NAME (please print) ____

UNIVERSITY OF CALIFORNIA

College of Engineering
Department of Electrical Engineering and Computer Sciences

EECS 145L: Electronic Transducer Laboratory

FINAL EXAMINATION December 17, 1998 12:30 - 3:30 PM

You have three hours to work on the exam, which is to be taken closed book.
Calculators are OK, use equation sheet provided.
You will not receive full credit if you do not show your work. Use back side of sheet if necessary.
Total points = 200 out of 1000 for the course.

1 ______________ (60 max) 2 ______________ (30 max) 3 ______________ (30 max)

4 ______________ (50 max) 5 ______________ (30 max)

TOTAL _____________ (200 max)

COURSE GRADE SUMMARY

LAB REPORTS (500 points max):
[5 short reports (lowest grade dropped)- 100 points max]
[5 full reports (lowest grade dropped)-400 points max]

4 __________ 5 __________ 6 __________ 7 __________ 11 __________

12 __________ 13 __________ 14 __________ 15 __________ 16 __________

17 __________ 18 __________ 19 __________ 25 __________

LAB TOTAL	____________	(500 max)
LAB PARTICIPATION	____________	(100 max)
MID-TERM #1	____________	(100 max)
MID-TERM #2	____________	(100 max)
FINAL EXAM	____________	(200 max)
TOTAL COURSE GRADE	____________	(1000 max)

COURSE LETTER GRADE

PROBLEM 1 (60 points)

In less than 50 words, describe the essential differences between the following two items:

1a. (12 points) [Common mode gain] and [Differential gain] of an instrumentation amplifier.

1b. (12 points) [Platinum resistance thermometer] and [Thermistor]

1c. (12 points) [Electrocardiogram (ECG)] and [Electromyogram (EMG)]

1d. (12 points) [Light emitting diode (LED)] and [Photodiode]

1e. (12 points) [Johnson noise] and [Shot noise]

PROBLEM 2 (30 points)

Describe how each of the following sensors converts a physical quantity into an electrical signal (resistance change, current, or voltage)

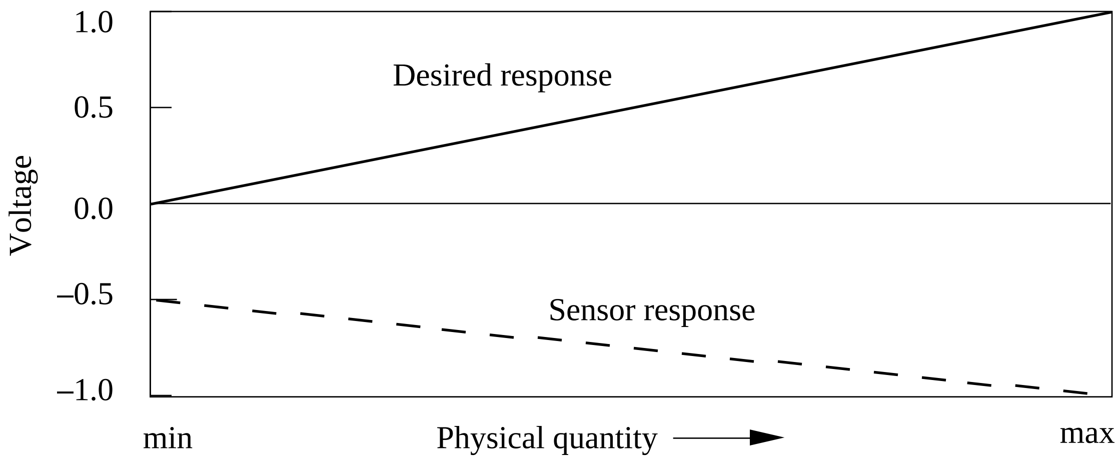
2a. (10 points) Resistive metal film strain gauge.

2b. (10 points) Digital position encoder (linear or rotary)

2c. (10 points) Thermocouple

PROBLEM 3 (15 points)

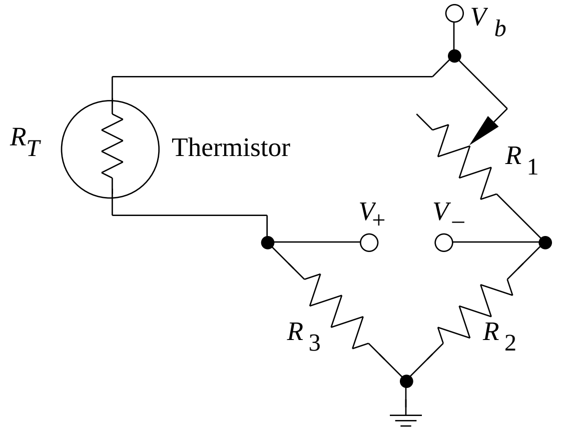
You have a sensor that produces a voltage from –0.5 V to –1.0 V, as shown in the figure below. The sensor has an output impedance of 100 kΩ.



3. (30 points) Design and sketch a circuit that transforms the sensor voltage to the 0.0 to +1.0 volt range. You may use any of the circuit components from the 145L lab, but keep it simple.

PROBLEM 4 (50 points)

You wish to measure air temperatures over the range from 0°C to 50°C using the thermistor bridge shown below.



Assume the following:

- $R_2 = R_3 = 5\ \mathrm{k}\Omega$.
- You use an instrumentation amplifier with a gain of 5: $V_0 = 5\,(V_+ - V_-)$.
- The thermistor resistance R_T vs. temperature T as shown in the table below

0°C	10°C	20°C	30°C	40°C	50°C
10.000 kΩ	6.667 kΩ	5.000 kΩ	3.333 kΩ	2.500 kΩ	1.667 kΩ

- $dR_T/dT = -150\Omega/°\mathrm{C}$ at 20 °C.

You then perform a series of experiments to explore the thermistor self-heating of your system and to determine the range of suitable bias voltages V_b.

Experiment 1: With V_b = 1 volt and the thermistor in **water** at 20°C, you adjust R_1 to make the amplifier output V_0 = 0.000 volts. (Assume that there is no self heating in water with V_b = 1 volt)

4a. (5 points) What are the values of R_1 and R_T?

4b. (5 points) What electrical power is consumed by the thermistor?

Experiment 2: You then move the thermistor to **air** at 20 °C, wait a while, and find that the amplifier output V_0 = 0.0075 volts (V_b = 1 volt).

4c. (5 points) What is the thermistor resistance R_T?

4d. (5 points) What is the temperature of the thermistor?

4e. (5 points) What electrical power is consumed by the thermistor?

Experiment 3: With the thermistor in air at 20 °C, you increase V_b to 10 volts, wait a while, and find that the amplifier output V_0 = 8.333 volts.

4f. (5 points) What is the thermistor resistance R_T?

4g. (5 points) What is the temperature of the thermistor?

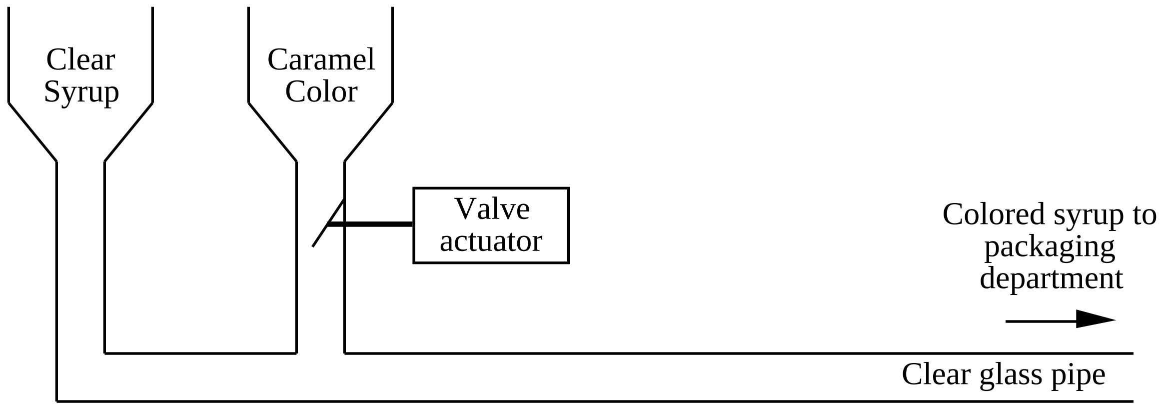
4h. (5 points) What electrical power is consumed by the thermistor?

4i. (5 points) From your calculations of experiment 3, what is the thermal dissipation coefficient in mW per C°?

4j. (5 points) Comment on the design factors that determine the approximate **minimum** and **maximum** bias voltages or this application.

PROBLEM 5 (30 points)

The Coca-Cola company has hired you to design a system to add "caramel coloring" to soda syrup. The plumbing is already designed and looks like the following:



5a (20 points) Design a system that continuously measures the color of the processed syrup, and uses negative feedback to control the flow of the "caramel color" to maintain a consistent color that is the same as a **standard sample**. Sketch your design in the diagram **above**, including all sensor, actuator, and circuit components, and the standard sample.

Note 1: Assume that the flow of the clear syrup is constant, regulated by an existing system that is not shown.

Note 2: The actuator closes the valve at 0 volts, and fully opens the valve at 5 volts and 5 amperes.

Note 3: Provide sufficient detail so that your design could be built by a student who has taken 145L.

5b (10 points) Imagine that the system has been running a while and that the "caramel color" feed bucket is nearly empty. What happens if a new batch of **darker** "caramel color" is added? Explain qualitatively how the system reacts to control the color of the final product.