# Radial Force

Fall 2023

## Introduction

The purpose of this experiment is to calculate – and then measure – the force a spring exerts on a mass when the mass is hanging vertically while in motion, and at rest.

## The Equipment: Meet "Bob"

The apparatus allows you to spin a known mass around in a circle: you can measure the radius of the circle and the speed of the mass and thereby infer the radial force from Newton's second law.

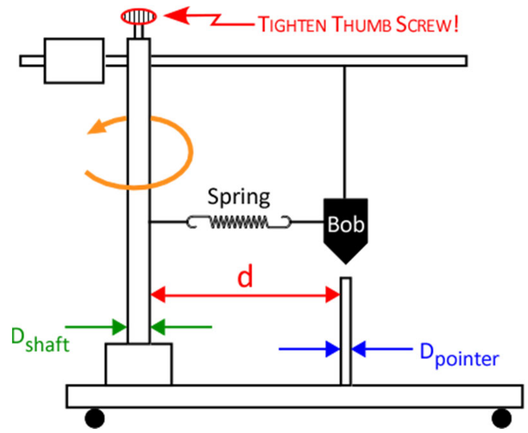


**Figure 1: Rotating Bob**

1. Follow the directions in "Reading a Vernier Caliper" to learn how this instrument is used for precision measurements.
2. Your instructor has already made the base level and checked the balance between Bob and the counterweight. ***It is important that the apparatus is balanced and level***, so let your instructor know if it needs further adjustment.
3. Remove Bob from the supporting string, measure its mass, then reattach it to the string. Adjust the pointer until it is directly under Bob.

## Calculating the Radial Force with Bob in Motion

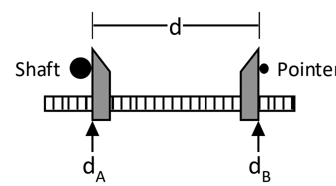


**Figure 2: Measuring 'd'**

In the steps below, you will take measurements to calculate the radial force exerted on Bob by the spring while rotating. Keep linear measurements in *cm* until you are ready to calculate the force!

4. The radius of Bob's orbit, *R*, is the distance from the center of the rotating shaft to the center of the pointer. You will calculate the radius as shown below, measuring the diameters of the rotating shaft and the pointer, $D_{shaft}$ and $D_{pointer}$, and the closest distance between them, *d* (Figure 1). Use vernier calipers to measure the shaft and pointer diameters, and a meter stick and calipers to measure *d* (Figure 2).

$$R = \frac{D_{shaft}}{2} + \frac{D_{pointer}}{2} + d$$

- *Recall that using the end of a meter stick can introduce measurement error. You must also record both measurements of $d_A$ and $d_B$ in your journal (Figure 2). Have your instructor check your radius before continuing; this is frequently where errors are made!*

5. Reconnect the spring and set the photogate to "pulse" mode, memory on. Spin Bob at a rate that stretches the spring until Bob is directly above the pointer. Measure the period of one rotation, *T* - while doing your best to hold the speed at which the pointer and Bob are aligned (this will take some practice). Collect *at least* 10 trials, recording the data in a table in your journal. *Keep Bob spinning during your measurements; don't stop and restart the rotation!*

6. Calculate the average period, $\langle T \rangle$ and record the minimum and maximum periods. Also calculate the % difference between the min and max periods. Explain what this % diff calculation tells you about the consistency of your period measurements.

7. ***Draw an FBD for a rotating Bob***. Call the radial force of the spring on Bob, $\vec{F}_{\text{Spring (rotate)}}$ ; this is the force needed to move Bob in a circle at a fixed speed.

8. ***Assuming that the motion of Bob is circular***, calculate the average tangential velocity and radial acceleration of Bob, and record in your journal:

Recall that $v_{tangent} = R(\omega)$

$= R(2\pi f)$

so, $v_{tangent} = \dfrac{R(2\pi)}{\langle T \rangle}$ and then: $a_{radial} = \dfrac{v_{tangent}^2}{R}$

9. Use your minimum and maximum periods to calculate the corresponding tangential velocity and radial acceleration. *Label your results correctly here – does the minimum period give you a min or max velocity?*

10. Use your FBD and Newton's laws to calculate the values of $\vec{F}_{\text{Spring (rotate)}}$ from your minimum, average and maximum radial acceleration.

## Measuring the Radial Force with Bob at Rest

11. Connect the 50-*g* mass hanger to Bob with the paper clip, and check that the string pulls straight over the pulley. Also check that the pulley rotates freely (if it doesn't then you're adding an additional force to the system!).

12. Add mass, $m_2$ until the spring is stretched so that Bob is lined up *above* the pointer (Figure 3). *Don't change the position of the point*!

13. **Draw a second FBD for this two-mass system *at rest*** (*Bob and the suspended mass*). Use your FBD with the data above and $g = 9.80$ $m/s^2$ to find the force of the spring pulling on Bob (when the spring is stretched to the same length as when rotating). Call this force $\vec{F}_{\text{Spring (rest)}}$ .

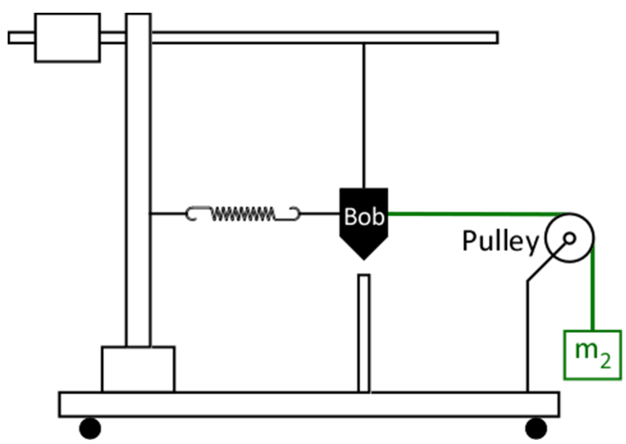


**Figure 3: Bob at rest**

## Discussion

- Restate your value of $\vec{F}_{\text{Spring (rest)}}$ and the *average* of $\vec{F}_{\text{Spring (rotate)}}$ , and calculate the percent difference between them. *If the difference is more than 10%, check your measurements and calculations.*

- Also restate the minimum and maximum values of $\vec{F}_{\text{Spring (rotate)}}$ . Did $\vec{F}_{\text{Spring (rest)}}$ fall within this range of possible values of $\vec{F}_{\text{Spring (rotate)}}$ ? What may have contributed to the error? Be sure to consider how consistently you were able to rotate Bob (step 6), and the assumption made about Bob's motion in this experiment.

- Which value of the *period* (minimum or maximum) corresponded to the larger value of $\vec{F}_{\text{Spring (rotate)}}$ ?