Voyager & Ozobot: A STEM Team to Study Circular Motion

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Ozobot "Evo" (ozobot.com) is a tiny one-inch diameter robot that can be quickly programmed to follow lines using a Google Blockly dialect known as OzoBlockly (ozoblockly.com). This lesson combines the ability to program Ozobot to move on a circle at constant speed with Voyager's ability to sense the resulting motion through its angular velocity sensor.

The purpose of this project is to show that *if speed is kept constant and the same for all objects moving in circles of different sizes, then the magnitude of the angular velocity is inversely proportional to the radius of the circle*. Alternatively, one could say that the product of the magnitude of the angular velocity by the radius is a constant, this constant being the linear speed of the object as it moves around the circle. This idea is encapsulated in the equation $v = \omega r$, where v is the linear speed, ω is the angular speed, and r is the radius of the circle.

PocketLab is mounted to the top of Ozobot using a thick, double-sided removable tape. This "STEM team" is then placed on an 8½ x 11 inch piece of paper with four circles of radius 1, 2, 3, and 4 radial distance units (RDU). A *pdf* file with these circles, suitable for copying for students, is included with this lesson. See Figure 1 for a photo of the experiment setup. Ozobot/Voyager is shown on the circle of radius 2 RDU.

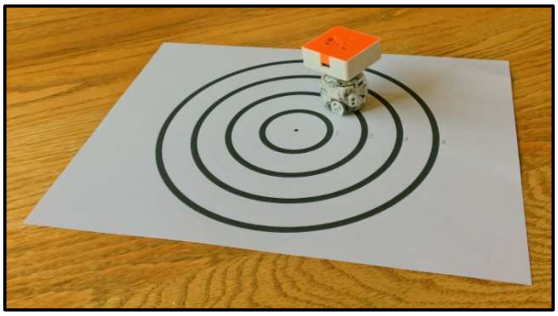

Figure 1

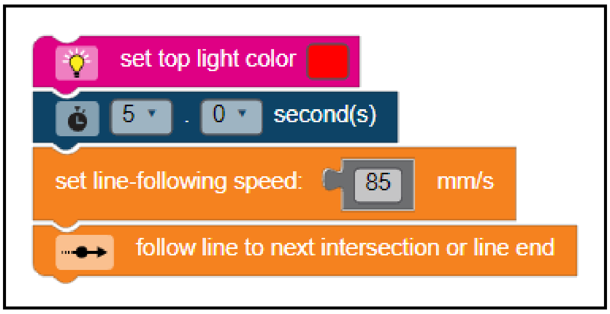

Figure 2

Ozobot has been loaded with the very simple OzoBlockly program shown in Figure 2. First, Ozobot's top light is set to the color red. A five second pause gives the student time to place the "STEM team" on the circle before Ozobot's wheels start turning. Ozobot's speed is then set to the desired value—any speed from 15 to 85 mm/s is within the allowed speed range for Ozobot. Finally, Ozobot is instructed to follow the line to the next intersection or line end. Since Ozobot is on a circle with no intersections and no line end, it will simply keep moving around the circle at the set speed until it is turned off or runs out of battery energy.

The angular velocity sensor was selected for Voyager and set to 25 points per second. With Voyager mounted as in Figure 1 and moving in the *x-y* plane, the *z* angular momentum is the component of interest.

Example Experimental Results

Angular momentum data is collected for the "STEM team" moving on each of the four circles for approximately 12 to 14 second runs each. The CSV files from the PocketLab app are imported into Excel, and the z-component of angular velocity for each of the four runs are combined into a single Excel workbook. A scatter graph that looks like the one shown in Figure 3 is then quickly produced in Excel.

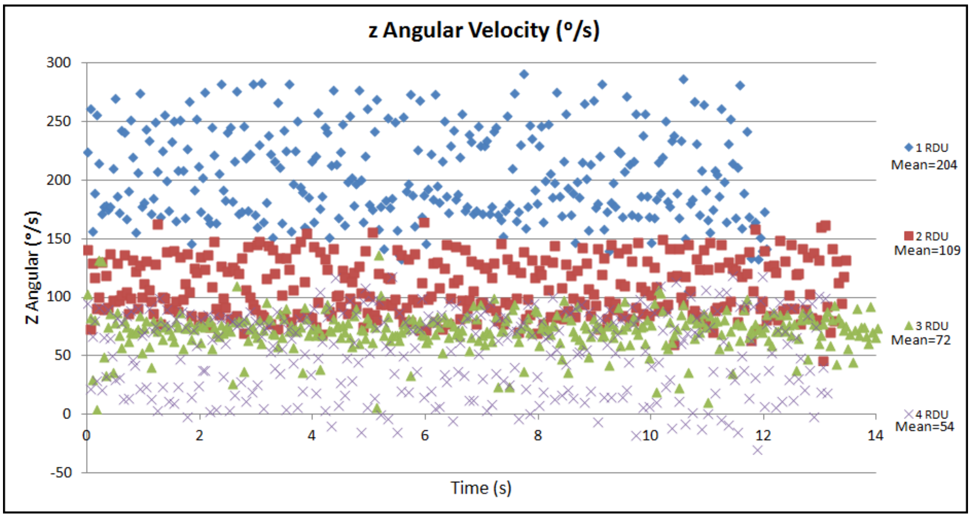

Figure 3

Although there is a great deal of variance in the z-component of angular velocity for any given run, the large number of points in each run does allow for computation of an average. The averages were calculated in Excel and have been displayed to the far right of Figure 3 for each of the four circles. It is clear that the average angular velocity decreases as the radius of the circle increases, suggesting some sort of an inverse relationship between these variables.

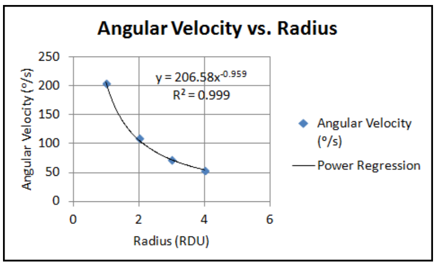

Figure 4

Radius (RDU)	Angular Velocity (°/s)	Radius*Angular Velocity (RDU°/s)	Linear Speed (m/s)
1	204	204	0.082
2	109	218	0.088
3	72	216	0.087
4	54	216	0.087

Figure 5

Figure 4 shows an Excel graph of angular velocity vs. radius. The trend/regression type of *power* was selected, where *y* is the angular velocity and *x* is the radius. The R^2 value of 0.999 indicates an excellent fit. The value -0.959 for the power, being very close to -1, provides convincing evidence that angular velocity and radius are *inversely proportional* when the linear velocity is kept constant. In this case, one would expect the product of angular velocity and radius to be constant. This is verified in the third column from the left in the table of Figure 5.

A final exercise for the student would be to compute the linear speed in m/s by using the equation $v = \omega r$. To do this, students would need to take some measurements of the radii of the circles in meters so they can convert from RDU to meters. In addition, they would need to convert angular velocity from °/s to radians per second, using the fact that 180° = π radians. The right-most column of Figure 5 shows the linear speeds computed in this way for our example experiment. We obtain an average value of 0.086 m/s, which is very close to the value of 85 mm/sec that was set for Ozobot in the OzoBlockly program of Figure 2!

Combining two different technologies (Voyager and Ozobot in this experiment) and making use of the best features of each opens up some very creative STEM projects for the science classroom.