Benha University
Faculty of Engineering
Mechanical Engineering Dep.

Measurements and Instrumentations
3rd year January 2015/2016
Final-exam

Time: Three Hours ***(attempt all Questions)*** ***(assume any missing data)***

QI (25 points)

a) Discuss the types of variable?

Independent Variable: A variable that can be changed independently of other variables.

Dependent Variable: A variable that is affected by changes in one or more other variables.

Control of Variables: Variables that can be held (controlled) at a constant value. This is used to find the relationship between independent and dependent variables.

Extraneous Variables: Are not or cannot be controlled during an experiment. May affect the measured variable and therefore confuse the relationship between cause and effect (independent and dependent variables) in the measurement.

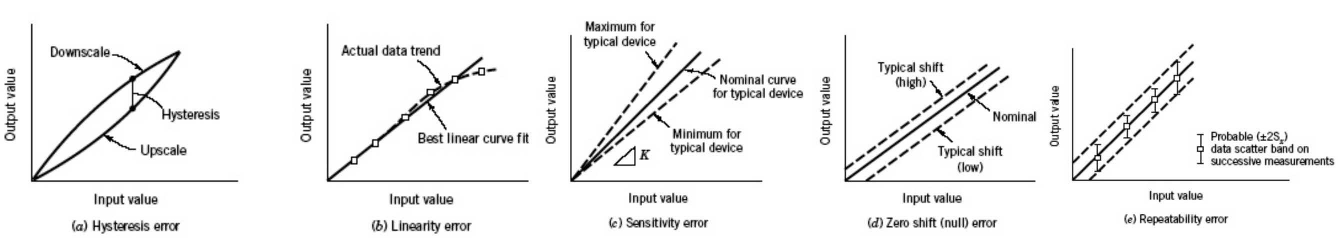
b) Define random errors, systematic errors, and how to minimize it with example?

Random Error: Are statistical fluctuations (in either direction) in the measured data due to the precision limitations of the measurement device. Random errors usually result from the experimenter's inability to take the same measurement in exactly the same way to get exact the same number.

Systematic Error: The portion of the absolute error that remains constant during repeated measurements. By contrast, are reproducible inaccuracies that are consistently in the same direction. Systematic errors are often due to a problem which persists throughout the entire experiment.

Type of Error	Example	How to minimize it
Random errors	You measure the mass of a ring three times using the same balance and get slightly different values: 17.46 g, 17.42 g, 17.44 g	Take more data. Random errors can be evaluated through statistical analysis and can be reduced by averaging over a large number of observations.
Systematic errors	The cloth tape measure that you use to measure the length of an object had been stretched out from years of use. (As a result, all of your length measurements were too small.) The electronic scale you use reads 0.05 g too high for all your mass measurements (because it is improperly trade throughout your experiment).	Systematic errors are difficult to detect and cannot be analyzed statistically, because all of the data is off in the same direction (either to high or too low). Spotting and correcting for systematic error takes a lot of care.

c) What are the types of errors with curve drawing?



d) Mark the following [**T**] for True, [**F**] for False and try to correct.

1) Replications are repeated measurements made during any single test run or on a single batch of items. [**F**] **Repetition**
2) The coincidence between outputs that steadily increased from a negative value to output that steadily decreased from a positive value is known as hysteresis. [**F**]
3) Static measurements require a data acquisition system. [**F**]
4) Inverted manometer fluids must not be soluble in the working fluid and should be of greater specific weight. [**F**]

QII (20 points)

a) What are the procedures for estimating the overall uncertainty?

1- Define the Measurement Process
2. List All of the Elemental Errors
3. Estimate the Elemental Errors
4. Calculate the Bias and Precision Error for Each Measured Variable
5. Propagate the Bias Limits and Precision Indices All the Way to the Result
6. Calculate the Overall Uncertainty of the results

b) How to apply design-stage uncertainty analysis?

- ✓ We apply design-stage uncertainty analysis when we don't have the system yet, or have not tested it yet.
- ✓ We either rely on the manufacturer's data, or on our own estimates
- ✓ Major facilities may need to be built and equipment ordered with considerable lead time.
- ✓ It is useful for selecting instruments, selecting measurement techniques, and obtaining an appropriate estimate of the uncertainty likely to exist in the measured data.
- ✓ At this point, the measurement system and associated procedures are but a concept.
- ✓ Usually little is known about the instruments, and in many cases they are still pictures in a catalog.

c) Consider the solution heat ($q_{solution}$) measuring instrument described by the following catalog data.

1. Resolution: 18 J
2. Range: 500 to 1500 J
3. Linearity: within 12J
4. Hysteresis: within 14J

When the measured quantity is 1450 J estimate:

I) The uncertainty attributable to this instrument (u_c) and the instrument design stage uncertainty (u_d) or absolute uncertainty AU.

Solution:

$$u_c = \pm\sqrt{u_L^2 + u_H^2} = \pm\sqrt{(12)^2 + (14)^2} = \pm 18.44$$

$$u_0 = \pm\frac{1}{2} resolution = \pm 0.5 \times 18 = \pm 9.0$$

$$u_d = \sqrt{u_0^2 + u_c^2} \ (P\%) = \sqrt{(9)^2 + (18.44)^2} = \pm 20.52 \text{ J}$$

Measured quantity is = 1450 J ±20.52 J

II)Calculate q_{total} and its associated AU and RU values, using the equation:

$q_{total} = -(q_{solution} + q_{cal}) = -(q_{solution} + C\Delta T)$

where $q_{solution} = 1450 \pm u_d$ J

C = 54 ± 7 J/°C, ΔT = 6.0 ± 0.1 °C

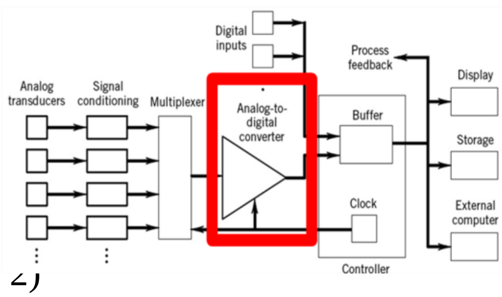
Solution:

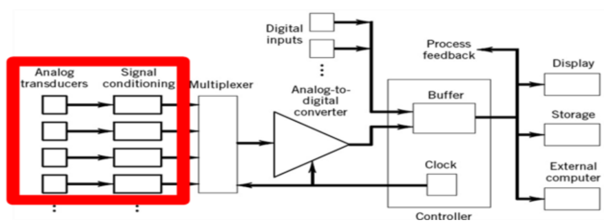
$q_{solution} = 1450 \pm 20.52$ J
$q_{cal} = C\Delta T =$ (54 J/°C) x (6.0 °C) = 324 J = 320 J
$RUq_{cal} = RU_C + RU_{\Delta T} = 7/54 + 0.1/6.0 = 0.14630 = 0.1$
$AUq_{cal} = RU x |q_{cal}| = 0.14630$ x 324 J = 47.4 J = 50 J
$q_{cal} = 320 \pm 50$ J (RU = 10%)
$q_{total} = -(q_{solution} + q_{cal}) = -(1450$ J + (54 J/°C)(6.0 °C)) = - (1450 J + 324 J) = -1774 J = -1770 J
$AUq_{total} = AUq_{solution} + AUq_{cal} = 20.52 + 47.4 = 67.92$ J= 70 J
$RUq_{total} = AU/|(q_{total})| = 67.4J/|-1774J| = 0.04$
$q_{total} = -1770 \pm 70$ J (RU = 4%)

QIII (20 points)

a) Draw on the general data acquisition signal flow the components that control:

1) Sampling rate 2) Signal type

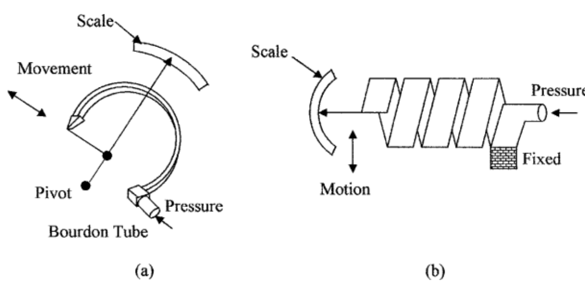




b) Discuss briefly with drawing the difference between the helical pressure tube and the circular Bourdon tube, and show how it can be coupled to a potentiometer to give a resistance value proportional to the pressure for electrical signals?

Bourdon tubes are hollow, cross-sectional beryllium, copper, or steel tubes, shaped into a three quarter circle, as shown in Fig.

Pressure sensors shown are (a) the Bourdon tube and (b) the helical Bourdon tube.

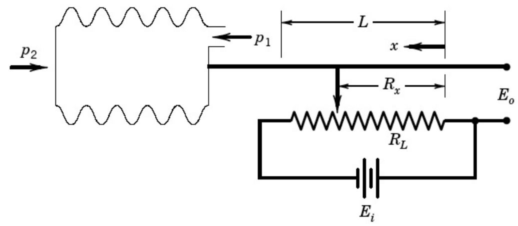


They may be rectangular or oval in cross section, but the operating principle is that the outer edge of the cross section has a larger surface than the inner portion.

When pressure is applied, the outer edge has a proportionally larger total force applied because of its larger surface area, and the diameter of the circle increases. The walls of the tubes are between 0.01 and 0.05 in thick. The tubes are anchored at one end so that when pressure is applied to the tube, it tries to straighten and in doing so the free end of the tube moves.

This movement can be mechanically coupled to a pointer, which when calibrated, will indicate pressure as a line of sight indicator, or it can be coupled to a potentiometer to give a resistance value proportional to the pressure for electrical signals.

Figure (b) shows a helical pressure tube. This configuration is more sensitive than the circular Bourdon tube.



c) Give considerations that should be taken when installing pressure sensing devices?

1. Distance between sensor and source should be kept to a minimum.
2. Sensors should be connected via valves for ease of replacement.
3. Over range protection devices should be included at the sensor.
4. To eliminate errors due to trapped gas in sensing liquid pressures, the sensor should be located below the source.

To eliminate errors due to trapped liquid in sensing gas pressures, the sensor should be located above the source.

6. When measuring pressures in corrosive fluids and gases, an inert medium is necessary between the sensor and the source or the sensor must be corrosion resistant.
7. The weight of the liquid in the connection line of a liquid pressure sensing device located above or below the source will cause errors in the zero, and a correction must be made by the zero adjustment, or otherwise compensated for in measurement systems.
8. Resistance and capacitance can be added to electron circuits to reduce pressure fluctuations and unstable readings.

QIV (25 points)

a) What are the temperature measuring devices and explain one of them?

- ✓ *Thermometers*
- ✓ *Bimetallic strip*
- ✓ *Pressure-spring thermometers*
- ✓ *Resistance temperature devices (RTD)*
- ✓ *Thermocouple*

c) How much will a 0.025-m^3-volume of the automobile tire at 25°C expand when the temperature is changed from 0 to 75°C? (Note: Volumetric thermal expansion coefficient for automobile tire (β) is 16.6 x 10^{-6} °C)

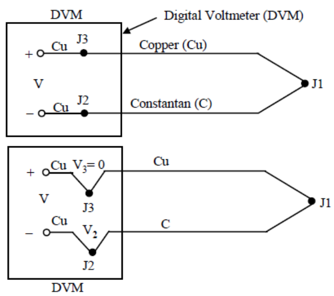
Solution:

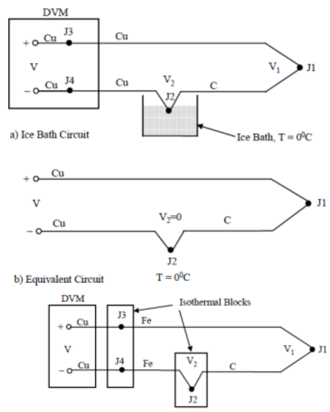
$V_0 = V_{25}[1+\beta(T_0 - T_{25})] = 0.025 + 0.025x\ 16.6\ x\ 10^{-6}\ (0 - 25) = 0.024989\ m^3$

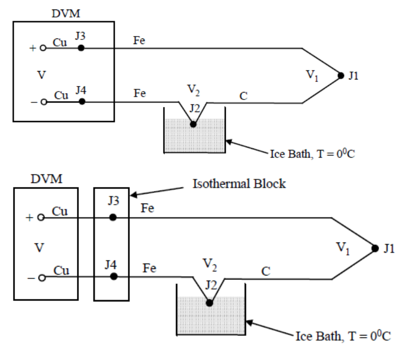
$V_{75} = V_{25}[1+\beta(T_{75} - T_{25})] = 0.025 + 0.025x\ 16.6\ x\ 10^{-6}\ (75 - 25) = 0.02502\ m^3$

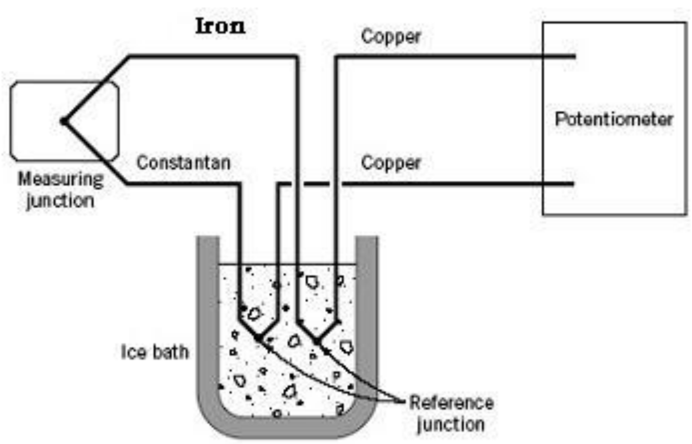
$V_{75} - V_0 = 0.02502 - 0.024989 = 3.175x10^{-5}\ m^3$

b) Explain briefly with sketches how the measure thermocouple voltages are modifying?









With best wishes
Dr. Mohamed Ramadan