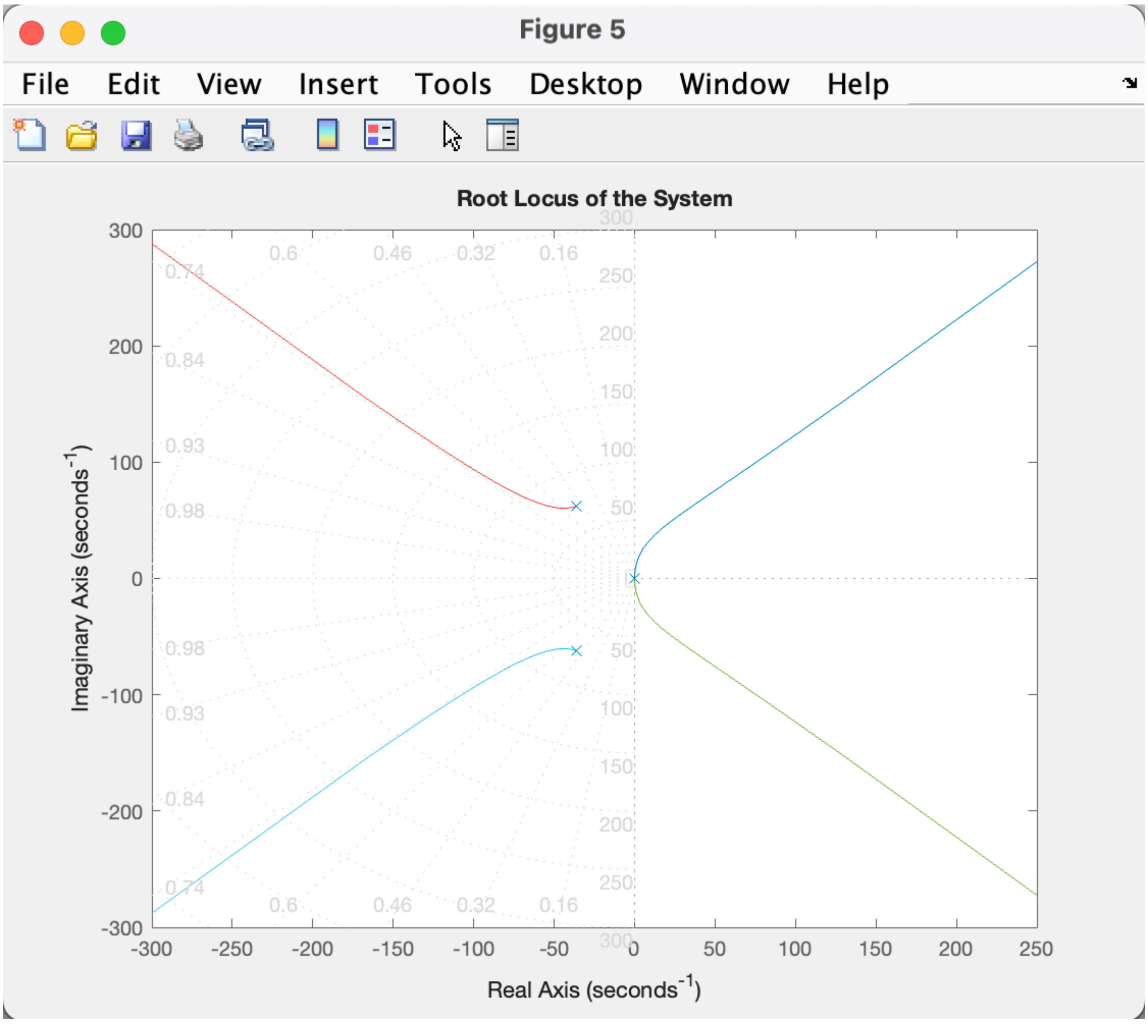
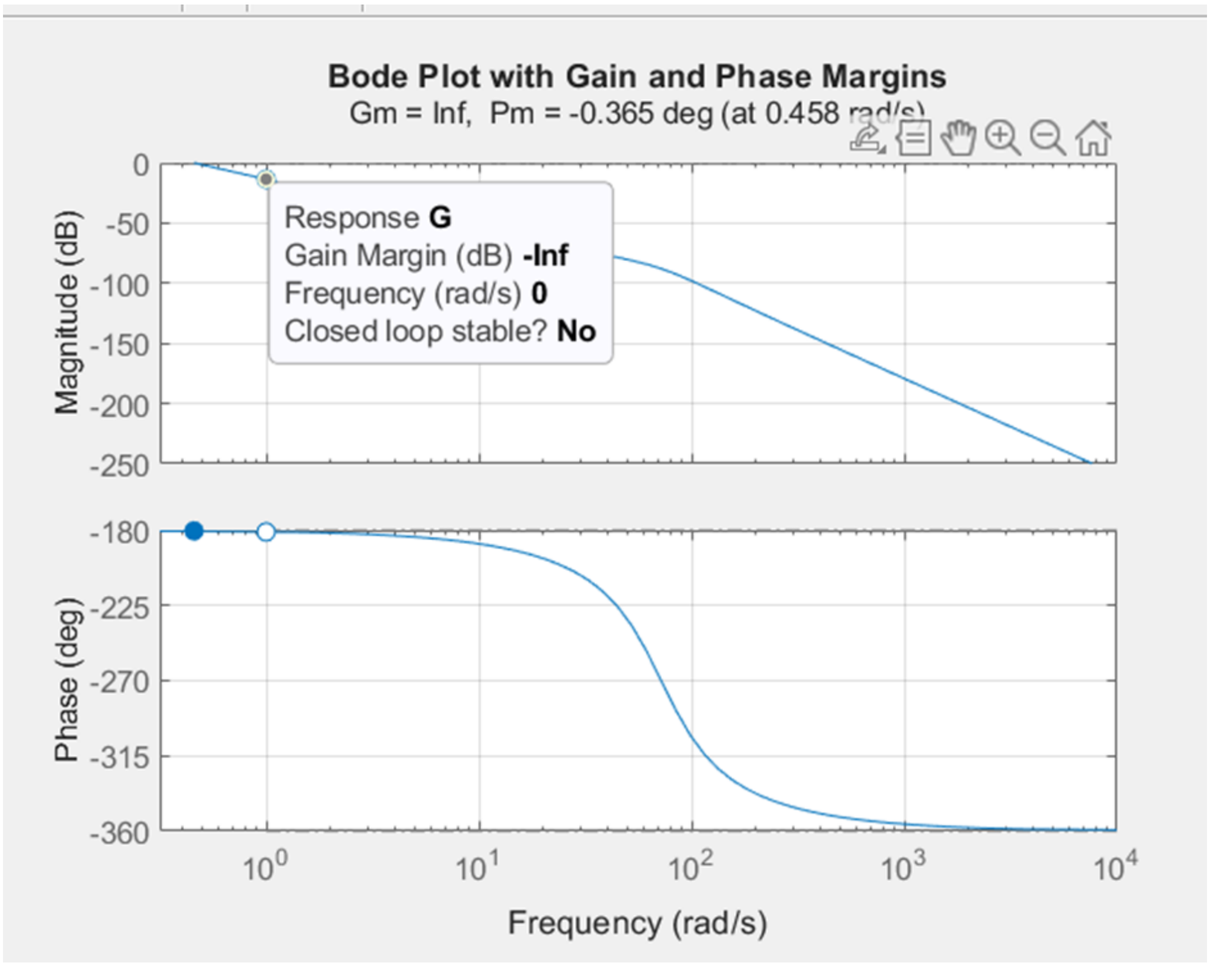
Task 8:



The only gain that will make the system marginally stable is 0 which mean that there will be no system as the numerator of the transfer function will be zero and any other gain will make the system unstable

Task 9:

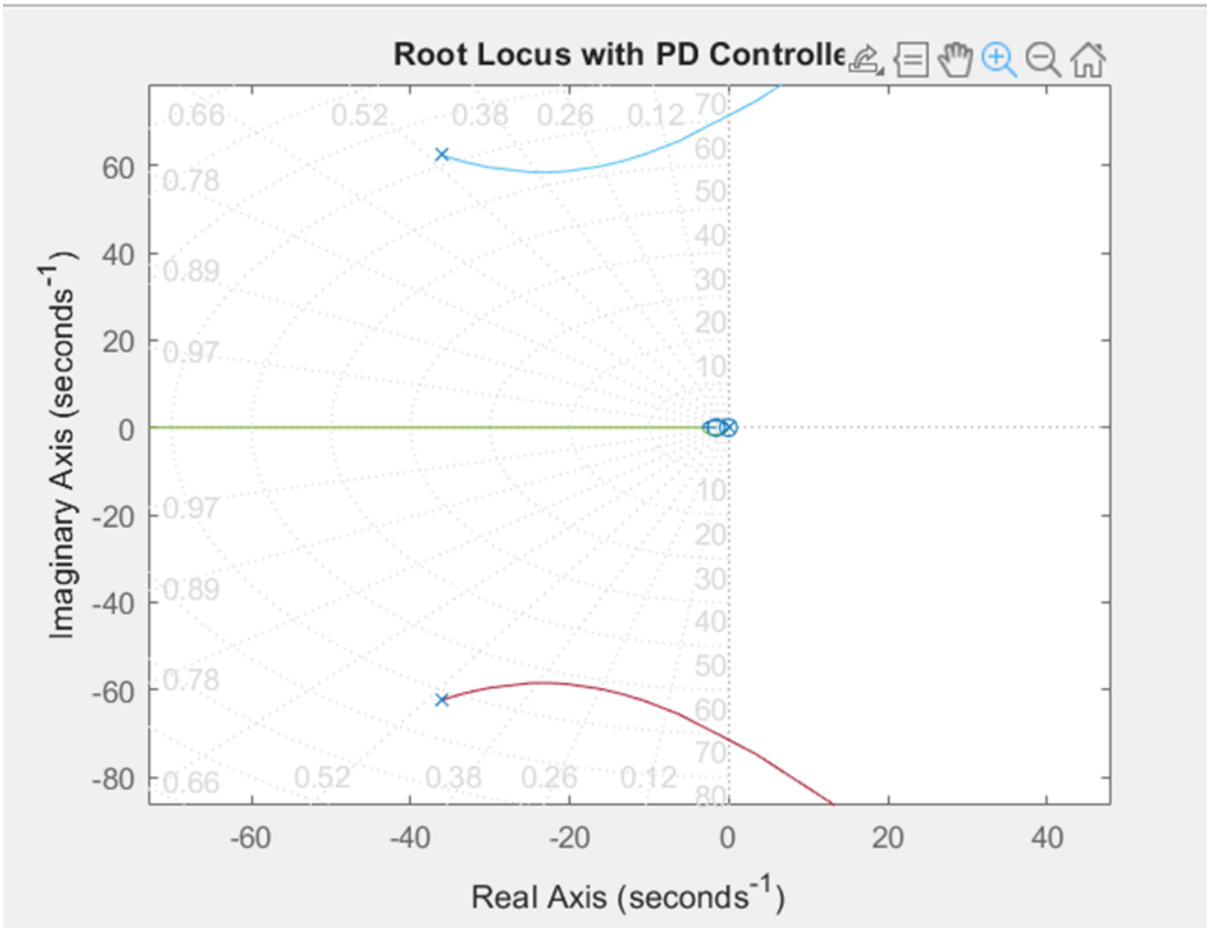


 # In the Bode plot provided, the gain margin (GM) is -ve infinite because the magnitude #plot never crosses the 0 dB line. This indicates that there is no frequency at which the #system has a magnitude of 1 (or 0 dB) while the phase reaches -180°.

Task 10:

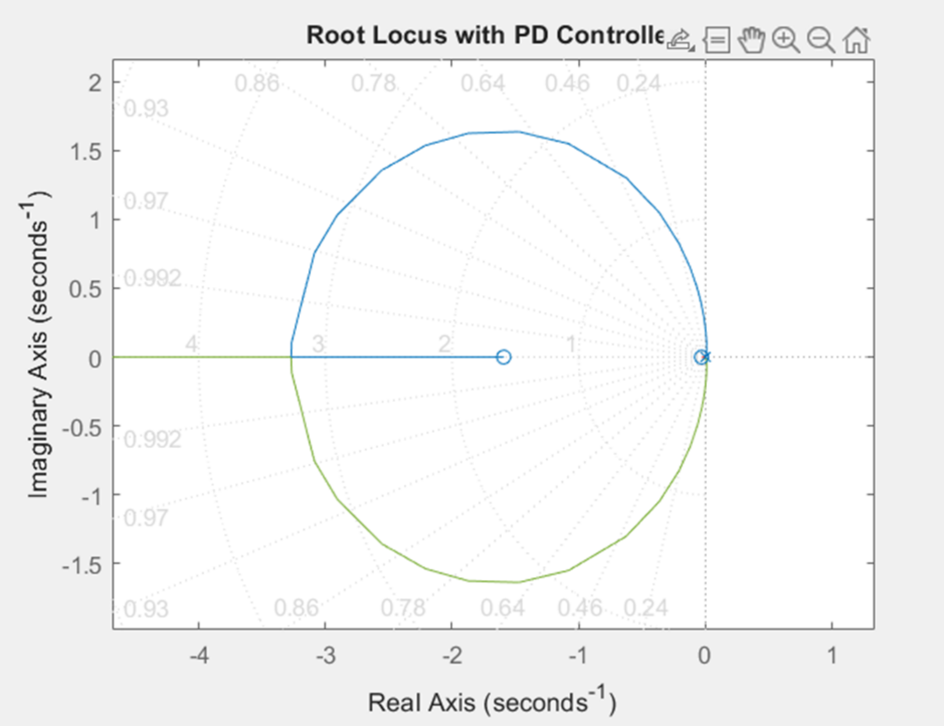
The goal of the pd is to reduce the steady state error (P controller) and adjust transient response of the system (D controller). Before adding it to the system, the static acceleration error constant(ka) was 0.21, resulting in a steady state error of approximately 4.76. After adding the PD controller, error was reduced to 0.1496. The use of a lag compensator was necessary to further reduce the steady state error to 0.01. If it was reduced solely by the PD controller, the overshoot would have increased and may reach infinity resulting in an unstable system. Our lag compensator here was designed based on our open loop transfer function cascaded with the PD controller transfer function.

Task 15:



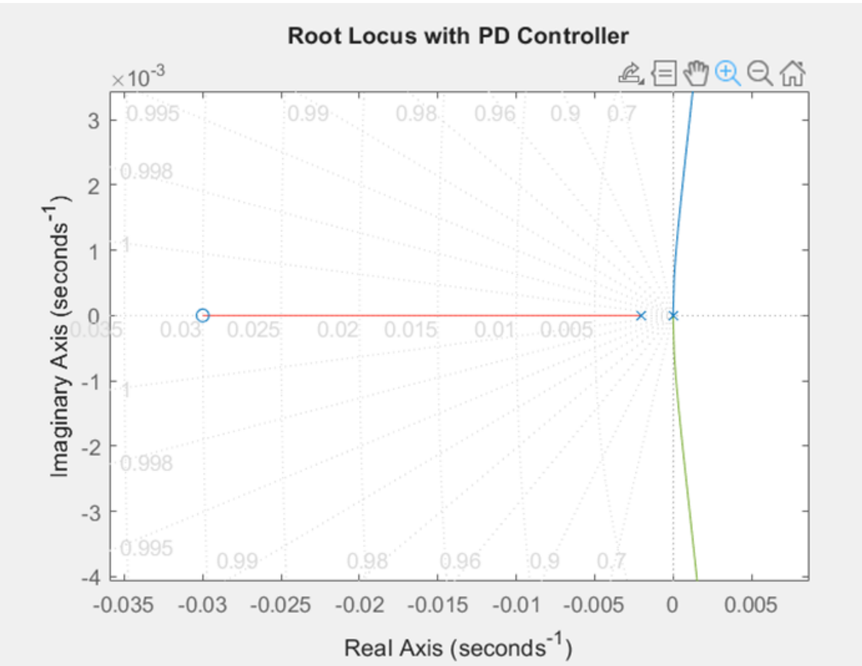
The direction of the poles was mirrored from the original root locus (before the pd lag controller) so there is an interval of gain that will allow the system to be stable

Yes, the stability was positively affected by adding the PD lag controller.

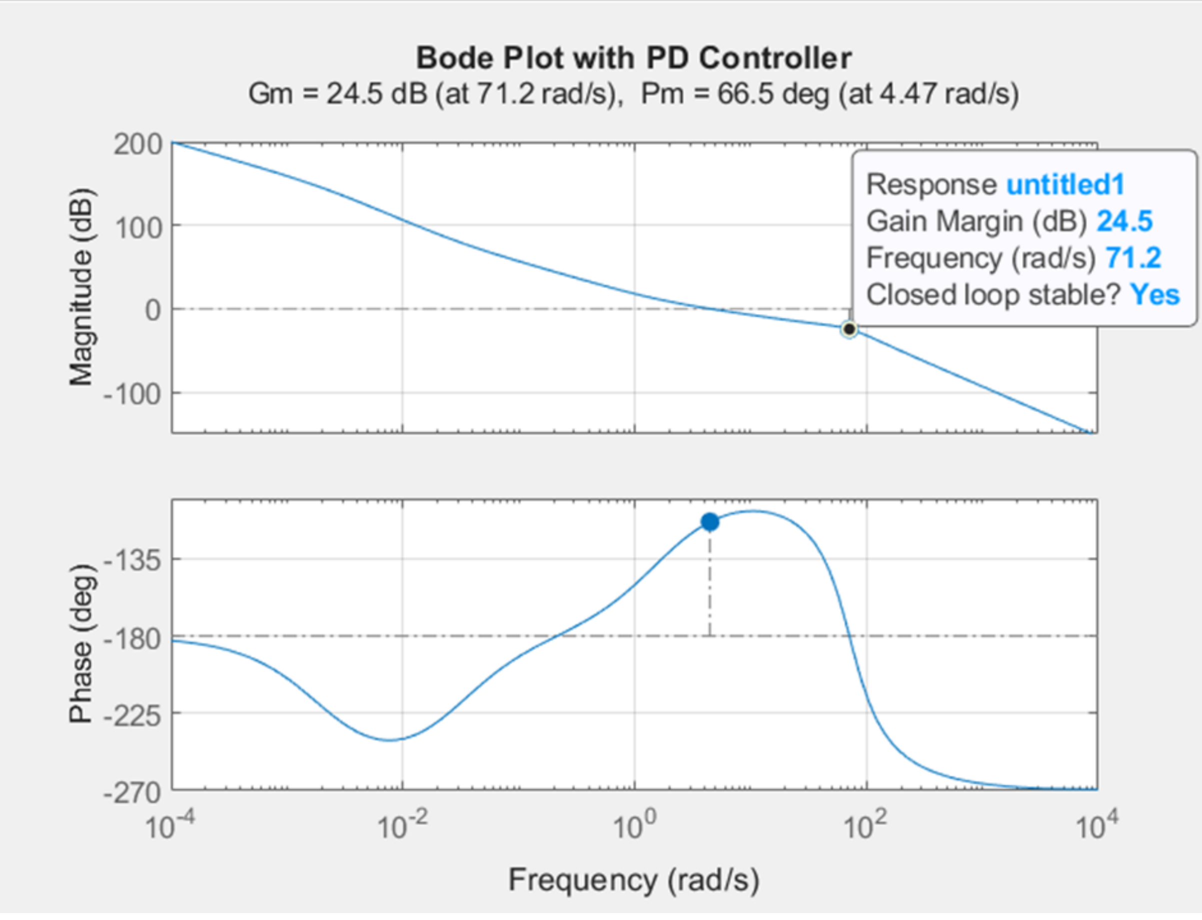


This is a zoomed in snapshot at the centre of the root locus. So, the pole and the zero added from the lag compensator attracted each other. Moreover, the poles at the origin broke away from each other and the PD controller added a zero that attracted one of the poles of the origin while the other move to infinity (because it didn't find any affection)

The next figure is extremely zoomed in snapshot at the origin.



Task 16:



As a result of adding pd and lag controller the system became stable we get the gain margin by seeing where the phase crosses the -180 in our case it crossed it twice and we chose the second phase crossover

We chose the second phase crossover because it likely reflects the critical dynamics of the system that are relevant for stability. The first -180° crossing may correspond to a higher-gain, less realistic operating condition, or it could reflect a secondary dynamic phenomenon (like a parasitic pole or minor resonance).

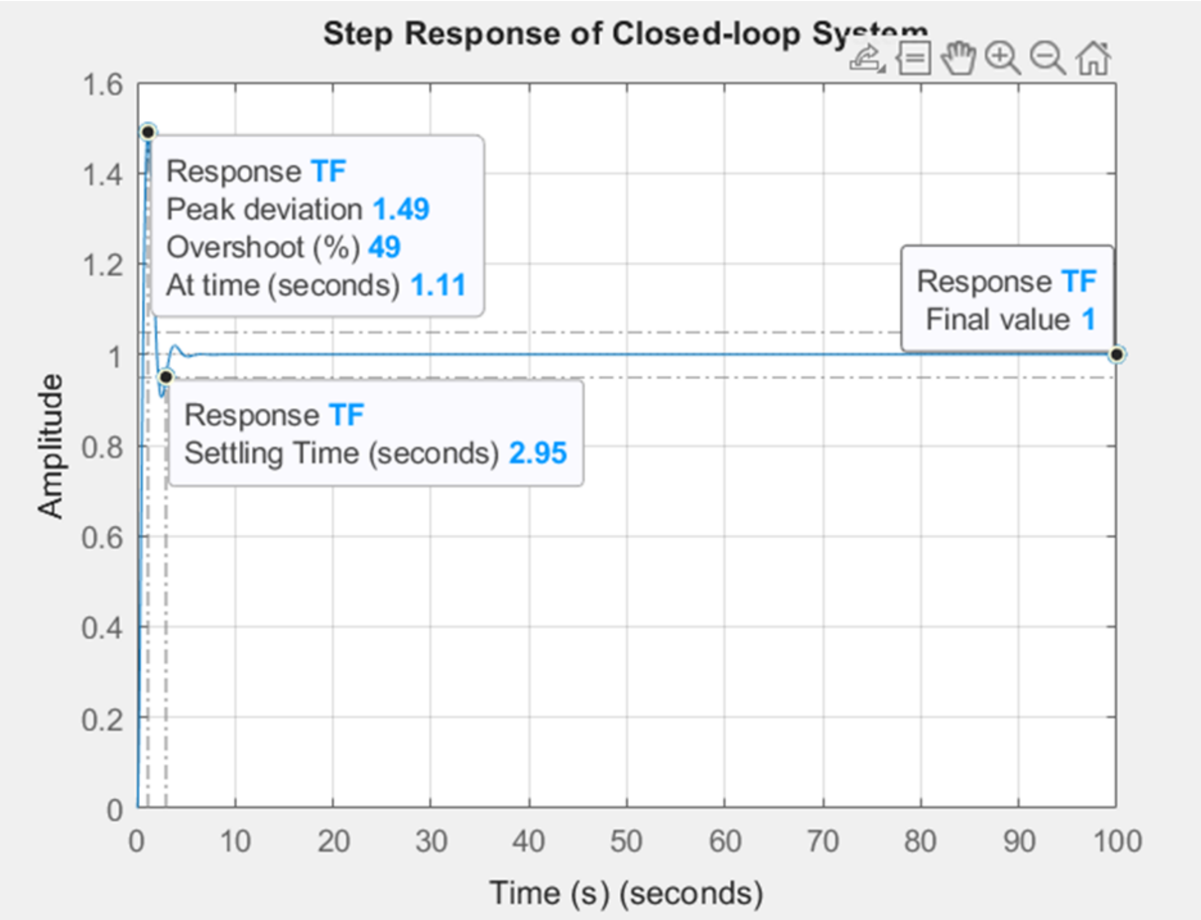
To calculate the phase margin, we took the intersection of the magnitude at 0 and we projected that point on the phase graph and subtracted -180 from the projected point

We concluded that both the phase margin and gain margin are positive and the phase crossover frequency bigger than the gain crossover frequency resulting in a stable system.

Task 17:

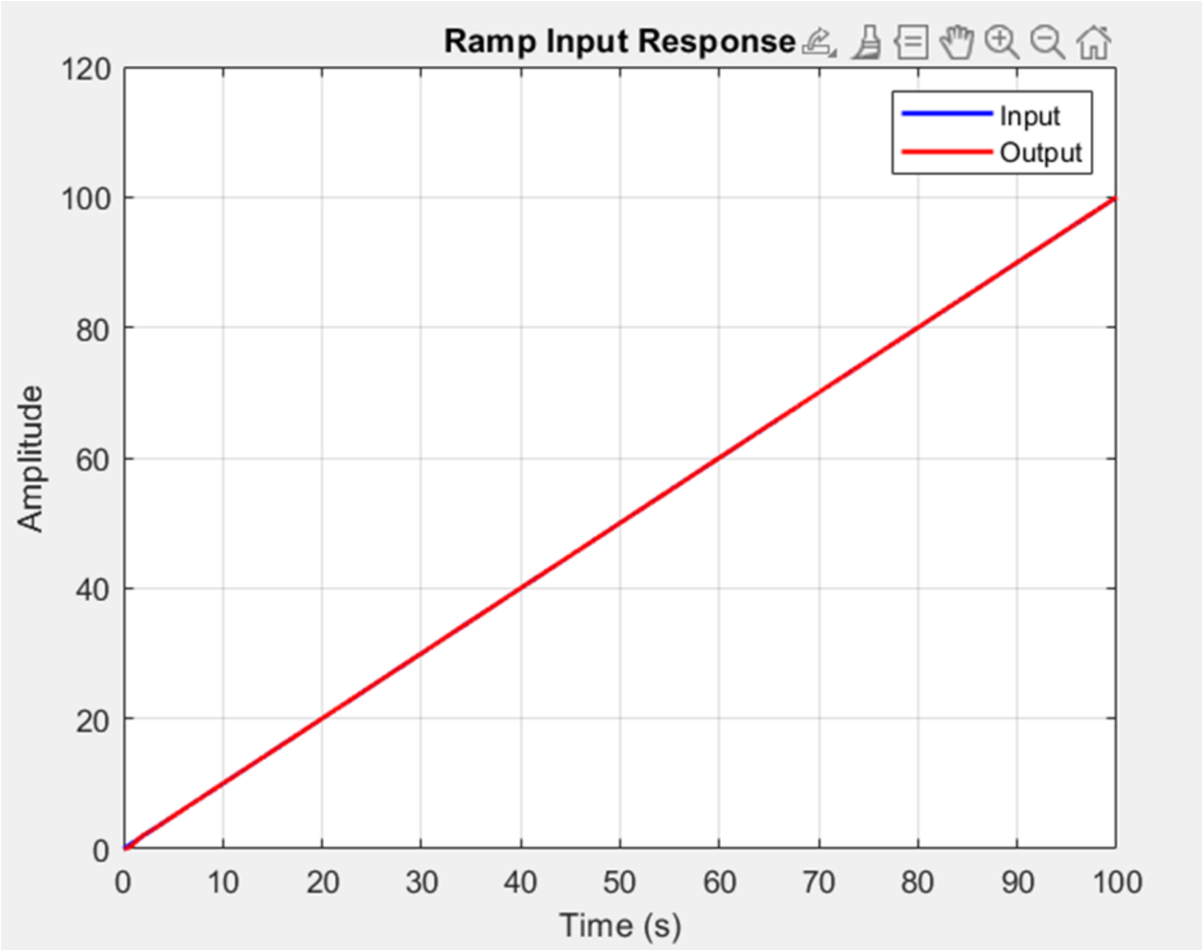
Closed loop poles were obtained from zeta and the undamped frequency and placed in our open loop transfer function. They gave an angle of approximately 124 degrees, implying there is a deficiency of 56 degrees to the required 180 degrees. This suggested we needed to use a lead compensator. The position of pole and zero were obtained from the graph, and Kc was obtained from the magnitude condition. After finishing its design, the steady state error due to parabola was 28.65% (not within 1% required). Therefore, the use of lag compensator was necessary to decrease the steady state error. In our problem, it is the case where $\boldsymbol{\gamma} \neq \boldsymbol{\beta}$*. We dealt with the lead compensator alone, getting its gain, pole and zero positions. Then, the lag compensator was designed based on our open loop transfer function cascaded with lead compensator transfer function to decrease error.*

Task 18:



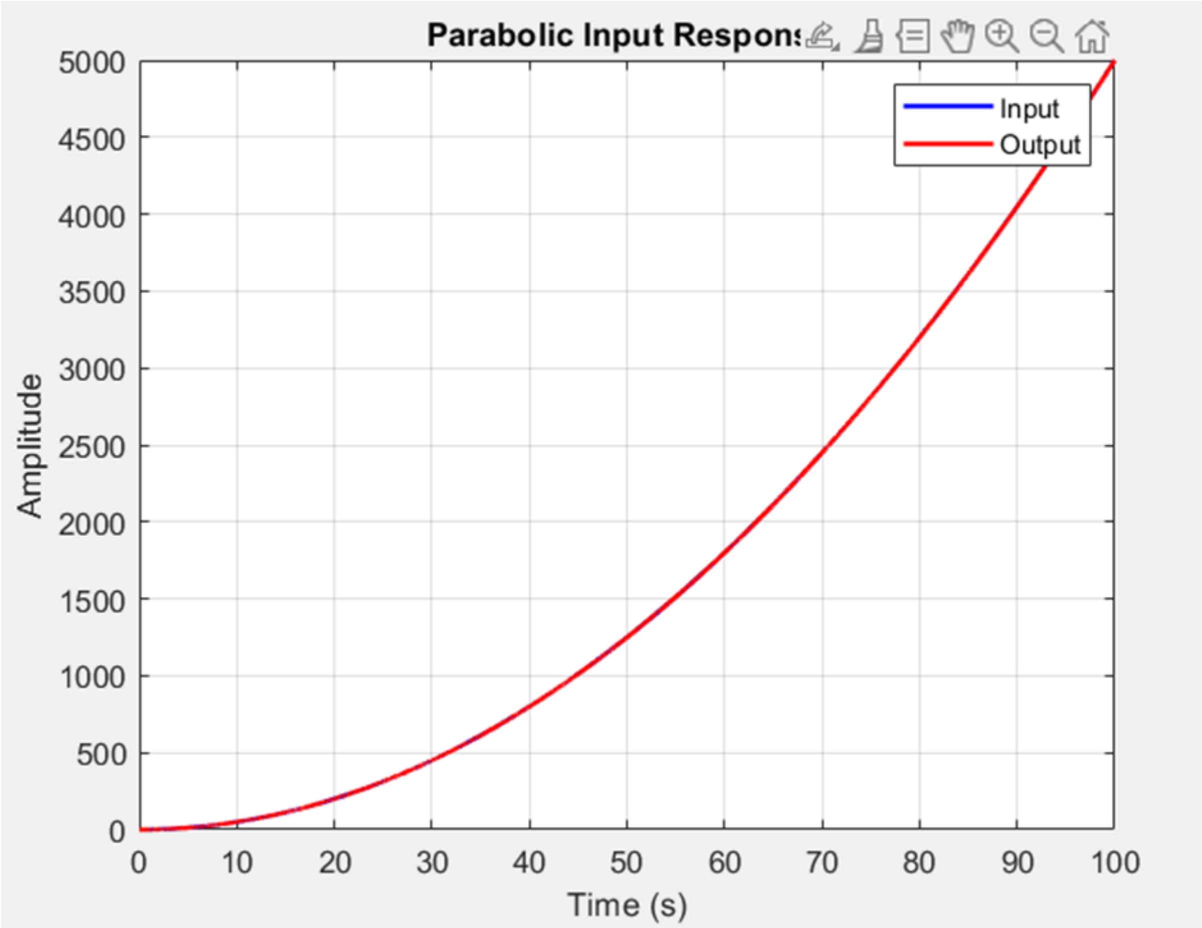
This is the step response of lead lag compensator cascaded with open loop transfer function before tuning. It can be seen from the graph that there is no steady state error, which makes sense because the static position error constant = infinity due to the high type of the system. However, the overshoot is very high (49%) and settling time is 2.95 sec which is why we need tuning.

As the system settle at 1 so it is stable with high overshoot.



The steady state error is zero because the static velocity error constant is infinity due to the high type of system. The input and output have very similar graphs with a very slight change in amplitude due to time.

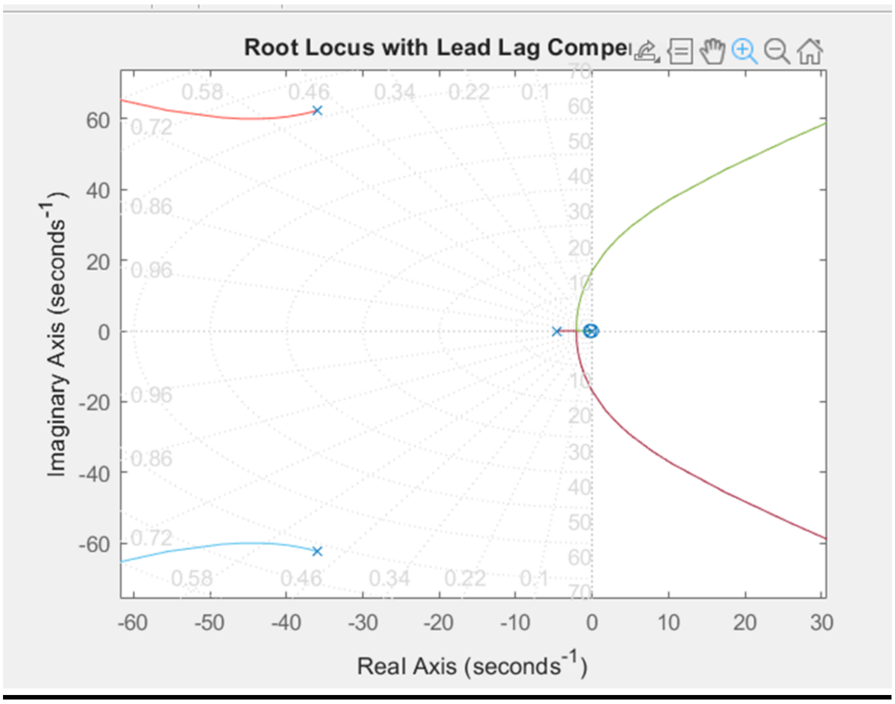
We can't say that it is stable or not because it doesn't settle at a certain value

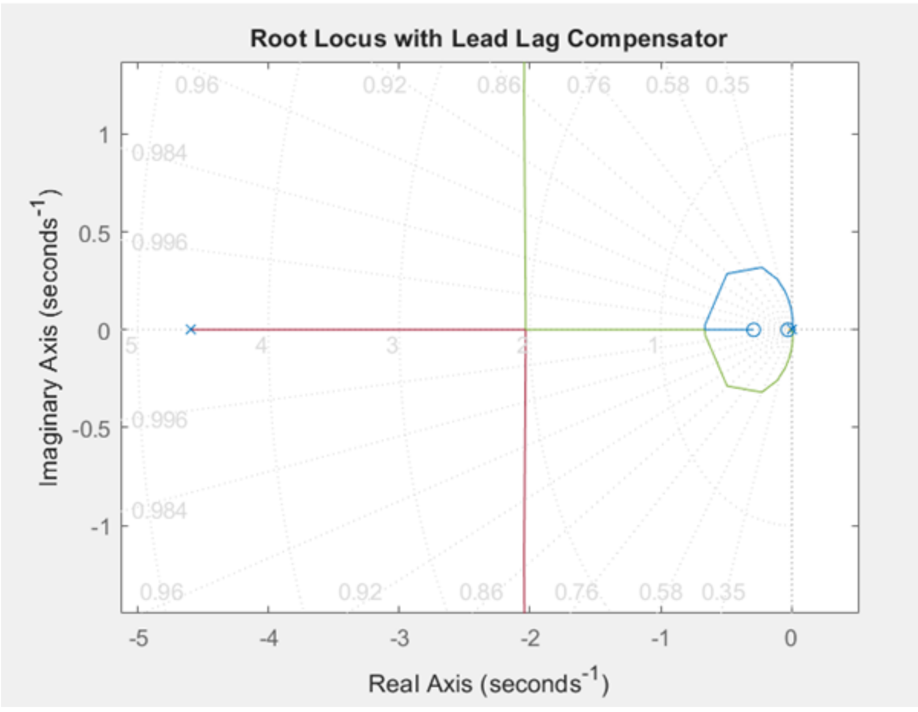


The input and output have very similar graphs with a very slight change in amplitude due to time. The steady state error is 0.2865.

We can't say that it is stable or not because it doesn't settle at a certain value

Task 22:

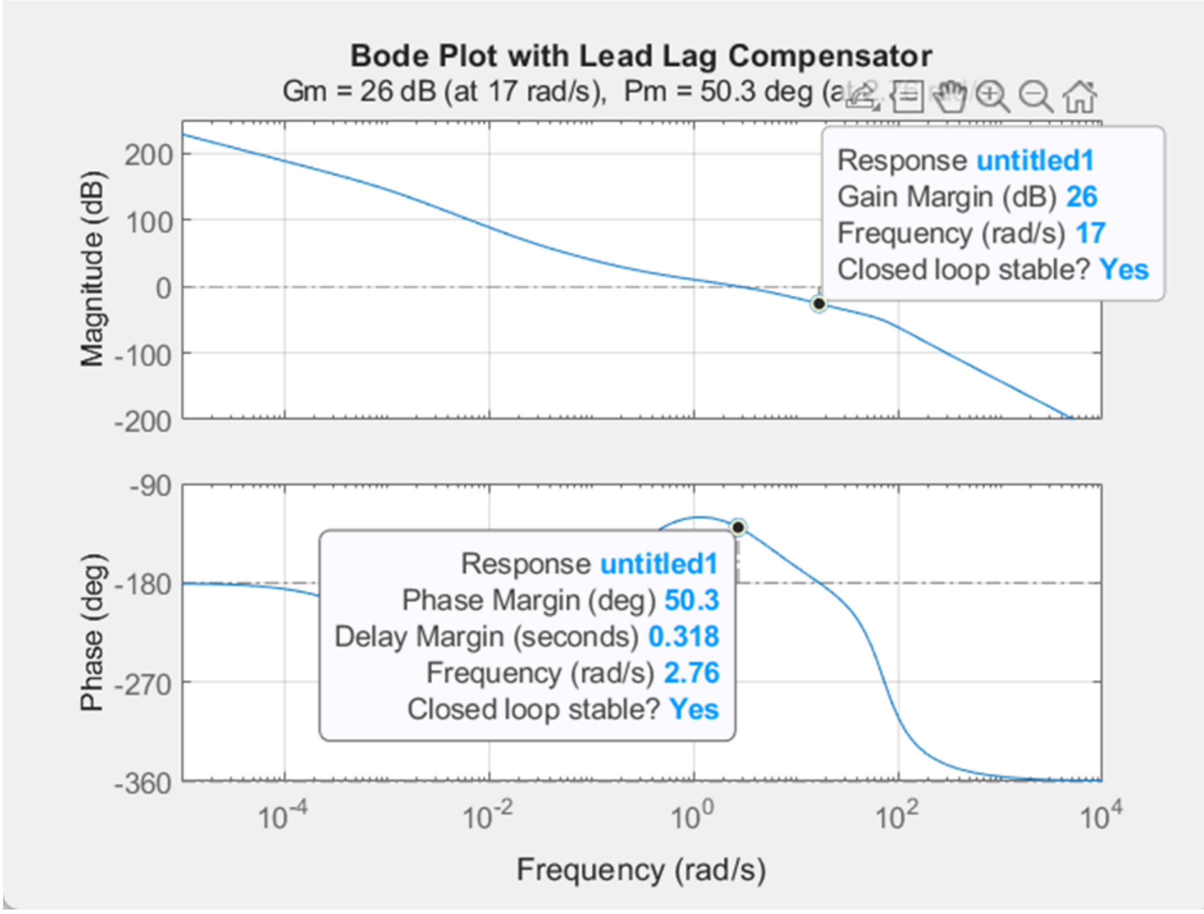




The lag compensator added a zero and a pole that got attracted to each other. In addition, the two poles at the origin broke away *and then broke in at some point one of them went to the zero of the lead while the other broke away with the lead pole*

There is a range in which all the poles and zeros are on the left side of the graph so there is some range of gain in which the system is stable.

Task 23:



Same as point 16

We concluded that both the phase margin and gain margin are positive and the phase crossover frequency bigger than the gain crossover frequency resulting in a stable system