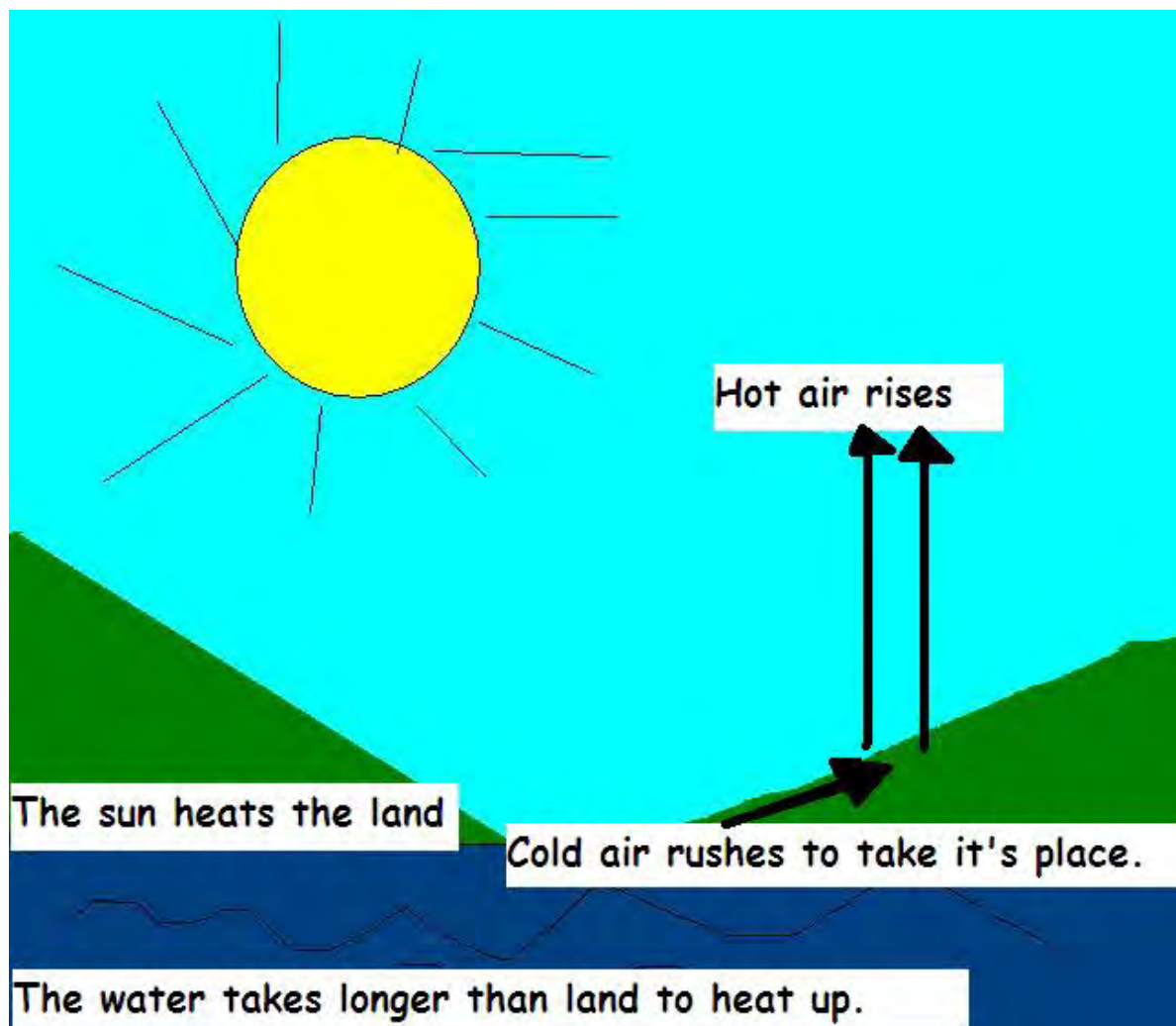


WIND ENERGY EXPERIMENTS

Wind is a form of solar energy. The sun shines on land and water, the land heats up faster than water, the warmer air over the land rises, the cooler air over the water moves in to replace it, causing winds. This wind flow, or motion energy, when harvested by modern wind turbines, can be used to generate electricity. Simply stated, a wind turbine is the opposite of a fan. Instead of using electricity to make wind, like a fan, wind turbines use wind to make electricity.

Although wind energy is free, the equipment needed to harness and store the energy can be expensive. Scientists and engineers are continuously working on creating more efficient technologies.



The following experiments will help you understand the use of wind energy:

Experiment 1: Converting Wind Energy into Electrical Energy. You will use a wind turbine to harness motion/kinetic energy and convert it to electrical energy (electricity).

Experiment 2: Connecting electrical loads to the energy source. You will use the generated electricity to power up electrical loads (lights and speaker).

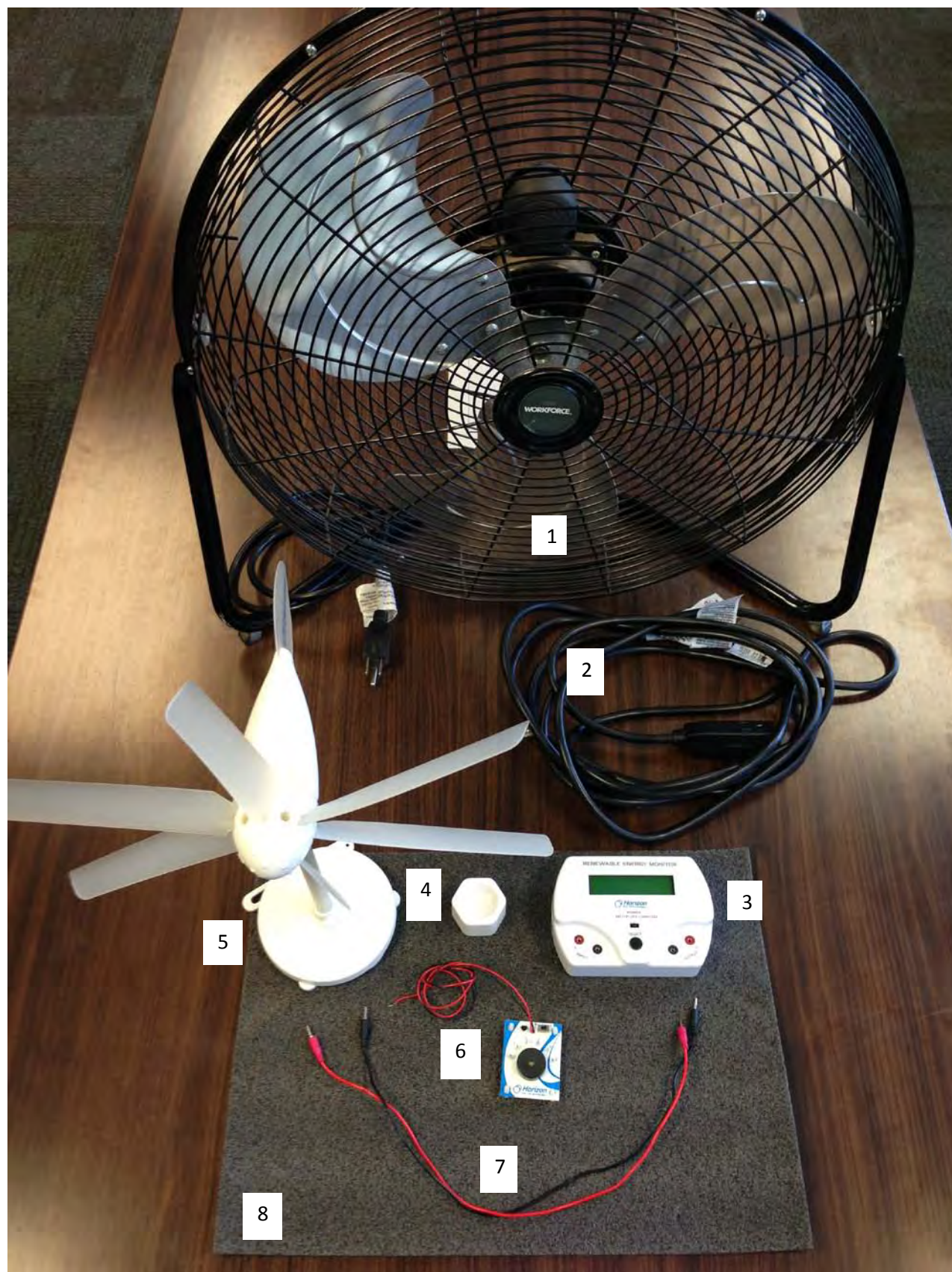
Experiment 3: The effect of wind direction on wind turbines. You will use yaw control to optimize the harnessing of wind energy.

Experiment 4: The effect of wind speed on wind turbines. You will use yaw control, and blade pitch control to optimize the harnessing of wind energy; as well as to protect the wind turbine components under extreme high wind conditions.

DIRECTIONS: Make sure you read the instructions thoroughly as well as refer to the photos provided to ensure that your experiments are successful.

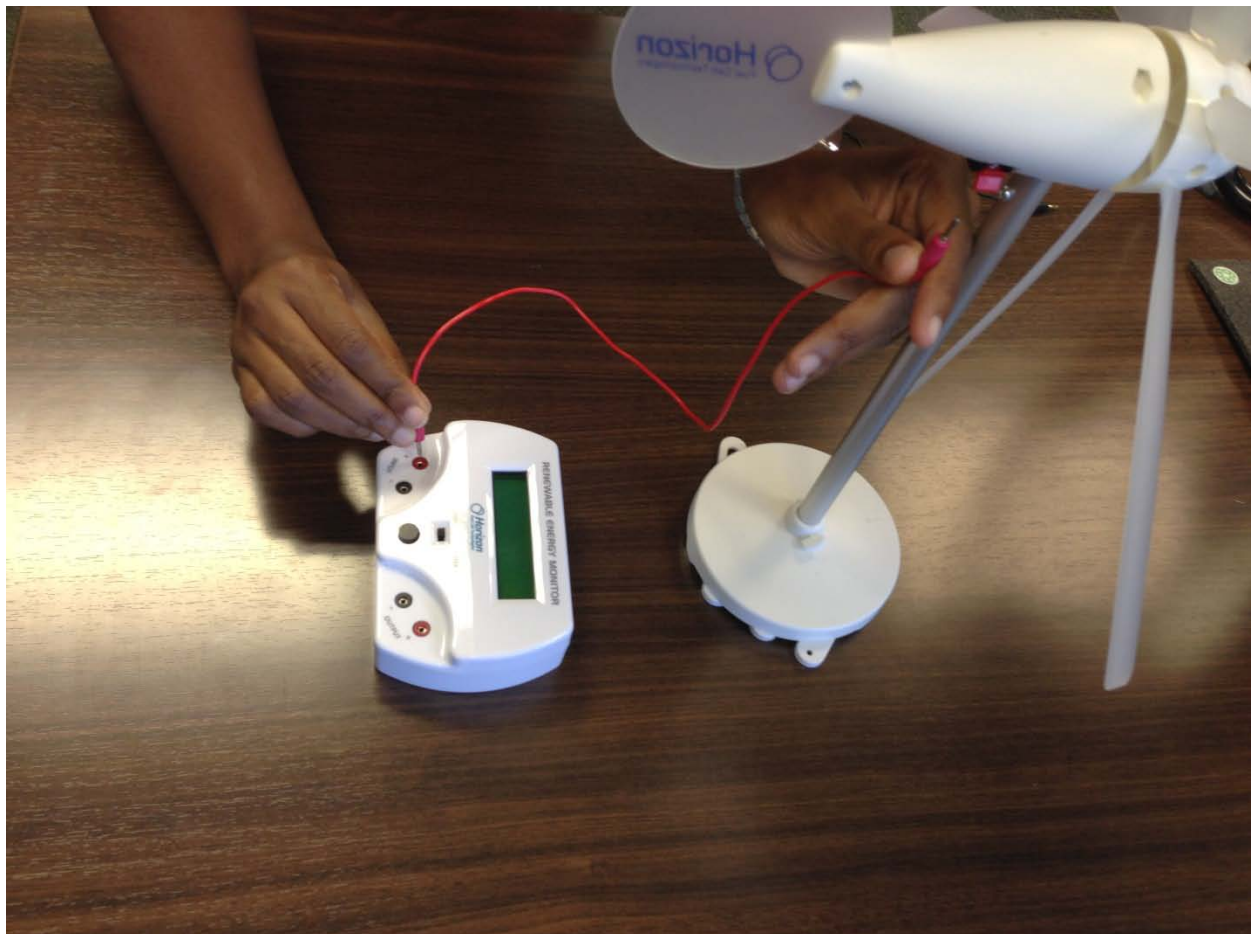
MATERIALS: Gather all the necessary materials onto a working table (refer to photo on the next page, and compare to the list below).

1. (1) portable 20" black fan
2. (1) extension cord
3. (1) renewable energy monitor (REM)
4. (1) rotor locking tool
5. (1) wind turbine
6. (1) LED voltmeter/music maker module
7. (1) pair of 16" red & black hook-up wires
8. (1) dark thin foam sheet (top inside cover of the kit box)



Set-up: Take the 20" black fan, dark thin foam sheet, renewable energy monitor (REM), wind turbine, rotor locking tool, the red wire, and the black wire. Set them on a separate area of your working table. Set the fan on the foam sheet (this is so the fan does not slide back at high speeds); place the wind turbine directly facing the front of the fan, about 24" away from it. Make sure the small screw in the pole under the turbine body is aligned with the tail, facing away from the fan. Place the REM under the tail of the wind turbine. Take the extension cord to a wall AC outlet and plug it in the wall socket. Set the other end of the extension cord on the table next to the fan. Make sure the fan is turned to OFF, then plug the fan into the extension cord.

From this point on, always work with care and avoid the wire ends touching each other. Always hold the wires with one hand on each end as illustrated in the photo below. This will help to ensure that the wire ends make contact only where you intend them to.



1. Gently pull up on the red tab under the wind turbine body (see photo below). Insert the red wire into the red (+) terminal on the wind turbine. Then release the tab. Insert the other end of the red wire into the red (+) REM INPUT terminal (left side).
2. Gently pull up on the black tab under the wind turbine body (see photo below). Insert the black wire into the black (-) terminal on the wind turbine. Then release the tab. Insert the other end of the black wire into the black (-) REM INPUT terminal (left side).

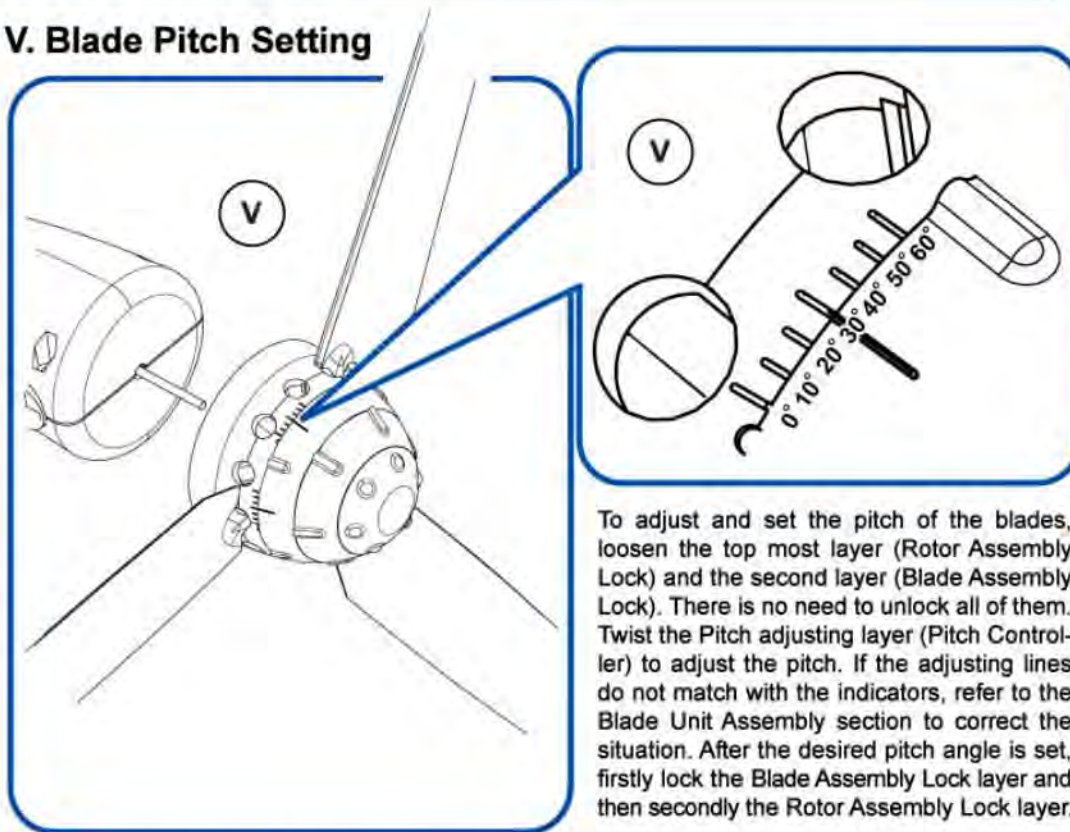


Your materials should now look like the top photo on the next page. Next you have to make sure the wind turbine blades are pitched at 55 degrees (refer to the bottom photo on the next page and the diagram on page 7).

NOTE: Use the rotor locking tool provided in the kit every time you untighten and tighten the Blade Assembly Lock & Rotor Assembly Lock layers.



V. Blade Pitch Setting



To adjust and set the pitch of the blades, loosen the top most layer (Rotor Assembly Lock) and the second layer (Blade Assembly Lock). There is no need to unlock all of them. Twist the Pitch adjusting layer (Pitch Controller) to adjust the pitch. If the adjusting lines do not match with the indicators, refer to the Blade Unit Assembly section to correct the situation. After the desired pitch angle is set, firstly lock the Blade Assembly Lock layer and then secondly the Rotor Assembly Lock layer.

Locking and Unlocking

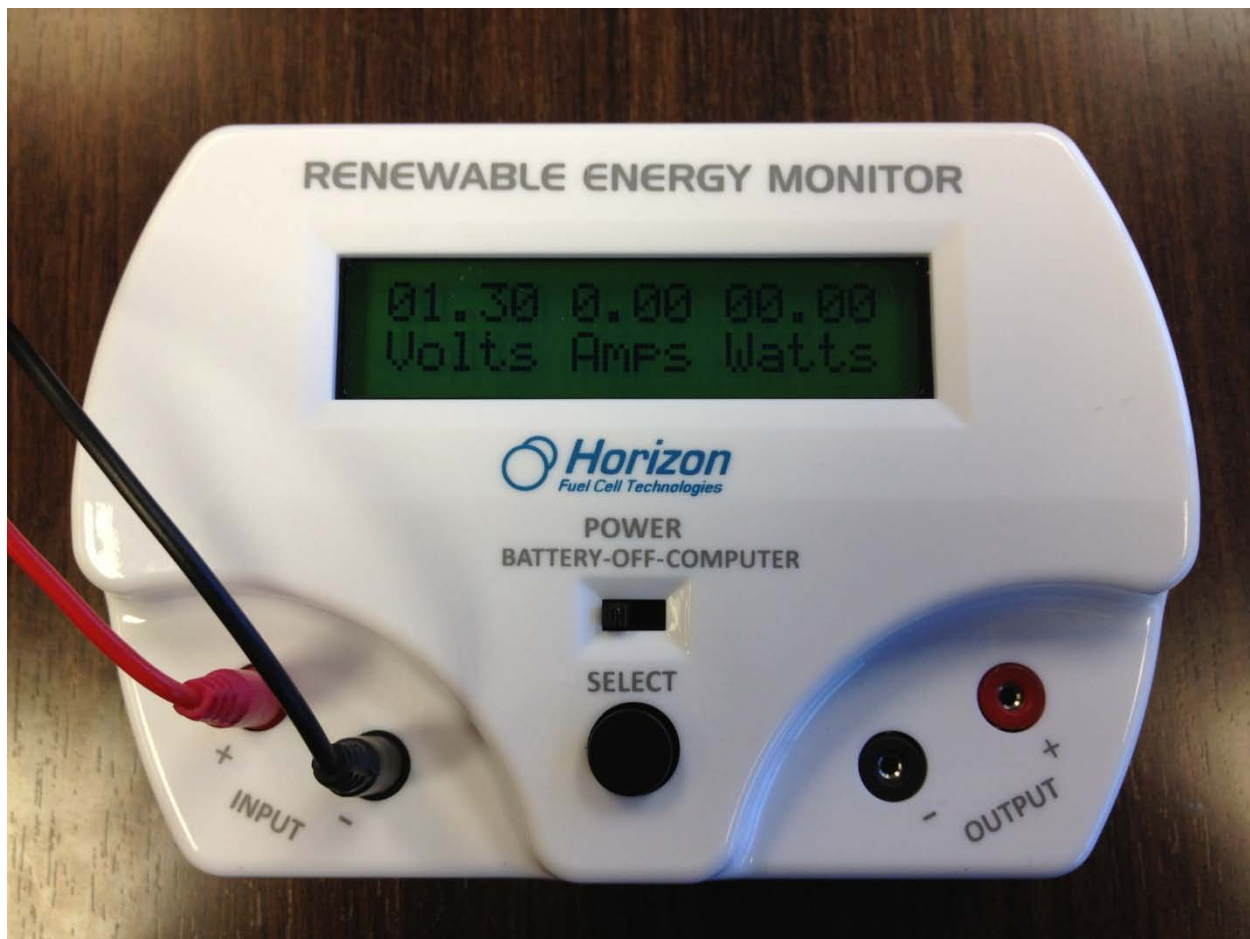
Apply reasonable force to secure the layers so that the adjusted pitch can stay at the desired position. DO NOT over tighten the layers, otherwise, you may have problems when you try to unlock the individual layers. If you mistakenly lock the layers too tightly, you may use a rubber mat to assist you in unlocking the layers. Wearing a rubber glove may also give you more friction and better grip in unlocking the layers. If this does not succeed, try locking the second layer slightly in so as to separate the Rotor Assembly Lock and Blade Assembly Lock layers. Afterwards, unlock the Rotor Assembly Lock layer and then the Blade Assembly Lock layer. This double nut mechanism is to prevent the rotor from coming apart when it is rotating at high speed.

The Pitch Angle

The blades themselves have different set angles at different sections to enhance the performance. This setting is to compensate the rotating speed of the blade at different radius (sections) so that the blades will not stall at a particular section. You may have to learn more about a parameter called Tip Speed Ratio to understand more thoroughly. This Ratio defines how fast the turbine is rotating under a wind speed environment. By changing the blade pitch, this ratio will be changed. Thus the output power of the turbine is changed. The pitch indicator on the rotor refers to the pitch at the tip of the blade. The line mark nearest the semi-circle is the 0 degree mark. Each line mark represents a change of 10 degrees. Therefore, the pitch is allowed to be adjusted from 0 to 55 degrees.

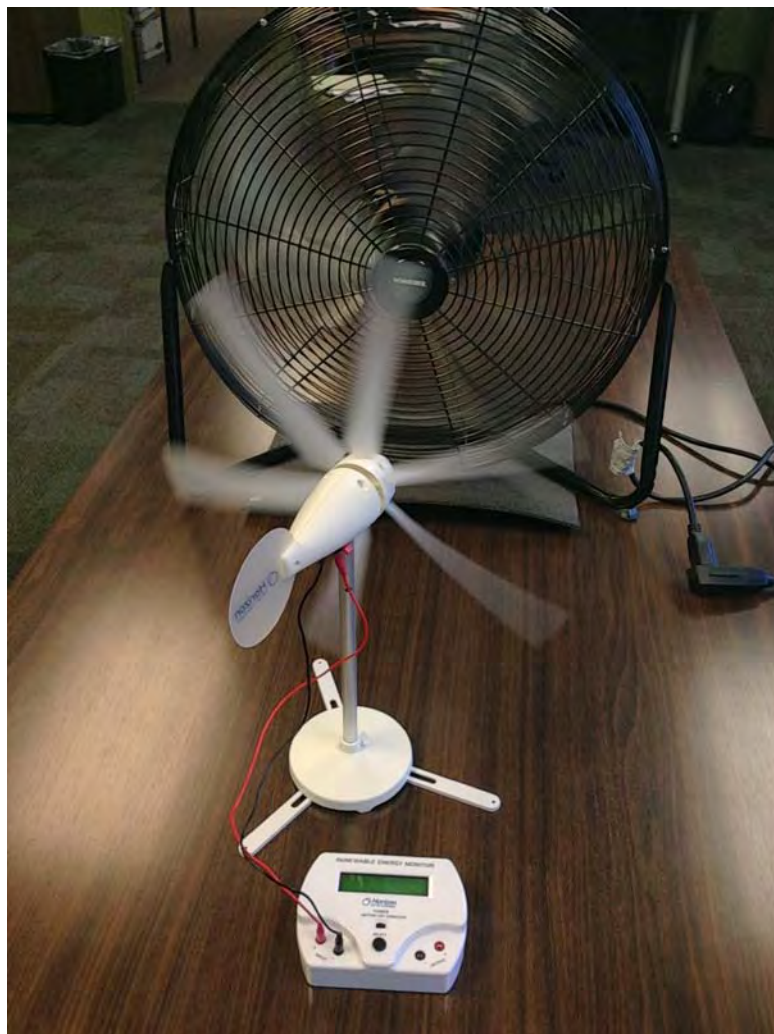
With the pitch set to "0" degrees, the rotor will not turn. At smaller pitch value settings, the start up wind speed has to be very high. Maximum output power occurs at a pitch of around 10 degrees. The start up wind speed is higher at a lower pitch setting. If the wind speed is low you should increase the pitch so that you can achieve a higher power output.

Now you are ready to turn on the REM. Slide the REM POWER switch from OFF to BATTERY. The REM display screen will show: **Volts-Amps-Watts** as illustrated in the photo below. If it doesn't, you can use the REM SELECT button to bring up that display screen. By pressing the button once, the REM switches to the next display screen. If you pass the display screen you want, keep pressing the button until you return to it, as there are only 4 display screens.



Experiment 1: Converting Wind Energy into Electrical Energy

Extend out the stabilizer legs under the base of the wind turbine. Make sure the wires do not get caught by the blades when they start spinning. Also take notice that they do not tug at the turbine body making it turn away from the fan (refer to photo below). Since the experiment takes place indoors, you will be simulating the wind with an artificial source (the fan). Turn the fan to HIGH. The blades will start spinning. Look at the REM screen and observe how many Volts are being generated. At any time you can use your fingers to gently hold on to the tail to eliminate the vibration and instability, this will normalize the readings a bit. Next, turn the fan to MEDIUM, and observe how the Volts reading decreased. Finally, turn the fan to LOW, and observe how the Volts reading decreased again. Now, turn the fan to OFF. The blades will stop spinning.



The lower the wind speed, the lower the amount of electricity the wind turbine was able to generate. Keep this experiment in mind, as we will revisit this concept later.

Set-up: Slide the REM POWER switch from BATTERY to OFF. Disconnect the red and black wires in no particular order from both the wind turbine and the REM. Set the REM and the wires back with the other materials you are currently not utilizing. Take the LED voltmeter/music maker module to your working area. Attach the LED voltmeter to the wind turbine. Gently pull up on the red tab under the wind turbine body. Insert the red wire from the LED voltmeter and then release the tab. The wire should now be securely connected in place. Give it a gentle tug to make sure. If it is not, carefully repeat the procedure. Do the same for the black wire. Remember to make sure the wires do not get caught by the blades when they start spinning. Also take notice that they do not tug at the turbine body making it turn away from the fan. Make sure the small screw on the pole is aligned with the tail. Your materials should now be assembled as in the photo below:



Experiment 2: Connecting electrical loads to the energy source

Slide the switch on the LED voltmeter/music maker module to VOLTMETER. Turn the fan to LOW, the wind turbine will start spinning. Observe the LED voltmeter; the LED light that is on indicates how much voltage is being produced by the wind turbine. Slide the switch to MUSIC and listen to how slowly the jingle plays, the LED will turn off. Now, turn the fan to OFF, the wind turbine will come to a stop and the music will stop playing, since there is no longer any energy being produced by the wind turbine to power up the electrical loads (LED's & speaker).

Now, using the rotor locking tool and what you learned from the diagram on page 7, adjust the pitch of the blades to 20 degrees. Place the wind turbine back in front of the fan, about 24 inches away from it making sure the small screw is aligned with the tail. Turn the fan to LOW, the wind turbine will start spinning. Listen to how fast the jingle plays now. Next, slide the switch to VOLTMETER, observe that more LED lights are on now, indicating a higher voltage reading than before (refer to photo below). The speed of the wind did not change, but by controlling the pitch of the blades on the wind turbine you were able to harness more energy and supply more power to the electrical loads. Turn the fan to OFF.



Set-up: Gently pull up on the tabs under the wind turbine body and disconnect the wires of the LED voltmeter from the wind turbine terminals and set the LED voltmeter next to the other materials you are not currently using.

The wind does not always blow in the same direction, so next you will simulate changing wind conditions. Carefully rotate the position of our wind source (the fan) 90 degrees on the table, so that now it is pointing towards the side of the wind turbine (see photo below). Make sure the small screw in the pole under the turbine body is aligned with the tail.



Experiment 3: The effect of wind direction on wind turbines

Hold the tail of the wind turbine with your fingers so that it doesn't move and turn the fan to LOW. Observe how the wind now is blowing from a complete different direction than before in relation to the wind turbine. Notice that the wind turbine is not spinning and consequently not harnessing any of the energy from the wind. Now, using your fingers let go of the tail and observe how the wind turbine blades start to catch the wind and the wind turbine body rotates ("yaws") into the direction the wind is blowing (see photo below). This is called passive yaw control. Active yaw control would be achieved by means of a mechanical system that when energized, rotates the wind turbine around, instead of it rotating freely as you just observed. You will explore this concept further during experiment #4.



Make sure the stabilizer legs under the wind turbine base are correctly in place. Turn the fan to MEDIUM, and observe the wind turbine speed up and the presence of increased vibration. Now turn the fan to HIGH, and observe the changes that occur in the wind turbine. The higher speeds cause more increased vibration and instability. Now, turn the fan to OFF. The wind turbine will come to a stop.

To optimize the harnessing of wind energy, wind turbines are oriented using yaw control so that they face the wind directly (perpendicular to the wind stream). Yaw control is also used to limit the power output and to protect the wind turbines when necessary in high wind conditions. Otherwise a runaway turbine will be overloading its rotors, mechanical power train, as well as its electrical generator leading to catastrophic failure. It is possible to yaw (rotate) the wind turbine out of the wind stream to decrease its rotational speed or stop it all together with the assistance of special brakes. In pitch power controlled wind turbines an electronic controller senses the power output of the turbine several times per second. If, at high wind conditions the power output level exceeds a prescribed safe level, an electronic signal is generated which turns or pitches the blades out of the wind decreasing the wind turbine rotational speed or stopping it all together (stall). At low wind conditions the power output level is lower and the blades are pitched back at the optimal angle of attack to catch more wind and increase the rotational speed of the wind turbine and its power output. Next, you will explore these concepts.

Set-up: Place the wind turbine directly facing the fan and about 24" away from it. Make sure the small screw on the post is under the tail and that the stabilizer legs are properly in place.

Experiment 4: The effect of wind speed on wind turbines

Remember the vibration and instability conditions you observed under extreme high winds during the last experiment? To avoid damage to the wind turbine you can use yaw control, and blade pitch control not only to optimize the harnessing of wind energy; but also to protect the wind turbine components under extreme high wind conditions. Turn the fan to HIGH, and observe the vibration and instability conditions that lead to wind turbine failure. Carefully use your fingers to hold the tail. Gently turn the wind turbine 90 degrees away from the direction of the wind, and observe how it slowly comes to a stop (see photo below). Turn the fan to OFF.



Full scale wind turbines have mechanical yaw control systems that rotate (yaw) the wind turbine automatically to protect against high wind conditions.

Set-up: Using the rotor locking tool and what you learned from the diagram on page 7, adjust the pitch of the blades to 0 degrees.

Make sure the wind turbine with the blades pitched to 0 degrees is directly facing the fan about 12" away from it and the small screw is aligned with the tail (see photo below). Turn the fan to HIGH, and observe what happens. The blades are pitched so that they cannot catch the wind, consequently the wind turbine does not spin. Of course there is no electricity being produced because there is no wind energy being harnessed, but in this case protecting the components of the wind turbine against failure is the priority. Full scale wind turbines have mechanical pitch control systems that adjust (pitch) the blades automatically to protect against high wind conditions. Turn the fan to OFF.

