

Circus Activity: Make and test your own Savonius wind turbine

Topic addressed:

When you have made your own Savonius wind rotor, test it to find out the best way of generating power most effectively.

Physics GCE AS and A Level specification references:

AQA A	3.4.5 Magnetic fields. Electromagnetic induction. Applications.
AQA B	3.4.3 Module 3, Imaging the Invisible. Most sections within the module are covered in this activity.
CCEA	5.5 Magnetic fields. 5.5.8 state, use and demonstrate experimentally Faraday's and Lenz's laws of electromagnetic induction. 5.5.9 recall and calculate induced e.m.f. as rate of change of flux linkage with time.
EDEXCEL Concept-Led Approach	4.4 Electric and Magnetic Fields. 94 investigate and explain qualitatively the factors affecting the e.m.f. induced in a coil...
EDEXCEL Context-Led Approach	10.3 Transport on Track (TRA). 94 investigate and explain qualitatively the factors affecting the e.m.f. induced in a coil...
International Baccalaureate (IB)	12.1 Induced electromotive force (e.m.f.). 12.1.4 Describe the production of an induced e.m.f. by a time changing magnetic flux. 12.1.5 State Faraday's law and Lenz's law.
OCR A	G485 Module 1: 5.1 Electric and Magnetic Fields. 5.1.3 Electromagnetism. (e) state and use Faraday's law of electromagnetic induction. (f) state and use Lenz's law.
OCR B	Module FP 1: Fields. FP 1.1 Electromagnetic machines. 2, scientific communication and comprehension of the language and representations of physics, by making appropriate use of the terms: (i) B-field, flux, flux linkage, induced e.m.f., eddy currents.
WJEC	PH5.3 ELECTROMAGNETIC INDUCTION (b) recall the laws of Faraday and Lenz. (e) relate qualitatively the instantaneous e.m.f. induced in a coil rotating at right angles to a magnetic field to the position of the coil, flux density, coil area and angular velocity.
SQA Advanced Higher	2.4 Self-inductance 3 State that an e.m.f. is induced across a coil when the current through the coil is varying. 4 Explain the production of the induced e.m.f. across a coil. 5 Explain the direction of the induced e.m.f. in terms of energy.

Student practical or teacher demonstration:

An activity for a small group of students to work on.

Time needed to complete the activity:

It takes around an hour for a student group to make the generator, but longer to test its efficiency.

Preparation and set-up time:

Once the rotor has been made, it takes around 10 minutes to set up the lab apparatus to support the rotor, with the coils connected beneath.

Resource list:

- two 20cm long pieces of guttering (11cm diameter will fit the template provided)
- thick cardboard or a disk of plywood/hardboard around 20cm in diameter
- 'end pieces for turbine' template
- thick cardboard or a piece of plywood/hardboard to fit the end pieces template
- a piece of wooden dowel 40cm long (approx 6mm dia)
- pile (brass bullet arrowhead) or the pointed end of a dart
- a wooden block of around 20cm side
- a Phillips head screw and a Phillips head screwdriver
- lab stand with boss
- a piece of dowel (approx 1 - 2 cm dia), 15 cm long with a metal cup hook (bent into an eye) screwed into the end to hold the vertical dowel
- 4 x Neodymium™ magnets (2cm diameter)
- 4 x steel washers
- 28 SWG grade copper wire – enough to make four coils with about 200 turns each
- 4 x spools (to make you own use 4 x 3cm long pieces of dowel and 8 x 4cm diameter cardboard discs)
- 6 x terminal blocks
- a light-emitting diode (LED)
- glue gun with glue
- Blu Tack™
- an air blower, e.g. an electric fan, a vacuum cleaner motor, or a leaf blower

Ideas for introducing/leading into the activity:

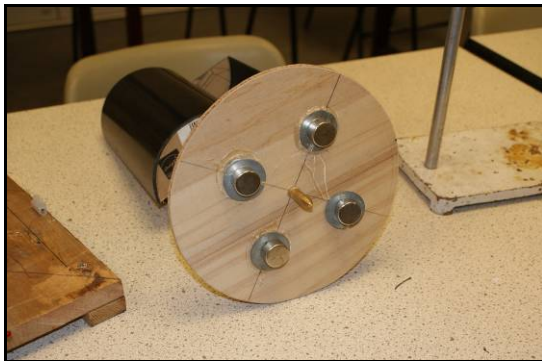
Ask students, if they wanted to make a wind generator with a vertical spindle, what would be the most effective shape of rotor to make.

Description of activity in detail:

Make your own Savonius generator by following these instructions:

- Cut out the end pieces for the turbine from a sheet of cardboard (using the 'end pieces for turbine' template) and glue them into the two ends of each piece of gutter.
- Pass the long dowel through the cardboard end pieces in the position shown.
- Cut out a 20 cm diameter disk of cardboard or plywood/hardboard and glue it into position near the foot of the dowel.
- Glue four steel washers to the underside of the cardboard disk in the positions shown.
- Place four Neodymium™ magnets on the four steel washers.
- Attach the dart end (or arrow pile) to the bottom of the dowel.
- Screw the Phillips screw into the centre of the wooden block (wooden strips can be glued to the underside of the wooden block for added stability as shown).
- Support the short length of wooden dowel in a retort stand clamp and use the cup hook to support the vertical dowel to allow the rotor to spin freely.
- Make 4 spools by cutting out 8 circular pieces of cardboard, each around 4 cm in diameter; stick the disks to the ends of the 4 short pieces of dowel.
- Wind around 100 turns of copper wire around each spool; use Blu Tack™ to attach each spool to the wooden block beneath the magnets.
- Connect the spools in series and then connect them to the LED; Blu Tack™ the LED in position.
- Use the air blower to turn the rotor and generate enough power to light the LED.

Experiment with the number of spools, number of copper wire turns on the spools and connecting the spools in series and in parallel to find the most efficient way to light the LED.



The Savonius generator at various stages while being made (©ESEU)



The completed Savonius generator (©ESEU)

Results expected:

If the rotor is able to turn freely, if the magnets are positioned just above the spools, if the spools are correctly spaced and correctly connected in series, then, when the rotor is turning at full speed, the LED will flash because of the alternating current generated.

Student learning outcomes:

Students can:

- describe the dynamo effect, that movement and magnetism can generate electricity
- make their own Savonius generator by following a recipe of instructions
- experiment with the parts of the generator that produce electricity, to discover the most efficient method
- explain why the LED flashes
- explain why the frequency of the flashes from the LED changes

Ideas for following up the activity:

Carry out an Internet search to discover the advantages and disadvantages Savonius rotors have over conventional propeller rotors.

Extension ideas for more able or faster students:

Ask the students in what ways the wind generator could be made more efficient. Possible answers might include:

- adding more vanes
- having lighter vanes
- making more efficient bearings
- adding more magnets
- adding more coils or turns of wire

The students could also:

- investigate the output using a cathode ray oscilloscope
- consider the implications for transmission of the electricity generated from a wind farm if the outputs from the individual turbines are not in phase
- investigate the output if the coils were connected in parallel

Underlying principles:

The gutter 'vaness' of the Savonius wind rotor catch the moving air and rotate away from it, thus rotating in the 'wind'.

In moving across the tops of the copper wire coils, the magnets change the magnetic field around the coils and so generate electricity by the dynamo effect.

The output from the system is a.c.

Useful web links:

<http://www.southcom.com.au/~windmill/>

<http://www.angelfire.com/ak5/energy21/microsavonius.htm>

http://www.shop4tools.co.uk/acatalog/Magnets_Neodymium_Ferrite_Red_Welding.php

Source of activity:

This apparatus and the associated activity was developed by John Perry, of the Education Department, Keele University from an article available at: http://re-energy.ca/t-i_windbuild-1.shtml

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Photographs by Chris King (ESEU).