NAME : ______________________________

ESE 406 - FALL 2010 –FINAL EXAM – Closed Book & Notes

No MATLAB / No Graphing or Symbolic Math on Calculator / No Laptops / No Internet
No Communication of Any Kind with Any Living Thing

- Choose one best answer (A through D) for each question by *circling the letter*.
- A correct answer is worth 2 points.
- No answer is worth 0 points.
- An incorrect answer is worth -1 point. Random guessing will lower your grade (on average).

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1. Which of the following is correct concerning the Nyquist plot for the system shown above?

   A. It is a plot of the real and imaginary parts of $G(j\omega)$ in the complex plane as ω is varied from 0 to ∞.
   B. It is a plot of $|G(j\omega)|$ versus ω.
   C. It is a plot of $\left|\dfrac{G(j\omega)}{1+G(j\omega)}\right|$ versus ω.
   D. It must be rendered in color.

2. Which of the following statements is NOT correct about a system with transfer function $\dfrac{Y(s)}{U(s)} = \dfrac{10(s+5)}{s^2+5s+25}$?

   A. It has a zero at $s=-5$.
   B. It has a pole with damping ratio $\varsigma = 0.5$.
   C. It has a pole with natural frequency $\omega_n = 25$.
   D. The steady-state response to a unit step input is 2 (that is, $\lim_{t\to\infty} y(t) = 2$).

3. If the Laplace transform of a signal is $Y(s) = L\{y(t)\}$, what does $\dfrac{Y(s)}{s}$ represent?

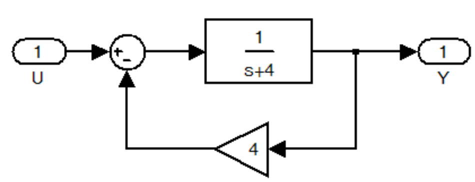
   A. The Laplace transform of $\int_0^t y(\tau)d\tau$.
   B. The Laplace transform of $\dfrac{dy}{dt}(t)$.
   C. The Laplace transform of $t \cdot y(t)$.
   D. None of the above.

4. In the $\mathbb{Z}$-transform of a discrete-time signal, $Y(z) = \mathbb{Z}\{y[k]\}$, what does $z^{-1}Y(z)$ represent?

   A. The $\mathbb{Z}$-transform of $y[k+1]$.
   B. The $\mathbb{Z}$-transform of $y[k-1]$.
   C. The $\mathbb{Z}$-transform of $y[k^{-1}]$.
   D. None of the above.

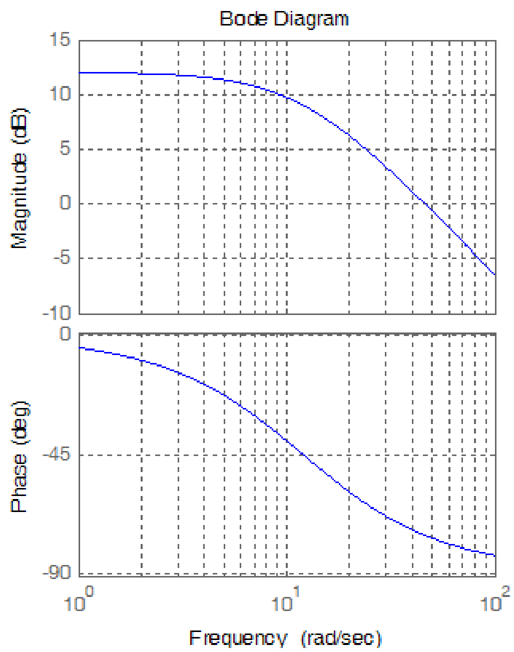
5. Which of the following systems will have an initial slope of 5 (that is, $\lim_{t\to 0^+} \dfrac{dy}{dt}(t) = 5$) in the response to a unit step input at $t=0$?

   A. $\dfrac{Y(s)}{U(s)} = \dfrac{(5s+1)}{s^2+5s+25}$
   B. $\dfrac{Y(s)}{U(s)} = \dfrac{(s+5)}{(s+1)}$
   C. $\dfrac{Y(s)}{U(s)} = \dfrac{5s}{(s+1)}$
   D. None of the above.



6. Which of the following transfer functions corresponds to the block diagram shown above?

   A. $\dfrac{Y(s)}{U(s)} = \dfrac{1}{s+8}$
   B. $\dfrac{Y(s)}{U(s)} = \dfrac{1}{s+16}$
   C. $\dfrac{Y(s)}{U(s)} = \dfrac{4}{s+8}$
   D. None of the above.



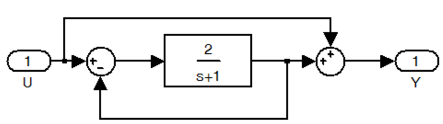
7. The frequency response plot shown above corresponds to which transfer function?

A. $G(s)=\dfrac{12}{s+12}$

B. $G(s)=\dfrac{12}{s+3}$

C. $G(s)=\dfrac{48}{s+12}$

D. None of the above.



8. Which of the following transfer functions corresponds to the block diagram shown above?

A. $G(s)=\dfrac{s+5}{s+3}$

B. $G(s)=\dfrac{s+3}{s+2}$

C. $G(s)=\dfrac{s+2}{s+3}$

D. None of the above.

9. A discrete-time transfer function, $G(z)$, represents a stable system if all of the poles of $G(z)$ are…

A. …inside the unit circle.
B. …outside the unit circle.
C. …on the real axis.
D. …on the imaginary axis.

10. A bode plot for the transfer function corresponding to the differential equation $\dfrac{dy(t)}{dt}=u(t-T)$ has a -180 degree phase crossover at a frequency of 2 Hz. Which of the following is a reasonable estimate of T ?

A. T = 45 seconds
B. T = 0.45 seconds
C. T = 0.125 seconds
D. None of the above.

11. Which of the following is NOT true of the system whose transfer function is $\dfrac{Y(s)}{U(s)}=\dfrac{4}{s-2}$?

A. The steady response to a unit step input is -2 (that is, $\lim_{t\to\infty} y(t)=-2$).
B. The system is first-order.
C. The system is unstable.
D. The response to a unit step will have an initial slope of 4 (that is, $\lim_{t\to 0^+}\dfrac{dy}{dt}(t)=4$).

12. Which of the following is NOT true of a first-order lag compensator?

A. It cannot be effectively implemented with a digital computer.
B. It is often used to improve low-frequency command tracking and disturbance rejection.
C. The phase of the compensator is negative for frequencies that lie between the zero and the pole.
D. It has effects which are similar to PI (proportional-plus-integral) feedback.

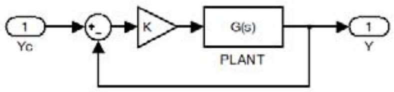
13. If the Laplace transform of a signal is $Y(s)=L\{y(t)\}$, what does $e^{-Ts}Y(s)$ represent?

A. The Laplace transform of $\int_0^T y(\tau)d\tau$.

B. The Laplace transform of $\dfrac{dy}{dt}(t)$.

C. The Laplace transform of $t\cdot y(T)$.

D. The Laplace transform of $y(t-T)$.



14. Which of the following is NOT true of the phase margin for the system shown above?

    A. It can be found from the bode plot of $KG(s)$ at the frequency where the magnitude is 0 db.
    B. It is a measure of stability robustness of the closed-loop system with respect to errors in the phase of the plant model.
    C. It can be found from the Nyquist plot of $KG(s)$ at the point where the plot crosses the negative real axis.
    D. It is typically measured in degrees.

15. A system governed by the differential equation $\dfrac{dy}{dt} = u$. If $y(0) = 0$ and the system is subjected to the input $u(t) = \cos(2t)$, the response will be

    A. $y(t) = t + \sin(2t)$
    B. $y(t) = t + \sin(2t) - \cos(2t)$
    C. $y(t) = \dfrac{1}{2}\sin(2t)$
    D. None of the above.

16. Which of the following is NOT true of the equation $Z = N + P$ with respect to the Nyquist plot of $G(s)$ for the system shown above?

    A. Z is the number of zeros of $G(s)$ that are in the right half-plane.
    B. P is the number of poles of $G(s)$ that are in the right half-plane.
    C. N is the number of clockwise encirclements of -1.
    D. The equation can be rewritten as $N = Z - P$.

17. Laplace Transforms are useful because they…

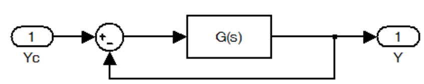
    A. …convert nonlinear equations into linear equations.
    B. …convert differential equations into algebraic equations.
    C. …convert matrix equations into scalar equations.
    D. All of the above.

18. What is the exact relationship between pole locations in the s plane of a continuous time system and pole locations in the z plane of an equivalent discrete-time system?

    A. $z = e^{-Ts}$
    B. $z = e^{Ts}$
    C. $z = \dfrac{-Ts + 2}{Ts + 2}$
    D. None of the above.

19. Which of the following is NOT true with respect to the transfer function $\dfrac{Y(s)}{U(s)} = \dfrac{K\tau s + 1}{\tau s + 1}$, with $\tau > 0$

    A. It is a stable system.
    B. The corresponding differential equation is $\tau \dfrac{dy}{dt} + y = K\tau \dfrac{du}{dt} + u$.
    C. It is a lag compensator if $K > 1$.
    D. It is a low-pass filter if $K = 0$.

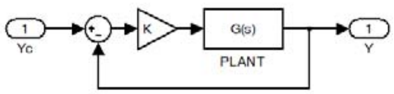


20. If $G(s) = \dfrac{32}{s\left(s^2 + 8s + 16\right)}$, what is a reasonable estimate of the gain margin of the system shown above?

    A. 12 db
    B. 6 db
    C. 3 db
    D. None of the above, because the closed-loop system is unstable.

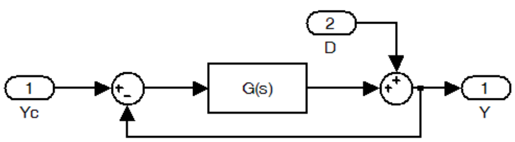
21. Which of the following is NOT a true statement about the Pade approximation for pure time delay?

  A. It is necessary in order to show the effects of time delay on a bode plot.
  B. It is necessary in order to employ the usual methods for constructing a root locus showing the effects of time delay.
  C. It is a rational polynomial transfer function.
  D. It has a zero in the right-half plane.



22. Which of the following is NOT true of the gain margin for the system shown above?

  A. It can be found from the bode plot of $KG(s)$ at the frequency where the phase is -180deg.
  B. It is a measure of stability robustness of the closed-loop system with respect to errors in the gain of the plant model.
  C. It can be found from the Nyquist plot of $KG(s)$ at the point where the plot crosses the unit circle.
  D. It is usually measured in decibels (db).

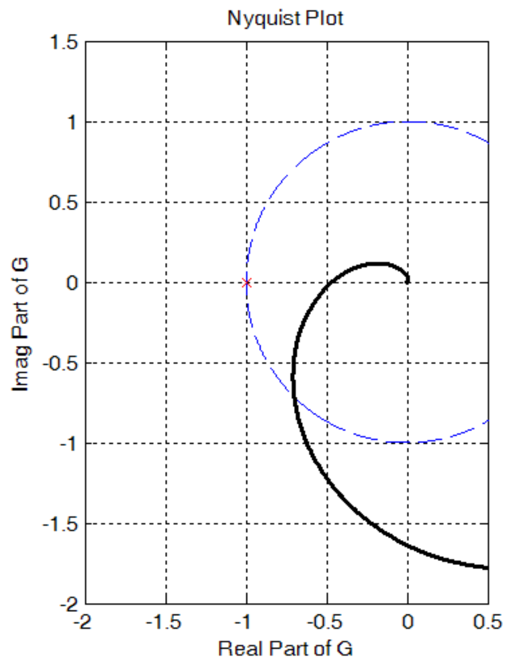


23. The system shown above is closed-loop stable with a phase margin of 60 deg at a frequency of 4 rps and a gain margin of 9 db at a frequency of 8 rps. Which of the following might NOT be true of the closed-loop disturbance rejection frequency response, $H(j\omega) \triangleq \dfrac{Y(j\omega)}{D(j\omega)}$, for this system?

  A. $\lim_{\omega \to 0} H(j\omega) = 0$.
  B. $|H(j\omega)| = 1$ when $\omega = 4$.
  C. $|H(j\omega)| = 1.55$ when $\omega = 8$.
  D. If $\lim_{\omega \to \infty} G(j\omega) = 0$, then $\lim_{\omega \to \infty} H(j\omega) = 1$.

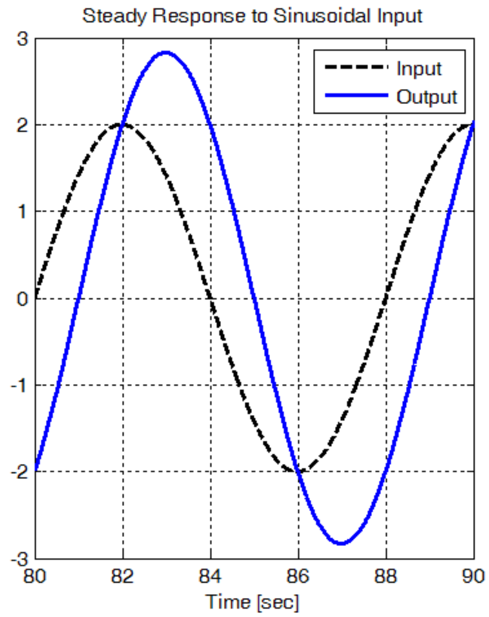
24. Which of the following is NOT correct regarding the differential equation $\dfrac{dy}{dt} = -uy^2 + 4$?

  A. It is a first-order equation.
  B. It is a non-linear equation.
  C. It is readily solved with Laplace Transforms if the initial condition, $y(0)$, is known.
  D. If the constant control $u = 1$ is applied, one possible steady-state solution is $y = 2$.



25. Which of the following is a NOT a valid inference with respect to the Nyquist plot of $G(s)$ for the system whose block diagram is shown above?

  A. The closed-loop system is stable.
  B. The closed-loop system will have an oscillatory mode at a frequency of about 1.7rps.
  C. The gain margin is about 6db.
  D. The phase margin is about 45deg.



26. What is the frequency of the sinusoidal input in the figure above?

    A. About 0.4 rps
    B. About 0.8 rps
    C. About 4 rps
    D. About 8 rps

27. On the bode plot of the transfer function corresponding to the figure above, what is the magnitude at the frequency of this input?

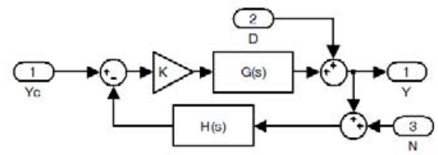
    A. About -9 db
    B. About -3 db
    C. About 3 db
    D. About 9 db

28. On the bode plot of the transfer function corresponding to the figure above, what is the phase at the frequency of this input?

    A. About -90 deg
    B. About -45 deg
    C. About +45 deg
    D. About +90 deg

29. If the system were known to be of the form $G(s) = \dfrac{K}{\tau s + 1}$, what is the value of K?

    A. About 0.1
    B. About 0.5
    C. About 1.0
    D. About 2.0



30. The system shown in the above block diagram will have good disturbance rejection at those frequencies where…

    A. $|G(j\omega)|$ is small.

    B. $|G(j\omega)|$ is large

    C. $|KG(j\omega)H(j\omega)|$ is small.

    D. $|KG(j\omega)H(j\omega)|$ is large

31. The system shown in the above block diagram will have good noise rejection at those frequencies where…

    A. $|G(j\omega)|$ is small.

    B. $|G(j\omega)|$ is large

    C. $|KG(j\omega)H(j\omega)|$ is small.

    D. $|KG(j\omega)H(j\omega)|$ is large

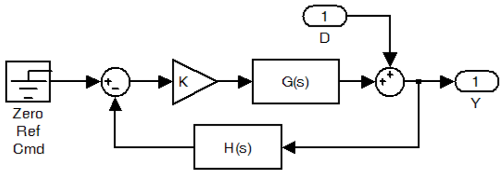
32. Which of the following is NOT true of a “chirp” signal?

    A. It contains energy across a specified range of frequencies.
    B. It must end with an abrupt step to zero to avoid the “Frobenius wave” problem.
    C. It is useful as an input to a system when estimating frequency response from experimental data.
    D. It can be generated in SIMULINK using the chirp node.

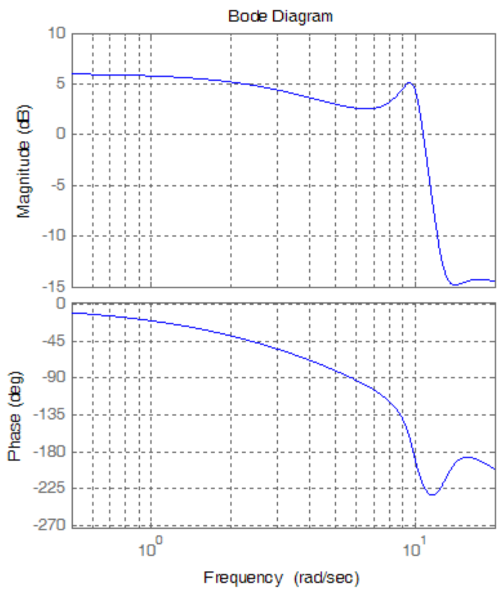
33. Which of the following statements is NOT correct with respect to the Bode gain-phase relationship?

    A. It gives an explicit relationship between the magnitude and phase of minimum-phase systems.
    B. It creates a practical limit on how fast the loop gain can decrease near the 0db crossover frequency without causing poor stability margins.
    C. It creates an upper limit on the magnitude of the loop transfer function at very low frequency.
    D. In contains an integral over frequency.

Consider design of a regulator (feedback designed to reject disturbances and hold the output at zero).



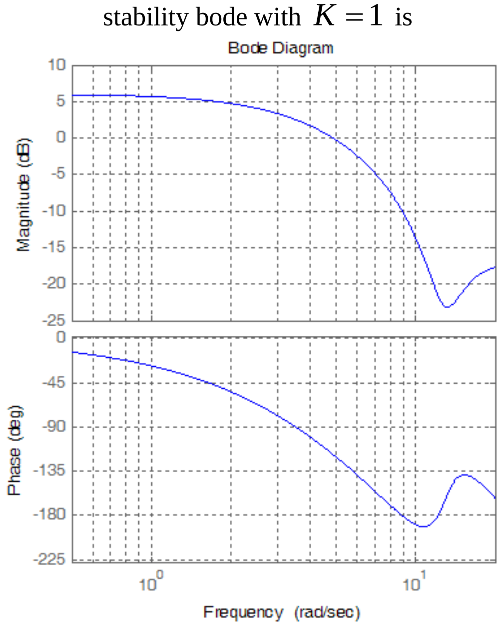
The following figure shows the frequency response for the plant, $G(s)$:



34. With proportional feedback ($H(s)=1$), which of the following is approximately the gain, K, at which the system will become unstable?

   A. 0.2
   B. 0.6
   C. 1.8
   D. 5.0

With a dynamic compensator, $H(s)$, the new loop stability bode with $K=1$ is



35. The new compensator is most likely to be:

   A. A notch filter
   B. A lag compensator
   C. A lead compensator
   D. A washout filter

36. With the new compensator, the gain, K, which yields a phase margin of 45deg is about:

   A. 0.56
   B. 0.79
   C. 1.25
   D. 2.00

37. With the gain, K, set at the value you used in the previous problem, the gain margin of the system is approximately:

   A. 0 db
   B. 4 db
   C. 8 db
   D. 11 db

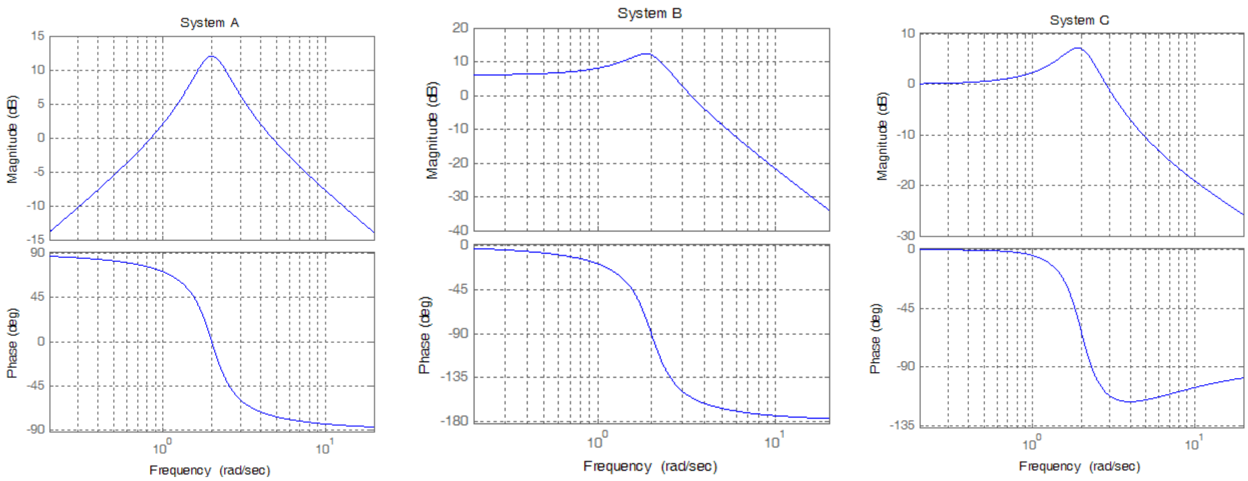
38. With the gain, K, set at the value you used in the previous 2 problems, the steady-state value of $\dfrac{Y(s)}{D(s)}$ in the *closed-loop* system is about…

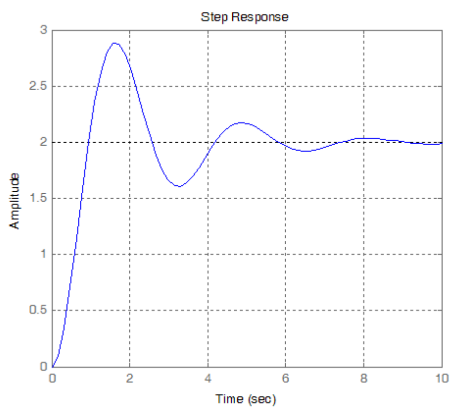
   A. -11 db
   B. -2 db
   C. 0 db
   D. 8 db

39. If *perfect* disturbance rejection ($\dfrac{Y}{D}\rightarrow 0$) is desired in steady-state, while maintaining the phase margin and accepting only a modest decrease in the gain crossover frequency of the previous problems, what additional compensation should be included in $H(s)$?

   A. PI compensation
   B. PD compensation
   C. lead compensation.
   D. washout filter

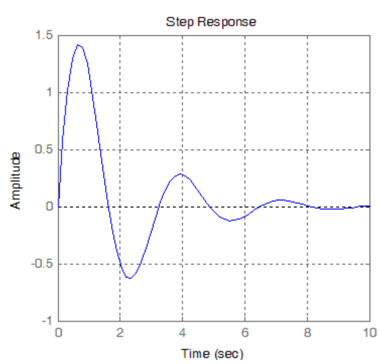
The following figures show the frequency responses for different transfer functions, G(s)





40. Using the ideas we studied in class, which system could reasonably be inferred to have the unit step response shown above?

    A. System A
    B. System B
    C. System C
    D. None of the above.

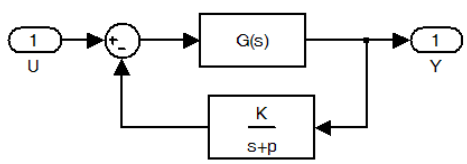


41. Using the ideas we studied in class, which system could reasonably be inferred to have the unit step response shown above?

    A. System A
    B. System B
    C. System C
    D. None of the above.

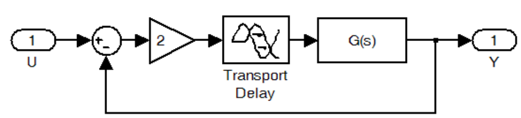
42. Using the ideas we studied in class, which transfer function could reasonably be expected to have no zeros?

    A. System A
    B. System B
    C. System C
    D. None of the above.



43. Which system would result in a stable closed-loop for all positive values of K and p in the block diagram shown above?

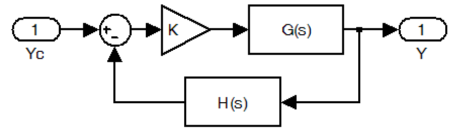
    A. System A
    B. System B
    C. System C
    D. All of the above.

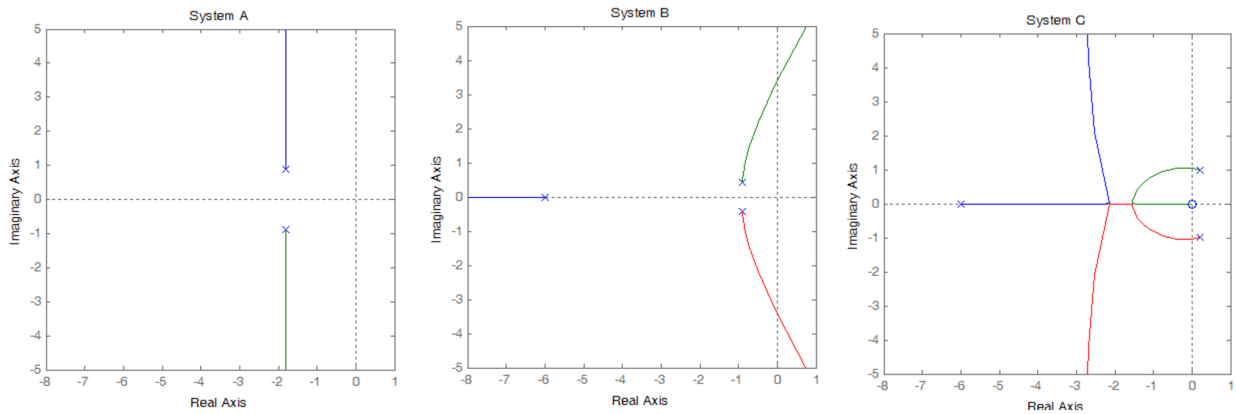


44. If system C were used in the feedback loop shown above, approximately how large would the pure time delay ("Transport Delay") have to be in order to reach neutral stability?

    A. About 0.15 Seconds
    B. About 0.30 Seconds
    C. About 0.45 Seconds
    D. None of the above, because this system cannot be made unstable by any amount of transport delay.

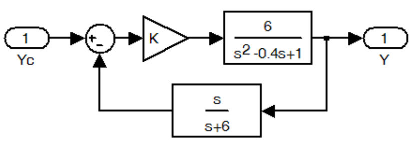
The following figures show the root loci for positive values of the gain K in systems which have block diagrams of the form shown at the right, but with different functions G(s) and H(s).





45. Which system is stable for all positive values of the gain, K?

    A. System A
    B. System B
    C. System C
    D. None of the above.



46. Which system could be the locus for K in the block diagram shown above?

    A. System A
    B. System B
    C. System C
    D. None of the above.

47. For system A, replacing the proportional gain, K, with what type of compensation would improve the damping ratio of the poles at large values of K?

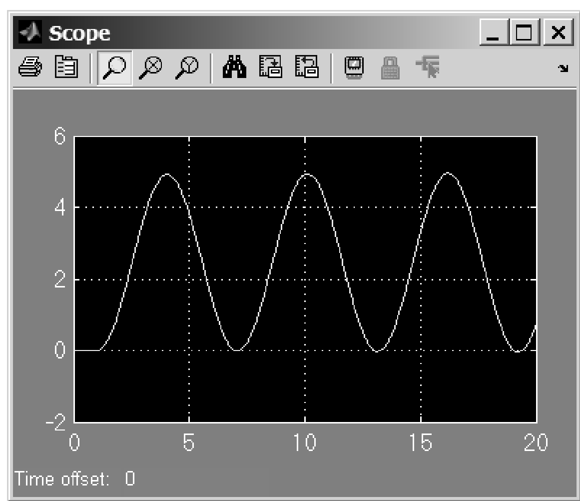
    A. PD Compensation
    B. PI Compensation
    C. A Low-Pass Filter.
    D. All of the above.

48. If the gain K is replaced with integral feedback, which system will be unstable for all positive values of the integral feedback gain?

    A. System A
    B. System B
    C. System C
    D. None of the above.

49. For system B, suppose that the gain, K, is chosen to yield a stable closed-loop system. Which of the following statements about the stability bode plot of the system might NOT be correct?

    A. The system will have a -180deg phase crossing between 3rps and 4rps.
    B. The system will have a finite, positive phase margin.
    C. The bode plot will show a finite, positive gain margin.
    D. The bode plot will have a finite gain in the limit of very low frequency ("DC gain").



50. If the gain, K, were increased just to the point of neutral stability, which system could have the closed-loop unit step response (input at t=1 sec) shown above?

    A. System A
    B. System B
    C. System C
    D. None of the above.