Radial Force & Riding an Elevator

Fall 2025

Introduction

In the first part of this experiment, you will calculate – and then measure – the radial force needed to make a mass travel in a circular orbit. In the second part, you will measure the acceleration of an elevator using a bathroom scale.

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 then calculate the radial force from Newton's second law.

1. 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.
2. Remove Bob from the supporting string, measure its mass, then reattach it to the string. Adjust the pointer until it is directly under Bob when viewed from the side. Record the number of the apparatus used on your sketch.

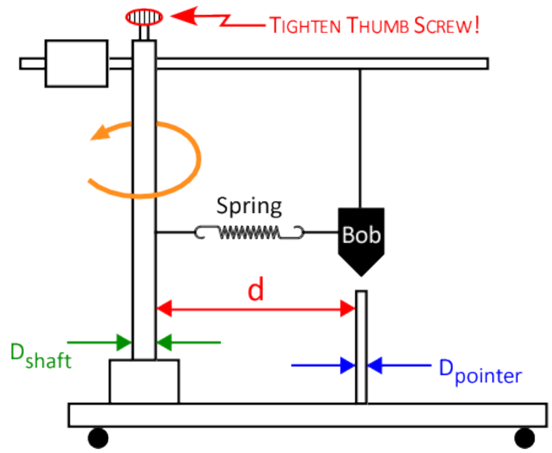

Figure 1: Rotating Bob

Calculating the Radial Force: Bob in Motion

You will first 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!

3. The radius of Bob's orbit, R_{orbit}, is the distance from the center of the rotating shaft to the center of the pointer. Calculate the radius of the orbit from the *radii* of the rotating shaft and the pointer, and the closest distance between them – note that the radius is not simply the measurement of *d* (*Figure 1*). Use vernier calipers to measure the diameters, but you'll need to use a meter stick and calipers to measure *d. Double check your measurement of the radius*; each person in the group should take their own measurements. Check the value of your measured radius with your instructor.
4. 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. Calculate the average period, $\langle T \rangle$ and write down the minimum and maximum periods. *Keep Bob spinning during your measurements; don't stop and restart the rotation!*
5. Calculate the % difference between the minimum and maximum periods. *Explain what this % diff calculation tells you about the consistency of your period measurements*.
6. ***Draw a Free Body Diagram (FBD) for a rotating Bob***. Call the force of the spring on Bob $\vec{F}_{\text{Spring(rotate)}}$, the force needed to move Bob in a circle at the fixed speed. Remember to specify the reference frame used in your FBD.

7. Calculate the velocity, v and radial acceleration, a of Bob (***assuming a circular orbit***), and record in your journal:

$$v = \frac{2\pi R_{orbit}}{\langle T \rangle} \qquad a = \frac{v^2}{R_{orbit}}$$

8. Use your FBD and Newton's laws to calculate $\vec{F}_{\text{Spring(rotate)}}$, the force exerted on Bob by the spring during rotation. *Note that the force units should be in Newtons!* Also, calculate the minimum and maximum values of the force (so that you have a range of values for $\vec{F}_{\text{Spring(rotate)}}$). *Be careful with labels here – does the minimum period give you a min or max velocity?*

Measuring the Radial Force: Bob at Rest

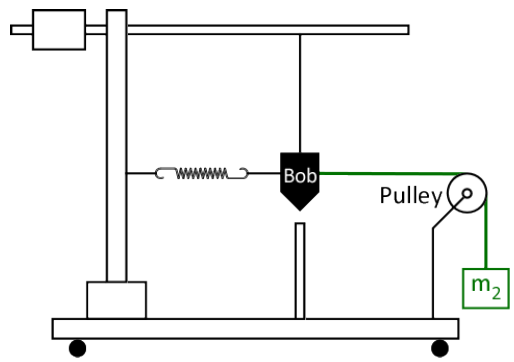

Figure 2: Static Bob

9. 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!).
10. Add mass, m_2 until the spring is stretched so that Bob is lined up *above* the pointer (*Figure 2*). *Don't change the position of the pointer*!
11. **Draw a second FBD for this two-mass static system** (*Bob* *<u>and</u>* *the suspended mass*) and use it with the data above and $g = 9.80$ m/s^2 to find the force exerted on Bob by the spring (when the spring is stretched to the same length as when rotating). Call this force $\vec{F}_{\text{Spring (rest)}}$.

Discussion

- Restate your values for $\vec{F}_{\text{Spring(rotate)}}$ and $\vec{F}_{\text{Spring (rest)}}$, and calculate the % difference between them. You should also restate the minimum and maximum values of $\vec{F}_{\text{Spring(rotate)}}$. *If the difference is more than 10%, check your measurements and calculations.*

- Discuss the sources of error in this experiment. Did the static spring force fall within the range of possible values of the rotational spring force? If it didn't, what contributed to the error? In your error discussion be sure to consider what your result from step 5 tells you about your ability to rotate Bob at a uniform rate. You should also consider the assumptions that are made in this experiment.

- Which value of the *period* (minimum or maximum) corresponded to the larger value of the rotational spring force?

Additional Exercise: Riding an Elevator

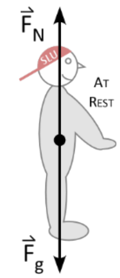

Figure 3: At Rest

In this experiment, you will measure the acceleration for the elevator in Bewkes Hall or Johnson Hall using a bathroom scale.

1. One person in your group will stand on an ordinary bathroom scale while still in the lab; record that person's mass at rest (in *kg*). {You will note that the Physics department spared no expense in traveling to Canada to purchase a metric bathroom scale!}
    - Both elevators are carpeted, so place the scale on top of a wood board to distribute the weight evenly.
2. Take your scale into one of the elevators and circle the name of the elevator used on the worksheet.
3. Inside the elevator, have the same lab partner stand on the scale. Ride up and down in the elevator, recording the maximum and minimum "weights" <u>while the elevator is starting or stopping</u> (*you must take an average of several measurements of each trip*.) Use long trips, going from the ground floor to the top, and vice versa. You will collect data for *four* excursions: starting and stopping for the trip up, starting and stopping for the trip down. Record your measurements on the worksheet.
    - *If you wish, you can record a video of the scale for each trip and then review the results later.*
4. In your journal, draw a *large* FBD for the static case at rest in the lab (*Figure 3*); try to <u>draw the force vectors to the same scale relative to each other</u>. *Which of these two forces does the scale measure?* Which force will change as you ride the elevator?
5. You will find four "bodies" on the worksheet, one for each trip. Note that $\vec{F}_g$ is already drawn on the first body. Add force vectors to these bodies, <u>again scaling them relative to each other</u>. Why do you think you would want to draw the force vectors like this?
6. From your FBDs and your measured weights, calculate the sum of the z-components of the force, $\sum \vec{F}_z$, and then your acceleration going up and down ($a_{z,up}$, $a_{z,down}$), for both starting and stopping. ***Hint***: *if your measured acceleration is close to or greater than* **g**, *then you are calculating the acceleration incorrectly!* Draw an up or down arrow in the appropriate worksheet column to indicate the *direction* of the acceleration and velocity while stopping or starting in each case. <u>*In your journal, be sure to include a sample calculation to show how your calculations were performed.*</u>
7. Discuss your results:
    - Did both forces change during the experiment, or just one? Which force changed during each trip? Why?
    - What was the state of the elevator's motion (accelerating? Constant velocity? Which way?) in the middle of an up or down trip? How could you tell from the scale reading?
    - Think about a downward trip you took. Describe how you (your body) felt at the different parts of the trip, and why.
8. Answer <u>and explain</u> the following two questions:
    - When an elevator accelerates upward, the tension in the elevator cable is
        a. less than the weight of the elevator
        b. the same as the weight of the elevator
        c. more than the weight of the elevator
    - When an elevator accelerates downward, the tension in the elevator cable is
        a. less than the weight of the elevator.
        b. the same as the weight of the elevator.
        c. more than the weight of the elevator.