Problem 1

1. What is the function of a transducer? Give one example of a primary transducer not discussed in class.

Transducer is a device that converts a primary form of energy into a corresponding signal with a different energy form.
Examples of primary transducers: 1) A manometer converts the applied pressure into variable displacement of the liquid within it enabling to measure the pressure. 2) The Bourdon tube converts air pressure to the rotary motion of a pointer used to indicate the pressure.

2. Describe one example of a sensor that makes a direct measurement and one that makes an indirect measurement. Explain as necessary to clarify how the measurement is direct or indirect. Choose examples from the world around you.

Direct: 1) Displacement sensor measuring diameter of blood vessel.
2) Temperature sensor measuring the temperature of a PC microprocessor
Indirect: 1) Displacement sensor measuring movement of a microphone diaphragm to quantify liquid movement through the heart.
2) Temperature sensor measuring body temperature to predict onset of a stroke.

3. What are the four different transducer types (modalities) for measuring displacement?

Displacement measurement transducers: resistive sensors, inductive sensors, capacitive sensors, piezoelectric sensors.

4. a) What are the two basic materials used for resistive strain gages?
b) Which of these is most sensitive? Describe in your words what "sensitive" means.
c) What is a disadvantage of the more sensitive strain gage material?

a) $Ni_{80}Cr_{20}$, $Pt_{92}W_8$.
b) $Pt_{92}W_8$ is more sensitive, because its gage factor is larger. Sensitivity refers to the amount of output change that results from a unit of input change.
c) It has higher temperature sensitivity.

5. For the 1-element Wheatstone bridge configuration show in p. 13 of the class notes, what is the change in output voltage if R3 changes from 1kΩ to 1.1kΩ? Assume R1 = 10kΩ, R2 = 1.2kΩ, and R4 = 10kΩ and that only R3 changes.

$$V_{out} = V_{cc}\left(\frac{R_3}{R_2 + R_3} - \frac{R_4}{R_1 + R_4}\right).$$

When R_3 is 1kohm, V_{out}=-0.045 V_{cc}. When R_3 is 1.1kohm, V_{out}=-0.022 V_{cc}.
ΔV_{out}=(-0.022 V_{cc})-(-0.045 V_{cc})=0.023 V_{cc}

6. You have been assigned to build a sensor using two resistive sensor elements that both exhibit an inversely proportional response to parameter Z given by R = Ro-Z•Ro. You decided to place the sensors in a Wheatstone bridge shown on the right such that Ra and Rd are sensor elements connected to the negative node of the power supply voltage Vps.

   a. Assuming Rb = Rc = Ro, derive the output voltage Vo as a function of parameter Z and Vps.

- if Ra = Ro (1-Z) and Rb = Ro → Vo+ = (Vps Ra) / (Ra+Rb)
  = [Vps (Ro(1-Z)] / [Ro(1-Z) + Ro]
  = Vps (1-Z)/(2-Z)
- if Rd = Ro (1-Z) and Rc = Ro → Vo- = (Vps Rd) / (Rd+Rc)
  = [Vps (Ro(1-Z)] / [Ro(1-Z) + Ro]
  = Vps (1-Z)/(2-Z)

Thus, Vo = Vo+ - Vo- = [Vps (1-Z)/(2-Z)] – [Vps (1-Z)/(2-Z)] = 0.
The output voltage would not vary with Z, so this is not a very good sensor!

   b. Can the bridge be constructed in a way that provides more sensitivity to parameter Z? If so, briefly describe.

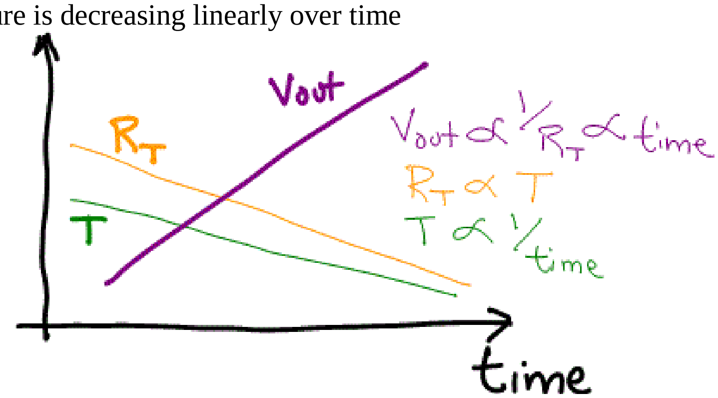
Swap the sensor resistor Rd with the non-sensor resistor Rc. This will create a “half bridge” (pg. 14 of class notes) that will cause Vo- to decrease any time Vo+ increases, and visa-versa. Alternatively, Ra could be swapped with Rb. However, if you were to swap both of these, you would be right back where you stated with Vo(Z) = 0

7. Briefly describe four different types of temperature sensors.

Thermoelectric devices: based on different electromotive forces established by dissimilar materials at two different temperatures
Resistance temperature detectors: metals with highly linear temperature coefficients
Thermsitors: thermally sensitive resistors formed with non-metal materials having high temperature sensitivity.
Radiant temperature sensors: detect photon energy associated with thermal spectrum in the infrared band.

8. Consider a resistive temperature sensor with a resistive divider readout circuit as shown on the right (copied from p. 13 of the Sensor notes). Assuming the following conditions, sketch/plot the general shape of the single-point output voltage, Vout, vs. time.

   i) the sensor is on top of the divider, like R_T in the figure
   ii) the sensor resistance increases as temperature increases
   iii) temperature is decreasing linearly over time



9. Describe some advantages and disadvantages of integrated circuit temperature sensors relative to other types of temperature sensors.

Integrated circuit temperature sensors have high accuracy, good linearity and low cost compared to other sensors. However, they have slow response compared to metal sensors, are sensitive to shock and have a limited temperature range compared to some sensor types.

10. Why is radiation thermometry often used in biomedical temperature measurements?

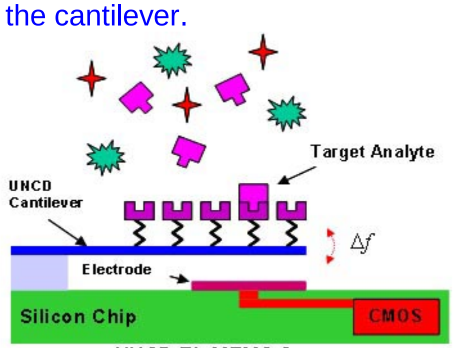
Because 1) it does not need to make contact to set temperature of the sensor; 2) it has fast response time; 3) it has good accuracy; 4) it is independent of user technique or patient activity.

11. What are the three main components of an optical measurement system?

Source, filter and detector.

12. Search the internet to find a biomedical sensor that uses MEMS technology. Briefly describe the sensor, its application and technology.

Answers will vary but an example is included below.
The bioMEMS sensor below can detect specific biological compounds present in a gas or liquid. Receptor biomolecules, such as antibodies, are attached to a micro-cantilever made of ultrananocrystalline diamond thin-film. The cantilever is integrated with silicon-based CMOS electronics and vibrated by an electrical field. The sensor is then exposed to a gas or liquid mixture containing biological toxins. The toxins are detected when they are selectively captured by the receptor biomolecules, which makes the cantilever heavier and changes its vibration frequency. Different biological toxins and other biomolecules can be detected by attaching different receptor molecules to the cantilever.



UNCD BioMEMS Sensor