MKT3822 – LAB 3 UYGULAMA 3 (APPLICATION 3)

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Açıklamalar (Instructions)

- Uygulama raporları dersin Classroom grubu üzerinden teslim edilecektir. (Application reports will be delivered through the Classroom group of the course.)
- Uygulama raporu tamamen Word üzerinde hazırlanmalıdır. Herhangi bir el yazısı eklenmemelidir. Denklemler ve türetmeler Word'ün denklem editöründe yapılacaktır. (Application report should be prepared completely on Word. Any handwriting should not be added. Equations and derivations must be made in the equation editor of Word.)
- Rapor **pdf** formatında teslim edilecektir. (The report should be submitted in **pdf** format.)
- Raporlar için verilen Word dosyası sayfaları silinmeden kullanılmalıdır. (The report must be prepared with given Word template without deletşng any pages.)
- Yüklenecek dosyanın adı için istenen format "**ÖğrenciNumarası_LAB3_GrupNumarası_AR3_İsim-Soyad**"
  (Örnek: "**12067055_LAB3_GR1_AR3_Yusuf-Penseci**")
  (File name must be: "**StudendID_LAB3_GroupNumber_AR3_Name-Surname**")

Puan Kırılacak Durumlar (Important Notes for Evaluation Points):

- **Dosya ismi format dışı olması durumunda puan kırılacaktır. Dosya ismi formata uygun olmaması halinde rapor değerlendirmeye alınmayabilir. (If the filename is out of format, points will be broken. If the file name does not correspond to the format, the report may not be evaluated.)**
- **Rapor dosyası dışında herhangi bir formatta hazırlanan raporlardan puan kırılacaktır. (If the report is prepared without template Word file, points will be broken.)**
- **Denklemler ve türetmelerin denklem editöründe yazılmaması halinde puan kırılacaktır. (If equations and derivatives are not written in the equation editor, points will be broken.)**
- **Raporların teslim tarihinden sonra gönderilmesi halinde puan kırılacaktır. (If the report is sent after the deadline, points will be broken.)**

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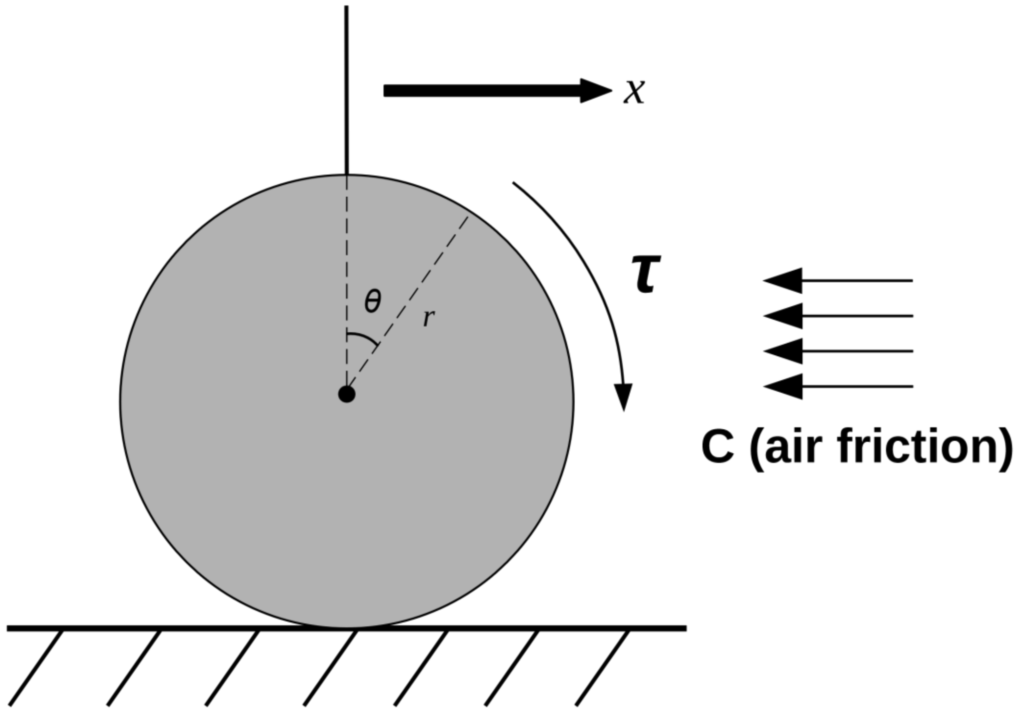

Şekil 1 Tek Tekerlek Modeli (**Figure 1** One Wheel Model)

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1. Kısım (Part 1)

Verilen sistem için hareket denklemlerini yazınız. Transfer fonksiyonu ile durum uzay modelini elde ediniz. (Derive equation of motion for a given system and obtain transfer function and state space representation.)

T is torque:

$$\sum M_o = J_o\ddot{\theta} + C\dot{\theta} = T$$

$$J_o\ddot{\theta} + C\dot{\theta} = T \Rightarrow \ddot{\theta} = -\frac{C}{J_o}\dot{\theta} + \frac{T}{J_o}$$

$$\dot{q} = -\frac{C}{J_o}q + \frac{T}{J_o}, \quad \dot{\theta} = q$$

$$\begin{bmatrix} q' \\ Q' \end{bmatrix} = \begin{bmatrix} -C/J & 0 \\ 1 & 0 \end{bmatrix} \begin{bmatrix} q \\ Q \end{bmatrix} + \begin{bmatrix} 1 \\ 1/J \end{bmatrix} T$$

$$G(s) = K_p + \frac{K_i}{s} + sK_d$$

Closed Loop Transfer Function:

$$C_{cl}(s) = \frac{C(s)G(s)}{1 + C(s)G(s)}$$

$$C_{cl} = \frac{\left(s^2K_d + sK_p + K_i\right)}{s(Js^2 + Cs) + \left(s^2K_d + sK_p + K_i\right)}$$

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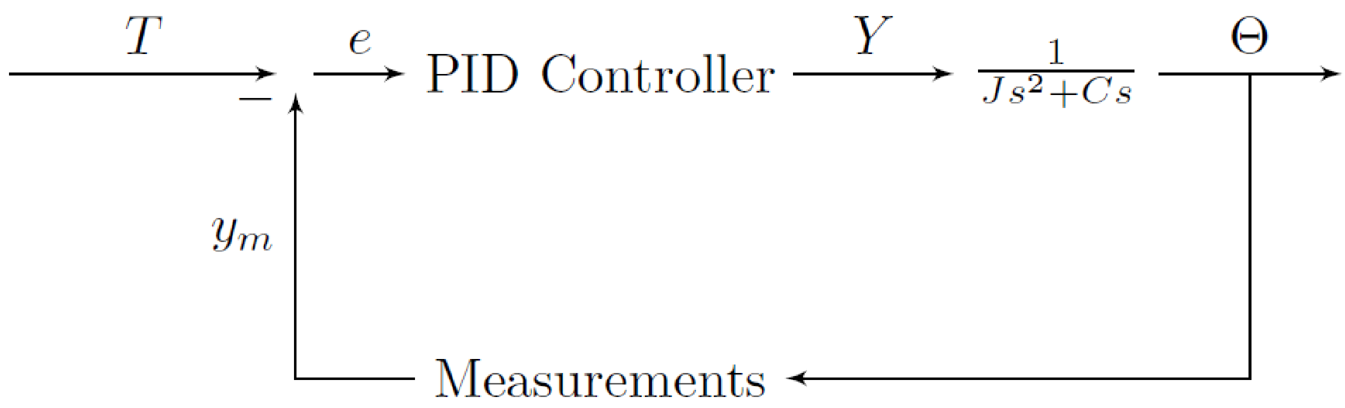
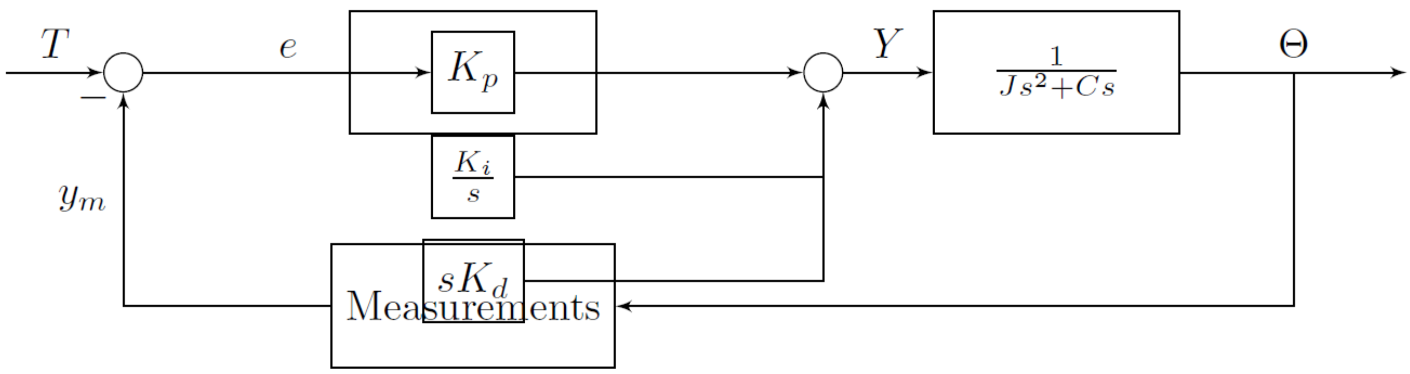
2. Kısım (Part 2)

PID kontrolcü için kapalı çevrim diyagramı çiziniz. (Draw closed-loop diagram for PID controller.)





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3. Kısım (Part 3)

CEselect=$(s+5)(s+10)(s+15)$ sağlayacak uygun PID kontrolcü katsayılarını seçiniz. (Choose proper PID controller coefficient (P,I,D) satisfying that CEselect=$(s+5)(s+10)(s+15)$.)

Given the characteristic equation:

$$s^3 + cs^2 + sK_D + sK_P + K_I = 0$$

or equivalently:

$$s^3 + s^2(C + K_D) + sK_P + K_I = 0$$

Given equation:

$$(s+5)(s+10)(s+15) = 0$$

results in:

$$s^3 + 30s^2 + 275s + 750 = 0$$

Comparing coefficients:

$$J = 1,$$
$$C + K_D = 30,$$
$$K_P = 275,$$
$$K_I = 750$$

with solutions for the PID controller parameters:

$$\boxed{K_P = 275, \quad K_I = 750, \quad K_D = 30 - C}$$

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4. Kısım (Part 4)

Kapalı çevrim sistemin simülasyonunu yapınız ve cevabını gösteriniz. (Simulate the closed-loop system and show the response of it.)

Note: Take reference signal as

$$\boldsymbol{r(t) = 5 + 2sin(2\pi ft)}$$

With f = 0.1 Hz

```
J = 1;        % Moment of inertia

C = 30;       % Damping coefficient

Kp = 275;     % Proportional gain

Ki = 750;     % Integral gain

Kd = 0;       % Derivative gain (Kd = 30 - C)

% Transfer functions

Gp = tf(1, [J, C, 0]);       % Plant dynamics: 1 / (Js^2 + Cs)

Gc = pid(Kp, Ki, Kd);        % PID controller

% Closed-Loop system

Gcl = feedback(Gc*Gp, 1);

% Reference signal: r(t) = 5 + 2sin(2πft)

f = 0.1;      % Frequency of sine wave

t = linspace(0, 100, 1000); % Simulation time

r = 5 + 2*sin(2*pi*f*t);    % Reference signal

% Simulate the system response

[y, t] = lsim(Gcl, r, t);
```

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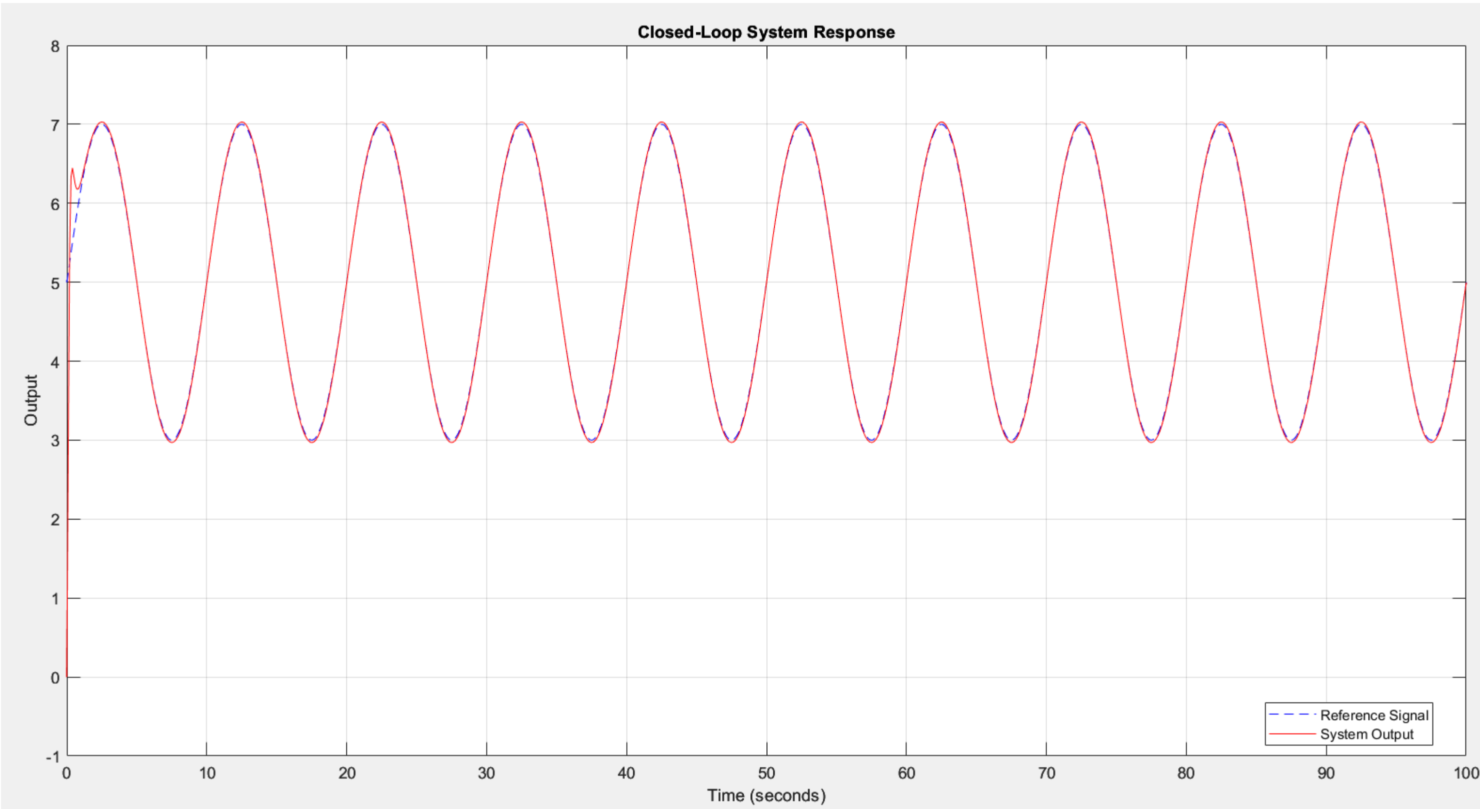
```
figure;

plot(t, r, 'b--', t, y, 'r-');

xlabel('Time (seconds)');

ylabel('Output');

title('Closed-Loop System Response');

legend('Reference Signal', 'System Output', 'Location', 'Best');

grid on;
```



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Initial Response

Overshoot: The system's initial response to the step change from 0 to 5 (as part of the sinusoidal input) might overshoot the set point depending on the aggressiveness of the PID controller, particularly the proportional and derivative gains.

Settling: After the initial overshoot, the system will settle towards the set point. The amount of overshoot and the settling time are influenced by the PID gains.

Steady State

Tracking: The output will attempt to track the reference signal as closely as possible. The effectiveness of this tracking is dependent on the tuning of the PID controller.

Stability: A well-tuned PID controller will result in a stable output that closely follows the sinusoidal reference signal with minimal steady-state error.

Phase and Amplitude

Phase Lag: There might be a phase lag between the reference and the output signals due to the dynamics of the system and the effect of integral and derivative control actions.

Amplitude Accuracy: The amplitude of the output signal should closely match the amplitude of the reference signal if the PID controller is effectively compensating for the dynamics of the system.