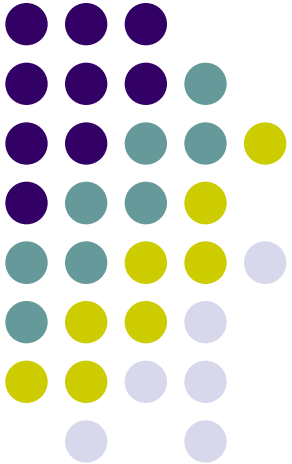
ME 482 – Rapid Product Development and Manufacturing

Chapter 5

Measurement Techniques (Part II)



Mechanical Engineering
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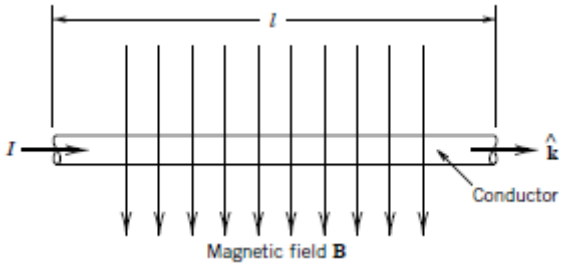
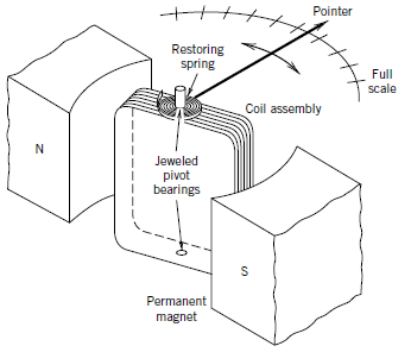
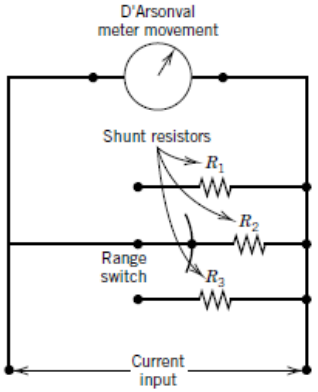
Current Measurements (Direct Current): The way to measure a DC electrical current is to use an analog device that responds to the force exerted on a current-carrying conductor in a magnetic field. Similarly, a current loop in a magnetic field experiences a torque. Most devices that use the D'Arsonval movement employ a pointer whose deflection increases with the magnitude of current applied.

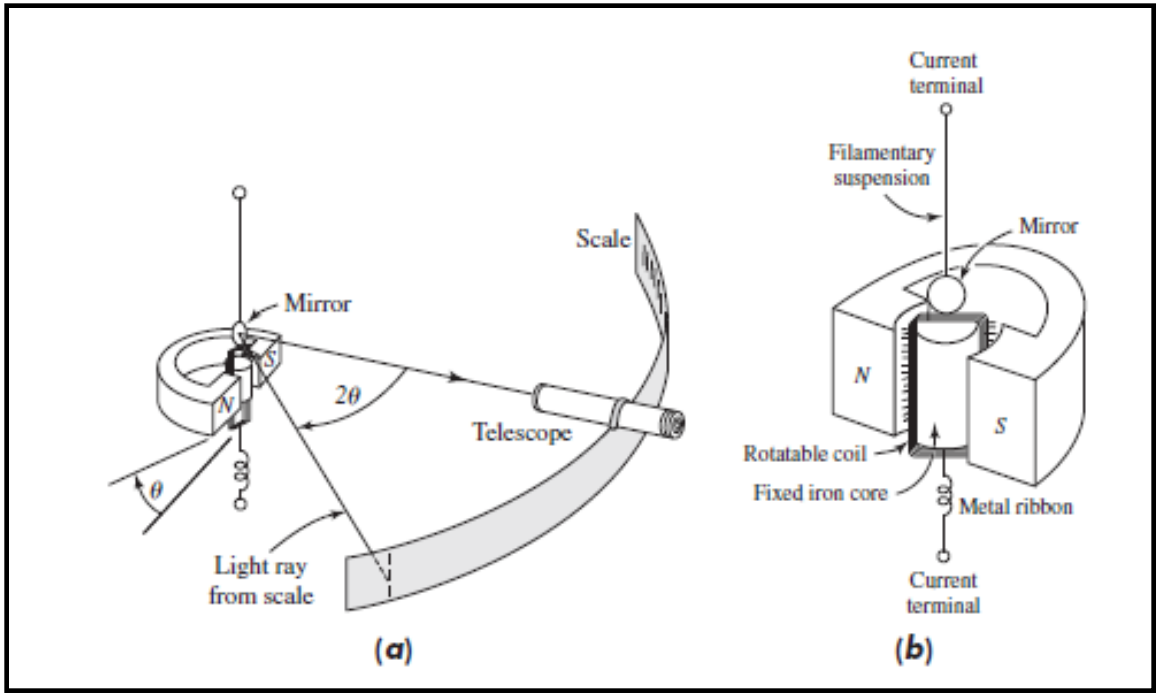




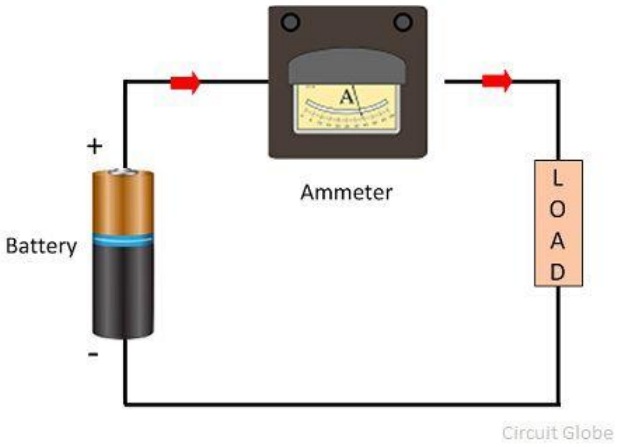


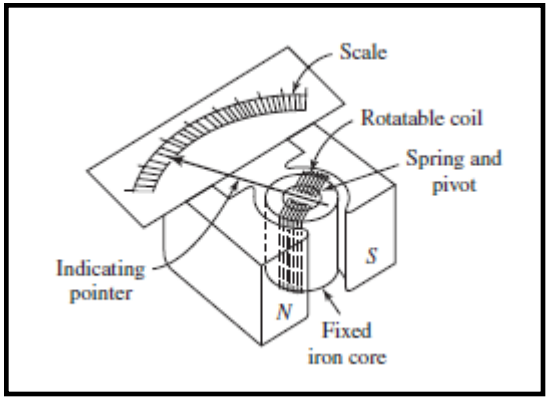
- **Galvanometer:** is a measuring device used to determine the magnitude as well as the direction of the current.
- **Ammeter:** (from Ampere Meter) is a measuring instrument used to measure the current in a circuit. *(DC ammeter – AC ammeter)*

Current Measurements (Direct Current):



Typical **galvanometer**. (*a*) Optical system; (*b*) D'Arsonval movement.

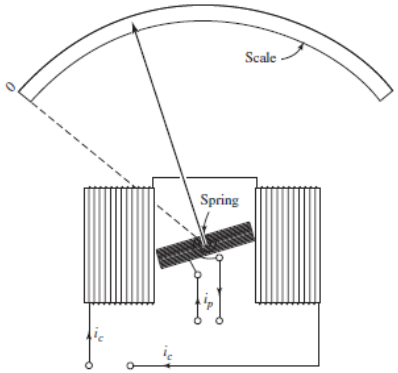




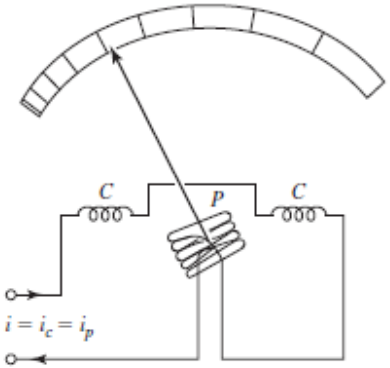
D'Arsonval movement used as a pointer-type instrument.

Current Measurements (Alternating Current): An AC current can be measured by using diodes to form a rectifier that converts the time-dependent AC current into a DC current.

- **Electrodynamometer:** is basically a D'Arsonval movement modified for use with AC current by replacing the permanent magnet with an electromagnet in series with the current coil.



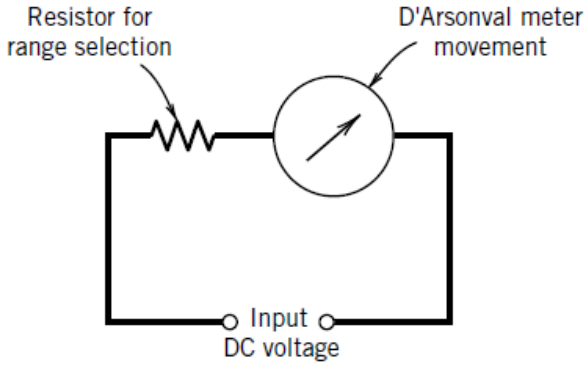
Basic features of **electrodynamometer** movement.



Electrodynamometer movement used as an ammeter.

- **Hall Effect Probe:** is a probe clamped over the current-carrying wire (conductor) to measure its unknown current flow for large AC current.

Voltage Measurements: A DC voltage can be measured in through the analog circuit shown in the figure. This basic circuit is employed in the construction of analog voltage dials and volt-ohmmeters *(VOMs)*, which for many years served as the common measurement device for current, voltage, and resistance.

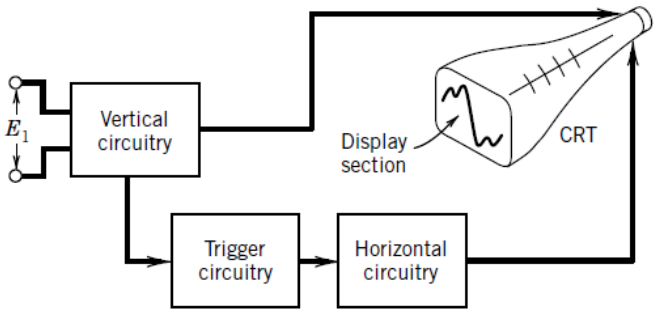


A DC voltmeter circuit.

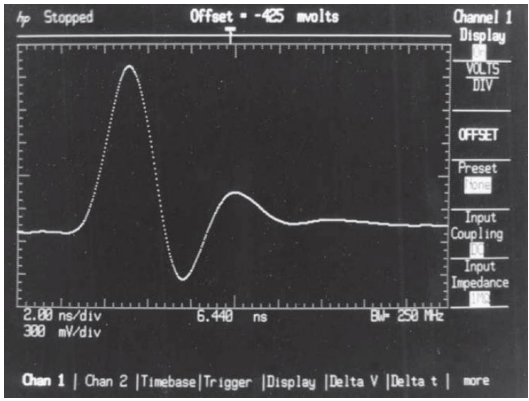
- **Oscilloscope:** is a practical graphical display device providing an analog representation of a measured signal. It is used to measure and to visually display voltage magnitude versus time for dynamic signals over a wide range of frequencies with a signal bandwidth extending commonly into the megahertz and gigahertz range.

Voltage Measurements:

- **Digital Oscilloscope:** Analog signals maybe converted to digital signals through a sampling process. Instead of displaying the analog signal directly, it first performs an analog-to-digital conversion and then stores the digital signals in a buffer memory. The signal may then be displayed on the screen. The signal may be stored on auxiliary devices for later study and manipulation with a computer.



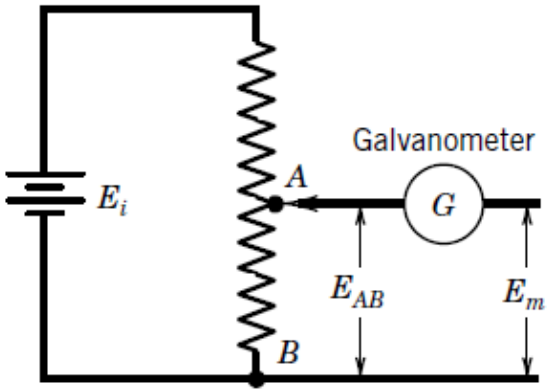
Basic cathode-ray tube oscilloscope.



Digital oscilloscope.

Voltage Measurements:

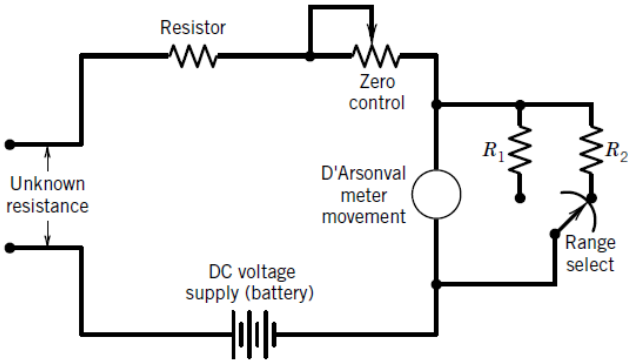
- **Potentiometer:** is a device used to measure DC voltages that are in the microvolt to millivolt range. Equivalent to a balance scale, a potentiometer balances an unknown input voltage against a known internal voltage until both sides are equal.



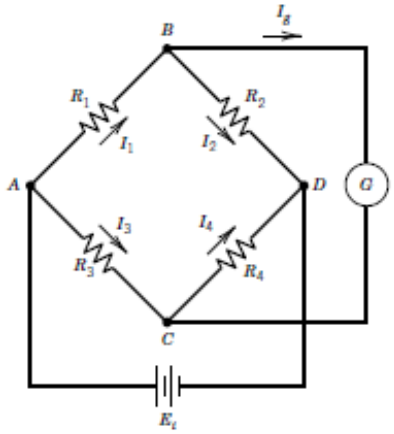
Basic potentiometer circuit.

Resistance Measurements:

- **Ohmmeter:** is one kind of electronic device mainly used for calculating electrical resistance of a circuit. Electrical resistance is a calculation of how much an object resists allowing the flow of current through it. There are different types of meters available such as *micro and milli-ohmmeters*.
- **Bridge Circuits:** A variety of bridge circuits have been devised for measuring capacitance, inductance, and, most often, resistance. A purely resistive bridge, called a Wheatstone bridge, provides a means for accurately measuring resistance, and for detecting very small changes in resistance.



Multirange ohmmeter circuits.



$$\frac{R_2}{R_1} = \frac{R_4}{R_3}$$

Basic current-sensitive Wheatstone bridge circuit (G, galvanometer).

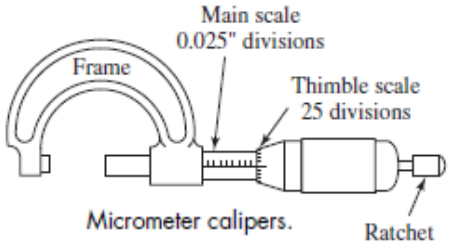
Transducers: transform values of physical variables into equivalent electrical signals. The Variable-Resistance Transducer is a very common device which may be constructed in the form of a moving contact on a slide-wire or a moving contact that moves through an angular displacement on a solid conductor like a piece of graphite. The variable-resistance transducer fundamentally is a device for converting either linear or angular displacement into an electric signal.

Some Examples of Variable Resistance Transducers

- Sliding contact devices *(i.e., potentiometer)*
- Wire resistance strain gauge *(the measurement of force,stress and strain)*
- Thermistors *(the measurement of temperature)*
- Thermocouple *(the measurement of temperature)*

Dimensional Measurements:

- **Vernier Caliper:** is used to measure outer dimensions of objects *(using the main jaws)*, inside dimensions *(using the smaller jaws at the top)*, and depths *(using the stem).*



- **Micrometer:** represent a more precise measurement device than the vernier calipers. When properly used, the micrometer can be employed for the measurement of dimensions within 0.0025 mm.

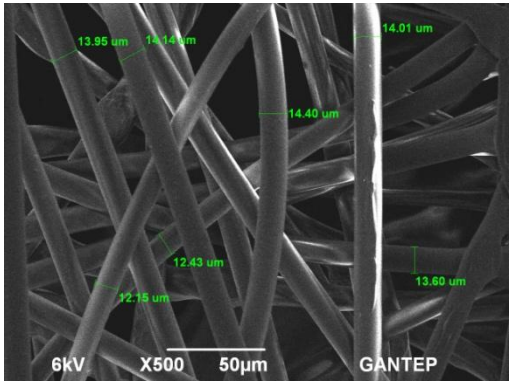
- **Dial indicators:** are devices that perform a mechanical amplification of the displacement of a pointer or follower in order to measure displacements within about 0.001 in.

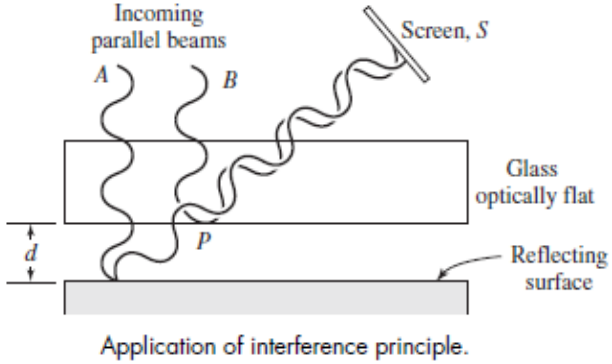
- **Gage Blocks:** are small steel blocks with highly polished surface. Because of their high accuracy, gage blocks are used for calibration of other measurement devices.

Displacement and Velocity Measurements

Optical Methods: An optical method for measuring dimensions very accurately is based on the principle of light interference. *(microscopes and telescopes)*

- **Scanning Electron Microscope (SEM):** is a device which is also used for the measurements of geometrical dimensions of fine patterns/molecules throughout any material in nano or micro levels with very high resolution.





Application of interference principle.

- **Interferometer:** is primarily used for calibration of gage blocks and other applications where extremely precise absolute dimensional measurements are required.

Displacement and Velocity Measurements

Displacement Measurements: Mechanical displacement may be measured with the aid of the electric transducers.

Linear Variable Differential Transformers (LVDT), *for example, can be used to sense displacements as small as 1 μin.*

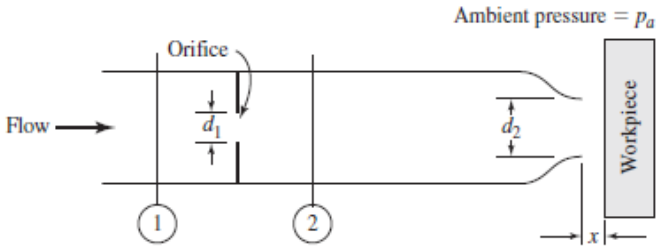
Capacitive Transducer

Variable-Resistance Transducer (angular displacement)

Ionization Transducer

Digital Displacement Transducers

- **Pneumatic Displacement Gage:** Air is supplied at a constant pressure and the change in flow is indicated by a change of pressure downstream from the orifice.

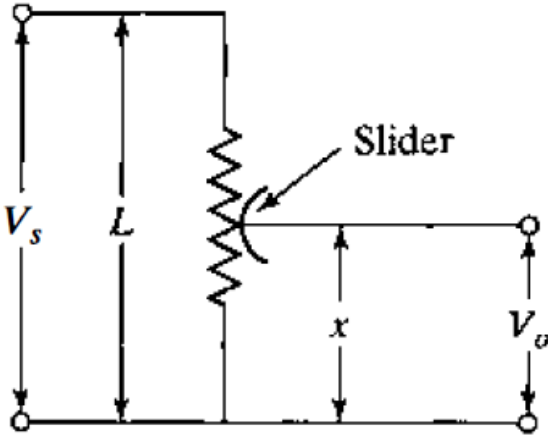


Pneumatic displacement device.

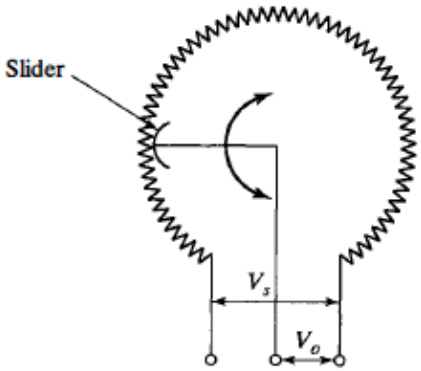
It is mainly used for small displacement measurements.

Displacement Measurements:

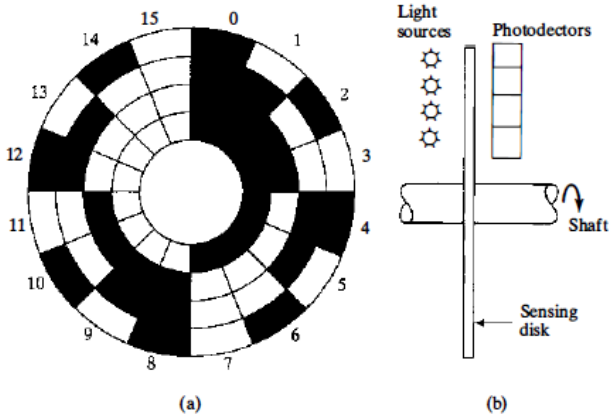
- **Potentiometer:** is a device in which the resistance varies as a function of the position of a linear or angular slider. Potentiometers are quite inexpensive, are readily available, and require no special signal conditioning. Angular potentiometers are used in radios and televisions as volume and tone controls.



Linear potentiometer.



Angular potentiometer.



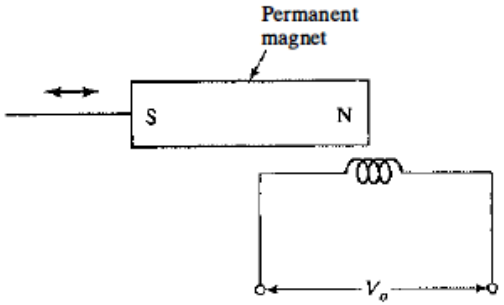
Digital encoder

- **Digital Encoders:** are devices that convert a displacement directly into a digital signal.

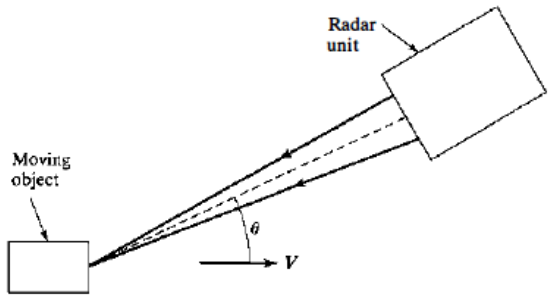
Displacement and Velocity Measurements

Velocity Measurements:

- **Linear Velocity Transducer (LVT):** is an inductive device suitable for measuring the velocity of components in machines.
- **Doppler Radar:** If a beam of radio waves is directed at a moving object, the frequency of radiation reflected from the object will be altered. *They are used by police to measure vehicle velocities, and they are often used to measure velocities in sports.*
- **Tachometer:** Many common machines have rotating shafts in which it is necessary to measure the angular velocity, commonly referred to as the shaft speed. They are generically called tachometers. *(photoelectric tachometer, stroboscopic tachometer)*



Linear velocity transducer.

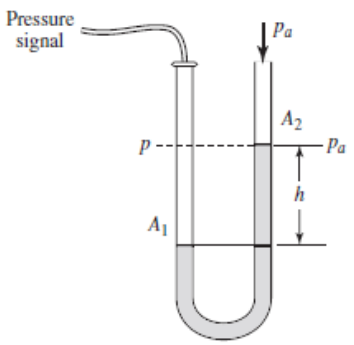


Doppler velocity measurement.

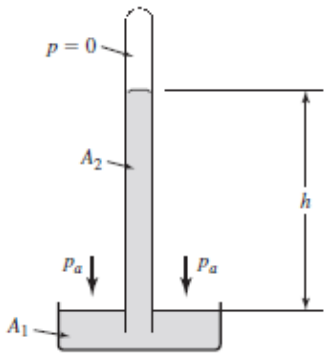
Pressure Measurements:

- **Manometer:** is a widely used device for measurement of fluid pressures under steady-state and laboratory conditions.
- **Barometer:** It is a device which is used in order to measure the atmospheric pressure.
- **Dead-Weight Tester:** It is a device used for balancing a fluid pressure with a known weight. It is used for static calibration of pressure gages.

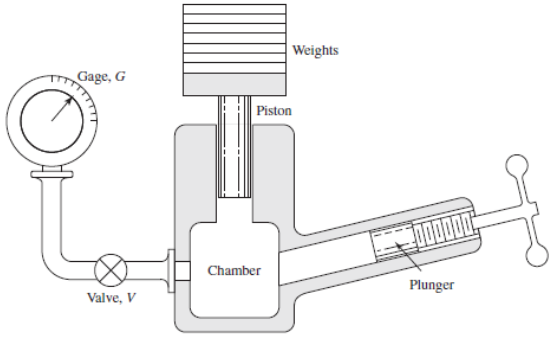
  Bourdon-Tube Pressure Gage: can be used for a wide range of application where consistent, inexpensive measurements of static pressure are desired.



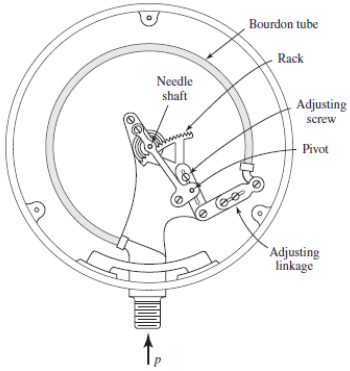
Manometer



Barometer



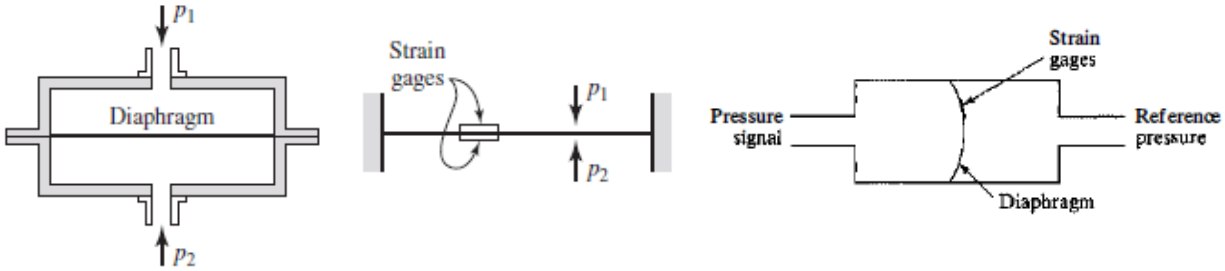
Dead weight tester



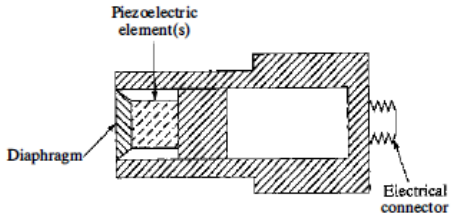
Bourdon-tube

Pressure Measurements:

- **Diaphragm and Bellows Gages:** represent similar types of elastic deformation devices useful for many pressure-measurement applications. The diaphragm will be deflected in accordance with this pressure differential and the deflection sensed by an appropriate displacement transducer. Electrical-resistance strain gages may also be installed on the diaphragm.

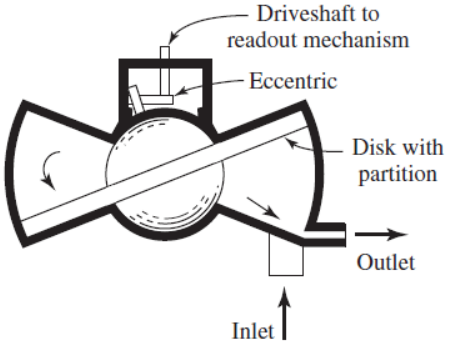


- **Piezoelectric Pressure Transducer:** These transducers generally use transverse-effect piezoelectric sensing elements. The piezoelectric material is very stiff, and the transducers have a high natural frequency in many applications.

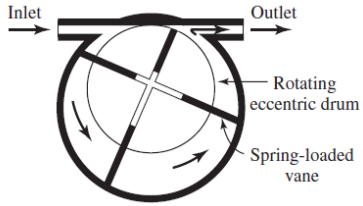


Flow Measurements:

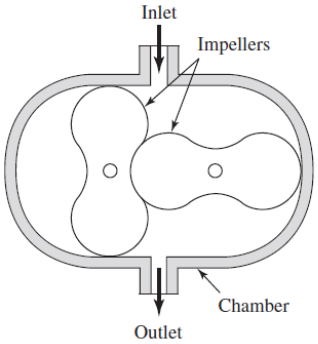
- Nutating-disk meter (Home-water meter)



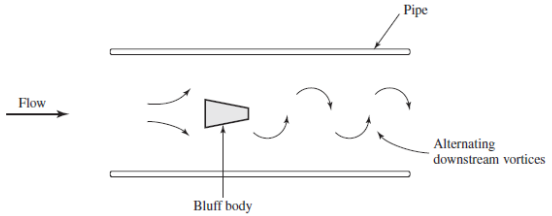
- Rotary-vane meter



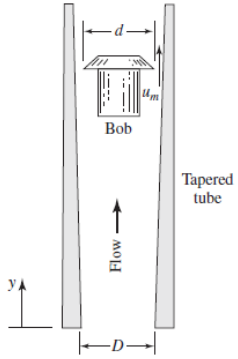
- Lobed-impeller meter



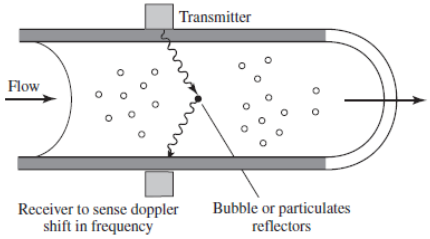
- Vortex-Shedding Flowmeters



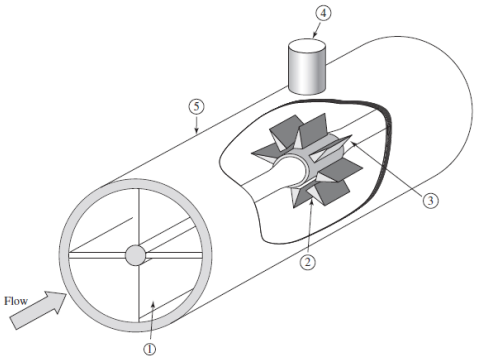
- Rotameter



- Ultrasonic flowmeter

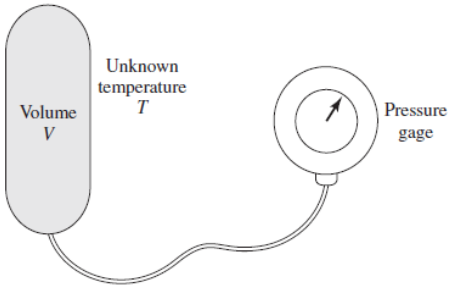


- Turbine Meters

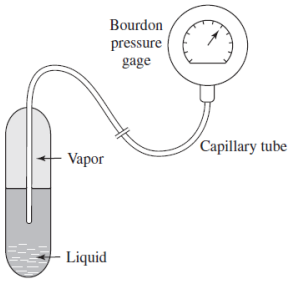


Temperature Measurements:

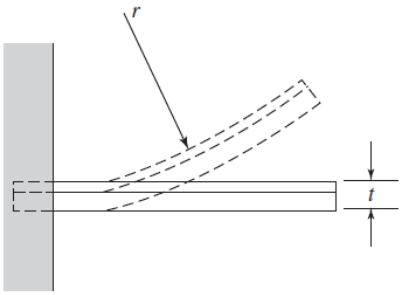
- **The Ideal-Gas Thermometer:** The behavior of an ideal gas at low pressures furnishes the basis for a temperature measurement device.
- **Capillary Tube Thermometer:** The liquid-in-glass thermometer is one of the most common types of temperature measurement devices.
- **Bimetallic strip:** Two pieces of metal with different coefficients of thermal expansion are bonded together to form the device.
- **Fluid-expansion Thermometers:** An increase in temperature causes the liquid or gas to expand, thereby increasing the pressure on the gage.



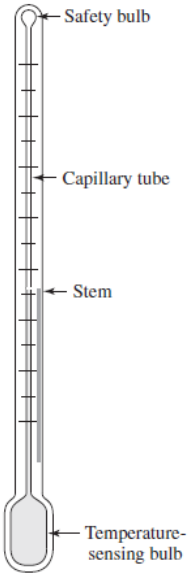
Ideal gas thermometer



Fluid expansion thermometer



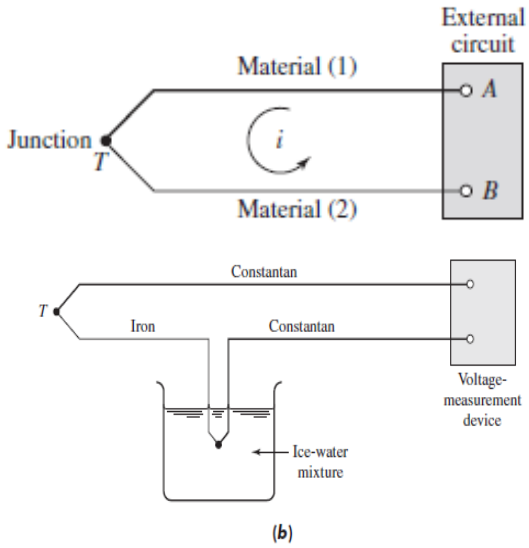
Bimetalic strip



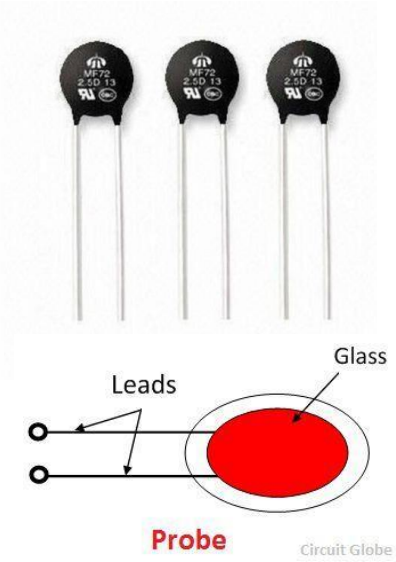
Capillary tube

Temperature Measurements:

- **Thermistor:** is a semi conductor device that has a negative temperature coefficient of resistance in contrast to the positive coefficient displayed by most metals.
- **Thermocouples:** It is the the most common electrical method of temperature measurement. When two dissimilar metals are joined together, an emf will exist between the two points A and B, which is primarily a function of the junction temperature.



Thermocouples



Thermistor

Data Acquisition

- **Data Acquisition (DAQ)** is the process of measuring an electrical or physical phenomenon*, such as voltage, current, temperature, pressure, or sound*. A DAQ system consists of sensors, DAQ measurement hardware, and a computer with programmable software.
- In a multi-point measurement process; collecting, storing, saving, processing and transferring of all measurements can be achieved via Data Acquisition System.