Kinetic Energy

Directions and Suggestions for Teacher

Purpose:

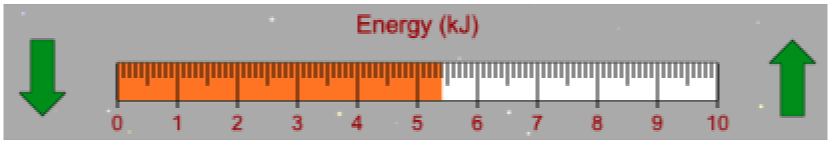
This lab is designed to give students an understanding of the relationship between the amount of energy given to an object and the speed the object will acquire. Students will adjust the amount of energy added to an astronaut and then see how that energy affects the speed the astronaut will obtain. Once they have their graphs they will use the graph(s) to create a mathematical model and then use the model to make predictions.

Virtual Part:

(https://www.thephysicsaviary.com/Physics/Programs/Labs/KineticEnergyWithPredictionLab/)

The virtual part of this lab should be conducted before doing anything live with the students. The purpose of the virtual part is to help the students develop the formula for kinetic energy. Once that is accomplished, they can do some live trials.

Measuring Kinetic Energy:



Students will be measuring the kinetic energy for each trial using the bar similar to the one shown above. Students will be estimating the energy to be given to the astronaut and recording the number in Joules. For the one above it would be approximately 5400 J.

Determining Speed:

Students will wait until the astronaut has passed through both gates and then they will record the time. Diving the distance between the gates (10 m) by the time will give them the speed of the astronaut with the indicated amount of energy.

Working Through the Lab:

Although there are more than fifteen different kinetic energies that are possible in the virtual program, students need not do all levels. I would not suggest less than 5 levels as it is a good practice to collect more data to have greater confidence in your results. The program will randomize the astronaut's mass, so all students will get different results. Students should not refresh the website while working or it will generate new values and thus make all the old data irrelevant. Below is a sample of what potential data might look like.

Data:

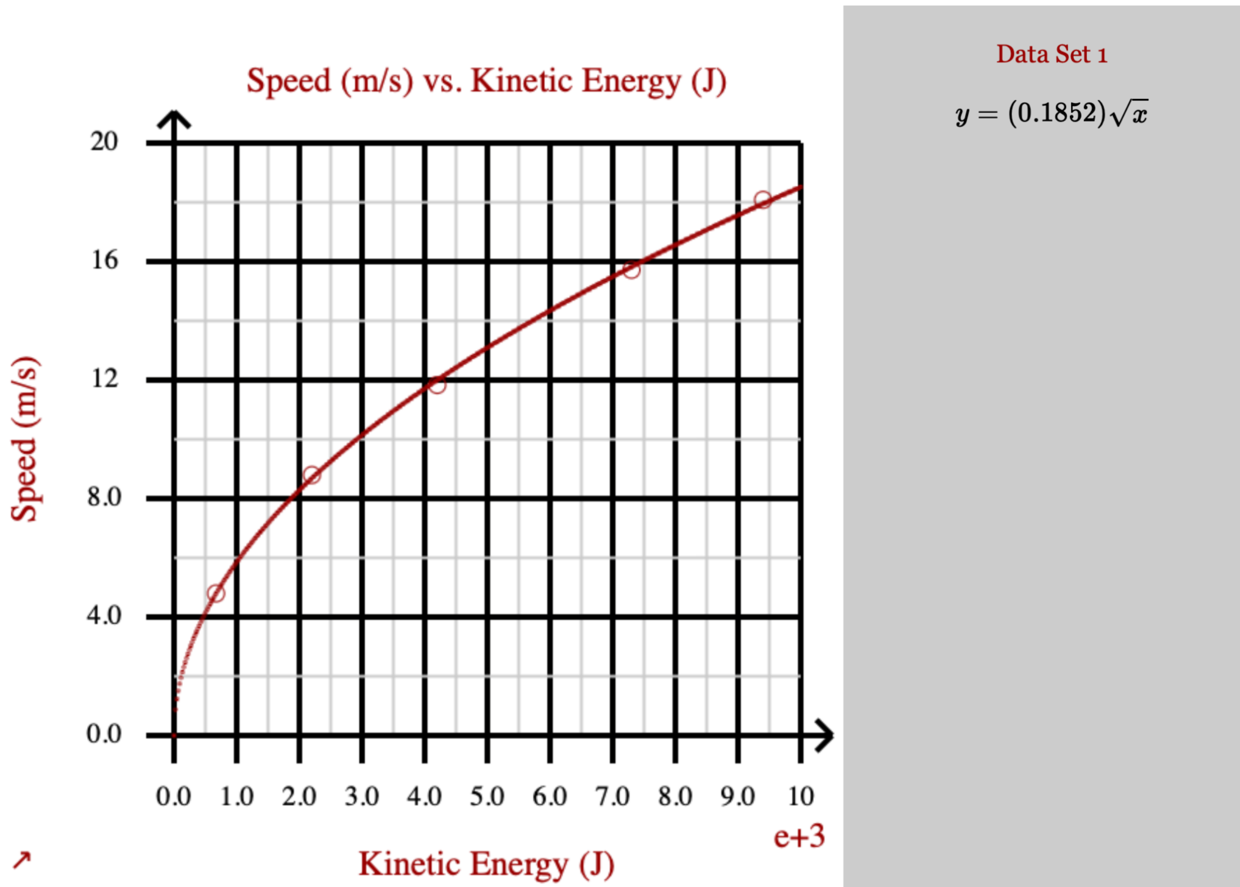
Kinetic Energy (J)	Time (s)	Speed (m/s)
670	2.085	4.80
2200	1.137	8.80
4200	0.845	11.83
7300	0.636	15.72
9400	0.553	18.08

Graphing Data:

(https://www.thephysicsaviary.com/Physics/Programs/Tools/Graphing/)

Once students have finished collecting data, they should graph it and find a relationship between the variables. The kinetic energy (J) is the independent variable and should be placed on the x-axis and the speed of the astronaut (m/s) should be on the y-axis. This graph should come out to be a square root graph.

I prefer always having the students transfer their graph onto their lab sheet by hand.



Equation:

For this graph students get a square root relationship between the variables. This indicates to them that a larger kinetic energy will correspond to a larger speed, but in a non-proportional way. Some of the students will pick linear for their graph type and although that may fit some of their data points rather well, if they did a nice range of kinetic energies, including some very small ones, they will see that linear is not the best curve fit to pick. Make sure they realize that zero kinetic energy means a zero speed and that their linear graph doesn't go through the origin and therefore cannot possibly be correct for this relationship.

The equation for an inverse relationship is given below.

$$y = (\text{graph constant})(x)^{0.5}$$

We want to continue to emphasize to them the idea that each of these letters has real physical significance. Looking at the axes, they should see that the y is the speed in m/s and the x is the kinetic energy in Joules. So the equation becomes:

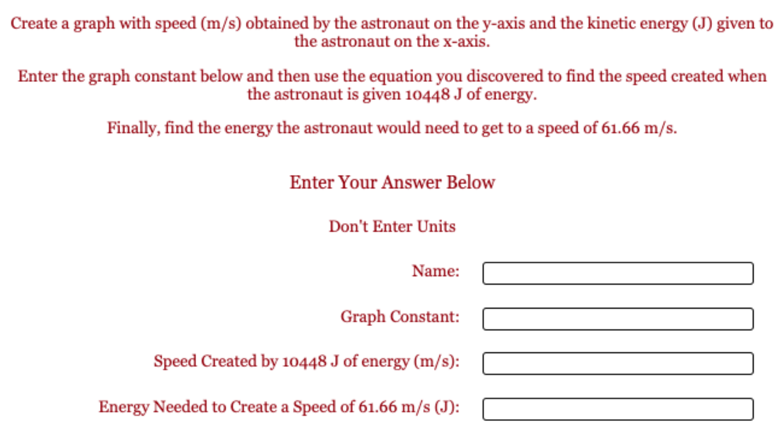
$$\text{speed} = (\text{graph constant})(\text{KE})^{0.5}$$

We then want students to think about the significance of the graph constant. We can prompt them what could have changed about the astronaut that would have given us speeds different from what they measured in the lab. Hopefully students will realize that the mass of the astronaut is the thing we could have changed that would have given us different speeds even if we had used exactly the same amount of energy. The graph constant is therefore related to the mass of the astronaut in some way. I would show them the connection between the graph constant and the mass once everyone is done with the lab.

Checking their work:

Once the students have reached the point where they have graphed and created an equation, they will then be able to check their work. They should simply hit “Finished” on the program to be brought to a form they can fill out to see if they did everything correctly. Remind students that they all will be getting different answers and that they shouldn’t worry if their answers differ from those of their classmates.

Make sure to stress that they should have graphed kinetic energy in Joules and speed in meters per second. They will be entering their graph constant when they curve fit their data with a square root relationship. They will then use their equation to make predictions for information for which they didn’t collect data.


Create a graph with speed (m/s) obtained by the astronaut on the y-axis and the kinetic energy (J) given to the astronaut on the x-axis.

Enter the graph constant below and then use the equation you discovered to find the speed created when the astronaut is given 10448 J of energy.

Finally, find the energy the astronaut would need to get to a speed of 61.66 m/s.

Enter Your Answer Below

Don't Enter Units

Name:

Graph Constant:

Speed Created by 10448 J of energy (m/s):

Energy Needed to Create a Speed of 61.66 m/s (J):

I would normally offer a small amount of extra credit added to the lab grade if they get all their answers correct. I would have them show me their completion certificate so I could record that they earned the extra credit. If a student doesn’t get everything correct, you can have them redo the lab by refreshing their page if time permits.

Live Part:

Although I usually try to do a live part for every lab that I conduct, this one is not easy to do in a live setting. At the start of the lab they don't know how to calculate kinetic energy and there are not really good tools for giving us a reading of kinetic energy. However, if you want to get the students actively involved in collecting data, wait until everyone is done with the lab and then take the formula that they developed and rearrange it to get a formula to calculate kinetic energy.

$$\text{speed} = (\text{graph constant})(\text{KE})^{0.5}$$

Becomes

$$\text{KE} = (\text{Speed}/(\text{graph constant}))^{2}$$

Which can then be equated to

$$\text{KE} = 0.5(\text{mass})(\text{speed})^{2.0}$$

You can then get creative and have the students mass different objects and then time them moving through different distances to get their kinetic energies. You can have them do almost anything at this point, but I give a few suggestions below.

1. **People:**
    a. Set up two traffic cones 10 meters apart and have the students time each other as they run through that distance.
    b. Allow the students a space ahead of the cones to accelerate to top speed before hitting the first cone.
    c. Most students can estimate their weight in pounds and then convert to kg.
    d. If you have access to a scale you can have the students optionally get their weight and then their mass.
2. **Toy Cars:**
    a. If you don't have time to go out and get the kinetic energy of the students as they run, you can set up a start and finish line in the class room for toy cars to move through.
    b. Use a scale for students to get the mass of the cars.
    c. You can use whichever tools are most convenient for getting the time it takes the cars to move from start to finish lines.

3. **Pre Recorded Videos**
    a. If you have no time for live data collection, you can have pre-recorded videos or videos from YouTube that students can use to get the Kinetic Energy of objects.
    b. You can use videos of track and field athletes or race cars. Students can look up the mass of the individual athlete or the type of car being shown in the video.

Conclusion:

I personally like to have students write out a conclusion by hand after they are done with the entire lab (live part and virtual part). Some things you can have students include in the conclusion.

1. **Restatement of the purpose.**
    a. This is a great way to open the conclusion
    b. It helps to reinforce the reason we were doing the lab.
2. **Brief Summary of the steps**
    a. I don't want too much here but I do want students to transition from the purpose to the results with a sentence or two summary of the steps.
    b. This part of the conclusion should paint with a very broad brush what type of data we were collecting and what remained constant when collecting data.
3. **Results**
    a. I want students to clearly state what type of relationship existed between the two variables we were examining.
    b. I want them to clearly explain what this means in simple to understand terms.
    c. Basically, they will be making sense of the equation they have discovered in the lab.
4. **Error**
    a. They should talk about their percentage of error from the lab (you can have them do this for the live part or the virtual part or both).
    b. They should brainstorm at least one possible source of that error and how it can be minimized if they redid the lab.
5. **Limitations to the model**
    a. Whenever possible I want them to think about when the mathematical model for the lab would break down and no longer apply.
    b. For instance, with this lab, the equation for kinetic energy will break down at very high speeds. Since most students are not familiar with relativity, you should not expect them to come up with this on their own. But it is a nice thing to mention at this time that the formula we have developed for KE will break down when the objects are moving at speeds approaching the speed of light. Encourage students to continue to take physics courses to see how this comes about.

Going Further

If you have the time, you could challenge the students with the following types of things.

1. You could ask the students to try sketching out another line on their graph that shows how things would change if the astronaut had a greater mass. They should do this in a different color than the original line.

2. Having students calculate the Kinetic Energy of some familiar objects will help them establish reference points for future calculations. Most students have no previous knowledge of energy in Joules so making them complete a table like the one below might be helpful going forward. You can prefill some of the boxes or have students look up values online.

Object	Typical Mass (kg)	Typical Speed (mph)	Typical Speed (m/s)	Kinetic Energy (J)
Fastball in MLB				
Bowling Ball from professional bowler				
NASCAR				
Top Olympic Sprinter				

This lab was created by Frank McCulley for thephysicsaviary.com.