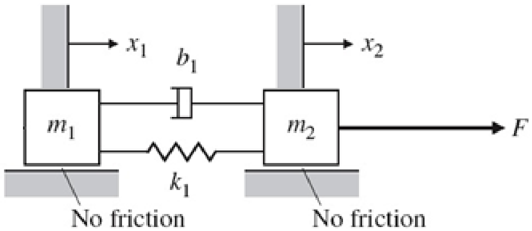
ESE 505 / MEAM 513 – Spring 2012 –Midterm Exam – *Closed* Book & Notes

- Choose one best answer for each question by *circling the letter* (unless other instructions given)
- 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).

==



1. The equation of motion for mass 2 above is:

   A. $m_2\ddot{x}_2 + b_1(\dot{x}_2 - \dot{x}_1) + k_1(x_2 - x_1) = F$
   B. $m_2\ddot{x}_2 + b_1(\dot{x}_2 + \dot{x}_1) + k_1(x_2 + x_1) = F$
   C. $m_2\ddot{x}_2 - b_1\dot{x}_1 - k_1x_1 = F$
   D. None of the other answers.

2. Which of the following is MOST CORRECT about how integral feedback is typically used in a feedback control system?

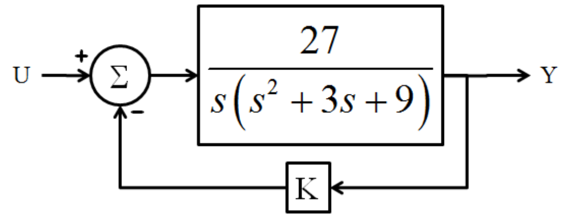
   A. …ensure zero steady-state error in the response to step inputs.
   B. …improve the stability of an oscillatory system.
   C. …ease implementation of the control design with a digital computer.
   D. …All of the other answers.

3. The Laplace transform of $\dfrac{dy(t)}{dt} + 6y(t-T)$ is…

   A. $(s + 6e^{-Ts})Y(s) - y(0)$
   B. $sY(s) - sy(0) + 6Y(s/T)$
   C. $(s+6)Y(s) + y(T)$
   D. None of the other answers

4. The unit step response for a system with transfer function $H(s) = \dfrac{4}{(s+1)(s+2)}$ is…

   A. $2 - 4e^{-t} + 2e^{-2t}$
   B. $4e^{-t} - 4e^{-2t}$
   C. $1 + \sin(2t) - 2\sin(t)$
   D. None of the other answers



5. The transfer function for the system shown above is...

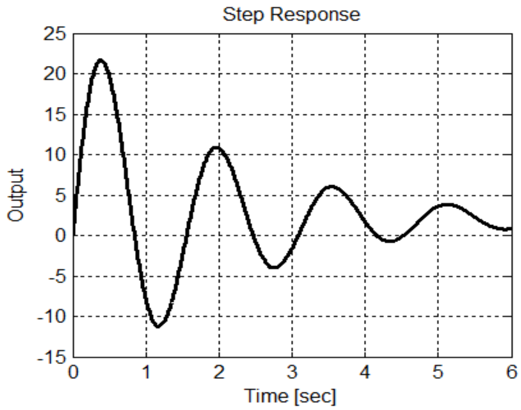
   A. $\dfrac{Y(s)}{U(s)} = \dfrac{27}{s(s^2+3s+9)+27K}$
   B. $\dfrac{Y(s)}{U(s)} = \dfrac{27K}{s(s^2+3s+9)}$
   C. $\dfrac{Y(s)}{U(s)} = \dfrac{27K}{s(s^2+3s+9+27K)}$
   D. None of the other answers

6. Which of the following statements is MOST CORRECT about the closed-loop system in the previous system?

   A. The system is unstable for all positive values of the gain, K.
   B. The system is unstable for sufficiently large K.
   C. The steady-state response (y_{ss}) to a unit step input is zero, for any positive K.
   D. The closed-loop poles are real for small positive values of the gain, K.

7. When the gain in the system shown above is chosen so that there is a closed-loop pole at $s = -3$, the system is found to exhibit a neutrally damped oscillation. Approximately what is the period of this oscillation?

   A. 1 sec
   B. 2 sec $\boxed{K=1}$
   C. 4 sec
   D. 9 sec



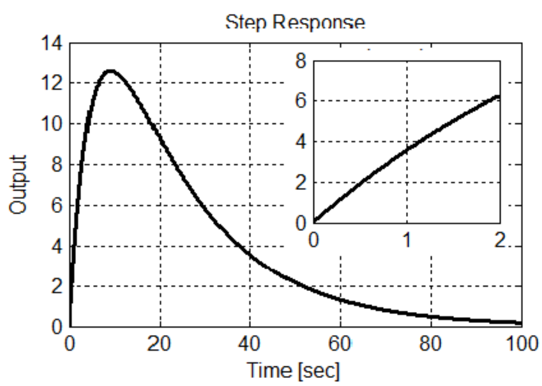
8. Using the ideas we learned in class, the step response shown above could reasonably be thought to correspond to which of the following transfer functions?

A. $G(s)=\dfrac{96s+32}{s^2+s+16}$

B. $G(s)=\dfrac{8}{s^2+s+4}$

C. $G(s)=\dfrac{16s}{s^2+s+16}$

D. None of the other answers



9. Using the ideas we learned in class, the step response shown above (detail for small times shown in the inset) could reasonably be thought to correspond to which of the following transfer functions?

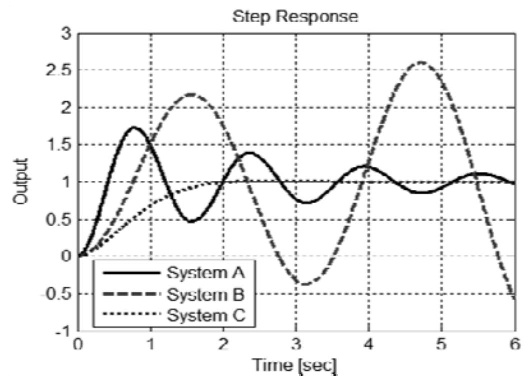
A. $G(s)=\dfrac{20}{5s+1}$

B. $G(s)=\dfrac{100s}{s^2+5s+100}$

C. $G(s)=\dfrac{400s}{(5s+1)(20s+1)}$

D. None of the other answers

The following 3 questions relate to the figure shown below, which shows the step responses of 3 different second-order systems with no zeros.



10. Which system has a damped natural frequency of approximately 2 rps?

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

11. Which system has a damping ratio that is larger than 0.5?

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

12. Which system is unstable?

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

A model[1] for the effect of the rate of hunting permit sales (u) on the number of white-tail deer (w) and the number of deer hunters (h) in Pennsylvania can be written as follows:

$$\frac{dw}{dt} = w^2 - hw$$

$$\frac{dh}{dt} = -\frac{h^2}{w} + u$$

13. What is the trim condition (with positive numbers of hunters and deer) corresponding to nominal permit sales, $u_o = 1$?

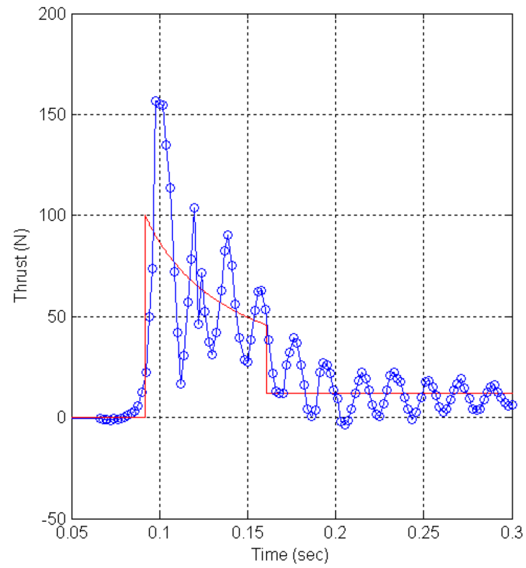
    A. $w_o = 4$ & $h_o = 2$
    B. $w_o = 2$ & $h_o = 2$
    C. $w_o = 1$ & $h_o = 1$
    D. $w_o = 0.5$ & $h_o = 1$

14. For the trim condition of the previous problem, what is the [A] matrix (with $x_1=w$, $x_2=h$)?

    A. $\begin{bmatrix} 1 & -1 \\ 1 & -2 \end{bmatrix}$
    B. $\begin{bmatrix} 2 & 1 \\ 0 & 2 \end{bmatrix}$
    C. $\begin{bmatrix} 1 & -2 \\ -1 & 2 \end{bmatrix}$
    D. $\begin{bmatrix} -1 & -1 \\ -1 & 2 \end{bmatrix}$

15. The wildlife department believes that the system is unstable, and decides to increase the hunting permits in proportion to a measurement of the deer population. In other words, they plan to use *positive*, proportional feedback, $\Delta u = K\Delta w$. For what gain will the populations be stabilized with this scheme?

    A. There is no gain that stabilizes the system.
    B. The wildlife department is mistaken; the system is already stable and remains stable for all positive K.
    C. The system is stable for $K > 1$.
    D. The system is stable for $K > \sqrt{2}$.



A professor teaching a MEAM laboratory course attempts to measure the thrust output of a water rocket on a test stand. The expected thrust is indicated by the smooth solid line above. The measured thrust is indicated by the line with symbols. The professor concludes that the force sensor has a transfer function of the following form:

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

16. Which of the following is the most reasonable estimate of ω_n?

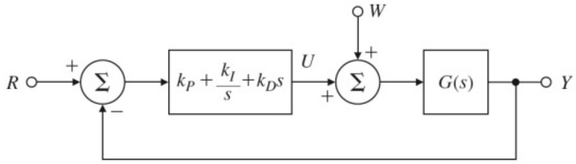
    A. $\omega_n \approx 2$ rps
    B. $\omega_n \approx 12$ rps
    C. $\omega_n \approx 60$ rps
    D. $\omega_n \approx 300$ rps

17. Which of the following is the most reasonable estimate of ζ?

    A. $\zeta \approx -0.2$
    B. $\zeta \approx 0.02$
    C. $\zeta \approx 0.2$
    D. $\zeta \approx 0.8$

[1] I made this up.

The questions on this page relate to control systems with the following architecture, with all of the compensator gains being non-negative (greater than or equal to zero):



18. Which gain in the compensator above is typically used to improve system damping?

    A. K_P
    B. K_I
    C. K_D
    D. None of the gains.

19. Which gain will typically require careful treatment when there are control authority limits to prevent "wind-up" issues?

    A. K_P
    B. K_I
    C. K_D
    D. All of the gains.

20. If the plant is of the form $G(s) = \dfrac{A}{\tau s + 1}$, which gain will cause closed-loop instability, if increased to a sufficiently large value?

    A. K_P
    B. K_I
    C. K_D
    D. None of the gains.

21. Which gain can cause problems with noise amplification and create very large plant inputs for rapidly changing user inputs?

    A. K_P
    B. K_I
    C. K_D
    D. None of the gains.

22. Which of the following alternative types of compensation can have similar effects to the compensation shown above when $K_I = 0$?

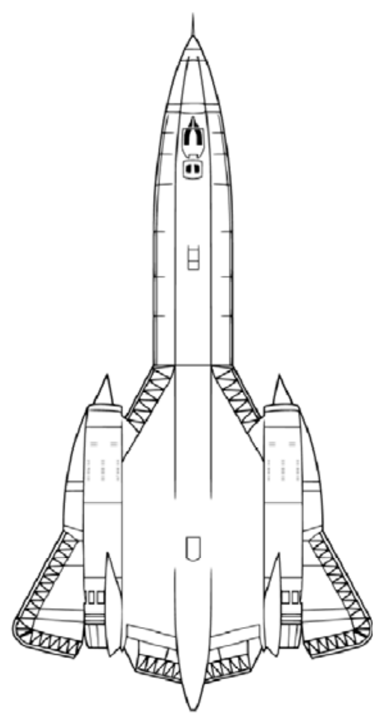
    A. Lead Compensation
    B. Lag Compensation
    C. Notch Compensation
    D. All of the above

23. If the plant is $G(s) = \dfrac{2}{s+2}$, and $K_D = 0$, which set of gains will result in the closed-loop poles being at $-1 + j$?

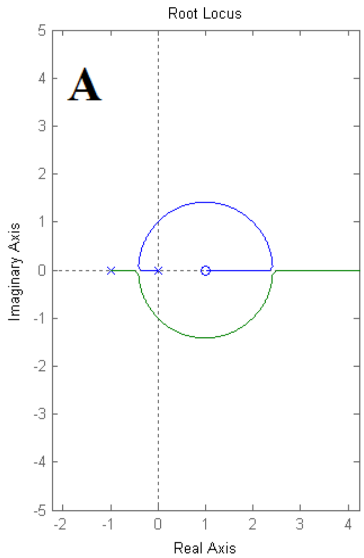
    A. $K_P = 1$, $K_I = 1$
    B. $K_P = 0$, $K_I = 1$
    C. $K_P = 4$, $K_I = 1$
    D. None of the other answers.

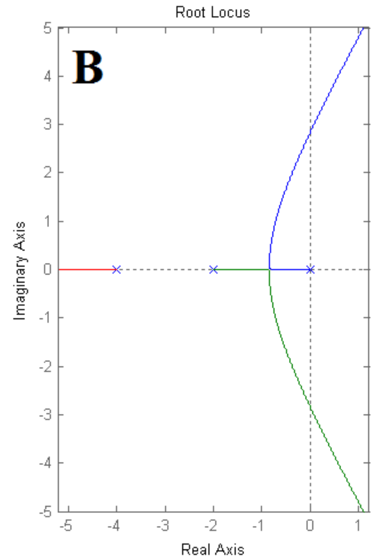
24. If the plant is $G(s) = \dfrac{2}{s^2+2}$, and $K_I = 0$, which set of gains will result in the closed-loop poles being at $-2 + 2j$?

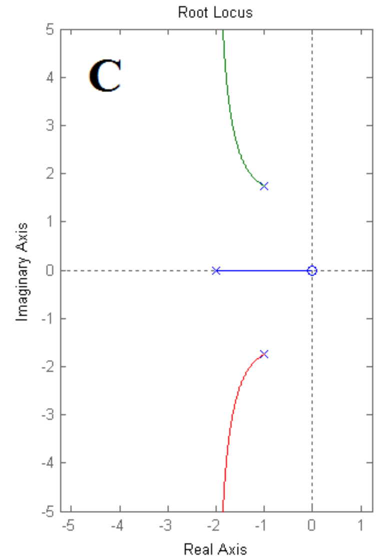
    A. $K_P = 3$, $K_D = 2$
    B. $K_P = 1$, $K_D = 0$
    C. $K_P = -2$, $K_D = 2$
    D. None of the other answers.



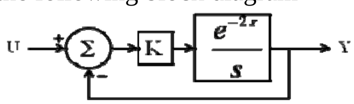
No Questions About the SR-71 Blackbird







25. Which root locus (top of page) corresponds to the following block diagram



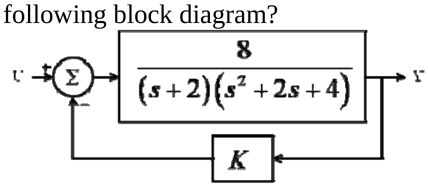
assuming that a first-order Pade approximation has been used to represent the time delay?

A. Root Locus A
B. Root Locus B
C. Root Locus C
D. None of the above.

26. For which root locus is there a gain which yields a neutrally stable closed-loop system which will exhibit an oscillation with a period of about 2 seconds?

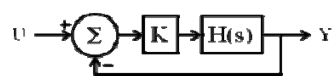
A. Root Locus A
B. Root Locus B
C. Root Locus C
D. None of the above.

27. Which root locus might correspond to the following block diagram?



A. Root Locus A
B. Root Locus B
C. Root Locus C
D. None of the above.

28. Suppose that each root locus represents a system with the following block diagram architecture:



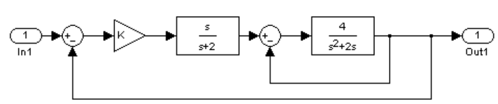
Which closed-loop system will have zero steady-state output to a unit step input for any positive value of the gain, K?

A. Root Locus A
B. Root Locus B
C. Root Locus C
D. None of the above.

29. For which root locus will the closed-loop system be stable, for all positive values of K?

A. Root Locus A
B. Root Locus B
C. Root Locus C
D. None of the above.

30. Which root locus might correspond to the following block diagram?



A. Root Locus A
B. Root Locus B
C. Root Locus C
D. None of the above.