Midterm #2 Solutions – EECS 145L Fall 2006

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

[3 pints of for not stating that R increases with increasing T]

[2 points off for not mentioning that in metals lattice distortion or scattering increases with T]

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

[2 points off for not stating that R decreases with increasing T]

[2 points off for not stating that electrons are promoted to conduction band with increasing T]

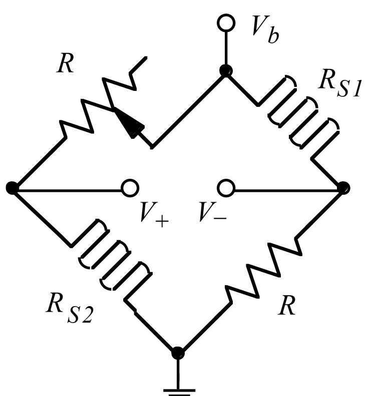
1d The solid state temperature sensor depends on the principle that if two matched transistors are connected at their bases, the difference between their base-emitter voltages is proportional to the product of (1) the absolute temperature and (2) the logarithm of the ratio of the currents passing though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

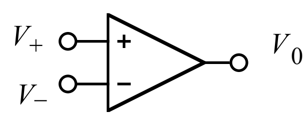
1e Tension increases the resistance by increasing length and decreasing cross-sectional area

Compression decreases the resistance by decreasing length and increasing cross-sectional area

[Note: some students read problem 1 as "how are the following temperature sensors used?" rather than "how do they produce their electrical signal?"] ["How" is defined in the dictionary as "in what way; by what means"]

2a





Instrumentation amp
V_b G = 434.7

Mount both strain gauges onto the aluminum plate

[5 points off if no amplifier shown]

[3 points off for no gain calculation or improper setup]

[3 points off if strain gauges are on the same side of the bridge]

[2 points off for not providing a variable resistor to set output = 0 at 0°C]

$R = 100\ \Omega$

$R_S = R + \Delta R$

$V+ - V- = V_b\ [\ (R + \Delta R)/(\Delta R + 2R) - (R)/(\Delta R + 2R)]$

$\Delta R/R = 2\ \Delta L/(L)$

$Vo = G V_b\ (\Delta R)\ /(\Delta R+2R) \approx G V_b\ \Delta R/(2R) = G V_b\ \Delta L/(L)$

$\Delta T = 1\ °C$ means $\Delta L/L = 23$ ppm

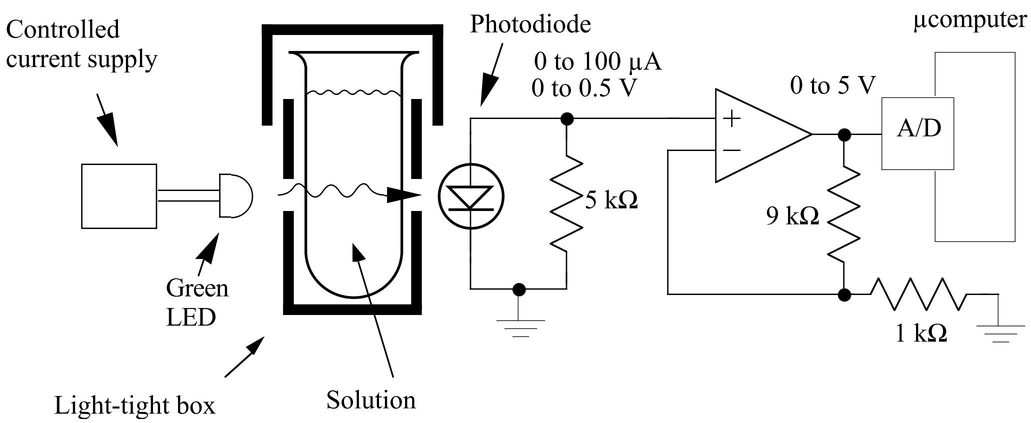
$V_0 = Vb\ G\ T\ (23 \times 10\text{-}6/°C) = T\ (10\ mV/°C)$

Vb G = 10 / 0.023 = 434.7; If Vb = 1 volt, G = 434.7

2b Adjust bridge resistor to make Vo = 0 at o°C.
Measure Vo at a range of temperatures
Fit a smooth curve to the Vo vs. T data
[2 points off for measuring Vo at only one temperature]

2c Voltage across each strain gauge ≈ V_b /2 (since $\Delta R \ll R$)
Power = $(V_b /2)^2/100\ \Omega$
If Vb = 1 volt, Power = 2.5 mW

3a



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.

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

[5 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]

[2 points off for incorrect amplifier gain]

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 $\log V_C$ vs. C that relates any V_C to the corresponding concentration C.

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

[3 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: $V = 5\ e^{-C}$ $dV/dC = -5\ e^{-C} = -V$

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

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

Note that V decreases exponentially with C, so at high C, σ_C becomes very large

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

[3 point off for not using an error propagation formula]

145L midterm #2 grade distribution:

Problem	
1	30.2 (2.9 rms) (35 max)
2	20.4 (2.6 rms) (25 max)
3	37.8 (3.4rms) (40 max)

maximum score = 100
average score = 88.4 (6.0 rms)

70-74	0	F
75-79	1	D
80-84	3	C
85-89	4	B
90-94	5	B+
95-99	3	A
100	0	
	GPA 3.0	