Team Number: ____

School/Team Name:_______________________________________

Student #1:____

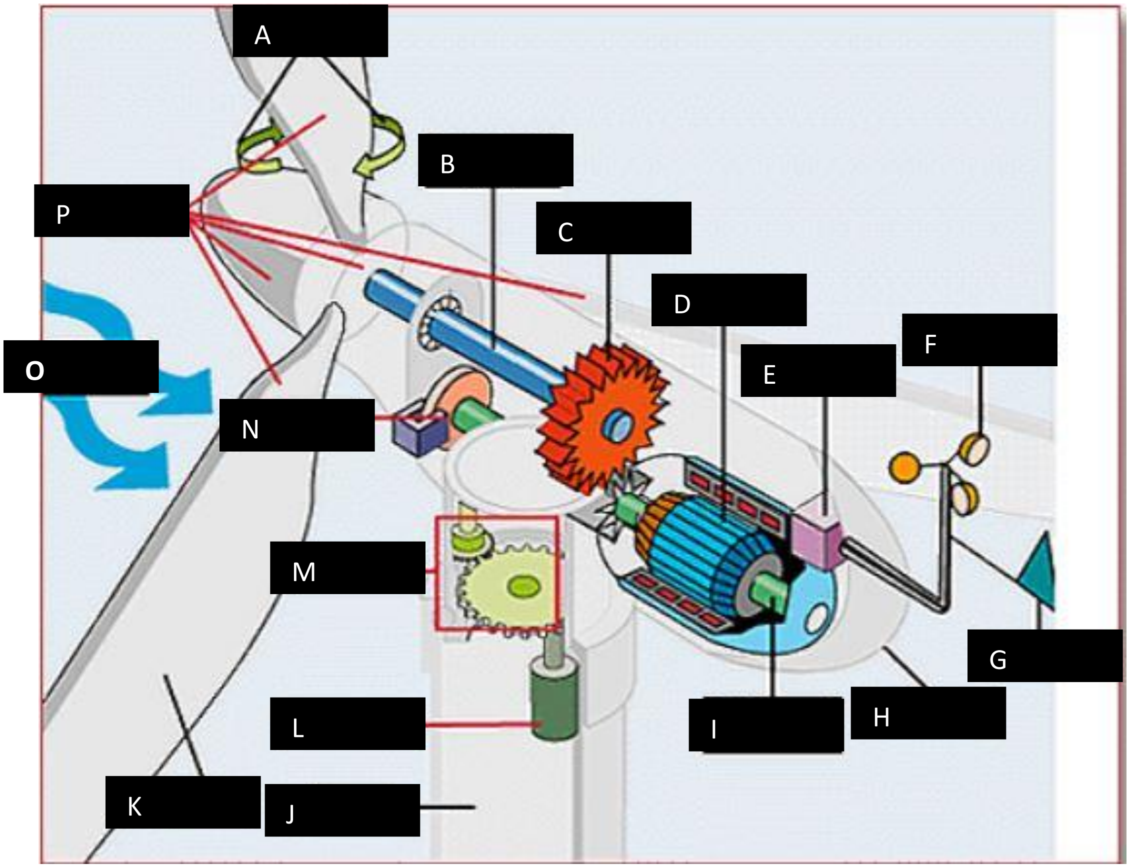
Student #2:____

Part 1 Exam Score (70 max)	
Part 2 Exam Score (12 max)	
Final Exam Score (82 max)	

Instructions: Students will have 25 minutes to complete this test to the best of their abilities. All answers must be in metric units and proper significant figures unless otherwise noted. Students are allowed a 3-ring binder with informational material, along with a calculator, protractor, ruler, and pens/pencils. Best of luck!

Part 1 (4 points per question unless otherwise noted):

1. Please match the words to their respective positions on the diagram (8pts).



I- High-speed shaft
H-Nacelle
G- Wind Vane
J-Tower
L-Yaw Motor
K-Blade
E-Controller
B-Low-speed shaft
O-Wind direction
P-Rotor
A-Pitch
D-Generator
F-Anemometer
N-Brake
M-Yaw drive
C-Gear box

Each answer is worth 0.5 points. Incorrect answers are worth 0 points

2. Which value is power *not* proportional to?
   a. Air density
   b. Rotor Pitch
   c. Cube of velocity
   d. Rotor Swept area

3. Write the formula for tip-speed ratio:

$$\lambda = \frac{Wing\ tip\ speed}{wind\ speed}$$

partial credit: 1 point for each correct term

4. The maximum theoretical efficiency is known as the Betz Limit (2pts), which is 59.3 (2pts)%.

1 point for 59%

5. Which country generates the most energy from wind power?
   a. United States
   b. Netherlands
   c. Germany
   d. Spain

6. Give two examples of disadvantages, and two examples of advantages of wind power.

One point per correct answer, no points for no answer, and -1 point per (blatantly) incorrect answer

Advantages:
-renewable
-zero emission
-high potential
-cost competitive with fossil fuels
-modular

Disadvantages:
-low energy density, need many turbines
-intermittent and uncertain supply
-distance from demand, need transmission
-potentially harmful to wildlife
-noise
-visual impact

7. The generators in most commercial wind turbines are LVRT devices (low voltage ride through devices). What does this mean?

a. The turbine's generator has the ability to continue functioning even during a period of lower than normal voltage experienced in the transmission without going offline.

b. The turbine generates specifically low-voltage current.

c. The turbine generates current using a doubly-fed induction generator.

d. The turbine and its generator will immediately go offline when it experiences low voltage in the transmission system until it is manually reset.

8. When was the first all-steel wind turbine introduced to the United States?

a. 1858

b. 1865

c. 1878

d. 1890

9. Please Match the blank boxes with the correct terms.

		Input	
		AC	DC
Output	AC	A	B
	DC	C	D

B-Inverter
D-Converter
A- Transformer
C-Rectifier

Each answer is worth 1 point. Incorrect answers are worth 0 points

10. ACSR Power Cables use two types of metals. What are they?

1. Steel
2. Aluminum

Each answer is worth 2 points. Incorrect answers are worth 0 points

11. Lenz's law is integral to the function of generators. What does this law say?

The direction of current induced in a conductor by a changing magnetic field due to Faraday's **law** of induction will be such that it will create a field that opposes the change that produced it.

~and/or~

Lenz's law states that when an emf is generated by a change in magnetic flux according to Faraday's Law, the polarity of the induced emf is such, that it produces an current that's magnetic field opposes the change which produces it.

4 points for conveying exactly what either of the two answers state, otherwise, +1 for mentioning magnetic flux, +1 for mentioning change in direction of current

12. What is not part of a Permanent Magnet Generator/Motor?
    - a. windings
    - b. operational amplifiers
    - c. insulation
    - d. magnets

13. Name four types of energy storages systems/devices.
    - -batteries
    - -capacitors
    - -compressed air (CAES)
    - -flywheels
    - -pumped hydro
    - -thermal

Each answer is worth 1 point. Incorrect answers are worth 0 points

14. What is the difference between energy density and power density? Give an example of an electromechanical storage device that has high power density but low energy density.

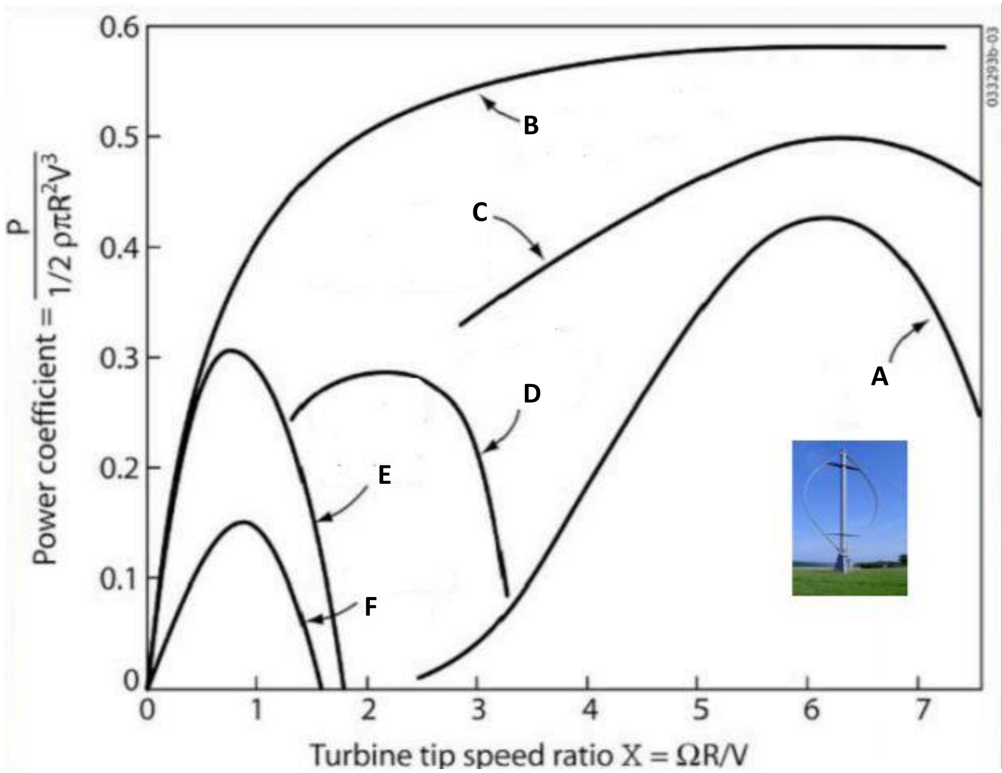
2 pts-Energy density is the amount of energy a system can store per unit mass or volume, while the power density is the amount of power a system can release at any given time per unit mass or volume, whereas power and energy are related by the fact that power is the flux of energy.

2pts-*Capacitor* (or high power lithium cell for 1 point)

15. Explain the conditions of stalling and luffing, and how they play into apparent wind direction.

1 pt-Stalling is when the attack angle is too steep, causing loss of lift.
1pt-Luffing is when attack angle is too shallow, causing extra drag.
2pts-must have attack angle between stalling and luffing to ensure that apparent wind direction is such that the airfoil, or blades, operate in an efficient regime.

16. Match the type of wind harvesting device to the graph below (6pts).



D-Dutch multi-blade turbine
F-Savonius Rotor
A- Darrieus Rotor
C-High speed 2 or 3 bladed turbine
E-American farm windmill
B-Ideal efficiency of propeller-type turbine

Each correct answer is worth 1 point. Incorrect answers are worth 0 points

Part 2 (6 points each):

17. The elevation of a turbine hub is increased from 30 meters to 60 meters. By what percent will the wind speed increase, and by what percent will the power output increase?

Using the Formula(2pts):

$$\frac{v(h_2)}{v(h_1)} = \left(\frac{h_2}{h_1}\right)^{1/7}$$

Wind speed increases by ~10% (2pts)
Power is proportional to cube of velocity (1pt)

Power output will increase by ~35% (1pt)

18. Calculate the resistive losses of transmitting 1kW of power over 1 km through a 1 cm ACSR wire (~1Ω/km) for both 100 volt and 1,000 volt lines.

Using the Formulas(2pts):

$I = P/V$

$P_{loss} = I^2 * R$

(2pts) 100 Volt line: $P_{loss} = \left(\frac{P}{V}\right)^2 \times R$

$$P_{loss} = \left(\frac{1000W}{100V}\right)^2 \times 1\Omega = \mathbf{100\ Watt\ loss}$$

(2pts) 1000 Volt line: $P_{loss} = \left(\frac{P}{V}\right)^2 \times R$

$$P_{loss} = \left(\frac{1000W}{1000V}\right)^2 \times 1\Omega = \mathbf{1\ Watt\ loss}$$