



# ***Mechatronic Instrumentations***

***002.0***

***Introduction***

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# Basic Concepts of Actuators

An actuator is a device that actuates or moves an object within a system. More specifically, an actuator is a device that converts energy into motion or mechanical energy. Therefore, an actuator is a **specific type of a transducer**

# Thermal Actuators

**One type of thermal actuator is a bimetallic strip. This device directly converts thermal energy into motion. This is accomplished by utilizing an effect called thermal expansion.**

# Kinetic Energy Increase Causes Atoms requiring bigger space than normal

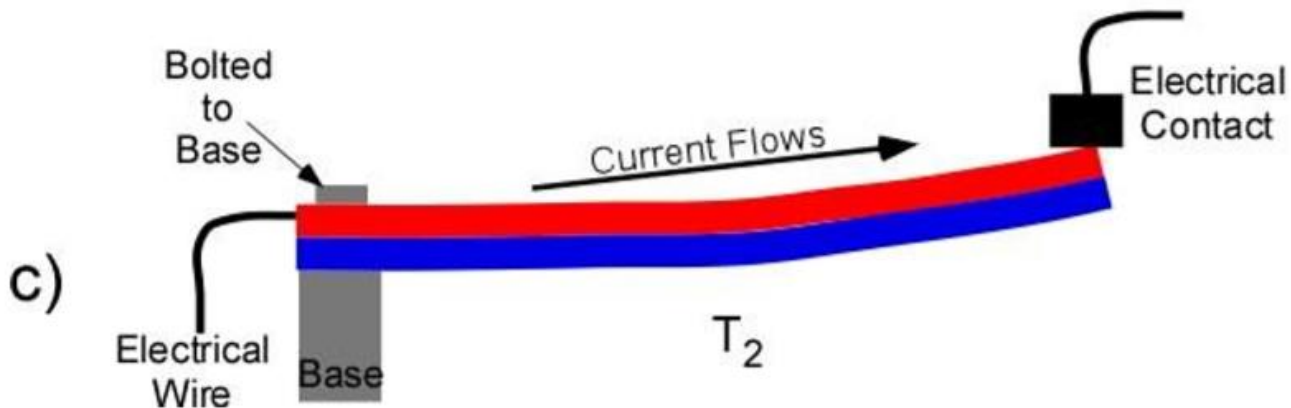
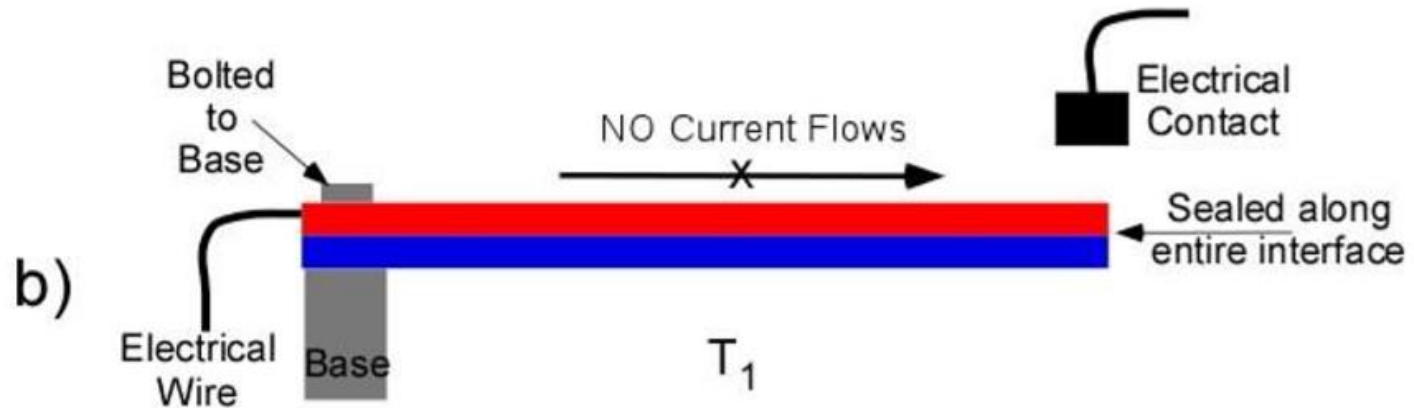
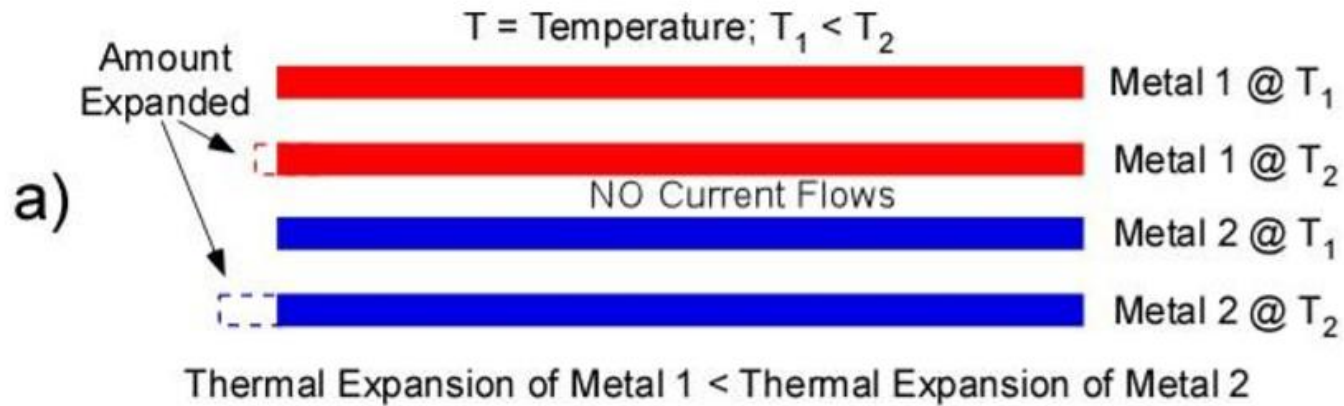
Thermal expansion is the manifestation of a change in thermal energy in a material. When a material is heated, the average distance between atoms (or molecules) increases. The amount of distance differs for different types of material. This microscopic increase in distance is unperceivable to the human eye. However, because of the huge numbers of atoms (or molecules) in a piece of material, the material expands considerably and, at times, is noticeable to the human eye.

# Displacement due to temperature

- Consider a piece of steel 25 meters long. If the temperature of the steel increases by 36°C, (the difference between a cold winter day and a hot summer day), that piece of steel lengthens approximately 12 cm. This change in length is the thermal linear expansion. It is calculated by using the following formula:

$$\Delta L = a L_0 \Delta T$$

- Where,  $\Delta L$  is the change in length,  $a$  is the coefficient of linear expansion,  $L_0$  is the original length, and  $\Delta T$  is the change in temperature in Celsius. If we are considering steel, the coefficient of linear expansion is  $1.3 \times 10^{-5}$ , the original length is 25 meters, and of course the change of temperature is 36°C. This results in an expansion of 11mm



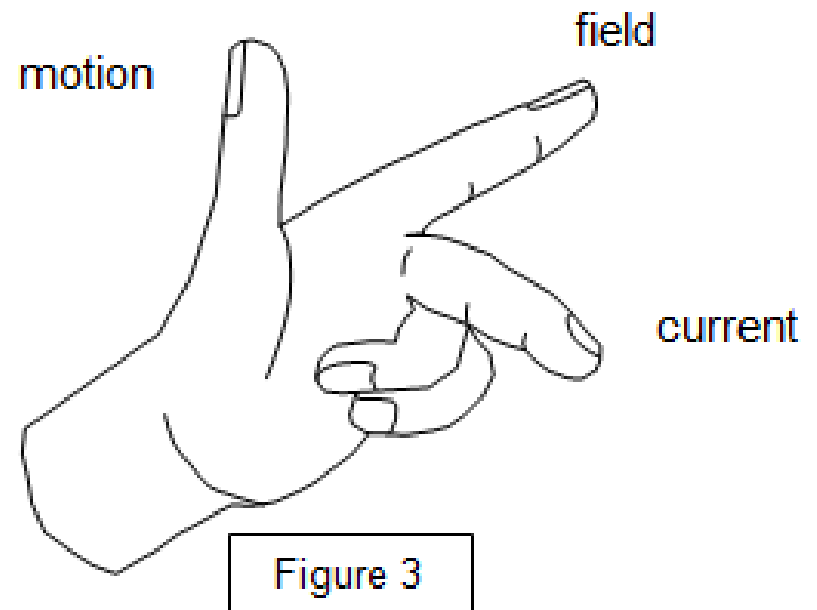
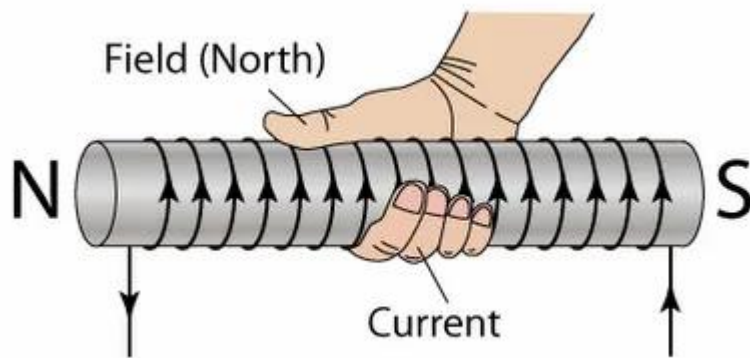
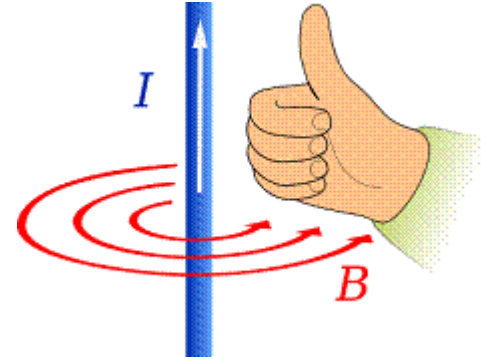
# Mechanical Actuator

**Mechanical actuators convert a mechanical input (usually rotary) into linear motion. A common example of a mechanical actuator is a screw jack. The figure below shows a screw jack in operation. Rotation of the screw causes the legs of the jack to move apart or move together. Inspecting the motion of the top point of the jack, this mechanical rotational input is clearly converted into linear mechanical motion.**



# Electric Actuator

## Fleming's Hand Rule



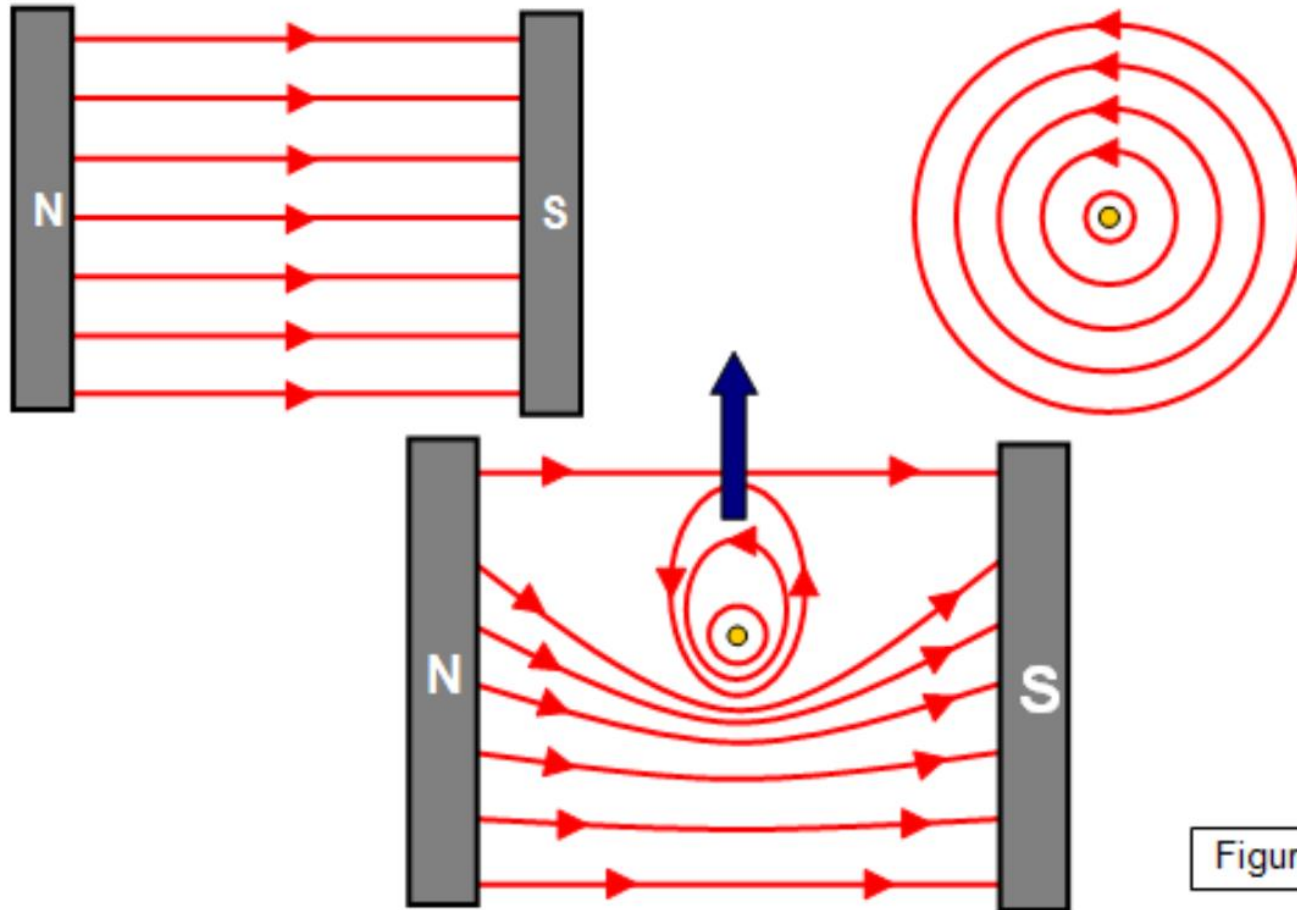
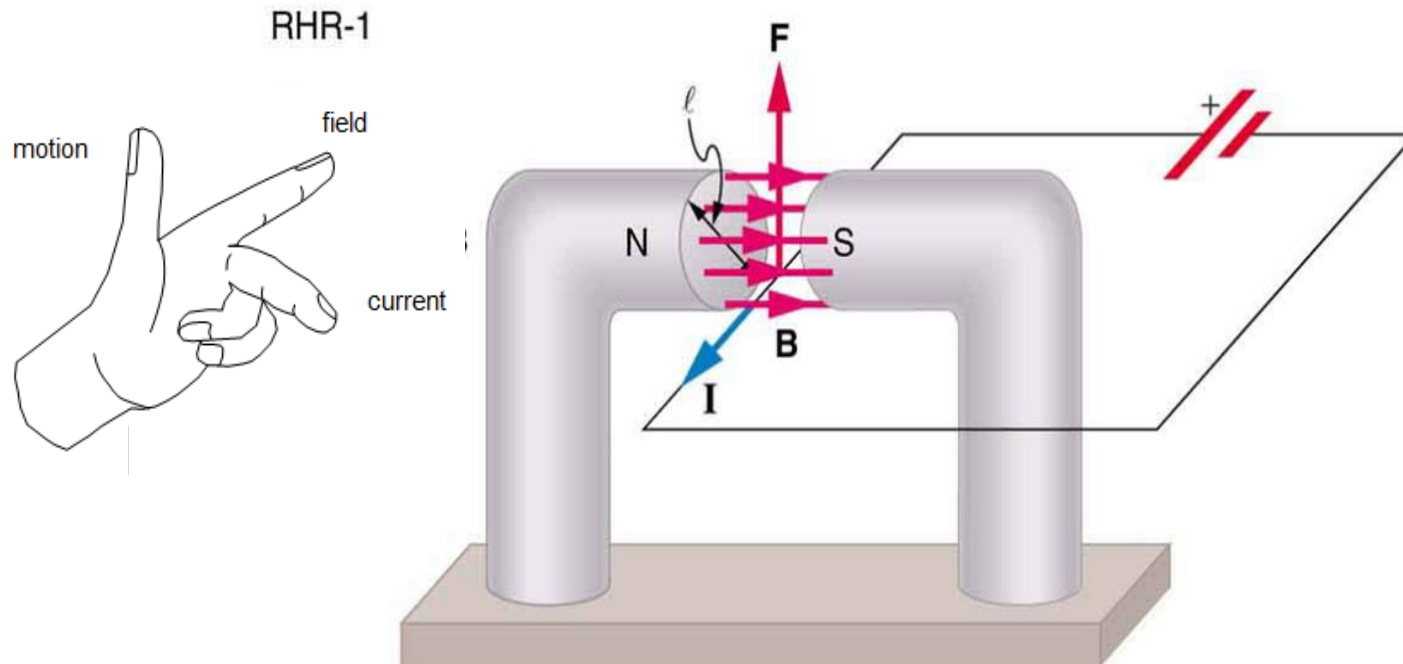


Figure 4

# Current Carrying Conductor in Magnetic Field

Because charges ordinarily cannot escape a conductor, the magnetic force on charges moving in a conductor is transmitted to the conductor itself.



The magnetic field exerts a force on a current-carrying wire in a direction given by the right hand rule 1 (the same direction as that on the individual moving charges). This force can easily be large enough to move the wire, since typical currents consist of very large numbers of moving charges.

# Principles of Electric motor (Electromechanical actuators)

$$F = IlB\sin\theta$$

Where:

- *F, is the force,*
- *I, is the electric current*
- *l, length of the conductor*
- *B, is the magnetic flux density*
- *θ, is the angle between the current and the flux*

# Exercise

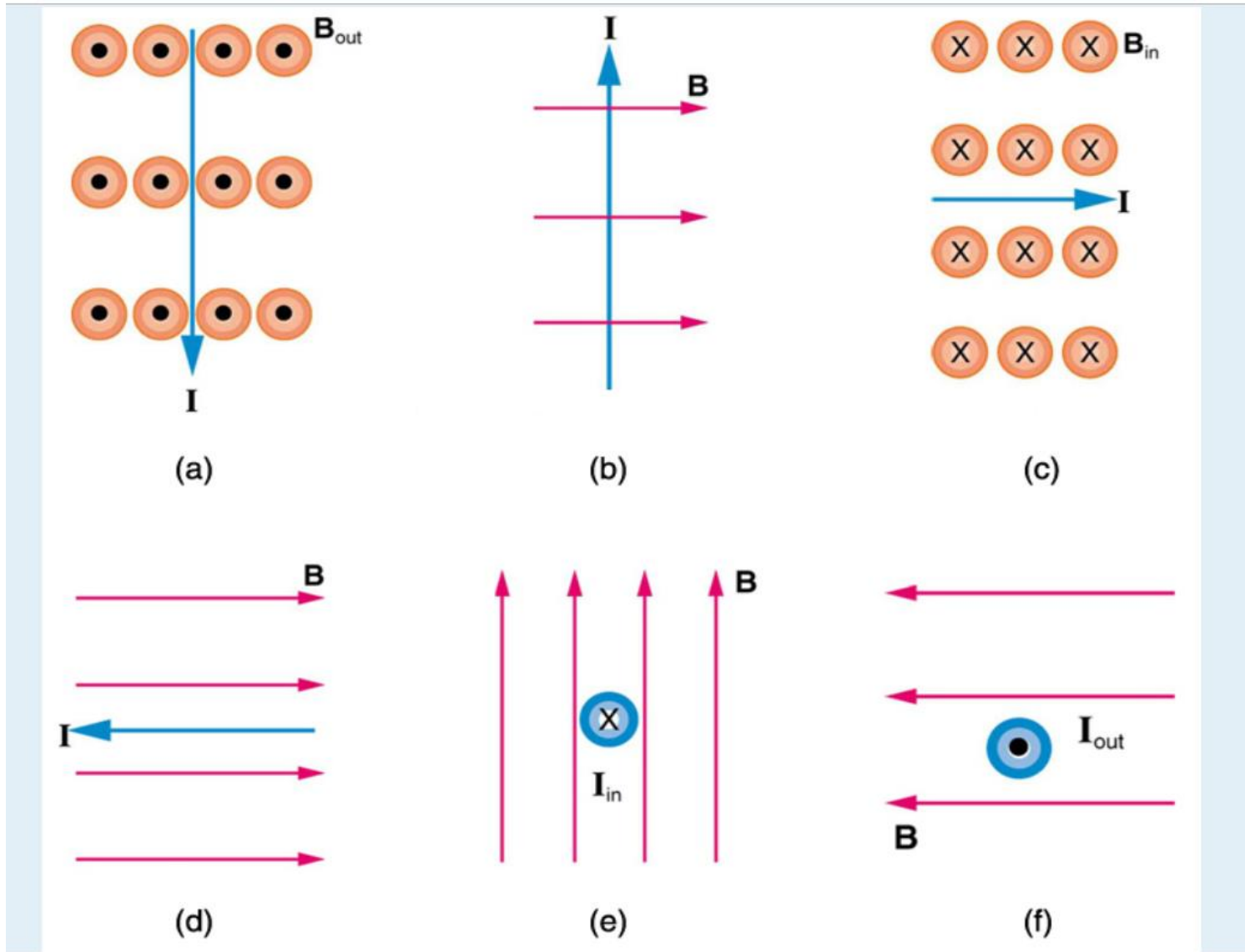
- Calculate the force on the wire shown in the previous figure, given  $B = 1.50 \text{ [T]}$ ,  $l = 5.00 \text{ [cm]}$ , and  $I = 20.0 \text{ [A]}$ .

# Solution

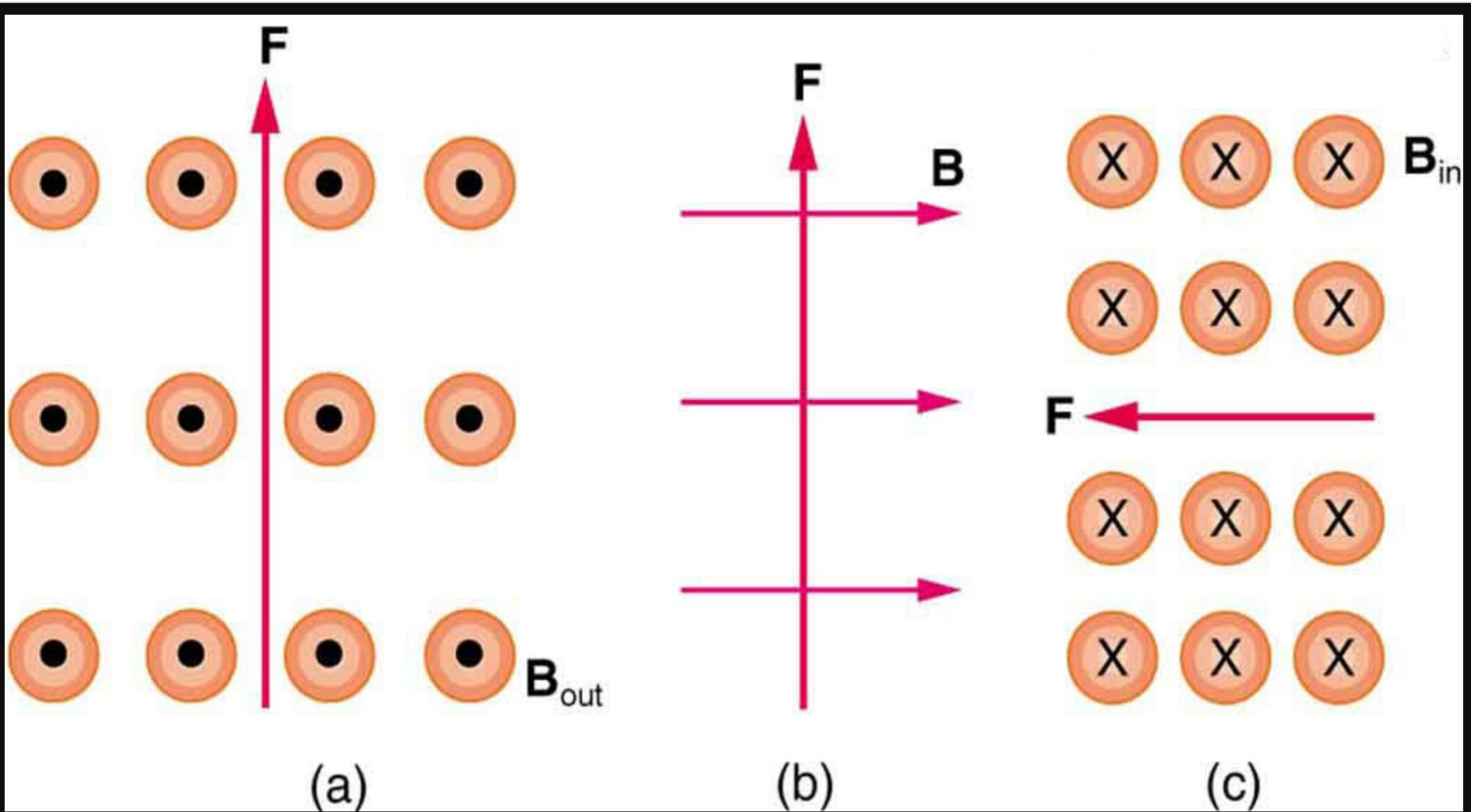
$$F = IlB\sin\theta$$

- $\theta = 90^\circ$
- $F[N] = 20 \times 0.05 \times 1.5 \times \sin(90)$
- $F[N] = 1.5 \text{ N}$
- **Imagine you have a coil of n turns placed in side a magnetic flux B ?**

# Question: Determine the direction of the force in the following cases



Question: What is the direction of the electric current that experienced these forces inside the magnetic field shown



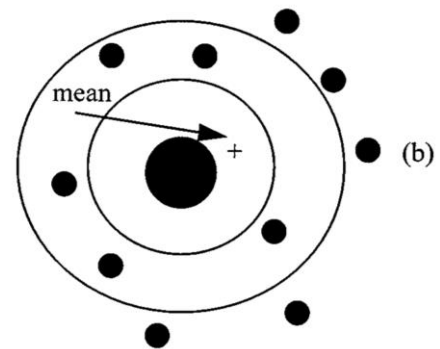
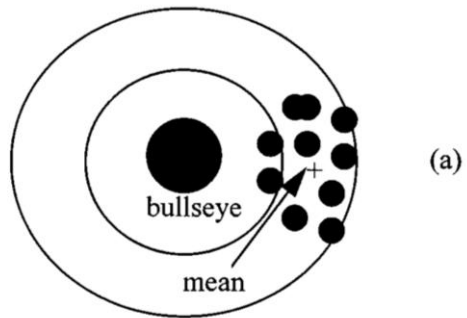
# Characteristics of instruments

**Measurement is a process of mapping actually occurring variables into equivalent values.**

**Deviations from perfect measurement mappings are called errors:**

# Characteristics of Instrument

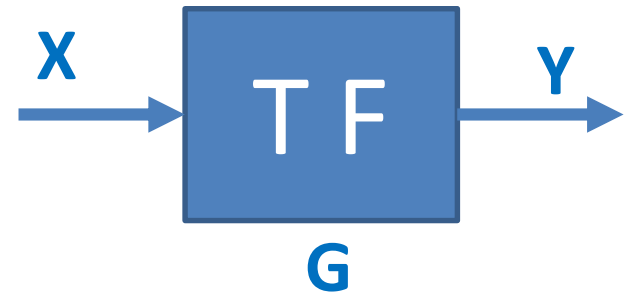
- **Static Characteristics of Instrument Systems**  
**Output/Input Relationship**
- **Drift**
- **Hysteresis and Backlash**
- **Saturation**
- **Bias**
- **Error of Nonlinearity**



# Transfer Function

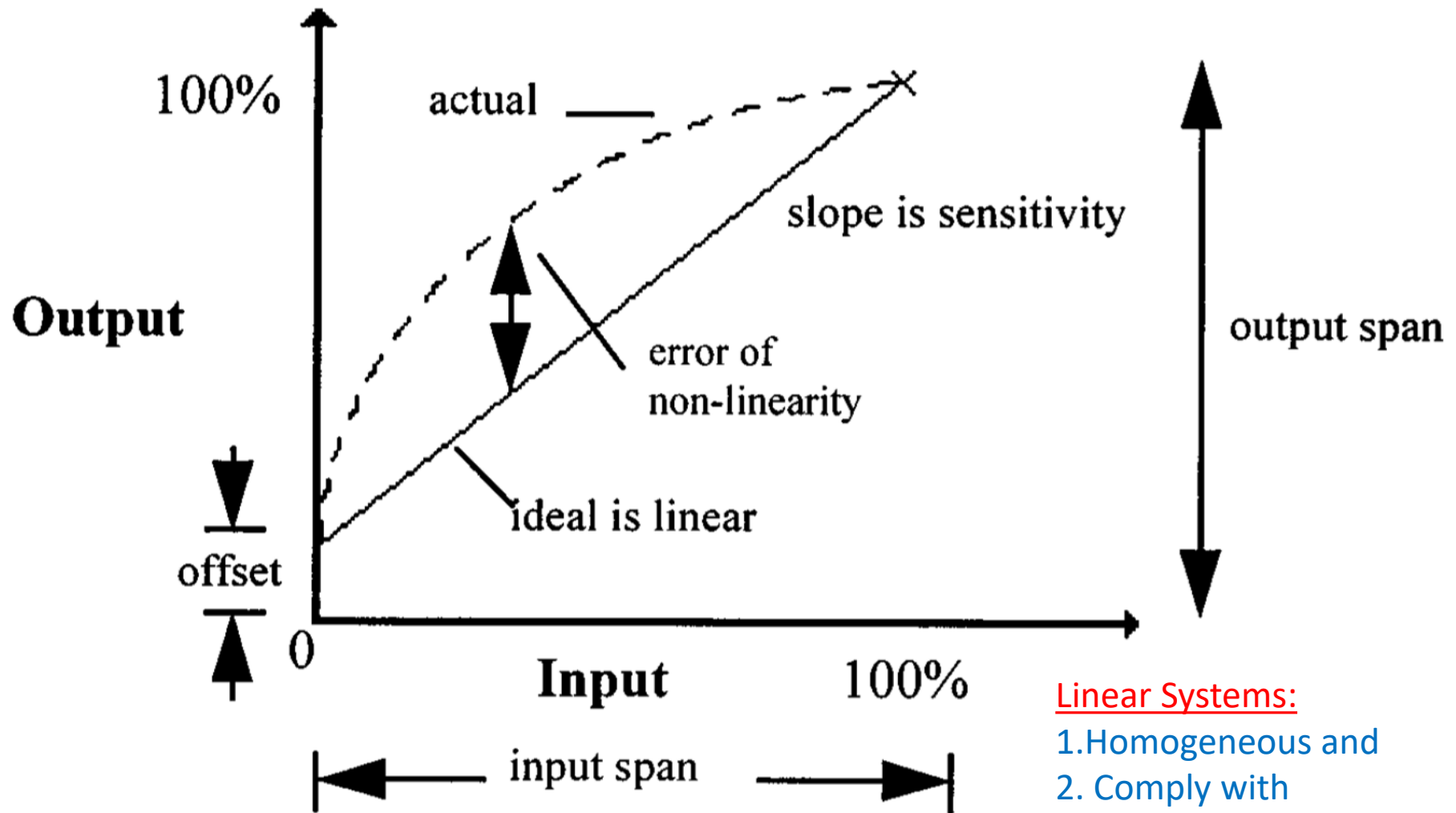
- T F = Ratio of Output to Input

- $TF = \frac{\text{Output}}{\text{Input}} = \frac{Y}{X} = G$



- Systems that are consisting of subsystems  $TF_{total} = G_1 x G_2 x G_3 \dots$

# Typical input-output characteristic curve of an instrument

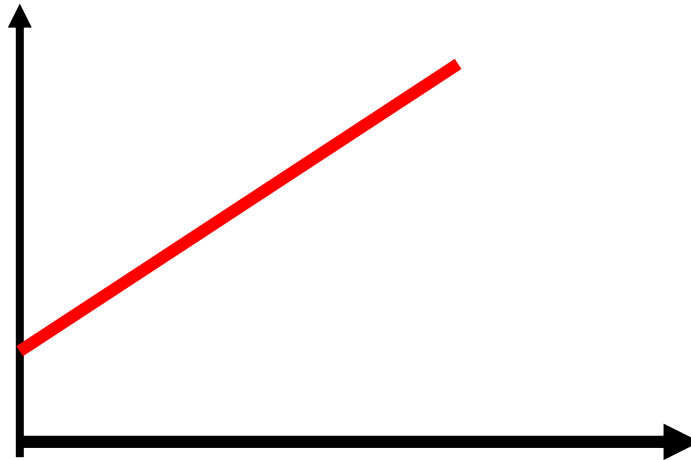


## Linear Systems:

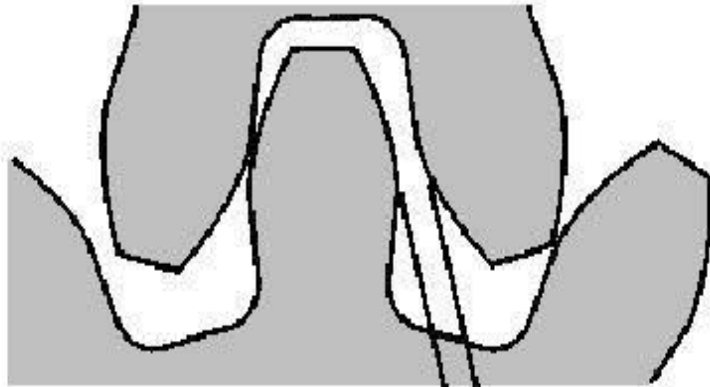
1. Homogeneous and
2. Comply with Superposition

# Drift

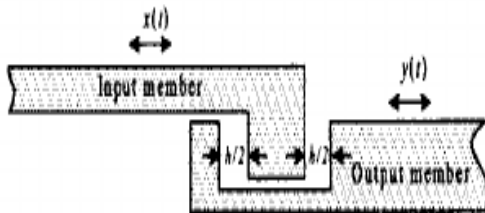
- Slackening of spring and stretchir
- DC voltage drift in amplifier



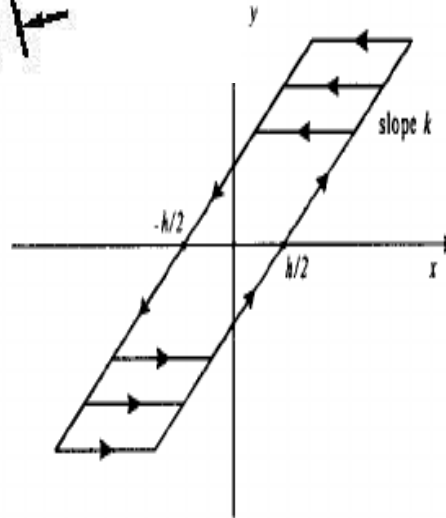
# Hysteresis and Backlash



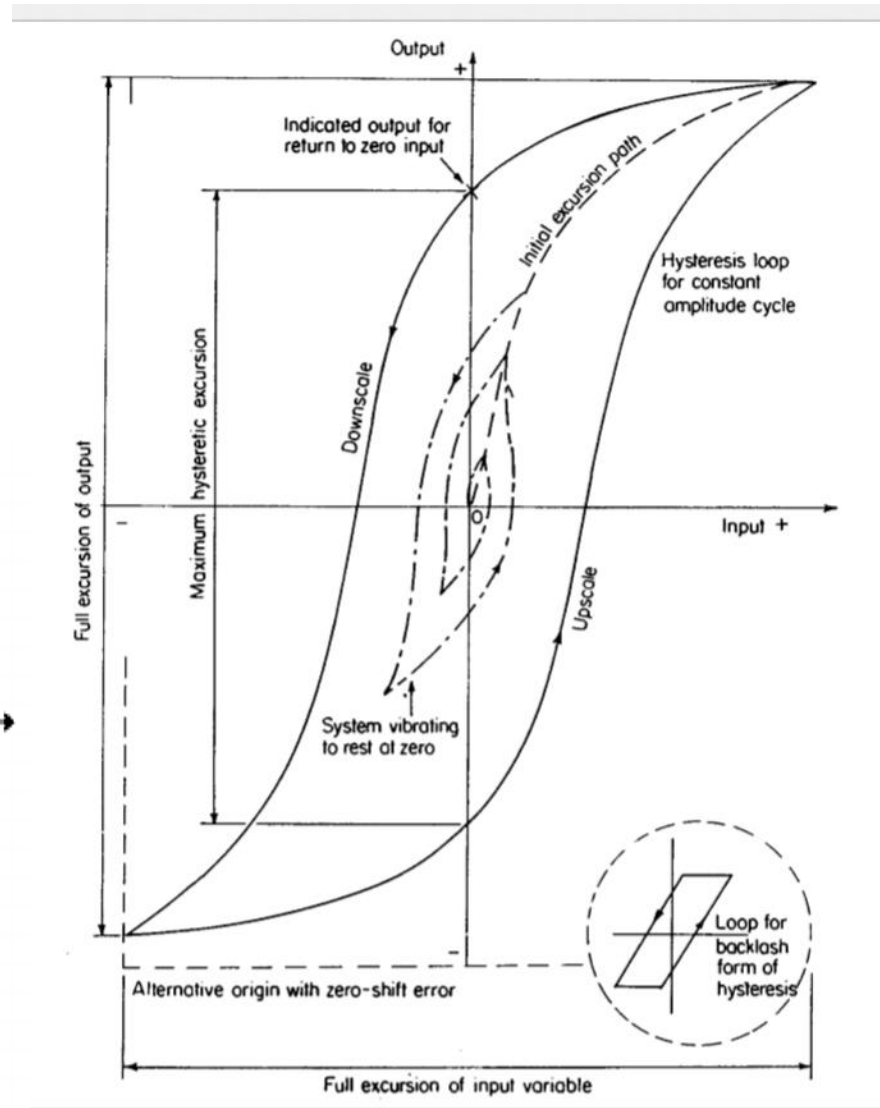
Backlash



a)

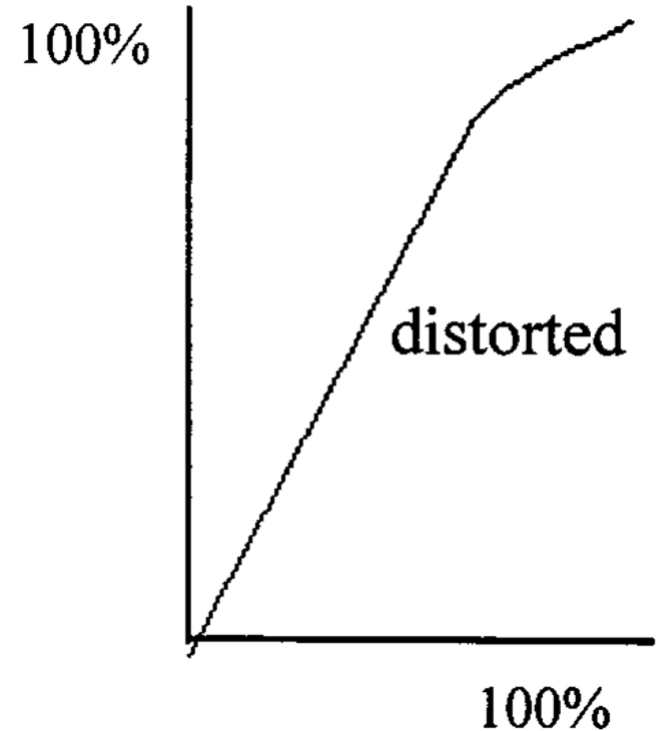
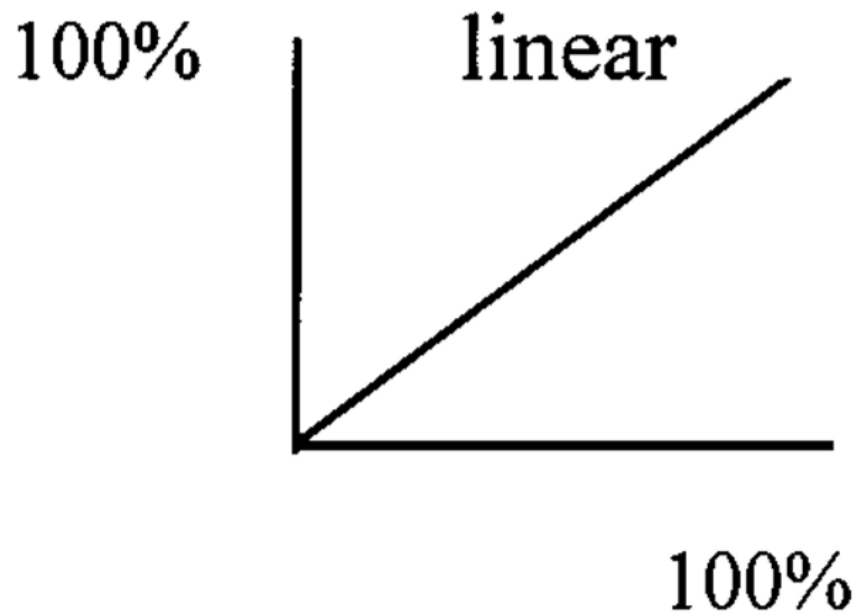


b)



# Saturation

Measurements are linear over certain part of the characteristic curve. (compression at top end)



# Bias

- Sometimes, the electronic signal processing situation calls for the input signal to be processed at a higher average voltage or current than arises normally. Here a dc value is added to the input signal to raise the level to a higher state as shown in Figure 3.10. A need for this is met where only one polarity of signal can be amplified by a single semiconductor element. This is usually done to overcome noise.

# Error due to nonlinearity

