

# Control Systems

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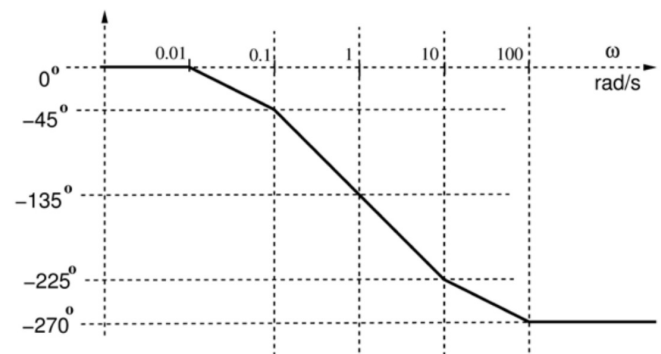


Fig. 2.1.1

**Solution:** Phase of this transfer function,

$$\phi(\omega) = -\tan^{-1}\left(\frac{\omega}{0.1}\right) - \tan^{-1}\left(\frac{\omega}{10}\right) - \tan^{-1}\left(\frac{\omega}{p_1}\right) \quad (2.1.1.2)$$

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From the plot,

$$-45^\circ = -\tan^{-1}\left(\frac{0.1}{0.1}\right) - \tan^{-1}\left(\frac{0.1}{10}\right) - \tan^{-1}\left(\frac{0.1}{p_1}\right)$$

(2.1.1.3)

$p_1$  is approximately 1, i.e., for  $p_1$  in 0.95 to 1.05 the  $\phi$  is approximately equals to  $-45^\circ$ .

2.1.2. Find the value of  $p_1$  using bode phase plot properties.

**Solution:** In asymptotic Bode plot for a single pole, the phase at pole is  $-45^\circ$  and the phase changes from 0 to  $-90$  in 2 decades i.e., from  $pole/10$  to  $10 \times pole$ .

Adding the bode phase plots corresponding to the 0.1, 10.

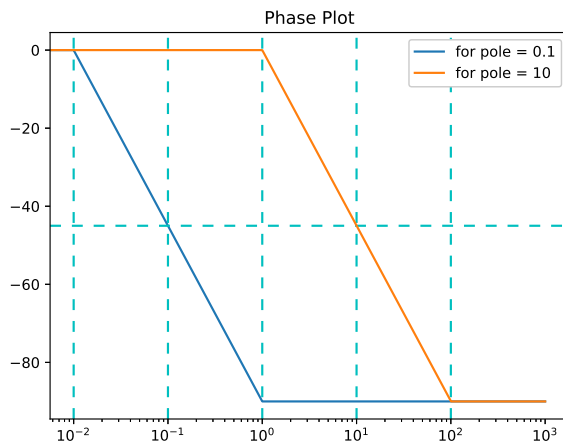


Fig. 2.1.2

The values before the 0.1 does not change when compared to figure 2.1.1, so  $p_1/10$  is greater than or equal to 0.1.

In the plot obtained by adding these two plots the slope at 0.1 doesn't change, but in figure 2.1.1 there is a change so  $p/10 = 0.1$

$$\Rightarrow p_1 = 1 \quad (2.1.2.1)$$

## 2.2 Example

### 3 SECOND ORDER SYSTEM

#### 3.1 Damping

#### 3.2 Example

### 4 ROUTH HURWITZ CRITERION

#### 4.1 Routh Array

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### 5 STATE-SPACE MODEL

#### 5.1 Controllability and Observability

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