系所組別：製造資訊與系統研究所甲組
考試科目：自動控制　考試日期：0223，節次：2

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1. (25%)

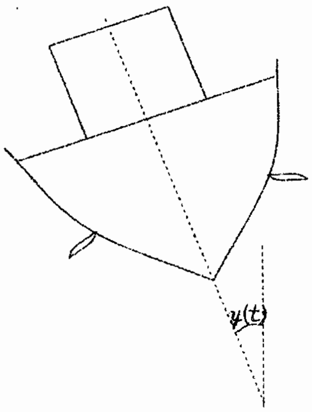
It is important to ensure the passenger comfort on ships by stabilizing the ship's oscillations due to waves. Most ship stabilization systems use fins to generate a stabilization torque on the ship, see figure below. The output signal is the angle *y(t)* and the control signal *u(t)* is the torque generated by the fins. The block diagram is given below.

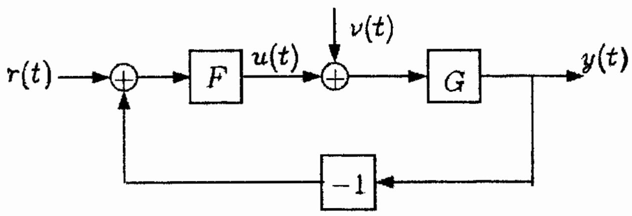
The transfer function for a given ship is $G(s)=\dfrac{9}{s^2+1.2s+9}$

(1) (10%) Suppose that the oscillations are to be controlled using a P-controller $u(t)=K(r(t)-y(t))$ where *r(t)* is the desired angle. How do the poles of the closed loop system depend on K > 0? Draw a root locus! Describe qualitatively how the step response for the closed-loop system depends on K > 0 (stability? speed? oscillations?).

(2) (10%) Suppose that the reference signal $r(t)=0$, that is, the desired angle for the ship is zero. What is the transfer function from the wave effect *v(t)* to the angle *y(t)*? Suppose that the wave disturbance can be described as a step disturbance with amplitude *a*. What is the angle *y* in stationarity?

(3) (5%) State a control structure so that the angle *y* will be zero in stationarity even if there is a step disturbance.





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2. (25%)

Assume the open-loop transfer function of a unit-feedback is,

$$G(s) = \frac{K(s+2)}{s(s-1)}.$$

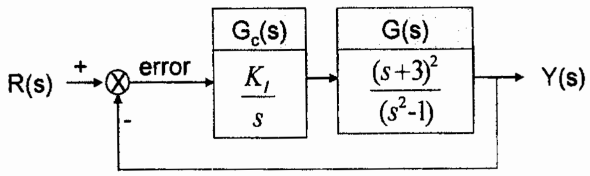
(1) (10%) Sketch the corresponding complete Nyquist plot.

(2) (5%) Determine the angular frequency and the point that the Nyquist plot intersects the real axis.

(3) (10%) Based on the Nyquist plot obtained above, determine the range of K such that the closed-loop system is stable.

3. (25%)

Given a plant $G(s)$ and its closed-loop block diagram with controller $G_c(s)$ shown below,



(1) (10%) Draw the Nyquist diagram and use Nyquist stability criterion to determine the range of K_I such that the closed-loop system is stable.

(2) (10%) Assume that you design a controller with $K_I = 2$, please draw the Bode diagram of the open loop $Gc(s)G(s)$ in the frequency interval 0.1~100 (rad/s).

(3) (5%) Continue (2); now, you are asked to implement your controller with hardware which will result in a pure time delay "T". Please find the range of T such that the closed-loop system is still stable. *(note: the gain cross over frequency in (b) is 3.3 (rad/s))*

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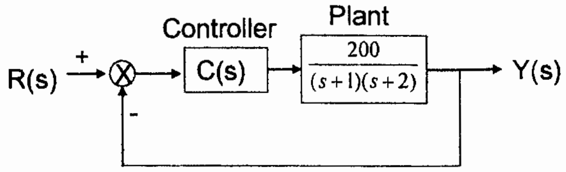
4. (25%)

Consider the closed-loop control system shown below



(1) (5%) For C(s) = 1, verify that the system is stable and find the steady-state error for the following inputs. (i) unit step (ii) unit ramp

(2) (5%) Repeat (1) when C(s) is a PI controller, with C(s) = 1 + 0.1/s

(3) (5%) Compare (1) and (2) to show that how the PI affect the steady-state error.

(4) (5%) Compare the damping ratio, ξ, of the closed-loop system when C(s) = 1 (P controller) and C(s) = 1 + 0.1s (PD controller)

(5) (5%) What is the effect of the derivative term in the PD controller on the settling time, t_s, of the system? Justify your answer by comparing the settling time in (d). Use $t_s = \frac{4}{\xi\omega_n}$. ($\omega_n$ is the natural undamped frequency)