gROW TULSA

Pulling Together • Developing Understanding • Creating Opportunities

Boat mass lab (high school level)

In this activity, you will learn how to calculate energy from a power versus time graph, and how to solve kinetic energy problems. You will use these two skills in order to find the virtual mass of your boat when on an ergometer. You will do one trial, but you will compare your results with your classmates.

First, you need to take a few strokes on an ergometer to find your “comfort” speed. This speed is important because you must keep it relatively constant throughout the lab.

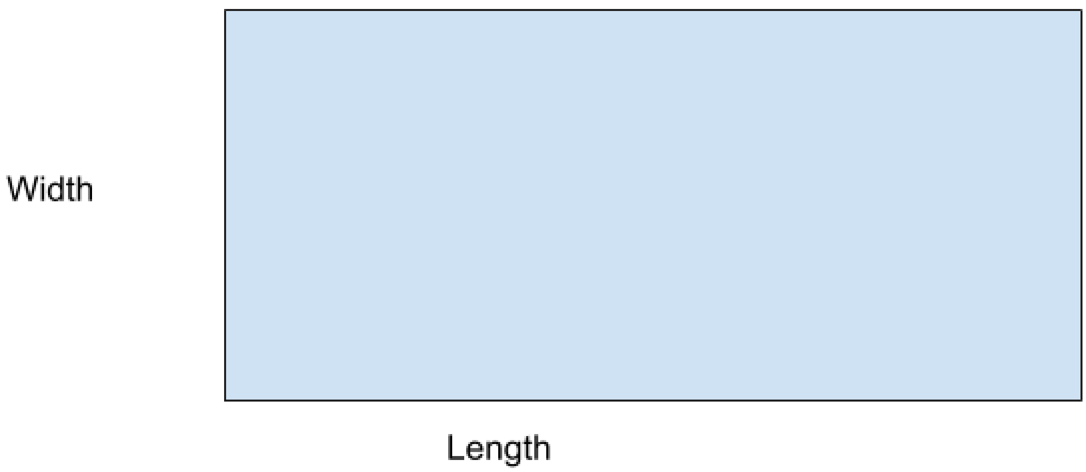
On the erg, there should be a graph of watts versus time. Watts is a measure of power. In other words, it measures the amount of energy being used over a given amount of time. The units for energy is joules, which is a shorter way of expressing the units kilogram meters^2 per seconds^2. Don’t worry, that is unimportant for this activity.

If energy is a measure of joules, and power is the measure of energy used in an amount of time, the units for power must be joules per second. This is another way of expressing watts.

When you multiply two units together, it is similar to multiplying variables. If you represent watts as x over y, where x is joules and y is time, you can multiply y (time) by x over y (joules per second) in order to get joules. Why is this useful? You can find the total amount of energy used in a power versus time graph by finding the area under the graph! If that doesn’t make sense, take a look at the drawings below:

Area = Length x Width.

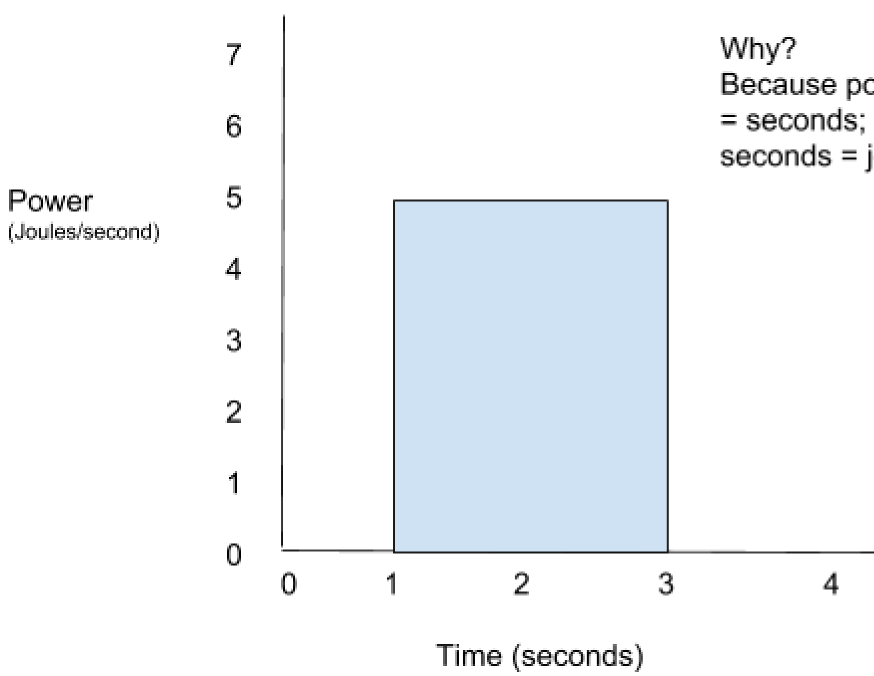
Units of area: meters^2. Why?
Because Length = Meters, Width = Meters; therefore, meters x meters = meters^2



Area = Time x Power

Area Units = Joules.

Why?
Because power = joules/second, time = seconds; therefore joules/second x seconds = joules.

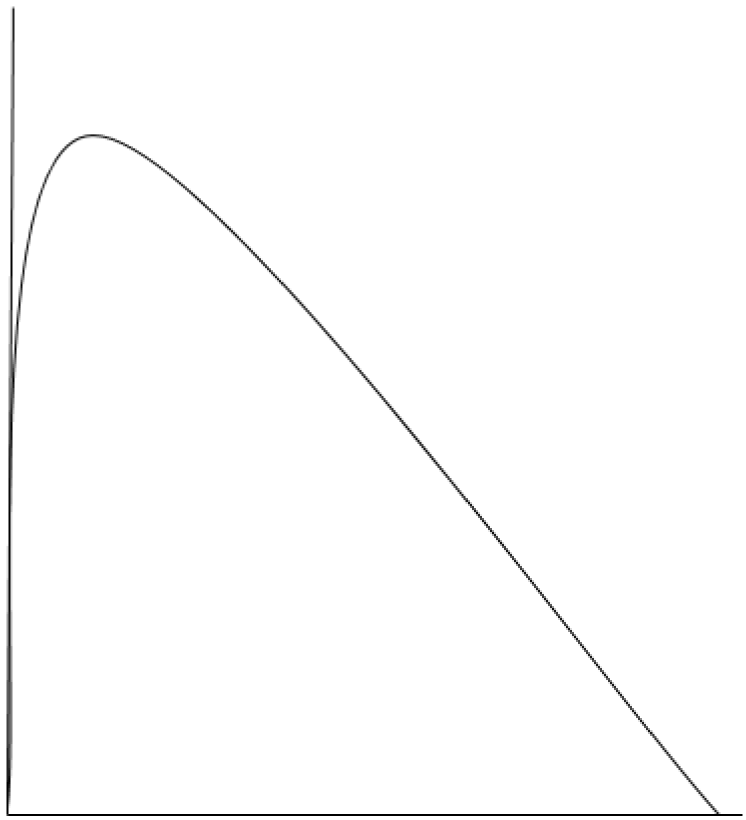


For the graph above, what is the total energy used?

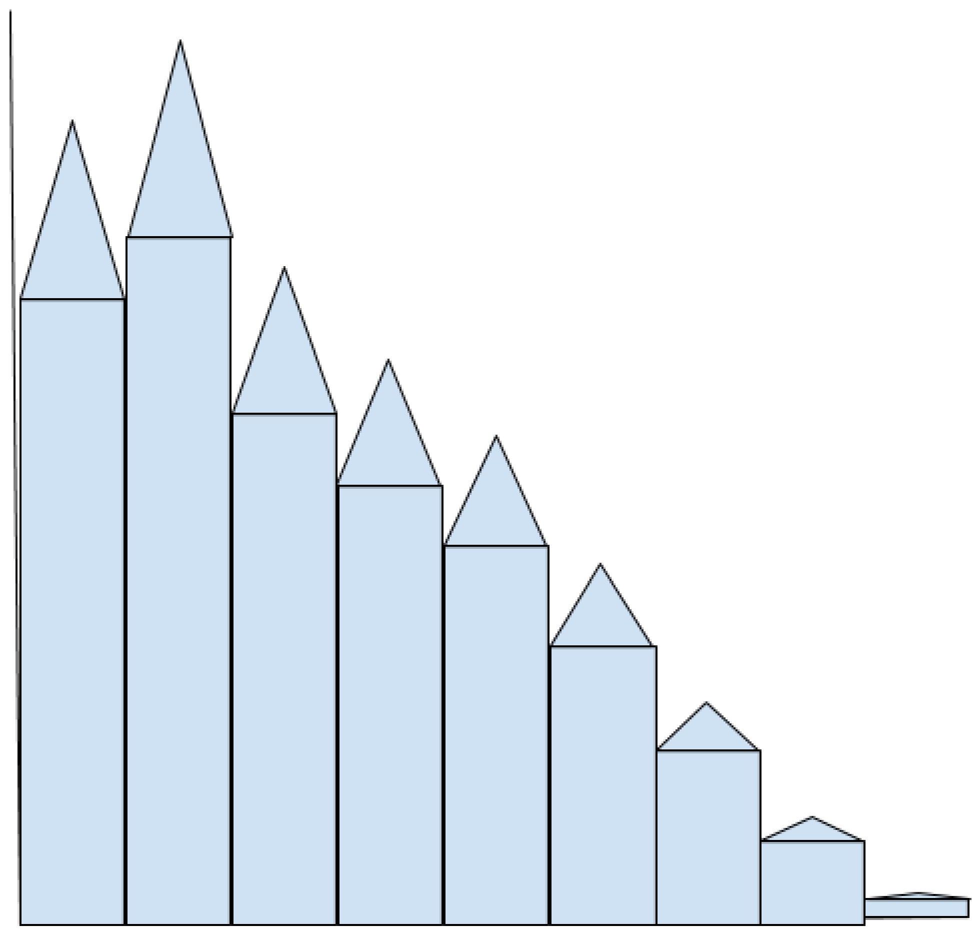
Scratch work:

Answer:

You can do the same thing for your graph of power versus time! Although it will not be entirely accurate, you can estimate your graph on a sheet of paper. Try to make the estimated graph as non-rounded as possible for simplicity's sake (unless you are familiar with integral calculus, then go for it!). For example, if you have a graph like this:



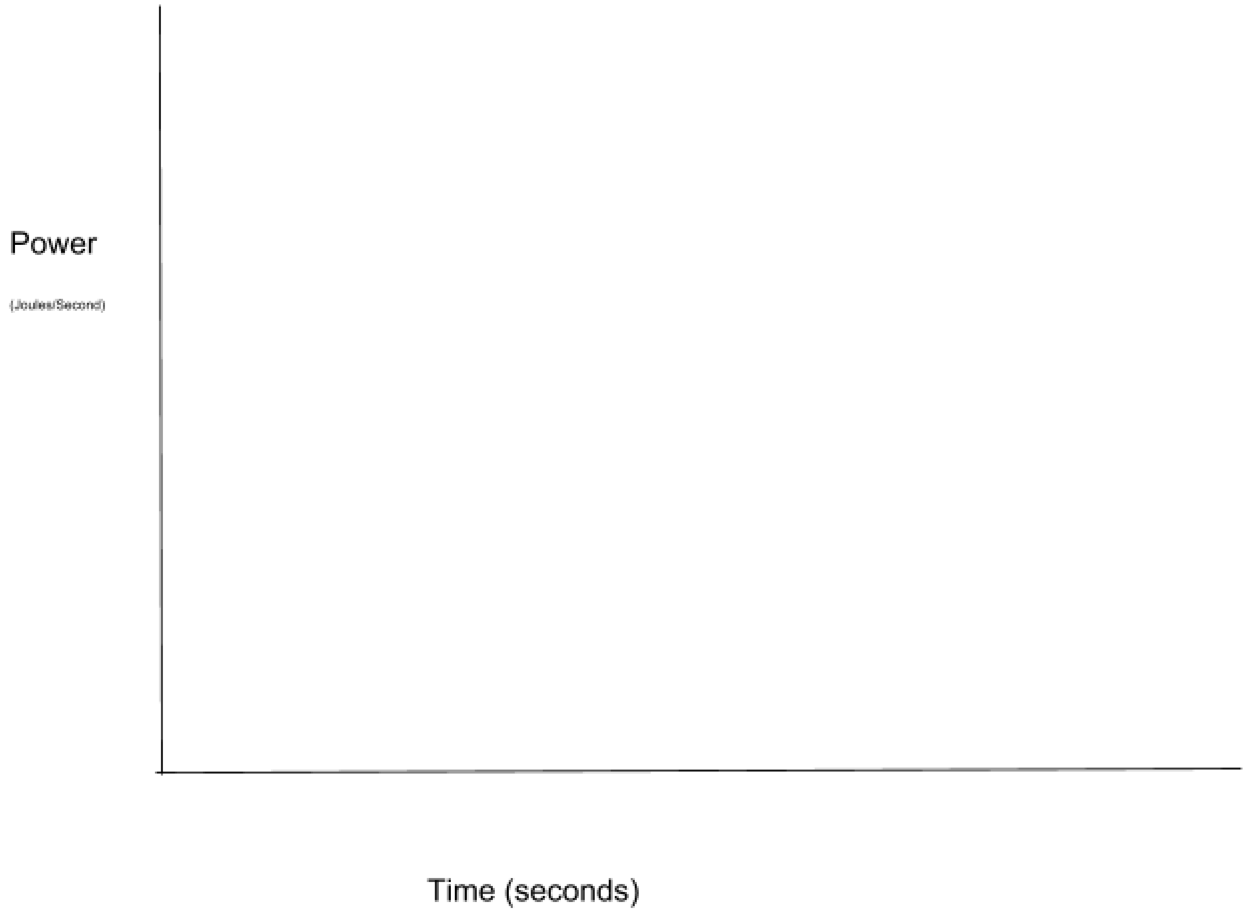
Change it to look like this:



*Notice that the more rectangles and triangle you add, the more accurate the graph will become. This is what calculus is all about.

Finding the area under your graph will give you the total amount of energy you used in one stroke. This will become crucial to finding the mass of your boat!

Draw your graph and find its area here:



What is the area?

Scratch work:

Answer:

Next, you will need to find your average velocity. Velocity is practically speed, but with given direction. For example, if you were rowing backwards for whatever reason, you would have a negative velocity. For the purposes of this experiment, we will only be using positive values so we can call it speed. After finding your energy used in one stroke, press the “display” and “units” button until you see something similar to the text below.

2:30 /500m

Think of this as a fraction. You are going, as in the example above, 2 minutes and 30 seconds every 500 meters.

You need to convert this fraction from minutes per 500 meters to meters per second. Simply flip your fraction; so the example above would become 500m/2:30.

Now figure that since there are 60 seconds in a minute, 2 minutes and 30 seconds must be 150 seconds.

Replace this with the denominator of the previous fraction to obtain 500m/150s.

The next part may require a calculator. Divide your meters by your seconds to get your speed in meters per second.

For the example above, what is the velocity?

Scratch work:

Answer:

What is your velocity on the erg?

Scratch work:

Answer:

Finally, you can find the mass of your virtual boat on your erg.

We can do this by setting the total amount of energy generated equal to the equation for kinetic energy. We are able to do this because the energy generated is mostly kinetic.

The equation for kinetic energy is ½ x Mass x Velocity^2. If you were paying attention earlier, you know this math checks out since the units are kilograms x meters^2 per second^2. Again, this is additional information that is unimportant.
We can simplify the equation to say that Energy = $1/2mv^2$.
Now solve for m. What is the equation for finding mass with this equation?

Scratch work:

Answer:

Now plug in your variables! Put in the area under your graph for energy, and replace v^2 with your velocity^2. **Don't forget to square!**

What is the mass of your boat?

Scratch work:

Answer:

Conceptual questions:

Now compare your answers with your classmates. Do you have the same boat masses? Are they different? By how much?

Why might the masses change if they did?

Why might the masses not change if they did?

Listed below are the average masses of different boats. What boat is your erg the closest to?

14 kg - Single Scull
27 kg - Double Scull
52 kg - Quadruple Scull
104 kg - Octet Scull
27 kg - Pair
32 kg - Coxed pair
50 kg - Four
51 kg - Coxed four
96 kg - Eight

Look up your boat on Google. Are you surprised by your result? Or does it seem accurate?