets, so that teachers, club leaders and parents can run it without extra preparation.

Full 15-, 20- and 32-week programmes are available from EduStore at edutrend.org.

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