Conservation of Energy

This is the outline of exercises that we want you to do in lab. This is a complement to the material in the lab manual. Please read the manual to learn about the tools and techniques; use this document to guide your experiments and calculations in the lab.

You should aim complete the first three problems below, or to design your own version of the activity. Then, see if you can make some progress on the fourth, possibly even a fifth activity. We encourage you to download the [Physics Toolbox Sensor Suite] on your smart device, available at https://www.vieyrasoftware.net/, to access the numerous sensors therein.

Problem #1: Mass on a String

The mass on a string is a simple system that we will use to describe a wide range of phenomena. Let's take a look at it - attach a racquetball to your string, and hold it above your desktop:

- You are about to raise the ball, and release it so that it swing back and forth. If you were to raise it 10 cm, how fast should it be going at the bottom of the arc?
  - Be sure to show your work!

Now, test your prediction:

- Lift the ball up by 10 cm, and let it go. It will swing repeatedly on the string. Record its motion and analyze it.
  - How does your measured velocity compare to your calculated value? Discuss.

Problem #2: Mass on a Spring

The mass on a spring is even more popular in physics, as you will see over the next few weeks. Hold the spring above the desktop. Note: **Do NOT stretch the springs out!** Always lift, *then* release the mass.

- When you attach the ball, the spring stretches a little bit. Use this to calculate the spring constant of your spring.
- You are about to raise the ball, and release it so that it bounces up and down. If you were to raise it 10 cm from its equilibrium position, how should:
  - A graph of position vs time appear?
  - A graph of velocity vs time appear?
  - On top of the appropriate graph, calculate and then sketch out what a graph of Elastic Potential Energy and a graph of Kinetic Energy should look like.
  - Discuss why your graphs ought to look this way.

Be sure to label and scale your graph so that your TA can understand what you are showing.

Now, test your prediction:

- Lift the ball up by 10 cm, and let it go. It will bounce repeatedly on the spring. Record its motion and analyze it.
  - Make sure you set your origin at the equilibrium spot - where the ball rests naturally. This is a pretty reasonable "zero".
  - You may export your position and time data into another program, or you could analyze your graphs at several critical points.
    - We suggest you **Export** your VideoPhysics data as a .ambl file, and then **Open In...** the **Graphical** App (not a .cmbl and the GraphicalGW app we've used in the past). There, you can click on the vertical axis of the graph, and next to the variable of your choice you can click on the ellipses (**...**), and when you select "**Add a Calculated Column**" you can choose then write up an expression appropriate for the form of energy you are analyzing.
      - Hint: What kind of potential energy do you want to consider? Your choice of a "zero" will depend on this.
  - How do the graphs of potential and kinetic energy vs time match your predictions? Discuss.

Problem #3: Time to Bounce

You've got a basketball at your station, which ought to be fairly bouncy.

- Have a labmate record video of the basketball undergoing several bounces.

Next, make some predictions:

- Analyze your video, and determine what your graphs of position vs time and velocity vs time look like.
  - Make sure you set your origin at the equilibrium spot - where the ball rests naturally on the ground.
  - What are the critical points of this bouncy-motion? i.e. what parts of the position and velocity graphs stand out as important?
  - On top of the appropriate graph, calculate and then sketch out what a graph of Elastic Potential Energy and a graph of Kinetic Energy should look like.
  - Discuss why your graphs ought to look this way.

You may export your position and time data into another program, or you could analyze your data at several of the critical points to figure out what the energy graphs do look like.

- How do the graphs match your predictions? Discuss.
- Discuss: What happens to the total energy in your system when the basketball is moving through the air?
- Discuss: What happens to the energy in your system when the basketball collides with the ground?

Problem #4: Time, and Time Again

We want to take some time to examine the behavior of an oscillator over time. The first steps:

- Hang your raquetball from either the spring or the string, and hold it fairly steady.
- Have a labmate prepare an iPad to record video of the motion.

Next, make some measurements:

- Set the ball into motion (again, lift then release the sphere) and record it over the course of a minute or few.

Noting the amplitude of the oscillation is a good indicator of the total energy in your system. Graph this out over time.

- How does the maximum energy in your system change over time? How would you describe this behavior?
- Why might it act this way? Discuss.

Problem #5: An Adventure of Your Own Choosing

And, of course, you are welcome to design your own experiments to explore CoE. A few ideas:

- You've got access to some wooden boards. If you roll the racquetball down them, can you demonstrate CoE?
  - What additional factors must be taken into account?
- You've lifted the spring straight vertically, which is a fairly straight-forwards problem. Wheat if you pulled it to the side? How can you demonstrate CoE in this situation?
  - Does using different springs, with differing spring constants, make a noticeable difference?
- Can you analyze video clips from sports or movies to explore CoE concepts?

And, as you are far more creative than I, you likely could come up with numerous other applications. Create your own experiment, let your TA know what you are doing (and why), and show us something neat!

Report

You'll be recording your work on the whiteboard tables as you go, and so be clear when summing up your process and your conclusions. Keep your discussions short, sweet, and to the point, please. Be sure to indicate what work you did on the report (as opposed to what your lab partners did).

Remember: The point of the report is to show your TA how well each of you understand the material, how well you designed and performed experiments, how well you can discuss your results, and how much of a scientist you were - not to show them you can parrot the textbook, always get the "right" answer, or do everything. The process, your reasoning, and your improvement are the key to earning full credit.

Be sure that each of your group members submit this assignment as soon as possible (ideally at the end o your lab), and take some time to consider how lab went for you and your peers, and how you can improve the experience next week.

Looking Ahead: Graphical Madness?

This isn't something to calculate today, but something to think about: You saw some pretty clean trading of energy between different forms - demonstrating a very clear conservation of energy! But the basketball had a bit of a hiccup - you've discussed where the energy "went", but why didn't it "come back"? Are there other systems you've encountered in your day-to-day life that act like this?