Bangladesh University of Business & Technology
Control System Lab
EEE 402

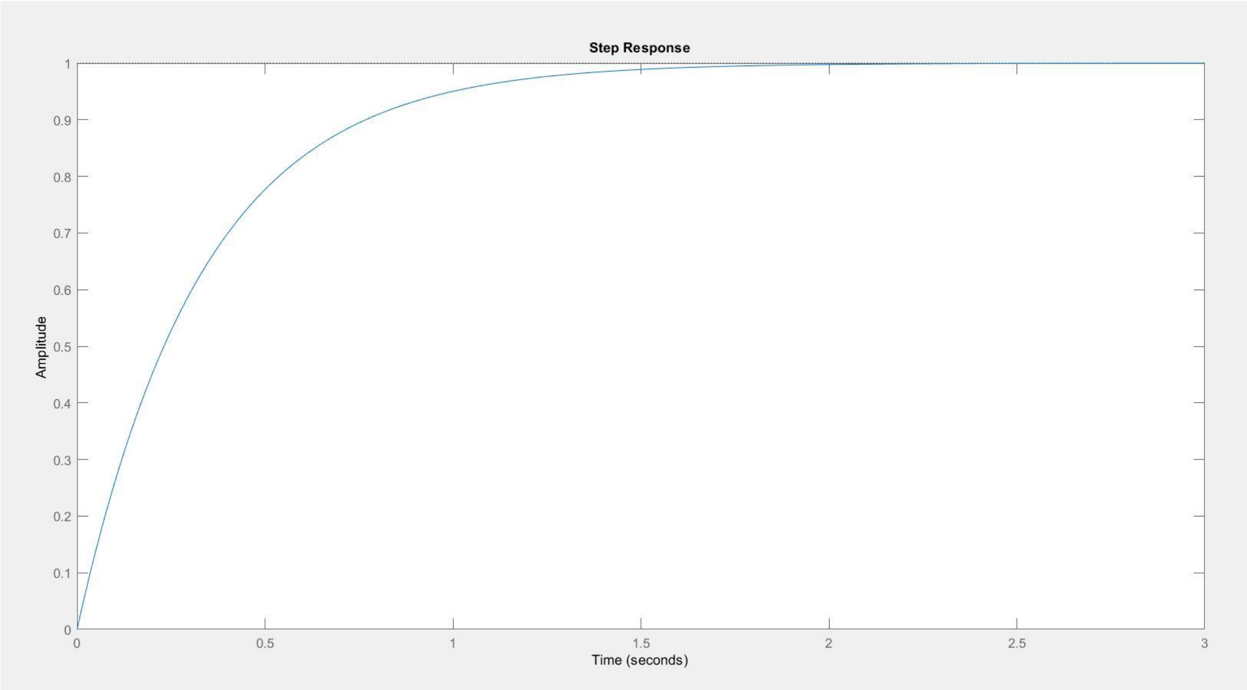
Experiment No: 05

Experiment Name: Familiarization with the 2^{nd} Order Systems and their time response.

Let's start our discussion with a 1^{st} order system.

$$G(s) = \frac{3}{s+3}$$

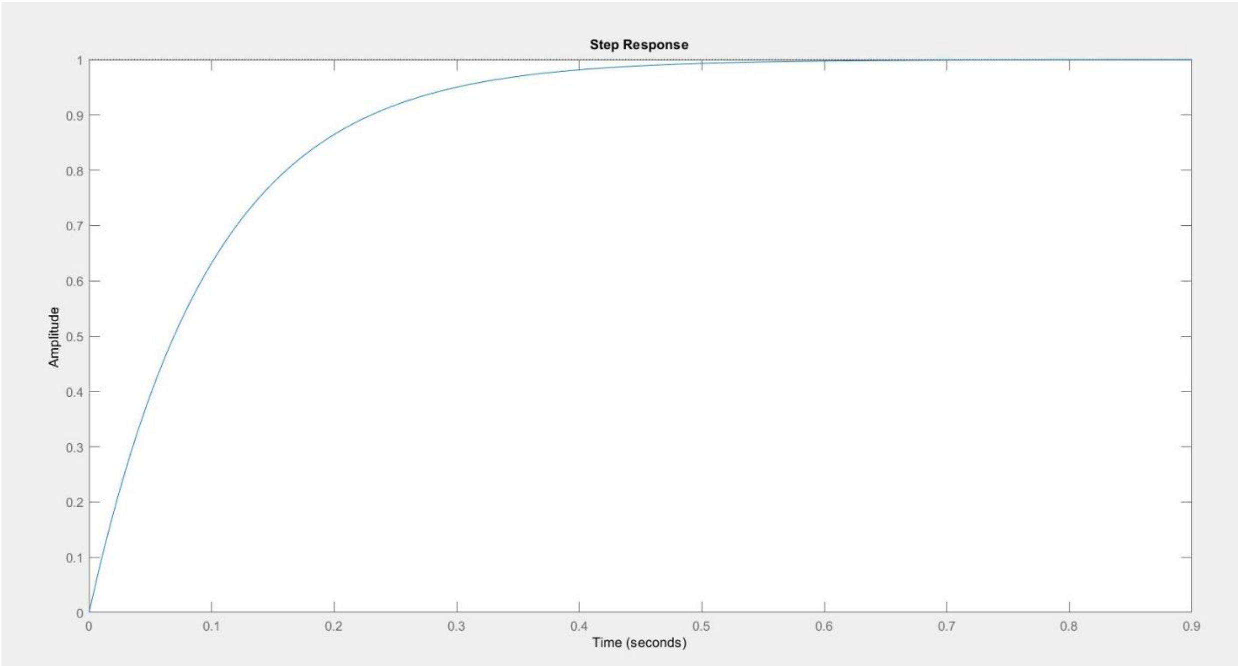
The step response of the system looks like this –



If we change the parameters of the system –

$$G(s) = \frac{10}{s+10}$$

The response becomes like this –



As you can see from these two response curves,

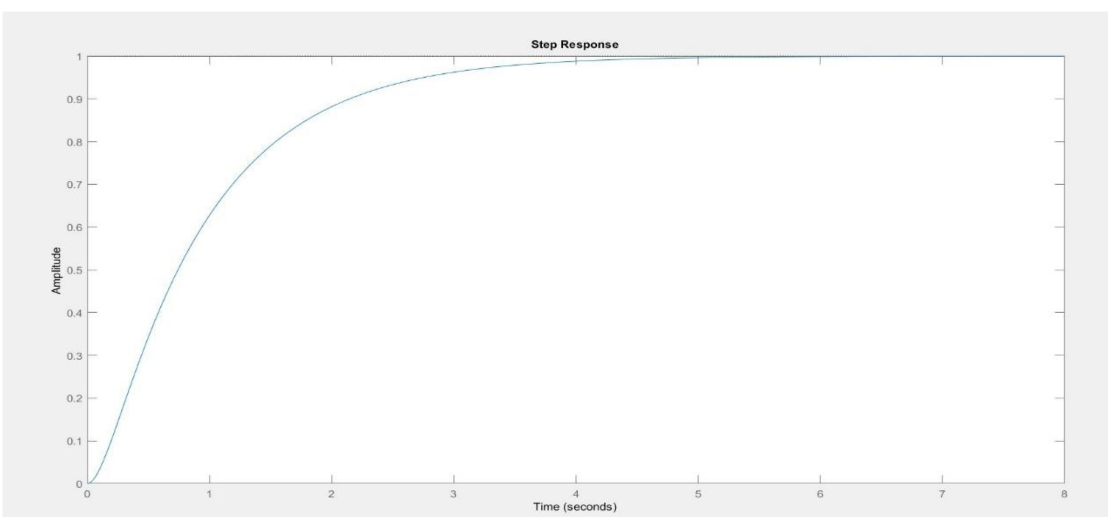
Changing the parameters only changes the ‘speed’ of the response, not the ‘form’ of the response.

[The settling time for the 2^{nd} system is only 0.391s while for the 1^{st} system, it is 1.3s]

Now, let’s look into 2^{nd} order systems –

$$G(s) = \frac{9}{s^2 + 9s + 9}$$

Time-response of that system looks like this –



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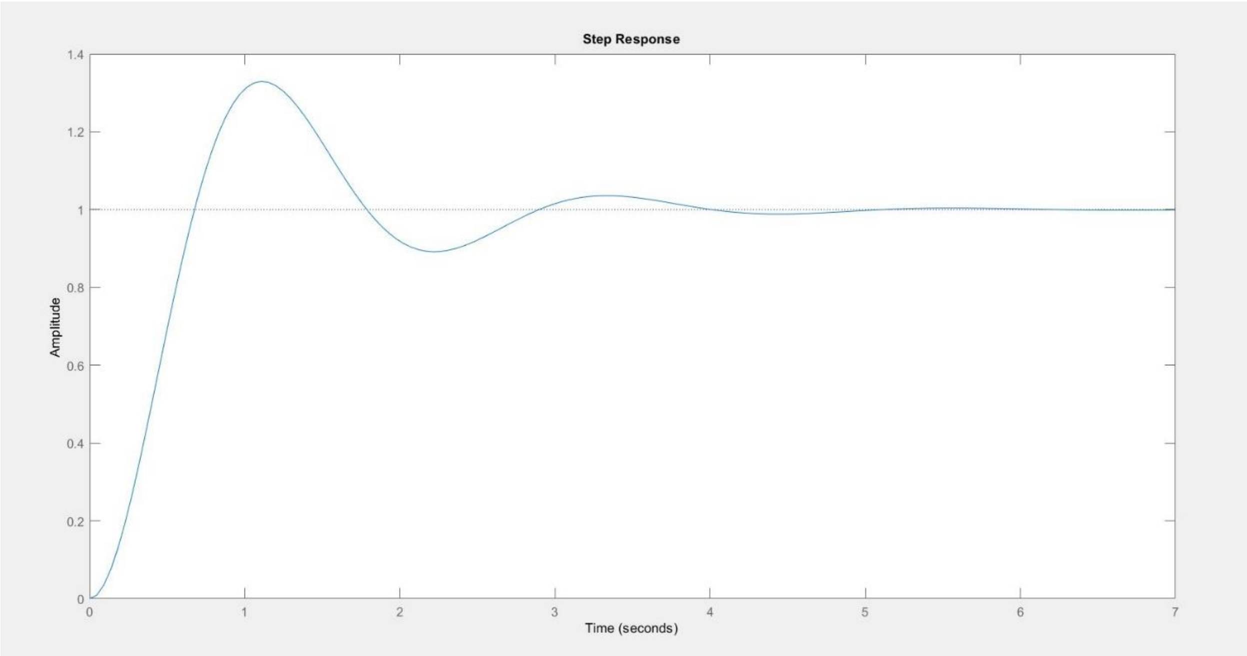
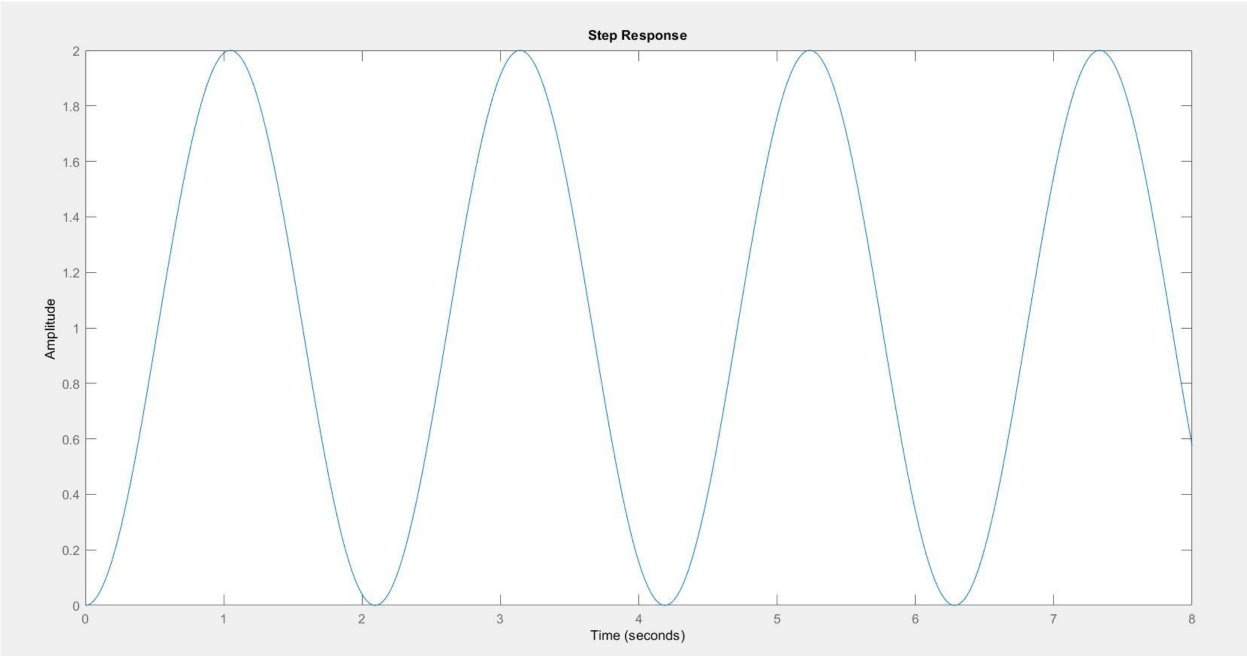
If we change the parameters of the system, the responses become –

$$G(s) = \frac{9}{s^2 + 2s + 9}$$



$$G(s) = \frac{9}{s^2 + 9}$$



$$G(s) = \frac{9}{s^2 + 6s + 9}$$

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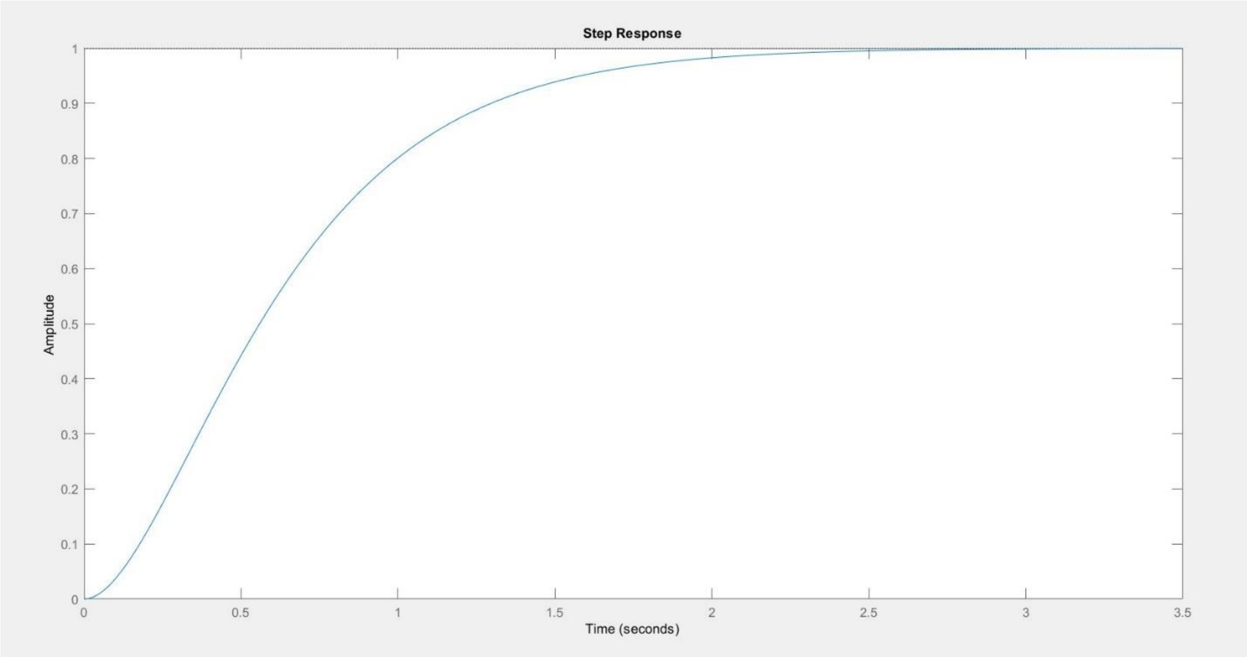
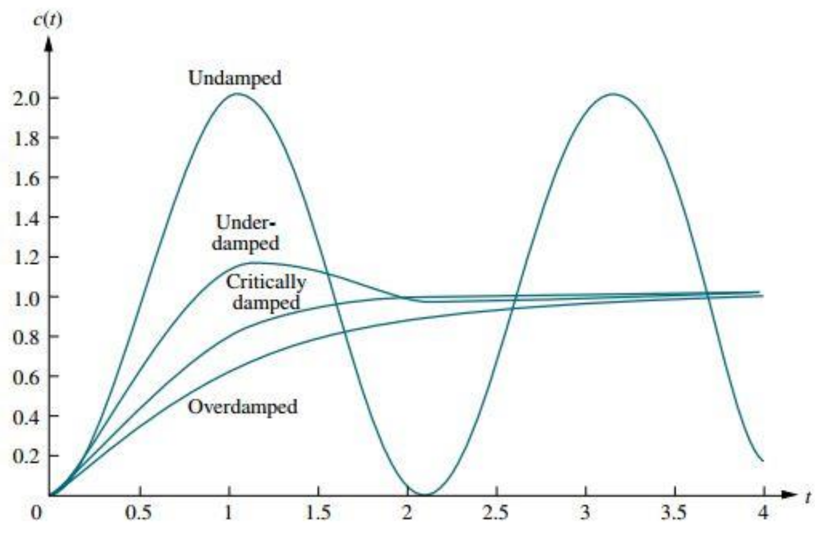


So, we can say – if we change the parameters of a 2nd order system, the form of response changes.

As we were changing the parameters of the system, we're changing the location of the poles and with it the response. Depending on the poles, 2nd order systems are divided into 4 categories –

1. Over damped – two real poles.
2. Underdamped – two complex poles.
3. Un-damped – two imaginary poles.
4. Critically damped – two real & repeated poles.

So, by finding out the location of the poles, we can determine the nature of the response.



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The nature of the response can also be determined from the 'damping ratio' value. When --

1. ζ=0 Undamped.
2. $0 < \zeta < 1$ – Underdamped.
3. $\zeta = 1 \quad - Critically\ damped$
4. $\zeta > 1 \quad - Overdamped.$

From the above examples, you can see that the value of ω_n does not affect the nature of the response; only scale it in time.

Exercise:

a. $G(s) = \dfrac{400}{s^2 + 12s + 400}$

b. $G(s) = \dfrac{900}{s^2 + 90s + 900}$

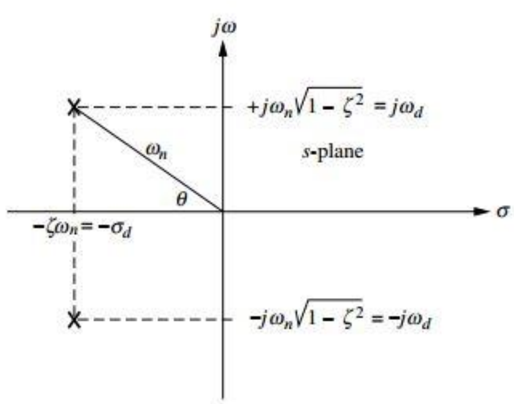
c. $G(s) = \dfrac{225}{s^2 + 30s + 225}$

d. $G(s) = \dfrac{625}{s^2 + 625}$

Find out the response of the above systems.
Find out the $\zeta\ and\ \omega_n$ values and characterize their response.

Question:

1. Explain how Tp, Ts and %OS vary with value of ζ & ω_n.
2. What is ω_d & σ_d ?



3. Find out the transfer functions for the systems below –