1. Theory

Spring force is the force required or exerted to compress or stretch a spring upon any object that is attached to it. When an object applies a force to a spring, then the spring applies an equal and opposite force to the object. It always acts to restore mass toward its equilibrium position. The Spring constant is a characteristic of a spring that measures the ratio of the force affecting the spring to the displacement caused by it. In other words, it describes how stiff spring is and how much it will stretch or compress. Springs with larger spring constants will have smaller displacements than springs with lesser spring constants for the same mass added. If a spring be clamped vertically at the end P and loaded with a mass m_o at the other end A. The spring extends to position O by adding a suitable weight to the free end A. If the extension is l, then

$m_o g = kl$

$$\therefore k = \frac{m_o}{l} g \ldots\ldots\ldots\ldots\ldots (1)$$

Now the period of vibration of the spring along a vertical line is given by,

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

$$T = 2\pi \sqrt{\frac{m_o + m'}{k}} \ldots\ldots\ldots\ldots\ldots (2)$$

Were,

$m' = effective\ mass\ of\ the\ spring$

$k = spring\ constant$

$m_o = loaded\ mass$

$g = gravitational\ constant$

$l = extension\ of\ the\ spring$

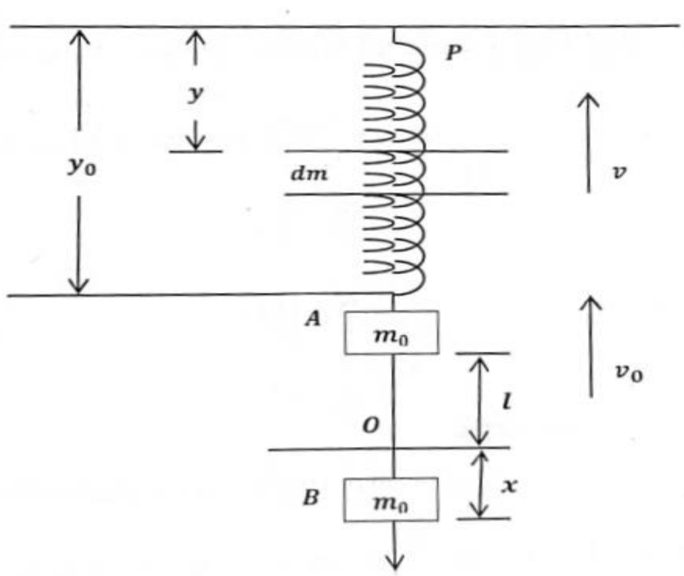

Figure 1: Measuring spring constant and effective mass

If we consider the kinetic energy of a spring and its load undergoing a simple harmonic motion, let the load m_o be moving with velocity v_o (as shown in the figure). At the same instant, an element dm of the mass m of the spring will also be moving up but with a velocity v which is smaller than v_o

It is evident that the ratio between $v \; and \; v_o$ is just the ratio between $y \; and \; y_o$

Hence, $\frac{v}{y} = \frac{v_o}{y_o}$

$$v = \frac{v_o}{y_o} y$$

Similarly, we have, $\frac{dm}{m} = \frac{dy}{y_o}$

$$dm = \frac{m}{y_o} dy$$

Now the kinetic energy of the spring element = $\frac{1}{2} v^2 dm = \frac{1}{2} \frac{v_o{}^2}{y_o{}^2} y^2 \frac{m_o}{y_o} dy = \frac{1}{2} \frac{v_o{}^2}{y_o{}^3} m y^2 dy$

And the kinetic energy of the spring = $\int_y^{y_o} \frac{1}{2} \frac{v_o{}^2}{y_o{}^3} m y^2 dy$

$$= \frac{1}{2} \frac{v_o{}^2}{y_o{}^3} m \left[\frac{y^3}{3}\right]_0^{y_o}$$

$$= \frac{1}{2}\frac{{v_o}^2}{{y_o}^3} m \frac{{y_o}^3}{3}$$

$$= \frac{1}{2}\left(\frac{m}{3}\right){v_o}^2$$

Then the total kinetic energy of the system = $\frac{1}{2}\left(m_o + \frac{m}{3}\right){v_o}^2$

Therefore, the effective mass of the system is $\left(m_o + \frac{m}{3}\right)$ and the effective mass of the spring,

$$m' = \frac{m}{3} \dots\dots\dots\dots\dots.(3)$$

2. Apparatus

The components required to carry out this experiment include: -

- A Spiral spring
- Convenient Masses
- Hanging Appeasement
- Clamp
- Stopwatch
- Scale

1. Discussion

The main objective of this experiment is to find out the spring constant and effective mass of a given spiral spring and to also compare the original effective mass with the experimental one. The spring constant is a physical property that describes the stiffness of a spring, which is the amount of force required to stretch or compress it by a certain amount. Force, which provides the extension, has a relation $F = -kx$ with the spring, where k is the spring constant and x the extension. Negative (-) is due to the direction of the spring, as the spring always tries to return to its original shape, which is in the opposite direction to the applied force. The higher the spring constant, the more force is required to stretch or compress the spring, and the stiffer the spring is. Conversely, a lower spring constant indicates a less stiff spring that requires less force to deform. While performing this experiment we followed some safety precautions. The extension measurements must be taken when the spring is in equilibrium, i.e, when the spring stops oscillating. We Kept the spring away from our face and body when measuring its spring constant, as it may snap or recoil if it is stretched or compressed too much. Excessive load should not be added which would elevate the spring beyond its elastic limit. Ruler should also be made sure to be parallel to the springand vertical while taking length measurements to avoid inaccurate readings. Systematic error (zero error) of the stopwatch along with human parallax error may contribute to inaccurate measurements. Essentially it is a low-risk experiment however adequate safety measures should alwaysbe appropriated. Boots should be worn in case masses fall and hit feet. After completing this experiment, we know that the spring constant is used in a variety of applications, such as in designing suspension systems for cars, calculating the displacement of oscillating systems, and determining the stiffness of materials. It is also important in understanding the behavior of elastic materials, including springs, rubber bands, and metals.

8. References

Resources for the:

- Practical Physics (by Dr.Giasuddin Ahmed & Md. Shahabuddin): Exp. 11: To determine the spring constant and effective mass of a given spiral spring (Page no-68).

- Video Link:

  https://www.youtube.com/watch?v=yjOcbjpTCFA

  https://www.youtube.com/watch?v=aZ0jDLNLFGc

  https://www.youtube.com/watch?v=XpSHdxGaWvs