BME/ECE 386 EXAM 1 (W19)   NAME:____________________________

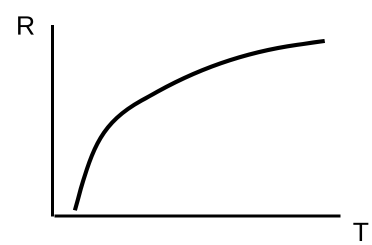
4 problems for 100 pts

Problem #1: Short Answers (25 pts)

(a) Strain Gauge (4 pts): A 350 ohm constantan strain gauge (G = 2.1) experiences a strain ε = -150 μstrain. Does the gauge resistance increase or decrease, and by how much? Express your answer in ohms.

(b) True or False (2 pts): An instrumentation amplifier should have high input impedance and small common-mode rejection ratio. **If you choose false, explain why.**

(c) Thermistor (2 pts): Shown on the right is a plot of resistance vs temperature for a thermistor. What is the sign of the tempco?



(d) Thermocouple (3 pts): A type K thermocouple is made from the junction of alumel and chromel wires. Alumel is an alloy of which two metallic elements? What about chromel?

(e) True or False (2 pts): An infrared thermometer uses a thermopile detector, which is basically a miniature array of thermistors. **If you choose false, explain why.**

(f) Action Potential (3 pts): The cardiac action potential involves the inward rush of silver ions (depolarization) and phosphorus ions (muscle contraction), followed by the outward rush of chlorine ions (repolarization). **Make corrections, wherever necessary, to the previous statement about the action potential in a cardiac muscle cell.**

(g) ECG (3 pts): Sketch a typical ECG waveform and label which portions are due to repolarization or depolarization of a specific section of the heart.

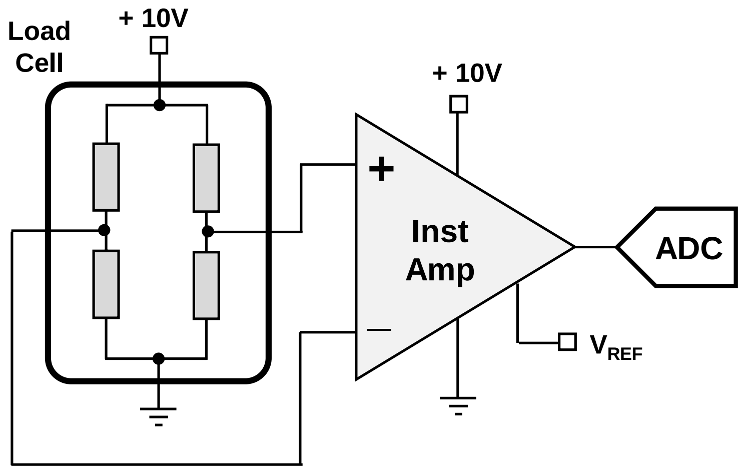
(h) ECG (3 pts): The electrical network of the heart consists of the Sino American node, internasal tracts, Arterial Vehicular node, Bundle of Hers, and Punjabi fibers. **Make corrections, wherever necessary, to the previous statement.**

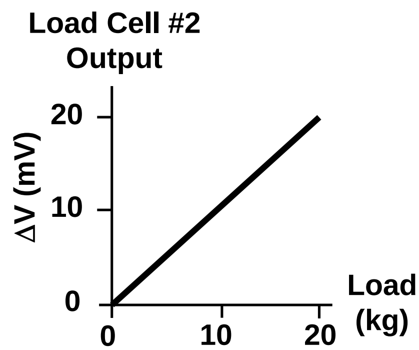
(i) ECG electrodes (3 pts): In order for current to flow into the body, which chemical reactions occur to silver and silver chloride?

Problem #2: Load Cell (25 pts)

You are asked to design a digital weighing scale. The customer wants to measure a maximum load of 3 kg with a sensitivity of 10 g. The supply voltage is V_S = +10V. The instrumentation amplifier has a differential gain Ad = 500, output noise voltage V_N = 2 mV_{RMS}, and V_{REF} = 2V. It is powered by +10V and GND, so you can assume the amplifier output is limited to 1V (min) and 9V (max). The ADC has 14 bits (0 to 10V).

You have two load cells available. Load Cell #1 has RO = 1.5 mV/V @ 5 kg. Unfortunately, the RO and L_{RATED} for Load Cell #2 are not known. However, Load Cell #2 has the testing curve shown in the right figure.





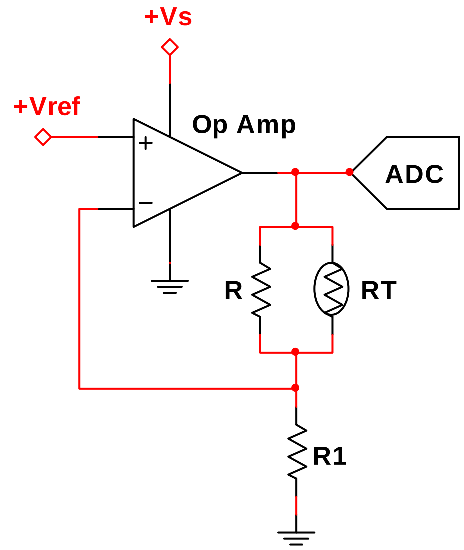
a) Which load cells (there may be more than one) satisfy the design specs? **For each load cell, you must clearly explain why it works or does not work.** Show all work!

b) Suppose your customer wants to replace the original ADC with an Arduino Uno, which has an ADC with 10 bits (0 to 5V). Can the Arduino Uno be used with one of the available load cells to satisfy both design specs? Show all work! NOTE: You can re-use any relevant results from part (a) (i.e. you do not need to re-do all calculations).

(extra sheet for work)

Problem #3: Temperature (25 pts)

You are asked to design an incubator temperature measurement system that operates from T = 10°C up to T = 50 °C. The magnitude of the sensitivity $|\Delta T_{MIN}|$ must be less than 0.05°C at T = 50 °C.



Consider the thermistor circuit shown to the right. It uses an op amp, a resistor R1, and a thermistor R_T in parallel with a resistor R. The thermistor has the properties shown below:

- **T = 50 °C: R_T = 5.76 kohm α = -3.58 %/°C**
- **T = 10 °C: R_T = 28.51 kohm α = -4.47 %/°C**

The op amp is powered by Vs = +5V and GND. Assume the op amp output is limited to within 1V of each power supply. The output noise voltage is measured to be V_N = 0.5 mV_{RMS}. The ADC has 12 bits and operates from +5V to GND.

a) Use the Golden Rules to show that: $V_{MEAS} = V_{REF} + \frac{V_{REF}}{R1}\left(\frac{R \cdot R_T}{R + R_T}\right)$. Show all work!

b) Assume that V_{REF} = 1V and R1 = 2.7 kohm. The available resistors are R = 10 kohm and 16 kohm. Which resistor (one, both, or none) satisfies all the design requirements? You must explain why a resistor is OK or not OK. Show all work!

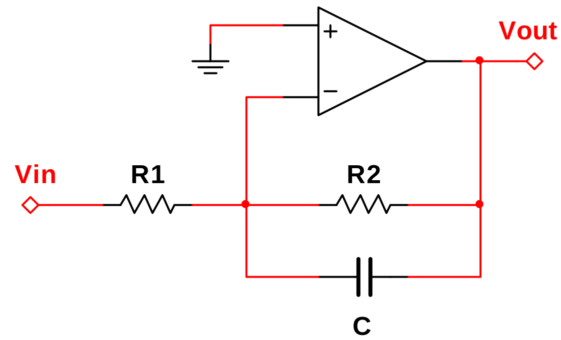
(extra sheet for work)

Problem #4: ECG Amplifier (25 pts)

You are asked to design a single-lead ECG system to monitor a person exercising on a stationary bike. Suppose the ECG input is a PQRST waveform with a 0.4 mV amplitude R-wave. The patient's heart rate is 150 beats per minute. Mismatches in the skin-electrode interface produce a constant 10 mV voltage difference between the two electrodes. The person's motion causes a severe common mode voltage resembling a 1 Hz sine wave with a peak-to-peak amplitude of 2 V_{PP}. The instrumentation amplifier has a differential gain A_d = 30 and CMRR = 75 dB.

a) Compute and sketch the instrumentation amplifier output over a 2 second interval. Label important features!

b) The op amp circuit shown to the right combines a low pass filter with an inverting amplifier. Use the Golden Rules to show that:



$$\frac{V_{out}}{V_{in}} = -G_o \frac{1}{1+jf/f_C}$$

NOTE: Clearly define G_O and f_C (e.g. in terms of R1, R2, and/or C)!

c) Let us assume that the circuit from Part (b) passes a signal frequency when $|V_{OUT}/V_{IN}| > 0.9G_O$. Suppose R1 = 1 kohm and R2 = 100 kohm. Assume the ECG signal has frequency content that spans from 1 to 30 Hz. What is the appropriate value for C in order to suppress noise? Choose a standard 10% capacitor value (see table on last page). Show all work!

(extra sheet for work)

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Standard Resistor Values (±5%)						
1.0	10	100	1.0K	10K	100K	1.0M
1.1	11	110	1.1K	11K	110K	1.1M
1.2	12	120	1.2K	12K	120K	1.2M
1.3	13	130	1.3K	13K	130K	1.3M
1.5	15	150	1.5K	15K	150K	1.5M
1.6	16	160	1.6K	16K	160K	1.6M
1.8	18	180	1.8K	18K	180K	1.8M
2.0	20	200	2.0K	20K	200K	2.0M
2.2	22	220	2.2K	22K	220K	2.2M
2.4	24	240	2.4K	24K	240K	2.4M
2.7	27	270	2.7K	27K	270K	2.7M
3.0	30	300	3.0K	30K	300K	3.0M
3.3	33	330	3.3K	33K	330K	3.3M
3.6	36	360	3.6K	36K	360K	3.6M
3.9	39	390	3.9K	39K	390K	3.9M
4.3	43	430	4.3K	43K	430K	4.3M
4.7	47	470	4.7K	47K	470K	4.7M
5.1	51	510	5.1K	51K	510K	5.1M
5.6	56	560	5.6K	56K	560K	5.6M
6.2	62	620	6.2K	62K	620K	6.2M
6.8	68	680	6.8K	68K	680K	6.8M
7.5	75	750	7.5K	75K	750K	7.5M
8.2	82	820	8.2K	82K	820K	8.2M
9.1	91	910	9.1K	91K	910K	9.1M

Standard Capacitor Values (±10%)						
10pF	100pF	1000pF	.010μF	.10μF	1.0μF	10μF
12pF	120pF	1200pF	.012μF	.12μF	1.2μF	
15pF	150pF	1500pF	.015μF	.15μF	1.5μF	
18pF	180pF	1800pF	.018μF	.18μF	1.8μF	
22pF	220pF	2200pF	.022μF	.22μF	2.2μF	22μF
27pF	270pF	2700pF	.027μF	.27μF	2.7μF	
33pF	330pF	3300pF	.033μF	.33μF	3.3μF	33μF
39pF	390pF	3900pF	.039μF	.39μF	3.9μF	
47pF	470pF	4700pF	.047μF	.47μF	4.7μF	47uF
56pF	560pF	5600pF	.056μF	.56μF	5.6μF	
68pF	680pF	6800pF	.068μF	.68μF	6.8μF	
82pF	820pF	8200pF	.082μF	.82μF	8.2μF	