Al-Mustaqbal University College
Biomedical Engineering Department

Subject: Biomedical Instrumentation Design.

Class (code): 4th (BME416)

Lecture: *4*

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- A transducer is a device that converts energy from one form to another.
- A sensor converts a physical parameter to an electric output.
- An actuator converts an electric signal to a physical output. An electric output from the sensor is normally desirable because of its advantages in further signal processing.
- Thermistors and thermocouples are employed to measure body temperatures.
- Electro-magnetic-radiation sensors include thermal and photon detectors.
- Direct displacement measurements are used to determine the change in the diameter of blood vessels and the changes in the volume and shape of cardiac chambers.
- Indirect displacement measurements are used to quantify the movements of liquids through heart valves. An example is the movement of a microphone diaphragm that indirectly detects the heart’s movement and the resulting heart murmurs.

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- These potentiometers produce a linear output (within 0.01% of full scale) as a function of displacement, provided that the potentiometer is not electrically loaded.
- The resolution of these potentiometers is a function of the construction.
- It is possible to achieve a continuous stepless conversion of resistance for low-resistance values up to 10Ω by utilizing a straight piece of wire.

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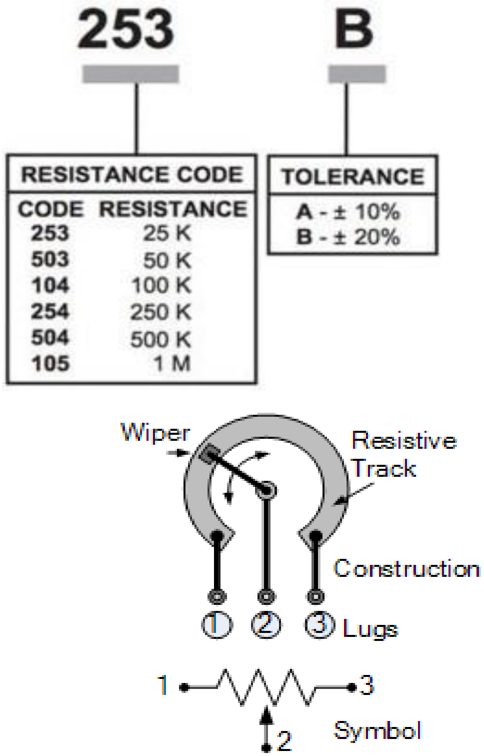
› The resistance wire is wound on a mandrel or card for greater variations in resistance, from several ohms to several megohms.

› The resistance variation is stepwise because the wiper moves from one turn of wire to the next.

› The fundamental limitation of the resolution is a function of the wire spacing, which may be as small as 20 μm.



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- STRAIN GAGES
- When a fine wire (25 μm) is strained within its elastic limit, its resistance changes because of the diameter, length, and resistivity changes.
- The resulting strain gages may be used to measure extremely small displacements on the order of nanometers.
- The basic equation for the resistance R of a wire with resistivity ρ (ohmmeter), length L (meters), and cross-sectional area A (meter squared) is given by:

$$R = \frac{\rho L}{A}$$

$$\frac{\Delta R}{R} = \underbrace{(1+2\mu)\frac{\Delta L}{L}}_{\text{Dimensional effect}} + \underbrace{\frac{\Delta \rho}{\rho}}_{\text{Piezoresistive effect}}$$

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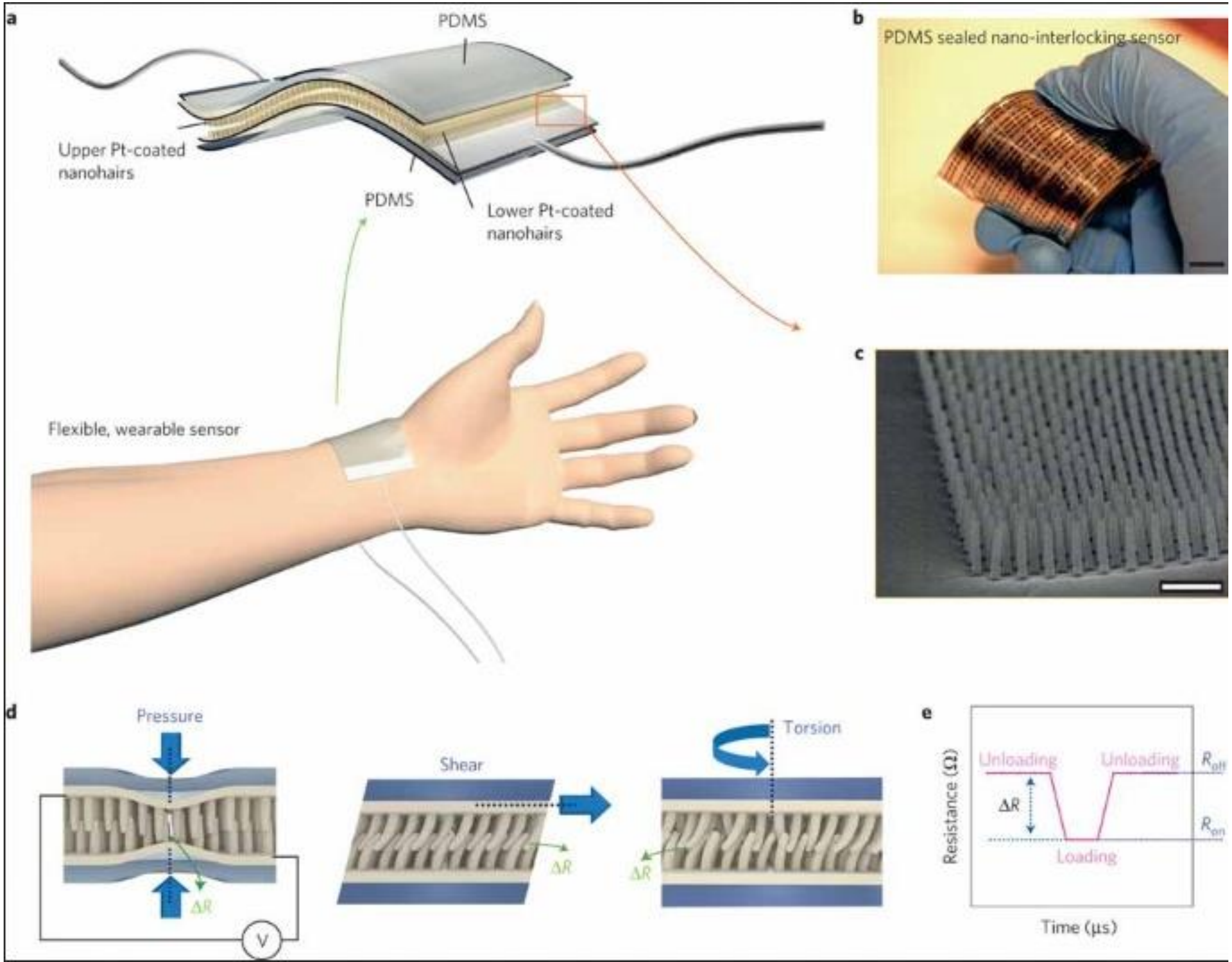

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› The gage factor G, found by dividing the last equation by ΔL/L, is useful in comparing various strain-gage materials.

$$G = \frac{\Delta R/R}{\Delta L/L} = (1+2\mu) + \frac{\Delta\rho/\rho}{\Delta L/L}$$

› Table 1 gives the gage factors and temperature coefficient of resistivity of various strain-gage materials. Note that the gage factor for semiconductor materials is approximately 50 to 70 times that of metals.

Table 1 Properties of Strain-Gage Materials

Material	Composition (%)	Gage Factor	Temperature Coefficient of Resistivity (°C^{-1}–10^{-5})
Constantan (advance)	Ni_{45}, Cu_{55}	2.1	±2
Isoelastic	Ni_{36}, Cr_8 (Mn, Si, Mo)$_4$ Fe_{52}	3.52 to 3.6	+17
Karma	Ni_{74}, Cr_{20}, Fe_3 Cu_3	2.1	+2
Manganin	Cu_{84}, Mn_{12}, Ni_4	0.3 to 0.47	±2
Alloy 479	Pt_{92},W_8	3.6 to 4.4	+24
Nickel	Pure	−12 to −20	670
Nichrome V	Ni_{80}, Cr_{20}	2.1 to 2.63	10
Silicon	(*p* type)	100 to 170	70 to 700
Silicon	(*n* type)	−100 to −140	70 to 700
Germanium	(*p* type)	102	
Germanium	(*n* type)	−150	

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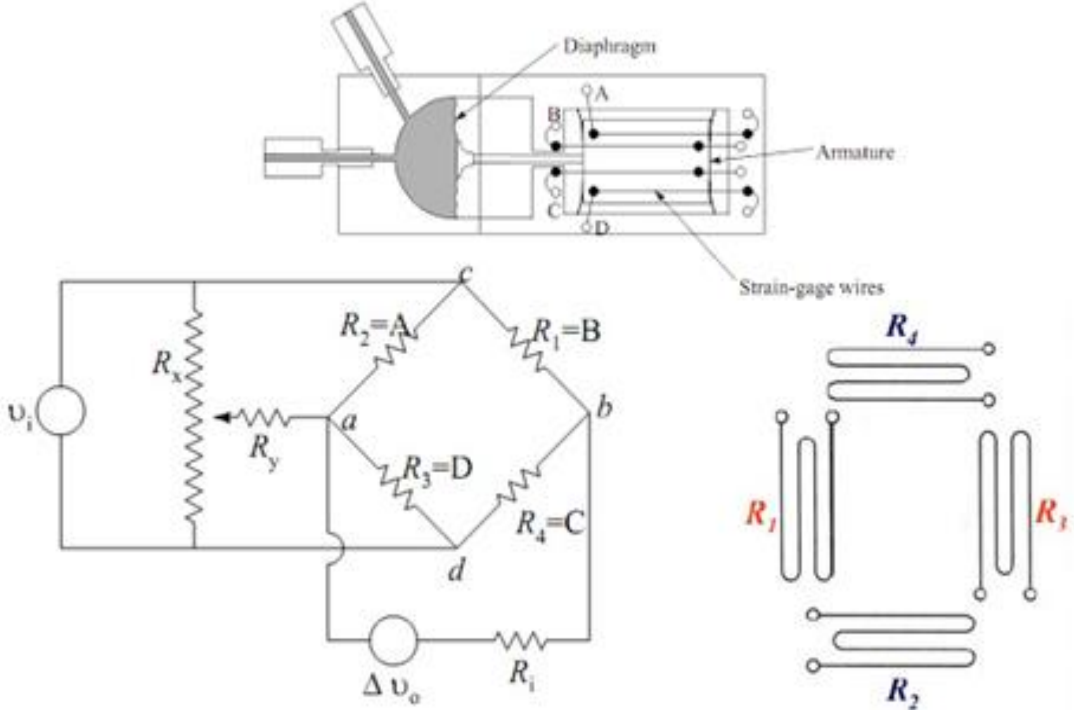
- ***Unbonded strain-gage unit*** has four sets of strain-sensitive wires connected to form a Wheatstone bridge.
- These wires are mounted under stress between the frame and the movable armature, so preload is more significant than any expected external compressive load.
- This is necessary to avoid putting the wires in compression. This type of sensor may convert blood pressure to diaphragm movement, resistance change, and an electric signal.



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- ***A bonded strain-gage*** element, consisting of a metallic wire, etched foil, vacuum-deposited film, or semiconductor bar, is cemented to the strained surface.
- The deviation from linearity is approximately 1%.
- One method of temperature compensation for the natural temperature sensitivity of bonded strain gages involves using a second strain gage as a dummy element that is exposed to the temperature variation but not to strain.
- When possible, the four-arm bridge should be used because it provides temperature compensation and yields four times greater output if all four arms contain active gages.

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- *External body temperature* is one of many parameters used to evaluate patients in shock, because the reduced blood pressure of a person in circulatory shock results in low blood flow to the periphery.

- *Infections*: are usually reflected by an increase in body temperature, with a hot, flushed skin and loss of fluids.

- *Anesthesia* decreases body temperature by depressing the thermal regulatory center. Physicians routinely induce hypothermia in surgical cases in which they wish to decrease a patient's metabolic processes and blood circulation.

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- In pediatrics, *special heated incubators* are used for stabilizing the body temperature of infants via accurate monitoring of temperature, and regulatory control systems are used to maintain a desirable ambient temperature for the infant.
- In *arthritis*, the temperatures of joints are closely correlated with the amount of local inflammation. The increased blood flow due to arthritis and chronic inflammation can be detected by thermal measurements.
- ***The specific site of body-temperature recording must be selected carefully so that it truly reflects the patient's temperature.***

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NORMAL BODY TEMPERATURE RANGES

°F	0 - 2 years	3 - 10 years	11 - 65 years	> 65 years
Oral	—	95.9 99.5	97.6 99.6	96.4 98.5
Rectal	97.9 100.4	97.9 100.4	98.6 100.6	97.1 99.2
Axillary	94.5 99.1	96.6 98.0	95.3 98.4	96.0 97.4
Ear	97.5 100.4	97.0 100.0	96.6 99.7	96.4 99.5
Core	97.5 100.0	97.5 100.0	98.2 100.2	96.6 98.8

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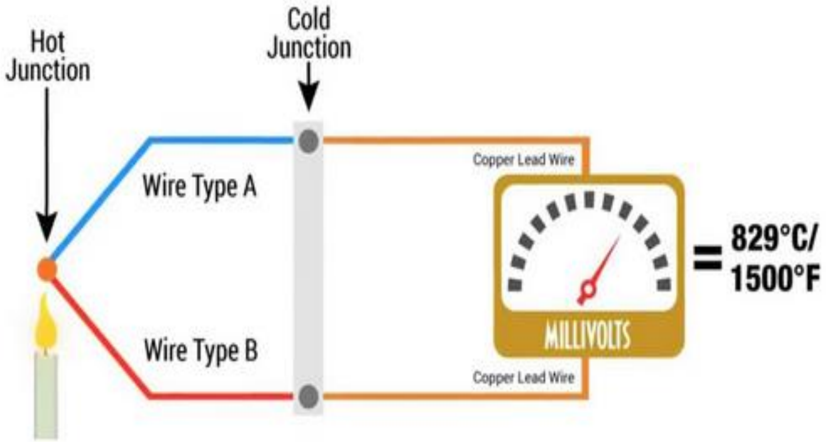
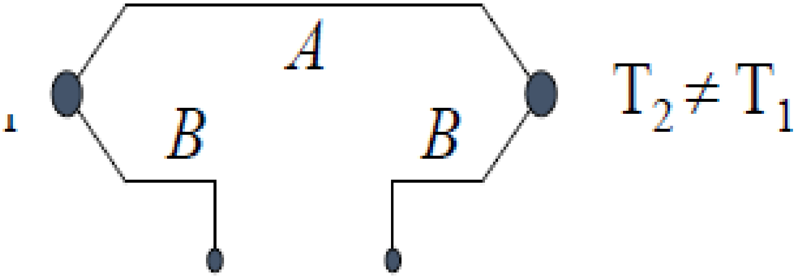
- The magnitudes of the Peltier and Thomson emfs depend on the metals chosen. The Seebeck voltage (appears due to current flows in the circuit, that is caused by the difference in temperature between the two junctions) .

- Thermocouple circuit with two dissimilar metals, A and B, at two different temperatures, T1, and T2, and f is the relative Seebeck coefficient of thermocouple (V/K). E is thermo emf.





$$E = f(T_1 - T_2)$$

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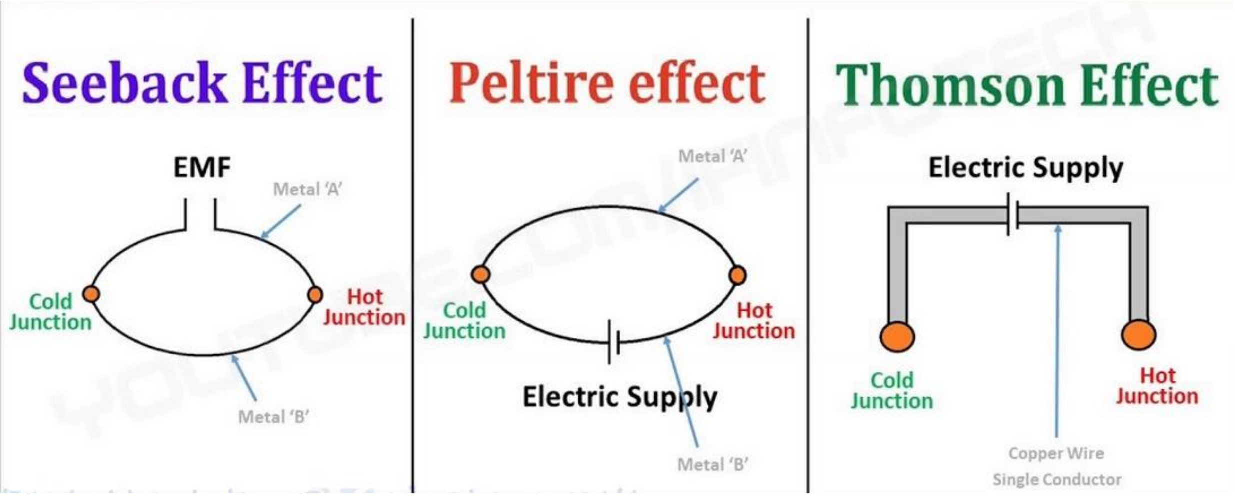
› Thermoelectric thermometry is based on the observation that an electromotive force (emf) exists across a junction of two dissimilar metals.

➢ ***Peltier emf:*** is an emf due solely to the contact of two unlike metals and the junction temperature. The net Peltier emf is roughly proportional to the difference between the temperatures of the two junctions.

➢ ***Thomson emf:*** is an emf due to the temperature gradients along each single conductor. The net Thomson emf is proportional to the difference between the squares of the absolute junction temperatures (T1 and T2).



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- Thermistors: semiconductors made of ceramic materials that are thermal resistors with a high negative temperature coefficient (NTC) .
- Their resistance decreases as their temperature increases (opposite to metals). The resistivity is between 0.1 and 100Ω.m,
- These devices are small in size (less than 0.5 mm in diameter), have a relatively large sensitivity to temperature changes (-3 to -5 %/°C), and have excellent long-term stability characteristics (±0.2% of nominal resistance value per year).

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- The empirical relationship between the thermistor resistance Rt, and absolute temperature T in kelvin (K) is:

$$R_t = R_o e^{\left[\frac{\beta(T_0 - T)}{T T_0}\right]}$$

- Where: β: material constant for thermistor, K

  T_o: standard reference temperature, K

- The value of β increases slightly with temperature. However, this does not present a problem for biomedical work (10 °C to 20 °C).

- β, also known as the characteristic temperature, is in the range of 2500 to 5000 K. It is usually about 4000 K.

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- The thermistor voltage-versus-current characteristic for a thermistor in air and water are plotted in this figure.
- Point A is the maximal current value for no appreciable self-heat.
- Point B is the peak voltage.
- Point C is the maximal safe continuous current in air.