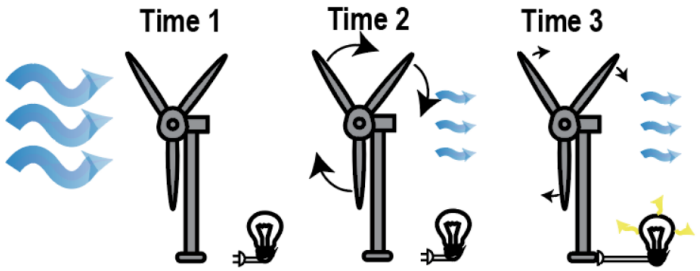
6Q2 - Quiz on the Physics and Design of a Wind Turbine

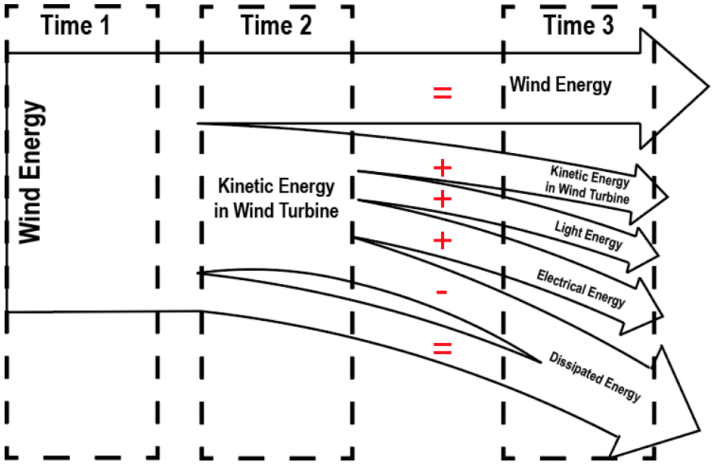
Name: KEY

Period: _____

Date: _____

The image below left shows at **Time 1** a gust of wind travels towards a wind turbine, at **Time 2** the gust of wind has past and the generator and light bulb are not plugged in, lastly at **Time 3** the generator is on and the light bulb plugged in. The image below right shows a Sankey diagram of the wind turbine described. Use the images below to answer questions 1-4.





1. Use the Sankey diagram estimate the overall efficiency of the wind turbine.
   A. 15%
   B. 40%
   C. 65%
   D. 90%

2. Which of the below changes below would BOTH create a more efficient wind turbine.

	Wind Energy being harnessed to turn blades (Time 1 to Time 2)	**Turbine converting kinetic energy into electrical energy (Time 2 to Time 3)**
A.	Wind turbine placed in a location with higher wind energy.	A more efficient light bulb is plugged in.
B.	Wind turbine placed in a location with higher wind energy.	The generator is lubricated to reduce the dissipated energy.
C.	Blades are curved to capture more of the wind's kinetic energy transferring it to the wind turbine's kinetic energy.	A more efficient light bulb is plugged in.
D.	Blades are curved to capture more of the wind's kinetic energy transferring it to the wind turbine's kinetic energy.	The generator is lubricated to reduce the dissipated energy.

3. Applying your learning to a large scale wind farm, which of the following factors would likely increase its power output?
   a. More wind turbines
   b. More efficient wind turbines
   c. More input wind energy
   d. More output wind energy
   e. More kinetic energy in the wind turbine
   f. Less light (used) energy
   g. Less electrical energy out
   h. Less dissipated energy
   i. Less efficient generators
   j. Less direct sunlight

4. The wind farm has now installed more efficient generators. Mark on the Sankey diagram between Time 2 and Time 3 above:
   + For an arrow that will grow **=** For an arrow that will stay the same size **-** For an arrow that would shrink.

Communicating your Design Choices

Claim, Evidence, Reasoning for Wind Turbine Design

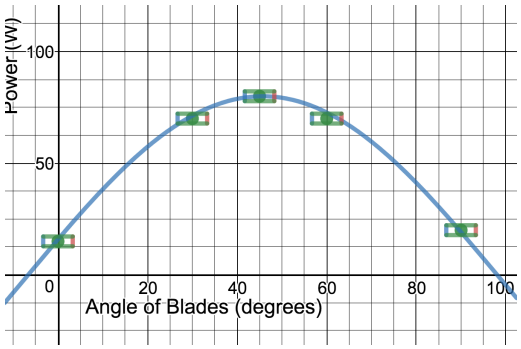
The following data was taken by an apparatus that was slightly different from our original towers. Use the following data and pricing to design the optimal wind turbine to create a power of at least 75 Watts within the $25,000 budget:

Figure 1: Material Costs

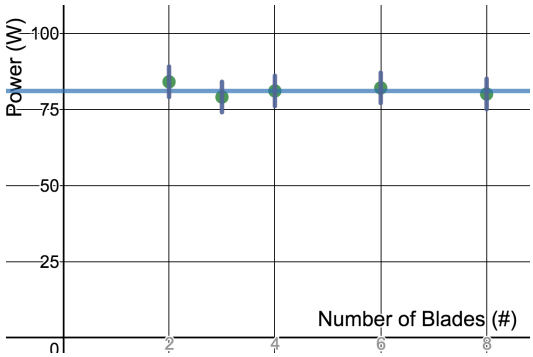
Number of Blade Holders (# of Pegs)	Total Cost of Blade Holders ($)
2	5,000
3	7,500
4	10,000
6	12,500

Total Area of Paper on All Blades (cm^2)	Total Cost of Paper on All Blades ($)
50	10,000
75	15,000
100	20,000
125	25,000

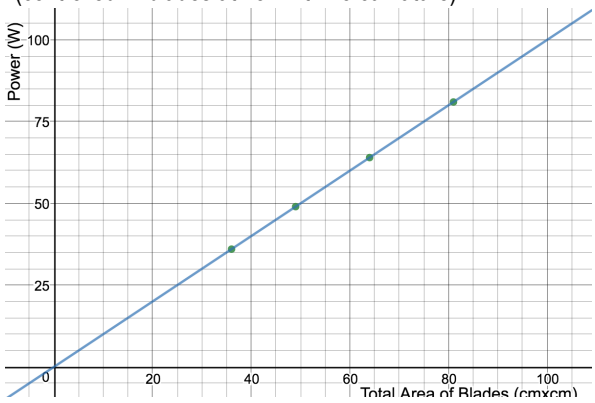
Graph 1: Power vs Angle of Blades
(controlled: 2 blades with a total area of 80 cm^2 and no curvature)



Graph 2: Power vs Number of Blades
(controlled: Total area 80 cm2 and blades at 45° with no curvature)



Graph 3: Power vs Total Area of Blades
(controlled: 2 blades at 45° with no curvature)



1. For this question you will use the claim, evidence, reasoning format to communicate your wind turbine design; specifically including the angle of blades, the number of blades, and the total area of the blades.

Claim. Evidence. Reasoning.
Student Example:
After evaluating and analyzing the different behaviors of wind turbine, I conclude that the most optimal design with a $25,000 budget would include having 2 blades which is tilted at an angle of 45 degrees, and having the total area of the blades be 100cm^2.

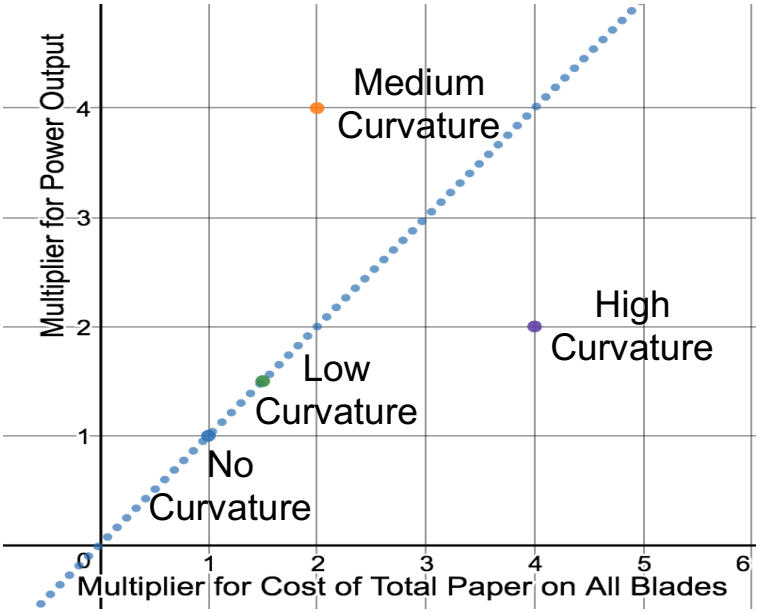
My first piece of evidence is Graph 1 that shows the angle of the blade and the amount of power being produced, the highest amount of power that is being produced is just over 75 W which is when the angle is at 45 degrees. Since the angle of the blade does not cost anything my design recommendation is to go with the highest energy producing angle which is 45 degrees, it fits perfectly with the budget of being free and meets the criteria of producing over 75 W.

My second piece of evidence is Graph 2 which demonstrates the number of blades and the cost of them. Graph 2 shows the number of blades and the amount of power it produces and it is pretty horizontal. There is not that big of a difference between the amount of power that is being produced between the different amount of blades but 2 blades produced the most amount of power which is over 75 W. Considering this and the fact that there is a $2,500 price difference and since having 2 blades is the cheapest option, I recommend building a wind turbine with only two blades. It is efficient and the least expensive option.

Graph 3 indicates that the area of the blades and the price of them, and the amount of area and the amount of power that is being produced, it is a linear graph. Therefore the optimal design should have 100cm^2 blades. With spending $5,000 on the number of blades already and having the angle be free, with a budget of $25,000, there is $20,000 dollars left to spend which can all go to the area. And since the bigger they are at the more power is produced it makes sense to go with the biggest area that fits within $20,000 which is 100cm^2 . It produces the right amount of energy and fit the budget so it makes sense to go with that one.

After creating your first design above, a new technology is developed to curve blades that you may want to consider incorporating into a your design proposal. Graph 4 below shows how the curvature multiples the power output versus how the curvature multiples just the cost for the total area of blades (paper).

Graph 4: Multiplier for Power Output vs Multiplier for Cost of Curvature of Blades
(controlled: 2 blades with total area of 100 cm^2 at 60°)



2. For this question you will use the claim, evidence, reasoning format to communicate only what changes you would make to your original design described above in question 1 in light of this new information about the effects of curvature.

Along with all of the previous parameters like having 2 blades at a 45 degree angle, the most efficient turbine after analyzing curvature would be to have low curvature with a total area of 50cm^2. Graph 4 shows the amount of power versus the cost multipliers for the total area of the blades from the curvature. The curvature that multiplies the power the most with the lowest amount of cost is low curvature. Due to the cost multiplier of 2, the total area would have to go down to a total of 50cm^2 With low curvature the cost multiplier is 2, so since there is a $25,000 budget, the area would have to be 50 since the price of that size area is $10,000, multiplies by 2 is $20,000 which fits the rest of the budge since $5,000 is the 2 blades. But since the energy multiplier is 4, the energy produced for 50 cm^2 that would multiply by 4 which produces a lot more power than before. So since this curvature, when changing the blade size, first the budget when maximizes the power by a lot, it makes a lot more sense to go with low curvature, it has the highest energy multiplier and one of the lowest cost multipliers.

Rubric	4	3	2
Claim	The design recommendation describes a wind turbine that optimizes the power. (2.5)	The design recommendation describes a wind turbine meets the power criteria for three parameters. (2)	The design recommendation describes a wind turbine that almost meets the power criteria. (1)
Evidence & Reasoning	+ Cites evidence and reasoning in communicating a design that accurately accounts for all trade-offs between price and performance. (1.5)		Cites evidence and reasoning in communicating a design that accounts for the blade angle and number of blades. (1)

<u>Helpful Consideration:</u> Use the color keyed instructions below to develop your CER paragraph

Claim: Write a sentence stating the parameters that would best create an optimal design.

Evidence: Summarize relevant data or trends in the graphs that inform your claim.

Reasoning: Write a statement that explains how your evidence leads to your claim about your design.

Optional, helpful sentence starters…

I claim the optimal design is …

My first piece of evidence is … that shows …
Since …. my design recommendation is ….

My second piece of evidence is … that demonstrates ...
Considering this and … , I recommend building a wind turbine with ….

My final piece of evidence is … which establishes that ...
Therefore the optimal design should have …

Additional optional, helpful sentence starters…

Under the given criteria and constraints the optimal design of the wind turbine is …

Graph 1 shows that, given all other parameters equal, the optimal ... , because ...
Considering this and the fact that ... my design recommendation for …

Graph 2 indicates that …
In light of this and ..., I recommend building the wind turbine with …

Graph 3 reveals a ... pattern between ….
Considering this pattern and the budget I recommend … so the overall design will have a power ...