ACTIVITY RE6

RENEWABLE ENERGY

Mechanical Power

SECTION A

Power is the rate at which energy is converted from one form to another.

$$\text{power}=\frac{\text{amount of work done}}{\text{how long it took}}$$

Where power is measured in watts (W), work is measured in joules (J), and time is measured in seconds (s).
For example, lifting a 1 kg mass a distance of 1 m in 1 s requires 9.8 W. This is a relatively small unit of measurement. Often when we use electricity, we need much more power than what it takes to lift a 1 kg mass a distance of one meter in one second. As a result, it is common to use multiples of watts, including kilowatts and megawatts. The table below includes multiples of watts that are commonly used.

Unit	Symbol	Number of watts	Sense of Scale
kilowatt	kW	1 thousand (10^3)	A surface area of 1 m^2 on Earth typically receives 1 kW of sunlight (on a clear day at mid-day).
megawatt	MW	1 million (10^6)	Large residential or commercial buildings may use several MW in electric power and heat
gigawatt	GW	1 billion (10^9)	Used for production levels of large power plants or consumption needs of power grids. The London Array, the world's largest offshore wind farm, is designed to produce a gigawatt of power.
terawatt	TW	1 trillion (10^{12})	1 trillion (1012) Enough energy to power a city of 200,000 people for a year.

In this experiment you will use a wind turbine to do the work of lifting a mass. You will vary the pitch of the blades of the wind turbine and measure the time it takes to lift a mass a given distance. Based on these measurements, you will calculate the mechanical power (in watts) generated by the turbine as it lifts the weights.
In order to generate electricity, this mechanical power will have to be converted to electrical power using an electric generator. Experiment 7, Generators, explores the topic of electric generators.

SECTION B

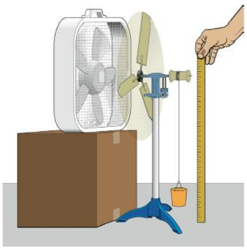
Experiment

Aim

To measure the

Materials

- KidWind Advanced Wind Turbine
- Stopwatch or timer
- Blade Pitch Protractor
- Box fan
- Weightlifter spool and bucket
- 10–15 washers
- Wind Turbine Hub 1 m of string
- Blade materials
- Tape
- Scissors and hot glue
- Balance
- Meter stick
- Safety goggles



Preliminary Questions

1. How does the wind cause a wind turbine or windmill to rotate?
2. How does the blade pitch of a windmill affect the power output?
3. Describe how power plants and wind turbines use mechanical power

Procedure

1. Set up the fan and turbine.
   a. Assemble the wind turbine with the nacelle set up for weight lifting, including connecting the weightlifter spool (see diagram). Do not attach the gears or generator.
   b. Connect three blades to the Hub. Space them evenly apart and set each one with a pitch of 25°.
   c. Position the fan so the centre of the fan is in line with the centre of the hub of the turbine. The fan should be about 25 cm from the turbine. Keep this distance the same for each run.
   d. Clear off your area and make sure that when the fan and the turbine are moving, nothing will be in the way.
2. Complete setting up the equipment.
   a. Start with 6–7 washers. Place them in the bucket, and then determine the mass of the washers and the bucket.

   Record the mass in the data table.

   b. Tie the string to the bucket. Use tape to connect the free end of the string to the weightlifter spool.
   c. Position the bucket so it is located directly below the spool.
   d. Hold the meter stick next to the string.
3. Collect data. Note: This process works best if one person is responsible for the fan, one person is responsible for the stopwatch and data collection, and one person is in charge of holding the meter stick and stopping the bucket as it reaches the top.
   a. Put on safety goggles.
   b. Hold the turbine blade with your hand to keep it from turning. Turn on the fan. After the fan has reached a constant speed, release the blade. Give the blade a gentle push as you release it.
   c. The spool will start to wind the string, and then the bucket will start to lift as the string winds onto the spool.
   d. You will need to measure the time it takes for the bucket to lift a 15 cm distance near the top of the trip. Looking at the meter stick, decide where you will start and end timing.
   Start the timer when the top of the bucket passes the starting point.
   e. Stop the timer just as the top of the bucket passes the ending point.
   f. Turn off the fan. Unwind the string and reposition the bucket and string.
   g. Record the time it took to lift the bucket the 15 cm in the data table.
   h. Repeat this process two more times for a total of three runs at this blade pitch.
4. Increase the pitch of the blades by 10° and repeat Step 3. Continue to collect data until you have collected data for 25°, 35°, 45°, and 55°.
5. If time allows, add more washers into your bucket and repeat Steps 2–4. Collect a second set of data for this new mass.

Data

Mass: ____________ kg
Distance to lift: ____________ m
Force: ____________ N
Work: ____________ J

Blade pitch (°)	Run	Time to lift (s)	Average time to lift (s)	Power (W)
	1			
	2			
	3			
	1			
	2			
	3			
	1			
	2			
	3			
	1			
	2			
	3			

Processing the data

1. Calculate the average time to lift for each pitch.
2. Calculate the force (weight) of the bucket and washers.
   Reminder: force (N) = mass (kg) × acceleration due to gravity (9.8 N/kg)
3. Calculate the work done (in joules) to lift the bucket and washers the 15 cm.
   Reminder: work (J) = force (N) × distance (m)
4. Calculate the power for each blade pitch. Reminder: $\text{power (W)} = \frac{\Delta\text{work (J)}}{\Delta\text{time (s)}}$

Analysis Questions

1. Describe the relationship between power and time to lift.

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2. Describe the relationship between blade pitch and mechanical power.

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3. What are some of the causes of inefficiency in converting moving air (wind), which has kinetic energy, to mechanical energy?

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4. If a typical electric generator is 80% efficient, how much electrical power (in watts) could your turbine generate? (Use your most powerful blade pitch.)

Further Questions

1. Compare your result to the data collected by other groups.
2. Test an additional blade variable or varying wind speeds to examine how a different variable affects efficiency

