Physics lab: the hooke's law and shm

Physics Lab: The Hooke’s Law and SHM Science Department SPH 4U Introduction Hooke’s Law is the law at which explains how the force exerted by an elastic device varies as the elastic device compresses and stretches. In order to mathematically analyze the force the equilibrium position is when the spring is at rest. When force is applied and the spring is being stretched the spring has the tendency of pulling back to the equilibrium position and vice versa. If the force applied to the spring causes it to compress the spring will push back and try to bring it back to equilibrium position. In both examples the direction of the force exerted by the spring is opposite to the direction of the force applied to the spring. The Hooke’s Law is the magnitude of the force exerted by a spring is directly proportional to the distance the spring has moved from equilibrium. The springs that obeys the Hooke’s Law is called an ideal spring because it contains no friction externally or internally. The force constant is (k) the proportionality constant if a spring. The equation Fx=-kx. Fx representing the force exerted by the spring, x is the position of the spring relative to the equilibrium and k as the force constant of the spring. For example springs that require a larger force to stretch or compress them have a large k values. According to the law if x is greater than 0 then Fx is less than 0. If the spring is stretched in the positive direction it pulls in the opposite direction. If the spring is compressed in the negative direction it pushes in the opposite direction. “-kx" is the force exerted by the spring, according to N3LM “+kx" if the force that was applied to stretch or compress it to position x. Hooke’s law for the force applied to a spring is Fx= kx. Even though this law has been referring to springs only, this law can apply to any elastic device. Elastic Potential Energy is energy that is stored in objects that are stretched, compressed, bent or twisted. To find an equation for elastic potential energy we consider the work done on an ideal elastic device that is being stretched or compressed. The area under the line on a force-displacement graph indicates the work. Since the force applied to an ideal spring depends on the displacement the area of the graph is a triangle. The final equation is W= 1/2x (kx) then shortened into W= 1/2kx2. The W representing work, k is the force constant of the elastic device and x is the amount of stretch or compression from the equilibrium position. Since work has been transformed into elastic potential energy we can write the equation as Ee= 1/2kx2. The elastic potential energy can then be transformed into a lot of different energy types such as kinetic energy, sound energy or gravitational potential energy. Simple Harmonic Motion is the periodic vibratory motion in which the force and acceleration is directly proportional to the displacement. SHM is a combination of Hooke’s Law and N2LM. Parameters of SHM may include the amplitude (A), period (T), frequency (f), position, velocity (v) and acceleration (a). Period and Frequency can be calculated with T= 2Ï€mk or f= 1/2Ï€mk. According to the LCE when mass is released the total energy of the system is the sum of elastic potential energy in the spring and the kinetic energy. The equation ET= 1/2 kx2+1/2mv2. Damped harmonic motion is periodic or repeated motion in which the amplitude of vibration and the energy decreases with time. Purpose In this lab we are testing real springs to determine under what conditions, if any, they obey Hooke’s Law. We are also exploring what happens when force constant of the springs are linked together either by the weight or the springs itself. This lab is to explore the difference between different springs and how it affects the force constant, displacement, frequency, total energy, amplitude and elastic potential energy. We also examine how the different masses affect the force constant, displacement, frequency, total energy, amplitude and elastic potential energy. As mentioned, we are exploring how combining two springs in series can make a difference in force constant, displacement, frequency, total energy, amplitude and elastic potential energy. Overall this lab is to determine the force constant for extension springs by static and dynamic methods and verify the Hooke’s Law. Hypothesis I personally believe that during the static method for each individual spring (short, medium and long) the more mass suspended there will be more of a stretch due to the final length and the force applied. I predict that the smaller the spring is the higher the force constant due to how condense the spring is and how much more force is going to be needed to stretch the spring compared to a larger spring. Larger springs should be easier to stretch resulting in a lower force constant. This then results in a faster time for the smaller springs in the dynamic method. I believe that the smaller the spring is the less time it would take to complete the 10 cycles due to the higher force constant causing a higher force exerted by the spring. For the method with springs in series I predict that there final length and stretch will not be affected due to the constant force constant and the applied force. I believe for this experiment I think the force exerted by the spring is the same as before and the final length will be the two lengths from medium and long springs before added together. Overall I think that this lab will agree with the Hooke’s Law and how the magnitude of the force exerted by the spring is directly proportional to the distance has moved from the equilibrium. The force exerted by the spring will increase as the distance the mass has moved from the equilibrium has increased for every spring. Equipment/ Materials See the attached Physics Lab Workbook (The Hooke's Law and SHM.) Procedures See the attached Physics Lab Workbook (The Hooke's Law and SHM.) Observation Below are the tables and graphs used to organize the information collected from this experiment: Static Method (Steps 3. 1 and 3. 2) Spring | Initial Length (m) | Mass Suspended (kg) | Applied Force F= mg (N) | Final Length (m) | Stretch (m) | Short | 0. 02 | 0. 02 | 0. 1962 | 0. 031 | 0. 011 | | | 0. 05 | 0. 4905 | 0. 065 | 0. 045 | | | 0. 07 | 0. 6867 | 0. 09 | 0. 07 | | | 0. 1 | 0. 981 | 0. 122 | 0. 102 | | | 0. 12 | 1. 1772 | 0. 146 | 0. 126 | Medium | 0. 033 | 0. 02 | 0. 1962 | 0. 069 | 0. 036 | | | 0. 05 | 0. 4905 | 0. 12 | 0. 087 | | | 0. 07 | 0. 6867 | 0. 17 | 0. 137 | | | 0. 1 | 0. 981 | 0. 227 | 0. 194 | | | 0. 12 | 1. 1772 | 0. 265 | 0. 232 | Long | 0. 06 | 0. 02 | 0. 1962 | 0. 07 | 0. 01 | | | 0. 05 | 0. 4905 | 0. 15 | 0. 09 | | | 0. 07 | 0. 6867 | 0. 205 | 0. 145 | | | 0. 1 | 0. 981 | 0. 31 | 0. 25 | | | 0. 12 | 1. 1772 | 0. 365 | 0. 305 | Static Method (Step 3. 3) Spring | Initial Length (m) | Mass Suspended (kg) | Applied Force F= mg (N) | Final Length (m) | Stretch (m) | Medium + Long (in series) | 0. 122 | 0. 02 | 0. 1962 | 0. 18 | 0. 058 | | | 0. 05 | 0. 4905 | 0. 33 | 0. 208 | | | 0. 1 | 0. 981 | 0. 58 | 0. 458 | Spring | Initial Length (m) | Mass Suspended (kg) | Time of 10 cycles (s) | Time of 10 cycles (s) | Time of 10 cycles (s) | Average Period T (s) | Medium | 0. 033 | 0. 02 | 3. 34 | 3. 81 | 3. 94 | 0. 37 | | | 0. 05 | 5. 59 | 5. 84 | 5. 91 | 0. 58 | | | 0. 1 | 8. 15 | 8. 19 | 8. 37 | 0. 82 | Long | 0. 06 | 0. 02 | 3. 25 | 3. 25 | 3. 21 | 0. 32 | | | 0. 05 | 6. 65 | 7. 18 | 7. 06 | 0. 7 | | | 0. 1 | 10. 75 | 10. 68 | 10. 06 | 1. 07 | Dynamic Method (Step 4. 1) Analysis Graph of force applied to the spring (vertical axis) versus the stretch of the spring from the equilibrium (horizontal axis) for each of the three springs tested in Steps 3. 1 and 3. 2 with a line of best fit for each spring. Calculation of Slopes Short Spring Slope M=(y2-y1)/(x2-x1) =(1. 1772-0. 1962)/(0. 126-0. 011) = 8. 55 Medium

Spring Slope M=(y2-y1)/(x2-x1) =(1. 1772-0. 1962)/(0. 232-0. 036) = 4. 913 Long Spring Slope M=(y2-y1)/(x2-x1) =(1. 1772-0. 1962)/(0. 305-0. 01) = 3. 258 Medium and Long Spring in series Slope M=(y2-y1)/(x2-x1) =(0. 981-0. 1962)/(0. 458-0. 058) = 1. 962 Spring | Force Constant k(N/m) | Short | 8. 55 | Medium | 4. 913 | Long | 3. 258 | Slopes of each individual spring The graphs, calculation and charts above show and compare the slops f the lines in the graph of the force applied to the spring vs the stretch of the spring. These slopes represent k which is the force constant meaning that the slope of the graph represents k (the proportionality constant) is the force constant. This also verifies that the short spring requires a larger force to stretch the spring resulting in that larger k value and vice versa. The long spring has the lowest k value meaning that the force constant is very small and needs a very small force to stretch or compress the spring. It is also noticed that the springs in series did not show results as expected. The springs in series had a exceptionally low k, force constant. This many have been caused by the many errors in this experiment. Part B Dynamic Method T= 2Ï€mk (SHM) T= 4Ï€2m/k k= 4Ï€2m/T Long Spring k= 4Ï€2m/T2 = 11. 67 = 4. 86 = 3. 80 Average Force Constant= 6. 78 Medium Spring k= 4Ï€2m/T2 = 7. 49 = 6. 57 = 6. 22 Average Force Constant= 6. 76 Results Method | Spring | Force Constant k(N/m) | Static | Short | 8. 55 | Static | Medium | 4. 913 | Static | Long | 3. 258 | Dynamic | Medium | 6. 76 | Dynamic | Long | 6. 78 | As seen the force constant is smaller when the spring is smaller meaning it takes more of a mass to have a larger displacement and vice versa in the static method. However in the dynamic method the differences are very minor. The theory of how a smaller and more compact ring has a higher force constant does not exist. This may be due to many factors has the experiment had many errors. The results of this lab mostly agree with Hooke’s Law. In the static method the Hooke’s Law is proven, the magnitude of the force exerted by a spring is directly proportional for the distance the spring has moved from equilibrium. However the dynamic method did not agree with the Hooke’s Law or the Simple Harmonic Motion. The periodic vibratory motion in which the force and the acceleration was directly proportional to the displacement and the dynamic method agree with the static method. This may have just been flawed by the design of this experiment or the fact that the springs were not ideal and did not obey Hooke’s Law due to the friction it experienced through the experiment. Discussion An equation that relates the total force constant to the two individual force constant of the two spring used in step 3. 3 is quite a challenge. Hoping that both springs agree with Hooke’s Law, we know that Hooke’s Law is F=-kx. The two springs in series have the same force exerted on both springs we then know F=-k1x1 and F=-k2x2. When trying to solve for both x’s x1 = -F/k1 and x2 = -F/k2. Meaning that the total displacement xt = x1 + x2 = -F/k1 - F/k2 = -F(1/k1 + 1/k2). So this results in the total force constant being kt= 1/(1/k1+1/k2). As seen in the graphs and chart above the values of force constant obtained by the static and dynamic methods vary. In the static method as the spring was smaller the force constant was greater meaning more force must be applied to enlarge the displacement. However in the dynamic method, the springs used did not matter as much and the force constant did not vary as much. Meaning the springs did not affect the force constant and how much for was needed to reach a certain displacement. There were many agreements and disagreements throughout this experiment especially between the two methods. Both methods verified that the mass suspended did change the displacement or the time of the cycles. However in the static method the spring did alter the force constant greatly and the force constant greatly but in the dynamic method the spring did not cause a great change in the force constant. The results of this lab mostly agree with Hooke’s Law. In the static method the Hooke’s Law is proven, the magnitude of the force exerted by a spring is directly proportional for the distance the spring has moved from equilibrium. However the dynamic method did not agree with the Hooke’s Law or the Simple Harmonic Motion. The periodic vibratory motion in which the force and the acceleration were directly proportional to the displacement and the dynamic method agree with the static method. This may have just been flawed by the design of this experiment or the fact that the springs were not ideal and did not obey Hooke’s Law due to the friction it experienced through the experiment. There were a few errors in this lab, one of them including the unclear procedures. The static method was pretty clear and concise whereas the dynamic method was hard to follow. The dynamic method may have gotten a large range of results. There wasn’t a exact measurement as to how far we have to make the displacement and how far the SHM had to be. This may have thrown some timing off and the end results off. Second the set up of this experiment was flawed. Even though we are testing real springs and not ideal springs there were way too much friction in this experiment for the results to be accurate. The friction created by the rubbing of the spring to the lab may have interfered with the results. During SHM the spring rubbed against the clamp every period. This may have caused a delay due to the friction. Also when the springs were connected in series, the spring between the two springs may have thrown the results off. Also the measurements for that part of the lab were hard to measure. There was one part of the springs that stay constant and did not move through the stretch of the spring. The connecting part of the two springs did not stretch or compress through the whole experiment however those couple of centimetres were included in the initial and final length even though there was no change. This again may have affected the results. In order to improve this lab the procedures need to be clear and quantitative. Also the springs attached to the clamp should be glue or tapes somewhat to minimize the friction. Lastly when doing the in series spring the part that is unaffected should be attached in such a way that it doesn’t create friction or affect the results. Overall this lab was pretty successful with a few sources of errors that can be minimized. For an Ideal spring, the force applied is proportional to the displacement regardless the length of x. Therefore, an ideal spring graph would be a straight line with the slope (k, spring constant) the same in all scenarios. For a real spring, the force applied is never proportional to the displacement of x because as more and more weight are being added to the spring; the spring is wearing out each time. Therefore, a real spring graph would look more spiked than straight as in an ideal spring graph. Conclusion Due to the fact that ideal springs are used as interpretations rather than real life examples, it makes sense that the force exerted by the spring will be proportional to the displacement it travels. However in this lab real springs are used therefore the graphs shown did not have exactly proportional displacements due to the force exerted. The number of times we used the spring, dictates a great amount of error in our investigation. Since we are not dealing with an ideal spring, real springs can wear out and stretch which causes the “ k" constant to change as they are being used numerous of times. It would be very hard to minimize an error like this one because everyone participating in this lab needed to record their results. Therefore, increase the source of error for the next person who uses it. Another error could be within the person recording the measurements. If we have the same person measuring the length of the spring (before and after), that gives us the measurements with respect to the individual, but if different person are measuring the lengths, we will have different intakes on how each individual read the measurements on the ruler. An ideal spring obeys Hook’s Law which states that the restoring force of a spring is directly proportional to a displacement. A real spring has mass and it can break therefore not making it proportional to a displacement. Overall the purpose of this lab was met and it was a successful lab. In this lab we were able to test real springs to determine under what conditions, they obey Hooke’s Law. We were also explore what happens when force constant of the springs are linked together either by the weight or the springs itself. We awere also able to explore the difference between different springs and masses and how it affects the force constant, displacement, frequency, total energy, amplitude and elastic potential energy. We were able to determine the force constant for extension springs by static and dynamic methods and verified the Hooke’s Law. The hypothesis made was correct, during the static method for each individual spring (short, medium and long) the more mass suspended there will be more of a stretch due to the final length and the force applied. The smaller the spring is the higher the force constant due to how condense the spring is and how much more force is going to be needed to stretch the spring compared to a larger spring. Larger springs should be easier to stretch resulting in a lower force constant. This then results in a faster time for the smaller springs in the dynamic method. The smaller the spring is the less time it would take to complete the 10 cycles due to the higher force constant causing a higher force exerted by the spring. For the method with springs in series I predict that there final length and stretch will not be affected due to the constant force constant and the applied force. I believe for this experiment I think the force exerted by the spring is the same as before and the final length will be the two lengths from medium and long springs before added together. However this was wrong and the final length was not just the two lengths added together. Overall this lab did agree with the Hooke's Law and how the magnitude of the force exerted by the spring is directly proportional to the distance has moved from the equilibrium. The force exerted by the spring did increase as the distance the mass has moved from the equilibrium has increased for every spring. This lab was successfully and safely completed and all the purposes were met and hypotheses were analyzed for the agreements and discrepancies. Applications There are many different springs in the world for many different reasons. There are compression springs, conical compression spring, torsion spring, extension spring, barrel spring, extended length coild spring, drawbar spring, magazine spring, spring pins, automotive springs, med springs, cantilever springs, die springs, garage door springs, garter springs, micro springs, rings, power, clock springs, rubber springs, waved springs, wire form and much more. However the not only are they all springs but the one other thing in common is that they are all used by humans in their everyday life. These springs aren't ideal they are real springs and the knowledge of force constant while using these springs is important. We need to know how much these springs can withstand while wearing out by the everyday use to ensure safety and quality. Bungee Jumping is known as one the most extreme sports in the world. The physics behind bungee jumping creates more attention to people who want to live life to the fullest. Bungee jumping cords are concerned real springs because they have mass, boundaries, and can wear out. Because all of Hook’s laws are violated, this sport can be defined as one of the most extreme and one of the most scientific. Just one minor mistake and not having the knowledge of force constant and Hooke’s Law can cost not only the spring but also someone’s life. Having even just basic physics knowledge about springs, SHM, Hooke’s law, Elastic Potential Energy and NLM is very important because they all apply to our everyday life.