Musculoskeletal Biomechanics

BIOEN 520 | ME 527

Session 3A

Tools of the Trade:
(Force, displacement, and DAQ)

Review: Session 2B...

- Reviewed the "Scientific Method"
- Examined study designs often used in biomechanical research
- Discussed two key input/output variables used in biomechanics
- Considered metrics used to characterize/ compare biomechanical properties
- Explored experimental models commonly used in biomechanics research along with other factors

In-Class Group Discussion...

[Q]: In the papers by Lee et al. and Whittaker et al., compare and contrast the study designs (including models and statistical analyses used in hypothesis testing)?
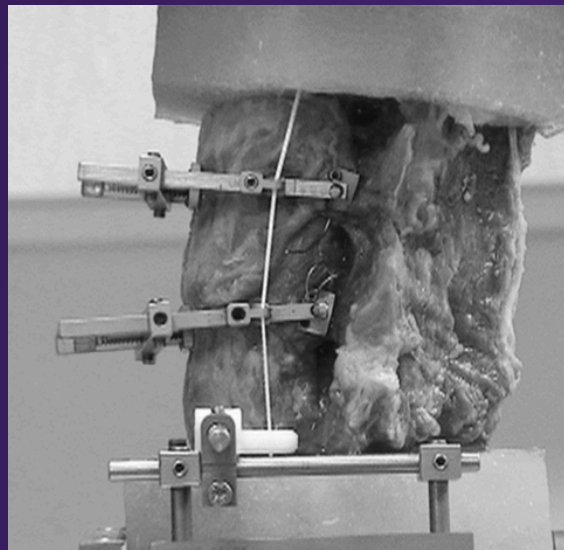
Session 3A Discussion Questions...

[Q]: What are ways to apply loads/displacements in biomechanics experiments?

[Q]: What is a transducer/sensor?

[Q]: When choosing a sensor, what characteristics should be considered?

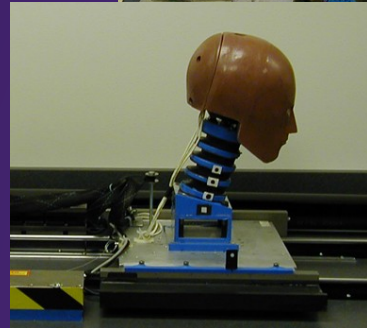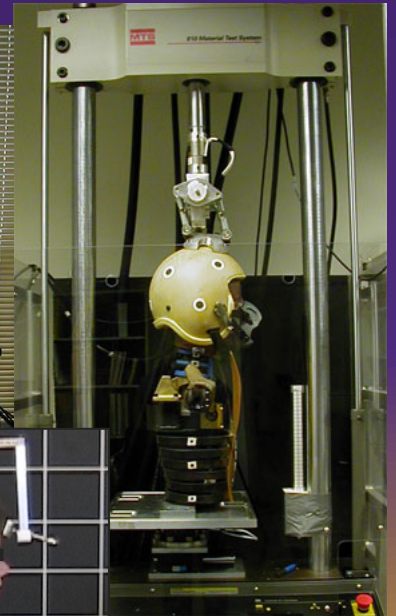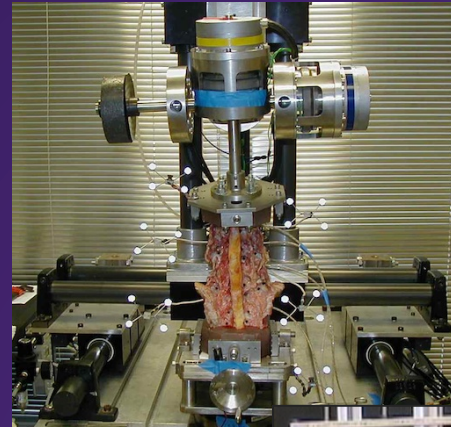[Q]: What sensors are used to measure loads?

[Q]: What sensors measure displacements?

[Q]: What is "DAQ" and why do we need it?
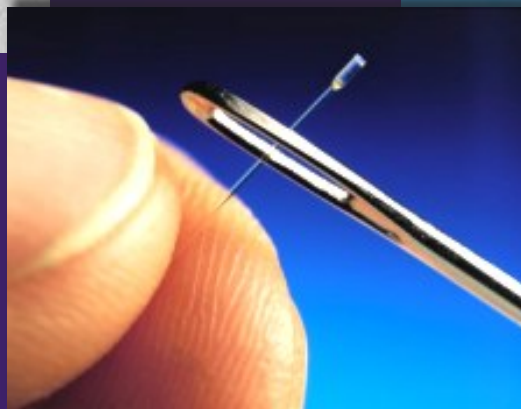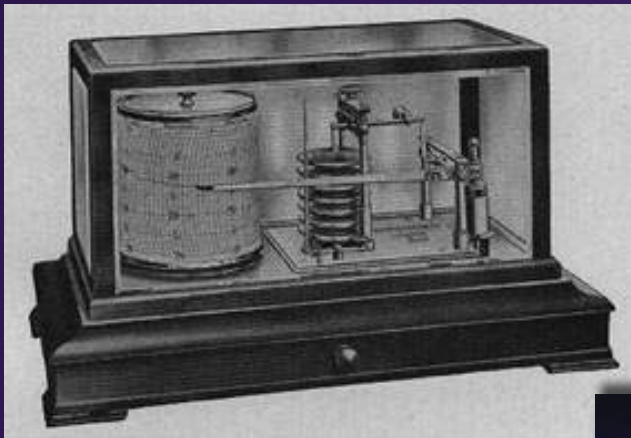
Test Frames/Apparatus…

[Q]: What types of equipment are used in biomechanical testing to apply loads/disp?

- *MTS/Instron machines*
- *Simulators*
- *Sleds*
- *Custom test frames*
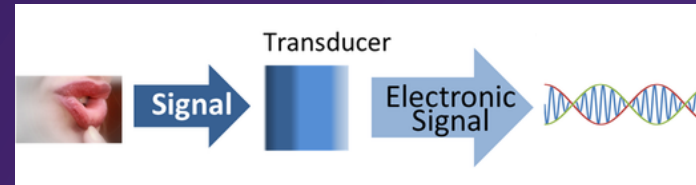- *Live animals*
- *Human subjects*

Transducers/Sensors…

[Q]:   What is a transducer?

Transducers/Sensors…

- Latin tranducere -- 'to convert

- A device that converts one form of energy to another (with the same information content as the original)

- Note: no transducer is responsive to only one form of energy…

Transducers/Sensors...

[Q]: What's the difference between a transducer and a sensor? (...often used interchangeably)

- *Both make measurements…*

- *Transducer* converts energy

- *Sensor* often contains a transducer, but may not (…no requirement to convert energy -- e.g., digital output)

Transducers/Sensors…

[Q]: In order to accurately quantify what's being measured, what characteristics are important when choosing a transducer?

Input $\longrightarrow$ Sensor $\longrightarrow$ Output
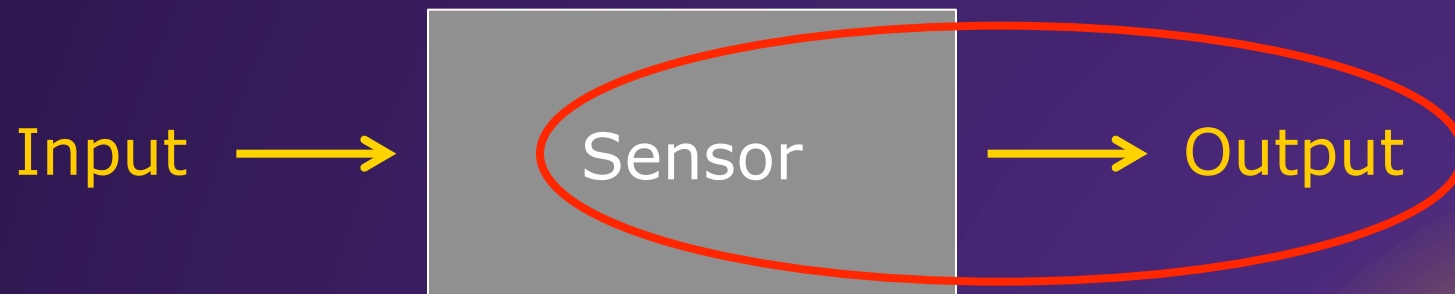
Transducers/Sensors...

Static Characteristics

- *Accuracy*

  Closeness of measurements to the true value (typically % FSO)

  Hi Accuracy Low Precision

- *Precision*

  Closeness of repeated measurements to one another (typically % FSO)

  Hi Precision Low Accuracy

Transducers/Sensors…

Static Characteristics

- *Resolution*

  Smallest discernable input increment (% FSO)

- *Sensitivity*

  Degree of responsiveness to an incoming signal (Output range / Input range)

W

Transducers/Sensors...

Static Characteristics

- *Threshold*

  Smallest change in discernable measurement (measurement units)

- *Range*

  Operational full scale range of the transducer (measured min - max values)

- *Linearity*

  Degree to which a calibration curve fits a straight line
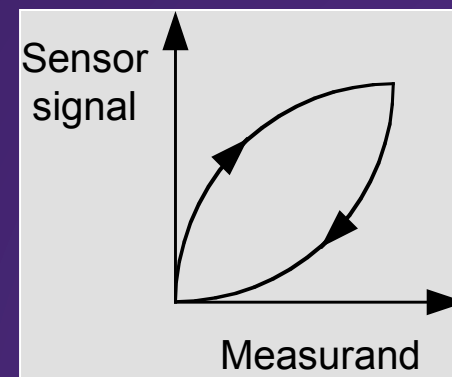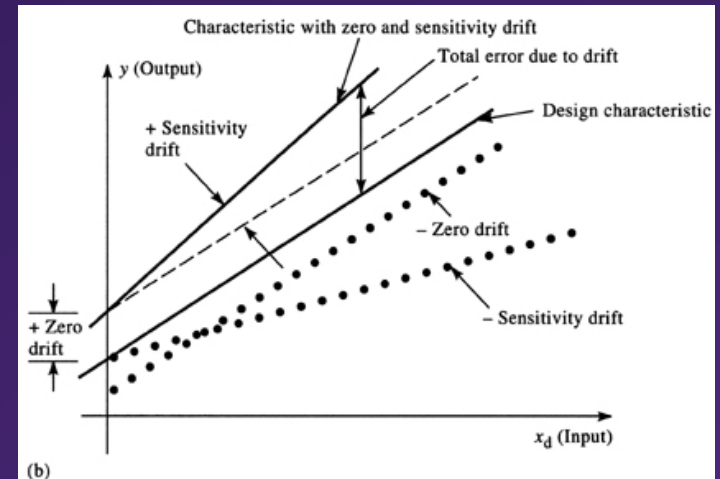
W

Transducers/Sensors...

Static Characteristics

- *Drift*

  Change in output for zero input over time (meas. units)

- *Hysteresis*

  Differing outputs for increasing and decreasing inputs (meas. units)

Transducers/Sensors...

Dynamic Characteristics

- *Frequency Response – The accuracy of a transducer's output within a specific band (% diff or dB)*

- *Transient Response – Transducer's response to a step change (time)*

- *Response Time – Time required for the output to rise to a specified percent of its final value as a result of a step change (time)*
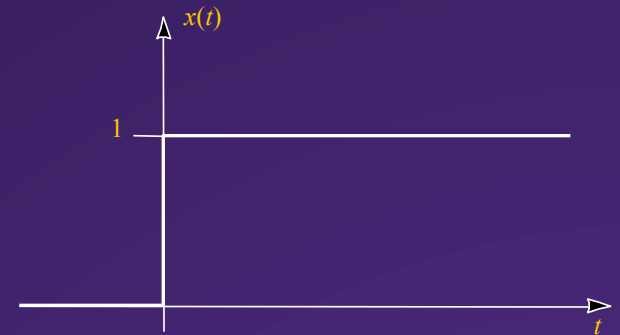
Transducers/Sensors…

Dynamic Characteristics

- *Rise Time - The length of time for the output to rise from 10% to 90% of its value*

- *Natural Frequency - The frequency at which the sensing element is set into free oscillation*

- *Damping - The energy dissipating characteristic which determines the upper limit of frequency response*
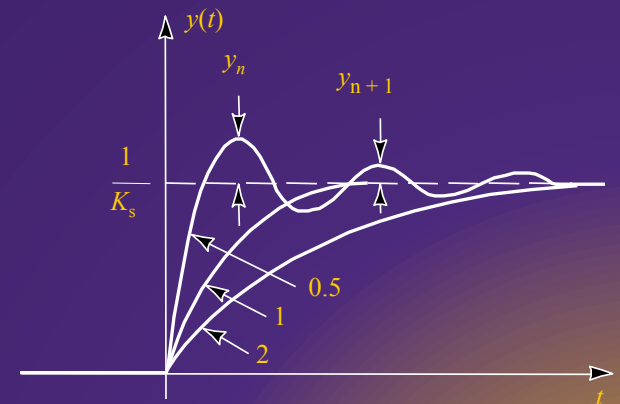
Force Measurement…

[Q]: What is the most common instrument used to measure forces?

Load Cell or

Force Transducer
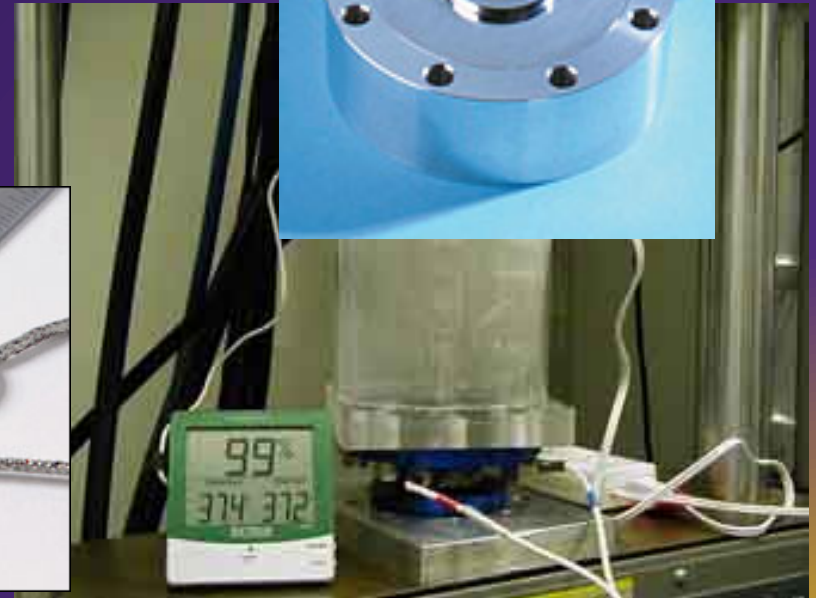
Force Measurement…

The two most common "transduction" methods for load cells are:

- Strain Gage

- Piezoelectric

Force Measurement…

- ## Strain Gage Force Transducer

  - Small deformations at high loads

  - Wide range of force measurement

 - Temperature compensated

  - Inexpensive

W

Force Measurement…

- ## Strain Gage Buckle Force Transducer

    - In-situ tension measurement

    - Bending of frame is measured by the strain gages

    - Has similar features to a strain gage load cell
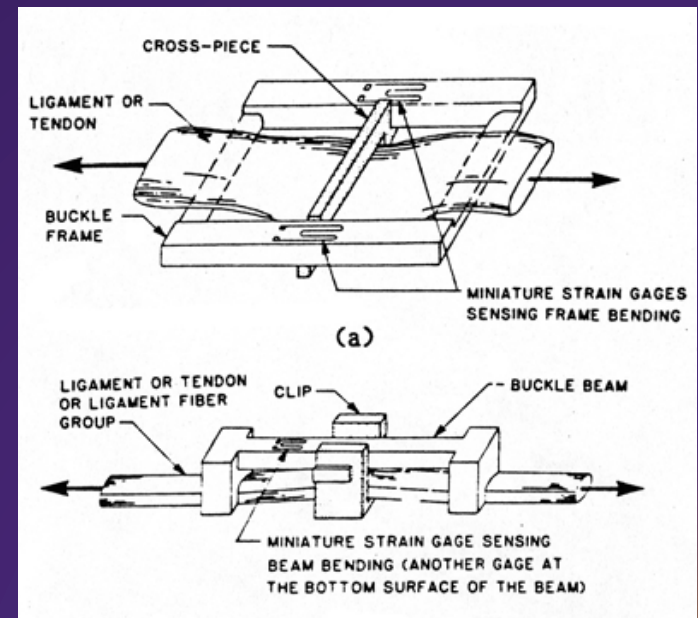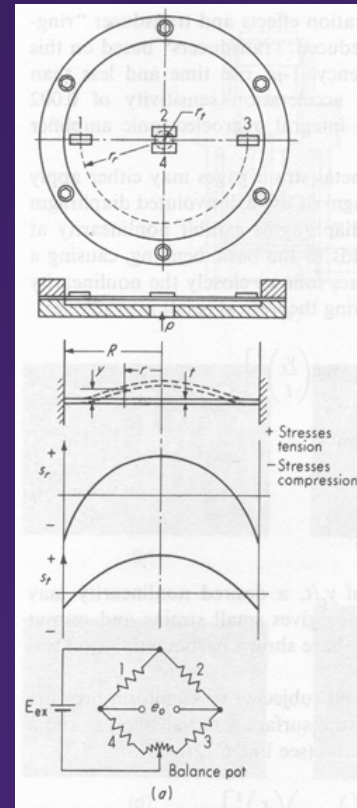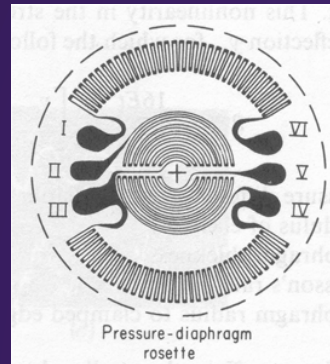
Force Measurement…

- ## Piezoelectric Force Transducer

  - Extremely sensitive with high signal output

  - Crystal deformations very small

  - Excellent dynamic characteristics

  - NOT for static applications

  - Charge amplifiers expensive
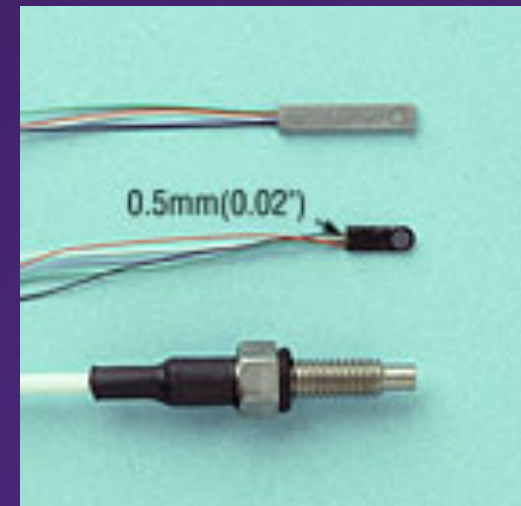
  - Nonlinear output
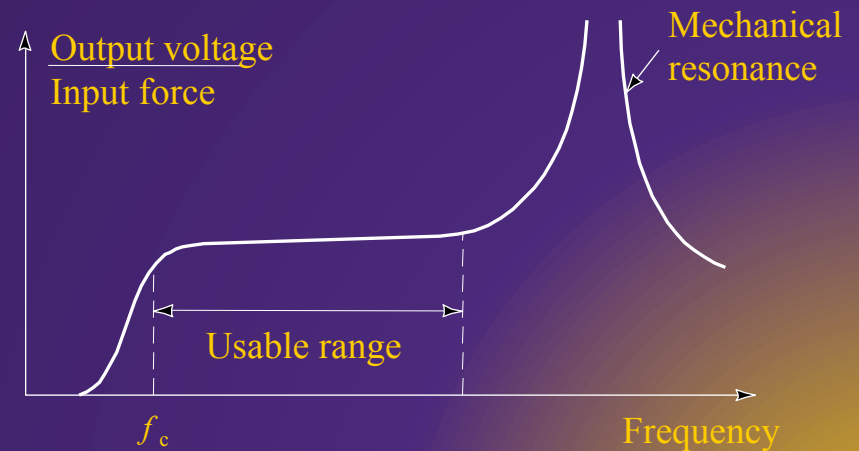
Pressure Measurement…

- ## Strain Gage Pressure Transducer

  - Diaphram design

  - 4-Gage system or

  - Rosette

Pressure-diaphragm rosette

Pressure Measurement...

- ## Piezoelectric Pressure Transducer

  - Similar characteristics to strain gage based force transducers

 - Better dynamic response, but not for static applications

Pressure Measurement…

- ## Fiber-Optic Pressure Transducer

  - Miniaturization possible

  - Range based upon bladder

  - Immune to RFI/EMI interference

  - Robust temperature response

  - Intrinsically safe
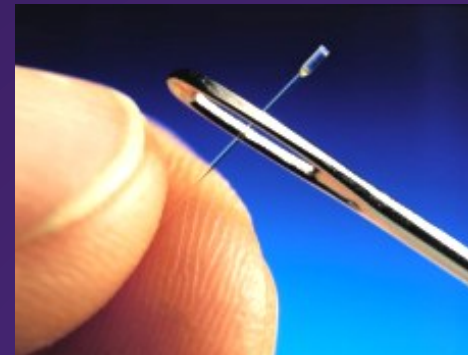
Pressure Measurement...

- ## Resistance Pressure Transducer

    - Pressure distribution over large areas

    - Long settling time

    - Not dynamic

    - Drift
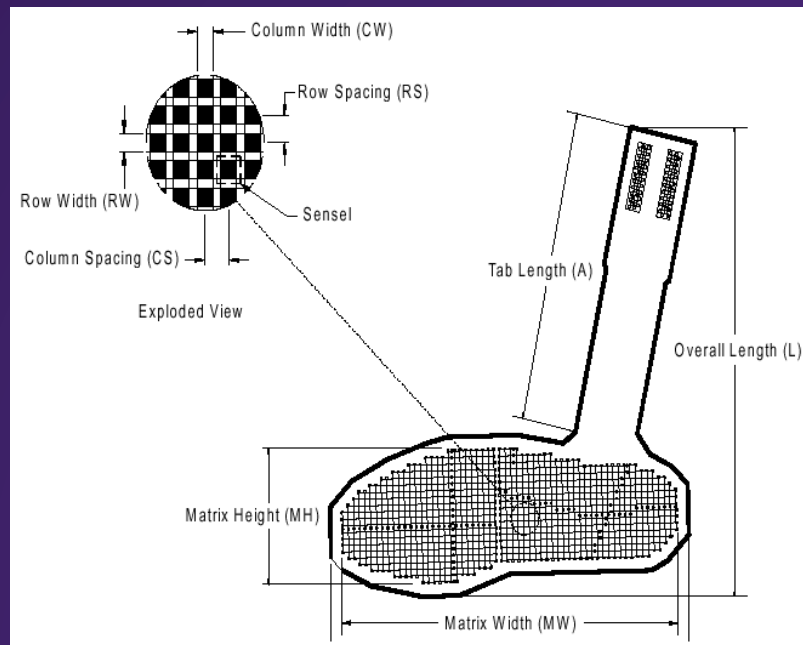
Pressure Measurement…

- ## Contact Film Pressure Transducer

  - 2 films placed together (developer + pockets of dye)

  - Can resolve joint contact pressures

  - Loading rate specific

  - Shear stresses not accounted for

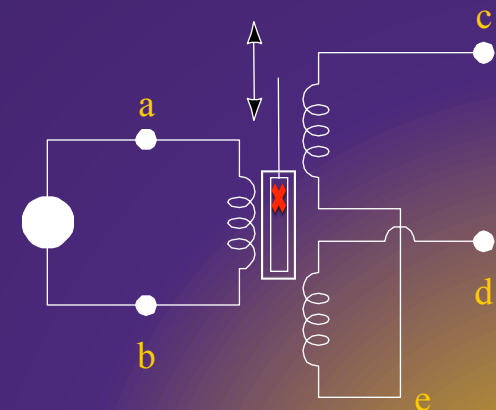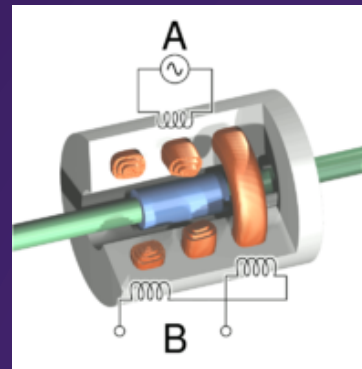 - One time use (and only peak pressure)

Cross section of Pressurex® film
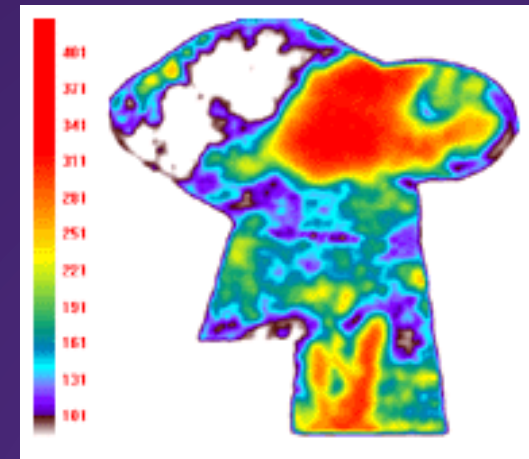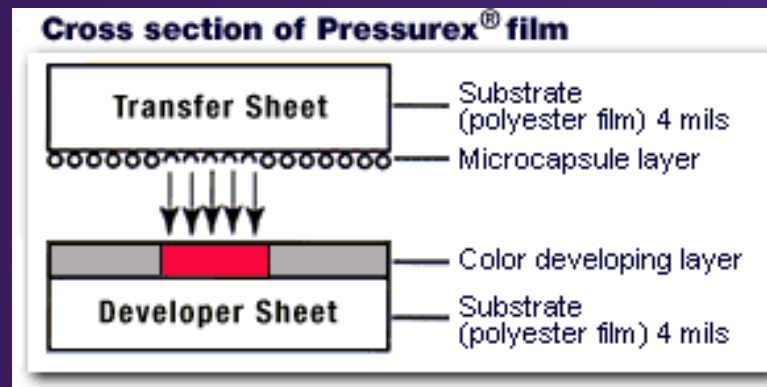
Displacement Measurement...

- ## Inductive Displacement Transducer

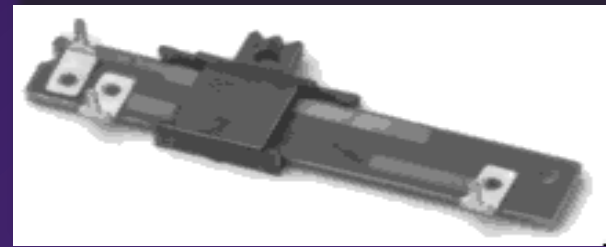 ### Linear Variable Differential Transformer

  - Low force requirements

  - Infinite resolution

  - Large ranges

  - Tunable dynamic response

Displacement Measurement…

- ## Resistive Displacement Transducers

  - Foil strain gages

  - Potentiometers (Linear or rotary)

  - Liquid metal strain gages

    (Large deformations, non-linear)

Displacement Measurement…
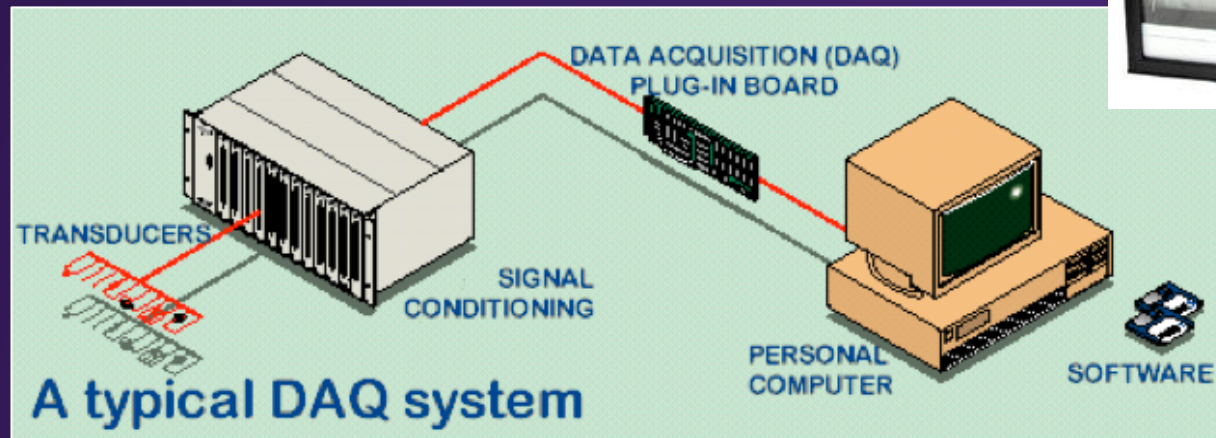
- ## Optical Motion Tracking Systems

    - Photodiode arrays

    - Video/Infrared systems

    - High-speed imagers

"DAQ"

[Q]: What is "DAQ" and why do we need it?

Data Acquisition system – automates data collection

A typical DAQ system

Main Considerations: Sampling Rate and "Bit" resolution (may limit sensor resolution...)

"Brain Teaser"…

If you have a 100kN load cell, what's the difference in sampling resolution between a 12 bit and 16 bit DAQ board?

DATA ACQUISITION (DAQ) PLUG-IN BOARD

TRANSDUCERS

SIGNAL CONDITIONING

PERSONAL COMPUTER

SOFTWARE

A typical DAQ system