For questions 1 and 3 match the instrument with its use

1. Oscilloscope
   a) Building circuits
   b) Controlling a voltage
   c) Measuring resistance
   d) Measuring voltage as a function of time
   e) Producing sine, square, and triangle waves
3. Potentiometer
   a) Building circuits
   b) Controlling a voltage
   c) Measuring resistance
   d) Measuring voltage as a function of time
   e) Producing sine, square, and triangle waves

For questions 5 and 7 assume that you measure a wave using the oscilloscope and characterize the wave as:

$$V(t) = (3 + 1.5sin(t))$$

5. What is the frequency of the wave?
   a) 1Hz
   b) 10 rpm
   c) $1\frac{radian}{sec}$
   d) 60Hz
   e) None of the above

7. What is the DC offset of the wave?
   a) 1.5V
   b) 4.5V
   c) 0V
   d) 3V
   e) None of the above

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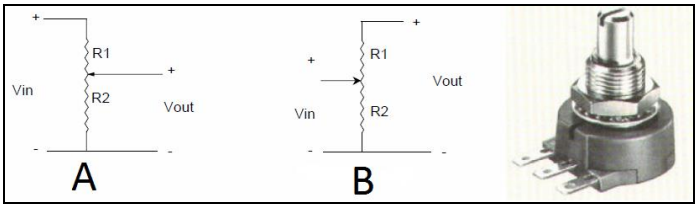
9. What is the correct circuit diagram for the potentiometer that you wired in lab? **A**



11. A band-pass filter attenuates:
   a) High frequencies
   b) A band of frequencies
   c) Low frequencies
   d) Low and high frequencies
   e) None of the above

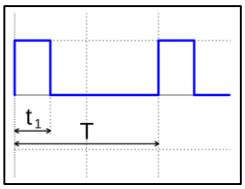
---

13. What is the period of a sine wave with a frequency equal to π Hz?
   a) 2π sec
   b) 1/π sec
   c) $1/(2\pi^2)$ sec
   d) $2\pi^2$ sec
   e) None of the above

---

15. The time constant of a first-order system tells when the output has gotten how far along the way to its steady-state value?
   a) 37%
   b) 63%
   c) 10%
   d) 90%
   e) None of the above

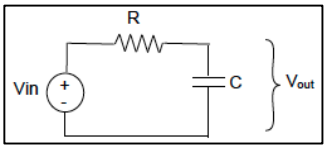
For questions 17 and 19 use the following figure of a PWM signal as reference:



17. What does t_1 refer to?
   a) Pulse frequency
   b) Period duration
   c) Pulse duration
   d) Period frequency
   e) None of the above

19. Let t_1 = 0.2msec and T=1.2msec. What is the duty cycle of the PWM signal?
   a) 6msec
   b) 600%
   c) 16.7msec
   d) 16.7%
   e) None of the above

For questions 21 and 23 use the following figure as reference:

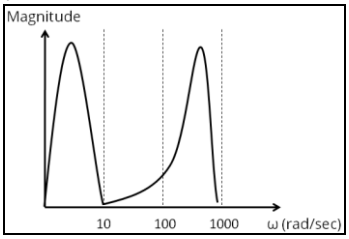


21. What is the equation that relates V_{out} to V_{in}?
   a) $V_{out} = V_{in}(1 - e^{-tRC})$
   b) $V_{out} = V_{in}(1 - e^{-t/RC})$
   c) $V_{out} = V_{in}(1 - e^{-t})$
   d) None of the above

23. If you now change the circuit so that the resistor switches place with the capacitor, what type of filter would you have?
   a) Notch filter
   b) Band-pass filter
   c) None of the above

For questions 25 and 27 assume that a test engineer has run a test on the behavior of a robotic arm and gives you a plot of the frequency response (see below). The specifications for the robotic arm state that the maximum frequency at which the arm can move is 10 rad/sec. You want to design a RC filter that will get rid of the noise of the signal. You have at your disposal the following components:

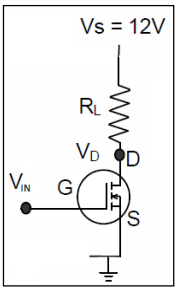
Resistors: 1Ω, 1kΩ, 10kΩ, 100kΩ
Capacitors: 1pF, 0.01μF, 1μF, 100μF
Choose the components that best suit your needs.
(hint: $\omega_{cutoff} = \frac{1}{\tau}$)



25. Value of R?
a) 1Ω
b) 1kΩ
c) 10kΩ
d) 100kΩ

27. Value of C?
a) 1pF
b) 0.01μF
c) 1μF
d) 0.1μF

For questions 29 and 31 assume that you create a circuit for controlling a light bulb with a MOSFET as shown below. You can model the light bulb as a resistor R_L. You can turn the light ON and OFF by controlling the input voltage to the MOSFET. You first decide to characterize the behavior of the MOSFET by measuring R_{DS} as a function of the input voltage and get the following values:



V_{IN}(volts)	R_{DS}(ohms)
0	100
2	90
3	80
3.9	4
5	0.01

29. Assume the light bulb shines the brightest when most current goes through it. It will shine the brightest when the input gate voltage (V_{IN}) is:
a) 0V
b) 2V
c) 3V
d) 3.9V
e) 5V

31. Assume R_L = 3996 ohms. What is the value of V_D that corresponds to an input gate voltage of 3.9 volts?
a) 12V
b) 0.12V
c) 1.2V
d) 0.012V
e) None of the above

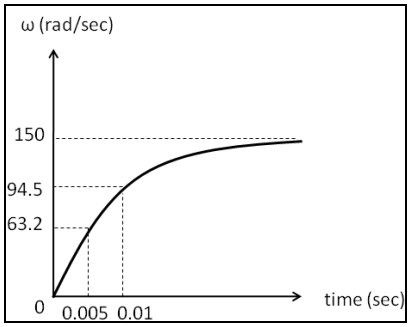
For questions 33, 35, 37, 39, and 41 assume you are working with a DC brushed motor. Assume the motor's torque constant and back EMF constant is B, the internal resistance is R, and the inductance L.

33. You hold the shaft fixed and apply a voltage V. What is the steady-state torque you will feel?
a) BV/R
b) L/R
c) R/BV
d) V/B
e) VR/B

35. You hold the shaft fixed and apply a voltage V. How long will it take for the torque to reach 63% of its steady-state value?
a) BV/R
b) L/R
c) R/BV
d) V/B
e) VR/B

37. You now run the motor and measure its current to be 1.2Amps and torque to be 8N.m. What is the value of the motor's constant B?
a) 0.15 A/N.m
b) 6.67 N.m/A
c) 0.3 A/N.m
d) 3.33 N.m/A
e) None of the above

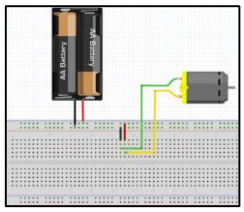
39. Assume that the time-response of the motor's no-load velocity is as shown below:



What is the time constant of the time-response?
a) 0.63sec
b) 0.0063sec
c) 10msec
d) 5msec

41. Using the plot above, what would be the value of the steady-state velocity if you double the inertia of the motor's shaft?
a) 300 rad/sec
b) 150 rad/sec
c) 100 rad/sec
d) 75 rad/sec
e) None of the above

43. Using the following diagram



Assume that you power the motor with a 6V battery and that the motor draws 250mA. What is the power, in watts, dissipated by the motor?

a) 0.024W
b) 24W
c) 0.375W
d) 1.5W
e) None of the above

For questions 44, 45, and 47 recall that the ODE for an RC low-pass circuit is given by:

$$RC\frac{dV_{out}}{dt} + V_{out} = V_{in}$$

45. What is the transfer function of this system?

a) $G(s) = \frac{1}{s+\frac{1}{RC}}$
b) $G(s) = \frac{1}{s+RC}$
c) $G(s) = \frac{\frac{1}{RC}}{s+\frac{1}{RC}}$
d) $G(s) = \frac{\frac{1}{RC}}{s+RC}$
e) None of the above

47. The response in the time-domain to a step change in voltage from 0 to 3V is given by:

a) $V_{out}(t) = (1 - e^{-t})$
b) $V_{out}(t) = \left(1 - e^{-\frac{t}{RC}}\right)$
c) $V_{out}(t) = 3(1 - e^{-t})$
d) $V_{out}(t) = 3\left(1 - e^{-\frac{t}{RC}}\right)$
e) None of the above

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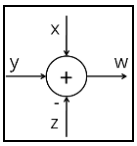
49. Based on the summation block shown below. What is the value of y?

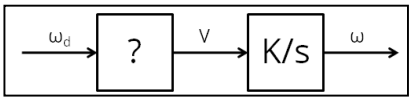


a) x + y – z
b) x * y * -z
c) w – z + x
d) w + z – x
e) None of the above

For questions 49 and 51 assume that you want to control the speed of a motor. You use a current amplifier with the motor and thus the speed of the motor is related to the input voltage to the current amplifier by the transfer function:

$$G(s) = \frac{K}{s}$$

You know very well the behavior of the motor and want to implement an open-loop controller for the motor.



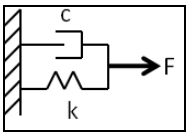
51. What should be the numerator of the transfer function in the controller box (?) to make the output (ω) equal to the desired input (ω_d)?

a) ω
b) ω_d
c) V
d) s
e) K

53. What should be the denominator of the transfer function in the controller box (?) to make the output (ω) equal to the desired input (ω_d)?

a) ω
b) ω_d
c) V
d) s
e) K

For problems 53 and 55 use the following diagram and recall that the equation of motion describing this system is of the form: $F = c\dot{x} + kx$



55. What is the transfer function of the system $(\frac{X(s)}{F(s)})$?

a) $G(s) = \frac{s}{sc+k}$
b) $G(s) = \frac{1}{s+ck}$
c) $G(s) = \frac{\frac{1}{c}}{s+\frac{k}{c}}$
d) $G(s) = \frac{s+1}{s+\frac{k}{c}}$
e) None of the above

57. What are the zeros of the transfer function?

a) $s = -1$
b) $s = 0$
c) $s = 1$
d) There are no zeros
e) None of the above

59. What are the poles of the transfer function?

a) $s = -\frac{k}{c}$
b) $s = 0$
c) $s = \frac{k}{c}$
d) There are no poles
e) None of the above

61. What function did you use in the Arduino IDE to create a PWM output signal?

a) createPWM()
b) digitalWrite()
c) analogWrite()
d) printPWM()
e) None of the above