Mechanical Control Systems (ME 4473)

Recitation - 9

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(Students are advised to actively use matlab during the Recitation session)

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1. **Agenda:**
    - Revision
    - Problems(Routh Hurwitz Criterion)

2. **Questions:**

    Bode Basics:

    - **What information does a Bode Plot provide?**
    - **Why do we look at a Gain and Phase plot in a Bode plot?**
    - **Magnitude equation for Bode Plot**
    - **What are the factors that we individually evaluate during the construction of a Bode Plot?**
        - ……………………..
        - ……………………..
        - ……………………..
    - **Fill in the blanks:**
        - A unit change in …………….in the rectangular coordinate system = 1 dec of variation in w in semi log coordinates.
        - Number of ……….. between two frequencies = $\log_{10}(w_2/w_1)$

Properties of Transfer Function Components:

- **How does a constant gain affect the Bode Plot?**
  Magnitude:
  Phase:

- **How do poles/zeros at origin affect the Bode Plot?**

  Magnitude:

  Phase:

  (Zero makes the signal lead ahead, pole makes the signal lag behind)

- **How do complex conjugate poles/zeros affect the Bode Plot?**
  Magnitude:

  Phase:

Bode Plot & Stability:

- **What happens in Magnitude & Phase Plot at the corner Frequency?**
  Magnitude:

  Phase:

  (Total Phase change occurs within the 2 decades: one before and one after the corner frequency)

- **Gain crossover point:**

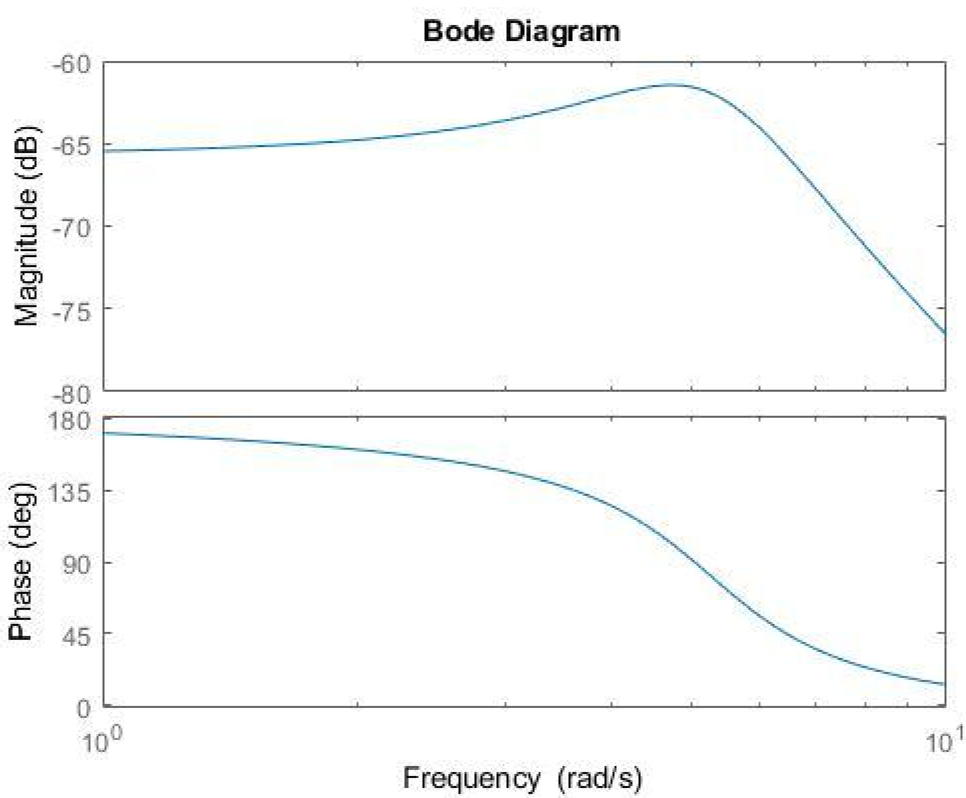
- **Gain Margin & Phase Margin:**
  - Gain Margin is measured ………….. from freq axis

  - Phase margin is measured …………….from deg = 180^0 axis.

- Matlab code for the Bode plot:....................

For a magnitude plot below, label:

1. Maximum Magnitude(M_{pw})
2. Resonant frequency(w_r)



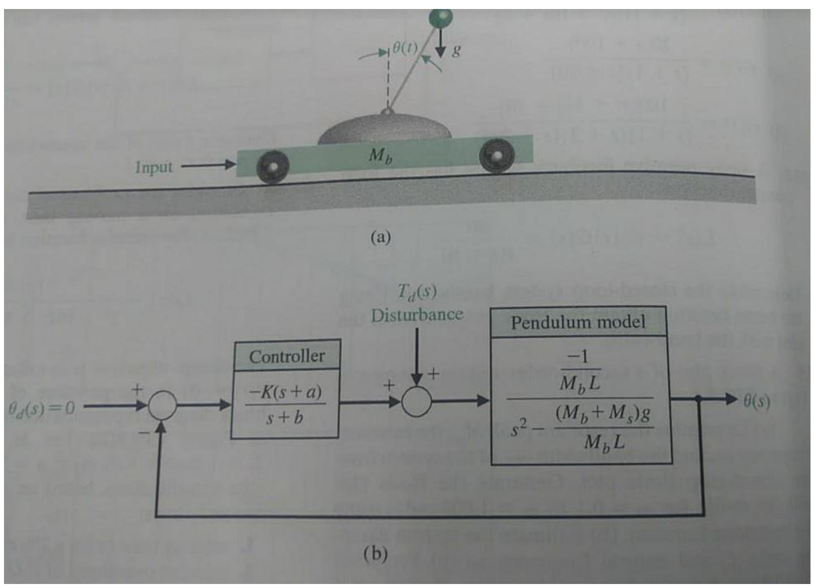
3. **Problems:**

CP8.8 Consider a problem of controlling an inverted pendulum on a moving base, as shown in the fig below:

a. **The transfer function of the system is:**

$$G(s) = \frac{-1/(M_b L)}{s^2 - (M_b + M_s)g/(M_b L)}.$$

The design objective is to balance the pendulum (i.e. Θ(t) ≈ 0) in the presence of disturbance inputs. A block diagram of the system is given below.



b. **Let M_s = 10kg, M_b = 100 kg, L = 1m, g = 9.81m/s^2, a = 5 and b = 10. The design specifications, based on the unit step disturbance are :**
   i. **Settling time(with 2% criterion) of $T_s \leq 10$ s**
   ii. **Percentage overshoot ≤ 40% &**
   iii. **Steady-state tracking error less than 0.1^0 in the presence of disturbance**

c. **Using the information provided above, compute:**

i. **Closed-Loop transfer function from disturbance to the output with K as an adjustable parameter.**

ii. **Range of K that will satisfy the steady state output requirement**

iii. **Expression to compute output maximum magnitude(M_{pw}) and resonant frequency(w_r) using equations (8.36) and (8.37)**

d. Write a matlab code to evaluate:

i. Closed-Loop transfer function from disturbance to the output with K as an adjustable parameter. Bode Plot of the closed loop system
@Matlab

ii. Automatically compute and output maximum magnitude(M_{pw}) and resonant frequency(w_r)
@Matlab

e. If the performance specification is not satisfied, change K and iterate the design using the first two scripts. For the third script:

i. Plot the response Θ(t) to a unit step disturbance with K as an adjustable parameter
@Matlab

ii. Label the plot properly
@Matlab

Bibliography:

- **Dorf, Modern Control Systems, 13th ed**