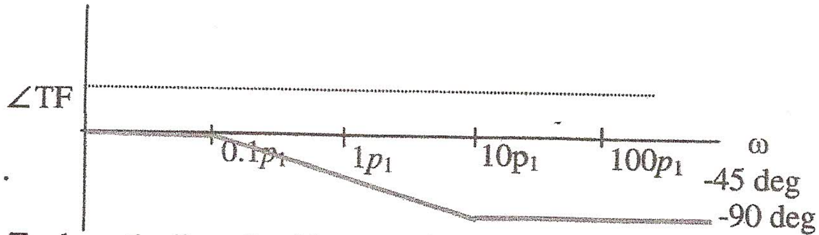
Effect of Poles not at the origin on Phase Angle:

Poles not at the origin, like $\dfrac{1}{\left|1+\dfrac{j\omega}{p_1}\right|}$, have no phase shift for frequencies **much lower** than p_1, have a -45 deg shift at p_1, and have a -90 deg shift for frequencies **much higher** than p_1.



To draw the lines for this type of term, the transition from 0° to -90° is drawn over 2 decades, starting at $0.1p_1$ and ending at $10p_1$.

When drawing the phase angle shift for **not-at-the-origin zeros and poles,** first locate the break frequency of the zero or pole. Then start the transition 1 decade before, following a slope of ±45° /decade. Continue the transition until reaching the frequency one decade past the break frequency.

SUMMARY OF STRAIGHT-LINE APPROXIMATION PROCEDURE STEPS(NO COMPLEX):

(Note that a decade is a **multiple** of 10 – 1,10,100,1000,etc)

1. Rearrange the equation into standard form:

$$H(s)=\frac{Kz_1z_2\cdots(s/z_1+1)(s/z_2+1)\cdots}{p_1p_2\cdots(s/p_1+1)(s/p_2+1)\cdots}$$

where K, z_1, z_2, etc are all constant values.

2. Determine the poles and zeros.

*Note: If there are more than one poles/zeros at the same break frequency(say there are r), just multiply the slope/phase changes by r. (ex. $(1+s/10)^2$ => it is a negative zero(numerator) and so it will change the slope by 2*20dB/dec and have a 2*45°slope/dec.*

3. Draw the magnitude plot:

   a. Determine starting value:

   Case 1: No pole or zero at the origin:

   $$\text{starting value} = 20\log_{10}\left(\frac{Kz_1z_2\cdots}{p_1p_2\cdots}\right)$$

   Case 2: A pole or zero at the origin:

   - Pick a frequency value less than the lowest pole or zero value.

- Plug in the frequency in the standard form equation above and take the magnitude. *This value is for that frequency only.* There is a constant slope going through this point. +20dB/dec slope if the location is a zero. -20dB/dec slope if the location is a pole.

b. Begin at the starting point. Start with the slope (0 slope if a constant, +20dB/dec slope if zero at origin, -20dB/dec slope if pole at origin). From left to right, at each zero add +20dB/dec to the current slope and at each pole -20dB/dec. Continue through each frequency.

4. Draw the phase plot:

a. Determine the starting value:

Case 1: No pole or zero at the origin:

If constant>0 then starting value = 0°

If constant<0 then starting value = ±180°

Case 2: A pole or zero at the origin:

starting value = +90° if zero at origin

starting value = -90° if pole at origin

b. Label each range of frequency according to the following(suggest putting on graph):

zero => from 1 decade before frequency to 1 decade after frequency: +45°slope/dec

pole => from 1 decade before frequency to 1 decade after frequency: -45°slope/dec

(eg if ω=10 and is a pole then range is $1<\omega<100$ with a slope of -45°slope/dec)

c. Look at each frequency range that has a slope. Add all slopes within that region. From left to right: start with starting value and slope of 0, continue until first region of change. Add all slopes within that region. Continue until the end is met. If no slope during a region the slope is constant (0).

Example

$$H(s) = \frac{100(s+100)(s+10)}{s^2(s+10K)}$$