Procedure

Section II: Methodology

Role of Student vs. Mentor

I found and designed the 3D hubs connected to the blades and with the assistance of Gustavo Rodriguez, printed these designs out. I set up the experiment with the wind tunnel, and Daniel Paradise and Eric Chardonnet supervised my use of the wind tunnel, before I switched to using a fan.

Equipment and Materials

To construct the online 3D hub and blades, TinkerCAD was used, and the blades were retrieved from online sources. The wind turbine blade was retrieved from me2space, licensed under creative commons attribution. The pterodactyl wing was retrieved from creazilla, created by Micheal (no last name provided). The penguin wing retrieved from ThingVerse, created by SpaceLord87. The bat wing was retrieved from SketchFab and was created by user neutralize. A (enter-specific printer) was used to print out the designs required for this project. For the initial proof of concept test, a drill was used to create a hole in the center of the hub. A 3/16" diameter metal rod was used as the axle, and a photogate was used to measure revolutions per minute (RPM). The website Youlean's online sound meter was used to record sound power levels in decibels on an iphone. A wind tunnel was used to conduct each experiment. Two pieces of angle iron sheets with predrilled holes that are 6" long were used, along with 2 flat iron sheets with predrilled holes, one screw, 4 nuts, 4 washers, a hacksaw, and Phillips head screwdriver were used.

Designing the 3D CAD Propellers

Each blade/wing was imported into TinkerCAD. The blade was rotated to a 25 degree pitch angle, and duplicated, creating three blades. The penguin wing was reduced in thickness to prevent it from breaking. Each blade was scaled to be 3.55" in length. Next, the hub was constructed. A cylinder with a diameter of 0.8” and a height of 0.517” was created. In the center of the cylinder, a 3/16” hole was placed (for the axle). Three rectangular prisms were connected to the hub equidistant from each other, starting from the bottom going to the top, and were 0. 636” long and 0.416” wide. The edges were slightly curved, to more accurately resemble the base of an actual wind turbine blade. The rectangular prisms used to connect the blades to the hub. These pieces were connected to be 3mm deep. Next, each wing was moved 3 mm deep into each of the rectangular prisms. Each of these designs were 3D printed at 0.1mm layers, with a 30% infill except for the penguin to increase functionality due to size, which was printed at 15%.

The Construction of the Wind Turbine Stand and Axle

Two 6” metal pieces with a perpendicular side were connected with a screw (enter specific name), with two pieces of metal with holes (enter specific name) clamped between them. A (enter specific name) was wedged between the two vertical pieces, with 4mm by 80mm screw in between it. Another screw was inserted above and below the pre existing holes, perpendicular to the screw wedged between the two metal pieces. A washer and nut were placed on the end of each screw**.** The propellor was placed on the screw wedged between the two pieces of metal acting as the axle, allowing the propellor to spin freely. The propeller was kept in one palace using washers and nuts on each end. (Reference Image 1).

Measuring Radians per Second and Angular Acceleration

The wind turbine apparatus was placed directly 31” in front of a fan, and the photogate was placed 3.25” to the right of the wind turbine, allowing each blade to break the photogates laser. On Vernier Analysis Pro, The photogate was set up to measure radians per second based on the number of times the blades break the laser. With the same set up, the angular acceleration (a) of each different design and wind speed was measured using the photogate. Vernier analysis automatically calculated angular acceleration. To obtain angular acceleration, the average acceleration was recorded from when the turbine was at rest until it hit its terminal velocity.

Measuring Sound Power Levels (dB)

To measure sound power levels, a phone using the built in decibel meter was placed 6” to the right of the wind turbine (directly parallel with the blades). Once the fan was started, after two seconds of running the phone would record the average decibel (dB) level over 10 seconds.

Statistical Tests

Two equations were used to find an approximation of the power generated by each turbine. One equation calculated for torque (T), and the other used torque to calculate power (P). To find torque, the moment of inertia (I) was calculated by summing the blades (treated as rods), and the central hub (treated as a cylinder).

$$T=I*a \quad (1)$$

$$I=\frac{1}{2} M (R1^2 + R2^2) \quad (2)$$

$$I=ML^2/3 \quad (3)$$

$$P=TW \quad (4)$$

Equation 2 using mass (M), the radius of the entire cylinder R1, and the radius of the smaller hole in the cylinder (R2) to find the moment of inertia. The third equation calculates the moment of inertia for a singular blade, instead using the length of the blade (L) rather than the radius.

Student’s t test

An ANOVA test was used to determine the significance between each different blade, for both sound levels and kinetic energy. Each different level of the independent variable (type of blade) and each different wind speed as well. A two-sample T-test was chosen because the means of two independent groups were compared.