Measurements and Instrumentation [SBE206A] (Fall 2018)
Tutorial 2

Dr. Muhammed Rushdi   Asem Alaa

December 11, 2018

Instrument types and performance characteristics

- Review of instrument types
  - Active and passive instruments.
  - Null-type and deflection-type instruments.
  - Analogue and digital instruments.
  - Indicating instruments and instruments with a signal output.
  - Smart and non-smart instruments.
- Static characteristics of instruments.
  - Accuracy and inaccuracy (measurement uncertainty).
  - Precision/repeatability/reproducibility.
  - Tolerance.
  - Range or span.
  - Linearity.
  - Sensitivity of measurement.
  - Threshold.
  - Resolution.
  - Sensitivity to disturbance.
  - Hysteresis effects.
  - Dead space.

---

1. Exercise

The following resistance values of a platinum resistance thermometer were measured at a range of temperatures. Determine the measurement sensitivity of the instrument in ohms/°C.

Resistance (Ω)	Temperature (°C)
307	200
314	230
321	260
328	290

1. Solution

2. Exercise

A spring balance is calibrated in an environment at a temperature of 20 °C and has the following deflection/load characteristic.

Load (Kg)	0	1	2	3
Deflection (mm)	0	20	40	60

It is then used in an environment at a temperature of 30 °C and the following deflection/load characteristic is measured.

Load (Kg)	0	1	2	3
Deflection (mm)	5	27	49	71

Determine the zero drift and sensitivity drift per °C change in ambient temperature.

2. Solution

3. Exercise

What is meant by:

- active instruments
- passive instruments

Give examples of each and discuss the relative merits of these two classes of instruments

3. Solution

4. Exercise

Discuss the advantages and disadvantages of null and deflection types of measuring instru- ment. What are null types of instrument mainly used for and why?

4. Solution

5. Exercise

Explain the difference between accuracy and precision in an instrument.

5. Solution

6. Exercise

Define sensitivity drift and zero drift. What factors can cause sensitivity drift and zero drift in instrument characteristics?

6. Solution

7. Exercise

Define sensitivity drift and zero drift. What factors can cause sensitivity drift and zero drift in instrument characteristics?

7. Solution

8. Exercise

A tungsten thermocouple has an output e.m.f. as shown in the following table when its hot (measuring) junction is at the temperatures shown. Determine the sensitivity of measurement for the thermocouple in mV/ $^\circ$ C.

mV	4.37	8.74	13.11	17.48
$^\circ$ C	250	500	750	1000

8. Solution

9. Exercise

1. An instrument is calibrated in an environment at a temperature of 20 °C and the following output readings y are obtained for various input values x:

y	13.1	26.2	39.3	52.4	65.5	78.6
x	5	10	15	20	25	30

Determine the measurement sensitivity, expressed as the ratio y/x.

2. When the instrument is subsequently used in an environment at a temperature of 50 °C, the input/output characteristic changes to the following:

y	14.7	29.4	44.1	58.8	73.5	88.2
x	5	10	15	20	25	30

Determine the new measurement sensitivity. Hence determine the sensitivity drift due to the change in ambient temperature of 50 °C.

9. Solution

10. Exercise

A load cell is calibrated in an environment at a temperature of 21 °C and has the following deflection/load characteristic:

Load (Kg)	0	50	100	150	200
Deflection (mm)	0.0	0.1	0.2	0.3	0.4

When used in an environment at 35 °C, its characteristic changes to the following:

Load (Kg)	0	50	100	150	200
Deflection (mm)	0.2	1.3	2.4	3.5	4.6

1. Determine the sensitivity at 21 °C and 35 °C.
2. Calculate the total zero drift and sensitivity drift at °C.
3. Hence determine the zero drift and sensitivity drift coefficients (in units of m/ °C and (m per kg)/(°C)).

10. Solution

---

11. Exercise

An unmanned submarine is equipped with temperature and depth measuring instruments and has radio equipment that can transmit the output readings of these instruments back to the surface. The submarine is initially floating on the surface of the sea with the instrument output readings in steady state. The depthmeasuring instrument is approximately zero order and the temperature transducer first order with a time constant of 50 seconds. The water temperature on the sea surface, T_0 , is 20 °C and the temperature T_x at a depth of x metres is given by the relation: $T_x = T_0$ 0.01x

1. If the submarine starts diving at time zero, and thereafter goes down at a velocity of 0.5 metres/second, draw a table showing the temperature and depth measurements reported at intervals of 100 seconds over the first 500 seconds of travel. Show also in the table the error in each temperature reading.
2. What temperature does the submarine report at a depth of 1000 metres?

11. Solution

---

12. Exercise

Write down the general differential equation describing the dynamic response of a second order measuring instrument and state the expressions relating the static sensitivity, undamped natural frequency and damping ratio to the parameters in this differential equation. Sketch the instrument response for the cases of heavy damping, critical damping and light damping, and state which of these is the usual target when a second order instrument is being designed.

12. Solution

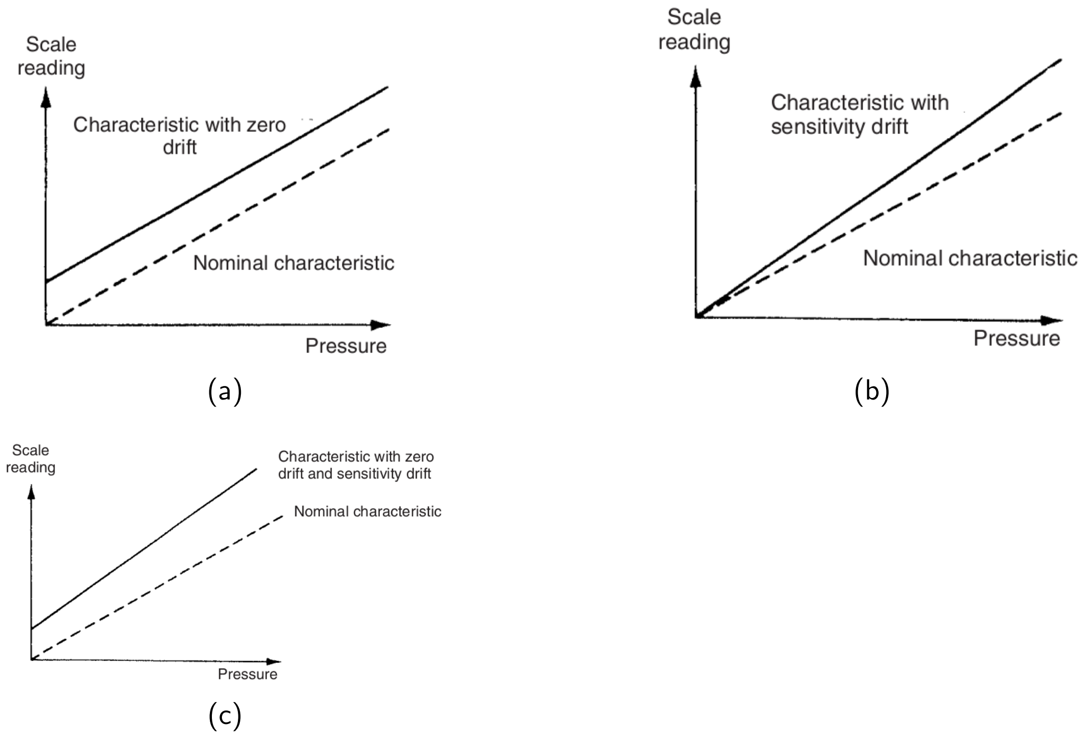

Figure 1: Comparison between (a) zero-dirft (b) sensitivity-drift (c) zero- and sensitivity-drift.

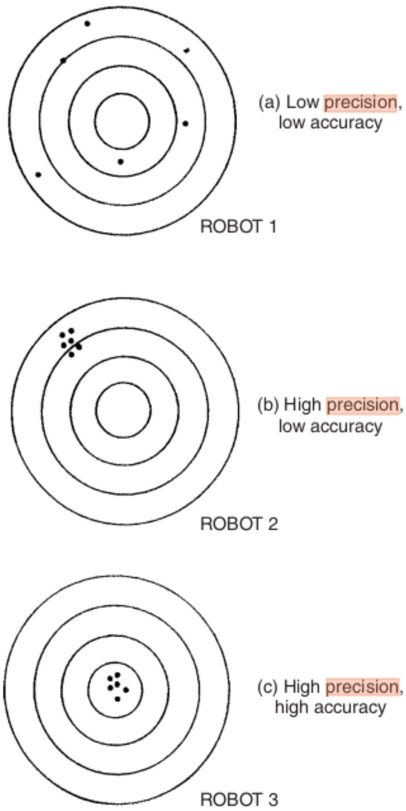

Figure 2: Comparison between accuracy and precision.