# Centripetal Force*

## Object

To verify the centripetal force formula for a rotating mass.

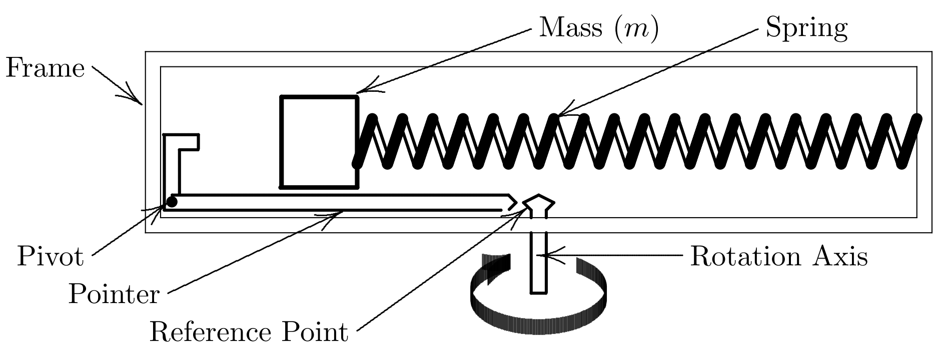
## Theory

If an object of mass $m$ rotates in a circular path of radius $r$ at a constant speed $v$ it can be shown to have a force acting on it that is directed towards the center of the circular path and has a magnitude given by:

$$F_c = \frac{mv^2}{r}. \quad (1)$$

In this experiment we shall measure $F_c$, $v$ and $r$ independently and check the accuracy of the above equation.

## The measurement method




The setup is shown above. The mass ($m$) is a cylindrical piece of metal. It is attached to one end of a spring. The other end of the spring is attached to the metal frame that holds the complete unit. This frame is rotated using a motor about the axis shown in the figure. The speed of rotation can be adjusted. As the speed is increased, the mass moves farther out stretching the spring. When it reaches a fixed position, it lifts the pointer up from its rest position. To precisely locate the position of the mass (the radius $r$ of the orbit), we adjust the speed to bring the pointer in line with a reference point built into the frame. Once this is achieved, the frequency $f$ of rotation can be measured. This can be done manually or through a computer interface.

To measure $f$ manually, engage the mechanical counter under the motor to count the number of rotations ($n$) for a known duration of time ($t$) that you can measure using a timer. Then

$$f = n/t. \tag{2}$$

To let the computer measure $f$, you can use the infrared sensor arrangement that is connected to the computer. The software determines $f$ by measuring the time taken between two interruptions of the infrared beam. The infrared beam is interrupted by a piece of cardboard attached to the rotating object. To run the software, open the file "Frequency"(in the "GenPhy1" folder on the desktop) and click the "connect" button to connect the sensor. Once the rotating object has reached the desired speed, click the green "Collect" button. Notice that the plotted values of $f$ have quite a variation. Some of this variation is of course expected. But there are some points on the graph that are very far from the median. Ignore these points. See if you can explain these points that have large error. At higher speeds the large errors may be too much and you may have to abandon the computer measurement method altogether.

Now it can be seen that

$$v = 2\pi r f. \tag{3}$$

As the rotation speed is adjusted to make the mass reach a predetermined radius, we can stop the rotation and then measure this radius $r$. To measure the force, we suspend the rotating object so the spring is vertical and the mass hangs down from it. This extends the spring due to a gravitational force. We hang some extra masses from it to bring the rotating mass down to the predetermined position where the pointer lifts up. If the extra mass added is $M$ then the total gravitational force required to extend the spring to this position is $(M+m)g$. As this extends the spring the same amount as when it was rotating, the two forces must be the same, that is,

$$F_c = (M + m)g. \tag{4}$$

## Some trials

Make the measurements as described above and find the percentage difference between the measured value of $F_c$ (equation 4) and its theoretically predicted value (equation 1). You can obtain more than one set of data by using different spring tensions. But make sure spring tension stays the same for each set of data.

Try to find the optimum conditions for this experiment.

Can you think of an alternate method for doing this experiment?