32445 Linked Springs, Series & Parallel

Purpose:

Following the usual investigation of Hooke's Law, two or three springs of equal spring constant are combined in series and in parallel to determine the effective total spring constant. Also, two or three springs, permanently linked in series, are made to support a 0.5 kg mass at each link and at the bottom in order to demonstrate coupled oscillations and the normal modes of vibration.

Required Accessories:

Support Stand with Rod and Clamp, Hooked Masses, Meterstick, Timer

Optional Accessories:

Sonic Ranger (MBL or CBL)

Method:

Springs in series are supported by a rod through the top spring loop and are extended by hanging hooked masses from the bottom loop. Springs in parallel are supported in common by running the support rod through what will be the top loops. The notched support is run through the bottom loops, with each loop in a separate notch, and the springs are extended by hanging hooked masses from the notched support. The notched support must be loaded symmetrically. The center and the two extreme notches are used with three springs, the other two notches are used with two springs. In this case, the remaining spring hangs out of the way while still linked to the center spring of the set. Data are taken either by measuring the extension of the spring system when incremental masses are attached, or by timing the oscillations of the spring system when set into motion by temporarily extending and releasing the hanging masses.

Also, two or three springs, permanently linked in series, are made to support a 0.5 kg mass at a loop at each link and at the bottom loop in order to demonstrate coupled oscillations and the normal modes of vibration. Pulling any one of the masses causes oscillations which will couple between all the masses. Pairs of masses can be displaced either in phase or out of phase with interesting results. While supporting the springs in series by hand, moving the top loop up and down at a frequency matching one of the normal modes will excite that mode.

Background:

Students will likely find, later in the year, that these spring constants have added just like a capacitor network, and not like a resistor network. That is, the spring constants of a parallel network are summed directly, while the spring constants of a series network are summed as inverses.

$$k_{(parallel)} = k_{(1)} + k_{(2)} + k_{(3)} + \ldots$$
$$k_{(series)} = 1/k_{(1)} + 1/k_{(2)} + 1/k_{(3)} + \ldots$$

Procedure:

There are two common ways of finding the spring constant. One is by graphing elongation of the spring versus the force producing it, and taking the slope of that graph. This is sometimes approximated by noticing the change in length brought about by an incremental change in the mass hanging from the spring. The expression: $F = ma = W = mg = -kx$ can be solved for "k" if "x" is the change in length. The negative sign usually means that it is the restorative force that is being described. In fundamental units, "k" is in N/m, but industrially is often given in N/mm.

The spring constant can also be found from the simple harmonic motion of the mass bouncing up and down on the end of the spring. By timing several oscillations to get a good average value (T), and by measuring the mass (m) hanging from the spring, the following expression can be solved for the spring constant:
Using either two or three springs, permanently linked in series, one can hang a 0.5 kg hooked mass at a convenient loop near each link and also at the bottom loop. To demonstrate coupled oscillations, pull and release any one of the masses causing oscillations. Pairs of masses can be displaced either in the same or opposite directions with interesting results. Next, support the springs in series with one hand and move that hand slowly up and down. Vibrations at a frequency that matches one of the normal modes, will excite that

mode of vibration. It is easy to explore. In this way, this apparatus, used perhaps early in the course, can come out again as a demonstration when dealing with resonant systems. Students can be led to the need for carefully supporting components that might vibrate, in an automobile or aircraft, for example, so that resonant vibrations do not lead to early material fatigue.

Time Allocation:

To prepare this product for an experimental trial takes less than five minutes. Actual experiments will vary with needs of students and the method of instruction, but are easily concluded within one class period.

Feedback:

If you have a question, a comment, or a suggestion that would improve this product, you may call our toll free number.