Midterm #2 Solutions – EECS 145L Fall 2002

1a The platinum resistance thermometer is a *conductor* and its electrical resistance increases with increasing temperature due to increasing disorder of the crystal lattice

[full credit for including "conductor" and R increases as T increases]

1b The thermocouple consists of two dissimilar metals joined at both ends. When the loop is broken a combination of two Thompson and two Peltier emfs produces a voltage that is proportional to the difference in temperature between the two junctions

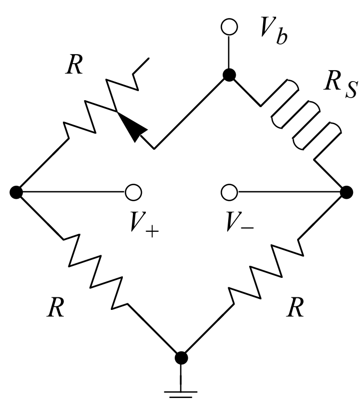
1c The thermistor is a *semiconductor* and its electrical resistance decreases with increasing temperature as more electrons are thermally promoted from the valence band to the conduction band

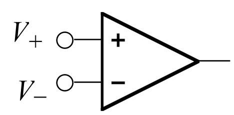
[full credit for including "semiconductor" and R decreases as T increases]

1d The solid state temperature sensor depends on the principle that if two matched transistors are connected at their bases, the difference between their base-emitter voltages is proportional to the product of (1) the absolute temperature and (2) the logarithm of the ratio of the currents passing though them. The current through the device is proportional to the absolute temperature.

[Note: some students read problem 1 as "how are the following temperature sensors used?" rather than "how do they produce their electrical signal?"]

2a





Instrumentation amp- gain 2000

$$V_+ - V_- = V_b\left(\frac{R}{2R} - \frac{R}{2R+\Delta R}\right) = V_b\left(\frac{\Delta R}{4R+2\Delta R}\right) \approx V_b\left(\frac{\Delta R}{4R}\right) = V_b\left(\frac{G_S}{4}\right)\left(\frac{\Delta L}{L}\right) = V_b\left(\frac{\Delta L}{2L}\right)$$

With a strain of $\Delta L/L = 10^{-3}$, the differential bridge output is 0.5 mV. To produce 1 V, an instrumentation amplifier with a differential gain of 2000 is required.

[3 points off for computing gain but omitting amplifier in circuit]

[3 points off for not computing gain but showing amplifier in circuit]

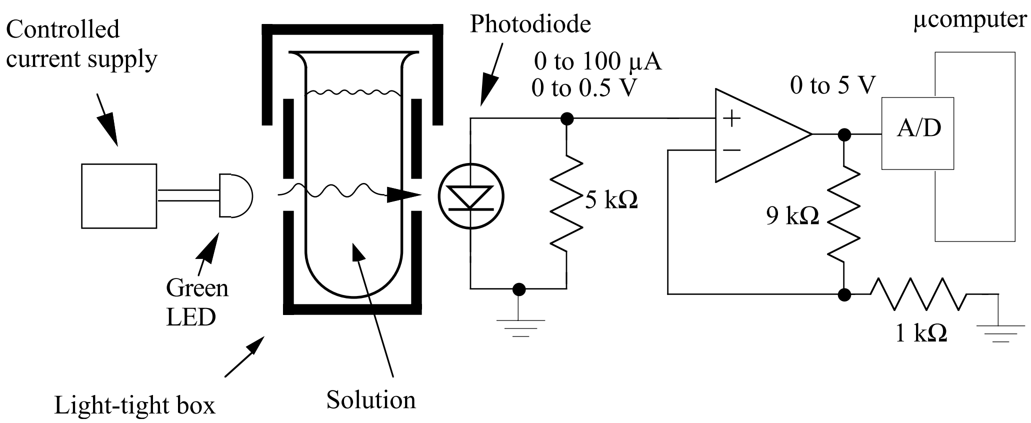
[5 points off for using a 2000V bridge bias- this would draw 2 x 10A and dissapate 2 x 20 kW!!]

2a Modify the circuit by placing the second strain gauge so that of both strain gauges change by the same amount, the bridge output does not change. In the drawing above, the second strain gauge would replace the fixed resistor below the fitst strain gauge. The variable resistor to the left would still be available to adjust the zero setting.

Mount the second strain gauge so that it experiences the same thermal expansion as the first strain gauge but not the same strain. For a flexable bar as in the strain lab, mount the second on the opposite side as the first. The the second strain gauge will experience the same thermal expansion but the oppositve strain. In other situations where the strain is in one direction only, the second strain gauge could be mounted perpendicular to the first so that it experiences the same thermal expansion as the first but not the strain.

[3 points off for showing the second strain gauge in the circuit (question 1) but not describing how it is to be mounted (question 2)]

3 a



The 5 kΩ resistor in parallel with the photodiode converts 100 μA into 0.5 V. A larger value will cause saturation at the forward voltage of about 0.6 V. A much smaller resistor will decrease the signal and reduce the signal-to-noise ratio. The noninverting amplifier provides a voltage gain of 10. A smaller resistor was okay, so long as the gain-resistance product was 50 kΩ.

[4 points off for not describing LET supply or using a fixed voltage supply]

[6 points off for using a 50 kΩ shunt resistor to provide 5 volts- the PIN photodiode has a maximum output of around 0.6 volts]

3b

$V_C = 10\, R\, I_0\, e^{-kLC} = 50\text{k}\, I_0\, e^{-kLC}$

V_C = A/D input voltage at lead concentration C (ppm)

I_0 = 100 μA = photodiode current when C = 0 (maximum current condition)

From information given, L = 1 cm, k = 1 ppm^{-1} cm^{-1} and

$\mathbf{V_C = 5\, e^{-C}}$, where V_C is in volts and C is in ppm.

3c

The minimum calibration procedure is to check the system using two very different concentrations. The best two are C = 0 and C large.

(i) Measure V_C for several known concentrations (including C = 0 for clear solution). Note that we cannot ***assume*** that a clear solution produces 5 V- the system might be out of calibration or a wire might be broken.

(ii) Fit a smooth curve to the data from (ii) as logV_C vs. C that relates any V_C to the corresponding concentration C.

[6 points off for a calibration procedure that uses the ideal curve and does not measure the system response to known concentrations]

[5 points off for a calibration procedure that measrues the response at only one concentration]

3d

For a single random variable, the error propagation formula reduces to $\sigma_f = |df/da|\ \sigma_a$

Approach 1: $V = 5\ e^{-C}$ $\quad dV/dC = -5\ e^{-C} = -V$

Approach 2: $C = -\ln(V/5)$ $\quad dC/dV = -(5/V)(1/5) = -1/V$

Using either approach, $\boldsymbol{\sigma_C = (1/V)\ \sigma_V}$

[4 points off for a simple substitution of C with σ_C and V with σ_V, which assumes a linear relationship]

145L midterm #2 grade distribution:

Problem	
1	22.3 (3.2 rms) (28 max)
2	21.7 (3.3 rms) (25 max)
3	33.2 (9.2 rms) (47 max)

maximum score =	100	
average score =	77.1	(rms = 12.2)
30-39	0	F
40-49	1	D
50-59	2	C-
60-69	3	C
70-79	6	B
80-89	10	A
90-99	2	A+
100	0	