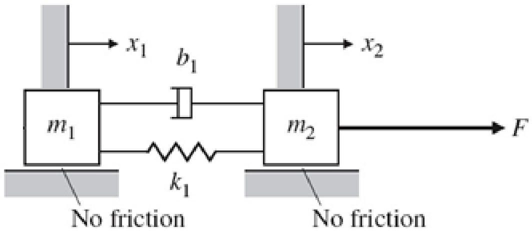
ESE 406 – Spring 2012 –Midterm Exam – *Closed* Book & Notes

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

2. Which of the following is CORRECT regarding the differential equation $\frac{dy}{dt} = \frac{1}{y} - \cos u$?

   A. It is a first-order equation.
   B. It is a linear equation.
   C. It is readily solved with Laplace Transforms if the initial condition, $y(0)$, is known.
   D. All of the other answers are correct.

3. Which of the following is the correct expression for the control required to trim the equation in the previous problem at $y_o = 2$?

   A. $u_o = \pi/2$
   B. $u_o = \pi/3$
   C. $u_o = \pi/4$
   D. $u_o = \pi/6$

4. Which of the following is the correct expression for the transfer function for small changes from the trim condition of the previous problem?

   A. $\frac{Y(s)}{U(s)} = \frac{2\sqrt{3}}{4s+1}$.
   B. $\frac{Y(s)}{U(s)} = \frac{1}{2s+2}$.
   C. $\frac{Y(s)}{U(s)} = \frac{2}{s+\sqrt{3}}$.
   D. None of the other answers.

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

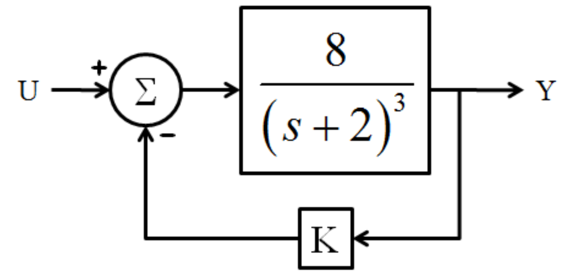
   A. …to ensure zero steady-state error in the response to step inputs.
   B. …to improve the stability of an oscillatory system.
   C. …to ease implementation of the control design with a digital computer.
   D. …All of the other answers.

6. The complex number $(1+j)e^{j\pi/4}$ is equal to…

   A. $1-j$
   B. $1/\sqrt{2}$
   C. $j\sqrt{2}$
   D. None of the other answers

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

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



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

   A. $\frac{Y(s)}{U(s)}=\frac{8K}{(s+2)^3}$

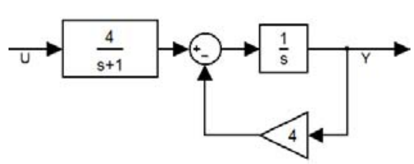
   B. $\frac{Y(s)}{U(s)}=\frac{8}{(s+2)^3+8K}$

   C. $\frac{Y(s)}{U(s)}=\frac{8K}{(s+2+8K)^3}$

   D. None of the other answers

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

   A. The system is stable for all positive values of the gain, K.
   B. The system is unstable for sufficiently large K.
   C. The system has zero error for sufficiently large K.
   D. The closed-loop poles are real for all positive values of the gain, K.



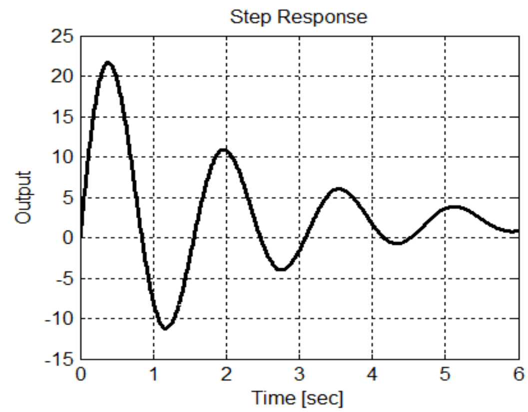
10. The transfer function for the system shown above is...

   A. $\frac{Y(s)}{U(s)}=\frac{4}{(s+1)s+16}$

   B. $\frac{Y(s)}{U(s)}=\frac{4}{(s+1)(s+4)}$

   C. $\frac{Y(s)}{U(s)}=\frac{4}{(s+1)s+4}$

   D. None of the other answers



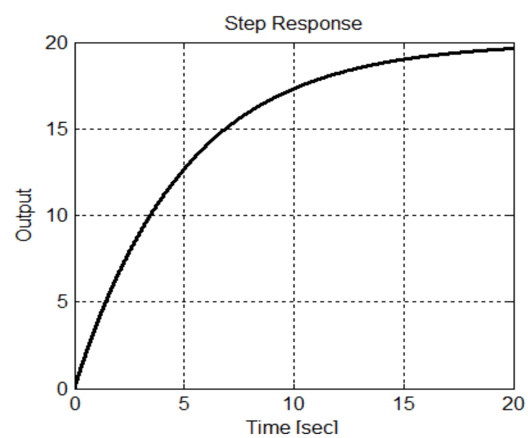
11. Using the ideas we learned in class, the step response shown above could reasonably be thought to correspond to which of the following transfer functions?

   A. $G(s)=\frac{8}{s^2+s+4}$

   B. $G(s)=\frac{16s}{s^2+s+16}$

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

   D. None of the other answers



12. 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?

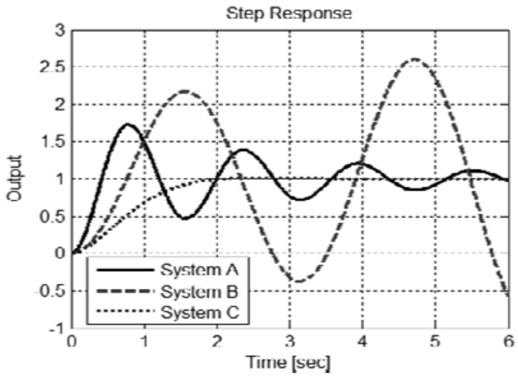
   A. $G(s)=\frac{20}{5s+1}$

   B. $G(s)=\frac{100}{s+5}$

   C. $G(s)=\frac{100s}{s^2+5}$

   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.



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

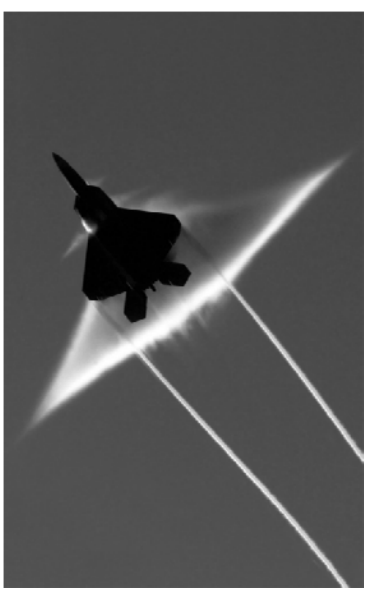
    A. System A
    B. System B
    C. System C
    D. None of the Systems

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

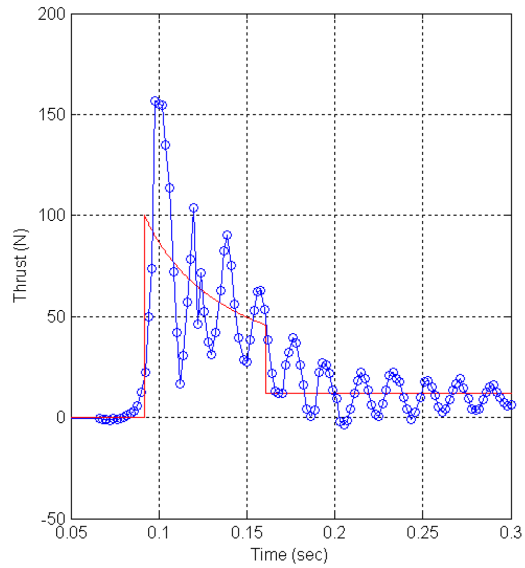
    A. System A
    B. System B
    C. System C
    D. None of the Systems

15. Which system is unstable?

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



No Questions About the F-22 Raptor



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:

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

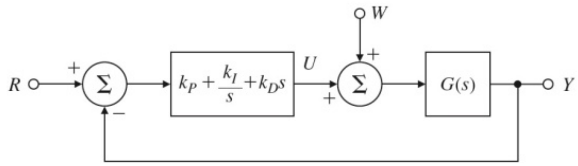
16. Which of the following is the most reasonable estimate of ω_n ?

    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. 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

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 often 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 $K_I = 0$?

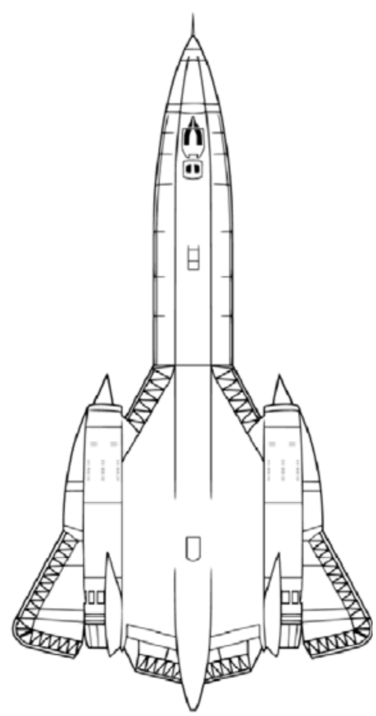
   A. Lead Compensation
   B. Lag Compensation
   C. Notch Compensation
   D. All of the above

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 $-1 \pm j$?

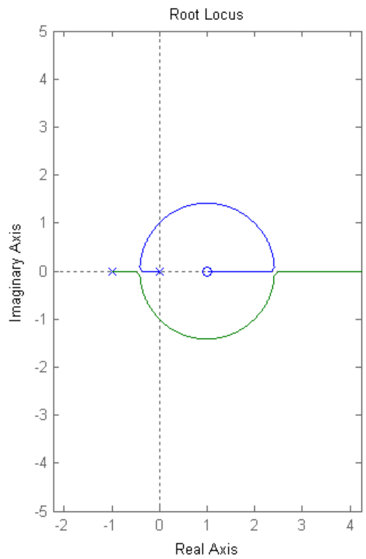
   A. $K_P = 1$, $K_I = 2$
   B. $K_P = 0$, $K_I = 1$
   C. $K_P = 4$, $K_I = 1$
   D. None of the other answers.

24. If the plant is $G(s) = \dfrac{2}{s^2+2}$, and $K_I = 0$, and $K_D = 4$, which value of K_P will result in a closed-loop damping ratio of 0.5?

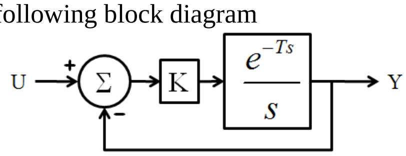
   A. $K_P = 3$
   B. $K_P = 5$
   C. $K_P = 7$
   D. None of the other answers.



No Questions About the SR-71 Blackbird



25. The root locus above corresponds to the following block diagram



where a first-order Pade approximation has been used to represent the time delay. How large is the time delay?

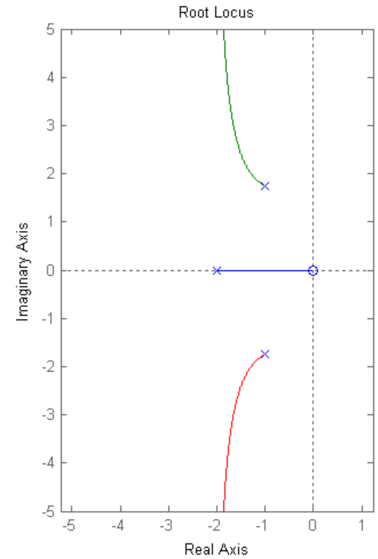
A. 0.5 sec
B. 1 sec
C. 2 sec
D. Cannot be determined from the figure.

26. If the gain of the system shown above is increased to the point of neutral stability, the system will exhibit undamped oscillations with a period of about...?

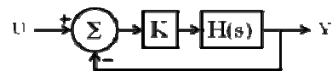
A. ...0.15 sec
B. ...1.0 sec
C. ...3.0 sec
D. ...6.0 sec

27. Which of the following is MOST CORRECT about the effects of replacing the proportional feedback in the system above with first-order lead compensation?

A. A lead compensator could be designed to make the closed-loop system stable for all positive values of K.
B. Lead compensation can improve the damping of the closed-loop poles for moderate gains, but there will still be instability at very large K.
C. Lead compensation would ensure zero steady-state error, which isn't currently achieved.
D. None of the above is reasonably correct.



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



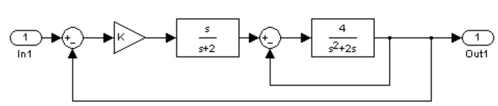
Which of the following is MOST ACCURATE about this system?

A. The system is unstable for large K.
B. For very large K, the oscillatory modes will have a damping ratio of 0.7.
C. For very large K, the zero at the origin will almost cancel the real pole, and the second-order mode will dominate the response.

29. For the system of the previous problem, which of the following is the MOST CORRECT inference about the steady-state response to a unit step input for an arbitrary positive gain K?

A. $y_{ss}=0$.
B. $y_{ss}=1$.
C. We cannot determine y_{ss} from the information given.

30. Suppose a student constructed the root locus shown above to study the closed-loop poles of a system with the following block diagram:



We might conclude that...

A. ...the student has done a great job!
B. ...the student has made a small mistake with the block-diagram algebra.
C. ...the student is probably enrolled at Drexel.