BIRLA INSTITUTE OF TECHNOLOGY & SCIENCE, PILANI (RAJASTHAN)
FIRST SEMESTER 2007-2008

AAOC C321 Control Systems
Comprehensive Examination (Closed Book)
Part- A and B

Date 08-12-2007 **Total Time: 3 Hrs** **Max Marks: 120**

Part- A

Time: 1 Hr. **Maximum Marks: 30**

NOTE: (i) Number of questions: 22
(ii) Number of blanks : 30
(iii) Each blank carries one mark.

Name: Sample Solution **ID No:** ________ **Sec. No.**

Q.1 Lumped parameters are characterized by differential eqn (differential eqs. / partial differential eqs.)

Q.2 System described by equation Y= $\frac{d^2x}{dt^2} + \frac{dx}{dt} + 7\sqrt{x}$, where X is input and Y is output is a Non linear TIV system (Non linear/linear and Time variant/invariant).

Q.3 In an ideal position control servo mechanism, back emf constant is numerically equal to Torque constant.

Q.4 For a unity negative feedback system, forward path gain is K/(s+9). Sensitivity of the system, in case of open loop and closed loop to small changes in K (K = 0.4) at ω= 1 rad/s is 1 and 0.958 ≈ 0.96 (But ≠ 1) respectively.

Q.5 In Q.4, if required time constant for closed loop system is 10 ms then the value of K and corresponding steady state gain is 91 and 0.91 respectively.

Q.6 If a first order system works in open loop mode, its steady state gain and the speed of response is high and Low or (sluggish) respectively, as compared to closed loop mode.

Q.7 A 6-stack stepper motor has 15 numbers of teeth if the angular displacement between stacks of stator teeth is 4° (assuming, stack rotor teeth aligns with its stator).

Q.8 In Synchro transmitter, at some position of its rotor, the voltage in one coil is maximum while across other two is zero, this position of the rotor is known as Electrical Zero and the same name is given to the control transformer rotor position if the rotors of synchro pair are at 90°.

Q.9 The Hydraulic actuator will work as an ideal integrator if leakage and Compressible flow are negligible. (compressible/turbulent)

Q.10 For the same horse power, hydraulic actuators are lighter than electrical motors. (lighter/heavier)

PTO

FD NB

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Q.11 Out of Pneumatic and hydraulic systems, which one has shorter response time? hydraulic systems.

Q.12 The Un damped step response of a second order system oscillates with constant frequency and magnitude.

Q.13 The response of a system for step input of 4 unit is $(1-e^{-4t})t\ u(t)$. If this system is excited by a input of $e^{-5t}\ u(t)$, the steady state value of the response is 0.05 or $\frac{1}{20}$ unit.

Q.14 The addition of only a zero in the closed loop transfer function results in reduced rise time and increased peak over shoot.

Q.15 For the system shown in Fig Q. 15, value of position error coefficient is ∞ and acceleration error coefficient is 5.

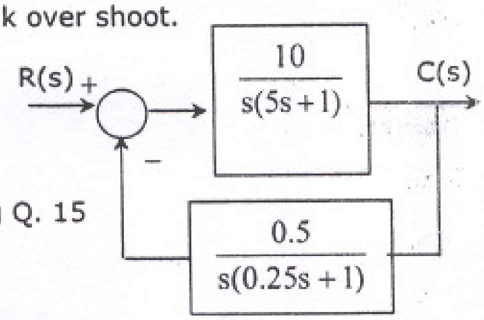

Fig Q. 15

Q.16 The open loop transfer function of a negative feedback system is $K/[(s+1)(s+3)]$. The range of K for which system exhibits the overdamped response, is $0 < K < 1$.

Q.17 The characteristic equation of a negative feedback system is $s^3 + 4s^2 + 5s + K = 0$. The range of K for system to be stable is $0 < K < 20$.

Q.18 For a system to be stable, the gain at phase cross-over frequency should be less than Zero db.

Q.19 The transfer function of a compensation network is $(s+5)/(s+0.5)$, this represents a lag network. (lead/lag)

Q.20 The maximum phase lead required from a lead network is 30°. The value of α (or a) is $\frac{1}{3}$ or 0.333.

Q.21 The frequency plot of a system is given in Fig Q.21. The gain margin is 7.96 ≈ 8 db and phase margin is 70°.

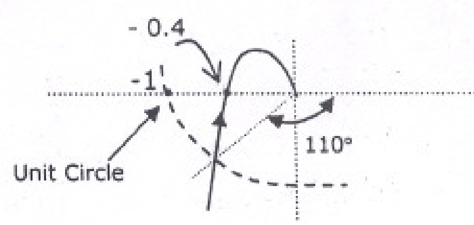

Fig Q.21

Q.22 In a compensation network, the zero location is at -0.5 and at dc frequency the network provides an attenuation of 14 db. The location of compensatory pole is −2.5 and the frequency, at which it provides maximum phase lead is 1.118 ≈ 1.12 rad/s.

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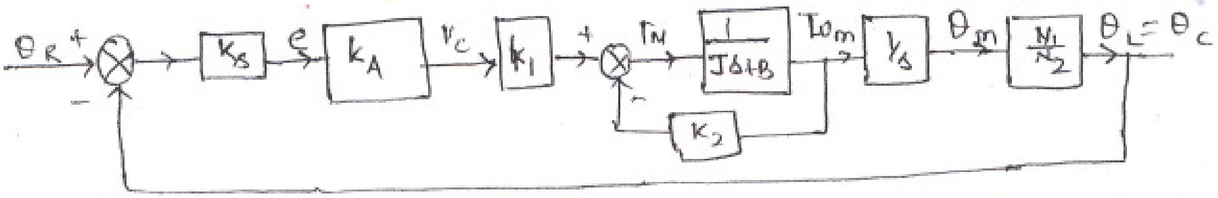
AAOC C321: Control systems; solution of comprehensive Exam I[st] Sem 2007-08

(1)

i) 

(8M)

$K_1 = \frac{5}{50} = 0.1$ Nm/v $\quad K_2 = \frac{5}{100} = .05$ Nm/rad/sec − (4M)

$J = a^2 J_L = 1 \times \frac{1}{4} = 0.25$ kgm^2 & $B_\theta = a^2 B_L = 1$ Nm/rad/s (2m)

ii) $\frac{\theta_L(s)}{\theta_R(s)} = \frac{120}{s^2 + 4.2s + 120}$ (3M)

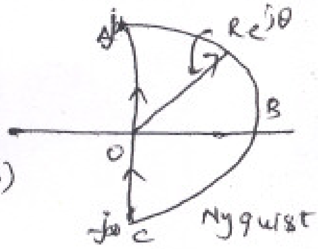
iii) $\theta_L(\infty) = \lim_{s \to 0} \theta_L(s) \Rightarrow 5^\circ = 5 \times \frac{\pi}{180^\circ}$ rad $= \lim_{s \to 0} \frac{m}{s} \times s \times \frac{120}{s^2 + 4.2s + 120} \Rightarrow m = 0.087$ unit (3m)

(2) $G(s)H(s) = \frac{K(1+0.5s)(1+s)}{(1+10s)(s-1)} \Rightarrow P = 1$ & $M(j\omega) = \frac{K(1+0.25\omega^2)^{1/2}(1+\omega^2)^{1/2}}{(1+100\omega^2)^{1/2}(1+\omega^2)^{1/2}}$

$\phi(\omega) = \tan^{-1} 0.5\omega + \tan^{-1}\omega - \tan^{-1} 10\omega - 180° + \tan^{-1}\omega$ (1)

$\omega = 0$; $M(\omega) = K$; $\phi(\omega) = -180°$
$\omega = \infty$; $M(\omega) = K/20 = .05K$; $\phi(\omega) = 0°$ (1)

OA is Polar plot
CO: complex conjugate of Polar Plot
ABC: $s = Re^{j\theta} \Rightarrow R \to \infty$ & θ from $\pi/2$ to $-\pi/2$ (maps with origin)

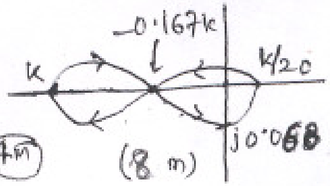


(3M)

R & X:

$R = \frac{K(5\omega^4 - 23\omega^2 - 1)}{(1+\omega^2)(1+100\omega^2)}$ R=0 at $\Rightarrow \omega = 2.15$ & $X = .068$

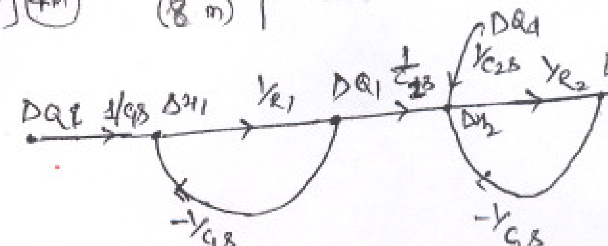
$X = \frac{K(7.5\omega - 19.5\omega^3)}{(1+\omega^2)(1+100\omega^2)}$ X=0 at $\Rightarrow \omega = 0.62$ & $R = -.167$ (4M)



(8 m)

or K>6
$K > \frac{1}{0.167} \Rightarrow K > 5.99$ system is stable (N=1, P=1, so Z=0) (3)

(3) $\Delta Q_i(s) - \Delta Q_1(s) = C_1 s \Delta H_1(s)$
$\Delta H_1 / R_1 = \Delta Q_1$
$\Delta Q_1 + \Delta Q_d - \Delta Q_0 = C_2 s \Delta H_2(s)$
$\frac{\Delta H_2}{R_2} = \Delta Q_0$ (4)



(3m)

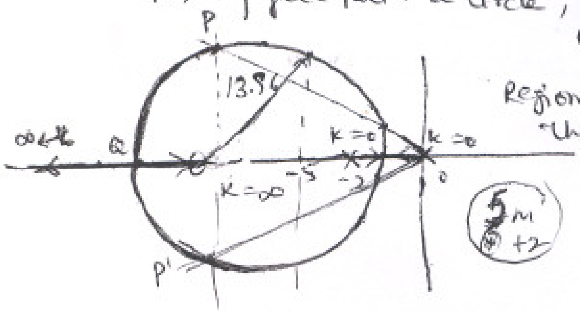
For $\frac{\Delta Q_0(s)}{\Delta Q_d(s)} \Rightarrow P_1 = \frac{1}{R_2 C_2 s}$; $\Delta_1 = 1 + \frac{1}{R_1 C_1 s}$

$L_1 = \frac{-1}{R_1 C_1 s}$; $L_2 = \frac{-1}{R_2 C_2 s}$; $L_1 L_2$ (Nontouching)

So $\frac{\Delta Q_0}{\Delta Q_d} = \frac{P_1 \Delta_1}{1 - (L_1 + L_2) + L_1 L_2} = \frac{1 + R_1 C_1 s}{R_1 R_2 C_1 C_2 s^2 + R_1 C_1 s + R_2 C_2 s + 1}$ (3)

(4) 2 OLP at −2 & origin
1 OLZ at −15

Break. Away pt = −1.0354 (−28.96 is invalid) (2)
Real part of locus between O & −2 and −15 & −∞ (2)
Complex conjugate part is a circle; radius: (13.96)
centre: (−15, 0) (4)



Region PQP' is the reqd region

(5M +2)

$\frac{C}{R} = \frac{K(s+15)}{s^2 + 2s + Ks + 15K}$

$2\zeta\omega_n = 2 + K$; $\omega_n = \sqrt{15K}$

Specification $\Rightarrow \frac{4}{\zeta\omega_n} < 800$ ms $\Rightarrow \zeta\omega_n \geq 5$

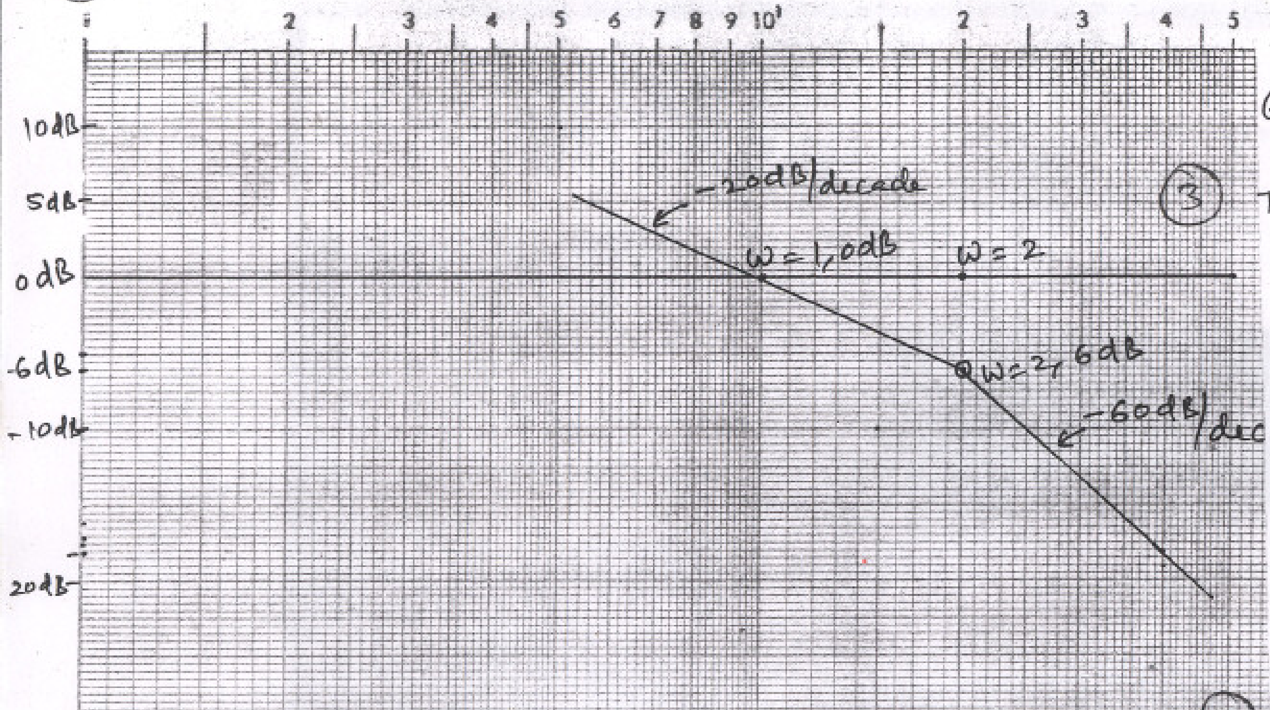
$M_p < 4.32\% \Rightarrow \zeta \geq 0.707$ & $\zeta \leq 1$

Solving we get $K \geq 25.84$ & $K < 55.83$

So range is $25.84 \leq K < 55.83$ (5)

$e_{ss} = \frac{5}{K_v} \Rightarrow \frac{5}{30} = 0.167$ (2M)

(5)



$G(s).H(s) = \dfrac{4K}{s(s^2+2s+4)}$

Time-constant Form: $\dfrac{K}{s\left(\frac{s^2}{4}+\frac{s}{2}+1\right)}$ (1)

Corner Freq = $\omega = 2$ (complex pole) (2m)

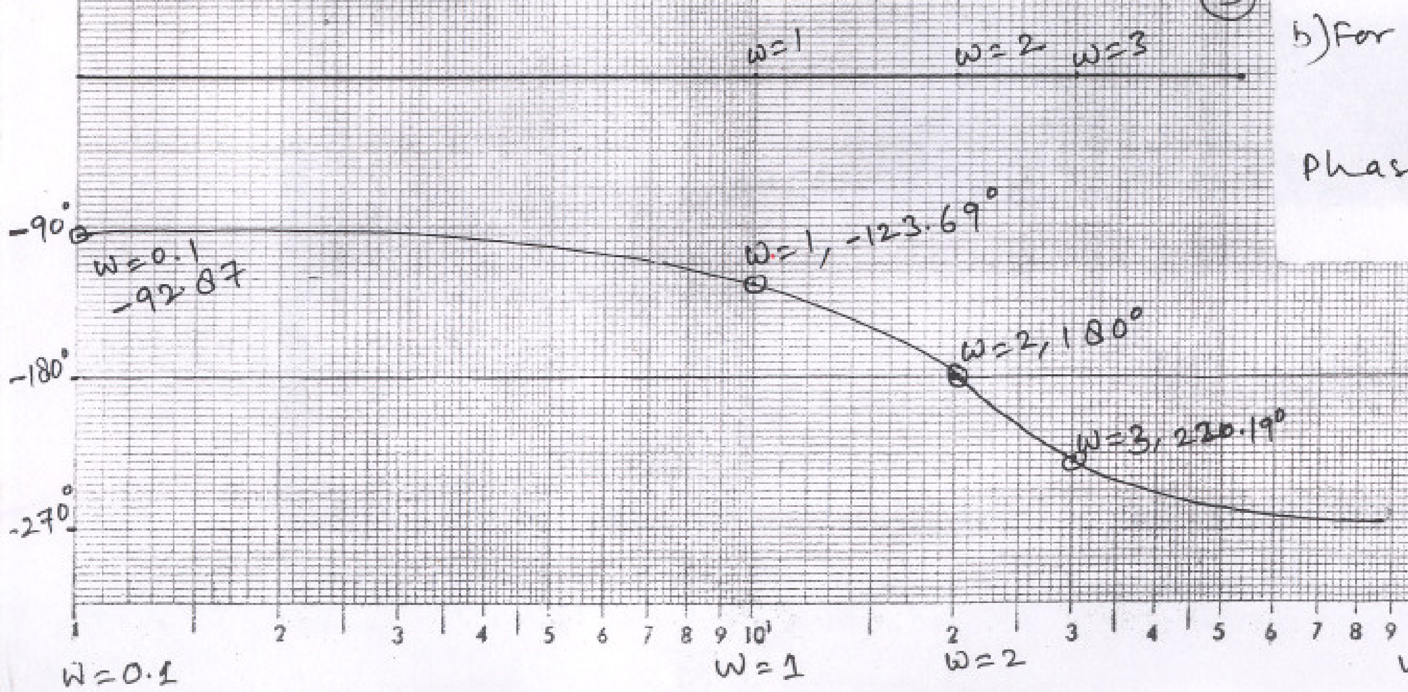
For K = 1, Plot is given

a) For K = 1, PM = 56.31°, GM = 6dB

For Just unstable system, K should be (5m)

b) For 6 dB Gain Margin
K should be "1" (2)

Phase Margin at K = 1, 56.3 (3)
System is Stable. (1)



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