Name ________________________

ECE Box # _____________

Problem	Score	Points
1	______	30
2	______	35
3	______	35

ECE2019 A2011
Sensors, Circuits, and Systems

Exam 2

- This is a **closed book, closed notes test**! Calculators are permitted, but **no pre-stored formulas or network communication are allowed!**
- **Collaboration, and other outside assistance are not allowed!**
- Show **all** your work. Partial credit may be given. If you think you need something that you can't remember, write down what you need and what you'd do if you remembered it. Be sure all numerical answers have correct units.
- Look for the simple, straightforward way to solve the problem for the question asked. **Don't get entangled in unnecessary algebra**.
- As in real life, some problems may give you more information than you need. Don't assume that all information must be used! It's your job to decide what's relevant to the solution.
- Manage your time wisely! Before you begin working, look through all the problems and decide how best to complete as much of the exam as possible in the allotted time. The point value of each part is indicated in brackets.

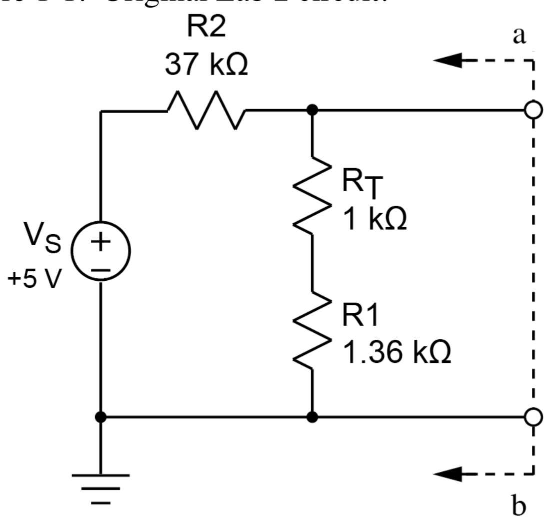
  You will have 55 minutes to complete this exam. There are three problems on a total of 7 pages.

1. This problem concerns analysis and design using Thevenin's theorem for the circuit of Lab 2, the resistive temperature sensor. To keep things simple we will assume temperature is not changing, so all resistors are constant at their T=300K values.

a) Analysis: Shown below in Figure 1-1 is a design for the Lab 2 circuit. Find the Thevenin equivalent circuit looking into the a-b pair of nodes. Sketch the Thevenin equivalent circuit in the box below, clearly indicating values for circuit elements in your Thevenin equivalent circuit. Accuracy ±5% required for full credit.

[15]

Figure 1-1. Original Lab 2 circuit.



Your Thevenin equivalent here:

Design: This part focuses on the +5V source V_S and resistor R2. In your design process for Lab 2, you were restricted to a value of +5V for the source, and your only design choices were R1 and R2. But it turns out we can improve the circuit's temperature accuracy if we allow an additional degree of freedom in the design, by not restricting the voltage source value to be +5V.

With three unknowns, it is too difficult to solve the equations on an exam, so I've done that for you: Figure 1-2 shows the new design values with $V_{S(NEW)} = +1.0V$, $R_{1(NEW)} = 645\ \Omega$ and $R_{2(NEW)} = 3.85\ k\Omega$ (R_T is unchanged). But if you went to build this in the lab, I would still want you to use the fixed +5V supply (rather than have to fiddle with the knobs on the adjustable supplies). Which brings us to your task for this part of the problem:

b) For the voltage divider circuit in Figure 1-3, choose resistor values R_{2A} and R_{2B} so the Thevenin equivalent looking into the c-d pair of nodes has a $V_{THEV} = V_{S(NEW)} = 1.0V$ and $R_{THEV} = R_{2(NEW)} = 3.85\ k\Omega$. Accuracy ±5% required for full credit.

[15]

R_{2A} = ______ R_{2B} = ______

Figure 1-2: New improved design

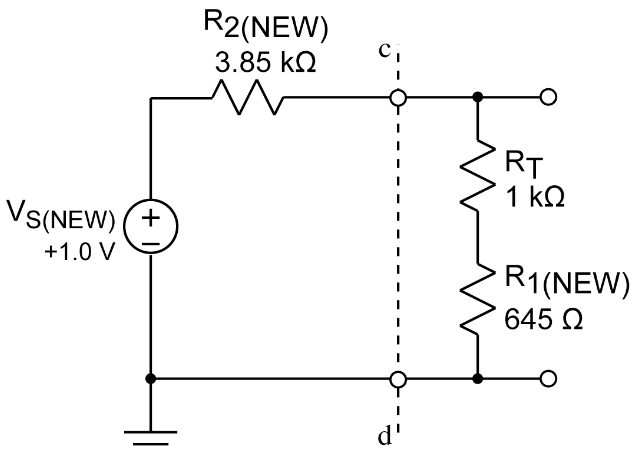
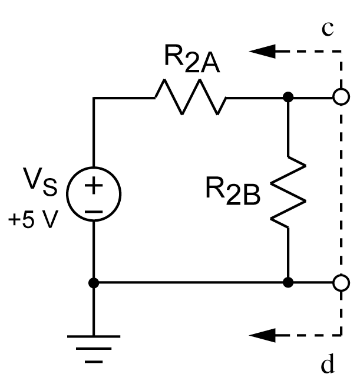


Figure 1-3: Realizing effect of $V_{S(NEW)}$ and $R_{2(NEW)}$ with $V_S = +5V$ and R_{2A}, R_{2B} voltage divider.



2. Six oscilloscope photos (A-F) are shown on the opposite page. Below are five circuits.

a) In the box in column (a), for each circuit, write the letter of one scope photo with waveforms that could be produced by that circuit. In some cases more than one photo may work; you only need to write one correct letter to receive full credit. Each scope photo may be used once, more than once, or not at all. **[25]**

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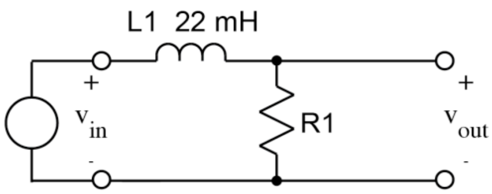
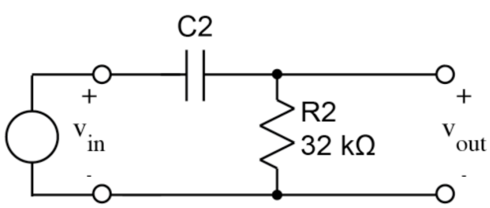
b) Each of the circuits has one component for which no value is given. Choose <u>any two</u> of the circuits, and in column (b) write the correct value given the waveform you selected. Accuracy ±5% required for full credit. **[10]**

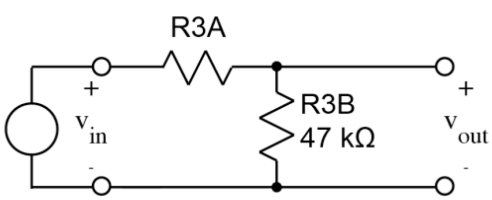
(a) **(b) (Choose any two)**



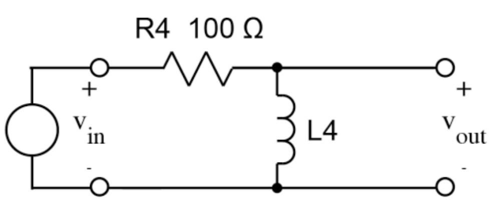
R1 = __________



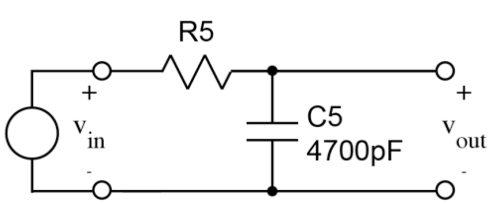
C2 = __________



R3A = __________

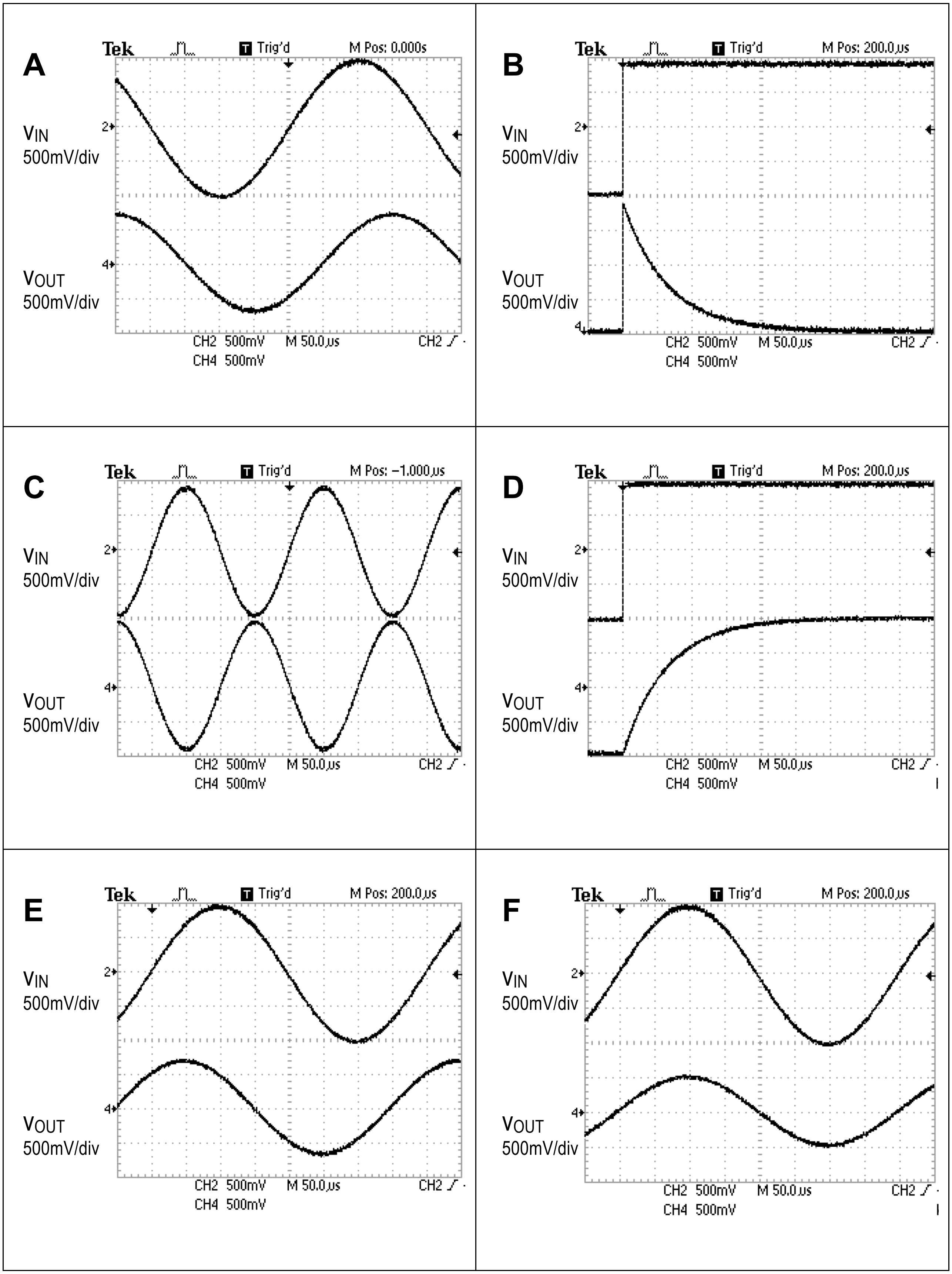


L4 = __________



R5 = __________

In all photos, the input and output voltages are shown on a vertical scale of 500 mV / div and a horizontal scale of 50 μsec / div.



3. This problem is concerned with the RC filter circuit shown at the top of the opposite page.

a) Is this a first-order or second-order filter? Circle one below and explain your answer. **[1]**

FIRST-ORDER **SECOND-ORDER**

EXPLAIN YOUR CHOICE: **[3]**

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b) Is this a lowpass or highpass filter? Circle one below and explain your answer. **[1]**

LOWPASS **HIGHPASS**

EXPLAIN YOUR CHOICE: **[3]**

In parts (c) and (d), the circuit is tested with sinusoidal input waveforms at frequencies of 1kHz, 10 kHz, and 100 kHz. An oscilloscope plot of the input and output waveforms for the f = 10kHz case is shown.

c) Using the axes adjacent to the oscilloscope plot, CAREFULLY sketch the output waveforms for the cases of f = 1kHz and f = 100kHz. Be sure to indicate the correct amplitude and phase relationship to receive full credit. Accuracy ±10% required for full credit. **[8]**

Note: Time scale varies between 1kHz, 10kHz, 100kHz plots. In each case a dashed line representing v_{in} is shown on the v_{out} plot to help you clearly indicate the correct magnitude and phase relationship.

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d) Using the spaces under the plots, provide values for the magnitude and phase of the transfer function $H(f) = v_{out} / v_{in}$ evaluated at 1kHz, 10kHz, and 100kHz. Magnitude can either be a number, or in dB, your choice. Phase must be in degrees. Accuracy ±10% required for full credit. **[9]**

In (e) and (f), the circuit is tested with a 5V step waveform. Assume $v_{in} = 0$ for all time $t < 0$.

e) Using the axes given, CAREFULLY sketch the output waveform over a time scale of 0 to 100μsec. Be sure to indicate the correct amplitude and waveform shape to receive full credit. Accuracy ±10% required for full credit. **[5]**

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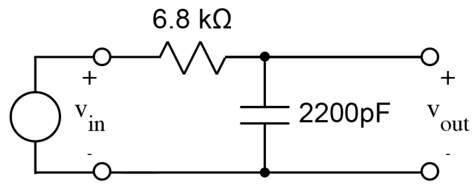
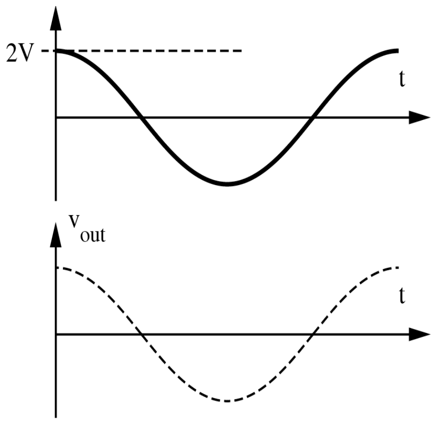
f) At what time $t_{(4.5V)}$ does v_{OUT} reach a value of +4.5V? Accuracy ±10% required for full credit. **[5]**

$t_{(4.5V)}$ = _______

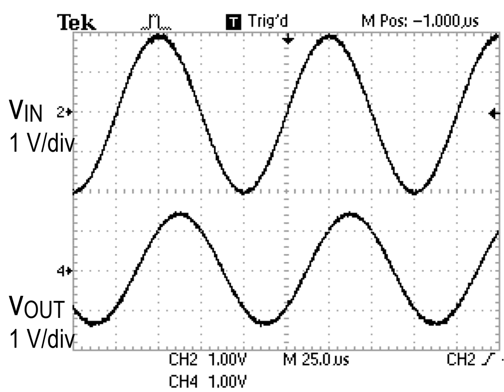


Plots for (c):

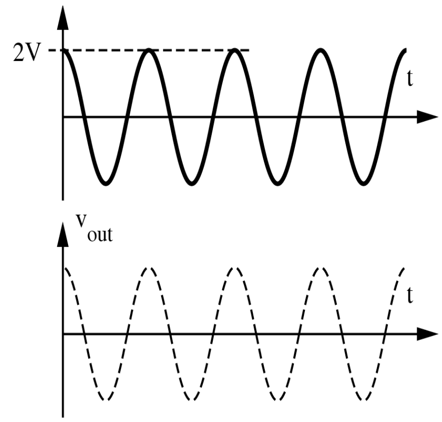
1 kHz



10 kHz



100 kHz



Answers for (d):

$\left|H\left(f = 1kHz\right)\right|$ = __________

$\angle H\left(f = 1kHz\right)$ = __________

$\left|H\left(f = 10kHz\right)\right|$ = __________

$\angle H\left(f = 10kHz\right)$ = __________

$\left|H\left(f = 100kHz\right)\right|$ = __________

$\angle H\left(f = 100kHz\right)$ = __________

Axes for (e):