(1) Choose from the followings FIVE correct statements (20%)

(a) It is impossible to improve the tracking performance by an open-loopcontrol system.

(b) It is impossible to achieve disturbance rejection by an open-loop control.

(c) As compare with a P control, a PI controller improves the steady state error at the cost of a smaller damping ratio when the undamped natural frequency of the control system is about the same.

(d) If the control system has two right-half plane zero, then it cause only time delay but no undershoot in step responses.

(e) In a feedback control system, if the plant has a pure integrator and the controller also has a pure integrator, then the steady state error tracking a parabola command is bounded.

(f) A D-term should be introduced into a PID controller when the response speed is too slow.

(g) The PID parameters obtained from the Z-N tuning formula results in an over-damped control system (i.e., $\varsigma > 1$).

(h) The performance of a feedback system is insensitive to plant uncertainty, but sensitive to sensor nonlinearity.

(i) A PI controller pushes the root locus of a control system towards the right-hand-side on the complex plane (as compared with a P control).

(j) An unstable plant may become stable when feedback control is introduced, and the undershoot effect in a plant can be removed by feedback control.

(2) Consider a number of control systems with unity feedback, and let the loop transfer function be L(s) = G(s) D(s), where G(s) and D(s) being, respectively, the plant and the controller, and

$$L(s) = \frac{K(s+1.5)}{s(s-0.5)(s^2+4s+16)}$$

Please calculate and draw its root locus including

[2a] branches on the real axis (3%)

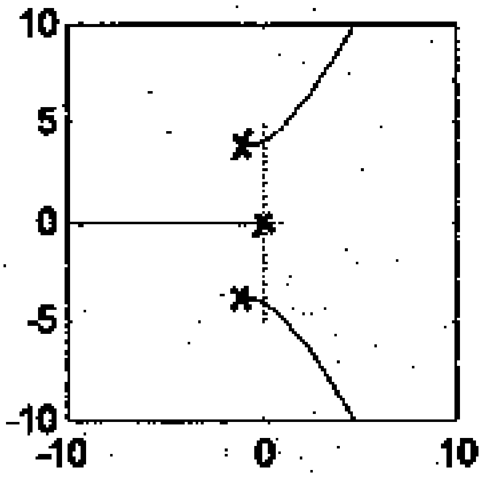
[2b] asymptotic lines which goes to infinity (3%)

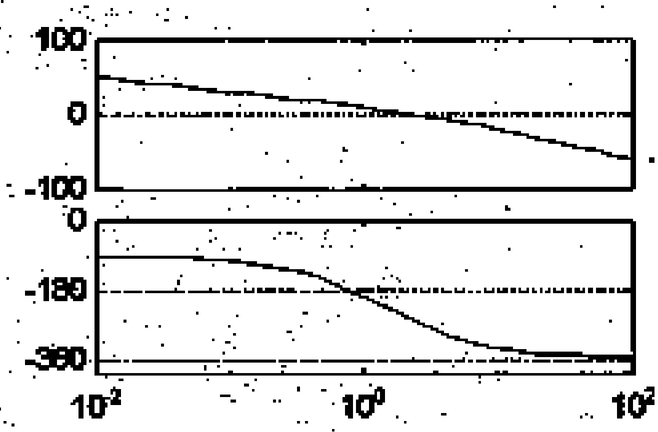
[2c] locations of its intersection points with the imaginary axis (3%)

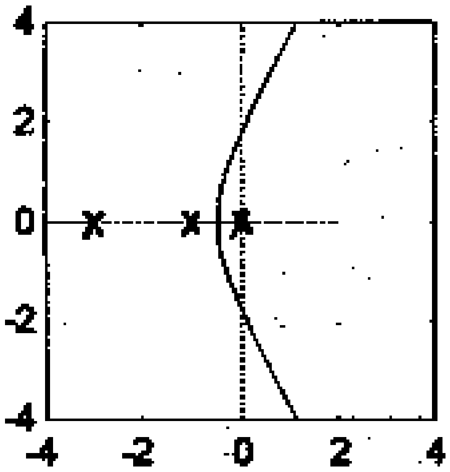
[2d] locations where the root locus departs from or arrives at the real axis (3%)

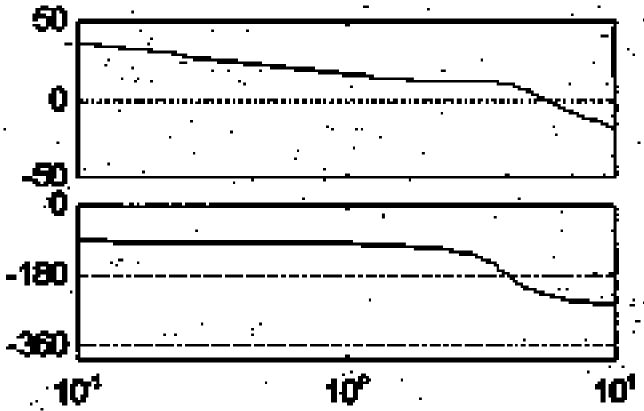
[2e] and sketch the complete root locus. (3%)

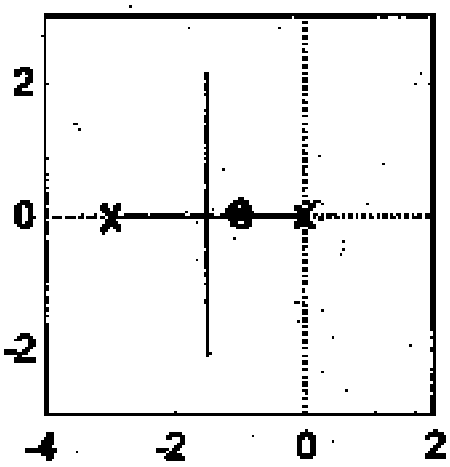
(3) Match the following root locus with correct Bode plots of their associated loop transfer function, all L(s) are stable, and briefly justify your decision. (16%)

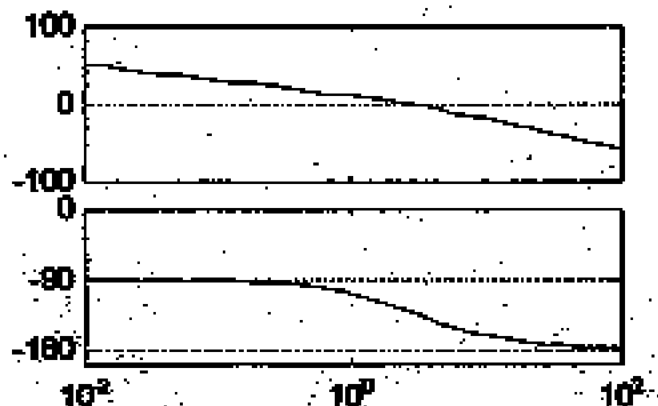

(3-a)

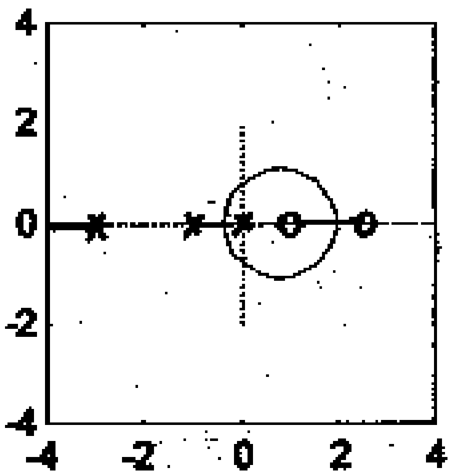

(3-A)

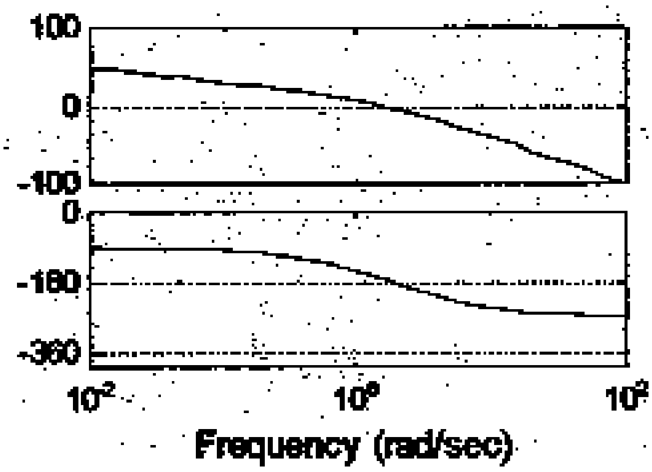

(3-b)


(3-B)


(3-c)


(3-C)


(3-d)



(3-D)

(4) Consider a unity feedback system whose transfer function is:

$$T(s) = \frac{981(s+11)}{(s^2+2s+9)(s+12)(s+100)}$$

Please estimate the rise time t_r, settling time t_s, and percentage overshoot M_P of the system, and the steady state error tracking a unit step command. (9%)

Please notice that some of the aforementioned terms are related to the followings: $4.6/\varsigma\omega_N$, $1.8/\omega_N$, $\exp(-\pi\varsigma/\sqrt{1-\varsigma^2})$.

(5) Consider a system with the state-space equations:

$$\dot{\mathbf{x}} = \begin{bmatrix} 0 & 1 \\ 9 & 0 \end{bmatrix}\mathbf{x} + \begin{bmatrix} 0 \\ 1 \end{bmatrix}u + \begin{bmatrix} 0 \\ 1 \end{bmatrix}d$$

$$y = \begin{bmatrix} 1 & 0 \end{bmatrix}\mathbf{x}$$

where $\mathbf{x} = [x \quad \dot{x}]^T$ is the state vector, u is the input, y is the output, and $d = \sin t$ is a sinusoidal disturbance.

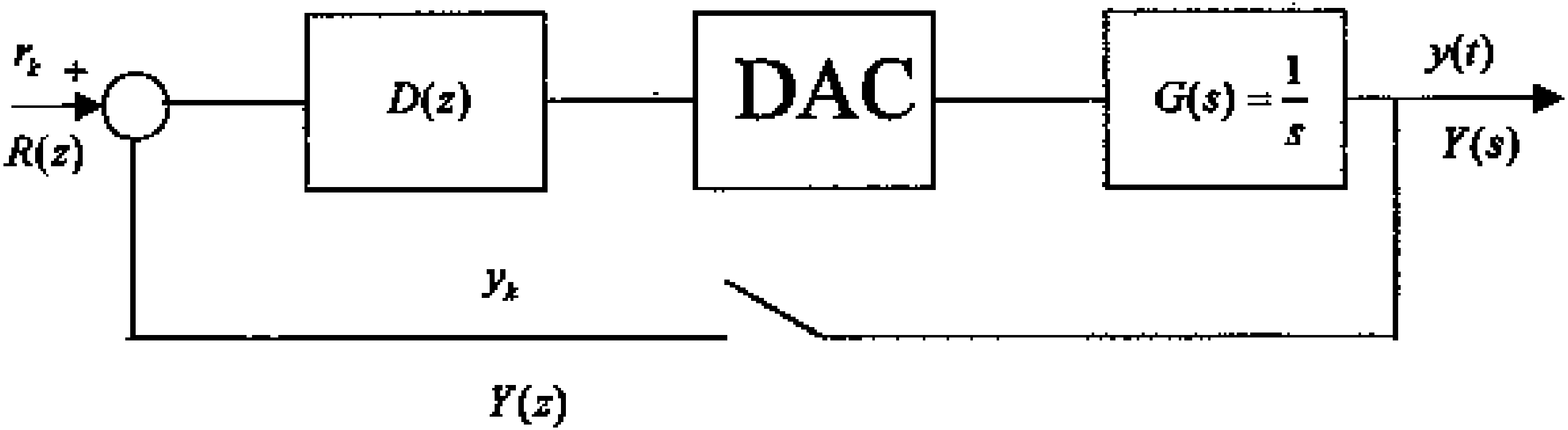
(i) Design a full-state feedback controller so that the closed-loop poles are located at $-5,-5$. Verify that your controller is indeed a PD controller. (6%)

(ii) Obtain the steady-state response of the output when the controller in (i) is applied to the system and the disturbance is present. (4%)

(iii) Design an estimator (observer) to estimate the state vector $\mathbf{x}$ using u and y. The estimator should have poles located at $-20,-20$. (8%)

(iv) Augment a state variable $x_0 = \int x$ to the original state vector and form a new state vector. Rewrite the state-space equations using the new state vector. Also design a full-state feedback controller so that the closed-loop poles are located at $-5,-5,-5$. Verify that your controller is indeed a PID controller. (7%)

(6) In this problem, you will explore the digital control of the integrator ($G(s)=\frac{1}{s}$)



plant shown below.

(i) Assume that you will try to control the plant with a proportional controller $D(z)=K$. Write the discrete-time, closed-loop transfer function $H(z)=Y(z)/R(z)$. (5%)

(ii) What is the closed-loop DC gain of the system? (3%)

(iii) Assume that the sampling period is 0.1 seconds. On the z-plane, draw a root locus plot which shows where the closed-loop poles go as K is varied from 0 to ∞. Can the system go unstable? If yes, for what values of K? (7%)