Another property of mesh mounts is demonstrated by Figure 26 [5]. As can be seen, in practice there is a sudden sharp drop from the resonant point, ensuring that isolation is achieved almost immediately. However, it is again safer to assume that isolation does not begin until $\sqrt{2}\, f_n$ is achieved.

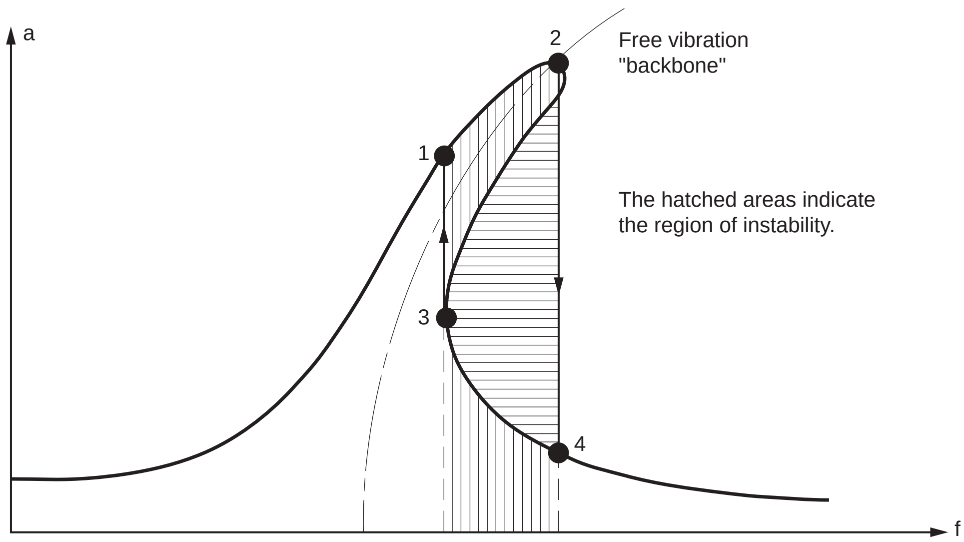


**Figure 26 Theoretical Frequency Response Curve for a Hardening Spring Type Resonant System**

## 5.0 MULTIDEGREE OF FREEDOM SYSTEMS, COUPLED MODES

Figure 27 demonstrates that there are six independent ways in which a body can move; i.e., it has SIX DEGREES OF FREEDOM. The reader must be aware from this that there is a potential of six independent natural frequencies, as well as possible coupled modes of vibration.

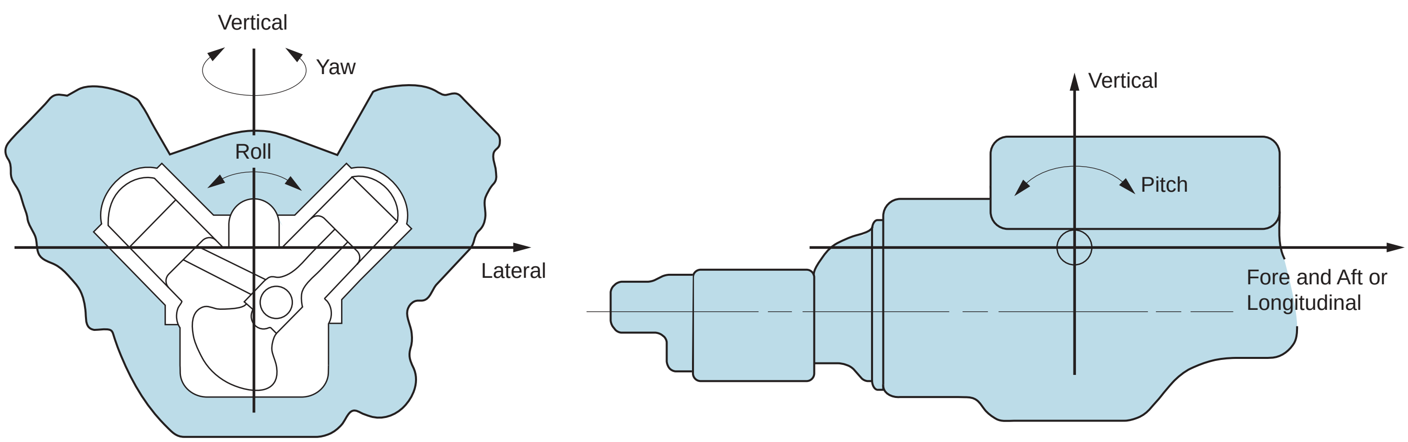


**Figure 27 Degrees of Freedom of a Solid Body**

The coupling concept can be illustrated on the example of a simpler "planar" system shown in Figure 28, which shows a mass supported by springs and constrained so that it can move only in the plane of the drawing [5]. Such a system has three coordinates which fully describe its configuration: translational coordinates x and y, and angular coordinate $\alpha$. If the system is symmetrical about axis y, then when excited by a sinusoidal force $F_y$, in the vertical direction along the axis of symmetry, the object will behave as previously shown (Figure 1), namely by vibrating in the vertical (y) direction. However, if the force vector does not coincide with the axis of symmetry, then the vertical force would excite vibratory motions not only in the y-direction, but also in x and $\alpha$ directions. When the mass is excited by a horizontal force $F_x$, both horizontal ($\ddot{y}$) or longitudinal mode and pitching ($\alpha$) vibratory motions are excited. These modes are said to be coupled when vibrations of one mode can be stimulated by a vibratory force or displacement in another. Coupling modes are in most cases undesirable. For example, many vibration-sensitive objects have the highest vibration sensitivity in a horizontal direction, while the floor vibrations are often more intense in the vertical direction. Coupling between the vertical and horizontal directions can be avoided by using vibration isolating mounts at each mounting point whose stiffness is proportional to the weight load acting on this mount (CNF mount) [1].

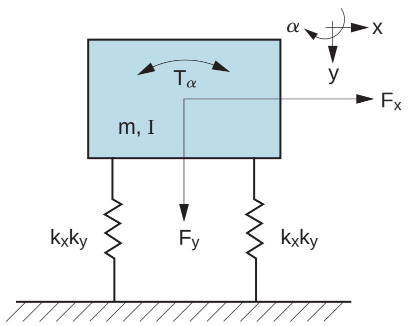


**Figure 28 Planar (Three-Degrees-of-Freedom) Vibration Isolation System**



## 6.0 STATIC LOAD DISTRIBUTION CALCULATION

In order to calculate the weight distribution between the mounting points, the position of the CENTER OF GRAVITY (C.G.) has to be determined first. It is a simple task only for an axisymmetrical object. Position of the C.G. can be obtained by computation or experiment. The computational approach is feasible in most cases to the manufacturer who has all relevant drawings containing the data on mass distribution inside the object. The experiment is suggested by the definition of the C.G. as the point of support at which the body will be in equilibrium. For example, a small object can be supported on a peg; when in equilibrium, a vertical line drawn through the peg will pass through the C.G. Unfortunately, this method is applicable only to small objects. For large objects, such as machine tools, the object is mounted, for the C.G. location purposes, onto three load cells LC1, LC2, LC3, as shown is the plane view in Figure 29. If the weight loads as sensed by these load cells are $W_1$, $W_2$, $W_3$, respectively, then coordinates of the C.G. are as follows:

$$\left.\begin{aligned} x_{C.G.} &= \frac{x_1W_1 + x_2W_2 + x_3W_3}{W_1 + W_2 + W_3}\,; \\ y_{C.G.} &= \frac{y_1W_1 + y_2W_2 + y_3W_3}{W_1 + W_2 + W_3}\,. \end{aligned}\right\} \quad (23)$$

After the C.G. position is known, weight distribution between the mounting points should be calculated. Such a calculation can be rigorously performed only for the case of an object with three mounting points (a statically-determinate problem). Unfortunately, only a relatively small percentage of objects requiring vibration isolation are designed with the "three point" mounting arrangement. If the number of the mounting points is greater than three, the accuracy of weight distribution calculations is suffering, unless the mounting surface of the floor is flat and horizontal and the mounting surface of the object is also flat. The tolerance on the "flatness" requirement should be a small fraction of the projected static deformations $x_{st}$ of the selected vibration isolators.

For example, if the vertical natural frequency of the isolated object is $f_n$ = 20 Hz, then, from Equation (4), $x_{st}$ = 0.0625 cm or 0.625 mm.

Similarly, for $f_n$ = 10 Hz, $x_{st}$ = 2.5 mm, and
for $f_n$ = 5 Hz, $x_{st}$ = 10 mm.

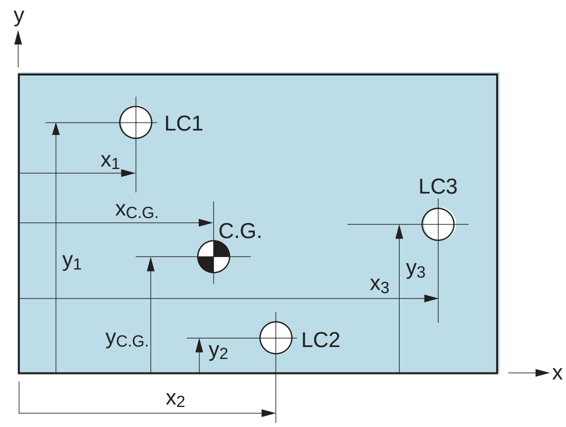


**Figure 29 Setup for Experimental Finding of the C.G. Location**