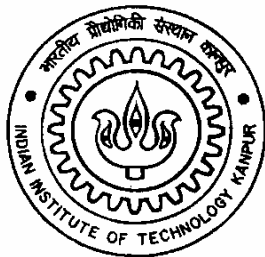

Sensors and Actuators used in Robotics



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Classification of sensors:

- ***Internal sensors*** : required for the basic working of a robot. They are used to monitor the internal state of the robot e.g. position, velocity etc.
 - ***External sensors***: for interaction with the environment.
-

Internal sensors:

- **Position**
- **Velocity**
- **Acceleration**

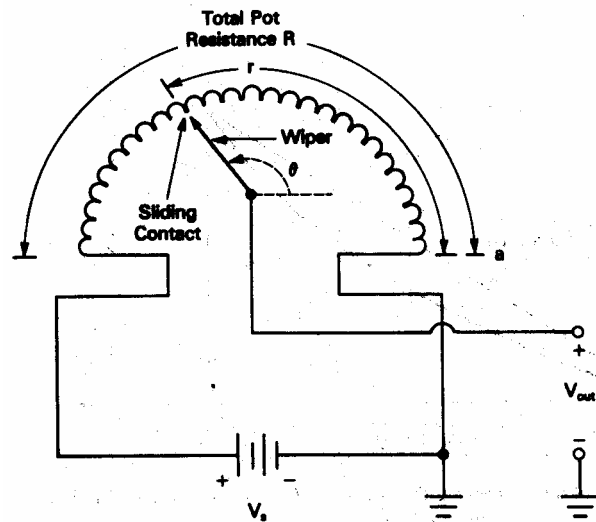
**e.g. potentiometers, encoders, LVDT,
Tachometers, Accelerometers**

External sensors:

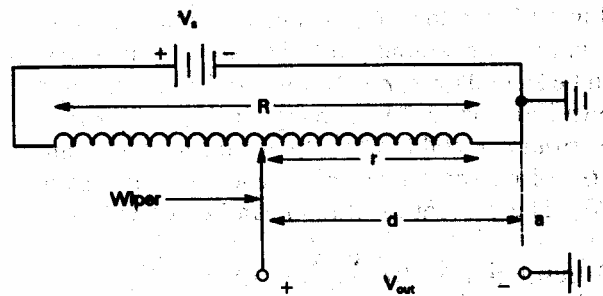
- **Touch**
- **Force**
- **Pressure**
- **Slip**
- **Proximity**

e.g. on/off switches, ultrasonic, force sensor, hall effect, inductive sensor, piezo sensor

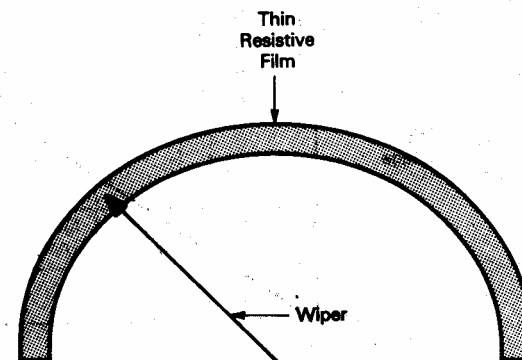
Position Sensor : Potentiometer



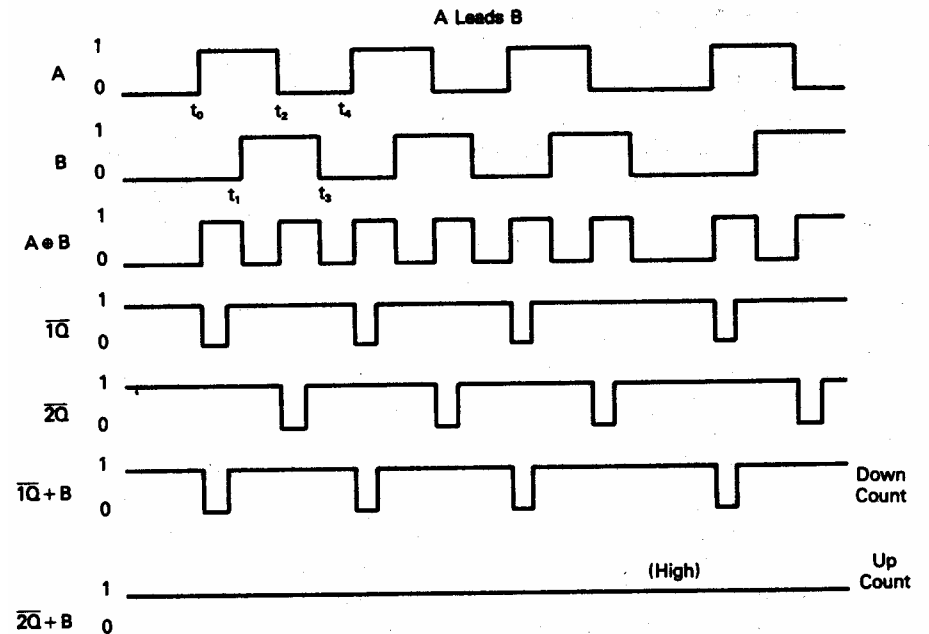
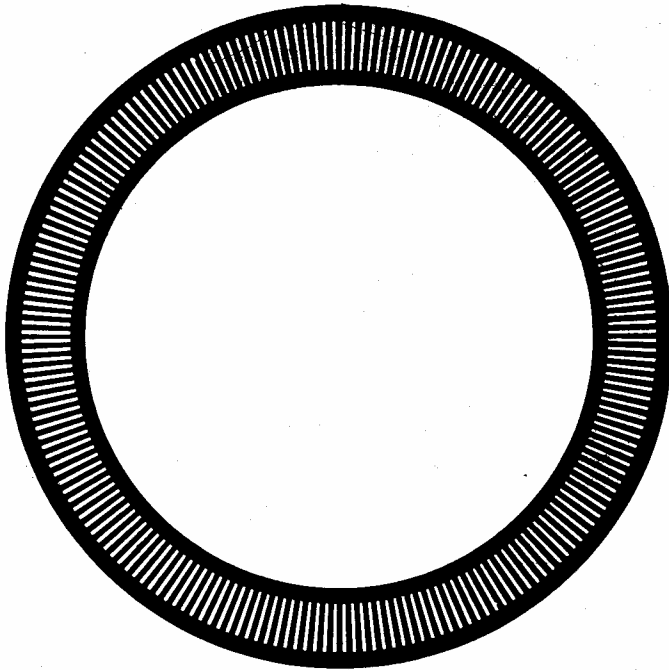
(a)



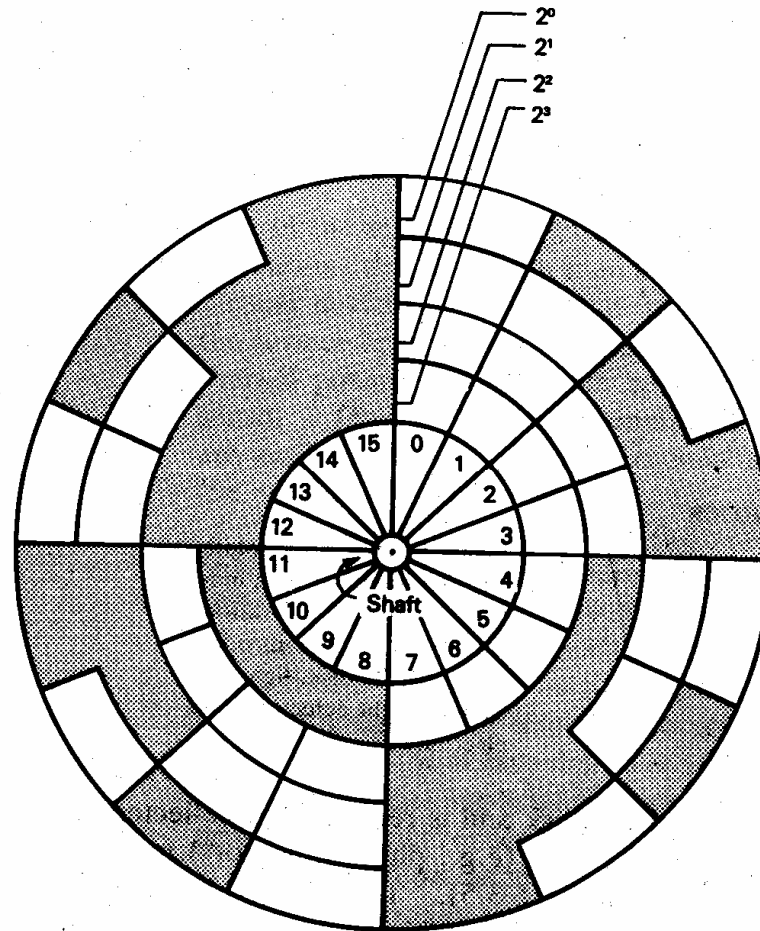
(b)



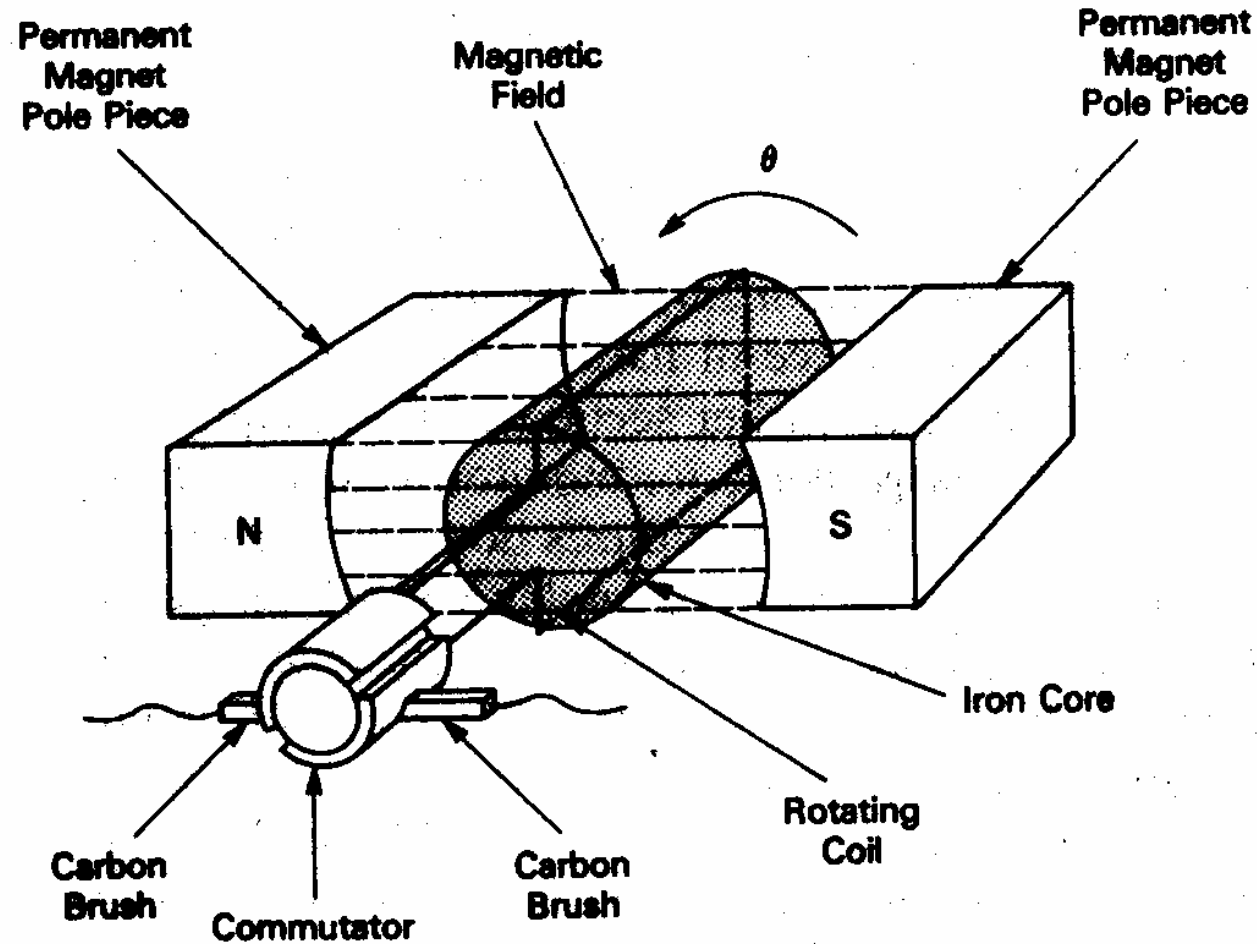
Position sensor: Incremental Encoder



Position sensor : Absolute encoder



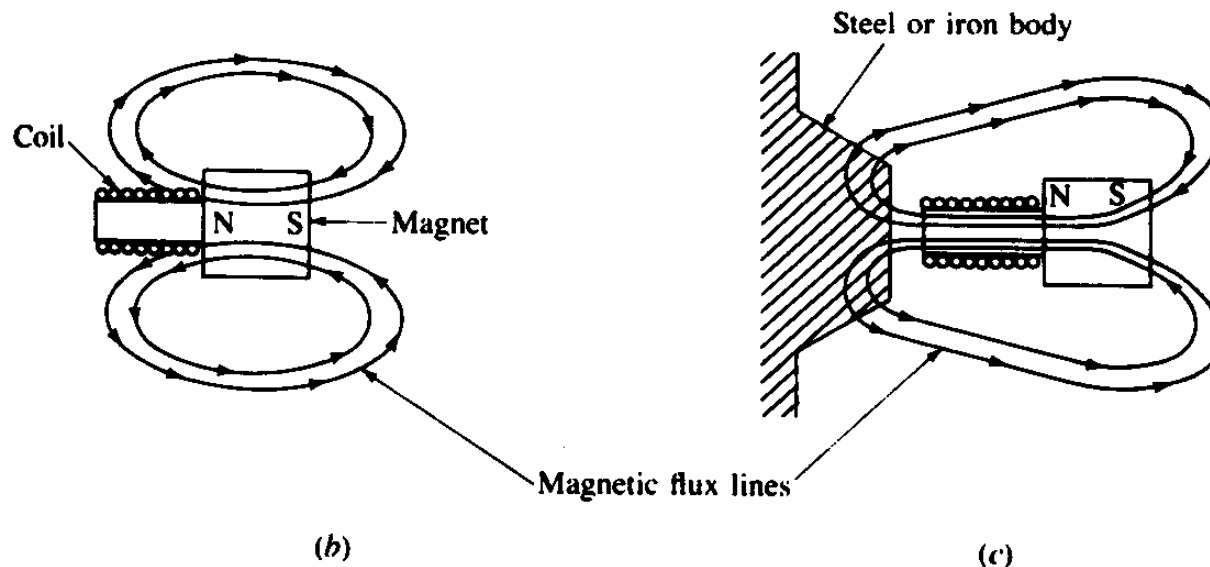
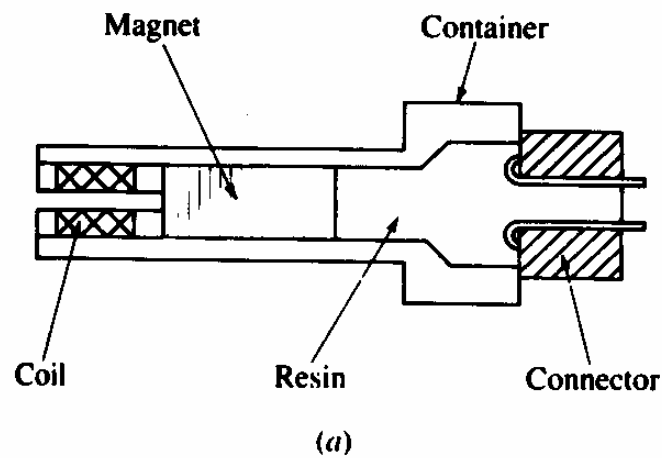
Velocity and acceleration sensors



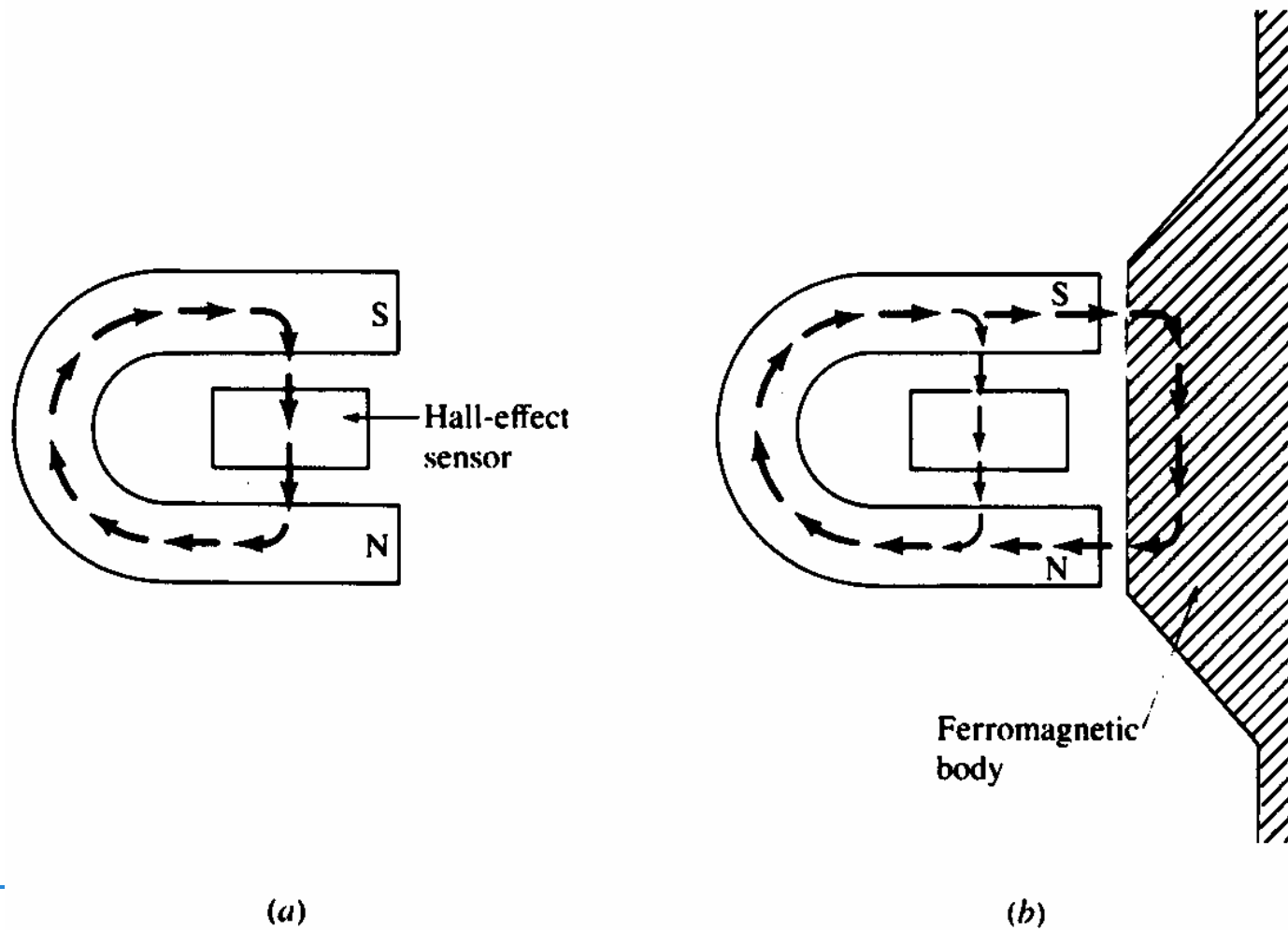
Touch sensors

- **On /Off switches**
 - **Emitter / receiver pairs.**
 - **Thermal / pressure sensors**
-

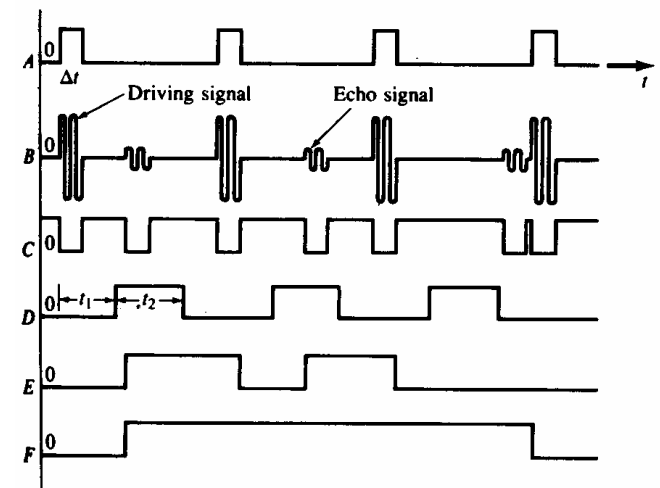
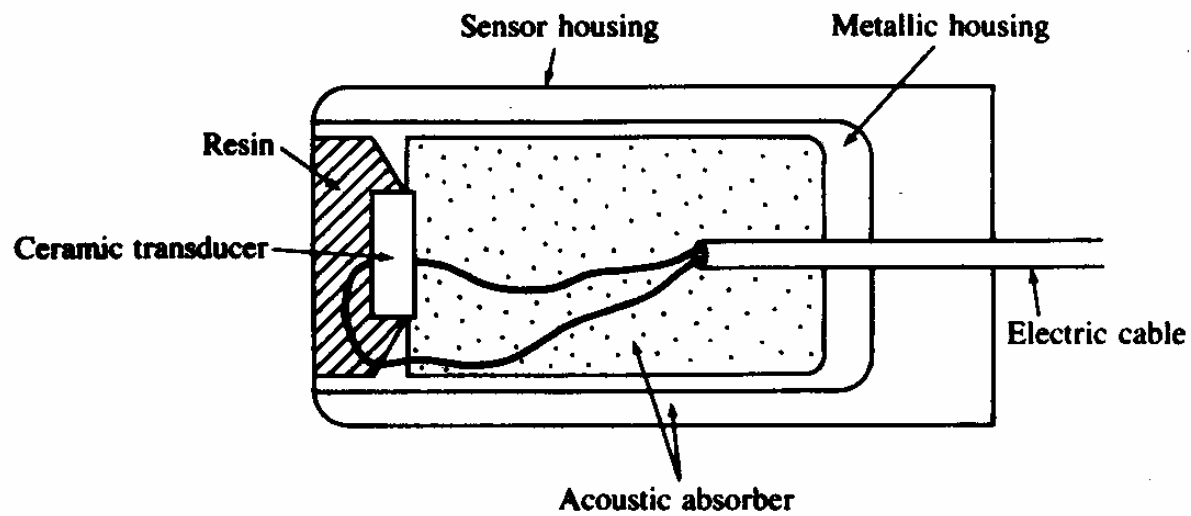
Proximity sensor : Inductive sensor



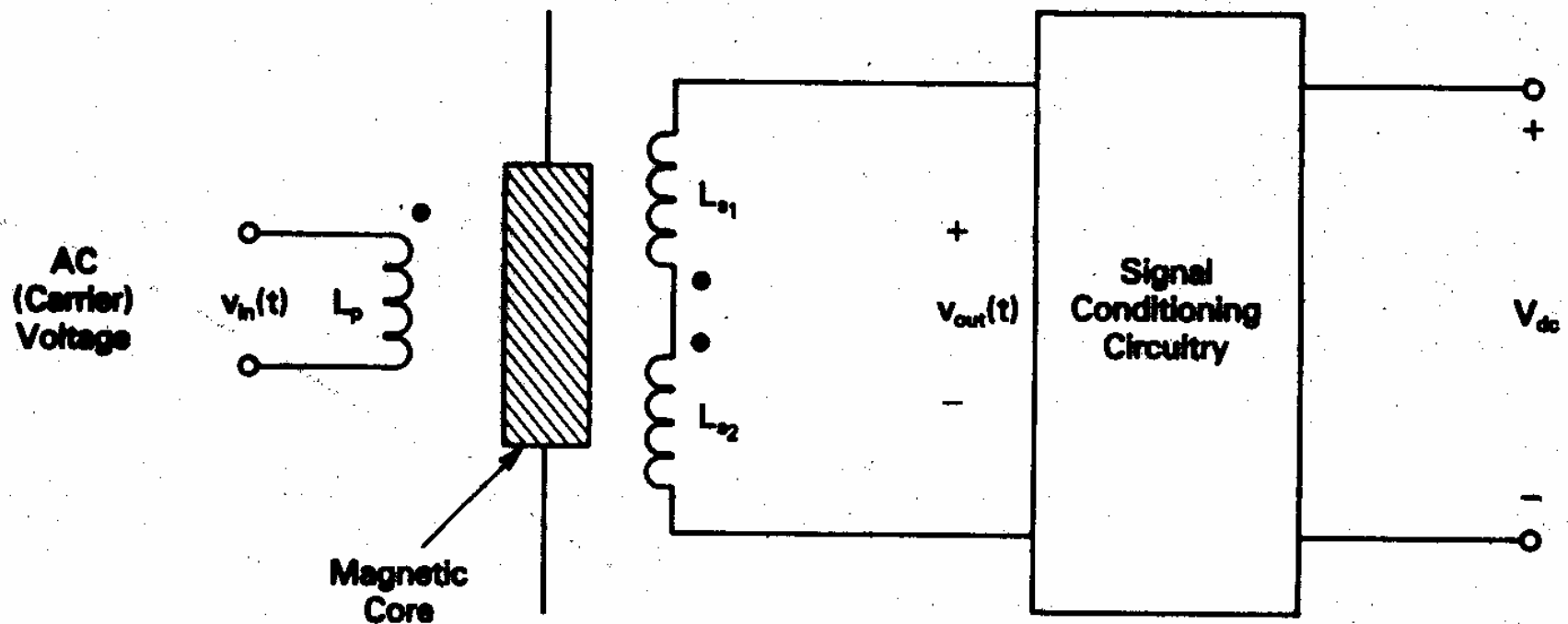
Proximity sensor: Hall effect sensor



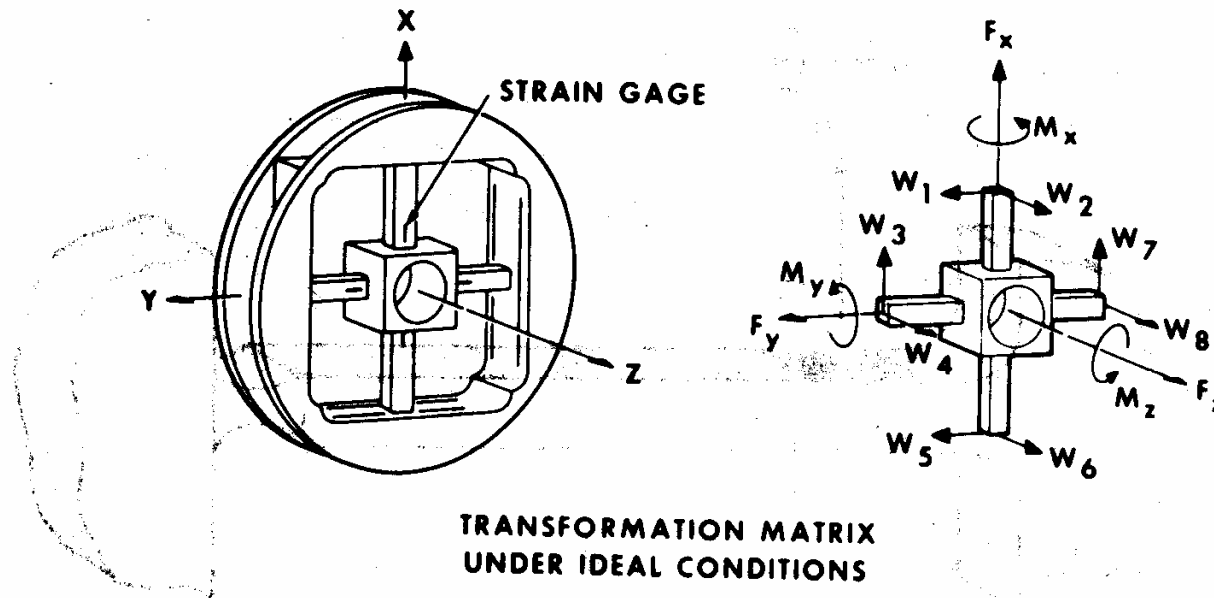
Range sensor : Ultrasonic sensor



Position sensor : LVDT



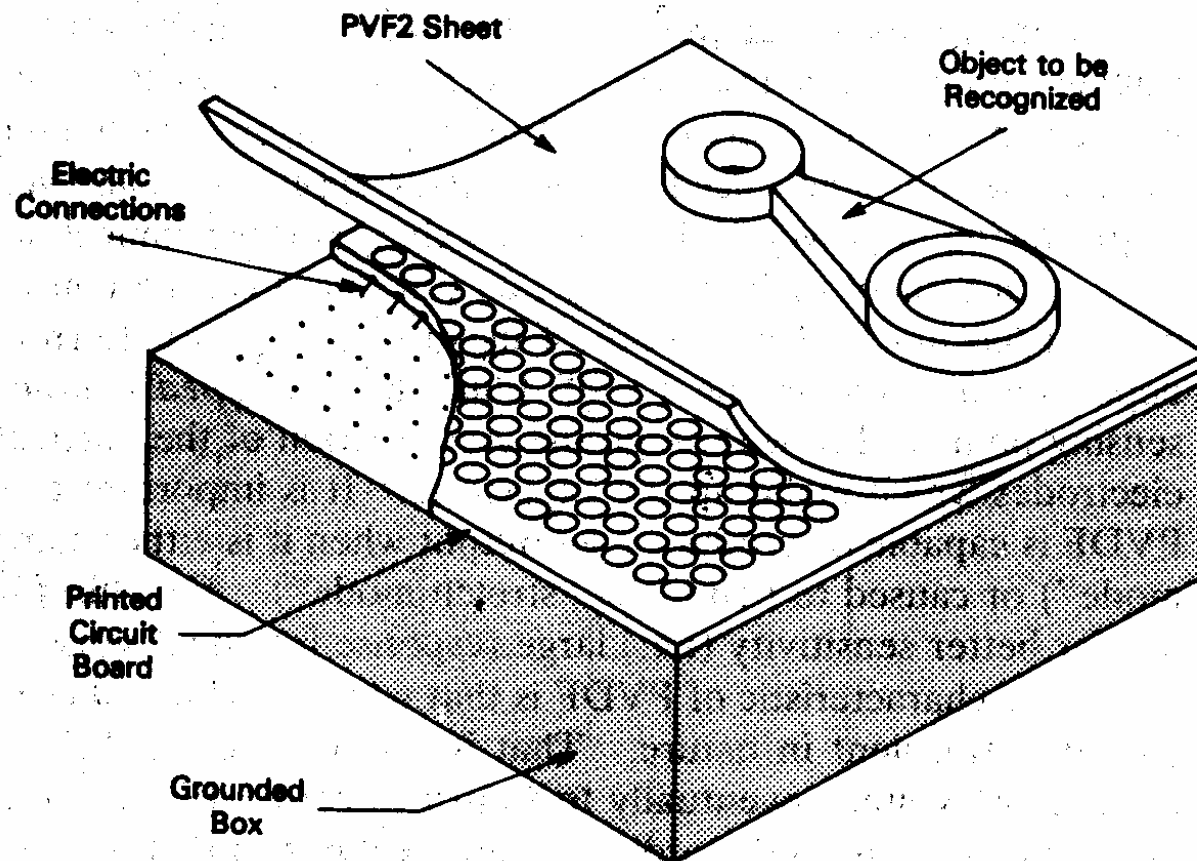
Robot wrist force sensor -3 axes



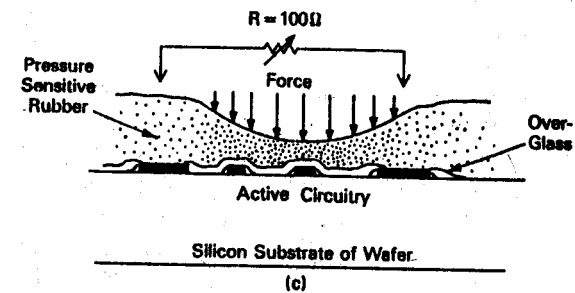
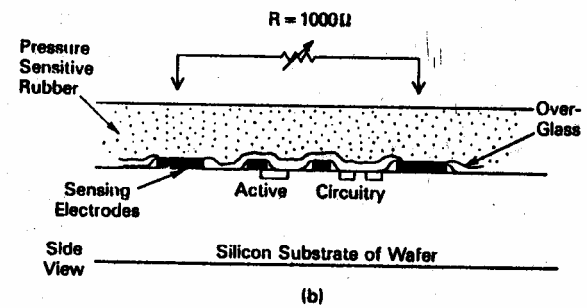
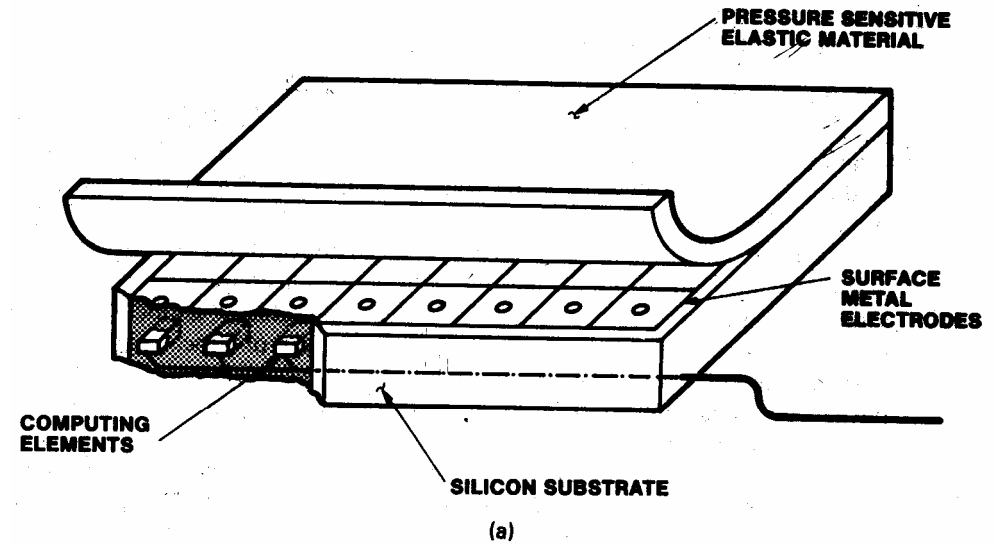
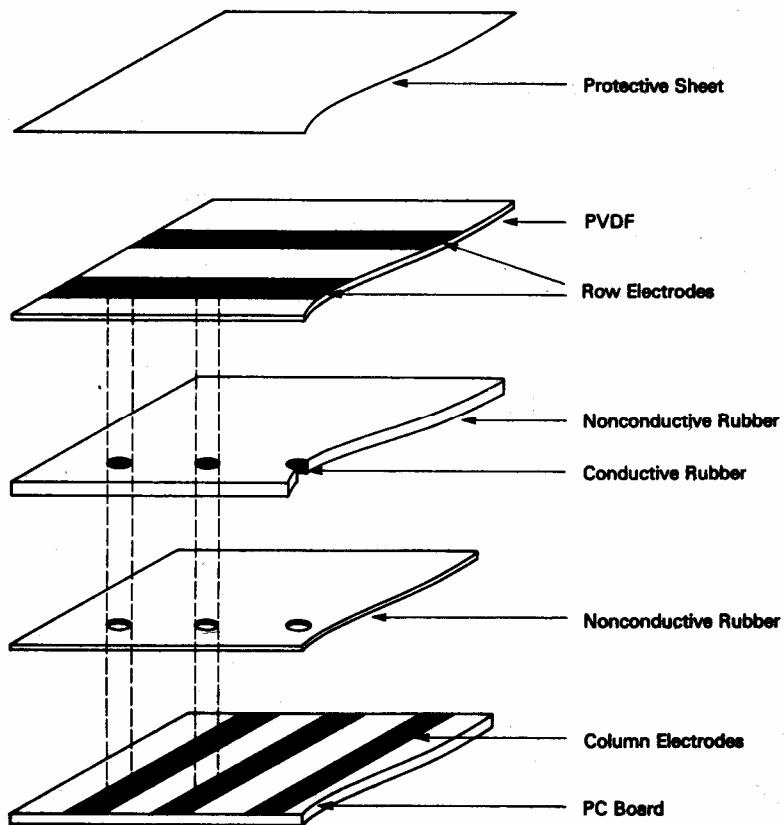
TRANSFORMATION MATRIX
UNDER IDEAL CONDITIONS

$$\begin{array}{c} \text{FORCES AND} \\ \text{TORQUES} \\ \text{REFERENCED} \\ \text{TO} \\ \text{X-Y-Z} \\ \text{SENSOR} \\ \text{COORDINATES} \end{array} \begin{bmatrix} F_x \\ F_y \\ F_z \\ M_x \\ M_y \\ M_z \end{bmatrix} = \begin{bmatrix} 0 & 0 & k_{13} & 0 & 0 & 0 & k_{17} & 0 \\ k_{21} & 0 & 0 & 0 & k_{25} & 0 & 0 & 0 \\ 0 & k_{32} & 0 & k_{34} & 0 & k_{36} & 0 & k_{38} \\ 0 & 0 & 0 & k_{44} & 0 & 0 & 0 & k_{48} \\ 0 & k_{52} & 0 & 0 & 0 & k_{56} & 0 & 0 \\ k_{61} & 0 & k_{63} & 0 & k_{65} & 0 & k_{67} & 0 \end{bmatrix} \begin{array}{c} W_1 \\ W_2 \\ W_3 \\ W_4 \\ W_5 \\ W_6 \\ W_7 \\ W_8 \end{array} \begin{array}{c} \text{FORCES} \\ \text{SENSED} \\ \text{AT} \\ \text{SPOKE} \\ \text{ELEMENTS} \end{array}$$

Touch sensor



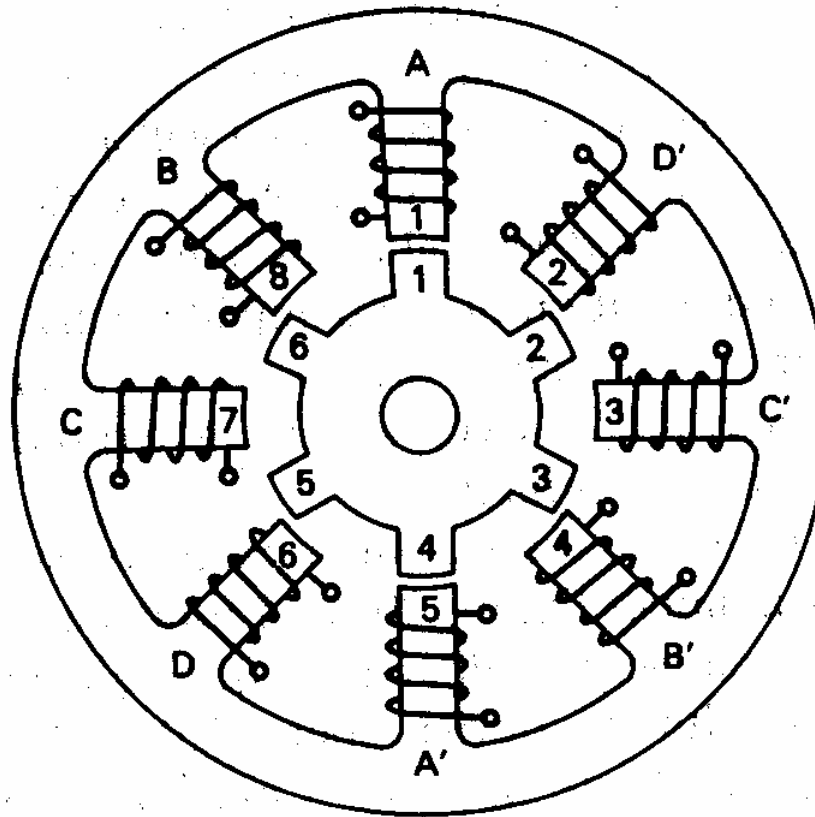
Pressure sensor



Actuators

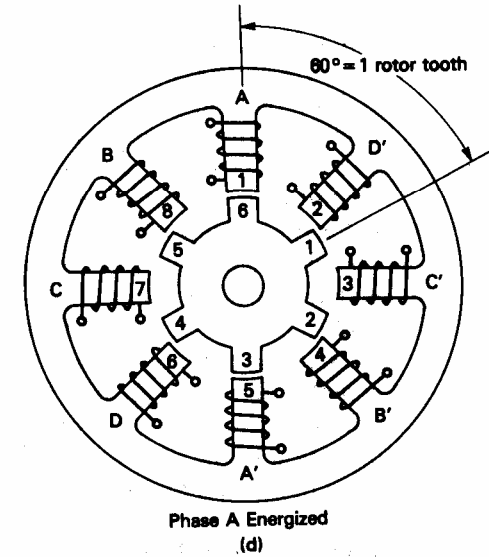
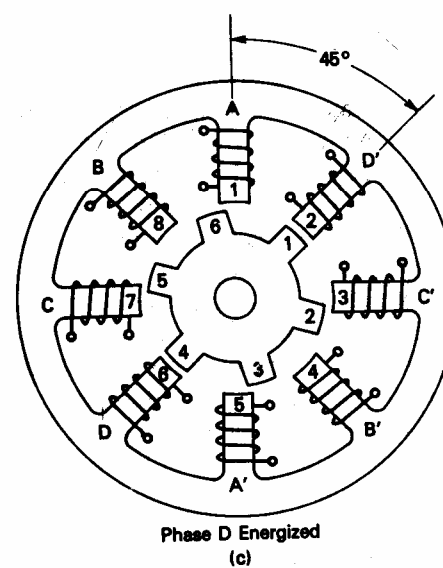
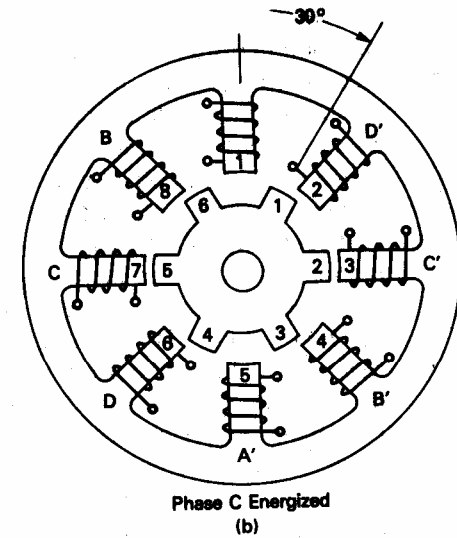
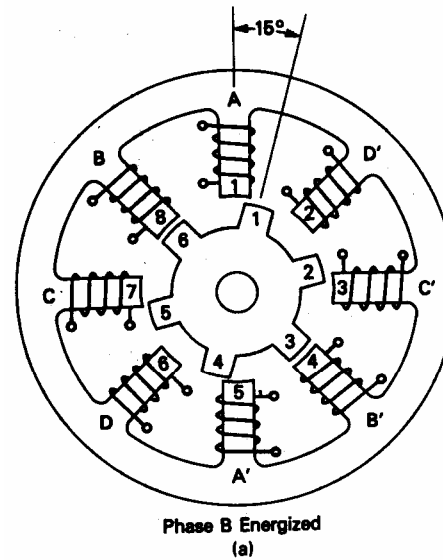
- *Electrical* : stepper motors, DC servo motors
 - *Pneumatic* : air pressure
 - *Hydraulic* : fluid pressure (oil pressure).
 - *Advanced actuators* : ultrasonic motors, artificial muscles, molecular motors.
-

Stepper motors : Variable reluctance, permanent magnet

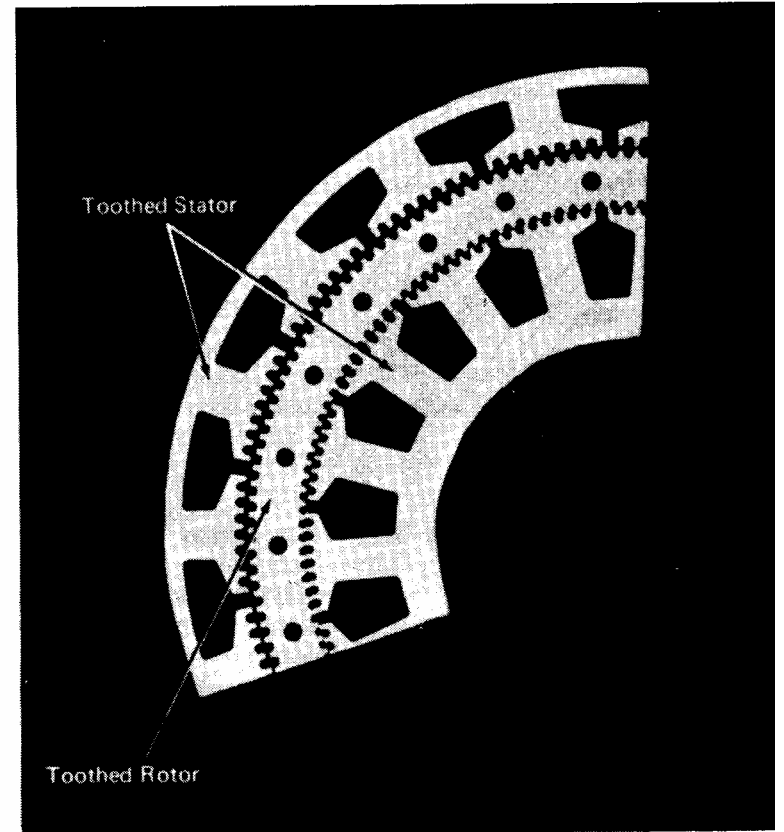
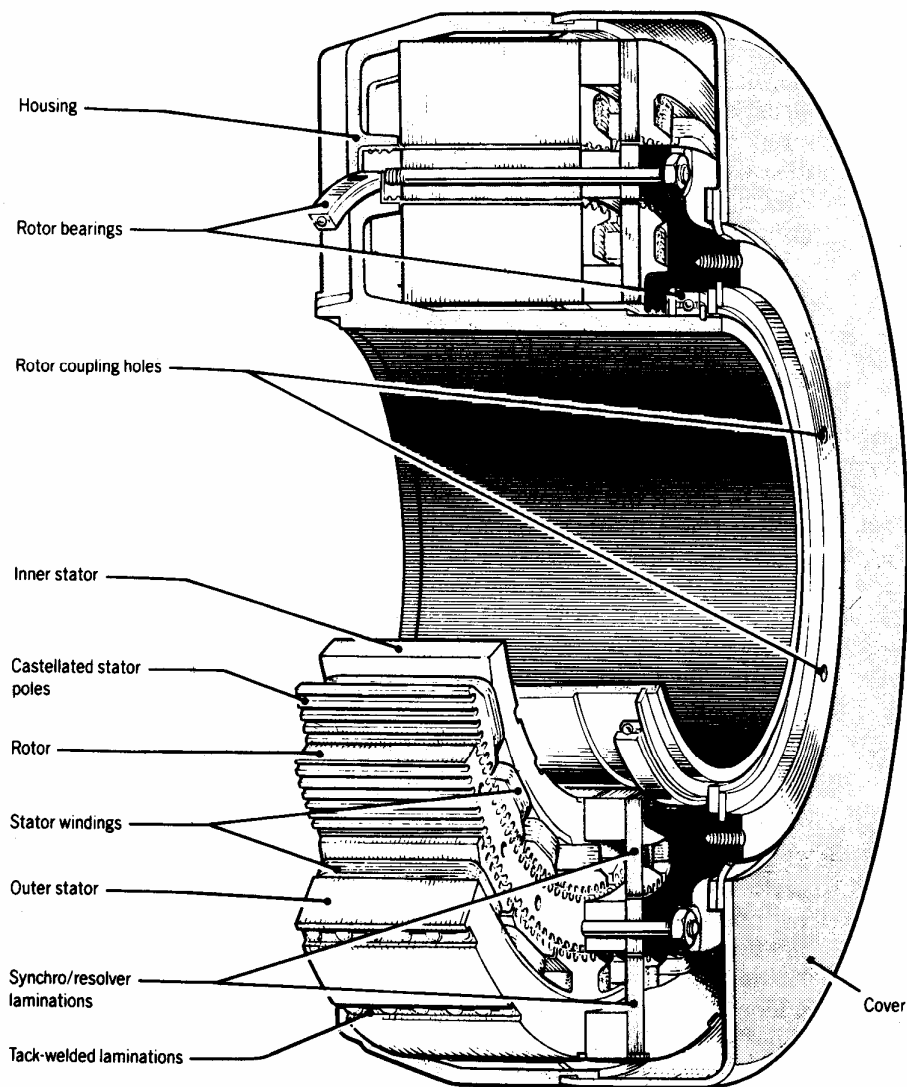


Working of a stepper motor

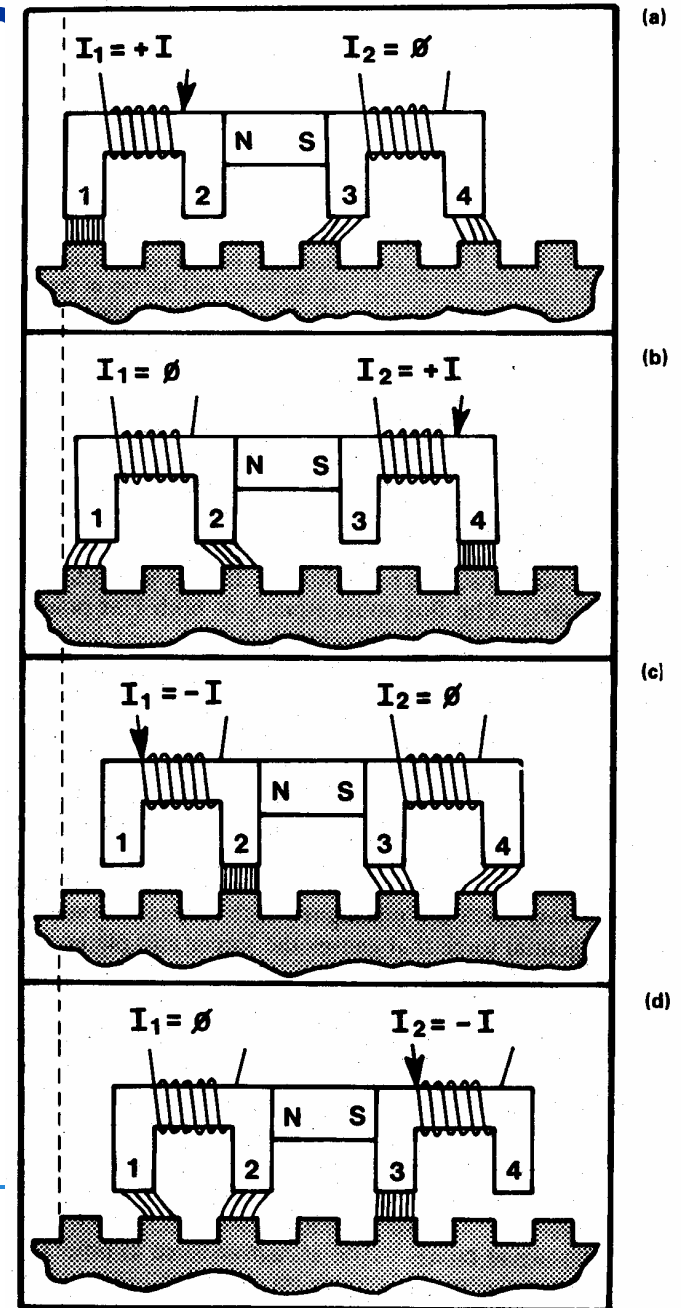
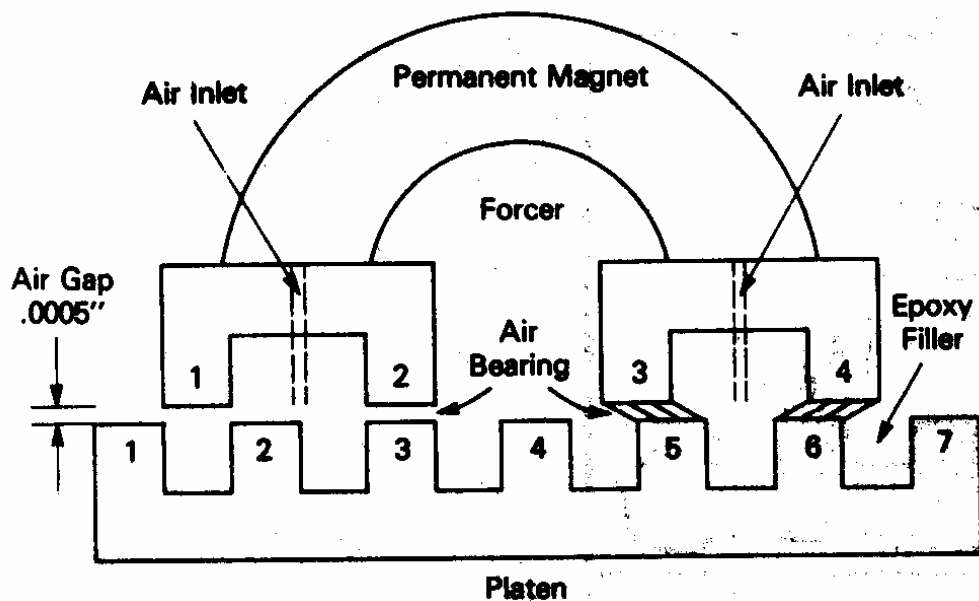
Sequence of rotation
(CW): B – C – D – A'



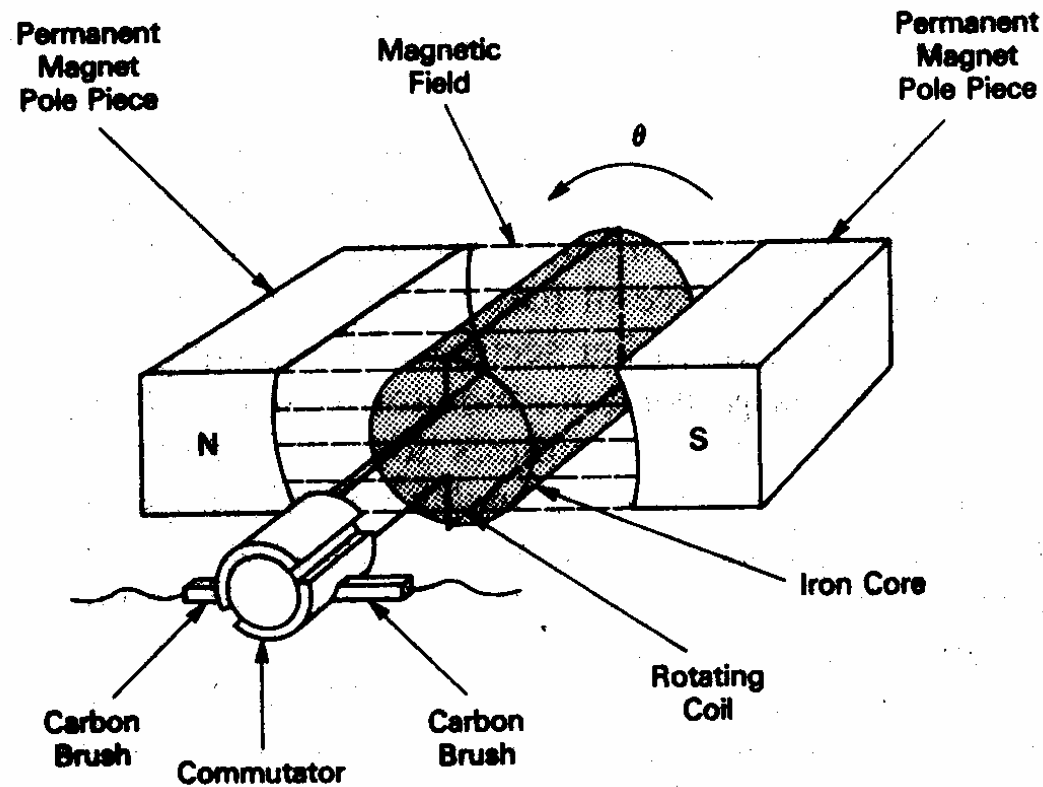
Mega-torque motors



Linear stepper motor



DC Motors : basic working



Brushless DC motors

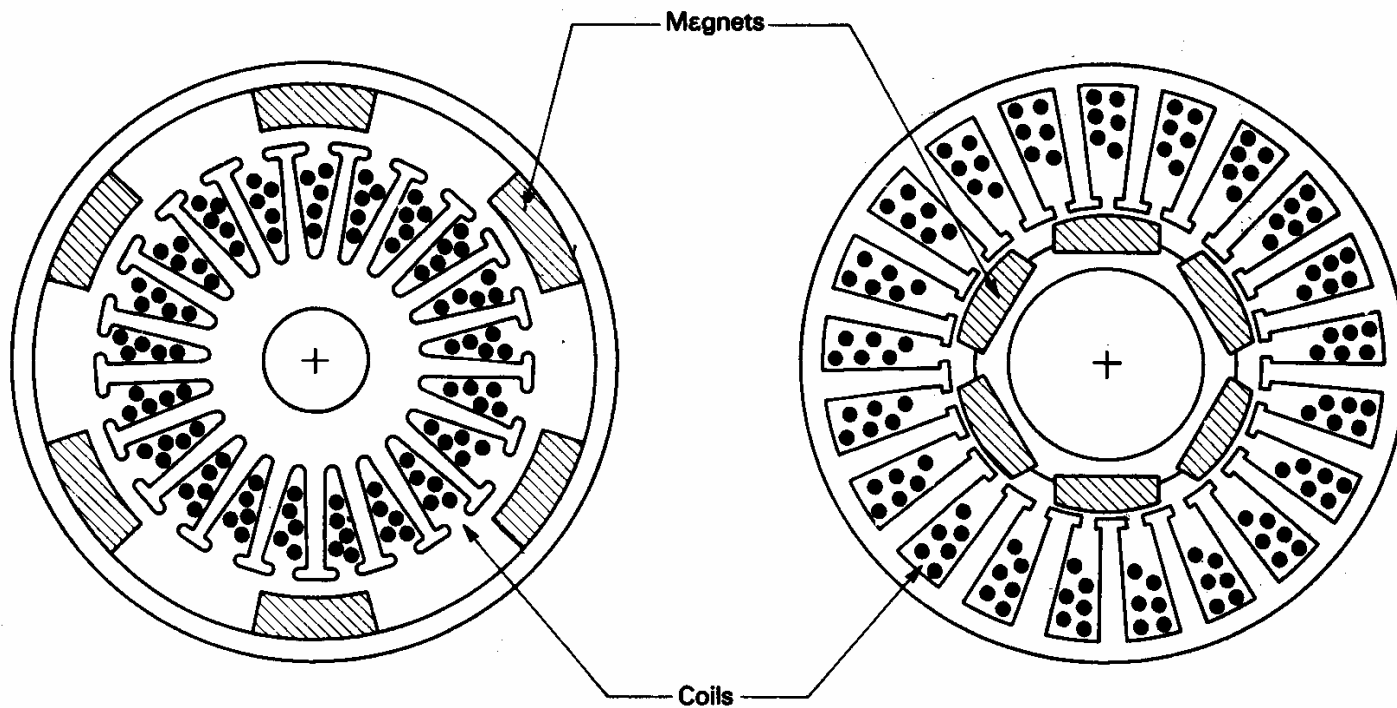


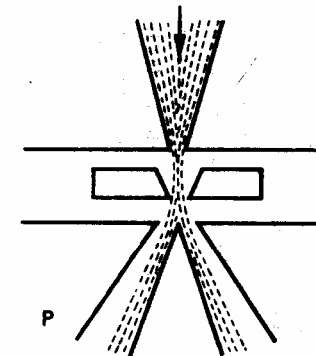
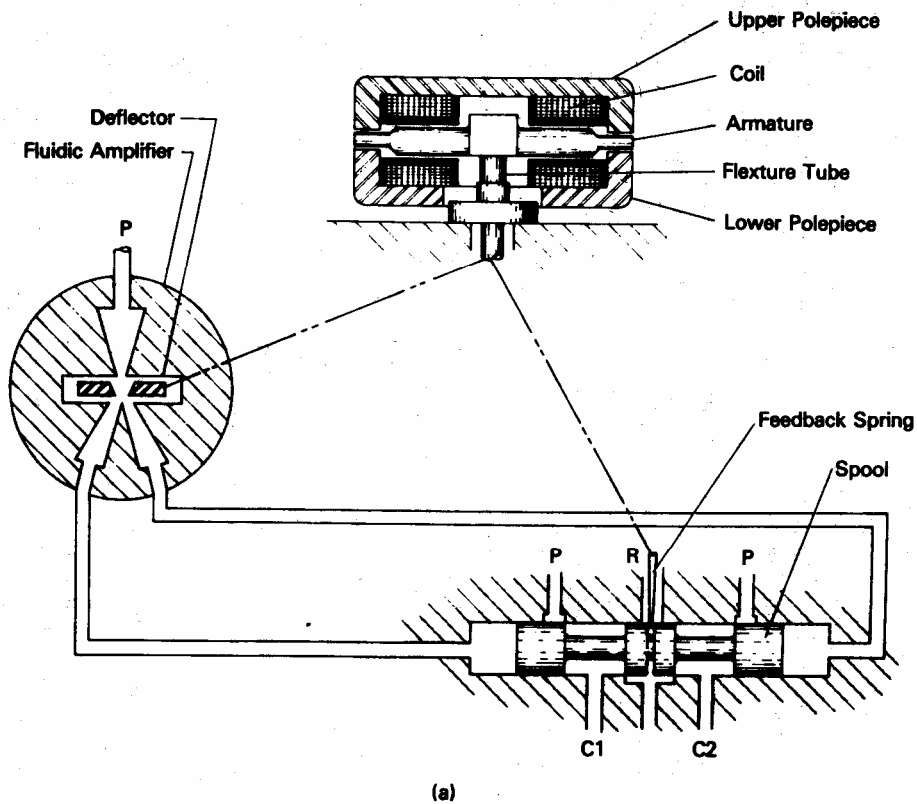
Fig. Brush type DC motor

Fig. Brushless DC motor

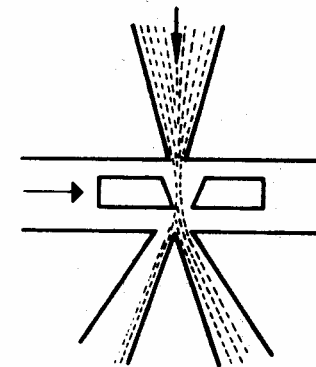
DC servo motors

- DC motors working in closed loop position control.
- ### Closed loop figure

Pneumatic actuators

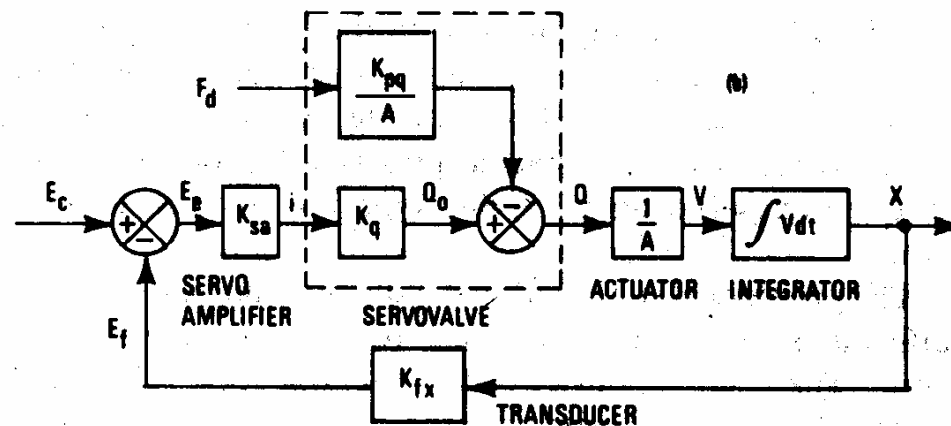
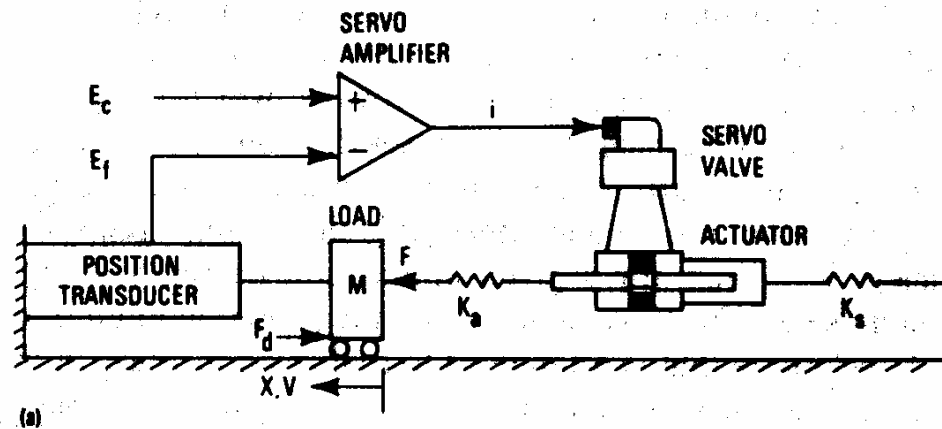


(b)



(c)

Hydraulic actuators: piston cylinder mechanism



Advanced actuators: small, low power consumption, micro motion

- **Ultrasonic motors** : micro robots, cameras, micro motion devices ..
 - **Artificial muscles** : prosthetic, bio applications..
 - **Molecular motors** : bio applications
-

Ultrasonic motors

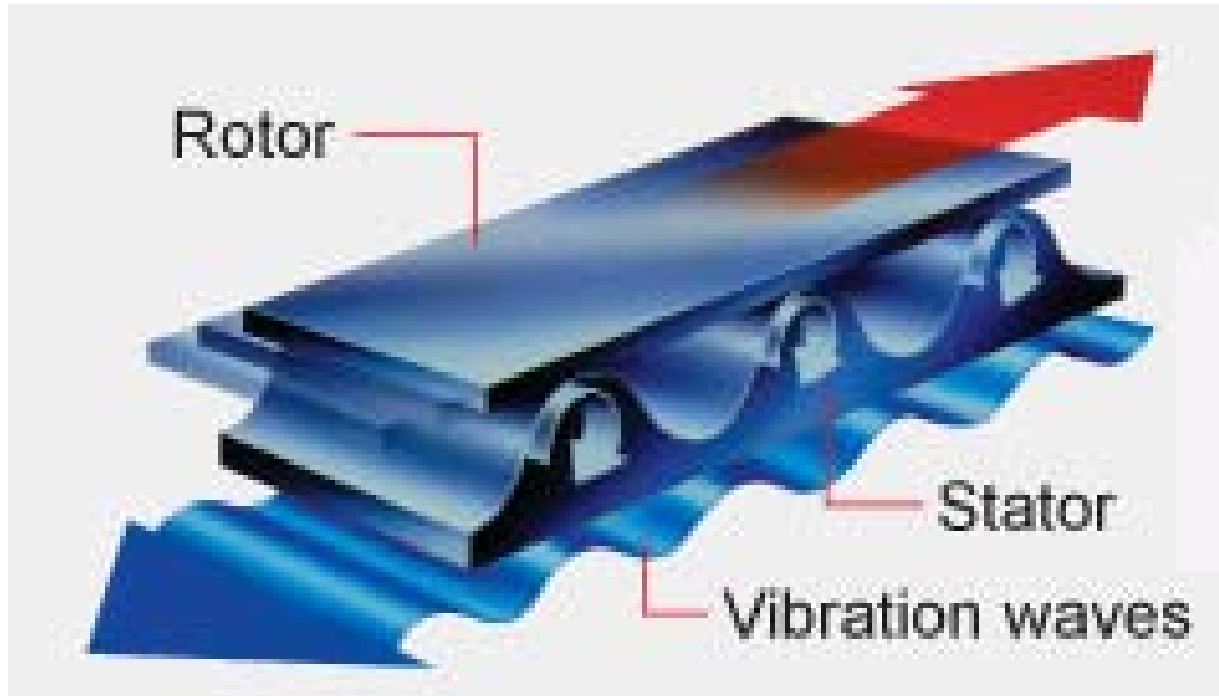


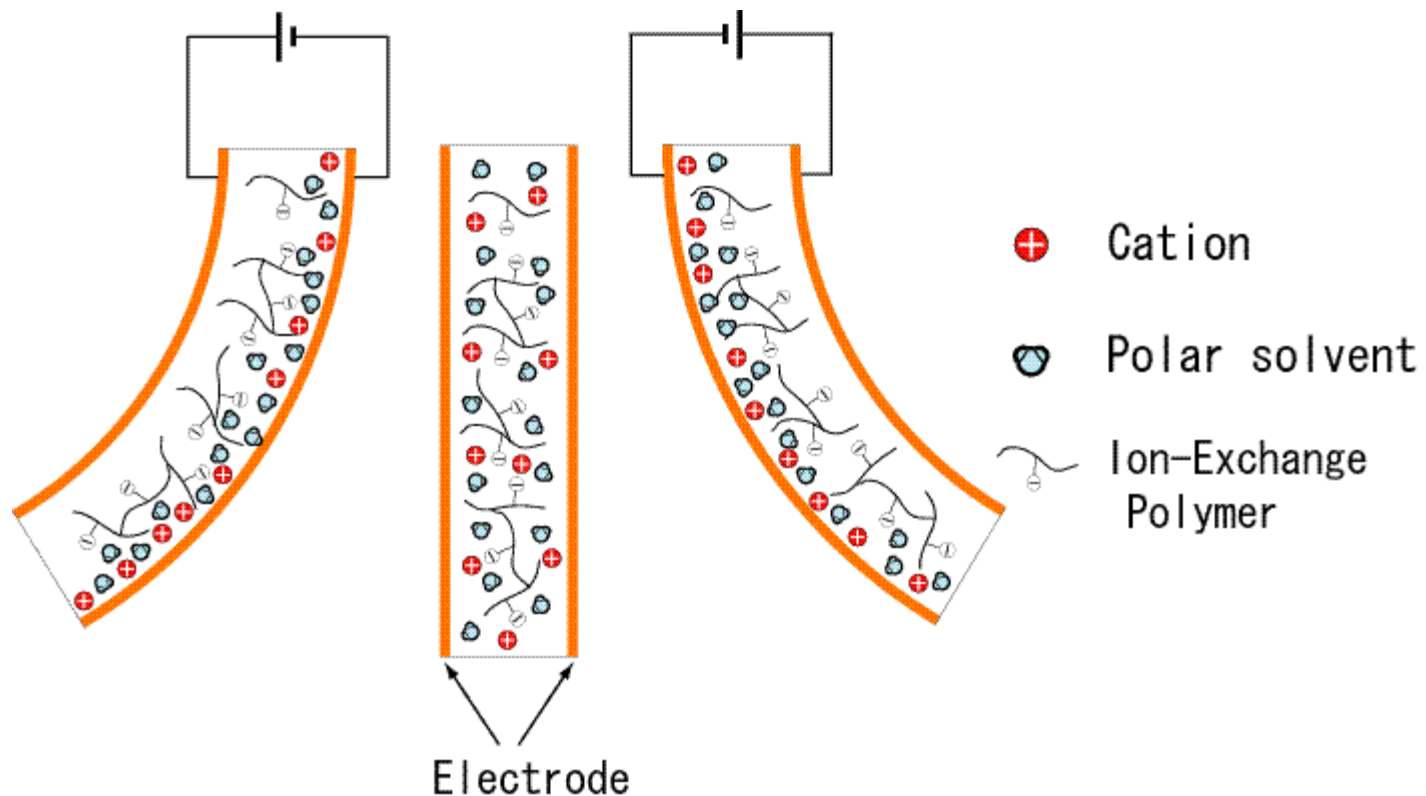
Fig. Motion due to dry friction and vibration.



Fig. Ring motors used in cameras.

Electro active Polymers

- Movement of ions and creations of micro channels.



Artificial muscles



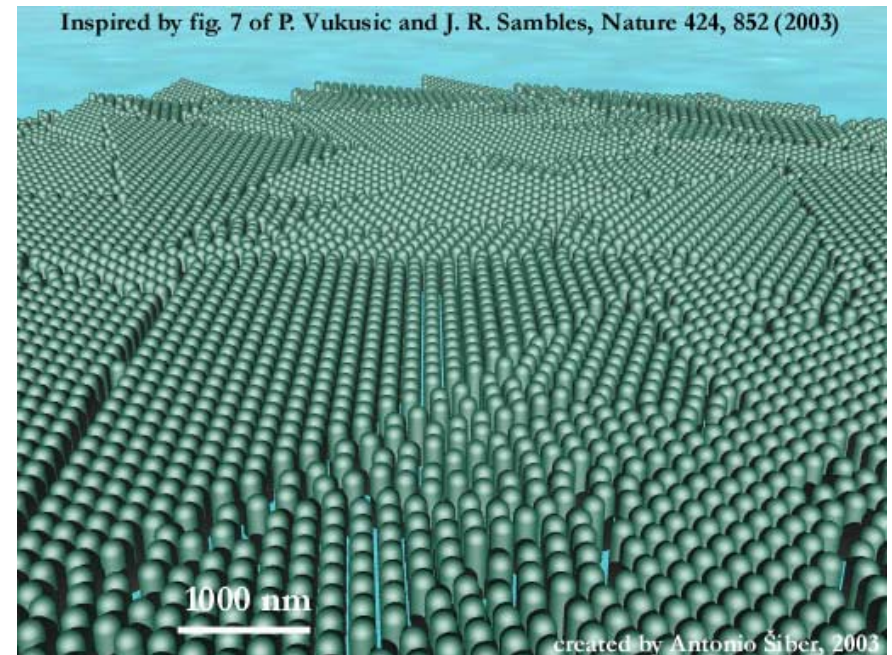
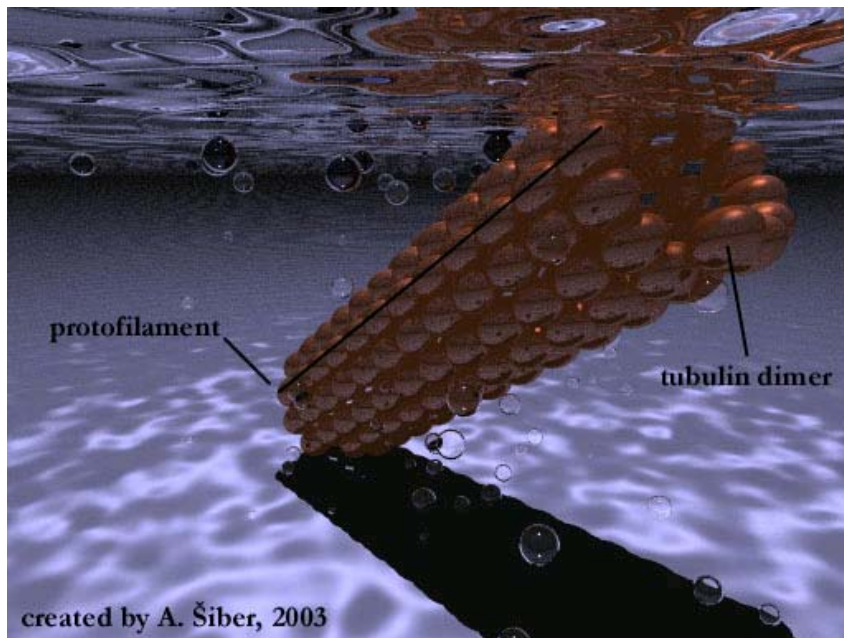
Fig. Hand.



Fig. Flying robot.

Molecular motors

Protein-based molecular motors harness the chemical **free energy** released by the **hydrolysis** of **ATP** in order to perform mechanical work.



END
