Simulated Centripetal Motion Lab

When an object undergoes centripetal motion, its trajectory follows a circle. Since the object is constantly changing direction, the velocity can not be constant, and therefore, there must be an acceleration or a force to keep the object on its circular path. As we know, the moon orbits the earth and the earth orbits the sun in approximately circular trajectories. In this case, the gravitational force is responsible for keeping the objects in their circular paths. We call the force that is responsible for the circular trajectory, the centripetal force. The centripetal force, and therefore the acceleration must always point to the center of the circle. In this lab, we will study an object motion due to the radial gravitational force.

Procedure

1. Start Virtual Physics and select Centripetal Motion from the list of assignments. The lab will open in the Mechanics laboratory.

2. The laboratory will be set up with a ball on the 2D experimental window. There is a rocket attached to the ball. It is set to launch the ball into orbit around a radial gravity sink, which will pull the ball towards the center of the screen, just like a satellite being put into orbit around a planet. After the rocket turns off, the only force acting on the ball is gravity. When you click Force the rocket will fire for 1 second. You will record the position, velocity, and angular velocity of the ball.

3. We will analyze the motion of the object using both rotational (polar) quantities (θ, ω, α) and translational (cartesian) quantities (x, y, v_x, v_y). Notice that the measured quantities can be changed at the top left hand side of the screen.

Recall: θ is the angle with respect to the x-axis, ω is the angular velocity, and α is the angular acceleration

4. Make sure the measured quantities are set for polar coordinates.

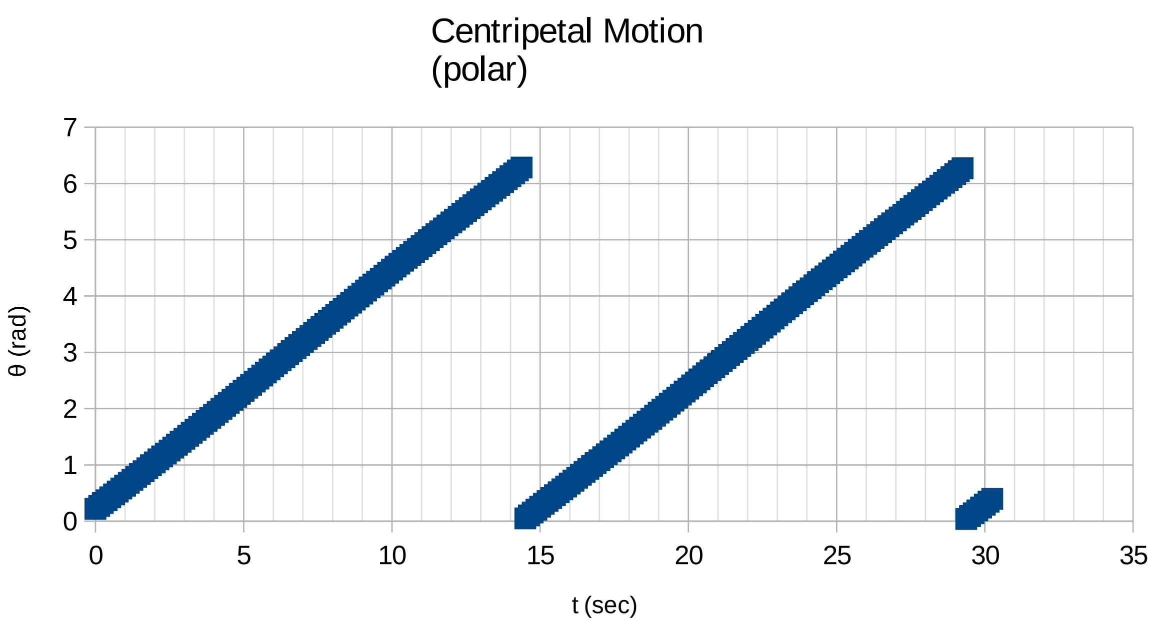
5. Click the record, and then hit the Force button to start the launch process. Record the polar quantities for a couple revolutions

6. Now switch the quantities to TOTAL, reset the experiment, and collect data again for a couple of revolutions.

7. Now switch the quantities to Cartesian, reset the experiment, and collect data again for a couple of revolutions

Question & Data Analysis

1. From the data collected in polar coordinates, plot the angle θ versus the time. Make sure to truncate the portion of the data corresponding to the rocket launch and shift the data back to the origin. (This is discussed in worksheet 3). Ensure the graph has the appropriate units and titles. Paste the graph below.



2. What trend is seen in the data (linear, quadratic, exponential, etc.)?

Linear (mod 2π)

3. Although the angular acceleration varies slightly throughout the objects trajectory, what can you conclude about the angular velocity and angular acceleration?

We see that the angular velocity remains more or less at a constant positive value and that the angular acceleration hovers close to zero.

4. In lecture, you will learn that rotational quantities obey similar kinematic equations as translational quantities.

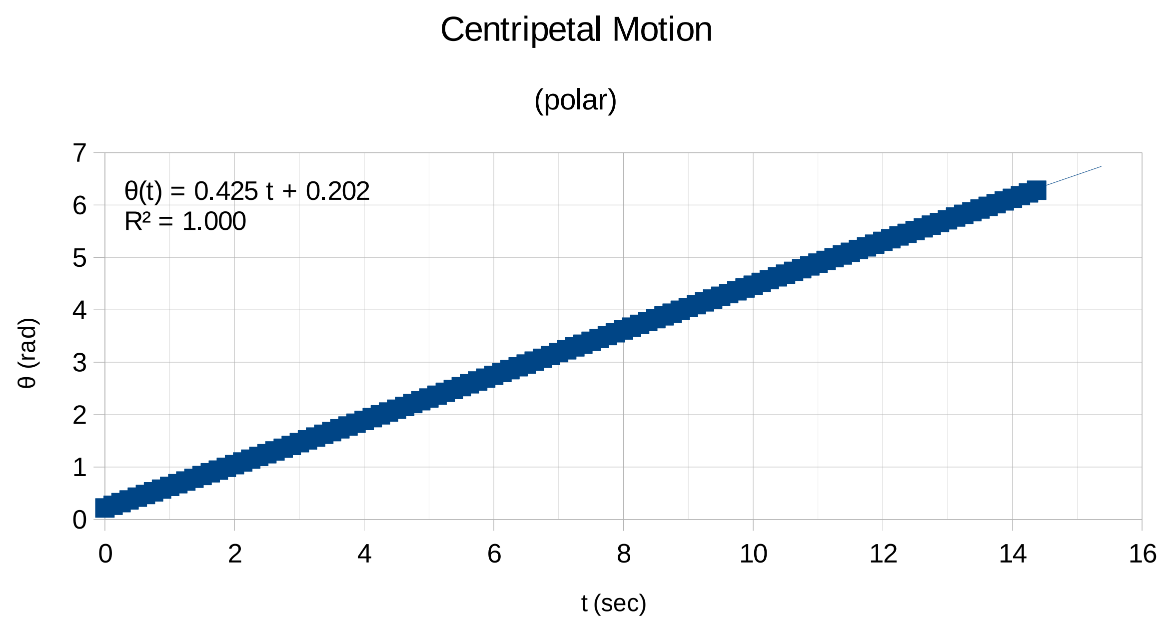
i.e. $\theta_f = \frac{1}{2}\alpha t^2 + \omega_o t + \theta_i$, and $\omega_f = \alpha t + \omega_o$

Using your answer from question 3 to simplify these equations, which equation can be used to fit the data plotted in question 1?

We can use $\theta_f = \frac{1}{2}\alpha t^2 + \omega_o t + \theta_i$ to fit the data plotted in question 1.

Simplified to: $\theta_f = \omega_o t + \theta_i$.

5. Fit the data plotted in question 1 to a linear equation. Make sure the appropriate trendline, R-squared value, units, and titles are visible. Paste the graph below.



6. Identify the fit parameters to the rotational quantities. Does the angular velocity from the fit agree with that directly measured from the simulation?

$\omega_{experimental}$ = 0.425 rad/s; $v_{polar} = \omega r = 0.425 * 60 = 25.5$ m/s

$\omega_{expected}$ = 0.422 rad/s

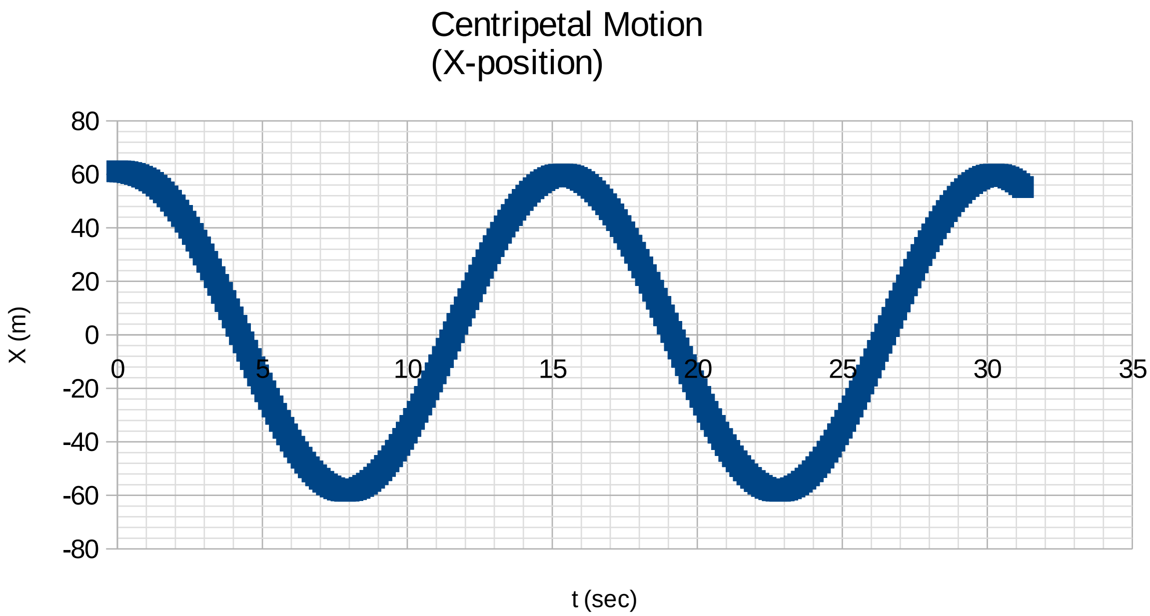
The angular velocity from fit matches closely to the one measured from the simulation.

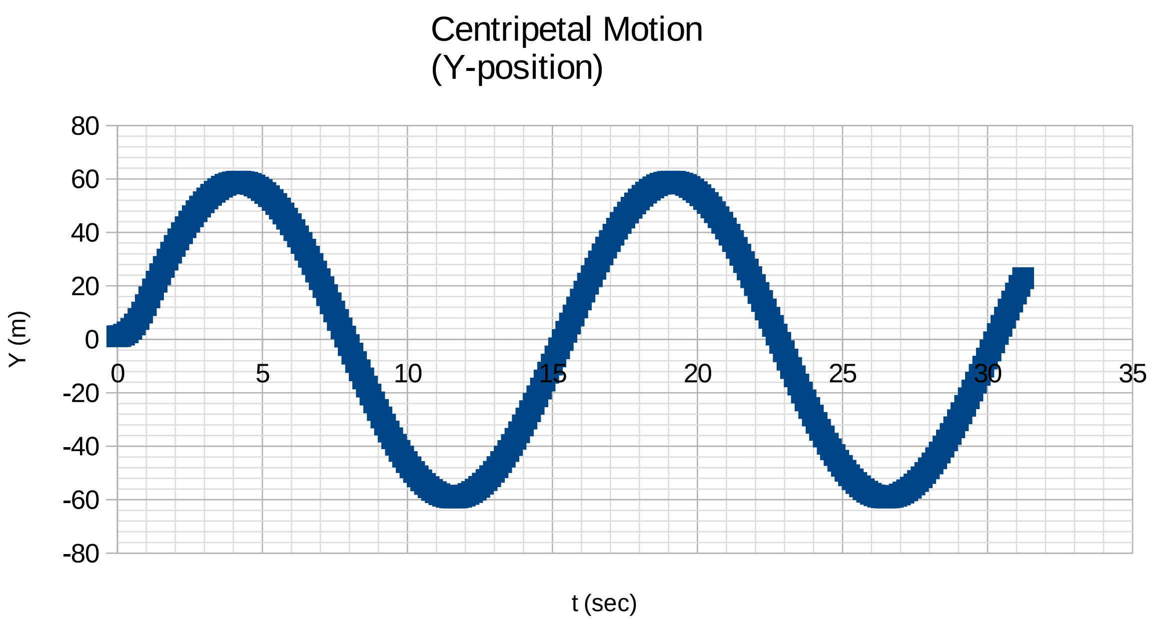
7. Now from the data collected in TOTAL mode, what can be concluded about the total velocity? (total velocity = magnitude of velocity = speed)

It remains more or less constant at around 25m/s.

8. Now from the data collected in cartesian coordinates, plot the x-component of the velocity versus time and plot the y-component of the velocity versus time. Make sure the graphs

have the appropriate units and titles. Paste the graphs below.





9. Write down the equation relating the x-component of the velocity to the magnitude of the velocity and the angle. Do the same for the y-component.

$v_x = v \cdot \cos(\theta)$; $v_y = v \cdot \sin(\theta)$

10. Do these equations agree with the plots of the x and y components?

Yes, they agree very closely.

11. Calculate the total velocity at 4 separate times using the x and y components of the velocity. Do the values you calculated agree with the total velocity measured in step 6.

t (sec)	**Vx (m/s)**	**Vy (m/s)**	**v_tot (m/s)**
2.73	-20.12	14.4	24.74
3.85	-24.62	3.69	24.89
4.35	-24.92	-1.54	24.97
9.73	17.68	-17.83	25.11

$v_{cartesian\_avg}$ = 24.93 m/s

v_{polar} = 25.5 m/s

The two measures of velocity match.