Directly proportional means one quantity is doubled by doubling a second quantity. If a force $x$ stretches a spring through a distance $y$, a force of $2x$ will stretch it through distance of $2y$. This relationship is shown graphically by a straight line connecting points of data also passing through the origin.

Hooke's Law only applies to those circumstances in which a spring does not exceed its elastic limit. The elastic limit of a substance is the load per unit area beyond which the stretch is not proportional to the stretching force. When the elastic limit is exceeded, the substance is permanently stretched. (In the case of this apparatus, the weight limit is 5 50 g slotted weights, or a maximum of 250 g.)

**Operation**

**Adjustment**

For accurate and reproducible results you need to adjust this apparatus. The indicator (pointer) should be brought as close to the scale as possible, with minimal distance between tip of pointer and physical location of the scale. Adjust pointer to a scale setting for zero which you have selected and recorded. Use mirrored strip on scale to judge exact location of the pointer by means of its reflection. To avoid parallax errors, read the scale only when directly in front of and on the same eye level as the pointer.

Adjust by these methods:

1. Move and/or rotate the millimeter scale
2. Loosen the thumb screw to move the spring hanger

**Figure left: deflection of spring. Figure right: example of a graphical depiction of Hooke’s Law.**

**Hooke's Law**

<table>
<thead>
<tr>
<th>Caution: To avoid permanently deforming your spring, do not exceed 250 g total weight. Add your slotted weights gradually in increments of 50 g or less.</th>
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**Procedure:**

1. **Record the pointer's initial position.** The coils of the spring should be slightly separated before taking your initial reading. Separation may be accomplished by preloading the spring with a small weight of about 10 g.
2. **Add a known weight to the hanger and record the deflection.**
3. Continue to add known weights and record the deflections. Be careful that the applied weight does not extend the pointer beyond the upper limit of the scale. This will deform the spring.
4. Repeat steps 1 through 3 to ensure precise readings.
5. **Graph the applied force ($F$) versus elongation of the spring ($x$).** Each point represents the stretch in millimeters that a given load produced. Values of stretch ($x$) given along the vertical are ordinates of the graph. Values of load ($F$) along the horizontal are the abscissas. If all measurements are accurate, a straight line fits the point upon the graph up to but not exceeding the elastic limit.

   \[
   F = \text{force (total weight)} \\
   x = \text{spring elongation} \\
   \text{The slope of the line is } K \text{ where:} \\
   F = Kx
   \]

   This relationship holds true for all elastic displacements. With this apparatus, it is probably impossible to exceed the elastic limit because the base provides a natural limit for the stretch of the spring.

**Harmonic Motion**

In simple harmonic motion, it has been found that Hooke’s Law holds at every stage of the movement of a taut, vibrating string. If you pull a taut string out of its equilibrium position, the amount of displacement from that equilibrium position is proportional to the force tending to restore it to that position.

If a string is released after being pulled, the restoring force accelerates it in the direction of the equilibrium position. As the string snaps back, it moves faster. As it approaches equilibrium, its displacement from that position becomes continually less; correspondingly, the restoring force becomes less. Although the string moves more rapidly as a result, the rate of gain of velocity decreases. When equilibrium is reached, the string can gain no more velocity. Its rate of motion is at a maximum.

In all cases of simple harmonic motion, it is crucial that the velocity changes smoothly at all times.

**Procedure:**

1. **Attach known weight** (ie. 100 g).
2. **Displace spring hanger** 2-3 cm.
3. **Release hanger.**
4. **Count the number of oscillations** per chosen time period ($\text{frequency}$.)
5. **Calculate the period of vibration** using the formula

   \[
   T = \frac{2\pi \sqrt{M/K}}
   \]

   where $T = \text{period (Time)}$ \\
   $K = \text{force constant of spring}$ \\
   slope of graph \\
   $M = \text{Mass of vibrating system}$

The mass ($M$) of this system is the total weight suspended from the spring.

In effect the period of simple harmonic motion depends only on the mass of the moving body and the proportionality constant between stress and strain. It allows accurate measurement of time merely by counting vibrations.

6. **Repeat the above 5 steps with different weights and springs.** Calculate the period of vibration and compare to values obtained experimentally.

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