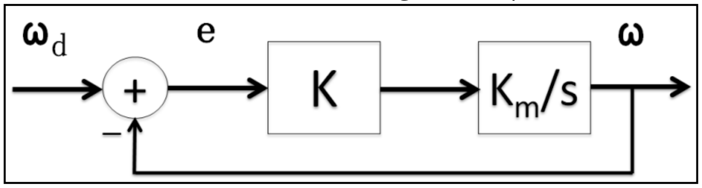
During lab we implemented a P-type velocity controller for a DC motor. The block diagram of our system was similar to the one shown here. Consider this block diagram for questions 1 and 3:



Find the transfer function relating ω and ω_d.

1. What is the numerator of the transfer function?

a) s
b) KK_m
c) s - KK_m
d) s + K/K_m
e) None of the above

2. Indicate how confident you are about your answer:

a) High b) Moderate c) Low d) Total guess

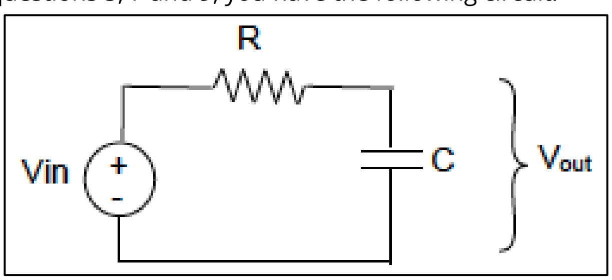
3. What is the denominator of the transfer function?

a) KK_m
b) s
c) s - KK_m
d) s + KK_m
e) None of the above

4. Indicate how confident you are about your answer:

a) High b) Moderate c) Low d) Total guess

For questions 5, 7 and 9, you have the following circuit:



and are provided with its transfer function:

$$\frac{V_{out}}{V_{in}} = \frac{RCs}{1 + RCs}$$

Find the magnitude ratio of the transfer function.

5. What is the numerator of the magnitude ratio?

a) RCω
b) $\sqrt{RC\omega^2}$
c) $j\sqrt{RC\omega^2}$
d) $\sqrt{1 + (RC\omega)^2}$
e) None of the above

6. Indicate how confident you are about your answer:

a) High b) Moderate c) Low d) Total guess

7. What is the denominator of the magnitude ratio?

a) $\sqrt{RC\omega^2}$
b) $\sqrt{1 + (RC\omega)^2}$
c) $1 + RC\omega$
d) $\sqrt{1 + j(RC\omega)^2}$
e) None of the above

8. Indicate how confident you are about your answer:

a) High b) Moderate c) Low d) Total guess

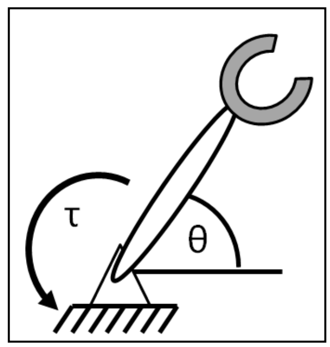
9. If the input voltage is given by: $V_{in} = \sqrt{2}\sin(1000t)$, find the amplitude of the output voltage if $R = 1k\Omega$ and $C = 1\mu F$.

a) $2\sqrt{2}$
b) $\sqrt{2}$
c) $1/\sqrt{2}$
d) 1
e) None of the above

10. Indicate how confident you are about your answer:

a) High b) Moderate c) Low d) Total guess

For questions 11 – 21 consider the following diagram of a 1 degree-of-freedom robotic arm.



11. You are creating a PD controller and know that the poles of the system are given by:

$$p_{1,2} = \frac{-K_d \pm \sqrt{K_d^2 - 4JK_p}}{2J}$$

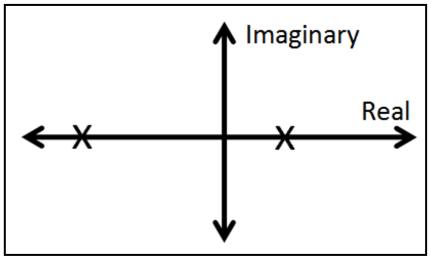
The inertia of the arm is 32 kg.m^2. What pair of Kp and Kd values would give you a critically-damped behavior?

a) Kp = 2, Kd = 16
b) Kp = -2, Kd = 16
c) Kp = 10, Kd = 50
d) Kp = 10, Kd = 25
e) None of the above

12. Indicate how confident you are about your answer:

a) High b) Moderate c) Low d) Total guess

13. Someone else sets the values for Kp and Kd and tells you that the poles are distributed as such:



Choose the behavior that best describes the system:

a) oscillatory
b) marginally stable
c) stable and underdamped
d) stable and critically damped
e) unstable

14. Indicate how confident you are about your answer:

a) High b) Moderate c) Low d) Total guess

15. We can write the transfer function of the PD controller as:

$$\frac{\theta}{\theta_d} = \frac{1/J(K_v s + K_p)}{s^2 + K_v/J \; + Kp/J}$$

The inertia of the arm is 32 kg-m2. What value would you need to set the proportional gain for a natural frequency of 2rad/sec?

a) $64\ N/m$
b) $8\ N/m$
c) $128\ N/m$
d) $16\ N/m$
e) None of the above

16. Indicate how confident you are about your answer:

a) High b) Moderate c) Low d) Total guess

17. Using the value that you found in question 15. What is the minimum value for the derivative gain so that your system does not oscillate?

a) $64\ N \cdot s/m$
b) $8\ N \cdot s/m$
c) $128\ N \cdot s/m$
d) $16\ N \cdot s/m$
e) None of the above

18. Indicate how confident you are about your answer:

a) High b) Moderate c) Low d) Total guess

We can write the dynamics of the PD controller as:

$$J\ddot{\theta} = -K_p(\theta - \theta_d) - K_d(\dot{\theta} - \dot{\theta}_d) = \tau$$

For questions 19 and 21 match the parameter in the control law with its equivalent in the mass-spring-damper system:

19. *Kp*

a) mass
b) spring
c) damper
d) input force
e) None of the above

20. Indicate how confident you are about your answer:

a) High b) Moderate c) Low d) Total guess

21. *Kd*

a) mass
b) spring
c) damper
d) input force
e) None of the above

22. Indicate how confident you are about your answer:

a) High b) Moderate c) Low d) Total guess

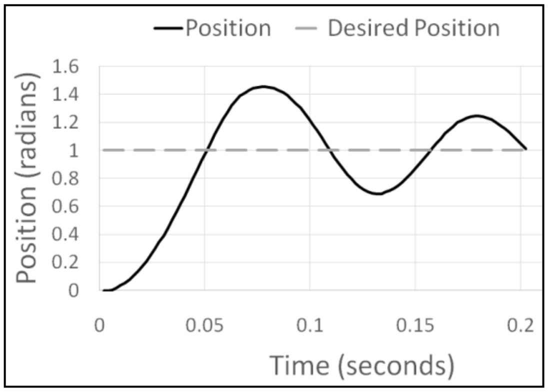
23. You are asked to design the control law for the steering angle of your robot. You want your control law to relate the error in steering angle to the torque applied by your motor. Assume G > 0 and that a positive input to the motor driver causes the shaft to rotate in the positive direction. What control law would work for this?

a) $u = -G(\theta - \theta_d)$
b) $u = G(\theta - \theta_d)$
c) $G = -u(\theta - \theta_d)$
d) $G = u(\theta - \theta_d)$
e) None of the above

24. Indicate how confident you are about your answer:

a) High b) Moderate c) Low d) Total guess

For questions 25 and 27. Imagine that to control the steering of your robot you use a PD controller. You try a set of proportional and derivative gains and find that your system's behavior is:



25. How could you change the value of the proportional gain in order for the steering to reach the desired position faster?

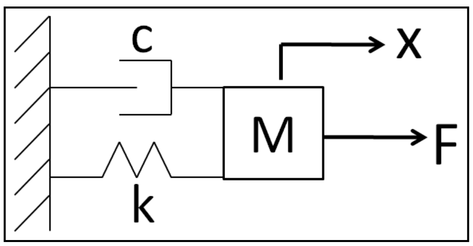
a) Increase it
b) Decrease it
c) Change its sign
d) Leave it unchanged
e) None of the above

26. Indicate how confident you are about your answer:
a) High b) Moderate c) Low d) Total guess

27. How could you change the value of the derivative gain so that the steering to NOT oscillate as much?
a) Increase it
b) Decrease it
c) Change its sign
d) Leave it unchanged
e) None of the above

28. Indicate how confident you are about your answer:
a) High b) Moderate c) Low d) Total guess

For questions 29 and 41 use the following diagram.



In class we modeled the behavior of the vibrating beam as a 1 degree-of-freedom system as shown above.

29. What is the differential equation of motion of the system?
a) $Ms^2 = F - cs - ks$
b) $M\ddot{x} = -c\dot{x} - kx$
c) $M\ddot{x} = F - c\dot{x} - kx$
d) $F = -c\dot{x} - kx$
e) None of the above

30. Indicate how confident you are about your answer:
a) High b) Moderate c) Low d) Total guess

31. What is its transfer function?
a) $\frac{X(s)}{F(s)} = Ms^2 + Cs + K$
b) $\frac{F(s)}{X(s)} = \frac{1}{Ms^2+Cs+K}$
c) $\frac{F(s)}{X(s)} = \frac{s^2+Cs+K}{M}$
d) $\frac{X(s)}{F(s)} = \frac{1}{Ms^2+Cs+K}$
e) None of the above

32. Indicate how confident you are about your answer:
a) High b) Moderate c) Low d) Total guess

33. What is the natural frequency of the system?
a) $\omega_n = \sqrt{1 - k/M}$
b) $\omega_n = \sqrt{M/k}$
c) $\omega_n = c/\sqrt{k/M}$
d) $\omega_n = \sqrt{k/M}$
e) None of the above

34. Indicate how confident you are about your answer:
a) High b) Moderate c) Low d) Total guess

35. What is the damping ratio of the system?
a) $\zeta = c/2\sqrt{kM}$
b) $\zeta = 2c\sqrt{kM}$
c) $\zeta = \sqrt{k/M}$
d) $\zeta = 2\sqrt{kM}$
e) None of the above

36. Indicate how confident you are about your answer:
a) High b) Moderate c) Low d) Total guess

37. Let m = 25kg, c = 10Ns/m, and k = 1 N/m. What statement best describes how the system would respond to an impulse?
a) The system is undamped
b) The system is critically damped
c) The system is overdamped
d) The system is underdamped
e) None of the above

38. Indicate how confident you are about your answer:
a) High b) Moderate c) Low d) Total guess

39. Using the same values for mass and damping as in question 37, you now double the stiffness of the system. What statement best describes how the system would respond to an impulse?
a) The system is undamped
b) The system is critically damped
c) The system is overdamped
d) The system is underdamped
e) None of the above

40. Indicate how confident you are about your answer:
a) High b) Moderate c) Low d) Total guess

41. As you may recall, the beam did not oscillate forever after you twanged it. Instead, the beam would eventually come to a stop. What equation best describes the actual frequency at which the beam was moving?
a) $\omega = \zeta\sqrt{\omega_n - \zeta^2}$
b) $\omega = \sqrt{1 - \zeta^2}$
c) $\omega = \omega_n\sqrt{1 - \zeta^2}$
d) $\omega = \omega_n\sqrt{1 + \zeta^2}$
e) None of the above

42. Indicate how confident you are about your answer:
a) High b) Moderate c) Low d) Total guess

When controlling the velocity of the DC motor in lab we arrived at the following equation to relate the motor's inertial load and the motor driver:

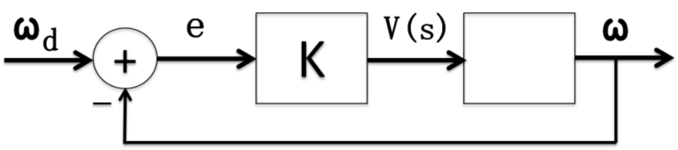
$$J\dot{\omega} = \alpha V = \tau$$

43. Fill in the block bellow with the correct transfer function:

a) s/J
b) α/Js
c) τ/Js
d) α/J
e) None of the above

44. Indicate how confident you are about your answer:
a) High b) Moderate c) Low d) Total guess

We then added a feedback controller to better control the velocity:



45. Using the transfer function from (43), what is the transfer function that relates ω and ω_d?

a) $\frac{K}{\frac{J}{\alpha}s+K}$
b) $\frac{1}{\frac{\alpha}{J}s+1}$
c) $\frac{1}{\frac{J}{\alpha}s+1}$
d) $\frac{K}{\frac{\alpha}{J}s+K}$
e) None of the above

46. Indicate how confident you are about your answer:
a) High b) Moderate c) Low d) Total guess

47. What is the time constant of this system?
a) α/J
b) J/α
c) $J/\alpha K$
d) $K/\alpha J$
e) None of the above

48. Indicate how confident you are about your answer:
a) High b) Moderate c) Low d) Total guess

49. In lab you found that friction led to some amount of steady-state error when controlling the velocity of the motor. The dynamics of the system with friction could be written as:

$$J\dot{\omega} = \tau - \tau_f$$

What type of controller would help you get rid of this steady-state error?
a) $\tau = -K_p e - K_i \dot{e}$
b) $\tau = -K_p \dot{e} - K_i \int e\,dt$
c) $\tau = -K_p e - K_i \int e\,dt$
d) $\tau = -K_i \int e\,dt$
e) None of the above

50. Indicate how confident you are about your answer:
a) High b) Moderate c) Low d) Total guess