```
clear
clc
```

A)

Checking controllability and observability of the system

```
Ag=[0 1 0 0 0;-0.1 -0.5 0 0 0;0.5 0 0 0 0;0 0 10 0 0;0.5 1 0 0 0]
```

```
Ag = 5×5
         0    1.0000         0         0         0
   -0.1000   -0.5000         0         0         0
    0.5000         0         0         0         0
         0         0   10.0000         0         0
    0.5000    1.0000         0         0         0
```

```
Bg=[0 1 0 0 0]'
```

```
Bg = 5×1
     0
     1
     0
     0
     0
```

```
Cg=[0 0 0 1 0]
```

```
Cg = 1×5
     0     0     0     1     0
```

```
Dg=0
```

```
Dg = 0
```

```
system_order = length(Ag)
```

```
system_order = 5
```

```
M = ctrb(Ag, Bg);
rank_of_M = rank(M)
```

```
rank_of_M = 4
```

```
N = obsv(Ag, Cg);
rank_of_N = rank(N)
```

```
rank_of_N = 4
```

The uncontrollable state indicates that M and N does not have full rank of system_order therefore the system is not controllable and observable

B)

Developing a controllable state variable model

```
[NUM,DEN] = ss2tf(Ag,Bg,Cg,Dg)
```

```
NUM = 1×6
         0         0         0         0    5.0000         0
DEN = 1×6
    1.0000    0.5000    0.1000         0         0         0
```

After canceling common factor z

```
NUM=[0 0 0 0 5];
DEN=[1 0.5 0.1 0 0];
[Ag, Bg, Cg, Dg] = tf2ss(NUM, DEN)
```

```
Ag = 4×4
   -0.5000   -0.1000         0         0
    1.0000         0         0         0
         0    1.0000         0         0
         0         0    1.0000         0
Bg = 4×1
     1
     0
     0
     0
Cg = 1×4
     0     0     0     5
Dg = 0
```

C)

Checking controllability and observability

```
system_order = length(Ag)
```

```
system_order = 4
```

```
M = ctrb(Ag, Bg);
rank_of_M = rank(M)
```

```
rank_of_M = 4
```

```
N = obsv(Ag, Cg);
rank_of_N = rank(N)
```

```
rank_of_N = 4
```

The system is controllable and observable because the M and N matrices have the same rank as the system.

D)

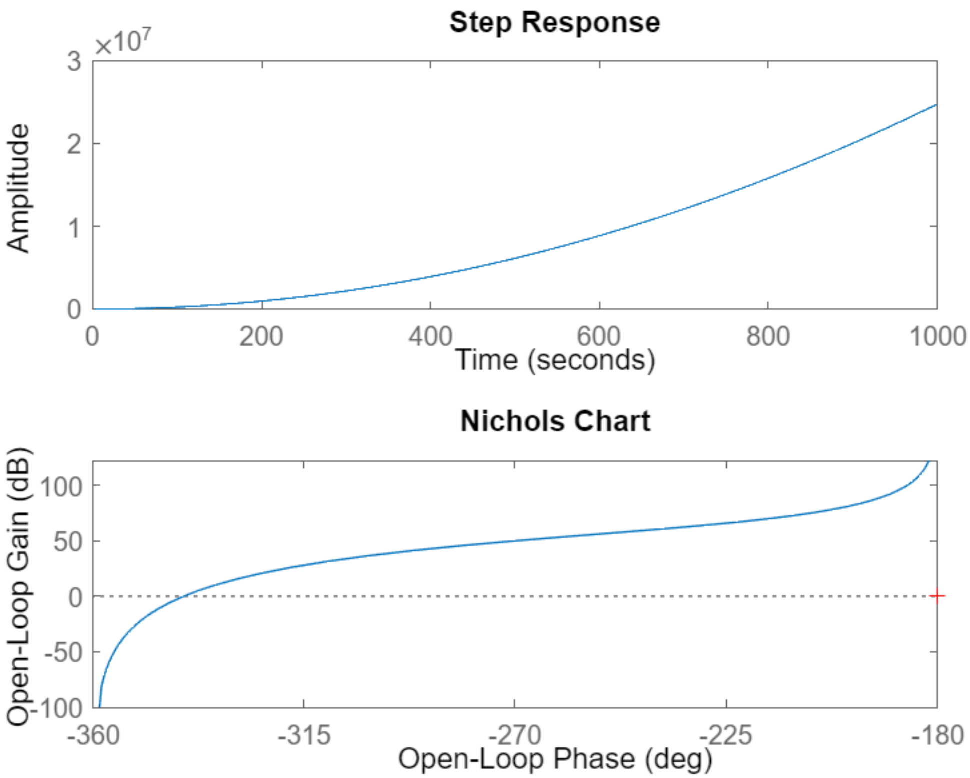
```
sys=tf(NUM,DEN)
```

```
sys =
```

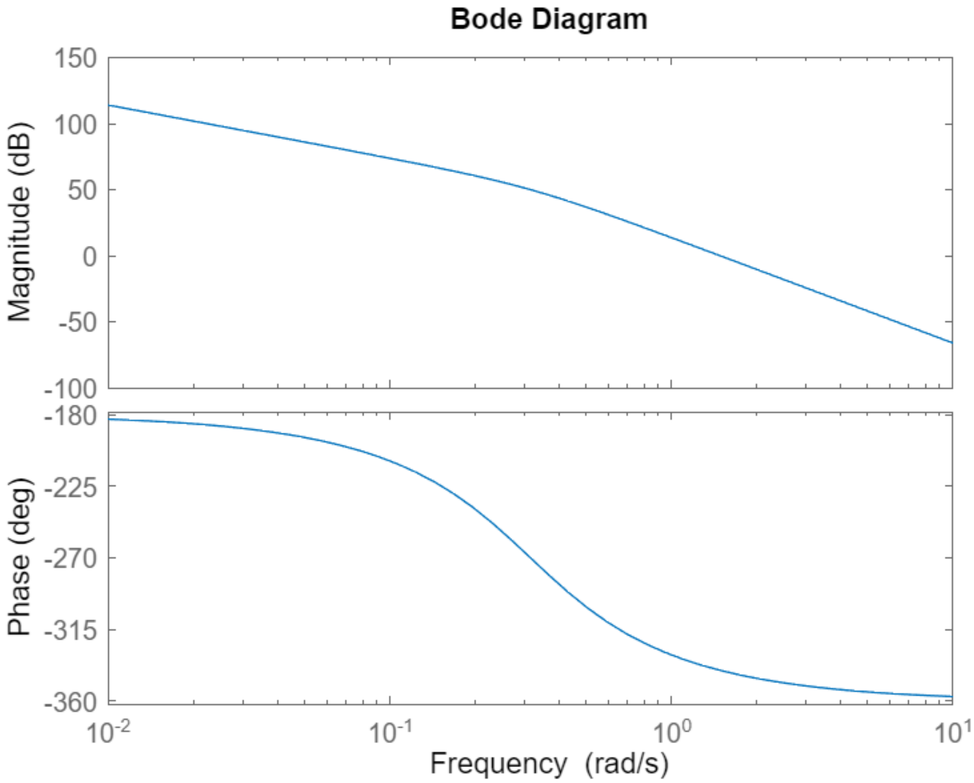
```
           5
  ----------------------
  s^4 + 0.5 s^3 + 0.1 s^2

Continuous-time transfer function.
```

```
subplot(211)
step(sys)
subplot(212)
nichols(sys)
```




```
figure
bode(sys)
```



System is unstable

Designing a state variable feedback controller to stabilize the system

```
[A,B,C,D] = tf2ss(NUM,DEN)
```

```
A = 4×4
   -0.5000   -0.1000         0         0
    1.0000         0         0         0
         0    1.0000         0         0
         0         0    1.0000         0
B = 4×1
     1
     0
     0
     0
C = 1×4
     0     0     0     5
D = 0
```

New desired poles for a stable system

```
new_desired_poles = [-0.25+0.25i -0.25-0.25i -0.5+0.5i -0.5-0.5i];
K = acker(A, B, new_desired_poles)
```

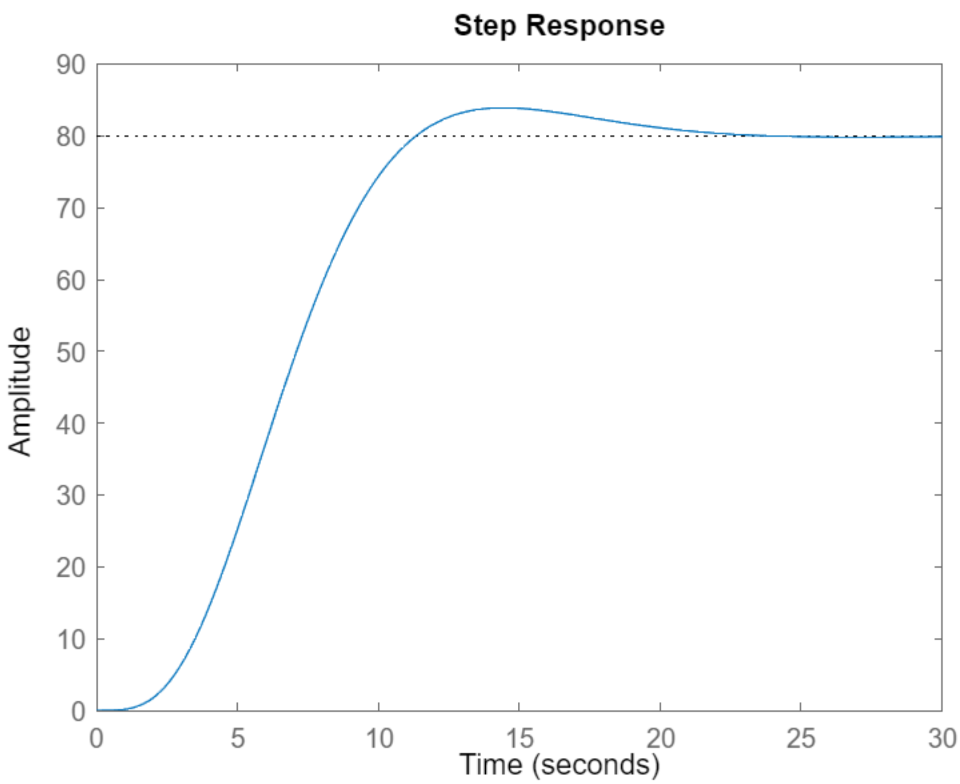
```
K = 1×4
    1.0000    1.0250    0.3750    0.0625
```

```
[num2,den2] = ss2tf(A - B * K,B,C,D);
```

```
H = tf(num2,den2)
```

```
H =
 
                       5
  --------------------------------------------
  s^4 + 1.5 s^3 + 1.125 s^2 + 0.375 s + 0.0625
 
Continuous-time transfer function.
```

```
step(H);
```



System has been stabilized using Ackermann's formula

The original system of 5th order was uncontrollable, unobservable and unstable. After pole-zero cancelation the system became observable and controllable yet unstable. The introduction of a controller rendered the system stable.

The number of state variables i.e. the rank of A matrix must be the same as the controllability matrix for the system to be controllable.