**Possible prelab questions for Lab 6**

**Read Lab 6.**

**1)** You are given these two equations:

 $Δx\_{gap}+ Δx\_{spoke}=d\_{spoke to spoke}$ **(1)**

And

$\frac{Δx\_{spoke}}{Δx\_{gap}}=Q.$ **(2)**

Please solve for $x\_{spoke}$ and $x\_{gap}$ in terms of $d\_{spoke to spoke}$ and $Q$.

$$X$$

Pulley with photogate

**2)** A car of mass, m1, is placed on a track and connected **both** a spring and a string which passes over a pulley and then is fastened to a hanging mass, m2. $X$ is the distance (in meters) that the spring has been stretched. $m\_{2}$ is H meters from the floor.

$$m\_{2}$$

$$m\_{1}$$

H

**Figure 1**

spring

a) How much *Gravitational potential energy* does $m\_{2}$ have?

b) How much *Spring potential energy* is in the spring?

c) If the car, string and $m\_{2}$ is travelling with speed $v$, how much *Kinetic Energy* does the system have?

Lab 6

Energy

This lab is designed to take a full 3 weeks to complete. You will have a prelab for each week as determined by your TA.

For this lab you will NOT be graded on any uncertainty calculations although it is part of step 37 b) at the very end so don’t forget what you have learned about uncertainty completely.

In this lab we will experimentally explore the relationship between Gravitational Potential Energy, Spring Potential Energy, Kinetic Energy, and Work done by Friction. Each group should gather the following equipment:

 1 laptop (turn this on immediately as it takes a long time to load. Also, start the “Logger Pro” software as soon as possible.)

 1 LabQuest

 1 PhotoGate

 1 cable for connection with the LabQuest

 1 stand

 1 “Superpulley”

1 “Pasco” track--leveled to the best of your ability!

1 “Pasco” car

1 string approximately 80 to 100 cm long

1 hook.

1 box of masses to hang on the hook.

1 Caliper

1 triple beam balance

1 box of springs

1 paper clip, bent to attach the spring to the car.

If you need any other equipment please let the instructor know. Reasonable requests will be honored.

**A 10% penalty will be assessed to any group who does not return all supplies neatly at the end of the lab period.**

**Task 1- Measuring the distance the car travels when the photogate is blocked and unblocked.**

The single largest source of error in all of our labs involving the photogates comes from measuring the distance the car travels while the gate is blocked and unblocked. If you look carefully at our pulleys you will notice that (except at the very edge) the spokes and gaps are exactly the same size. This means that the distance the car travels while the laser is **blocked**, should be the same as the distance the car travels while the laser is u**nblocked**. But experimentally that is not the case as we will see.

**Procedure**

1. We know from previous labs, that since there are 10 spokes, the distance from one spoke to the next is $d\_{spoke to spoke}=circumference/10$. Re-measure the circumference, and compare your result to what you reported in Lab 4. Record $d\_{spoke to spoke}$ in your excel sheet.
2. Because I claim that the spokes and gaps are different sizes we can say for sure that

 $∆x\_{spoke}+ ∆x\_{gap}=d\_{spoke to spoke} .$ **(1)**

Where $Δx\_{spoke}=$ the distance the car travels while the laser is **blocked** and $Δx\_{gap}=$ the distance the car travels while the laser is **unblocked**.

1. We need to solve for $∆x\_{spoke}$ and $∆x\_{gap}$, and the most accurate way to do this is to measure the ratio $\frac{∆x\_{spoke}}{∆x\_{gap}}$ carefully. In order to do this we will **remove the string from the pulley temporarily**.
2. Spin the pulley by hand. Press the collect button while the pulley is spinning. This should generate a ton of data points as the pulley spins with nearly **constant velocity**.
3. Pass this data set to Excel. (You do not need to use the entire data set. Some chunk in the middle with approximately 20 data points should be sufficient.)
4. Use the “Gate State” column from Logger pro to figure out which times represent when a spoke was in the laser, $Δt\_{spoke}$ and when a gap was in the laser, $∆t\_{gap}$.
5. Create two columns, $Δt\_{spoke}$ and $Δt\_{gap}$ so that your data looks like

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| dspoke to spoke | δdspoke to spoke |  |  | Q |  |
|   |   |  |  |   |  |
|  |  | Average Δtspoke | Average Δtgap |  |  |
|  |  |   |   | ΔxGap | δΔxGap |
| Spinning the pulley |  |  |  |   |   |
| Time | State | Δtspoke | Δtgap |  |  |
| t1 | 1 | t2-t1 |   | ΔxSpoke | δΔxSpoke |
| t2 | 0 |   | t3-t2 |   |   |
| t3 | 1 | t4-t3 |   |  |  |
| … | 0 |   | t5-t4 |  |  |

**Watch out for end of data errors! Notice that if I don’t have a t5 time, my last** $Δtgap$ **will be incorrect because it will be using a cell reference that is empty.**

1. From your two columns, $∆t\_{spoke}$ and $∆t\_{gap}$, calculate the averages using Excel’s Average(##:##) function.
2. Here is the magic step: Since we have the wheel spinning at **constant velocity** we know $∆x\_{spoke}=v ∆t\_{spoke}$ and $∆x\_{gap}=v ∆t\_{gap}$. So

$$\frac{∆x\_{spoke}}{∆x\_{gap}}=\frac{v ∆t\_{spoke}}{v ∆t\_{gap}}=\frac{ ∆t\_{spoke}}{ ∆t\_{gap}}.$$

Or

 $Q=\frac{∆x\_{spoke}}{∆x\_{gap}}=\frac{\overbar{ ∆t\_{spoke}}}{ \overbar{∆t\_{gap}}}.$  **(2)**

13) Taking advantage of your work. Use equations (1) and (2) along with your answer to Possible Prelab question 1 to solve for both $∆x\_{spoke}$ and $∆x\_{gap}$.

**Task 2- Measuring the Energy of a complex system.**

We will build an experimental setup to test our results of theory question 2. See theory question 2 for a picture of the intended setup.



Here is a picture of how to attach the spring.



**Procedure**

**Please read through the following steps and perform a “dry run” so you understand why you are doing the measurements I request before you actually take the data.**

1. How much mass does the car have? **Record this value in Excel.**
2. Slide the “bumper” from the end of the track to roughly the middle of the track.
3. Attach the RED spring to the post at the top center of the bumper**. Record the K value and the “Tension at zero stretch” for the spring from Lab 5.**
4. Using one of your paperclips, attach the spring to the Pasco car using the small hole in the top front center of the car. Tie your string to the piston bumper on the car, pass it over the pulley and down to the 50 g mass hook. At this point your equipment should resemble Figure 1.
5. With only the 50g mass hook on the string, you spring should not be stretched. Record the position of the car as $X\_{no stretch}$ in the excel sheet.
6. Add a few hundred grams to the hook. We want enough weight that the car has enough room to bounce several times without the spring banging into the track.
7. Record the total amount of mass hanging on the string, $m\_{2}$ and the position of the car when it is at rest, $X\_{equilibrium}.$ When measuring the position of the car be consistent, always use the same end of the car.
8. Displace the car from equilibrium and release it. We want the car to bounce left and right **for at least 4 bounces**, but we do NOT want to over stretch the spring, or have the spring bang against the track or have the dangling mass hit the floor. If your chosen displacement satisfies these criteria, record the initial position of the car, $X\_{initial},$ and collect a full data set and drop it into the cells that are waiting in Excel.

**Important:** Make sure you hit the collect button and wait 3 seconds before releasing the car from $X\_{initial}$. You cannot move the car during this time as it will corrupt your data.

After the data run is complete, the computer should naturally create a plot of velocity vs time that has many bumps or hills that get smaller (We will be recreating these curves more accurately in Excel). If you see something else make sure you call the instructor over.

1. After you finish taking your data and the car has finally stopped moving, make sure that it has returned to $X\_{equilibrium}$.
2. Look at your data set and make sure it passes the following requirements:
	1. Did the plot in LoggerPro show at least 8 bumps?
	2. Is the first time that is recorded more than .5 seconds? Otherwise your car might have started moving before the LabQuest was collecting data.
	3. Are your first couple of times very close together like all the rest of the data? Otherwise you might have slightly moved the car with your hand while waiting for the LabQuest to take data.

If any of these answers were no, please retake your data, double checking your value for $X\_{initial}$.

1. Take a second data set as a back-up in case something strange appears in your data, but you will only NEED the first. Make sure you record the new $X\_{initial}$.

Hint for speeding up your data entry: At the bottom of the data in your excel file, in the 10 cells to the right of your final time, put a small mark like “q” so that when you use CTRL+SHIFT+DOWN you go to the bottom of your data instead of the bottom of the worksheet.

1. Finally, to make sure you have all measurements you will need to calculate the Potential and Kinetic energies. (Figure 1 is a good reference).
2. You may put away your equipment, the rest of the lab will be done working through Excel.

**Analysis**

From your large data set I would like for you to construct several scatter point plots. Once you create one you should be able to double click on the points in the graph, and then drag the colored box in the data representing the plotted values from one column to the next.

1. Create a speed column. Now because the block moves a different distance depending on whether the laser is blocked or unblocked I recommend using a function like “IF” so that the computer can use the appropriate function at the right time. One way to implement this is “=if( State1, $Xspoke/(t2-t1), $Xgap/(t2-t1))” and please use the cell references rather than copying the formula into excel verbatim.

The researcher should play with this formula a bit, maybe look up in the Excel help file, and explain how this function works in the procedure.

1. Create a Speed vs Time scatter plot to evaluate your work so far.
	1. If you have a double plot (you have big bumps overs little bumps) that looks like

Then more than likely you have not measured $x\_{spoke} $and $x\_{gap}$ correctly, or maybe you have mixed them up. It is also possible that your “if” function is not working correctly yet. Call your instructor over if you cannot solve the problem.

1. To create a Velocity vs Time plot we need to show the computer which way the car is traveling.
	1. First create a column called the “Direction Flag.” This will hold the information about whether the car is traveling in the positive direction, 1, or in the negative direction, -1. For right now, fill this column with 1’s all the way to the bottom of your data.
	2. In the next column, we will create our velocity data. Because Velocity is Speed and Direction, we will use the formula, Velocity1=Speed1\*DirectionFlag1. Fill the velocity column with this formula. You can now create the Velocity vs time plot, but it will look exactly like the speed vs time plot.
	3. Now we want to find the places where the velocity is zero. If you just start reading the values in the velocity column they should start fairly close to zero, and then increase for a while and then decrease back toward zero.

**Right between where the velocity is decreasing and then increasing again, there will be one point with a random amount of speed** (maybe small, maybe large). This is the place where wheel stopped spinning and then started spinning the opposite direction. **We want to force that point to zero by deleting the 1 in the “direction flag” column.** Here is an example:

|  |  |  |
| --- | --- | --- |
| Speed | Direction Flag | Velocity |
| … | … | … |
| 37.94972893 | 1 | 37.94973 |
| 24.89597041 | 1 | 24.89597 |
| 26.56271561 | 1 | 26.56272 |
| 11.70921013 | 1 | 11.70921 |
| 12.05630451 | 1  | 12.0563 |
| 11.42521381 | 1 | 11.42521 |
| 25.30730296 | 1 | 25.3073 |
| 23.34734174 | 1 | 23.34734 |
| 36.0031795 | 1 | 36.00318 |

|  |  |  |
| --- | --- | --- |
| Speed | Direction Flag | Velocity |
| … | … | … |
| 37.94972893 | 1 | 37.94973 |
| 24.89597041 | 1 | 24.89597 |
| 26.56271561 | 1 | 26.56272 |
| 11.70921013 | 1 | 11.70921 |
| 12.05630451 |  |  |
| 11.42521381 | 1 | 11.42521 |
| 25.30730296 | 1 | 25.3073 |
| 23.34734174 | 1 | 23.34734 |
| 36.0031795 | 1 | 36.00318 |

Complete this for all the zeros in your data. There should be about 8 zeros if you have 4 full bounces. This should divide you Direction Flag column into sections of 1’s broken by the places where the velocity is zero. Half of these sections should be -1’s.

* 1. Based on the initial position and the equilibrium position, was the car increasing its position at the very beginning or decreasing its position at the very beginning?
		1. If the position was decreasing, highlight your first 1 in the “direction flag” column, change it to a -1, COPY hit CTRL+SHIFT+DOWN to highlight everything until the first zero and then PASTE. Thereby changing all the directions in the first section to negative. The next section should have positive velocities, so leave these “Direction Flags” as 1. The following section has negative velocity so change all these Direction Flags to -1. Etc.
		2. If the initial position of the car is increasing, keep the first section of direction flags as a 1, but the second section of direction flags need to be forced to -1. Etc.
	2. Check that your Velocity vs. Time plot now makes sense and is correct.
1. We know that every time the photogate sends a signal the moves the car has moved by either $Δx\_{gap}$ or $Δx\_{spoke}$ depending on whether the Gate state is a 1 or a 0. Also depending on whether the Direction Flag is positive or negative the position either increased or decreased by $Δx.$
	1. So for your SECOND position cell enter

=$Position1+DirectionFlag2\*if\left(State2, \$xspoke, \$xgap\right)$

and please use the cell references rather than copying the formula into excel verbatim.

* 1. After getting the first position formula to work, copy and paste the formula into the entire position column except Position1. For Position1 we want the formula to read

=$\$X\_{initial}+DirectionFlag1\*if\left(State1, \$xspoke, \$xgap\right)"$.

* 1. Create the Position vs time graph. Check to make sure that your position starts at $X\_{initial}$ and the mass bounces evenly above and below $X\_{Equilibrium}.$ How do you interpret the fact that the bounces on the graph get smaller and smaller?
1. Follow the steps of 30) to create a Height column for the vertical height of $m\_{2}.$ **If you did not measure the initial height of** $m\_{2}$ **and cannot figure it out, you should assume that it is zero.** (A small penalty will be deducted for not measuring this value, but the rest of your experiment will still work just fine.)
2. Create the Gravitational Potential Energy (GPE) column. As this requires only multiplication, you should be able to create your own formula. However, be careful with units, we need all Energies in (J)=($Joules=\frac{kg m^{2}}{s^{2}}$). You are welcome to fix units in this column, or go back to your yellow cells and adjust units of everything there.
3. We also want to create a Spring Potential Energy (SPE) column.
	1. First, we need to create a column representing the stretch of the spring at each moment in time, $Δx$. You should be able to figure this out based on the cars position at each moment and the position of the car when the spring is not stretched.
	2. Second, because the spring does not strictly obey Hook’s law instead of the normal Spring Potential energy Formula we have $SPE=\frac{1}{2} k\*(Δx)^{2}+Tension\_{at zero stretch}\*\left(Δx\right). $
4. Using your velocity vs time data create column of Kinetic Energy (KE) following the normal formula.
5. Finally, add the Kinetic Energy to both the Potential Energies to create a column of Total Energy as a function of time.
6. The DA should provide two plots for the PI to analyze.
	1. Create a plot with the GPE, SPE, and the KE all plotted against time.
	2. Create a plot of just the Total Energy vs time.
7. The PI should use the two energy graphs to answer the following questions:
	1. We know for sure that the GPE, SPE, and KE graphs oscillates up and down. Why does this oscillation occur? You should frame your answer in terms of either the flow of energies of the system or the forces causing those energies to flow, but not both.
	2. More than likely the Total energy curve oscillates up and down (maybe a lot or maybe just a tiny amount) because it is made from three other energies that are oscillating. Is this ok? What causes the total Energy to decrease on average? What causes the total energy to increase (if it does)? What roll does uncertainty play in the total energy of the system?

BONUS: (For ambitious groups that want to complete the total energy story)

We learned that the cars on the tracks have an acceleration due to friction of about $a\_{friction}≈-5\frac{cm}{s^{2}}$. Calculate the WORK done by this frictional Force and include this Energy lost to friction in your analysis of the total energy of the system.

**Important points that should be discussed by each member:**

**DA:** Do not provide the raw data for part 1 of this lab. Make sure that the $Δx\_{gap}$ and $Δx\_{spoke}$ are included in your part 2 data table. They will be graded for accuracy.

 For part 2 only provide the yellow cells from the top of the spreadsheet and the first four rows of your calculated data. You do not need to include all 200+ points of data in the report.

 Make sure every number in the spreadsheet has a header with a descriptive name and the units for that value.

 Make sure that the two graphs that you are providing to the PI have units, labels, title, etc. Also do your best to adjust the formatting to make the data as legible as possible (make sure that your data points have distinct symbols, if the points overlap a lot maybe decrease the size of the points…

**Researcher:**

Your job is to explain how a couple of length measurements and a ton of time measurements from the LabQuest became these bouncing energy curves.

Because step 30) carefully explains how do create the Position column of data, and step 31 states that Height is similar, you should carefully explain how your group determined the Height column and then add a small line like “and the position column was calculated in a similar fashion.”

 When discussing the Spring potential energy, you should absolutely mention the formula that was given $SPE=\frac{1}{2}kΔx^{2}+Tension\_{at zero stretch}\_{ }Δx$. However there are at least four different $Δx$ type values. You should explain what exactly $Δx$ is in this instance and why you calculated it the way that you did.

 When discussing GPE and KE, please explain which mass was chosen for the $m$ in each equation and why.

Don’t forget the yellow highlighted instructions on page 7.

**PI:**

You have the shortest but most difficult part of this report to write.

When discussing the triple graph of GPE, SPE, and KE you should address questions like: When GPE is increasing where does that energy come from? Why are the variations in KE so much smaller than the variations in GPE and SPE?

When discussion the total energy graph, make sure you address the sources and sinks of energy. Where did this energy come from? After a long time the car stops moving; so where did the energy go?

Don’t forget the yellow highlighted instructions on page 10.