# UNIVERSITY OF RUHUNA

## Faculty of Engineering

End-Semester 6 Examination in Engineering: December 2015

**Module Number: ME 6319** **Module Name: Automatic Control Engineering (Old Curriculum)**

**[Three Hours]**

[Answer **all questions**, each question carries 10 marks]

Q1. a) Consider the quarter car model shown in the Figure Q1(a). The spring $k_1$ represents a tyre and the spring $k_2$ and $c$ represents the shock absorber. The mass of the quarter car is $m_2$ and that of the tyre is $m_1$. Assuming that the input displacement as the road surface variation given by $r$, find the transfer function of the model $Y(s)/R(s)$.

[6.0 Marks]

b) Find the transfer function, $E_o(s)/E_i(s)$ of the cascade circuit shown in Figure Q1(b).

[4.0 Marks]

Q2. It is important to ensure passenger comfort on ships by stabilizing the ship's oscillations due to waves. Most ship stabilization systems use fins or hydrofoils projecting into the water to generate a stabilization torque on the ship. A simple block diagram of a ship stabilization system is shown in Figure Q2. The rolling motion of the ship can be regarded as an oscillating pendulum with a deviation from the vertical of $\theta$ degrees. The transfer function of a typical ship is given as follows with $\omega_n = 3$ rad/s and $\zeta = 0.20$.

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

Obtain the open-loop response for a step-disturbance and determine the peak overshoot and oscillation period.

[10.0 Marks]

Q3. A control system for an automobile suspension tester has negative unity feedback and a process

$$G_c(s)G(s) = \frac{K(s^2 + 4s + 8)}{s^2(s + 4)}$$

We desire the dominant roots to have $\xi$ equals to 0.5. Using the Root Locus, show that $K$=7.35 is required and the dominant roots are $s = -1.3 \pm j2.2$.

[10.0 Marks]

Q4. Figure Q4 shows a speed control system where the wheel and motor dynamics is given by;

$$G_P(s) = \frac{s+6}{(s+2)(s+4)}$$

A controller is designed as;

$$G_C(s) = \frac{K}{s+9}$$

For a unit step-input, under no external disturbances, it is desired to have the steady-state speed within 5% of the desired speed (steady-state error should be 5%). Determine the required gain $K$ to achieve the steady-state requirement. For this gain, determine the steady state error for unit step disturbance ($T_d = 1/s$) when $R(s) = 0$.

[10.0 Marks]

Q5. A robot arm has a joint-control loop transfer function

$$G(s)H(s) = \frac{300(s+100)}{s(s+10)(s+40)}$$

Sketch an approximated Bode diagram and indicate phase and gain margins. Discuss about the stability of the closed-loop system.

[10.0 Marks]

Q6. Obtain the Polar plots for the systems represented by following functions.

a) $$G(s) = \frac{1}{s(s+1)(s+2)}$$

[5.0 Marks]

b) $$G(s) = \frac{1}{s(s+1)^2}$$

[5.0 Marks]

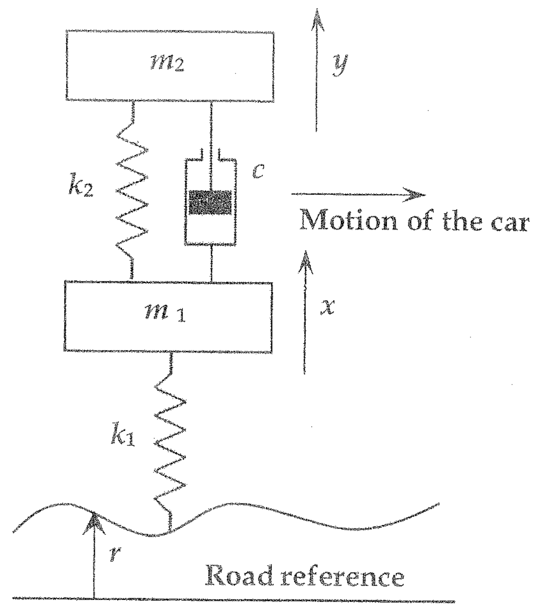



Figure Q1 (a)

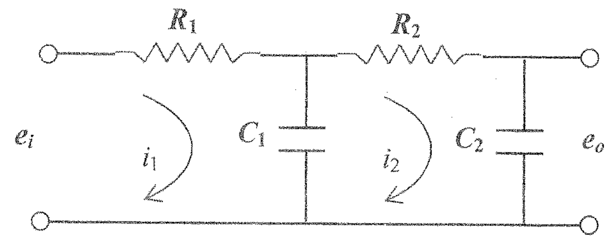
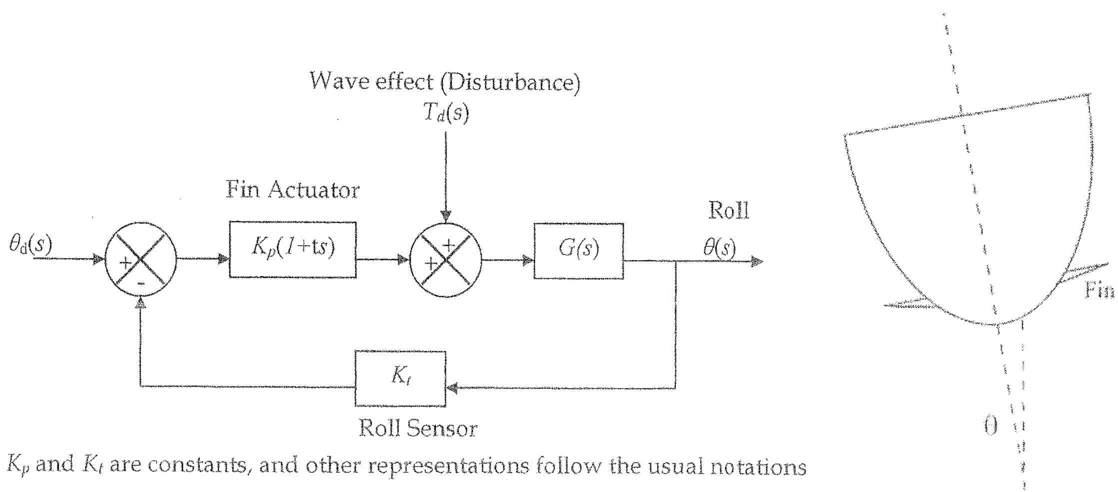



Figure Q1 (b)




$K_p$ and $K_t$ are constants, and other representations follow the usual notations

Figure Q2

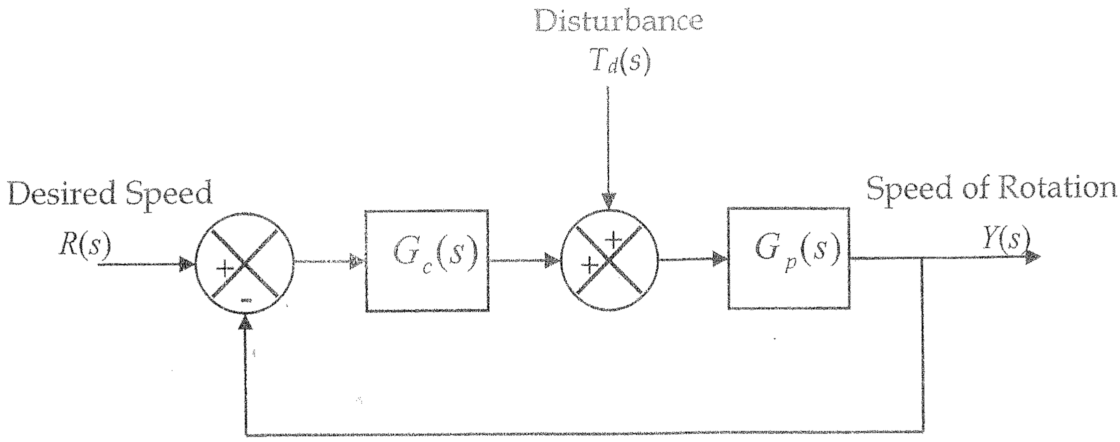

Disturbance
$T_d(s)$
Desired Speed
$R(s)$
+
$G_c(s)$
+
+
$G_p(s)$
Speed of Rotation
$Y(s)$

**Figure Q4**