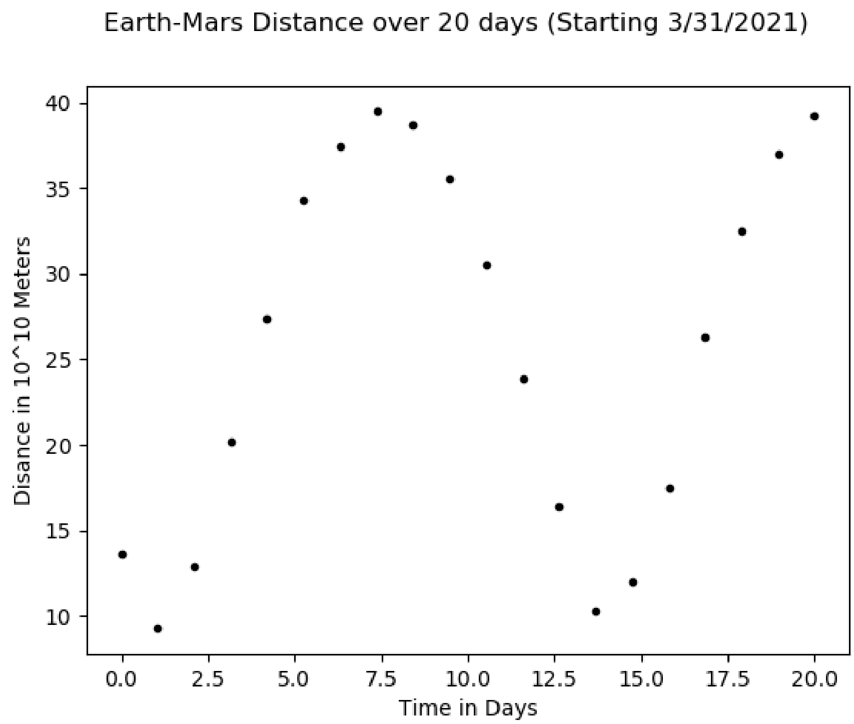

Figure 1: Distance between Earth and Mars over time as determined by the equations from Section 1.1.1

1 Initial Results

Since the distance traveled is calculated in tenths of a degree, the computer used was not powerful enough to plot a full year in any reasonable amount of time. The best that could be done was a period of ten days. Since the velocity takes units of meters per second, time was fed in in intervals of 86400 seconds. The resulting graph of the distance between Earth and Mars, Figure (1), was unreasonable. Since Earth is closer to the sun, its average radius will be lower. According to the velocity equation given in the last section, this means the average velocity of Earth should be considerably higher than that of Mars. Thus, Earth should make a full orbit before returning to close proximity with Mars. This should put the time period of the Earth-Mars distance on the scale of about a year. However, figure (1) shows an orbital period of about 15 Days. This could have been due to Earth's speed being calculated too high but figure(1) shows that both planets take a maximum velocity at their semimajor axis, and a minumum 180 degrees after. This is to be expected from equations of the form $a(1 + cos(\theta))$ where a is a constant.

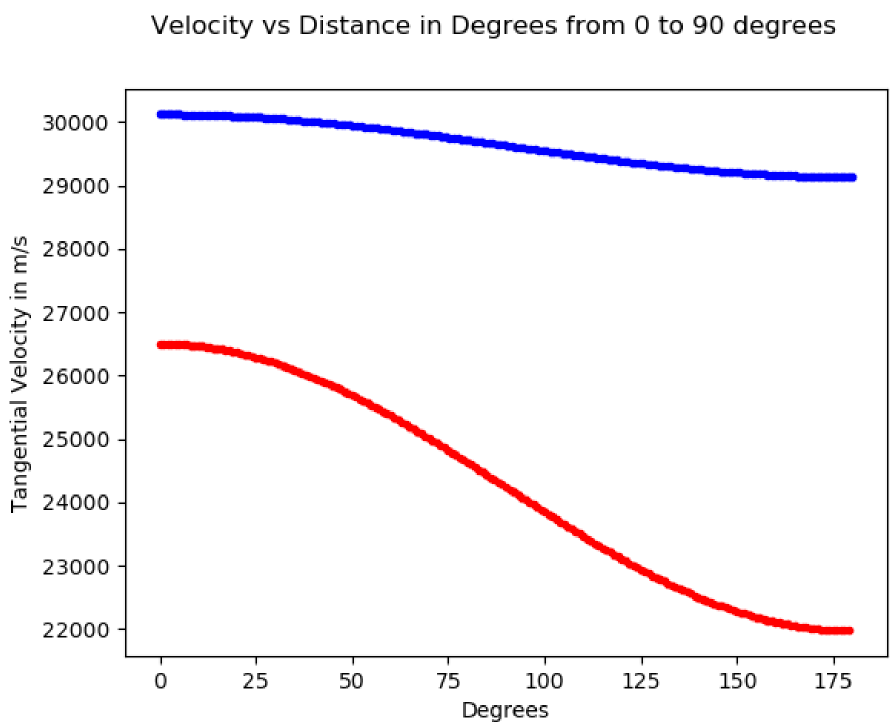

Figure 2: Velocity of Earth and Mars over 180 degrees of rotation

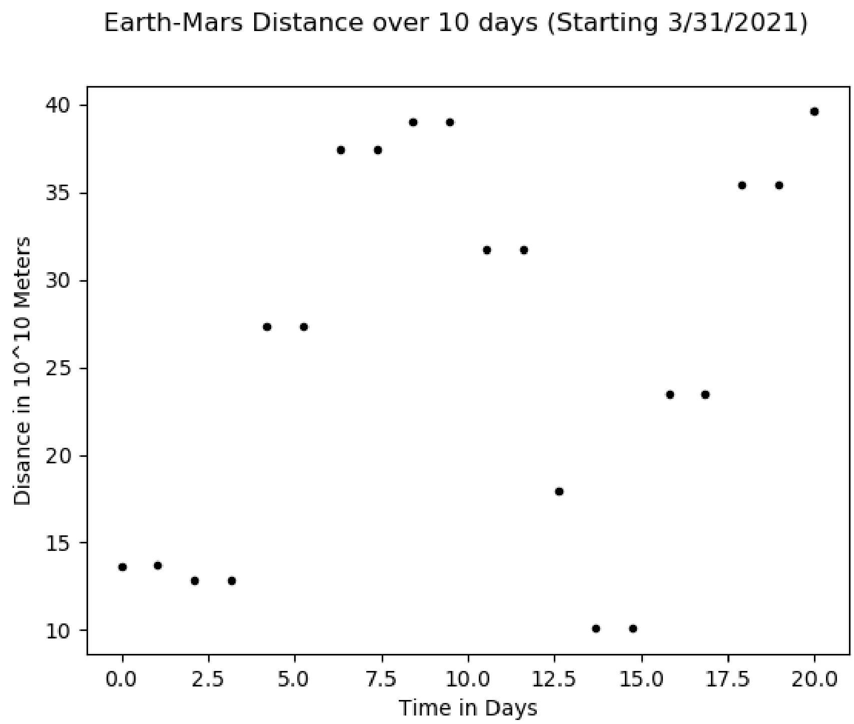

Figure 3: Plot of Difference over time where the $\Delta\theta = 1$ degree

2 Trouble Shooting

The issue appeared to be the width of the $\Delta\theta$ intervals, as a larger interval will result in a decreasingly accurate velocity - this is expanded on in section 3. To test this, another plot was generated with $\Delta\theta = 1$ degree rather than 1 tenth of a degree. Were this the cause for the smaller distance period, the new figure would have a noticably smaller orbital period. However, the new plot (figure (2)), while less accurate, has roughly the same distance period. All of the constants used in the program were double and triple checked, but the source of this strangely small distance period is still unclear.

3 Visualizing Velocity Error

It is helpful to visualize the error in the approximation of constant velocities over small intervals of $\Delta\theta$. In order to get an idea of the error of assuming these constant velocities, it is helpful compare the starting velocity of an interval (the one used) to the velocity half way through that interval. This error is shown

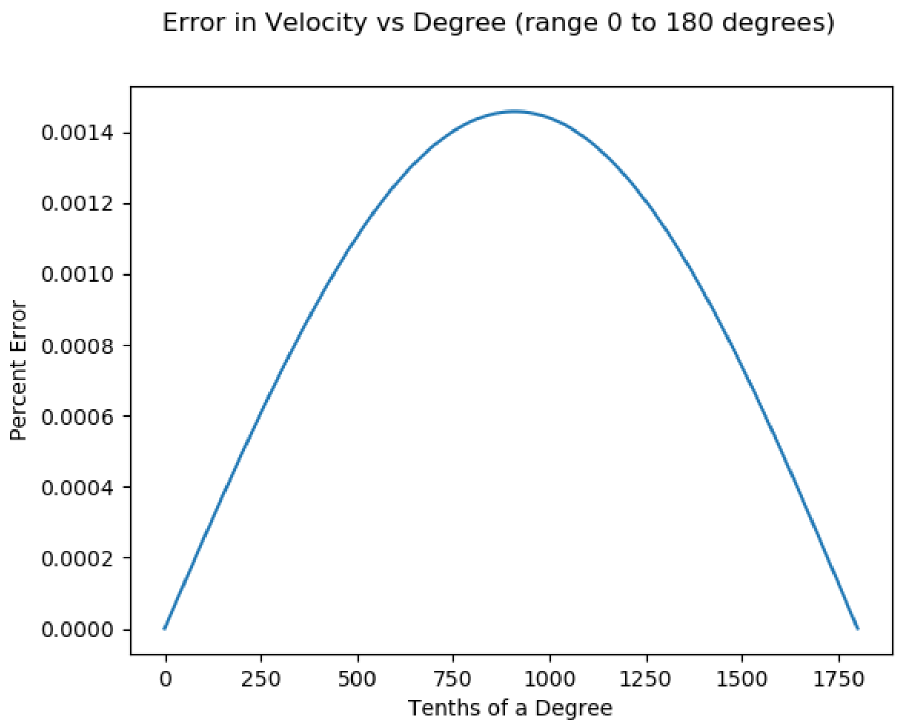

Figure 4: Error based on variation of velocity between two tenths of a degree

in equation 1, where v_1 is the velocity at one tenth of the corresponding value on the x-axis and v_2 is the velocity 0.05 degrees later. Figure(3) shows that the error peaks out at 90 degrees and never exceeds .0014%. While this would seem to indicate that the method is reliable, the final results make this doubtful.

$$Error = \frac{|v_2 - v_1|}{v_2} 100 \tag{1}$$

where v_1 is the velocity at one tenth of the corresponding value on the x-axis and v_2 is the velocity 0.05 degrees later

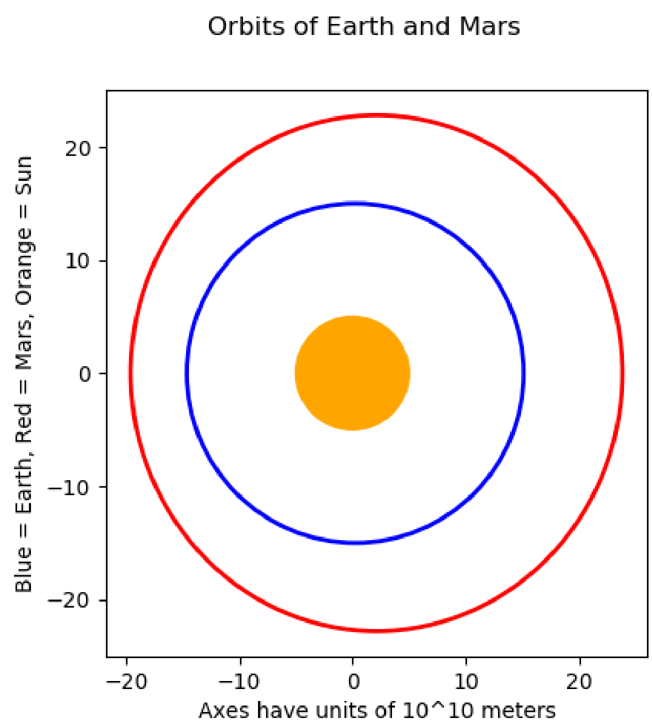

Figure 5: Orbits of Earth and Mars based on Kepler's laws. Both are simplified to 2D