MECE 3320 – Measurements & Instrumentation

Basic Concepts of Measurement Methods

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Need for Measurements

- Several general needs: rate of flow in a pipe; mass flux of contaminants in a river – flow quantities can be measured directly or indirectly.
- Measurements necessary for correlation of dependent variables: lift and drag of various vehicles are dependent on density and velocity of flow.
- Measurements used as a diagnostic for determining various quantities: velocity measurements to determine noise sources.
- Measurements for verification of theory.

Basic Quantities

Quantity	Unit	Symbol	Definition
Length	**meter**	m	The metre is the length of the path travelled by light in vacuum during a time interval of 1/299 792 458 of second.
Mass	**kilogram**	kg	It is equal to the mass of 1000 cc of water at 4^0C (maximum density).
Time	**second**	s	The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium 133 atom.
Electric current	**ampere**	A	The ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per metre of length.
Thermodynamic temperature	**kelvin**	K	The kelvin, unit of thermodynamic temperature, is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water.
Amount of substance	**mole**	mol	The mole is the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon 12; This value corresponds to the number of Avogadro
Luminous intensity	**candela**	cd	The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency $540*10^{12}$ hertz and that has a radiant intensity in that direction of 1/683 watt per steradian

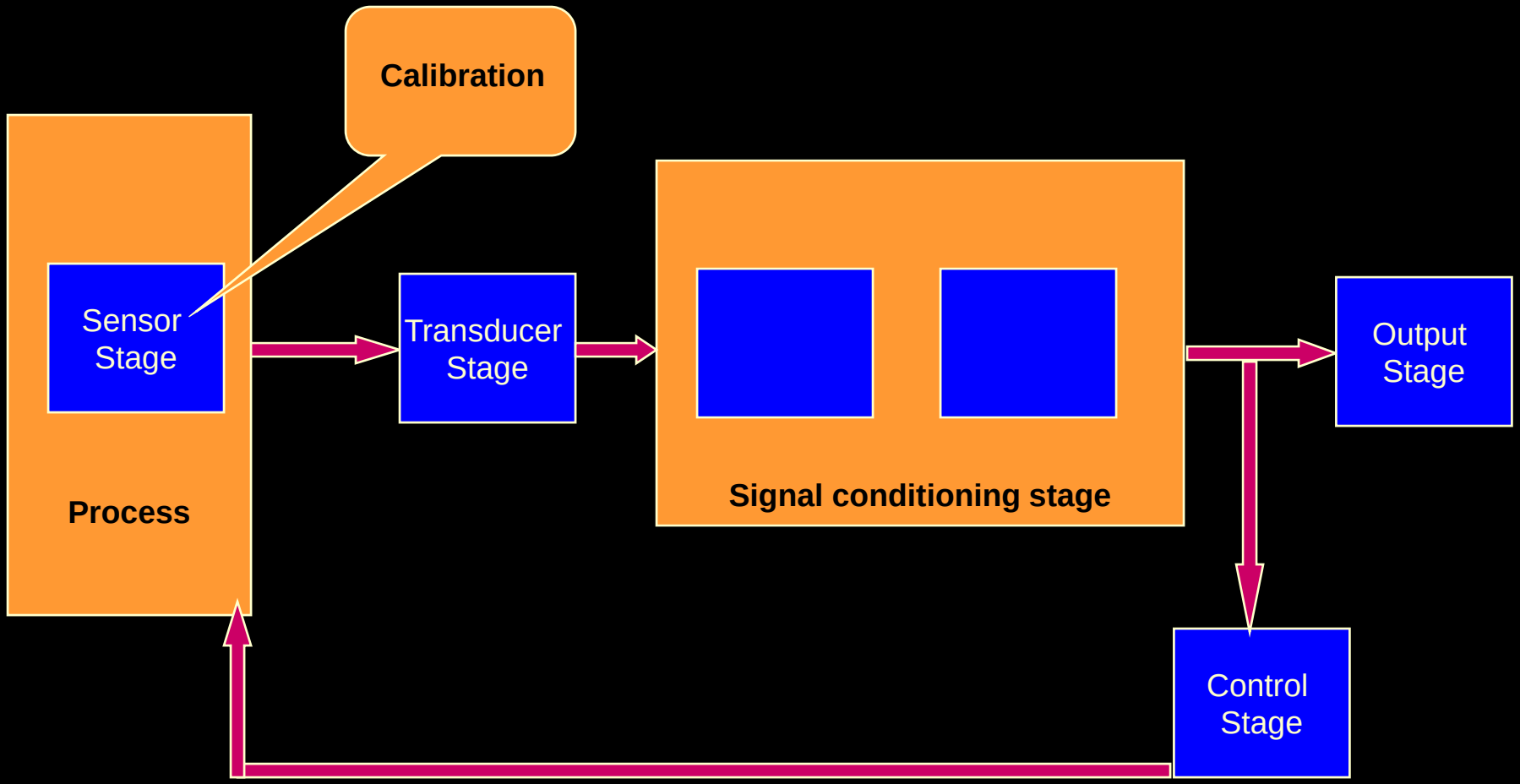
Source: www.themeter.net

Derived Quantities

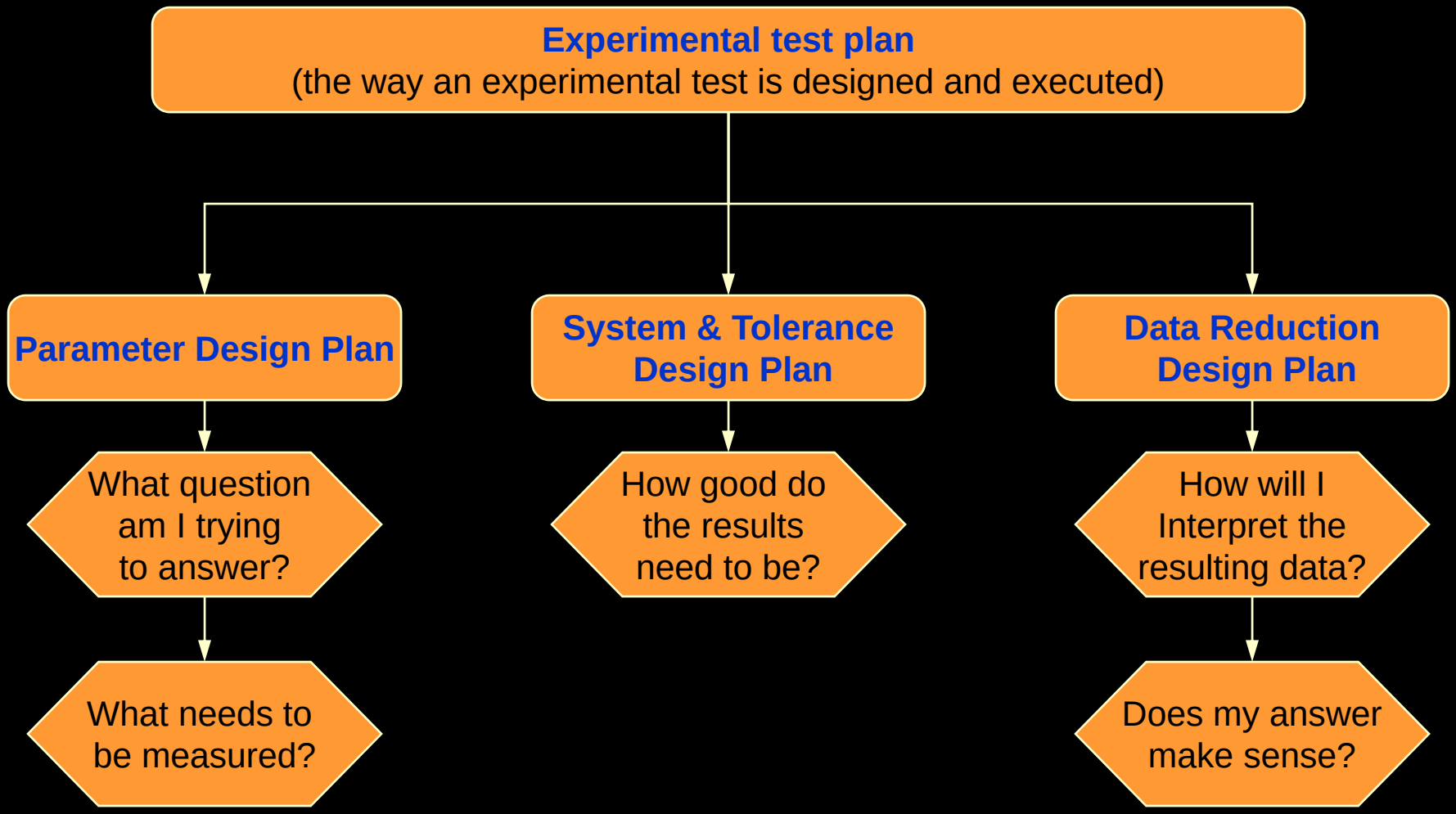
Derived quantity	Name	Symbol
area	square meter	m^2
volume	cubic meter	m^3
speed, velocity	meter per second	m/s
acceleration	meter per second squared	m/s^2
wave number	reciprocal meter	m^{-1}
mass density	kilogram per cubic meter	kg/m^3
specific volume	cubic meter per kilogram	m^3/kg
current density	ampere per square meter	A/m^2
magnetic field strength	ampere per meter	A/m
amount-of-substance concentration	mole per cubic meter	mol/m^3
luminance	candela per square meter	cd/m^2
mass fraction	kilogram per kilogram, which may be represented by the number 1	kg/kg = 1

Source: physics.nist.gov

General Measurement System



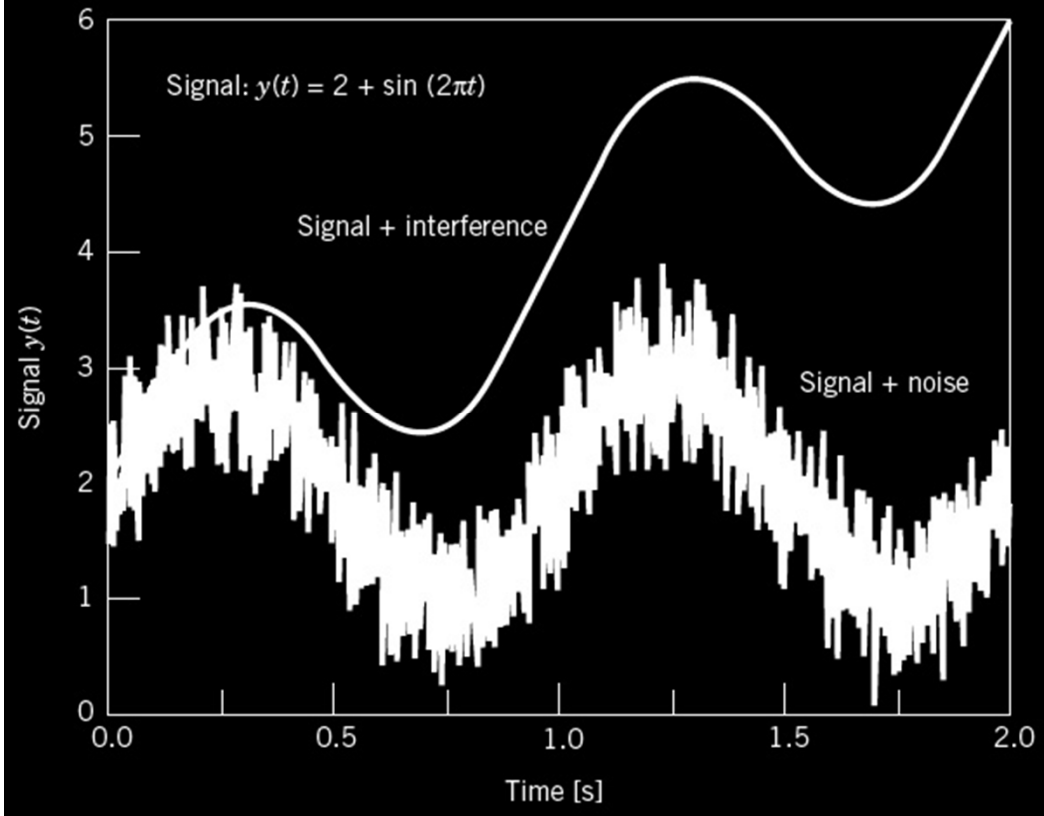
Experimental Test Plan



Some Definitions

- **Independent Variable:** Variable that can be changed independently of other variables.
- **Dependent Variable**: Variable that is affected by changes in one or more other variables.
- **Extraneous Variables:** Variables that are not or cannot be controlled during measurements.
- **Parameter:** A functional grouping of variables. E.g. Reynolds number.

Noise & Interference

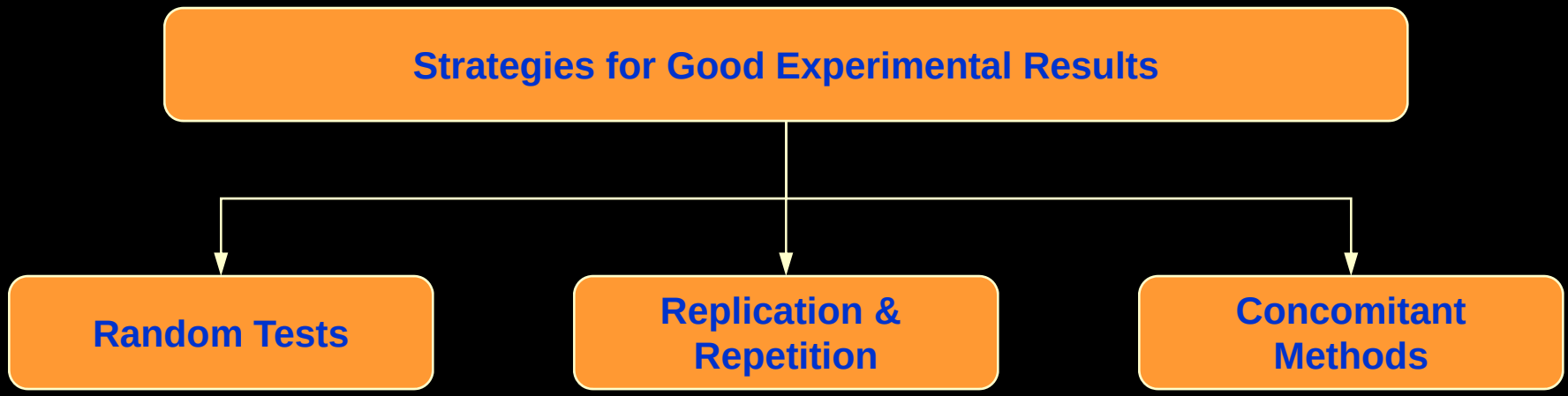


- **Noise:** Random variation of the value of a measured signal.
- **Interference**: Undesirable deterministic trends in the measured value.

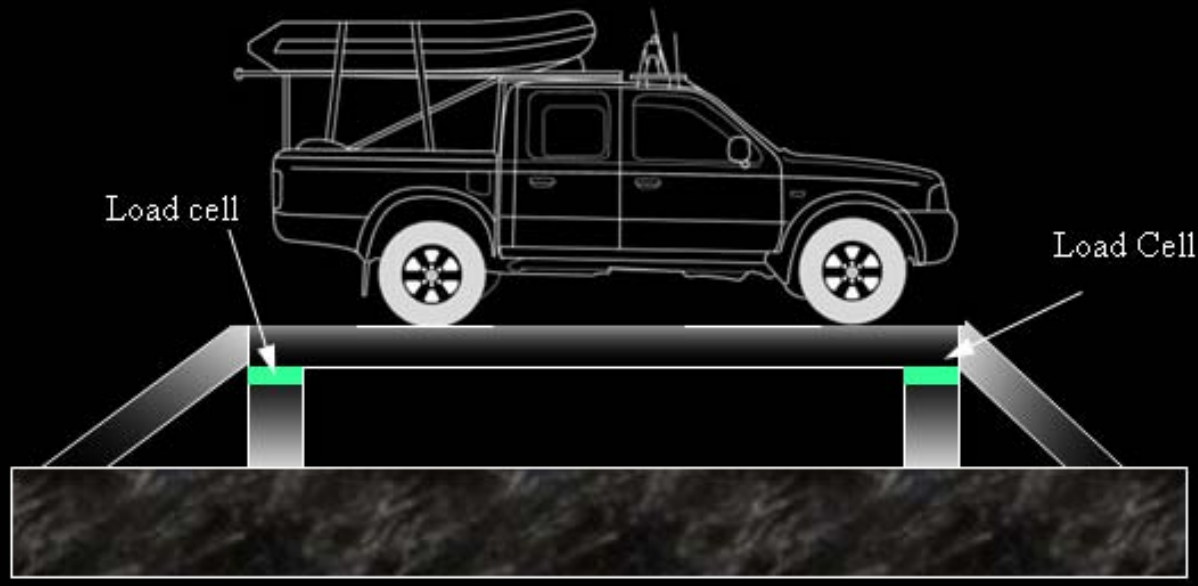
How do you minimize?

- Repetition
- Replication

Strategies for a Good Test



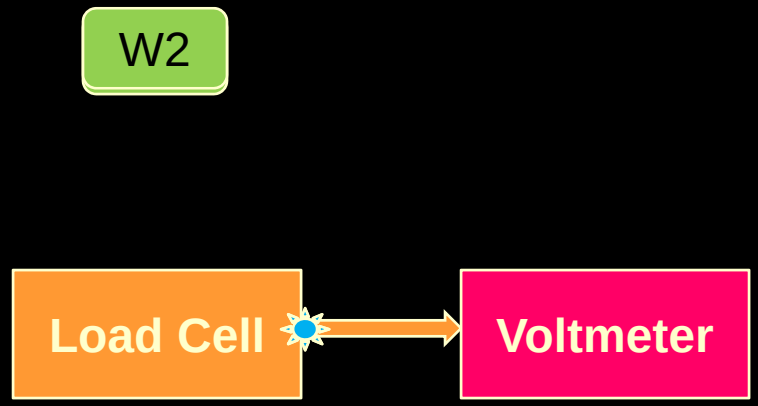
Calibration

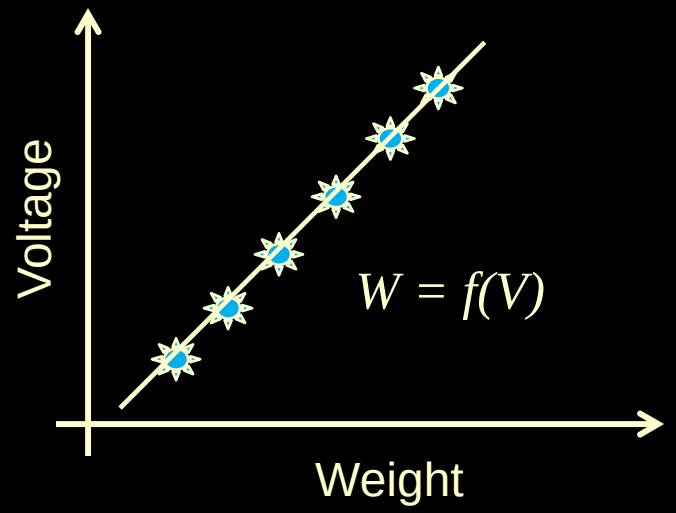


How do you make sure that the reading given out by the load cell is the correct weight of the car?

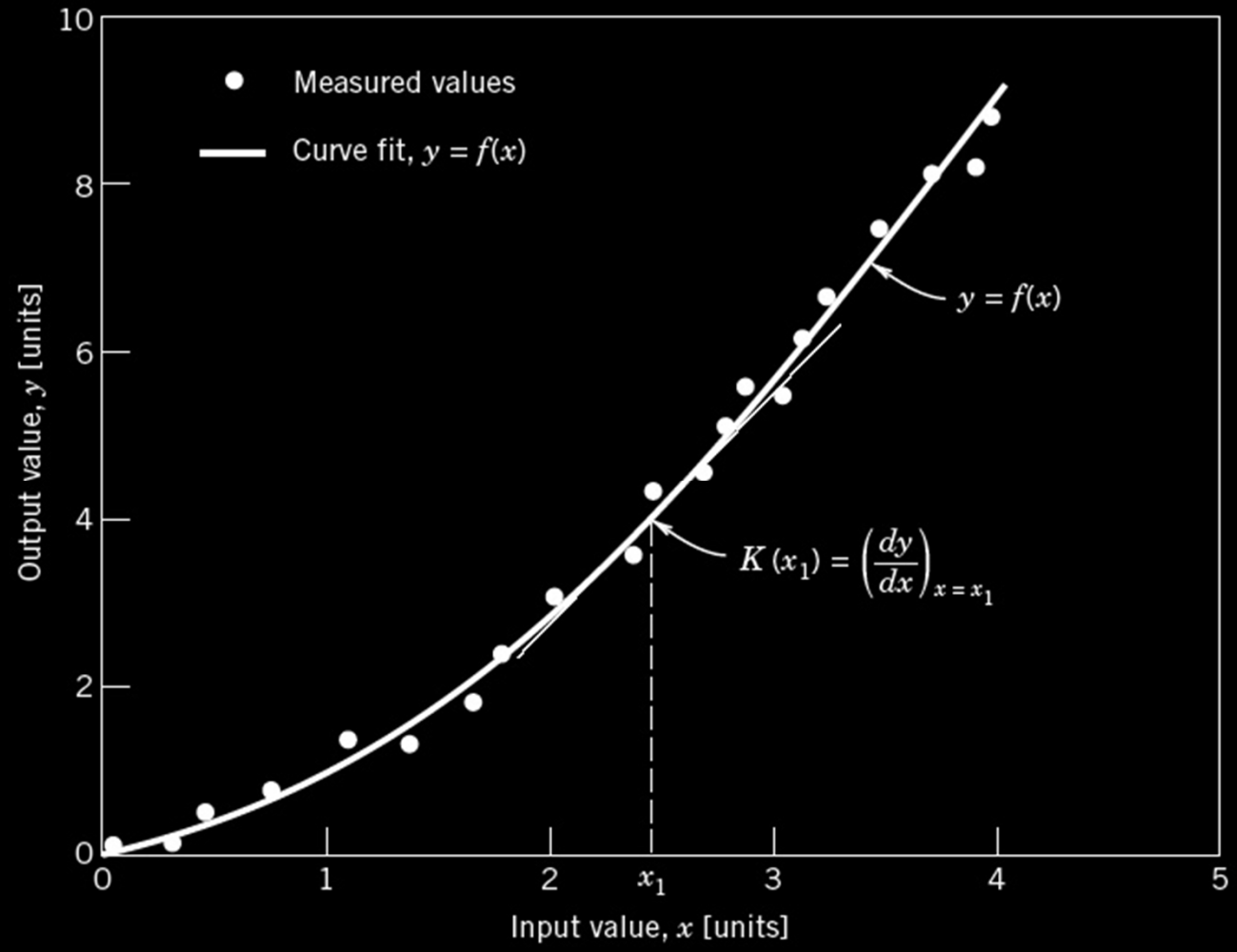
Calibration Contd.

- A calibration applies a known input value to a measurement system for the purpose of observing the system output value.
- The known value used for the calibration is called the standard.





Calibration Contd.



Calibration Contd.

- **Static Calibration:** Describes the static input-output relationship for a measurement system. 'Static' implies that the values of the variable involved do not vary with time.
- **Dynamic Calibration**: Determines the relationship between an input of known dynamic behavior and the measurement system output.
- **Static Sensitivity:** Slope of the static calibration curve $K = \left(\frac{\partial y}{\partial x} \right)_{x=x_1}$
- **Range:** The limits defining the operating range of the system (Full-Scale Operating range - FSO)
- **Resolution:** The smallest increment in measured value that can be discerned.

Accuracy and Error

- **True Value:** The exact value of a variable.
- **Measured Value**: Value of the variable indicated by the measurement system.
- **Error = measured value – true value**
- **Accuracy:** Degree of closeness to the true value.

Random and Systematic Error

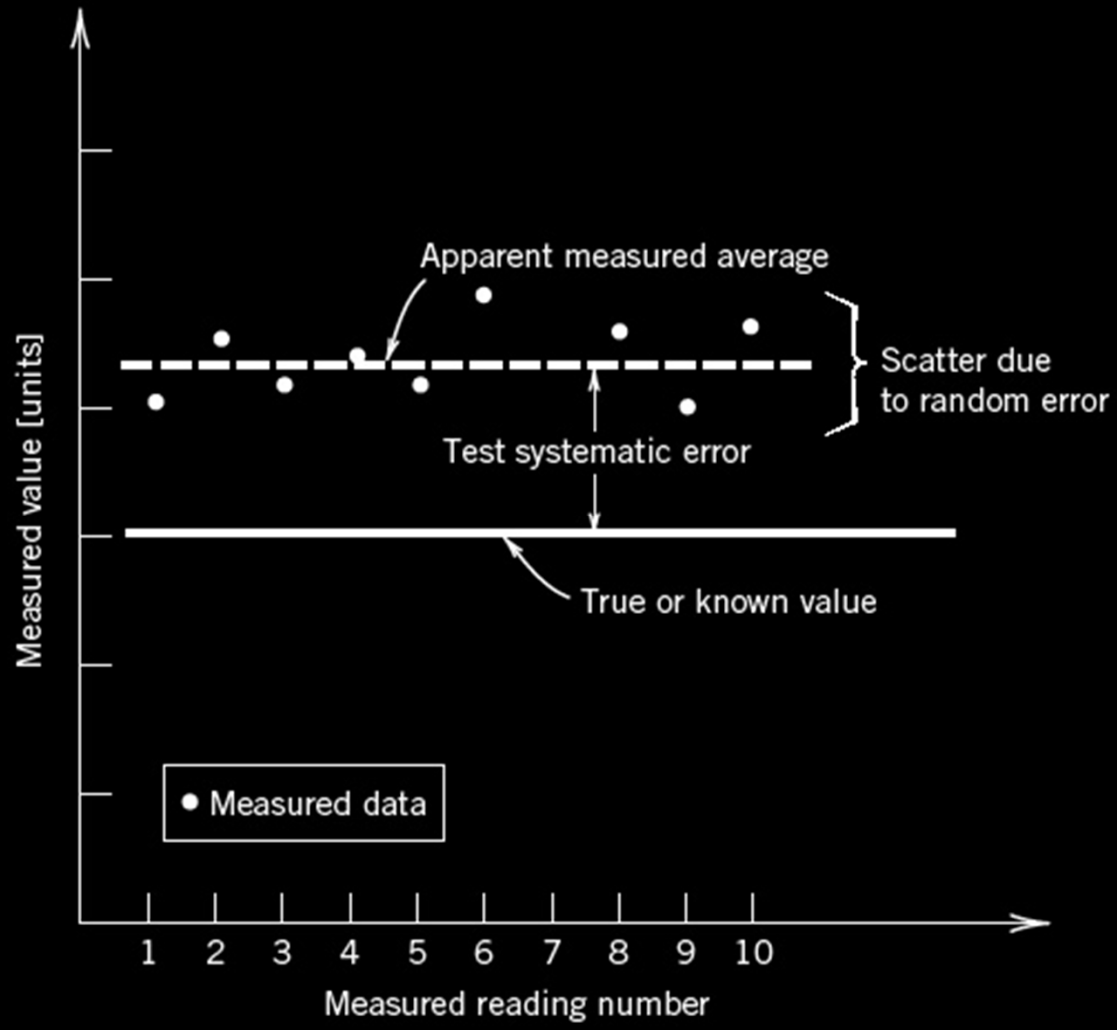
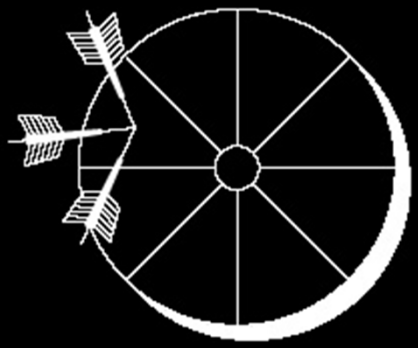
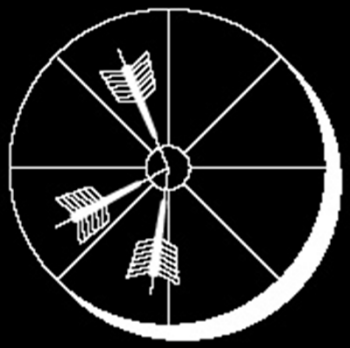


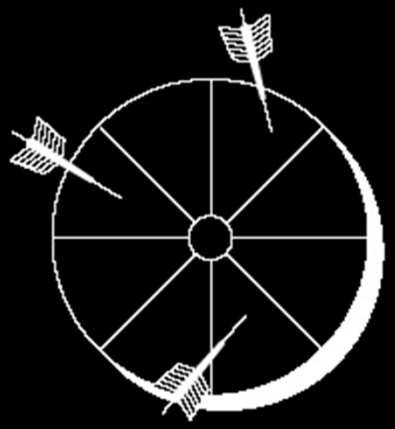
Illustration of Random, Systematic Error & Accuracy



(*a*) High repeatability gives low random error but no direct indication of accuracy



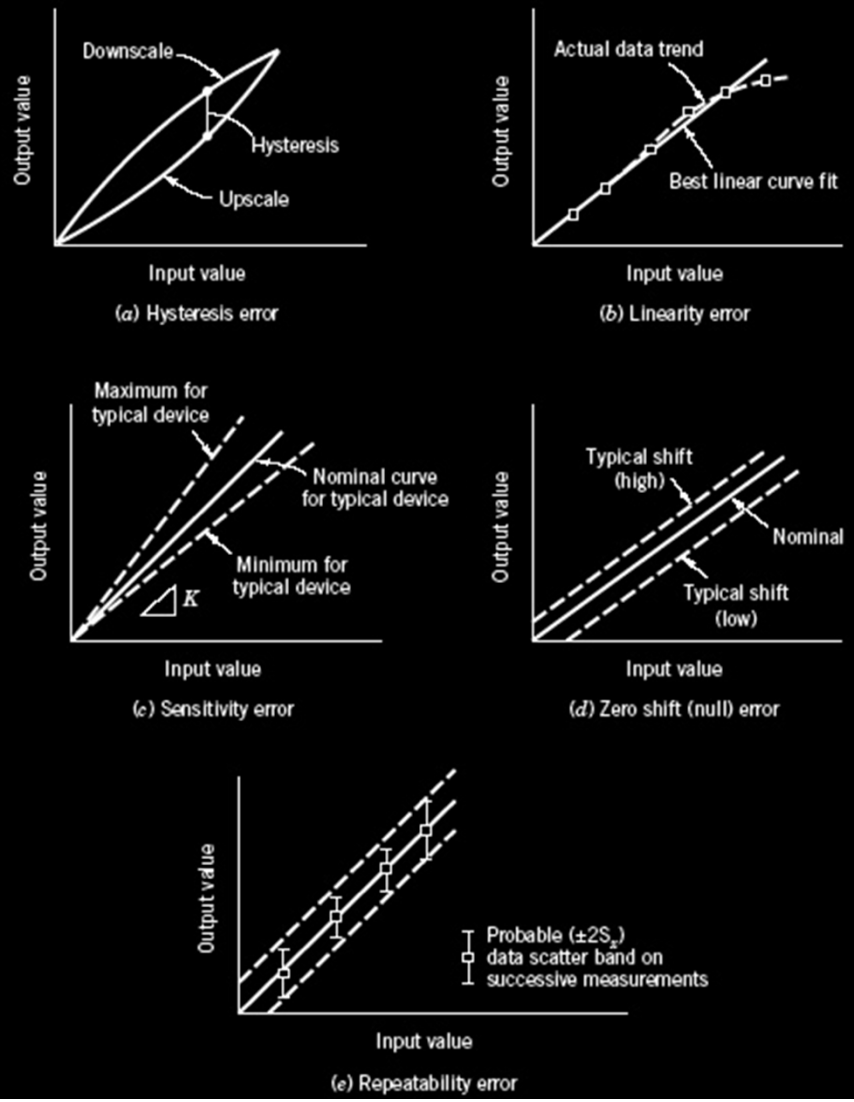
(*b*) High accuracy means low random and systematic errors



(*b*) Systematic and random errors lead to poor accuracy

❖ *Uncertainty* of a measurement system is the result of several interacting random, systematic errors, calibration procedure and the standard used to provide the known value.

Instrument Errors



Overall Instrument Error

$$u_c = \sqrt{\left[e_1^2 + e_2^2 + \ldots\ldots\ldots e_M^2\right]}$$

HW1, Quiz-1 Posted on Black Board