# ESE 406 – ESE 505 – MEAM 513 – Spring 2013 –Midterm Exam
## *Closed* Book & *Closed* Notes & *No* Calculators!

- 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).

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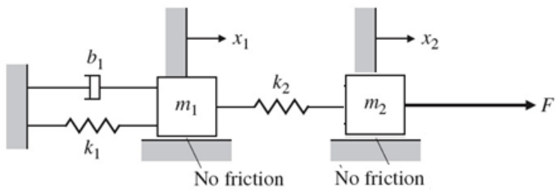
1. Which of the following is equal to $\dfrac{2}{1+e^{j\pi/2}}$ ?

   A. $\sqrt{2}e^{-j\pi/4}$
   B. $1-2j$
   C. $2e^{-1-j\pi/2}$
   D. None of the other answers




2. 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. $m_2\ddot{x}_2 + k_2(x_2-x_1) = F$
   C. $m_2\ddot{x}_2 + k_2x_2 - b_1\dot{x}_1 - k_1x_1 = F$
   D. $m_2\ddot{x}_2 + k_2x_2 - m_1\ddot{x}_1 - b_1\dot{x}_1 - k_1x_1 = F$

3. Consider the following dynamic system:
   $\dfrac{dx}{dt} = -2(1-u)\sqrt{x}$ & $y=\sqrt{x}-1$
   What control is required to trim the system so that the output is 1?

   A. $u_o = 0$
   B. $u_o = 1$
   C. $u_o = 4$
   D. $u_o = 15$

4. For the system & trim condition of the previous problem, what are the $[A]$ & $[B]$ matrices of the linearized system?

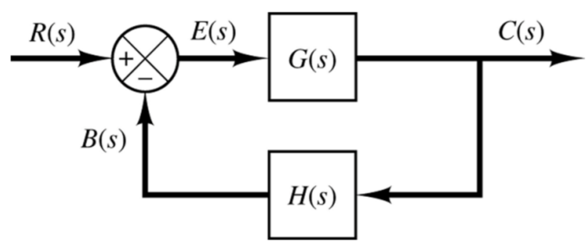
   A. $[A]=[0]$ $[B]=[4]$
   B. $[A]=[-4]$ $[B]=[-2]$
   C. $[A]=[2]$ $[B]=[2]$
   D. None of the other answers.

5. The Laplace transform of $3\dfrac{dy}{dt}$ is...

   A. $3sY(s)-3y(0)$
   B. $\dfrac{Y(s)}{3s}-y(0)$
   C. $Y(s)-3sy(0)$
   D. None of the other answers

6. The solution to the ODE $3\dfrac{dy}{dt}+y=1$ with $y(0)=4$ is...

   A. $y(t)=1+3e^{-t/3}$
   B. $y(t)=1+e^{-3t}$
   C. $y(t)=3+e^{-3t}$
   D. None of the other answers



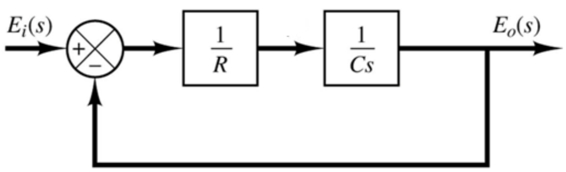

7. The transfer function corresponding to the block diagram shown above is...

   A. $\dfrac{C(s)}{R(s)} = G(s)-G(s)H(s)$
   B. $\dfrac{C(s)}{R(s)} = \dfrac{G(s)H(s)}{1+G(s)H(s)}$
   C. $\dfrac{C(s)}{R(s)} = \dfrac{G(s)}{1+G(s)H(s)}$
   D. None of the other answers.

8. Which of the following is NOT a true statement about the transfer function

$$G(s) = \frac{2s+36}{\left(s^2+18s+324\right)}$$

A. The system is stable.
B. The poles are complex with natural frequency $\omega_n = 18$ and damping ratio $\varsigma = 0.5$
C. The zero is on the negative real axis at $z = -36$
D. The steady-state (“DC”) gain of the system is $\frac{1}{9}$.




9. The closed-loop pole for the system shown above is located at...

A. $s = RC$
B. $s = -RC$
C. $s = \frac{1}{RC}$
D. $s = \frac{-1}{RC}$

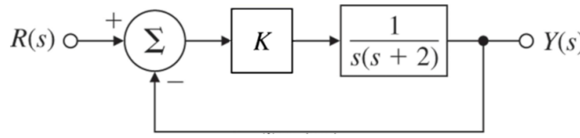
10. In the previous problem, the steady-state response to a unit step input, $e_i(t) = 1$, is...

A. $\lim_{t\to\infty} e_o(t) = 0$
B. $\lim_{t\to\infty} e_o(t) = 1$
C. $\lim_{t\to\infty} e_o(t) \to \infty$ (closed-loop instability)
D. We need to know the initial condition of the integrator to know the steady-state response of the system.

11. Which of the following is NOT correct concerning the differential equation

$$\frac{d^2y}{dt^2} - 9y = \frac{du}{dt} - 9u$$

A. The differential equation is nonlinear.
B. The system described by the equation is unstable.
C. The equation is second order.
D. The corresponding transfer function is $\frac{Y(s)}{U(s)} = \frac{s-9}{s^2-9}$




12. For the system shown above, what value of $K$ will yield a closed-loop damping ratio of 0.2?

A. $K = 0.2$
B. $K = 1$
C. $K = 5$
D. $K = 25$

13. With $K$ set to the value determined in the previous problem, approximately what period will oscillations be observed in the step response?

A. $T \approx 1.25\,\text{sec}$
B. $T \approx 6\,\text{sec}$
C. $T \approx 30\,\text{sec}$
D. The closed-loop system will not oscillate when the damping ratio is positive.

14. With $K$ set to the value used in the last 2 problems, what is the approximate settling time of the step response (using the approximate 1% criterion, $t_s \approx \frac{4}{\sigma}$)

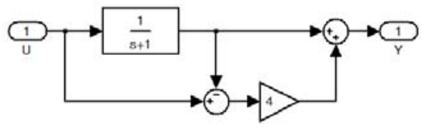
A. $t_s \approx 1\,\text{sec}$
B. $t_s \approx 4\,\text{sec}$
C. $t_s \approx 16\,\text{sec}$
D. $t_s \approx 128\,\text{sec}$

15. If we wanted to reduce the settling time found in the previous problem, which modification to the controller would make the most sense?

A. Add derivative feedback.
B. Add integral feedback.
C. Reduce the value of $K$ by about 50%.
D. None of the other answers would reduce the settling time.

16. A linear system has the state matrix $[A] = \begin{bmatrix} -1 & 0 \\ 4 & -2 \end{bmatrix}$. The system is...

A. ...stable.
B. ...unstable.
C. ...either stable or unstable, depending on the initial condition.
D. ...either stable or unstable, depending on the $[D]$ matrix.




17. Which transfer function corresponds to the block diagram shown above?

    A. $G(s) = \dfrac{(s+4)}{(s+1)}$

    B. $G(s) = \dfrac{(4s+1)}{(s+4)}$

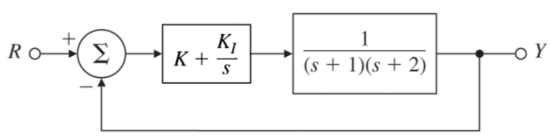
    C. $G(s) = \dfrac{(4s+1)}{(s+1)}$

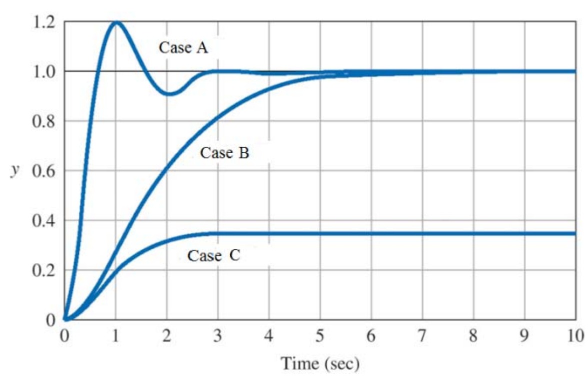
    D. None of the above

18. Which of the following statements is NOT correct concerning the differential equation:

    $$\frac{dy}{dt} + \sin(3y) = 2u$$

    A. It is a first-order differential equation.
    B. It is a non-linear differential equation.
    C. The Laplace transform of the equation with zero initial conditions is
    $sY(s) + \sin[3Y(s)] = 2U(s)$
    D. To solve, we need to know $u(t)$ and $y(0)$.



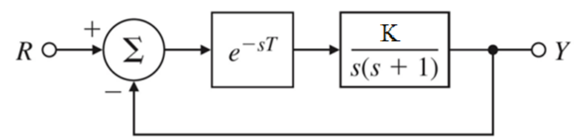




19. The unit step responses shown above correspond to 3 different sets of gains in the block diagram shown above. Which set of gains could reasonably correspond to $K = 1$ & $K_I = 0$?

    A. Case A
    B. Case B
    C. Case C

20. Suppose we fixed $K = 1$ in the system of the previous problem. Which of the following is MOST ACCURATE about the effects of increasing $K_I$?

    A. Increasing $K_I$ will increase the closed-loop damping ratio of one pair of poles for all $K_I > 0$.
    B. Increasing $K_I$ will decrease the closed-loop damping ratio of one pair of poles, but the system will remain stable for all $K_I > 0$.
    C. Increasing $K_I$ will decrease the closed-loop damping ratio of one pair of poles, ultimately leading to instability for a sufficiently large value of $K_I$.
    D. The effect of integrator gain on stability depends on the initial condition of the integrator (which is a state in our dynamic compensator).




21. If we want to make a "root locus" to show how the closed-loop poles depend on $K$ for the system shown above, ...

    A. ...we need to linearize $e^{-sT}$.
    B. ...we need to approximate $e^{-sT}$ using a Pade approximation, such as

    $$e^{-sT} \approx \frac{-s + \frac{2}{T}}{s + \frac{2}{T}}.$$

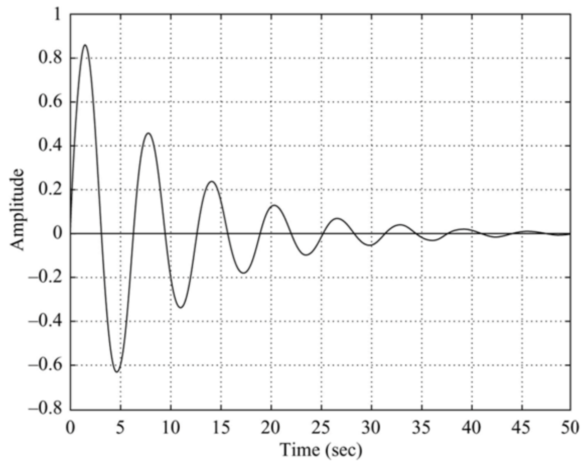
    C. ...we need to rewrite the closed-loop denominator as a Fredholm Equation.
    D. ...we need to add integral feedback to eliminate the steady errors that make the root locus technique fail to work.

22. The partial-fraction expansion of $Y(s) = \dfrac{2}{s(s-2)}$ is

    A. $Y(s) = \dfrac{2}{s} + \dfrac{-2}{(s-2)}$

    B. $Y(s) = \dfrac{-1}{s} + \dfrac{1}{(s-2)}$

    C. Neither of the above.
    D. We need initial conditions to do a partial-fraction expansion.



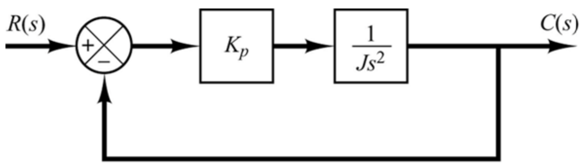

23. The unit step response shown above might reasonably be thought to correspond to which transfer function?

   A. $G(s) = \dfrac{s}{s^2 + 0.2s + 1}$

   B. $G(s) = \dfrac{6}{s^2 + s + 6}$

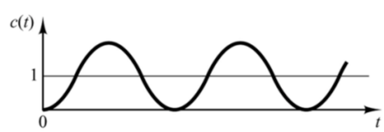
   C. $G(s) = \dfrac{6s + 1}{s^2 + 0.2s + 1}$

   D. None of the other answers.



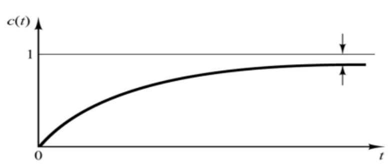

24. Consider the control system shown above with $J > 0$ and $K_P > 0$. Which of the following shows the correct character of the unit step response?

   A.

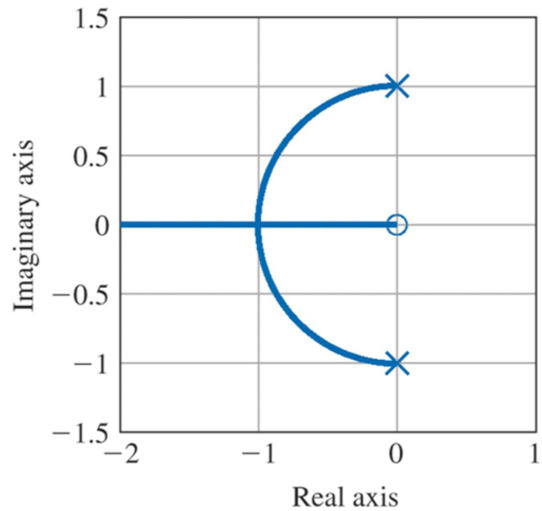


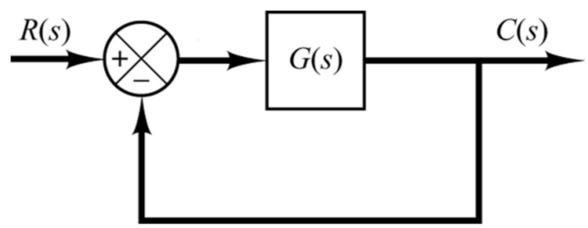

   B.


   C.




   D. None of the other answers.




25. The root locus on $K$ shown above corresponds to the unity-feedback block diagram above for which of the following $G(s)$?

   A. $G(s) = \dfrac{2Ks}{s^2 + 1}$

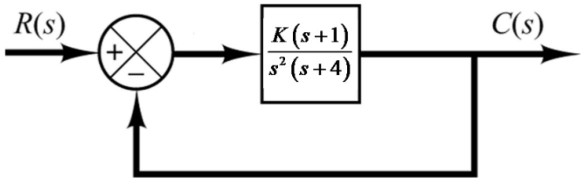
   B. $G(s) = \dfrac{1}{s(s + K)}$

   C. $G(s) = \dfrac{K(s+1)}{2s^2 + (2 - K)}$

   D. All of the other answers.

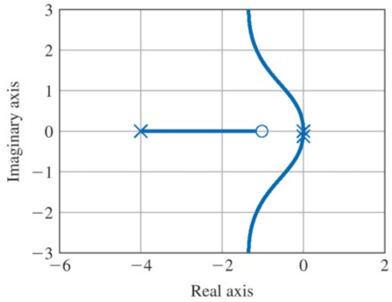
26. Which of the following is true of the closed-loop system from the previous problem if $K$ is chosen so that the closed-loop damping ratio is 1.1?

   A. The steady-state error in response to a unit step input will be zero.
   B. The initial response to a unit step will have a non-zero slope.
   C. The closed-loop response to a unit step will not oscillate (no terms containing $\sin \omega_d t$ or $\cos \omega_d t$).
   D. All of the other answers are correct.

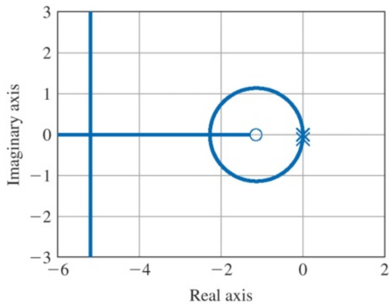



27. Which of the following corresponds to the root locus for the system shown above?

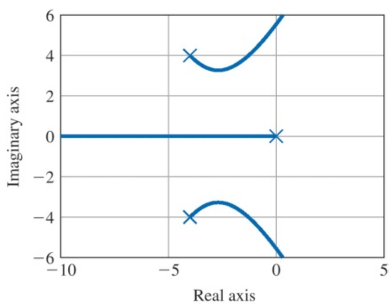
A.




B.



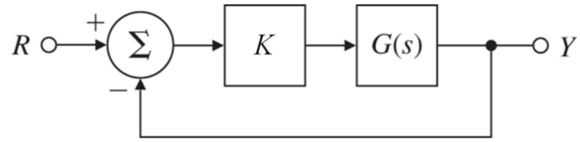

C.




D. None of the other answers

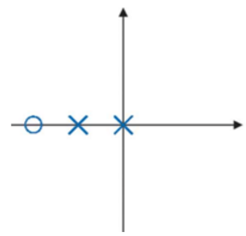
28. What is the maximum damping ratio of the oscillatory poles in the previous problem?

   A. About 0.2
   B. About 0.5
   C. About 0.9
   D. For all $K$ greater than some nominal value, the poles are always on the negative real axis (damping ratio greater than 1).

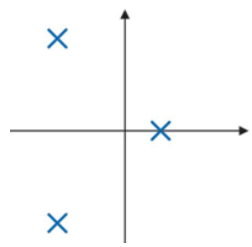



29. Each answer below shows the poles and zeros of a transfer function $G(s)$ which is used in a block diagram of the form shown above. For which transfer function will the closed-loop system be unstable for some values of $K > 0$?

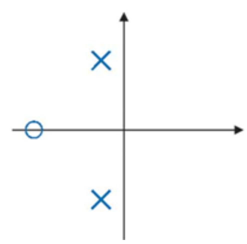
A.



B.



C.



D. All of the above are stable for all $K > 0$.

30. Which of the following statements is NOT correct concerning derivative feedback?

   A. It is usually used to improve damping.
   B. It has infinite gain at high frequency, which can result in noise rejection issues.
   C. It can only be used in conjunction with proportional and integral feedback (PID control).
   D. It is sometimes used in the feedback path only, to avoid excessive actuator usage with rapidly changing inputs.