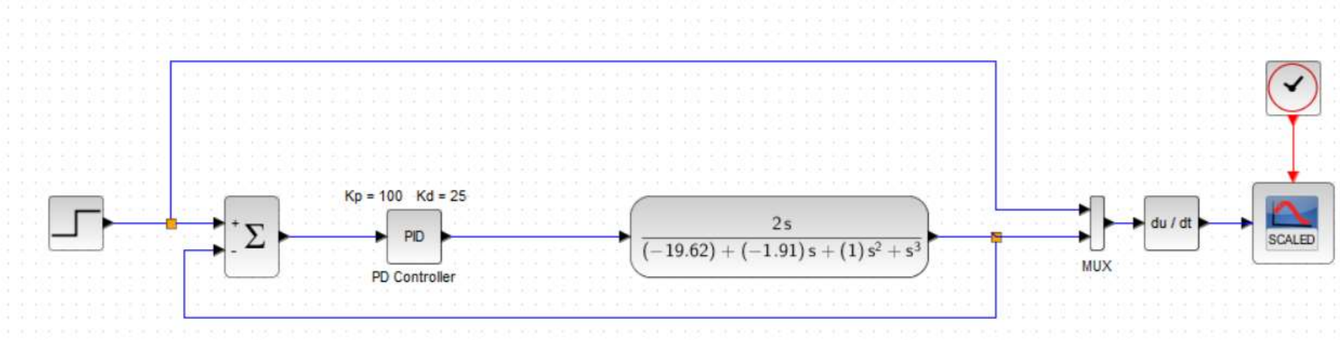
Day 6 & 7 – Implement the PD Controller

Xcos Block Diagram:

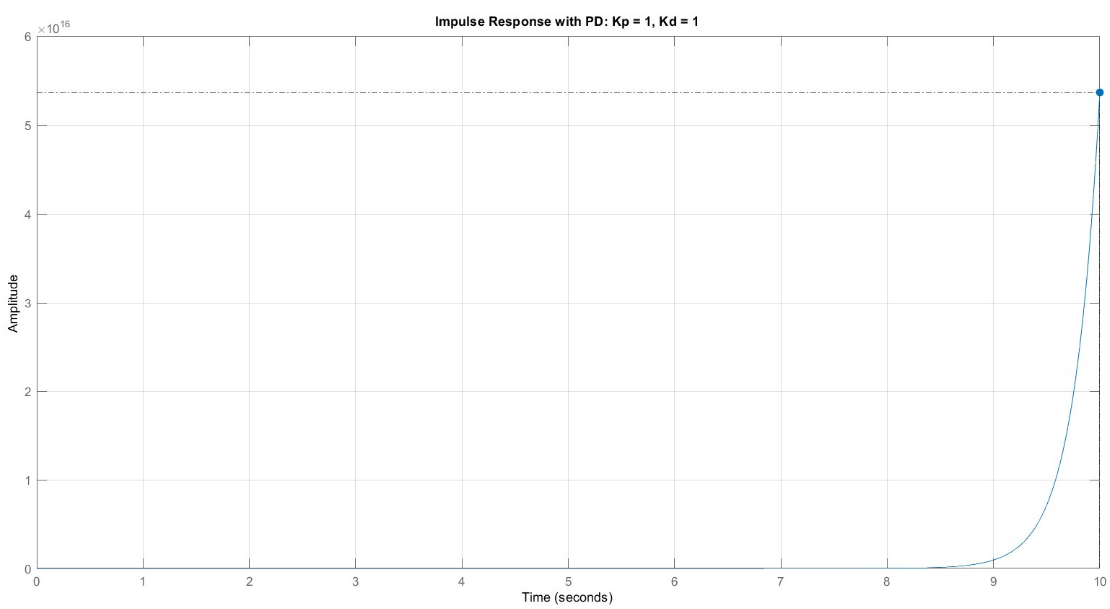


Combination of K_p and K_d:

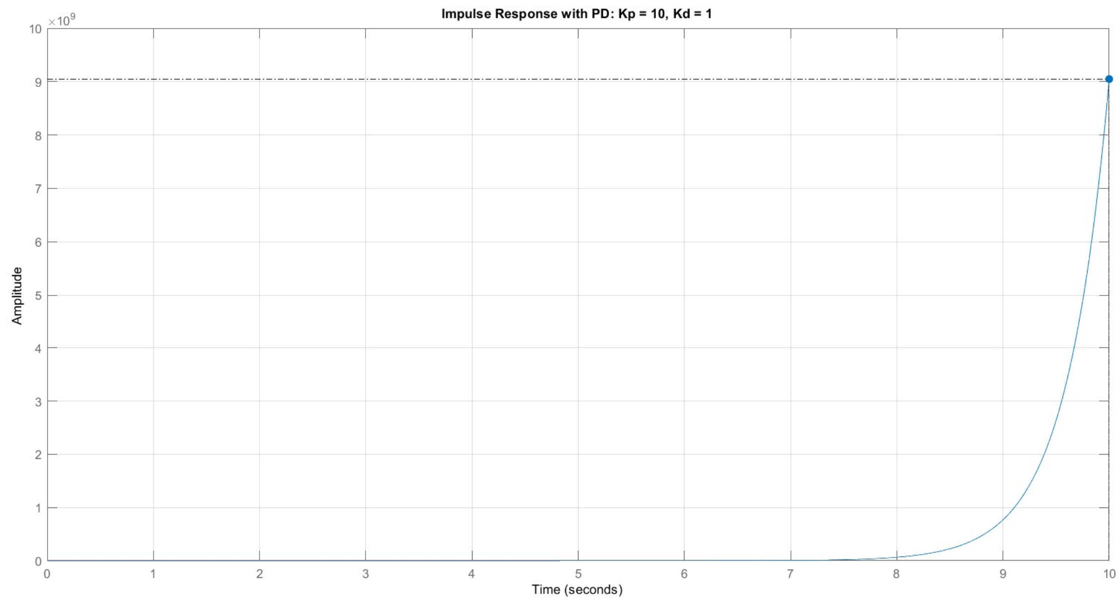
Cases	K_p	K_d
Case 1	1	1
Case 2	10	1
Case 3	100	1
Case 4	100	10
Case 5	100	20
Case 6	100	25

The impulse response for the above cases:

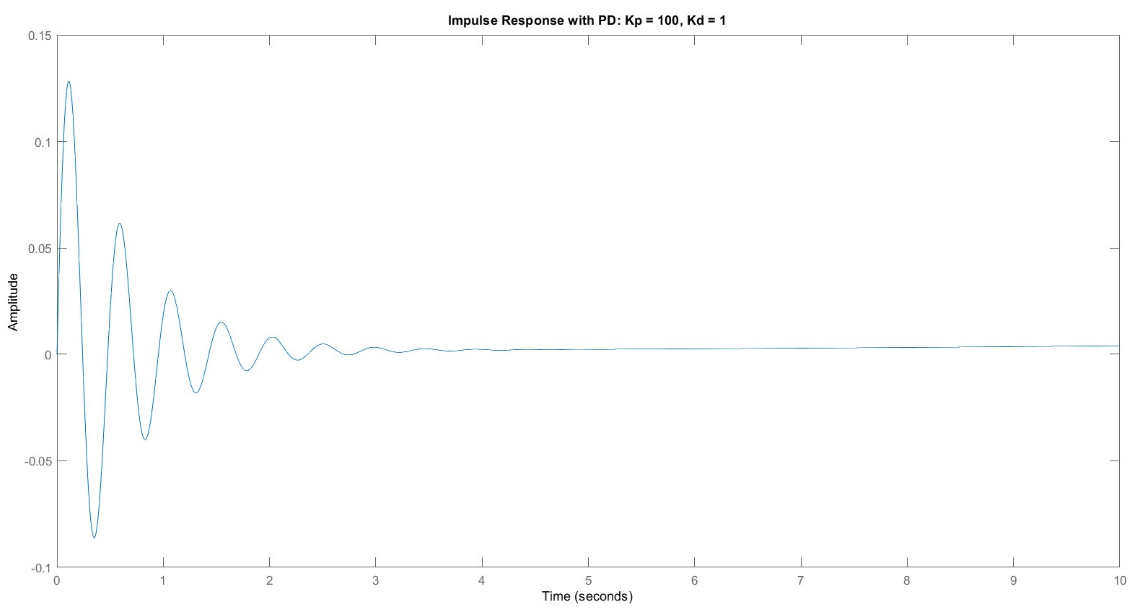
<u>Case 1:</u>



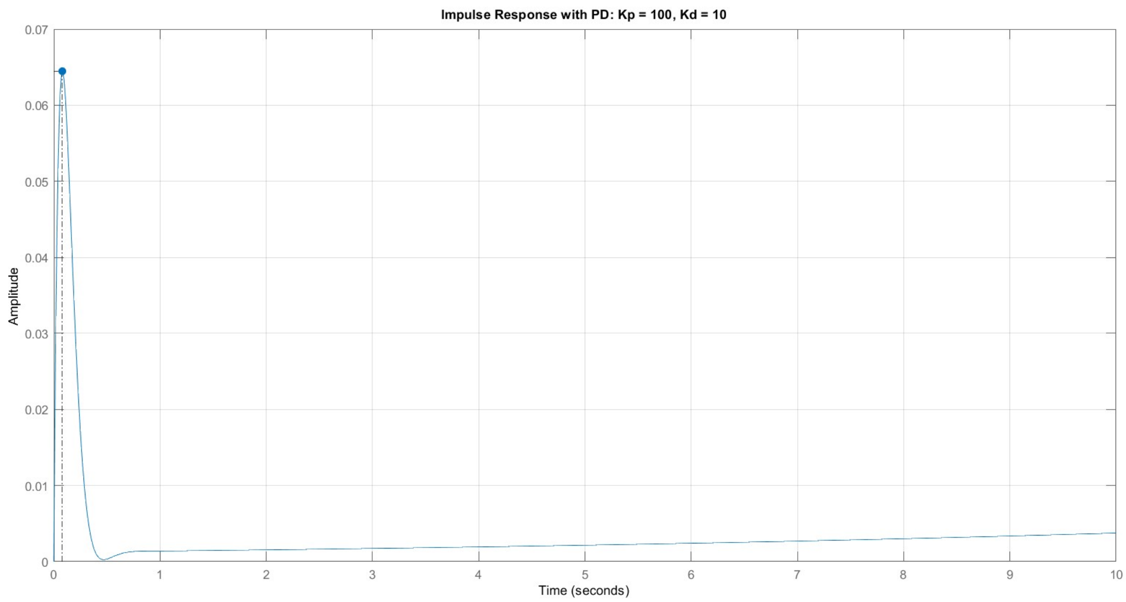
Case 2:


Impulse Response with PD: Kp = 10, Kd = 1
×10^9
Amplitude
Time (seconds)
0
1
2
3
4
5
6
7
8
9
10

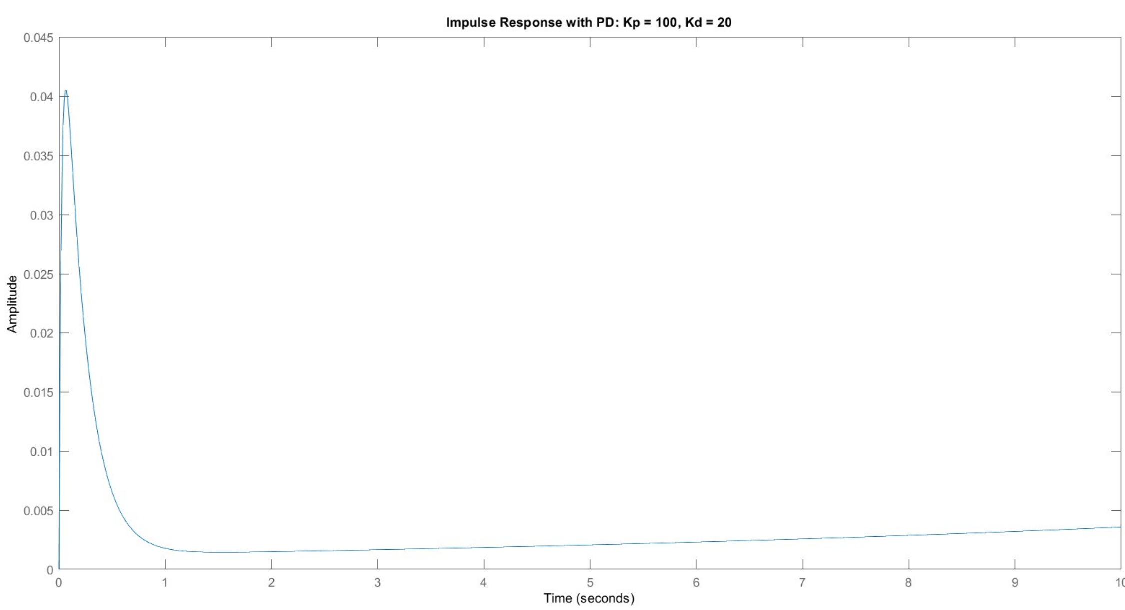
Case 3:


Impulse Response with PD: Kp = 100, Kd = 1
0.15
0.1
0.05
0
-0.05
-0.1
Amplitude
Time (seconds)
0
1
2
3
4
5
6
7
8
9
10

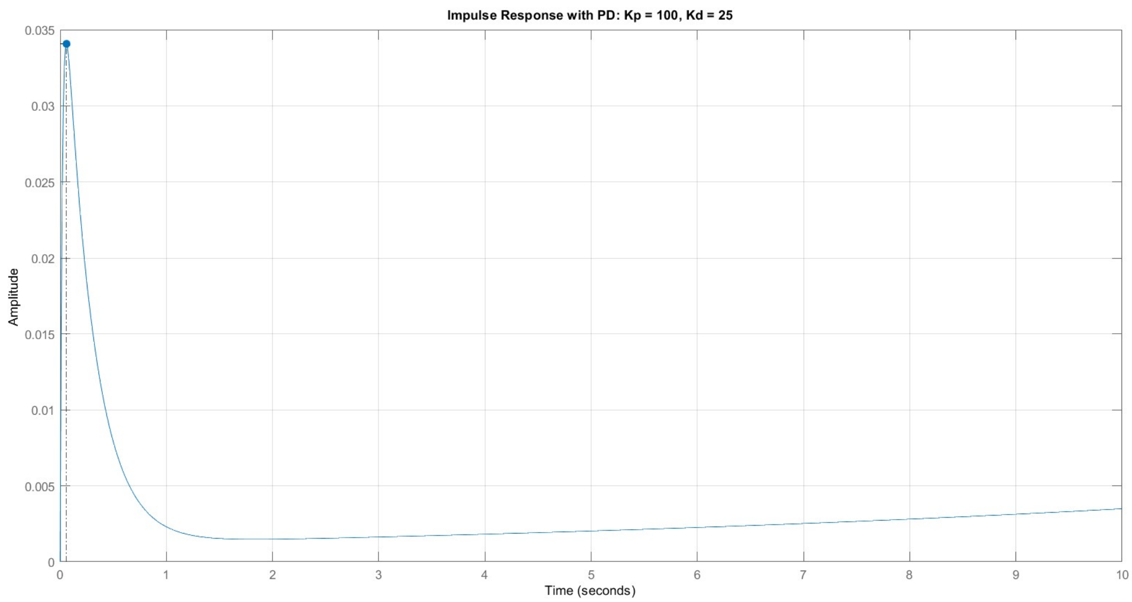
Case 4:


Impulse Response with PD: Kp = 100, Kd = 10
Amplitude
Time (seconds)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0 1 2 3 4 5 6 7 8 9 10

Case 5:


Impulse Response with PD: Kp = 100, Kd = 20
Amplitude
Time (seconds)
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0 1 2 3 4 5 6 7 8 9 10

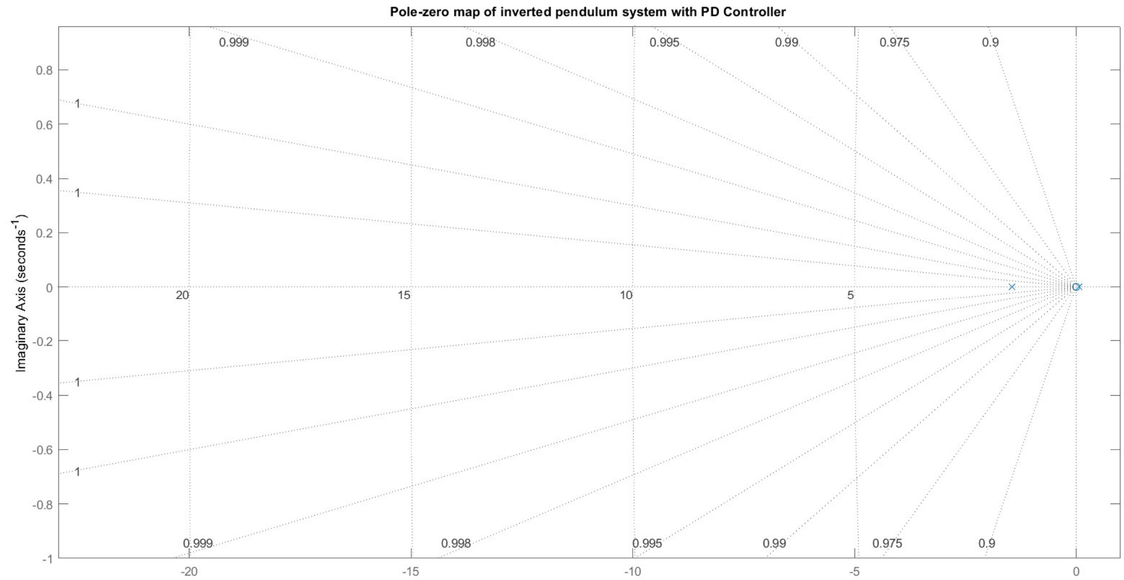
Case 6:

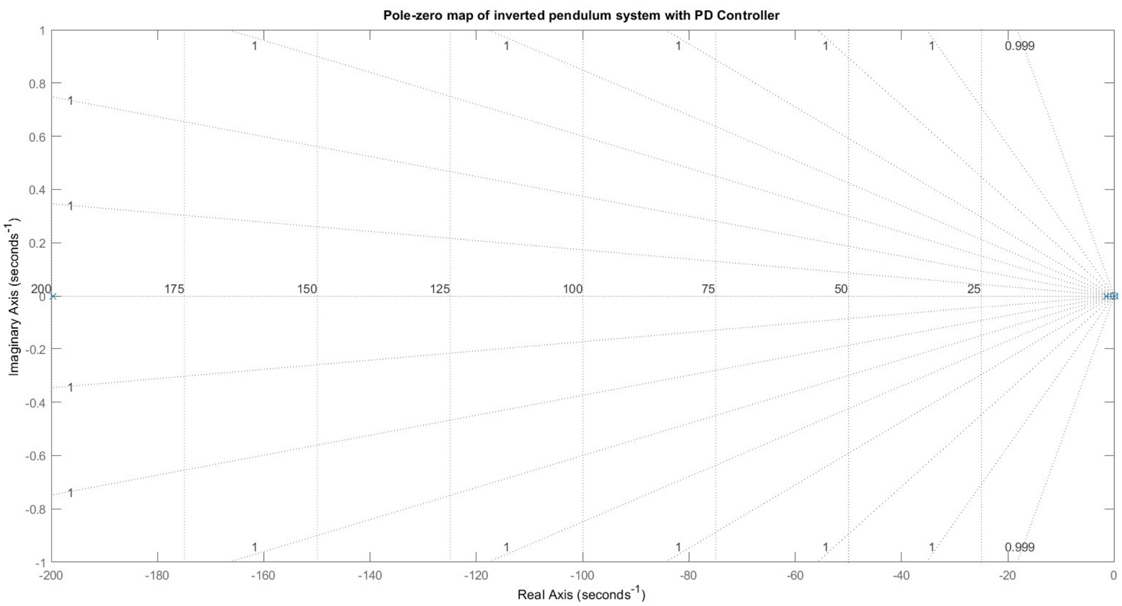


Comments:

Cases	Comments/Remarks
Case 1: $K_p = 1$, $K_d = 1$	Unbounded output → unstable response
Case 2: $K_p = 10$, $K_d = 1$	Unbounded output → unstable response
Case 3: $K_p = 100$, $K_d = 1$	Oscillatory response for some time, then gets stable
Case 4: $K_p = 100$, $K_d = 10$	Settling decreases and response contains only maximum overshoot and no oscillations
Case 5: $K_p = 100$, $K_d = 20$	Decreasing maximum overshoot and rise time and settling time
Case 6: $K_p = 100$, $K_d = 25$	Optimum response, gets stable at 0 with min overshoot and rise time, settling time.

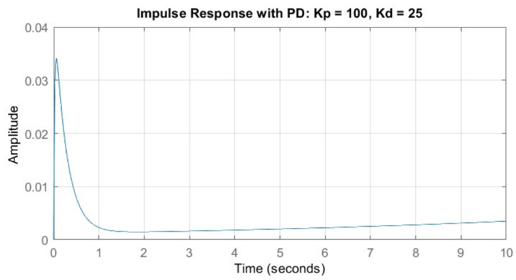
Pole – Zero Plot for best K_p and K_d (*Case 6*):

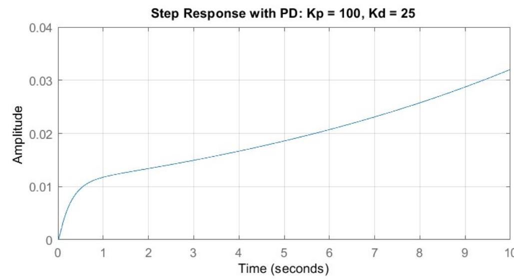


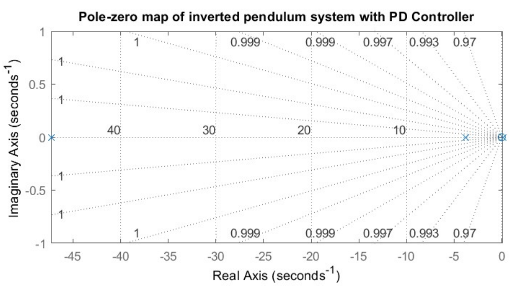


On observing the pole and zero plot, I found that one pole of the closed loop system is at location 0.0105 i.e., lies on the RHP. This leads to the instability of the system. So, on trying to bring the pole on the LHP of the s-plane, by changing the values of gains K_p and K_d, the pole can be brought on the LHP, but at the cost of increase the in transient parameters of the system i.e., the settling and the rise time increases and the gain required for the same also is very high which may result in instability.

Impulse, Step response and pole-zero plot:







Conclusion/Outcomes:

- By using the PD Controller, trying to stabilize the inverted pendulum system.
- **K_p:** On increasing the proportional gain K_p, the unbounded output gets bounded at a certain value of K_p, this parameter increases the peak overshot M_p.
- **K_d:** On increasing the derivative gain K_d, the transient response gets improves and the oscillations are overcome which were caused due the K_p gain. This brings the response near to 0 and stabilizes it.
- Hence, by using PD controller, tried to stabilize the system by observing the impulse response of the system, but one pole of the system lies in the RHP. To bring that pole in LHP on further increasing the K_p and K_i values will distort the transient and steady state behaviour.
- So, this can be overcome by using a PID controller.