NAME (please print) _____ SID _____

UNIVERSITY OF CALIFORNIA, BERKELEY
Electrical Engineering and Computer Sciences Department

EECS 145L Electronic Transducer Lab
MIDTERM #2 (100 points maximum)
November 15, 2006

(closed book, calculators OK, equation sheet provided)
(You will not receive full credit if you do not show your work)

PROBLEM 1 (35 points)

Describe briefly how each of the following temperature sensors produces its electrical signal:

1a (7 points) The platinum resistance thermometer

1b (7 points) The thermocouple

1c (7 points) The thermistor

1d (7 points) The solid-state temperature sensor

1e (7 points) The metal-film strain gauge

PROBLEM 2 (25 points)

After considering how sensitive strain gauges are to the thermal expansion of the element to which they are bonded, you invent a temperature sensor that consists of two resistive strain gauges cemented to a small aluminum plate and a circuit designed to produce an output of zero at 0°C and a sensitivity of 10 mV/°C.

Assume the following:

- You use the two strain gauges in a bridge circuit
- The two strain gauges have unstrained resistance 100 Ω, gauge factor = 2
- The thermal expansion coefficient of aluminum is 23 ppm/°C (ppm = parts per million)

2a (15 points) Sketch your circuit design, including all components and wires.

2b (5 points) Describe how a user would calibrate your sensor.

2c (5 points) Compute the power dissipated by the strain gauge.

PROBLEM 3 (40 points)

A test kit is available for measuring the levels of lead in eating utensils (cups, bowls, plates, etc.). The utensil is first soaked in hot acetic acid (vinegar) and the acid is mixed with a reagent chemical. If no lead is present, the mixture is clear. If a small amount of lead is present, the mixture is yellow. If a dangerous amount of lead is present, the mixture is dark orange.

Design a system for determining the concentration of lead in ppm, using the following:

- a green LED
- a PIN photodiode
- a microcomputer with A/D converter (input range 0 V to +10 V).
- Any other circuit components from the 145L course

Assume the following:

- The light intensity A passing through the solution is given by $A = A_0\ e^{-kLC}$, where C is the lead concentration in ppm, L is the thickness of the solution in cm, and the extinction coefficient for green light is $k = 1\ \text{ppm}^{-1}\ \text{cm}^{-1}$.
- The thickness of the solution $L = 1$ cm.
- The LED shining through a clear solution produces a photodiode current of 100 μA, and your design should convert this into a signal of +5 V at the A/D converter of the microcomputer.
- You have adjusted your amplifier for zero offset output voltage.
- You operate the photodiode in photovoltaic mode.
- You do not need analog filtering

3a (20 points) Sketch a block diagram including and labeling all essential components and typical voltage levels. (You can show the A/D and microcomputer as a single block).

3b (7 points) Derive the expression for the A/D input voltage as a function of the lead concentration C.

3c (7 points) Describe how a user would calibrate the system.

3d (6 points) Derive an expression for the uncertainty in concentration σ_C as a function of voltage noise σ_V at the A/D input.