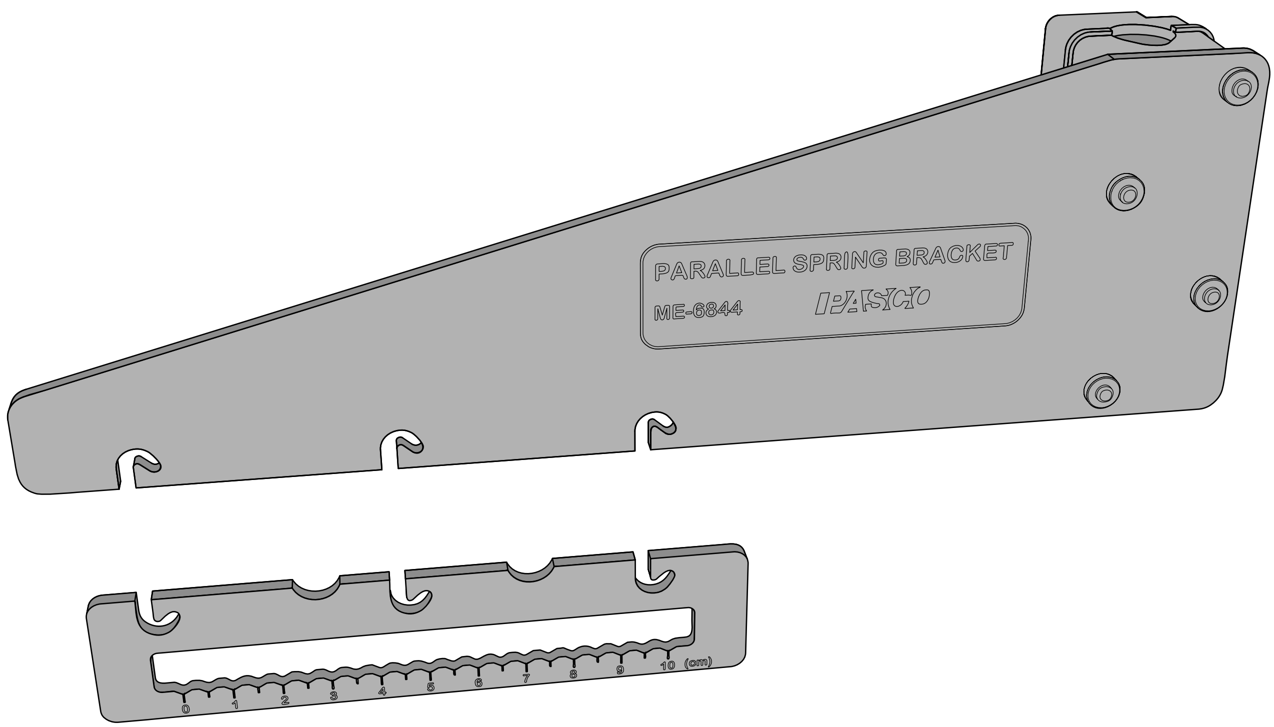
Parallel Spring Bracket

ME-6844



Included Equipment	Part Number
Suspension Bracket Parallel Hook Bar	ME-6844
Thumbscrews (2 pieces)	617-016
Additional Equipment Recommended	
Series/Parallel Spring Set	ME-6842
Equal Length Spring Set	ME-8970
Hooked Mass Set	SE-8759
Large Table Clamp	ME-9472
45 cm Rod	ME-8736
Meter Stick	SE-8695

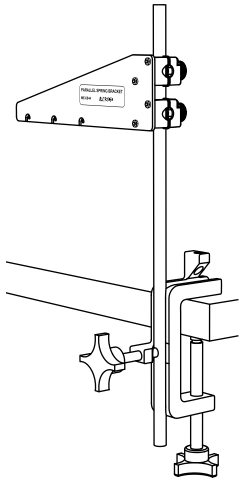
Introduction

The Parallel Spring Bracket allows springs to be combined in series and parallel. Masses can be hung in offset positions to compensate for springs of different strengths.

The Parallel Spring Bracket is ideal for:

- exploring how spring constants add when springs are arranged in series or in parallel,
- demonstrating the analogy between combinations of springs and combinations of capacitors, and
- exploring torque acting on the hook bar by placement of the mass and springs at different positions.

Set-up



1. Assemble the suspension bracket, a large table clamp and a rod as illustrated. The table clamp (rather than a base) and a relatively short rod are recommended for maximum stability.

2. Hang any combination of springs from the suspension bracket.

3. Attach the parallel hook bar to the bottom of the spring combination.

4. Hook a mass onto the notched slot of the parallel hook bar. The mass should be large enough to stretch all springs at least slightly.

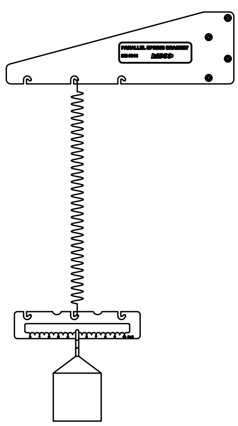
5. Move the mass left or right along the notched slot to find the position that makes the hook bar as close to horizontal as possible.

6. Check that all springs are stretched. You should be able to see between the coils of every spring. If one of the springs is not stretched, increase the hanging mass.

Sample Configurations

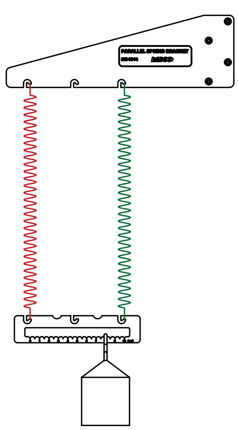
Single Spring

Though the hook bar is not necessary to attach a mass to a single spring, it does provide a convenient point from which to measure changing displacement.



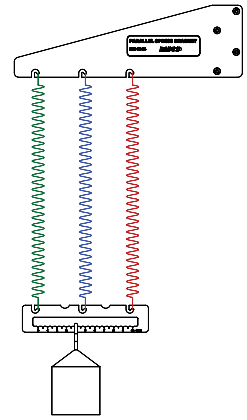
Two Parallel

Two springs (10 N/m and 40 N/m) from the Series/Parallel Spring Set (ME-6842) are combined in parallel. The hanging mass is placed off center to make the hook bar level.



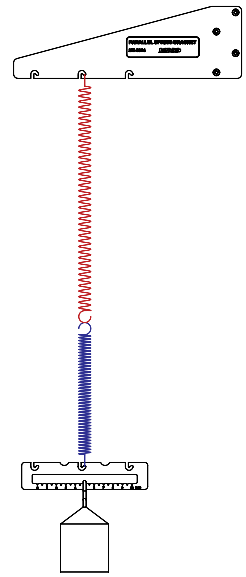
Three Parallel

Three different springs (40 N/m, 20 N/m, and 10 N/m) from the Series/Parallel Spring Set are combined in parallel.



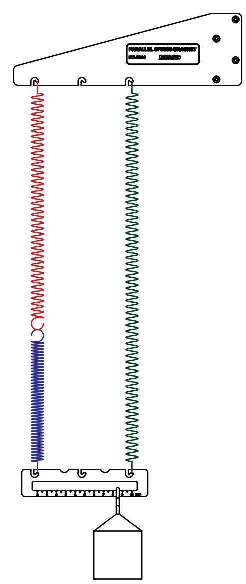
Series

Two springs are linked end-to-end to form a series combination.

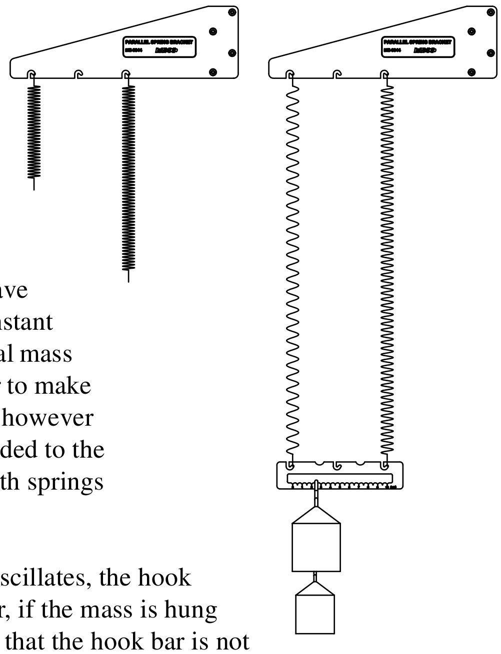


Series and parallel

Two short springs from the Series/Parallel Spring Set are linked in series. That combination is in parallel with a single long spring from the Equal Length Spring Set (ME-8970). When not stretched, the long spring is twice the length of each of the short springs.



Parallel Springs of Different Length

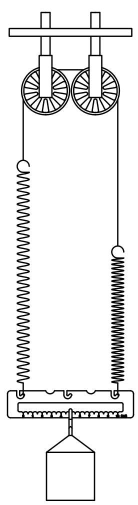


A long spring from the Equal Length Spring Set and a short spring from the Series/Parallel Spring Set are combined in parallel. Both springs have the same spring constant (40 N/m). The initial mass is placed off-center to make the hook bar level; however addition mass is added to the center to stretch both springs equally.

When the system oscillates, the hook bar rocks. However, if the mass is hung from the center (so that the hook bar is not level) it oscillates without rocking.

A similar effect can be achieved using two identical springs with one vertically offset using string.

Modified Series



With this combination of springs, string, and pulleys, the balance point of the hanging mass is always at the center of the hook bar regardless of the spring constants or lengths.

Measurements and Calculations

Spring Constant

Use the following method to measure the spring constant of a spring or combination of springs.

1. With the initial mass hanging from the hook bar (so that all springs are slightly stretched), measure the distance from the floor to the bottom of the hook bar.

2. Add some mass (typically about 500 g) to the hanging mass.

3. Measure the distance from the floor to the bottom of the hook bar again.

4. Calculate the change in force (the weight of the additional mass), ΔF.

5. Calculate the change in position of the hook bar, Δx.

6. Calculate the resultant spring constant using

(eq. 1) $$k = \frac{\Delta F}{\Delta x}$$

The above equation lacks the negative sign usually found in expressions of Hooke's Law because F in this case is the applied force rather than the force exerted by the springs.

For better precision, increase the hanging mass incrementally and make a graph of ΔF versus Δx. The slope of the best-fit line is k.

Addition of Spring Constants

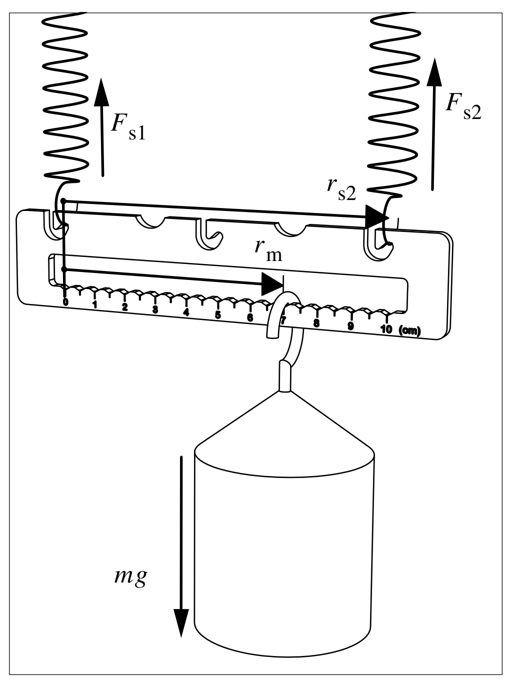
The combination of springs is analogous to the combination of capacitors. The equivalent spring constant of two or more springs in parallel is

(eq. 2) $$k_{eq} = k_1 + k_2 + k_3 + \ldots \quad \left(\begin{array}{c}\text{parallel}\\ \text{combination}\end{array}\right)$$

For springs in series, the equivalent spring constant is

(eq. 3) $$\frac{1}{k_{eq}} = \frac{1}{k_1} + \frac{1}{k_2} + \frac{1}{k_3} + \ldots \quad \left(\begin{array}{c}\text{series}\\ \text{combination}\end{array}\right)$$

Force and Torque



The objects attached to the hook bar (springs and hanging mass) each exerts a torque and a force on it. When the system is static, the net torque and net force are both zero.

When the hook bar has two springs and one mass attached to it, it is possible to determine the three separate forces:

(eq. 4) $$F_{net} = F_{s1} + F_{s2} - mg = 0$$

The axis about which the torques are measured is chosen to be at the “0 cm” mark. Spring #1 is attached at the axis, therefore its torque is zero. The net torque is

(eq. 5) $$\tau_{net} = r_{s2}F_{s2} - r_{m}mg = 0$$

Solving for F_{s2} yields:

(eq. 6) $$F_{s2} = \frac{r_m}{r_{s2}}mg$$

Combining equations 4 and 6 gives us:

(eq. 7) $$F_{s1} = \left(1 - \frac{r_m}{r_{s2}}\right)mg$$

Period of Oscillation

The period of oscillation of a mass on a spring (or combination of springs) is

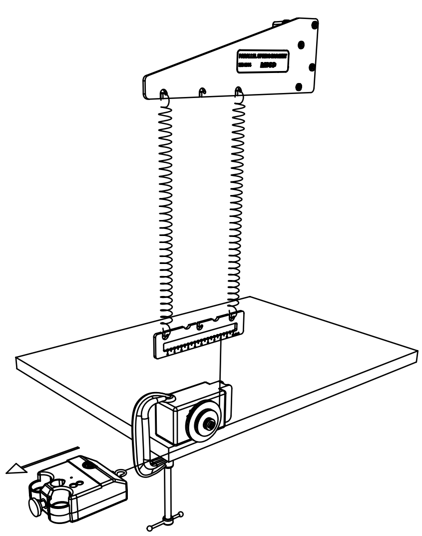
$$T = 2\pi\sqrt{\frac{m}{k}}$$

The mass, m, should include the hanging mass, the mass of the hook bar, and 1/3 of the mass of the springs.

To demonstrate this relationship for any combination of springs, use a stop watch to measure the period of oscillation. Increase the hanging mass in steps. Make a graph of T^2 versus Δm. The slope of the best-fit line is $4\pi^2/k$.

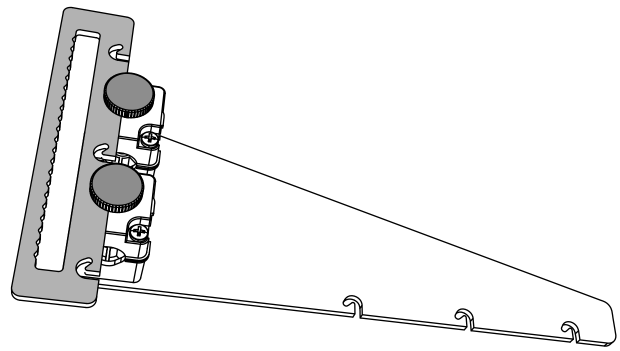
Sensor-based Measurement

To measure the spring constant using a rotary motion sensor (RMS) and a force sensor, set up the equipment as illustrated. Pull the force sensor to stretch the spring combination. Make a graph of force (measured by the force sensor) versus linear position (measured by the RMS). The slope of the best-fit line is the spring constant.



Storage

To keep the bracket and hook bar together when not in use, clamp the hook bar under the thumbscrews as illustrated.



Technical Support

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