Physics Lab 12: Spring Fever

Goals: Improve communication and teamwork capacities**;** Improve ability to make careful measurements and record observations; Discover the force law for a mass on a vertical spring; Use a motion detector to investigate the motion of the mass on a vertical spring; Observe periodic motion.

Equipment: You will be oriented to the location and proper use of the equipment for this lab. At the end of the session, return the equipment to its original configuration and location.

Groups & Lab Notebook: You will work in groups of 2. Update your Table of Contents. General Lab Notes guidelines apply.

You have previously calculated the force of gravity acting on an object of mass m near the surface of the earth. We give the force of gravity of the earth acting on the mass m the special name weight w (or weight force F_w) of mass m. Recall: $F_w = w = mg$, where g is 9.8 m/s^2 and the force points down. Since m and g are typically constant, F_w is also constant.

You have also read about other forces which are not constant. One such force is the tension force F_T or T of a rope, string, chain, etc. pulling on an object; the tension force acts parallel to the rope and pulls. Another is the so-called normal force F_N or N of one surface on another surface in direct contact; this force acts perpendicular to the surface and pushes (note that one meaning of normal is perpendicular).

As you will see again and again, the tension force and the normal force (among many others) vary depending on the situation. Consider standing in an elevator. The normal force of the floor on you points up (normal forces are perpendicular to the surface and push, so in this case the normal force points up). While the direction of the normal force in this case is always up (at least for standard elevators!), the magnitude of this force can be different. Take the case where the elevator is moving at constant velocity. Then, the acceleration is zero, so the net force is zero. Since the forces acting on you are your weight force $F_w = mg$ pointing down and the normal force F_N pointing up, then since $F_{net} = F_N - F_w = ma = 0$, we conclude that $F_N = F_w = mg$. However, now consider the case where the elevator is moving up but slowing down. Then, the acceleration points down, so the net force points down. In this case, then, $F_N < F_w = mg$. Note that what is cumbersome in words is greatly clarified using free-body force diagrams and equations, and you are highly encouraged to draw free-body diagrams for the two cases described in this paragraph on your own time.

How can forces like the tension force and the normal force vary? To begin to answer this question, in today's investigation, you will study another variable force: the spring force. You probably know that the more you force you apply to pull or push on a spring, the more the spring extends or compresses. Thus, by Newton's third law, the greater the extension (stretch) or compression of a spring, the more force the spring exerts. In the first part of today's lab, you will determine the relationship between the stretch length of a spring and the force the spring exerts. In the second part of today's lab, you will use a motion detector to measure the motion of a mass subjected to this varying spring force, and observe periodic motion. Periodic motion is the subject of next week's study, so this serves to concretize the upcoming material.

Part 1: Spring Force

CAUTION: make sure you don't over-stretch the spring. Make sure you only use the springs and masses specified in the steps below.

a) After the equipment orientation and introduction, obtain your equipment and set up as in the demonstration station. You do not need to set up the motion detector yet. Note that the springs are labeled strangely. For our purposes, the labels are just for identification.
b) Start with the spring labeled 1N. Hang it vertically with no mass attached.
c) Carefully measure spring 1N's unstretched length with respect to its attachment point (probably where you've placed it on the hook). You will measure all your subsequent lengths from the same attachment point, and you are interested in recording by how much the spring has stretched. In other words, while you will measure the length of the spring for each new attached mass, the quantity you are interested in is the extension of the spring compared to its unstretched length. Example: the unstretched length of the spring is 7 cm. You attach a mass and the stretched length of the spring is 12 cm. Then, the spring has stretched 12 cm – 7 cm = 5 cm, and so 5 cm is what you would record.
d) When a mass is hanging from the spring, two forces act on the mass: its weight force pointing straight down, and the spring force acting straight up. We know that there must be a force acting up by the following reasoning: when the mass is in ***equilibrium*** (at rest), the acceleration is zero; since the acceleration is zero, the net force is zero; since the weight force points down, there must a force acting up to make the net force equal zero. Following similar reasoning, the magnitude of the spring force must equal the magnitude of the weight force. Draw a free-body force diagram showing the mass as a dot with two arrows: one pointing down labeled F_w and one pointing up labeled F_{spring}. Use Newton's second law and the condition that the systems is in equilibrium, along with your free-body force diagram, to show that the magnitude of the spring force F_{spring} equals the magnitude of the weight force F_w.
e) For spring 1N, carefully measure the extension when you have added 50 g (note that the mass hangar by itself is 50 g) to the bottom of the spring and the mass has come to rest (equilibrium). Carefully measure the extension for the

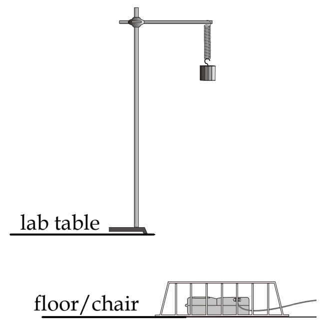
following total masses (so including the mass hangar) in equilibrium: 50 g, 75 g, 100 g, 125 g, 150 g. Make sure not to go above 150 g; if it looks like it might stretch too much past 125 g, stop at 125 g.

f) Organize your results in a table, with the stretch of the spring (in meters) in the first column, and the weight of the mass (in Newtons) in the second column. Self-check: 50 g weighs 0.49 N. Recall that the weight of the mass is equal to the spring force (at equilibrium).

g) Repeat with spring 2N, for 50 g, 100 g, 150 g, 200 g, 250 g (if the higher masses look like they will over-stretch the spring, stop). Organize your results in a new table, as before.

Part 2: Periodic Motion

CAUTION: The Motion Detector will be on the floor, with a mass hooked to a spring moving up and down above the detector. Use the protective screen and take care to make sure the mass does not fall onto the Motion Detector.



(image modified from Vernier Physics with Computers)

a) Your goal is to obtain good position vs. time graphs that show several cycles of up and down motion (one cycle is called a ***period***) for various combinations of spring, mass, and initial displacement as shown in the table below

b) **Each time you change a mass or a spring, allow the system to come to equilibrium, and then Zero the sensor. Set the Triggering (under Experiment: Data Collection) to Start Data Collection when Increasing Across 0.**

c) Modify your set-up as in the demonstration station and in the figure. Attach Spring 1 to the spring hook and attach 50 g to the bottom of the spring. Let the mass come to its ***equilibrium*** (rest) position; you can help it out by gentling damping the vibrations. Draw a sketch of your experimental setup in your notebook.

d) Gently pull the mass straight down 2.5 cm (0.025 m) from equilibrium, and release it from rest (this distance is the ***amplitude***). Measure the subsequent motion. Rename your best position vs. time graph that shows several cycles in the same run as 'spring01'.

e) Repeat using the parameters in the table. You should already have done the first set of parameters.

Spring	Mass (g)	Amplitude (cm)	Data run name		Spring	Mass (g)	Amp. (cm)	Data run name
1N	100	2.5	spring01		2N	75	5	spring05
1N	100	5	spring02		2N	100	5	spring06
1N	100	10	spring03		2N	150	5	spring07
1N	100	15	spring04		2N	300	5	spring08

Analysis: Part 1 – Spring Force

(if you don't complete this during class time, complete before Wed. May 21)

a) Look at your tables of spring stretch and weight (recall that the magnitude of the weight force is equal to the magnitude of the spring in the equilibrium condition), which is the same thing as a table of spring stretch and spring force, for both the 1N and 2N spring. Do you notice a pattern?

b) One way to reveal or confirm a pattern is to make a graph. Launch the LoggerPro file Spring Force Law which you can find in the program share under Handouts: Week 7 Lab. Enter your data for the 1N spring from Part 1f) in the appropriate table. Make sure you have converted your data to the right units. It should automatically plot the points for you. Autoscale so that the data fits the screen; as needed change the axes so you can highlight all the data should you choose. What pattern do you see?

c) Highlight the data and fit a line. Record your slope (with units) and b value (with units).

d) Is your b value (the y-intercept) close to zero? Why does this make sense (hint: the input is the stretch and the output is the spring force. If the stretch is zero, what would the spring force be? How does this connect to the y-intercept of the graph?)?

e) The slope m gives a quantity known as the spring constant k. What are the units for the spring constant?

f) Repeat for spring 2N. Compare the spring constants. How does these numerical results match your observations?

From this analysis, we can see that the model for the spring force law is linear in spring stretch: the more the spring stretches, the greater the spring force: $F_{spring} = kx$, where F_{spring} is the spring force which is parallel to the spring and can push or pull, depending on if the spring is compressed or extended; k is the spring constant, and here x is the stretch of the spring as measured from its unstretched length.

Analysis: Part 2 – Periodic Motion

(if you don't complete this during class time, complete before Wed. May 21)

a) Make a graph that shows spring01 through spring04 on the same graph. This investigation had the same spring and the same mass, but changed the amplitude. Does changing the amplitude have much effect on the period (the repeat time) of the periodic motion in this case?

b) Make a graph that shows spring05 through spring08 on the same graph. This investigation had the same spring and the same amplitude, but changed the mass. Does changing the mass have much effect on the period?