Mechanical Control Systems (ME 4473)

Recitation - 11

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1. **Agenda:**
   - Revision
   - Problems(Root Locus)

2. **Revision:**
   a. **Suppose you are a Controls Engineer assigned to work in designing an Automatic Controller for a plant. At what point in the design process would you go about evaluating the root locus?**

   b. **Does the poles of a system change their location by themselves during a normal operation of the system?**

   c. **Your boss says that the natural frequency needs to be below w_n, damping ratio above ζ, and Time to decay the system modes to half T_d. For Each of these conditions, sketch the allowable regions for the poles in the complex plane.**

d. **What causes the poles to change their location?**

e. **Why wouldn't a zero move?**

f. **Fill in the blank:**

   i. **RL Magnitude Condition :** ………………………………..

   ii. **RL Phase Condition :** ……………………………………..

   iii. **Angle of Departure:**

   ……………………………………………………………………

   ……………………………………………………………………

g. **What are the steps to find the root locus of a control system?**

   Step 1: Identify the…………………………………….
   (These poles correspond to the points where K = 0)

   Step 2: Identify the……………………………………...
   (These zeros correspond to the points where K → ∞)

   Step 3: Calculate the angles at which loci goes to inf

Step 4: Calculate the point along the real axis where the asymptotic line(s) intersects = center of gravity(c.g.)

Step 5: On a given section(real axis), the root locus can be found in the section only if

……………………………………………………………………………………

…………………………………………………………………………………...

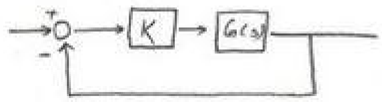
Step 6: Calculate the angle of departure from all complex poles and angles of arrival to all complex zeros

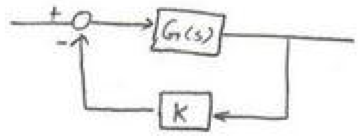
Step 7: Calculate the point where branches of the root locus cross the imaginary axis

(.......................................)
(Gives the max value of K)

Step 8: Calculate the break-away points along the real axis

h. **For the two systems provided below, would they have the same or different root locus?**

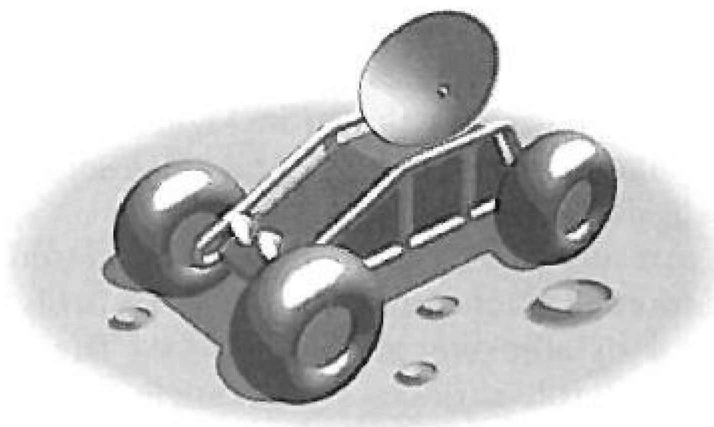




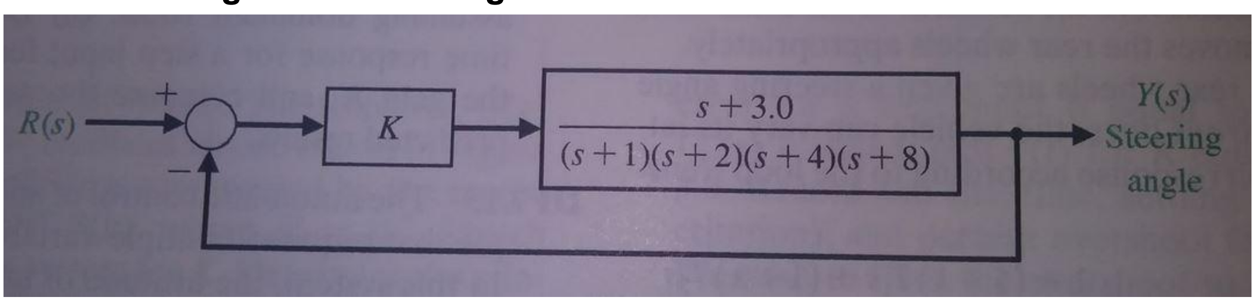
i. **If the angle of departure of one of the poles of complex conjugate poles is a^0, what is the angle of arrival of another pole?**

3. **Problems:**

D.P.7.12 A rover vehicle designed for use on other planets and moons is shown in the figure below:



The block diagram for steering control is shown below:

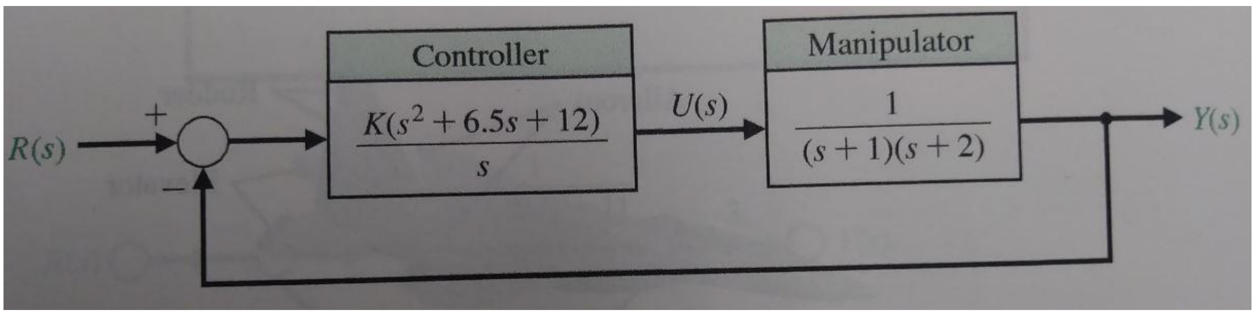


a. **Sketch the root locus as K varies from 0 to 1000. Find the roots of K = 100, 300 and 600.**

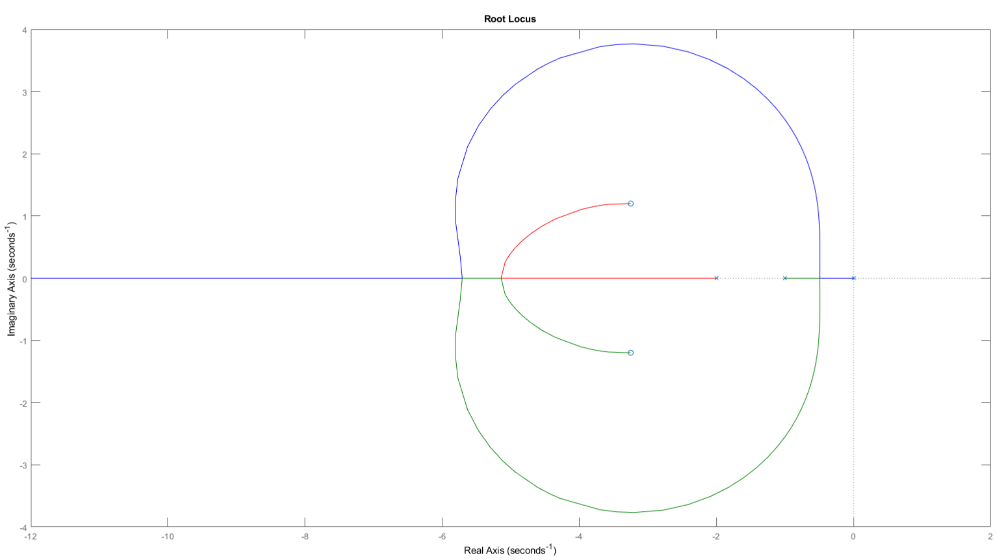
b. Predict the overshoot, settling time(2% criterion), and steady state error for a step input, assuming dominant roots.

c. Determine the actual time response for for a step input for 3 values of the gain K, and compare the actual results with the predicted results

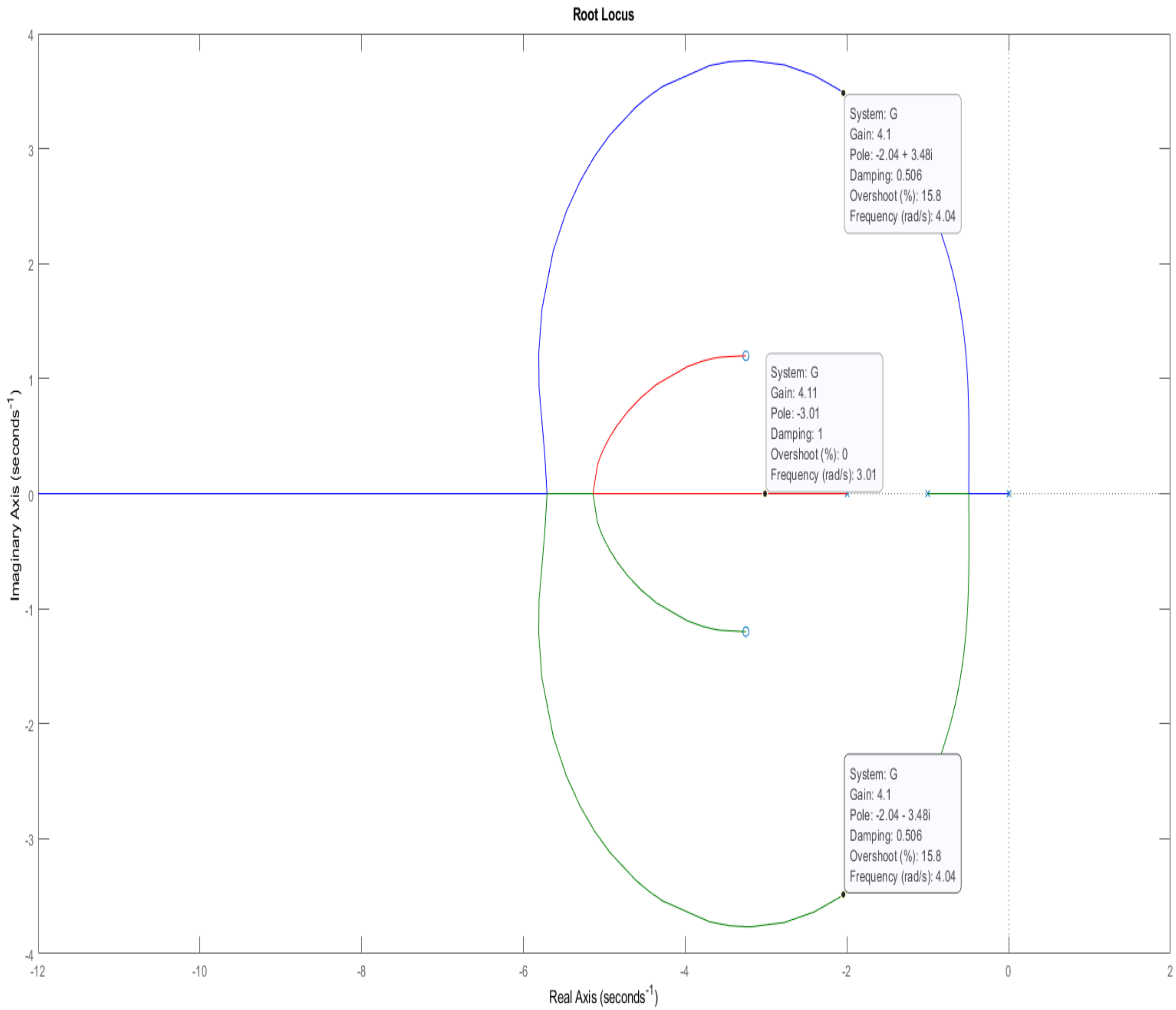
D.P.7.3 A rover vehicle has been designed for maneuvering at 0.25 mph over Martian Terrain. Because Mars is 189 million miles from Earth and it would take upto 40 mins each way to communicate with Earth[22,27], the rover must act independently and reliably. Resembling a cross between a small flatbed truck and jeep, the rover is constructed of three articulated sections, each with its own two independent, axle-bearing, one-meter conical wheels. A pair of sampling arms-one for chipping & drilling, the another for manipulating fine objects - extended from its front and end like pincers. The control of the arms can be represented by the system shown below.



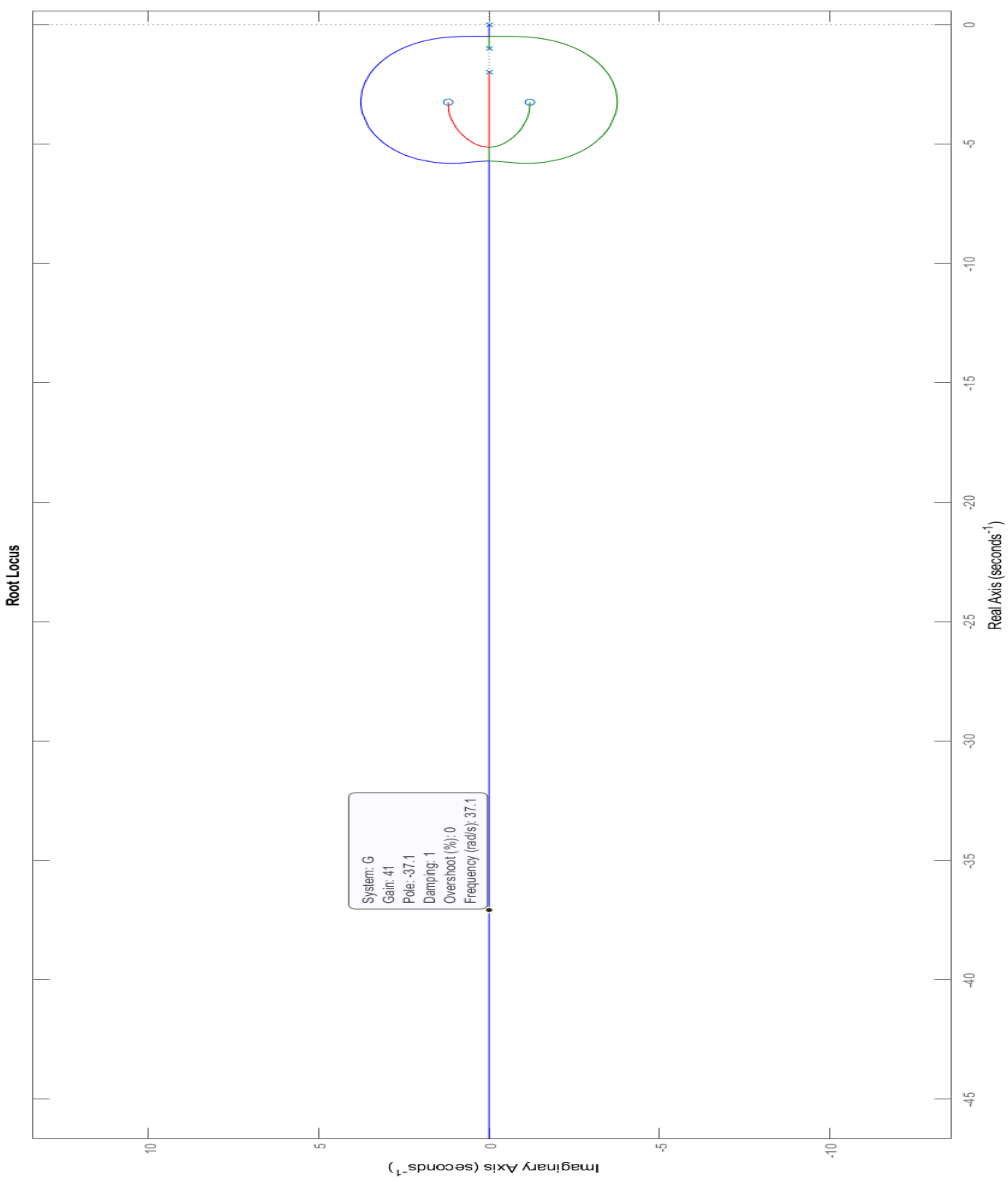
a. **Sketch the root locus for K & identify the K for K = 4.1 and 41.**



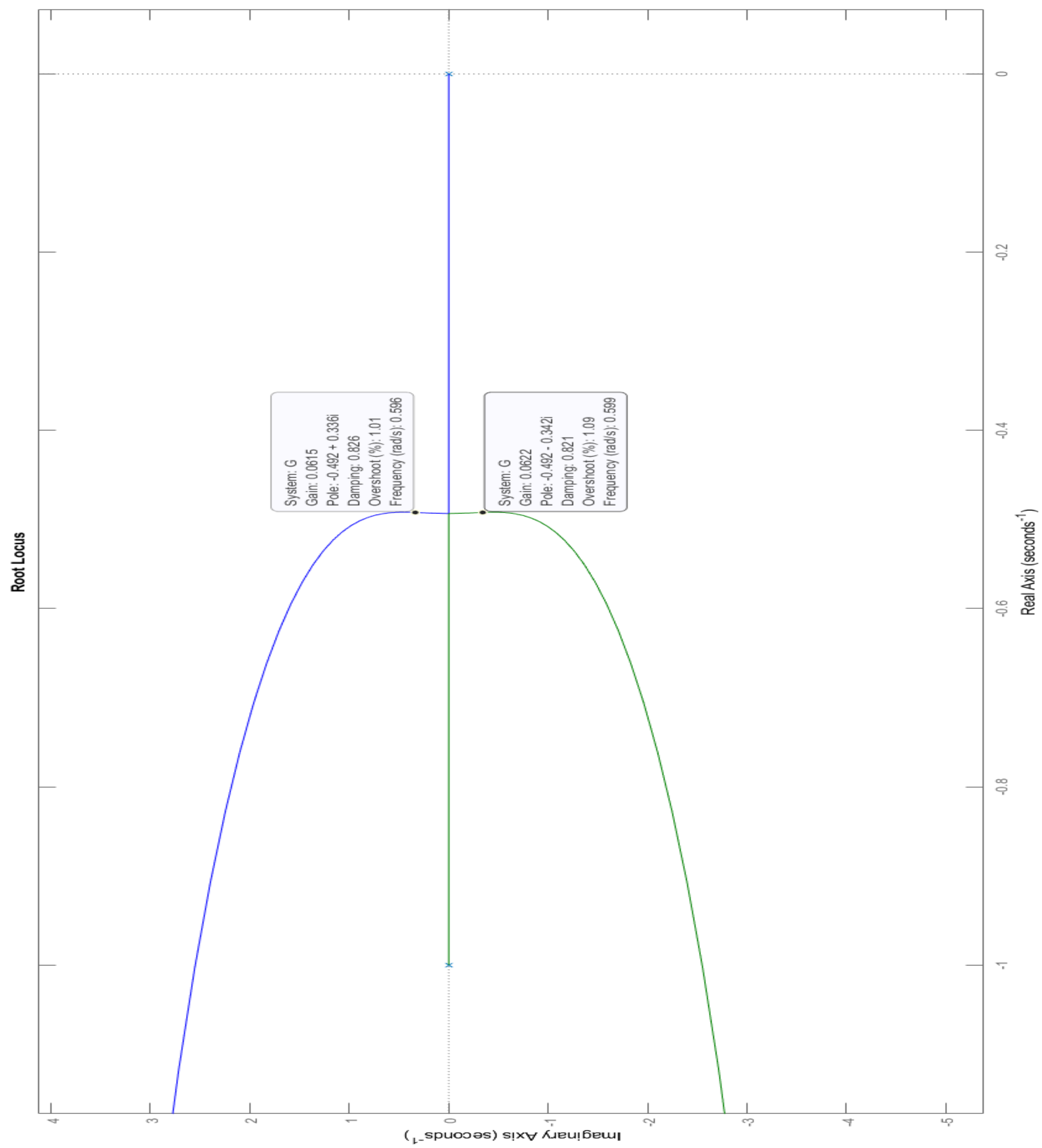
K = 4.1:


Root Locus
System: G
Gain: 4.1
Pole: -2.04 + 3.48i
Damping: 0.506
Overshoot (%): 15.8
Frequency (rad/s): 4.04
System: G
Gain: 4.11
Pole: -3.01
Damping: 1
Overshoot (%): 0
Frequency (rad/s): 3.01
System: G
Gain: 4.1
Pole: -2.04 - 3.48i
Damping: 0.506
Overshoot (%): 15.8
Frequency (rad/s): 4.04
Imaginary Axis (seconds^-1)
Real Axis (seconds^-1)
4
3
2
1
0
-1
-2
-3
-4
-12
-10
-8
-6
-4
-2
0
2

K = 41:


Root Locus
System: G
Gain: 41
Pole: -37.1
Damping: 1
Overshoot (%): 0
Frequency (rad/s): 37.1
Real Axis (seconds^{-1})
Imaginary Axis (seconds^{-1})

b. Determine the gain K that results in the percent overshoot to a step of P.O = 1%.



c. **Determine the gain that minimizes the settling time (with a 2% criterion) while maintaining a percent overshoot of P.O. ≤ 1%**

Bibliography:

- **Dorf, Modern Control Systems, 13th ed**
- **https://www.youtube.com/watch?v=CRvVDoQJjYI, Root Locus Method**