FORCE AND CIRCULAR MOTION

I. Rolling Around

Suppose you wish to move a ball around a circular path on your table at a roughly constant speed. You may apply whatever forces to it you wish. Think about these questions and try to answer them *before* you begin playing with the ball. Write out your *expectations or predictions*. If you already "know" the answers from your class or textbook, then write out what feels the most "natural" to you based on your experiences, whether this agrees with what you've been told in class or not.

- Once the ball has already started rolling, in what direction(s) should you apply force to get it to move in a circle?
- What directions of forces would make the ball speed up or slow down? (These should, therefore, be avoided when you practice moving the ball with constant speed in a few minutes.)
- If you want the ball to move around the circle at a higher (but still constant) speed, how should you change the magnitude and direction of the force(s), if at all?
- If you want the circle to be smaller, how should you change the force(s)?

Take the ball and place it on your table. To make sure you are following a circular path rather than some other vaguely round shape, you can use the provided sheet with two concentric circles drawn on it. (Start with the bigger circle.) You can apply forces to the ball – gently – by tapping it with your pencil or pen. Do not "push" the ball around by keeping your pencil in contact with it. Just tap. Make the ball roll in a large circle with a constant speed (or as close as you can get).

- In what direction(s) do you have to tap in order to make the ball go around?
- Roll the ball faster, but try to keep it on the same circular path as before, and maintain the new speed. How, if at all, does your tapping have to change?

- Try a smaller, tighter circle. What is your tapping like now?

If you tap the ball infrequently, its path will be more like a polygon with many straight sides than a true circle.

- If you were to make more frequent taps in order to smooth out the path, how – if at all – should the direction(s) and magnitude(s) of the taps/forces change?

- What if you could apply force continuously (in a way that did not interfere with the rolling motion of the ball)?

II. An Ideal, Simulated Environment

In this simulated environment, it is possible for us to deal with "ideal" situations like you encounter in many of your homework problems. For example, the simulation is initially set up so that there is no friction. Also, you can apply forces to the ball "magically" from a distance without having to touch it in a way that slows it down.

Take a few minutes to let everyone in your group play with the simulation. Try different speeds and circle-sizes, and just try to get a feel for how to guide the ball successfully. In particular, try to keep the ball's speed roughly constant. If you are slowing down and speeding up a lot, there is still room for improvement.

- By watching the vectors on the ball and on the trail it leaves behind, what can you say about the forces that lead to a successful circular trek?

- Calculate the theoretical value of the centripetal force needed to move the ball in a circle using the mass, radius, and velocity that you used in the simulation. How close is this value to the magnitude of the force that you applied? Assuming there is not an error in how the simulation is written, what are some possible explanations for the difference (if any) between your calculated and observed forces?

"Tap" the ball using the joystick to guide it around the circular path as you did with the physical ball. Try hitting it about once every 1-2 seconds. Gradually try making your taps more frequent until you are applying a force continuously (that is, the magnitude of the force vector should never go to zero).

- How does the magnitude of the force you apply change as you shift from intermittent to continuous force?

III.Frictional, Simulated Environment

In order to make the simulation more realistic we can incorporate friction. Suppose the coefficient of friction, μ, were some small, but nonzero value. This could effect your method for rolling the ball in a circle. First, think about these questions:

- Would the magnitude of the force you apply need to change for a given radius and velocity when friction is turned on?
- What about the direction of the force you apply?
- Now, make the change to μ (something around 0.004) and investigate. What changes do you have to make? How does this match your prediction?

Now consider making μ larger, around 0.008 or 0.009, such that the ball will stop moving in only a second or so if you don't keep pushing it.

- What sort of forces would be required then?
- Test your prediction using the simulation and discuss.
- If you want to move the ball around the same circle but at a higher speed (say, twice as fast), how should the direction and magnitude of your force change, if at all?
- Test your prediction using the simulation, and evaluate your prediction. If you were right, explain why changes are/are not needed. If you were wrong, explain why you were wrong (ie. what did you forget to consider, and why does it matter?).

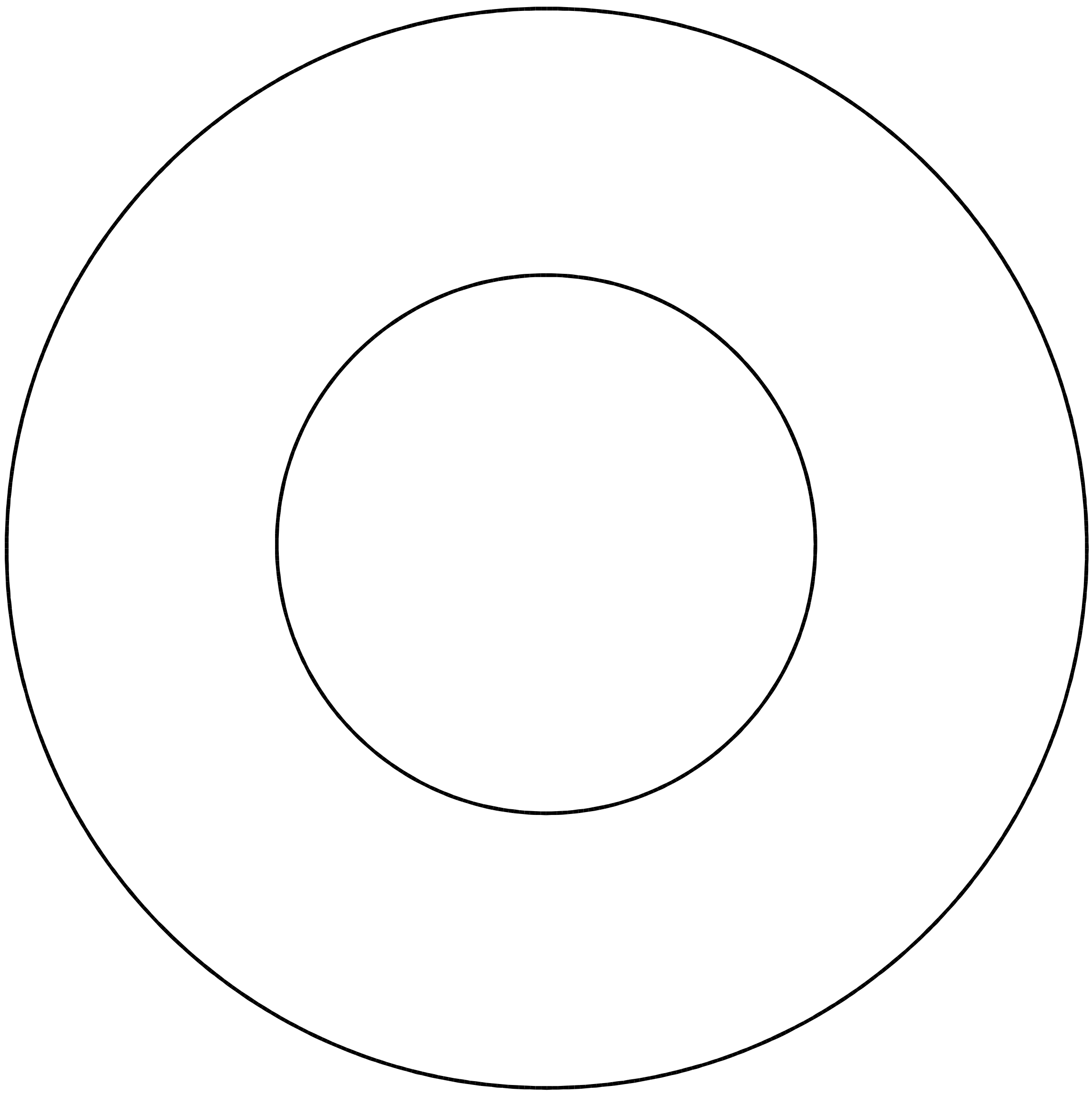
IV. Dragging Around

The last simulation, with very high friction, is more like the experiences you may have had in "real life" with pushing objects around. With your equipment, there should be a round puck as well as the ball. The puck, obviously, will not slide for very long once you stop applying an external force to it. Use your pencil to move the puck around in a circle just as you did with the ball earlier.

- Describe the forces/taps you are using.

- Move the puck around with a higher speed. How does this change things, if at all?

- Do these two results match the experience you had with the high-friction simulation? If not, explain what is different and why.



Tips on using the simulation:

You can start and stop the simulation with the “start” and “stop” buttons, or by just hitting the space bar when the green simulation area has focus (ie. you clicked on it last).

When the simulation is stopped, you can reposition the ball by dragging it with the mouse.

When the simulation is stopped, you can adjust the ball’s velocity vector by holding SHIFT and trying to drag the ball with the mouse.

Using the control panel, you can reduce the ball’s mass, making it respond more easily to your applied forces. This may help you to get a feel for things.

You can change the size of the dashed circle by dragging the mouse along the green background area.

To “reset” the simulation, stop it and then load the original “config” file. You can do this by using the menus to “Open Config...” or by hitting the “open” button on the toolbar.