Due: Monday September 17

Problem 1
Briefly define each of the following in biomedical instrumentation terms. A single phrase should be sufficient, but avoid copying directly from the notes. Some of these may require checking in a medical dictionary.

a. measurand: **the quantity being measured**
b. direct operational mode: **sensor *directly* observes desired measurand without going through an intermediate sensor/calculation/etc.**
c. invasive: **requires entry into the living body (as by incision or by insertion of an instrument)**
d. generating mode: **instruments that gather energy needed to operate from the environment or patient**
e. real-time measurements: **desired quantity is available immediately (in physiological terms) after it is measured**
f. interfering input: **signals inherent to the measurement/instrument that inadvertently impact the output and have no correlation to the measurand**
g. correlation coefficient: **a measure of how well paired observations match, i.e. does the output track the input linearly**
h. zero drift: **a shift (or drift) in the zero-input (baseline or offset) value of a measurement**

Problem 2
List the common categories by which biomedical instruments are *classified*

- **Quantity being sensed**
- **Principles of transduction**
- **Organ system**
- **Clinical specialty**

Problem 3
Below is a list of factors that set design criteria for biomedical instrumentation. Properly identify each as either a medical, signal, environmental, or economic factor.

a. availability	a. **economic**
b. size and shape	b. **environmental**
c. measurement linearity	c. **signal**
d. material toxicity	d. **medical**
e. stability over temperature	e. **environmental**
f. input impedance	f. **signal**
g. compatibility to commercial standards	g. **economic**
h. patient discomfort	h. **medical**
i. measurement range	i. **signal**

Problem 4

(a) Using mathematics software like Matlab or Excel, determine the following for the data set below using only basic mathematics +, -, ×, √, etc. operations –not library functions. Show enough of your work, code, etc. to show you have followed the rules. Some useful equations provided at the end.

X (input)	0.5	1.5	2.0	5	10.0
Y (output)	0.9	3.05	4.0	9.9	20.5

(a) Using the formulas given (calculations done in Excel)

i. mean input	3.8
ii. mean output	7.67
iii. output standard deviation	7.91
iv. output coefficient of variation	103%
v. correlation coefficient	0.99985

(b) Which of these statistics would be useful in analyzing the data as an input/output set? Which biostatistics would not be useful and why.
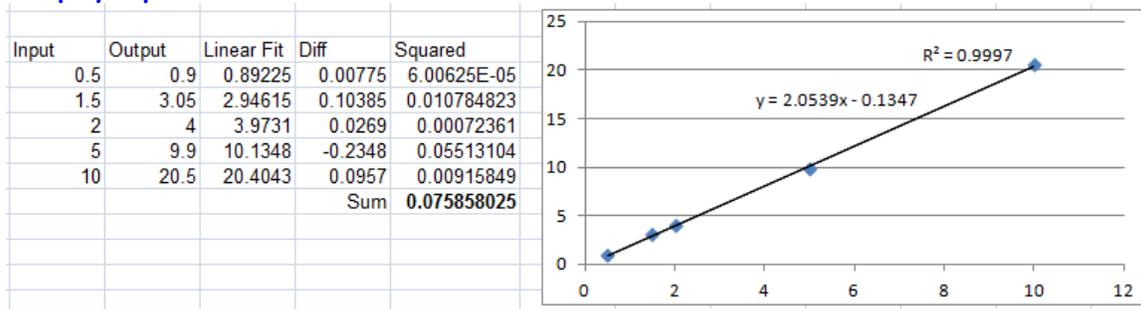
(b) The input is changing over a range of values so the input mean is not useful. Because the input is varying, the output mean has no analytical value; it would if the output data were taken repeatedly at the same input point. Likewise, the output standard deviation has no analytical value, which is evident in the coefficient of variation having a value over 100%. These statics are useless alone, but several of the values are needed to compute the correlation coefficient, which is the only statistic that has analytical value here. Indeed, the correlation coefficient shows the input and output are very well correlated at nearly +1.

Problem 5

To demonstrate you have the skills to complete this problem, describe in your own words what you did to obtain the results for each step; don't just show a plot/equation/etc.

a) Plot the input/output data from Problem 4 and use a software program (Matlab, Excel) to determine the best linear fit to the data. Show the linear fit equation (slope and intercept)

The image below is taken from Excel and shows the input and output values and a plot on the right of these values. To also plot a linear fit of the data, in Office 2010, select the plot window, click the Layout menu tab, click in Trendline and choose Linear Trendline. To get the fit equation to display on the plot, follow the same steps and, in the Trendline menu, select More Trendline Options (bottom) and put a check next to "Display Equation on Chart".

Input	Output	Linear Fit	Diff	Squared	
0.5	0.9	0.89225	0.00775	6.00625E-05	
1.5	3.05	2.94615	0.10385	0.010784823	
2	4	3.9731	0.0269	0.00072361	
5	9.9	10.1348	-0.2348	0.05513104	
10	20.5	20.4043	0.0957	0.00915849	
			Sum	0.075858025	

$R^2 = 0.9997$

$y = 2.0539x - 0.1347$

b) Linear fits are generally found using a "least squared error" technique as described in the Ch. 1 Basics notes. For each input data point, calculate the linear fit value. Then calculate the sum of the squared difference between the data set output and the linear fit. Report this value and show your work (code or clip of Excel file).

These results were calculated in Excel and are shown in the snapshot under part (a). The sum of differences squared was 0.7585. By itself, this is not a very useful number, but note that this should be the smallest possible value; if the fit equation were changed even slightly, this value should increase to represent weaker fit.

c) How well a set of data matches its linear fit is often described by the R^2 value, or R-squared. What is the real/formal name for this statistic (not in notes but easy to google)? How does it relate to other statistics used in problem 4.

Coefficient of determination is the full name for R^2. It is the squared value of the correlation coefficient.

d) Try to plot the R^2 value on your plot from part (a). This is pretty easy in Excel and it useful to know how to do. Explain briefly how this is done (click here, there, etc.).

R^2. is included on the plot in part (a). To get it displayed in Excel (2010), follow go to the Layout > Trendline > More Trendline Options menu and put a check next to "Diplay R-squared value on chart".

Problem 6
(a) A first-order low-pass instrument has a time constant of 20ms. Find the maximal sinusoidal input frequency that will keep the output error due to frequency response (loss due to high frequency cutoff) less than 5%.
(b) Find the phase angle at this frequency

(a) Restated, this question asks us to determine the max frequency at which the output magnitude falls to only 95% of its DC value (creates an error of 5%).

The magnitude is given by $|H(j\omega)| = \dfrac{K}{\sqrt{1+\omega^2\tau^2}}$

and we want to know when this reaches 0.95K, so

$$\frac{K}{\sqrt{1+\omega^2\tau^2}} = 0.95K$$

$$1 = (0.95)^2(1+\omega^2\tau^2)$$

$$\boxed{\omega = 16.4\text{rad/sec} \Rightarrow f = \frac{\omega}{2\pi} = 2.62\text{Hz}}$$

(b) The phase angle ϕ is given by $\angle H(j\omega) = \arctan(-\omega\tau)$ **so,**

$$\boxed{\phi = \tan^{-1}\left(\frac{-\omega\tau}{1}\right) = -0.317\,radian = (0.317)*\left(\frac{360}{2\cdot\pi}\right) = -18.2°}$$