ENGR-2300

Electronic Instrumentation

Quiz 1

Fall 2022

**Print Name _____   RIN _____**

Section ___

I have read, understood, and abided by the Collaboration and Academic Dishonesty statement in the course syllabus. The work presented here was solely performed by me.

Signature: _____

Date: _____

On all questions: SHOW ALL WORK. BEGIN WITH FORMULAS, THEN SUBSTITUTE VALUES AND UNITS. No credit will be given for numbers that appear without justification. Unless otherwise stated in a problem, provide 3 significant digits in answers. Read the entire quiz before answering any questions. Also it may be easier to answer parts of questions out of order.

I. **Voltage Dividers (20 points)** As stated on the cover page: Round answers to 3 significant digits. Show formulas first and show your work. No credit will be given for numbers that appear without justification.
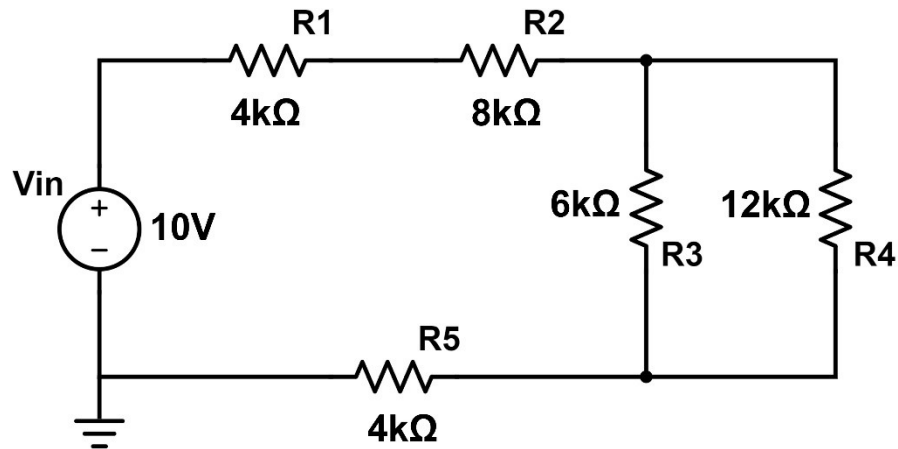

a.) (4 pts) Find the voltage across R3.

b.) (3 points) Find the current though R4.

c.) (4 pts) Beakman's motor consists of a spinning wire loop whose leads are sanded in such a way that the circuit is open for half of a cycle (circuit A) and closed for half a cycle (circuit B).
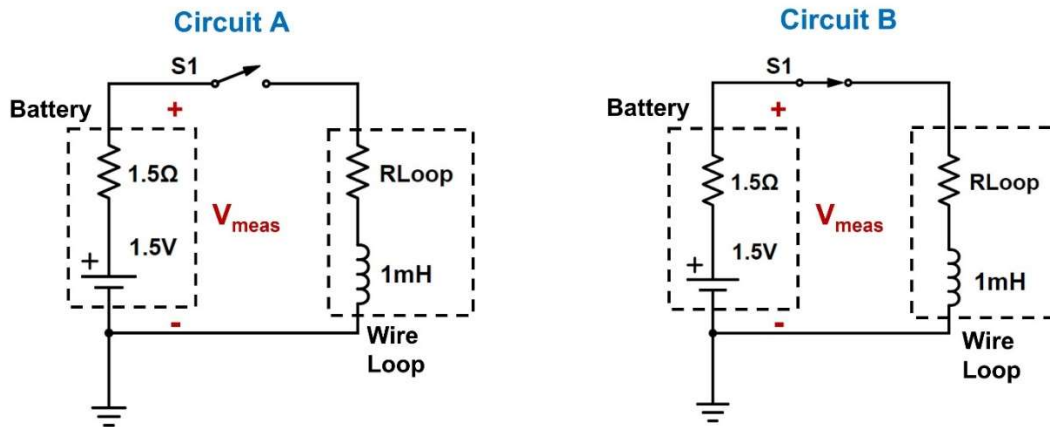

If the voltage across the battery is measured while the motor is operating, the plot below is observed on the oscilloscope: when the circuit is open (A), 1.5 V is measured across the battery and when the circuit is closed (B), 0.75 V is measured.
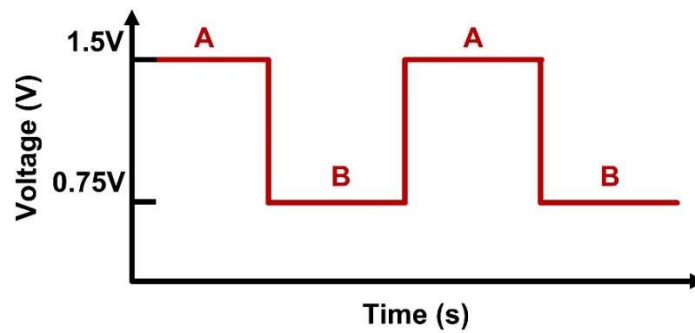
If the battery voltage is 1.5 V, the battery's internal resistance is 1.5 Ω, and the inductance of the wire loop is 1 mH, what is the value of RLoop, the resistance of the wire loop?

d.) (3 pts) How much power is delivered to the wire loop in the Beakman's motor when the circuit is closed (circuit B)?

e.) (3 pts) Below is the circuit diagram for the measurement of the input voltage ($V_{in} = V_{RA1}$) and output voltage ($V_{out} = V_{R2}$) of a voltage divider circuit. A1+ and A1- are the differential leads of channel 1 of the M2K, which has input impedance RA1 = 1 MΩ and A2+ and A2- are the leads for channel 2 of the M2K, which has input impedance RA2 = 1 MΩ.
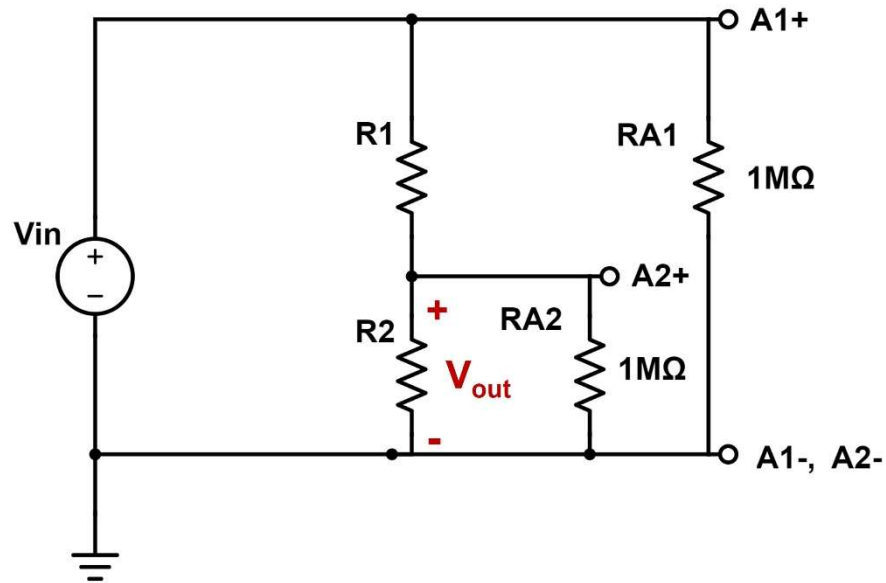
Under which conditions do we need to be concerned that the input impedance of channel 2 (RA2) will noticeably affect the voltage measurement across R2?

f.) (3 pts) Why don't we need to be concerned about the effect of the input impedance of channel 1 (RA1) on the measurement of V_{in}?

II. **Filters (20 points)** *Note: Page 2 of this quiz has background information. The crib sheet may also be useful.*

It is often necessary to filter noise at specific frequencies out of an audio signal. One example is the noise at 60 Hz, generated by the main AC wall plug power in a building. If the cable that carries an audio signal is not properly shielded and is near a power cable, a humming sound at 60 Hz will be picked up by the audio cable. If the audio has already been recorded and the 60 Hz hum is present, it is necessary to use a filter to remove it. Although a high quality factor band-stop filter, which rejects a very narrow range of frequencies, is typically used, we can use the knowledge learned up to this point in this course to construct a simple high pass filter to remove the 60Hz noise.

The filters explored so far in this course are called first-order filters and consist of a resistor and a single capacitor or inductor in series. As shown in the plot of the magnitude of the transfer function of a high pass filter below, below the corner frequency, first-order filters attenuate a signal at a rate of 20 dB/decade, or in other words, the magnitude of the transfer function changes at a rate of 20 dB per every change of a power of 10 in frequency.
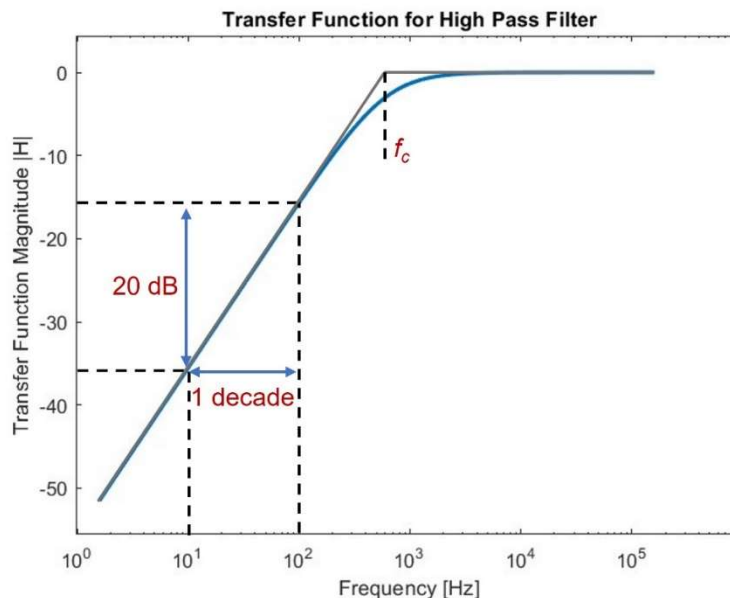
a.) (4 pts) To filter out the 60 Hz noise, we want to design a high pass filter whose attenuation at f = 60 Hz is 40 dB (i.e., $|H(j\omega)|$ = -40 dB at 60 Hz). Assuming that the corner frequency f_c is located where the linear approximation of the filter at low frequencies crosses 0 dB (as in the plot above), what corner frequency (in Hz) should the high pass filter we are designing have?

b.) (3 pts) To implement our high-pass filter, we will use a design with a resistor R = 1 kΩ and a capacitor C, as shown below.
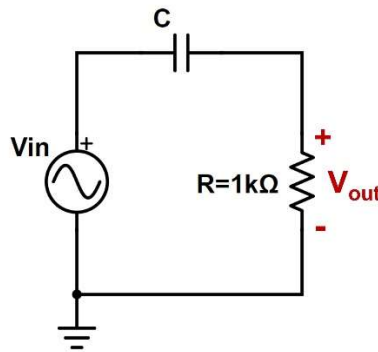
Using the value determined for the corner frequency in Q2.1, calculate the capacitance C required for the filter.

c.) (4 pts) Write the transfer function $H(j\omega)$ for this filter and then find the expression for its magnitude $|H(j\omega)|$.

d.) (3 pts) Alternatively, we could implement the filter using a resistor R = 1 kΩ and inductor L in series, as shown below.
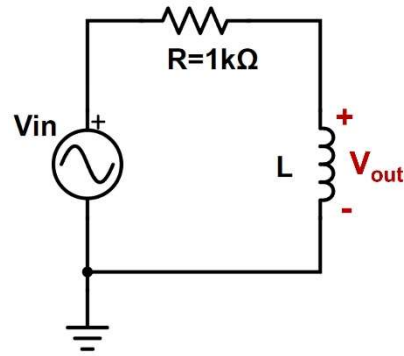
What value of L is required to implement a high-pass filter with the same corner frequency as calculated in Q2.1?

e.) (4 pts) Write the transfer function $H(j\omega)$ and the magnitude of the transfer function $|H(j\omega)|$ for this filter as well.
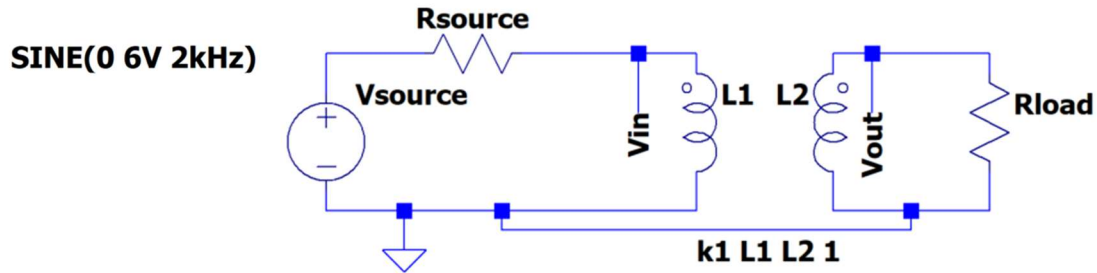
f.) (2 pts) Choose one to answer (check the box of the question you're answering):

What property of capacitors and inductors (as opposed to resistors) allows us to construct filters with them?

   OR

Given a choice between using a capacitor or an inductor in a high-pass filter for use at very high frequencies, which would you choose and why?

III. Phasors and Transformers (20 points)

Assume L1 and L2 form an ideal transformer with full coupling. The transformer has these specifications: **a=3, L1= 5mH**

a. (2pts) Determine the value of L2 that will allow the transformer to match the given a and L1 values:

L2=_____

b. (4 pts) Determine the ratios Vout/Vin, and Iout/Iin

Vout/Vin=_____

Iout/Iin=_____

c. (3 pts) Find the value of Rload that results in Rin = 3kΩ (Rin is Vin/Iin)

Rload=_____

d. (3 pts) Assume that the transformer above is an air core transformer operating at a sufficiently high frequency for normal operation. Now suppose that we replace the air core with a ferrite core similar to the one used in Experiment 3. Will this change the Vout/Vin ratio? Why or why not?

e. (2 pts) Suppose that the coupling coefficient between the two coils is decreased. What effect will this have on Vout/Vin?

E I   You must include units.   9   *A. Patterson and J. D. Rees*

Z1

Vin

Z2

0
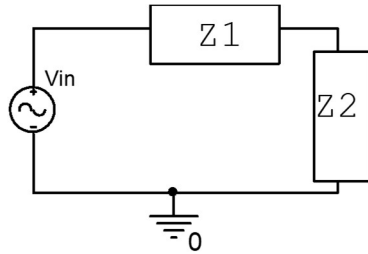
This circuit shown above has 2 complex impedances, Z1 and Z2, connected as shown.

f.   (3 pts) Suppose that Z1 consists of a 1 microfarad capacitor and Z2 consists of a 2 millihenry inductor. If Vin is a 5V sinusoidal voltage with frequency 5 kHz, what is the input impedance of the circuit?

g.) (3 pts) What does the phase of the input impedance approach as the frequency of Vin becomes very high?

**IV. Concepts and miscellaneous (20 points)**

   a.) (3 pts) Suppose that you have a battery with an open circuit voltage of 2V and an
   unknown battery resistance. You create a circuit that discharges the battery through a 10-
   ohm resistor. Draw a circuit diagram of this, including the battery resistance Rbatt.

   b.) (3 pts) Suppose that you measure the battery voltage while it is discharging into the 10
   ohm resistor and find it to be 1.5V. What is the battery's resistance?

c.) (6 pts) Suppose that you wished to use your Analog Discovery Board or M2K Board to test the resistance of two batteries at the same time by discharging each one into a 10 ohm resistor in a separate circuit. Create a diagram of the two discharging circuits below, then show how you would connect the board to the circuits by drawing lines between the AD2/MDK board and the circuits. Note that the M2K and the Analog Discovery 2 have the same wiring and colors.
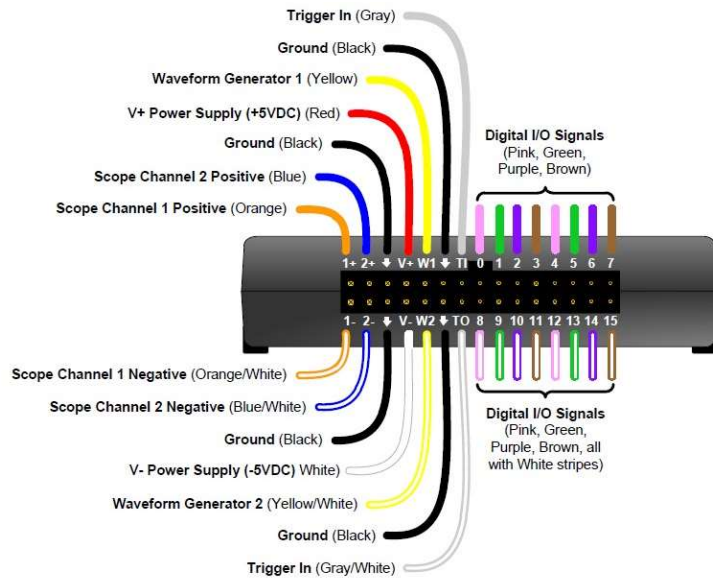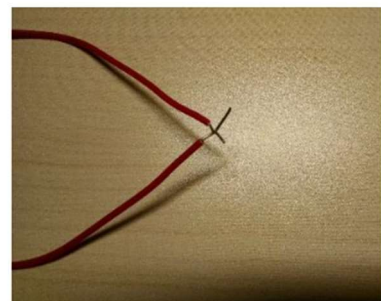

Miscellaneous Questions

d.) (1 pt) Is the image shown at the right
1. a short circuit?
2. an open circuit?
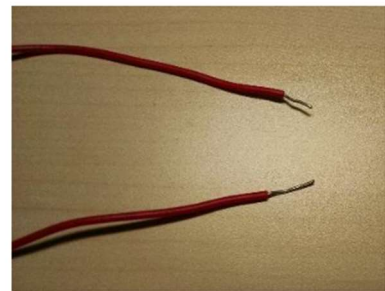
e) (1 pt) Is the image shown at the right a
1. a short circuit?
2. an open circuit?

f.) (1 pt) In the standard voltage divider configuration shown at the right, resistor R1 is much smaller than resistor R2. Is the power dissipated in R1

1. Much greater than the power dissipated in R2
2. Much less than the power dissipated in R2
3. About the same as the power dissipated in R2
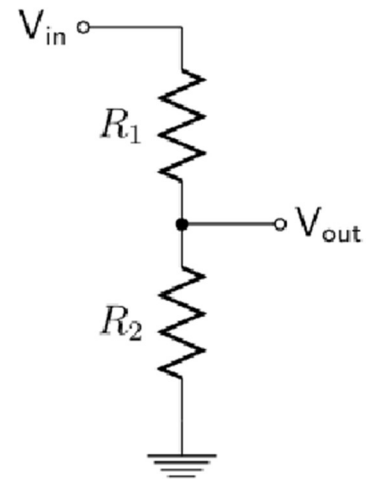
g.) (1 pt) A capacitor works by:

      1.) Storing energy in an electric field
      2.) Storing energy in a magnetic field
      3.) Storing energy in a resistance

h.) (1 pt) An inductor works by:

      4.) Storing energy in an electric field
      5.) Storing energy in a magnetic field
      6.) Storing energy in a resistance

i.) (2 pt) Explain why an inductor has a series resistance.

j.) (1 pt) Name one of the teaching assistants or undergraduate student assistance for the course.