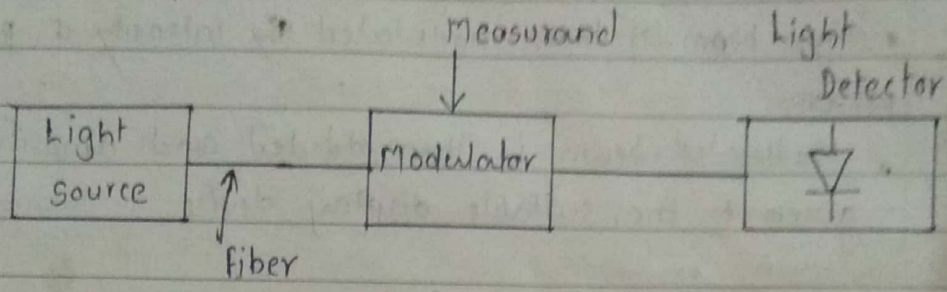
* Fiber optic Temperature Sensor :-

- It is used for the measurement of liquid level, fluid flow, temp., pressure and motion etc.
- It is a low weight transducer and hence can respond over the wide range of frequency.

Principle of operation



- Basic block diagram of fiber optic sensor is as shown in fig.
- It consists of following important blocks.

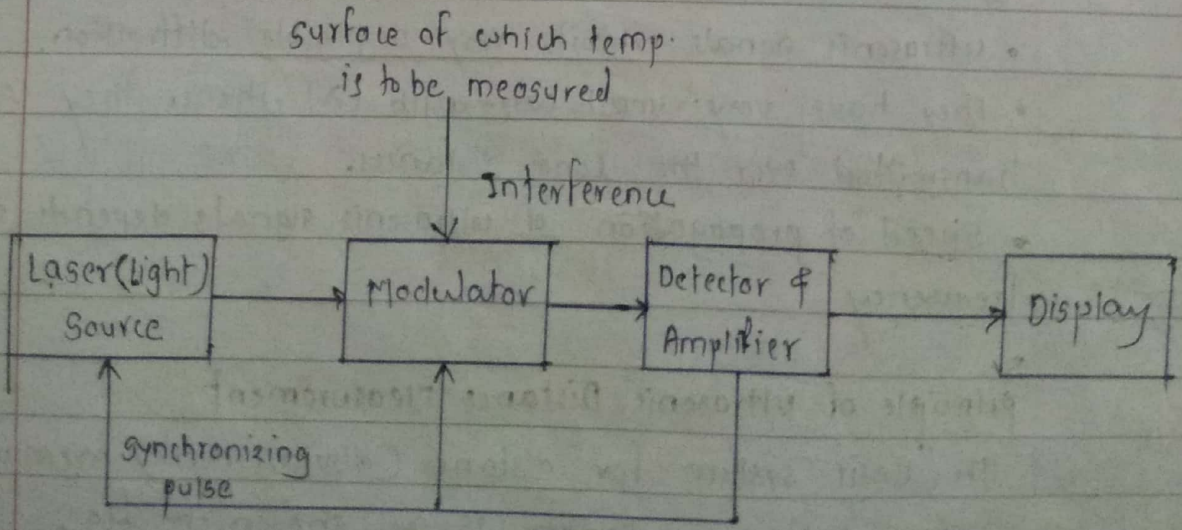
Light source - It continuously ~~emit~~ provides beam of light with constant intensity, frequency and phase polarization.

optic fiber - It is used to transmits the information from one place to other place.

Modulator - Basically, Modulator is used to increase the strength of signal in terms of intensity, frequency, phase or polarization properties for transmitting the signal over long distances. this signal is then sent to detector through fibe

Detector - Detector demodulates the modulated, and convert them into the intensity modulation.

Set up for Temperature Measurement :



- A set up for temperature measurement is as shown in fig.
- Here Laser diode is used as light source. Light is continuously emitting from light source and is passed to the modulator.
- The light beam is incident on the surface of which the temp. is to be measured.
- Then, light is reflected from the surface, and is collected & measured by fiber optic sensor called as Black body sensor
- Light beam is then modulated by intensity & phase modulation process
- Modulated beam is then detected and amplified and given to the suitable display device

Advantages:
- It can measure wide range of temp. upto 2000°c
- Compact and light in weight
- High Resolution
- It doesnot require any external bias.

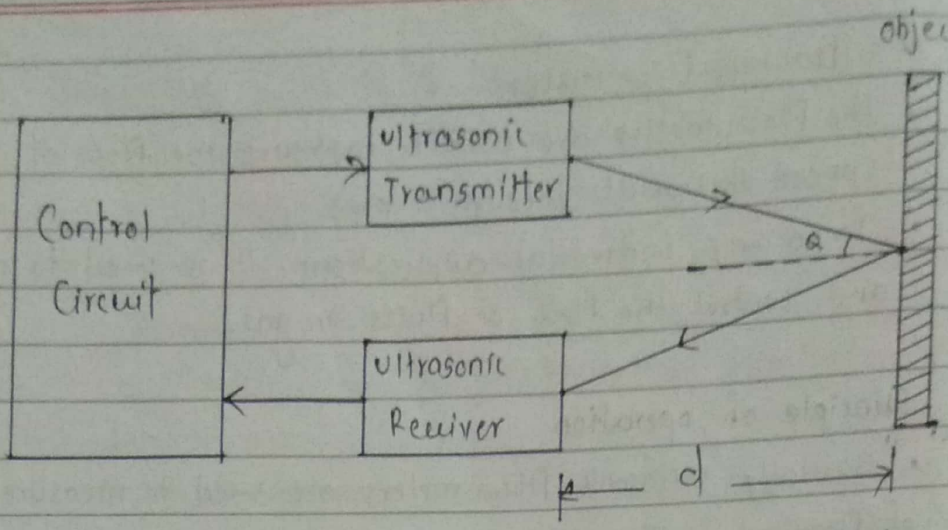
Applications:
- Basically fiber optic temperature sensors are used in ships & large building where there is need to transmit the data over large distance.
- Also used for meayurement of Temperature.

* Ultrasonic Displacement Sensor

Some important characteristics of ultrasonic signals are
- Ultrasonic signals exhibits very negligible diffraction.
- They have very small wavelength (λ), hence they can be transmitted over the long distances.
- Speed of propagation of ultrasonic signals depends on their frequency

Principle of Ultrasonic Distance Measurement

The Basic system for distance (displacement) measurement using ultrasonic sensor is as shown in fig.



- Ultrasonic waves are transmitted with the help of ultrasonic transmitter.
- If the object is detected, then waves are incident on that object and reflected from the object. ~~with~~ ~~on~~
- Then reflected signal is received by ultrasonic receiver and given to the control circuit
- The duration between the transmitted and received pulse is used to determine the distance or position of the object

$$\text{Distance } d = \frac{V.t.\cos\theta}{2}$$

where; V = is speed of ultrasonic wave
t = time for ultrasonic wave to travel to object & back to receiver
Q = Incident Angle.

Applications:

In robotic application,

- To avoid the collision of objects
- To sense the distance of the object

* Ultrasonic flow meter:

- The flow meters are used to measure the flow of liquid/stea (speed of liquid) through a pipe.
- In many industrial applications, it is used to measure and control the flow of fluids or gas.

Principle of operation

- "Basically, ultrasonic flow meters are used to measure the velocity of flowing medium by monitoring the interaction between the flow steam and ultrasonic wave."
- Ultrasonic waves are transmitted by transmitter and received by ultrasonic receiver.
- Two methods are used for measuring flow are;

1) Transit time flow meter.
2) Doppler effect flow meter.

1) Transit time flow meter:

- In this, there are two sets of transmitter and receiver are used.
- One of them set is used to determine the transit time in direction of flow and other is used to determine the transit time against the direction of flow.
- It works on the principle that, the effective velocity of sound in a moving medium is equal to addition of velocity of sound relative to the medium and velocity of flow.

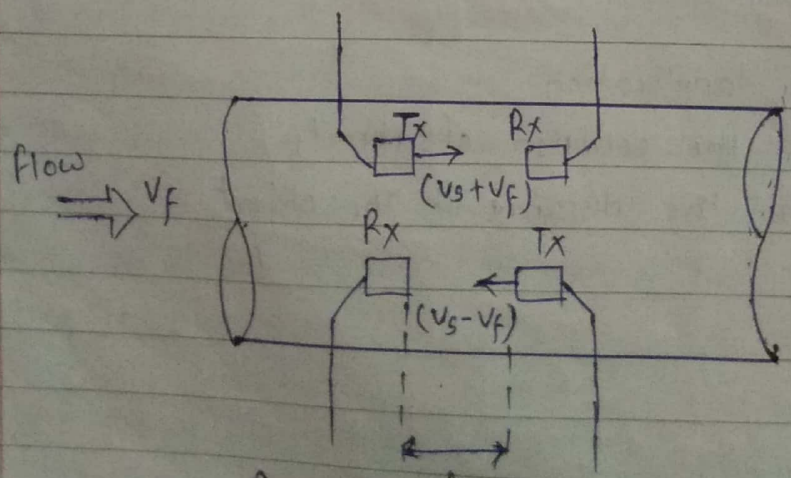


fig. Transit time flow meter.

where; V_f = Velocity of flow
V_s = Velocity of ultrasound
L = Distance between transducer

Then

$$\text{Transit time} = \frac{\text{Distance}}{\text{Velocity in that direction}}$$

Let

t_u = Upstream transit time (in the direction of flow)
t_d = Downstream transit time (in the direction against flow)

Then

$$t_u = \frac{L}{V_s - V_f} \quad \& \quad t_d = \frac{L}{V_s + V_f}$$

But transit time $\Delta t = t_u - t_d$ ---- ①

$$\Delta t = \frac{L}{V_s - V_f} - \frac{L}{V_s + V_f}$$

$$\Delta t = L\left[\frac{V_s + V_f - V_s + V_f}{(V_s - V_f)\cdot(V_s + V_f)}\right]$$

$$\Delta t = L\cdot\left(\frac{2V_f}{V_s^2 - V_f^2}\right)$$

But from equation

$$\Delta t = t_u - t_d$$

$$\therefore t_u - t_d = \frac{2LV_f}{V_s^2 - V_f^2}$$

If $V_s \gg V_f$ then V_f^2 is neglected

$$\therefore t_u - t_d = \frac{2L\cdot V_f}{V_s^2}$$

$$\boxed{\text{flow Velocity } V_f = \frac{V_s^2\cdot(t_u - t_d)}{2L}}$$

2) Doppler effect flow meter

- When ultrasonic waves are incident on a moving medium (fluid), then there is change in frequency of ultrasonic wave, this is called as doppler effect.
- Doppler flow meter uses this principle to measure flow in a tube.
- In this, a pair of transmitter and receiver are used of which are placed opposite to each other
- As sound waves travels from source to receiver, then its velocity will be either increased or decreased due to the doppler effect.

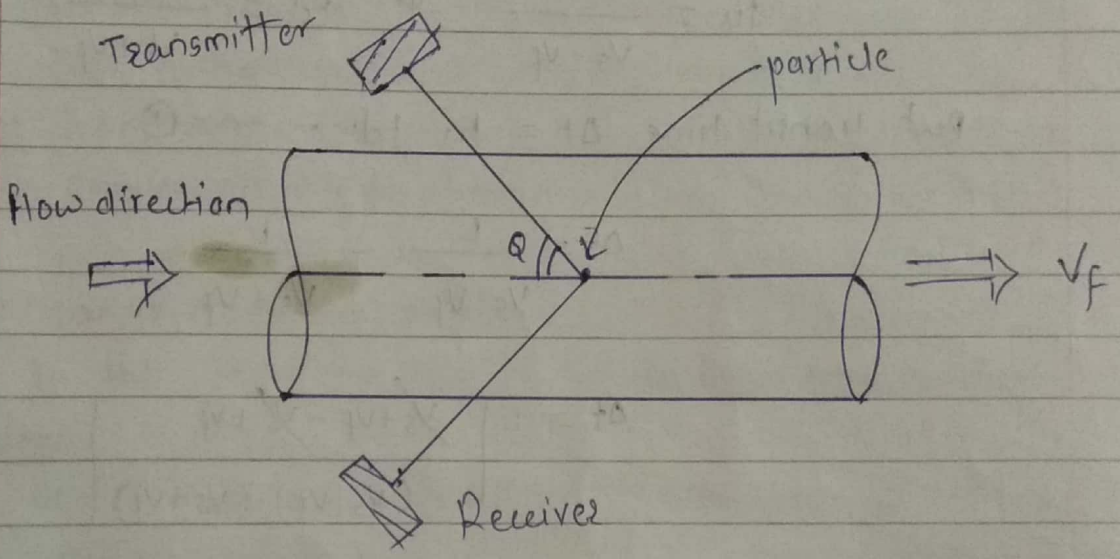


fig. Doppler flow meter.

The flow velocity is given by

$$V_f = \frac{V_s \cdot \Delta f}{2 f_s \cdot \cos\theta}$$

where; ~~V_s = ultrasonic~~

V_s = velocity of ultrasonic wave

Δf = frequency shift due to doppler effect.

f_s = frequency of source

θ = Angle between the transmitter & the axis of the pipe

Advantages of Ultrasonic flow meter

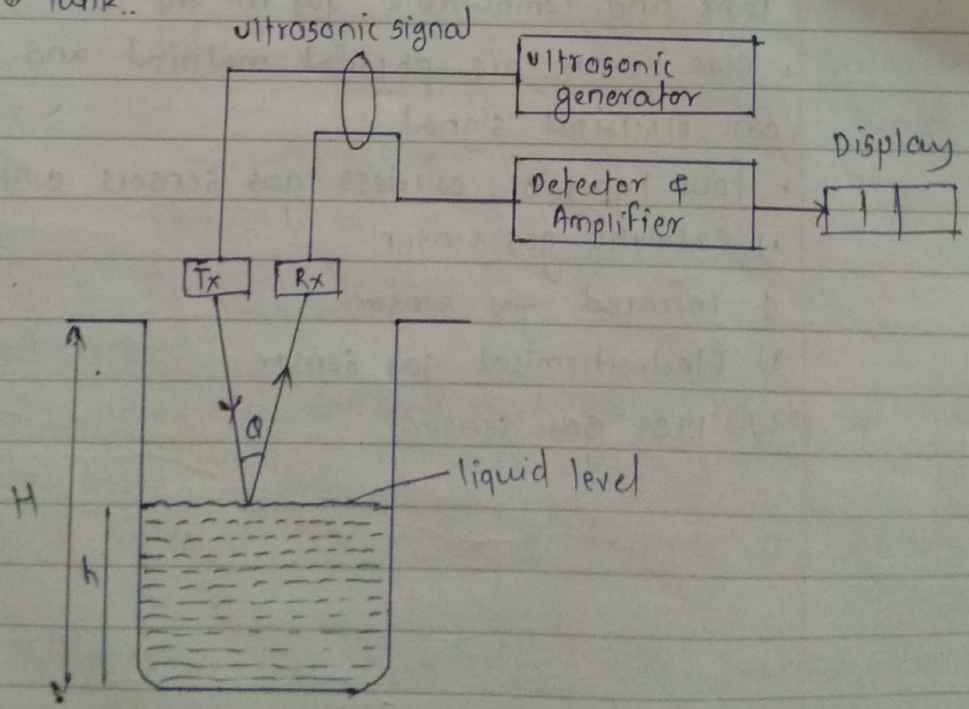
- Construction is very simple
- There is linear relationship blw the output & velocity of fluid
- provides good accuracy
- Suitable for liquids as well as for gases
- Frequency response is good & output is of electrical nature

Applications:

- Ultrasonic flow meters are widely used in industrial & biomedical engineering fields.
- In industrial appliances, water, milk, oil etc
- In biomedical field, for measuring respired gas or air.

* Ultrasonic level Sensor

- Ultrasonic level sensors can be used to measure the liquid level in a tank
- It works on the principle of reflection of ultrasonic wave from liquid surface.
- An ultrasonic transmitter-receiver is mounted at the bottom or top of a tank.



- ultrasonic wave is transmitted downward by the transmitter.
- the beam is reflected back from the surface of the liquid in the tank.
- then reflected beam is received by the receivor.
- Transit time is measured between the start of transmissio and start of reception.

Advantages & Disadvantages of ultrasonic level sensor

Advantages:

- Installation is easy
- This technique can be used for liquid and solid as well.
- This is non-disturbance technique.

Disadvantages

- System is costly
- Electronic circuitry required for detection, amplification, synchronization ie et it is a complex circuit.

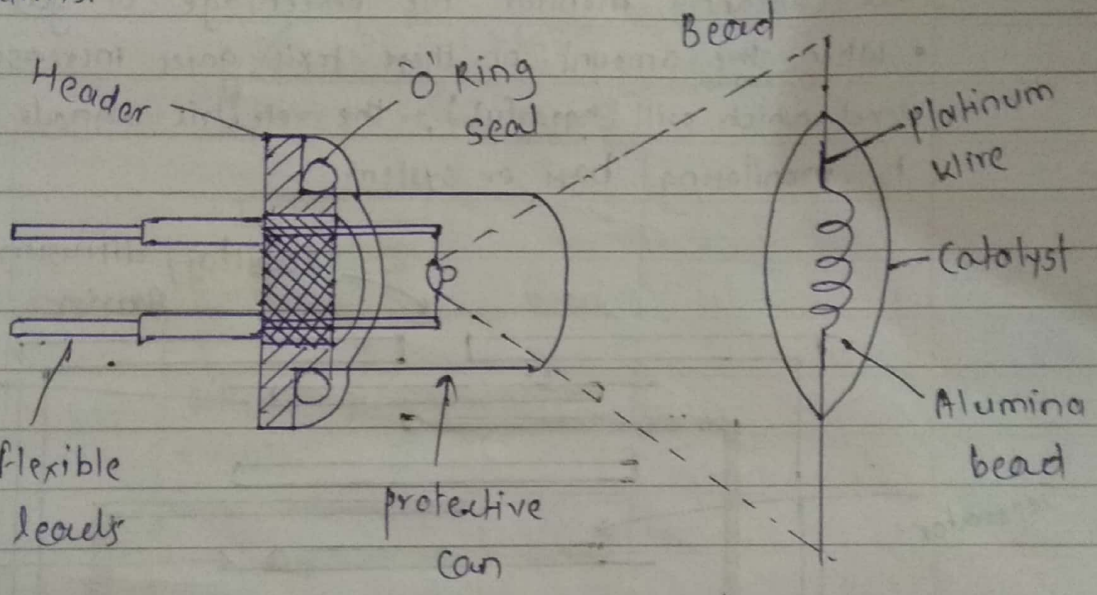
* Gas Sensor

- Gas sensors are used to detect or monitor the toxic and combustible gas in the air.
- Gas sensors are physical material and convert it into an electrical signal.
- four types of wireless gas sensors which are as follows

1) Catalytic gas sensor
2) Infrared gas sensor
3) Electrochemical gas sensor
4) MOS gas sensor

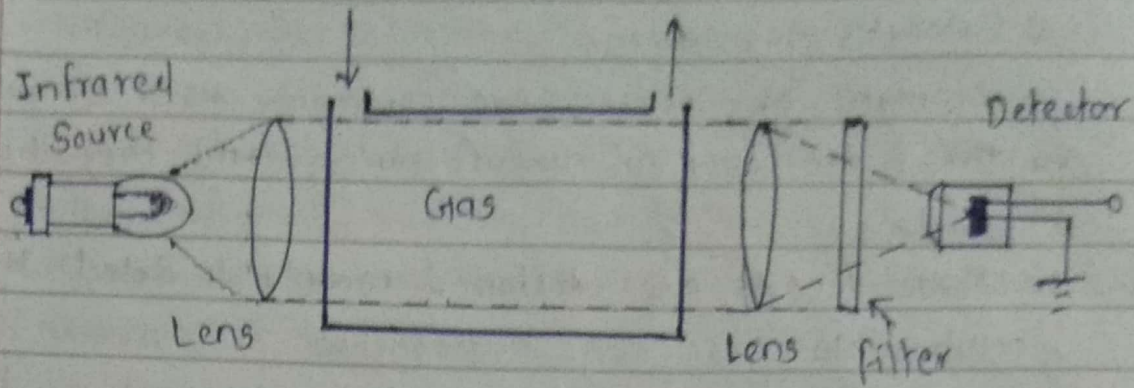
1) Catalytic gas sensor:

- Catalytic gas sensors are commonly used sensor.
- These are easy in manufacturing and they have high efficiency
- These sensors are designed mainly to detect the combustible gas eg. Hydrocarbon
- In this sensor, platinum treated wires are used in manufacturing.
- When hydrocarbon gas passes through this platinum wire then catalytic oxidation occures
- Because of this oxidation, there is change in resistance in the wiring.
- When this reaches to a specific point, sensors sets off Alarms.



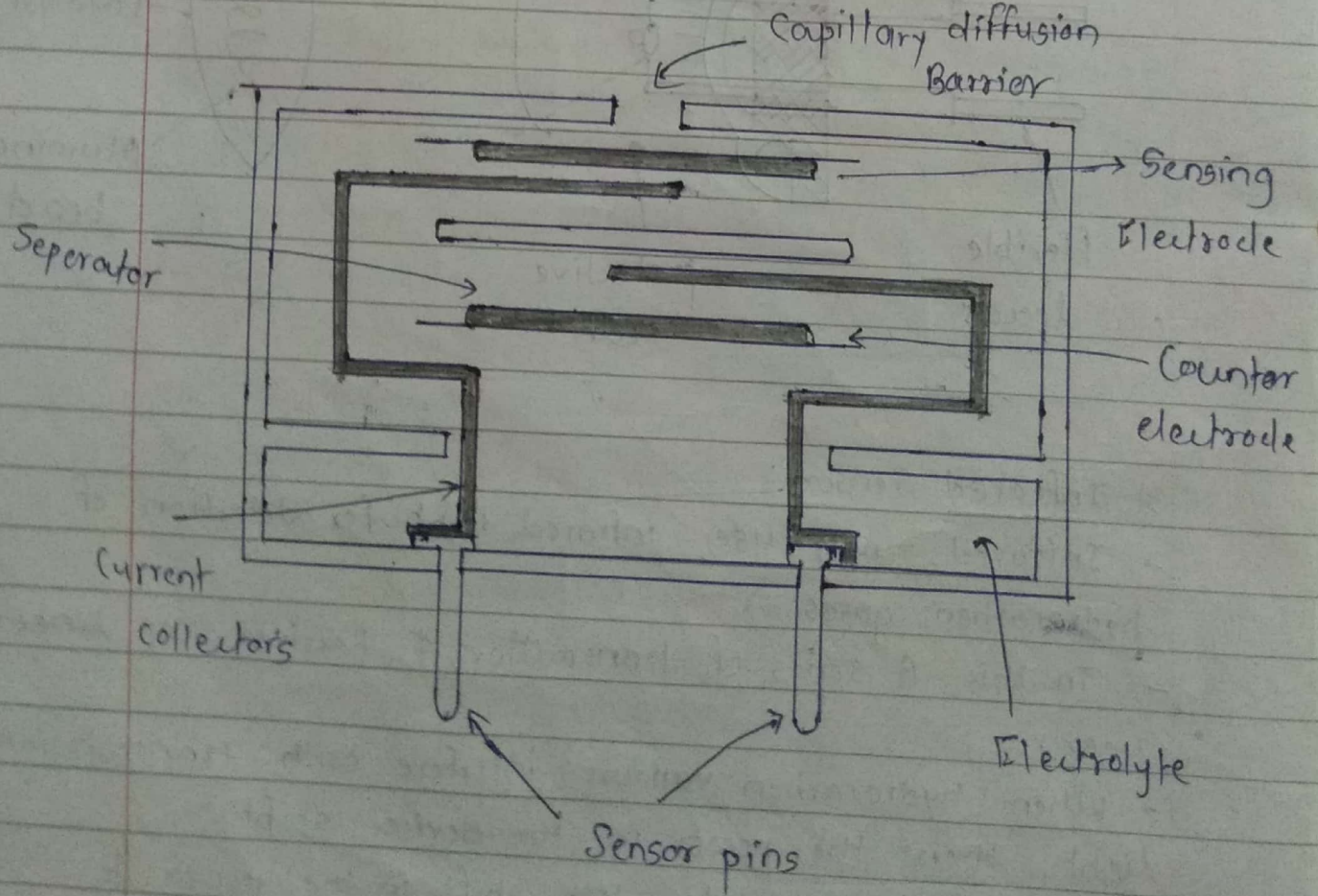
2) Infrared Sensor:

- Infrared sensor uses infrared light for detection of hydrocarbon gases.
- In this, A series of transmitter & Receiver are ~~used~~ used.
- When hydrocarbon vapours interfere with transmission of light, then the power in the devices shift.
- The sensor calculates the shift in the power to determine the amount of hydrocarbon present in the air.



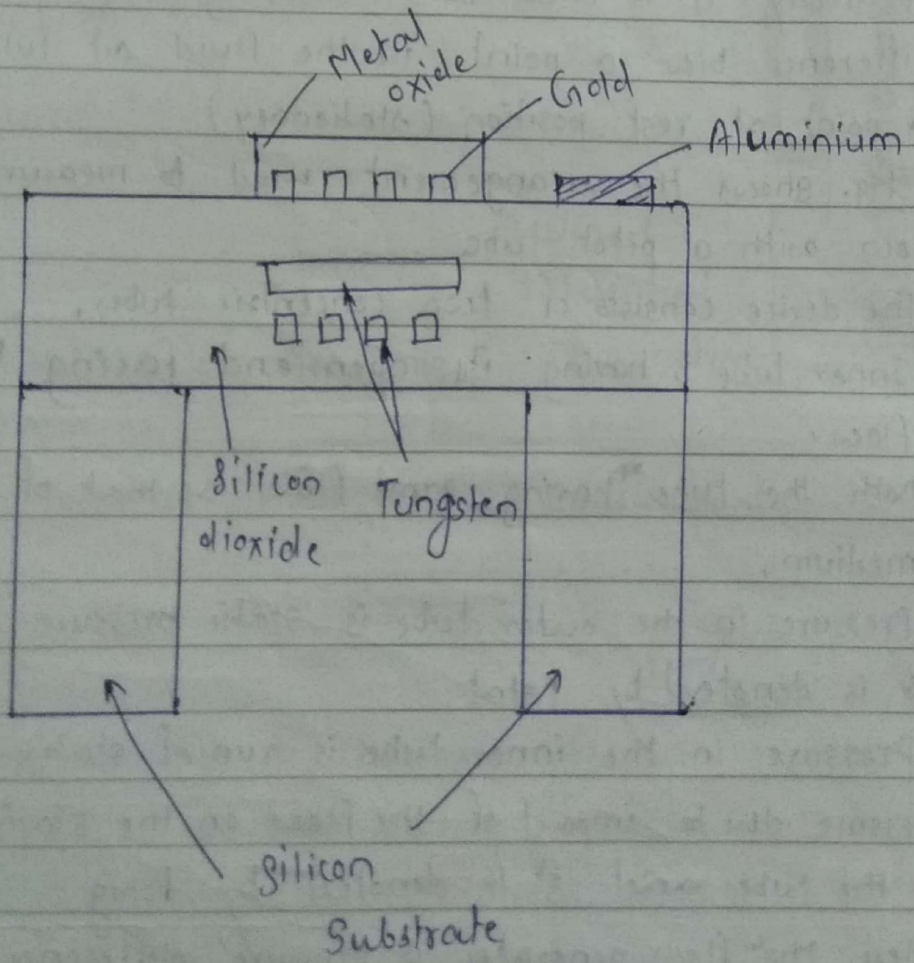
3) Electrochemical Sensor:-

- Electrochemical sensors are used to detect or monitor the level of Toxic gases present in the air. Such as Nitrogen oxide, Monoxide & chlorine. etc
- In this, electrodes are used and along with these sensors are constantly monitor the percentage of gas in the air
- When the amount of these toxic gases increases (at certain level which will harmful), the electric signals are sent to monitoring base or system



4) Metal oxide semiconductor gas sensor (MOS)

- It use chemical reaction to detect the presence of harmful gases such as Carbon ~~maxi~~ monoxide.
- In this sensor, A tungsten or tin oxide films are used.
- When this tungsten or ~~thin~~ tin oxide films interacts with carbon monoxide, it undergoes chemical reaction.
- When this happens, it triggers the alarm.
- One of the benifit of MOS is that they are stable and reliable in relatively low humidity



• Wind Sensors (Anemometer)

- Wind sensors are basically vector flow transducers i.e velocity measuring device.
- In such device, magnitude & direction of flow are sensed.

Two common Methods
1) Pitot tube
2) Hot wire Anemometer.

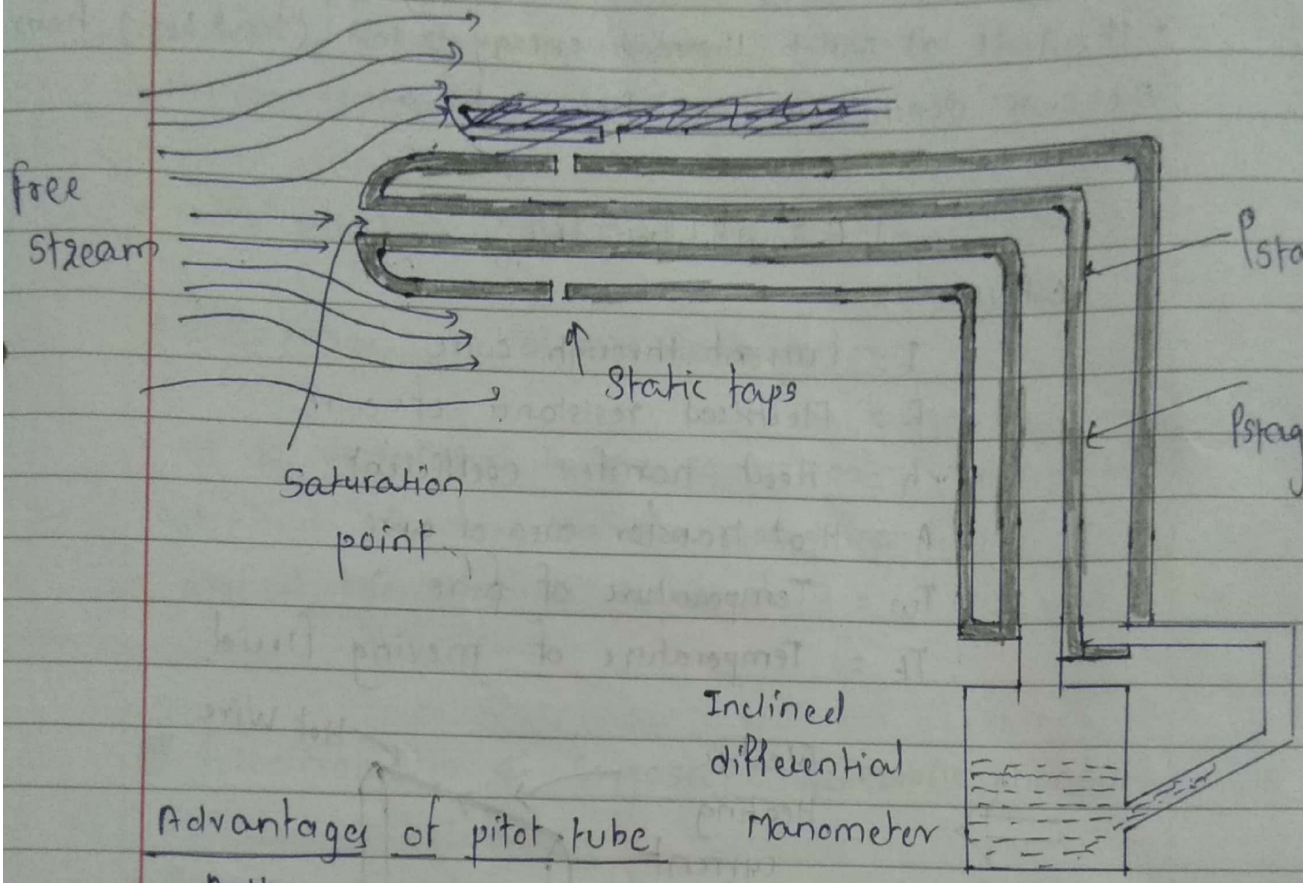
1) Pitot tube

- Basically it is used for measuring the pressure difference b/w a point in the fluid at full flow and a point at rest position (stationary)
- fig. shows the arrangement used to measure the vector flow with a pitot tube
- The device consists of two concentric tubes,
- Inner tube is having its open end facing the oncomin flow.
- Both the tubes having same fluid as that of flowing medium.
- Pressure in the outer tube is static pressure in the fluid it is denoted by P_{stat}
- Pressure in the inner tube is sum of static pressure and pressure due to impact of the flow on the stationary fluid in the tube and it is denoted by P_{stag}
- Here, the flow generates a pressure difference across the two parts of tube which is measured by Manometer
- The flow rate is given by

$$\text{Flow rate} = \frac{2(P_{stag} - P_{stat})}{\rho}$$

~~Where~~; V_f = ~~f~~ velocity of flow

V_s = velocity



Advantages of pitot tube

- Better accuracy
- Inexpensive method of flow measurement

Disadvantages of pitot tube

- Less sensitive to change in flow
- Suitable for high velocity flow.
- It is a laboratory instrument & not suitable for industrial application.
- It is useful for gas flow only & not applicable for liquid or slurry.

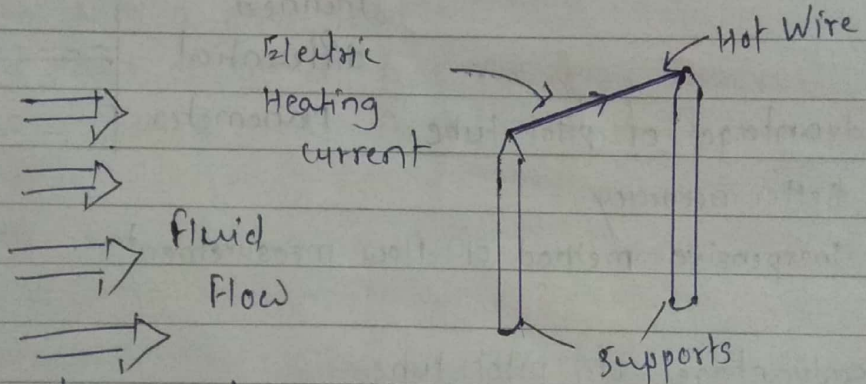
Hot Wire Anemometer

- The hot wire anemometer consists of small resistance wire element which is electrically heated and placed in the moving fluid as shown in following fig.
- The rate at which thermal energy is lost (heat loss) from the wire depends on the flow rate as

$$I^2R = hA(T_w - T_F)$$

where,

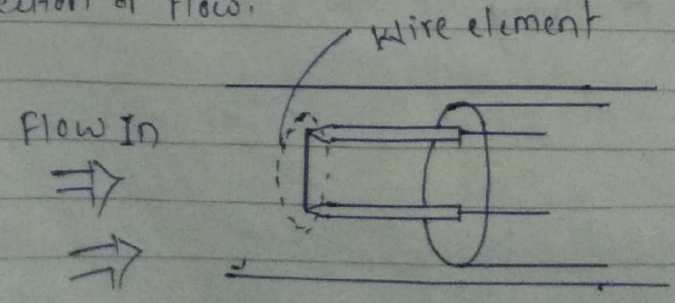
I = Current through wire
R = Electrical resistance of wire
h = Heat transfer coefficient
A = Heat transfer area of wire.
T_w = Temperature of wire
T_F = Temperature of moving fluid.



- The coefficient of heat transfer h is a function of fluid velocity 'v' and two constants C_0 & C_1

$$h = C_0 + C_1\sqrt{v}$$

- The output of hot wire anemometer is also a function of direction of flow.



Advantages of Hot wire Anemometer

- Wide range of flow measurement
- Better accuracy
- Portable device & easy to handle
- o/p of hot wire anemometer is electrical hence it is easy to interface with analog or digital device
- Probe size is small
- useful for both gases and liquids

Disadvantages of Hot wire Anemometer

- o/p is proportional to the square root of velocity hence operating characteristics are non-linear.
- Skilled operation is required

⊛ Accelerometer & Gyroscope (In Mobile phone)

- Gyroscope are also known as Angular Rate Sensor or Angular velocity sensor's.
- Gyroscope is the device that sense the angular velocity (Angular velocity is the change in rotational angle per unit time)
- Accelerometer in mobile phones are used to detect the orientation of the phone.
- Gyroscope adds an additional dimension to the information which is supplied by accelerometer by ~~tracking~~ tracking rotation or twist.
- Accelerometer measures the linear acceleration of movement ~~wheel~~ while Gyroscope measures angular rotational velocity.
- Both the sensors are used to measure the rate of change (just measures rate of change for different things)

- Gyroscope in Smartphone is calibrated to give a reading of zero when the device kept on plane horizontal surface.
- Any change in orientation of device is measured by gyroscope.

Eg: View a picture keeping your phone horizontal, rotate the phone to vertical position, then we will observe that, the picture also get rotate as your phone (you have to kept the auto-rotation 'on' in your mobile sensor settings).

- There are three types of Gyroscope
  i) Rotary gyroscope
  ii) Vibrating ~~gyroscope~~ structure gyroscope
  iii) Optical gyroscope

- Gyroscope are mostly used as a basis for inertial navigation systems.
- Main difference b/w accelerometer & gyroscope is that one can sense the rotation & other cannot.

Applications of Gyroscope & Accelerometer

- A gyroscope is used in navigation, compasses & large boats
- Accelerometers are basically found in Engineering, Machinery, H/w monitoring, building & structural monitoring, navigation, transport & even consumer electronics

⑨ Magnetometer

- Basically Magnetometer is a device which measures Magnetic field. It can be used as a compass.
- Magnetometer sensors utilizes modern solid state technology to create "Hall effect sensor."
- Hall effect sensor detects the earths magnetic field along three perpandicular axes X, Y & Z respectively
- Hall effect sensor produces voltage which is proportional to the strength and polarity of the magnetic field along the axis.
- The sensed voltage is converted to digital signal for representing the magnetic field intensity.
- There are two types of Magnetometer
  1) Scalar Magnetometer
  2) Vector Magnetometer.

1) Scalar Magnetometer

- That measures only magnitude of vector paving through the sensor regardless of the direction.

  eg. Quantum Magnetometer

2) Vector Magnetometer

- That measures flux density value in specific direction in 3-dimensional space (Require both direction as well as Magnitude)

  eg. Fluxgate Magnetometer

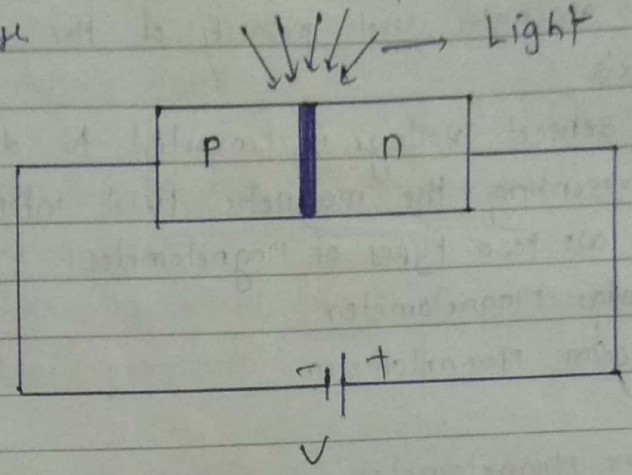
⑩ Radiation Sensor

Types of Radiation Sensor :

1) photo diodes
or Photo electric transducer
2) Photo conductive transducer
3) Photo voltaic cell. (PV cell)

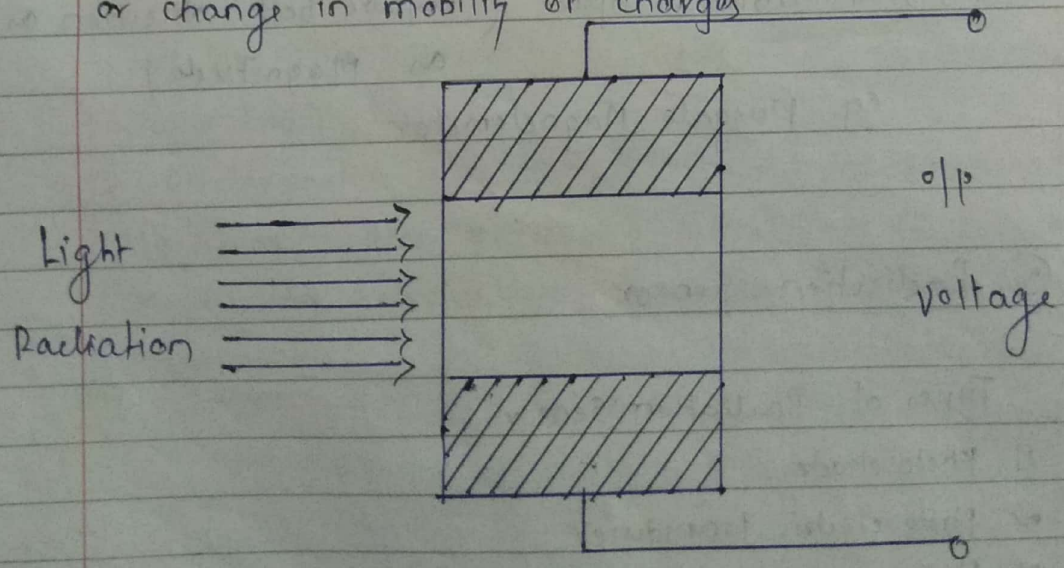
1) Photo-diodes

- Basically, construction of photo diode is very simple.
- In this, photodiodes are connected in reverse bias condition (Reverse bias means, +ve terminal of supply is given to 'n-type' and -ve terminal of supply is given to 'p-type') and gives very high resistance.
- When the light is falls / incident on the junction, the resistance of the diode will drop and the current will increase



2) Photo electric transducer :-

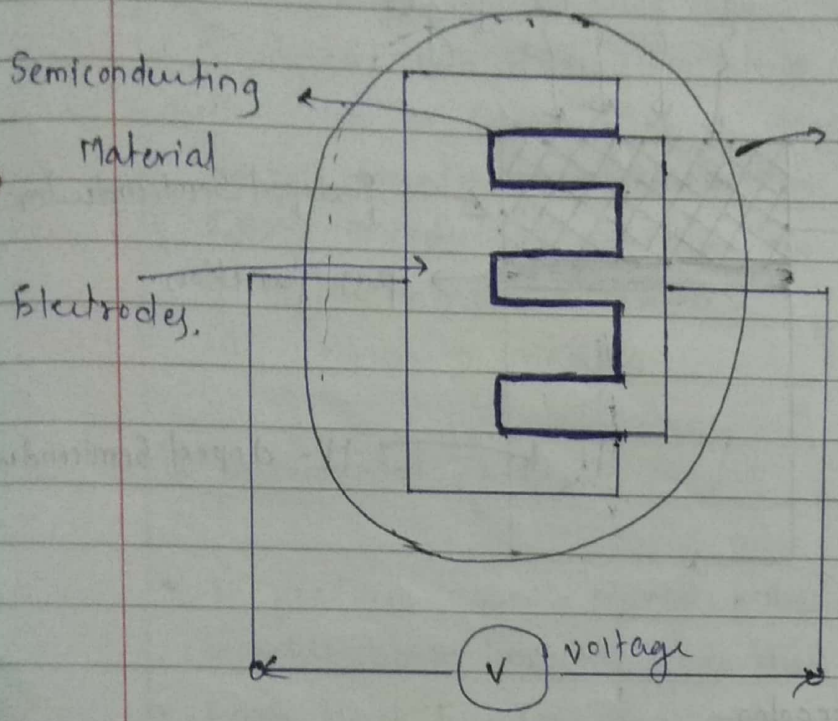
- When light radiations like x-ray. are falls / incident the semiconductor, the radiation energy is absorbed by the semiconductor produces the movable charges (current) or change in mobility of charges



- This will cause change in resistance, or current or volta which is measured by suitable digital circuitry at the output

③ Photo conductive transducer :-

- It consists of two transducers which are seperated by a thin layer of s/c material such as selenium, germanium etc. mounted inside the glass tube
- When the light is falls on the glass tube, resistance of semiconductor material changes

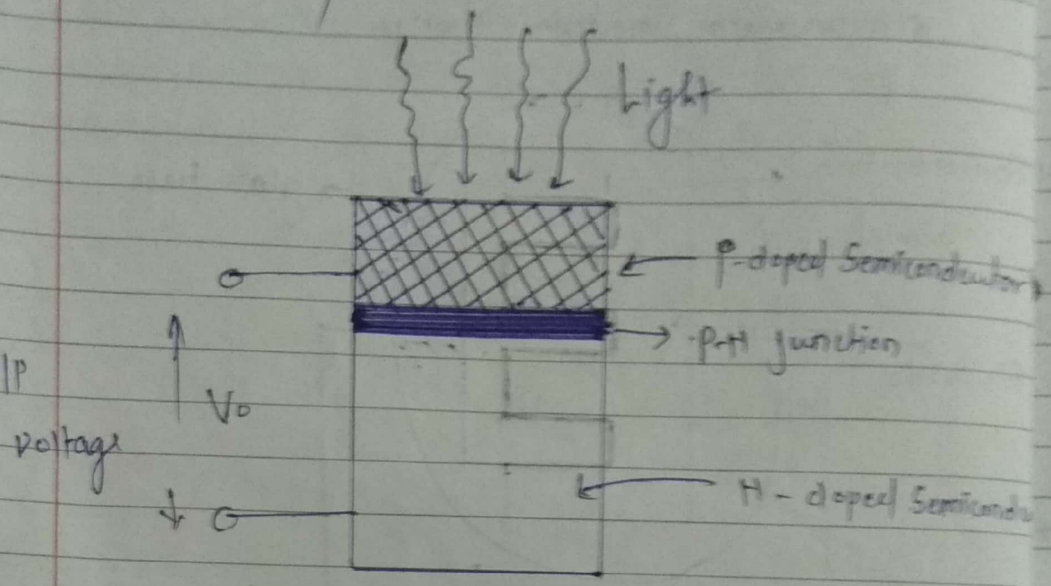


- The change in resistance results ~~in~~ change in current flow when voltage applied across the electrodes
- Then change in current is ~~displ~~ measured and displayed by a suitable digital circuitry at the o/p.

④ Photo voltaic cell (PV cell)

- Photo voltaic cell is made up of a ~~sandwich~~ sandwich of p-doped s/c over N-doped s/c which is as shown in following fig.
- When light falls on the cell, the photons striking the cells passes through the thin p-doped upper layer and absorbed by the electrons in the N-doped lower

- Because of this, there will be conduction of electron & holes
- Due to this, emf (potential difference / voltage) will set up across the junction.
- The current or voltage o/p is measured ~~by~~ of light intensity



IMP

Optical Encoder

Basics:

Encoder: It is an device that receives alphabets or symbols and convert them into binary code

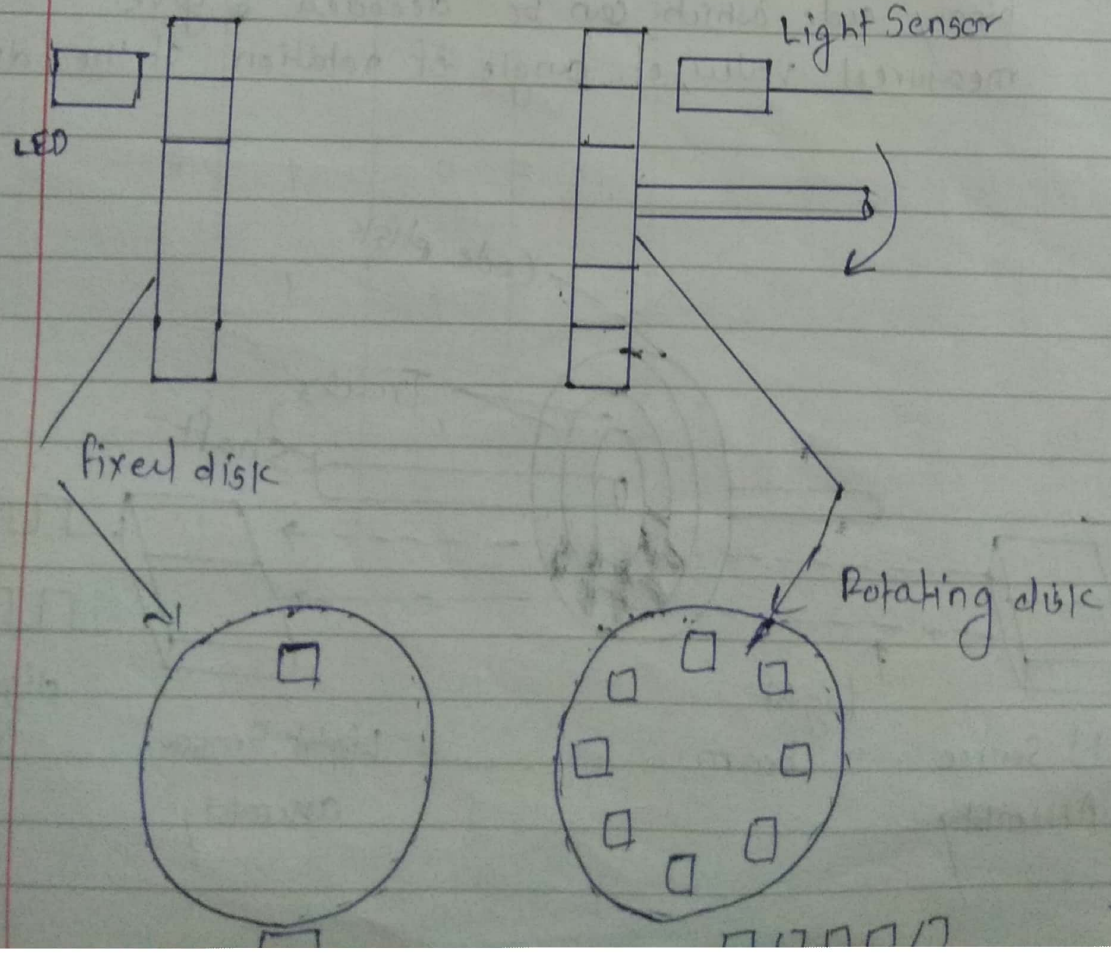
Decoder: It is an device that receives binary coded information and convert them into numbers or symbols or alphabets.

- An optical encoder is a device which is suitable for the measurement of angular position
- An optical encoder has following four main parts
  - a) Light source
  - b) Code disk
  - c) Light detector
  - d) Signal Conditioner

- Light rays are emitted from the light source and sensed by light detector and signal conditioner amplifies the signal to a redable form.
- Code disk is placed in btw light source and light detector Code disk has slots or in it.
- Light rays are emitted by the source passes through the slots of code disk & only the light passing through the slot is sensed by detector.
- A digital optical encoder is a device that converts motion into a sequence of a digital pulses
- Optical Encoders are linear or rotary configuration
- Rotary encoders are divided into two type
  i) Incremental encoder
  ii) Absolute encoder.

i) Incremental encoder

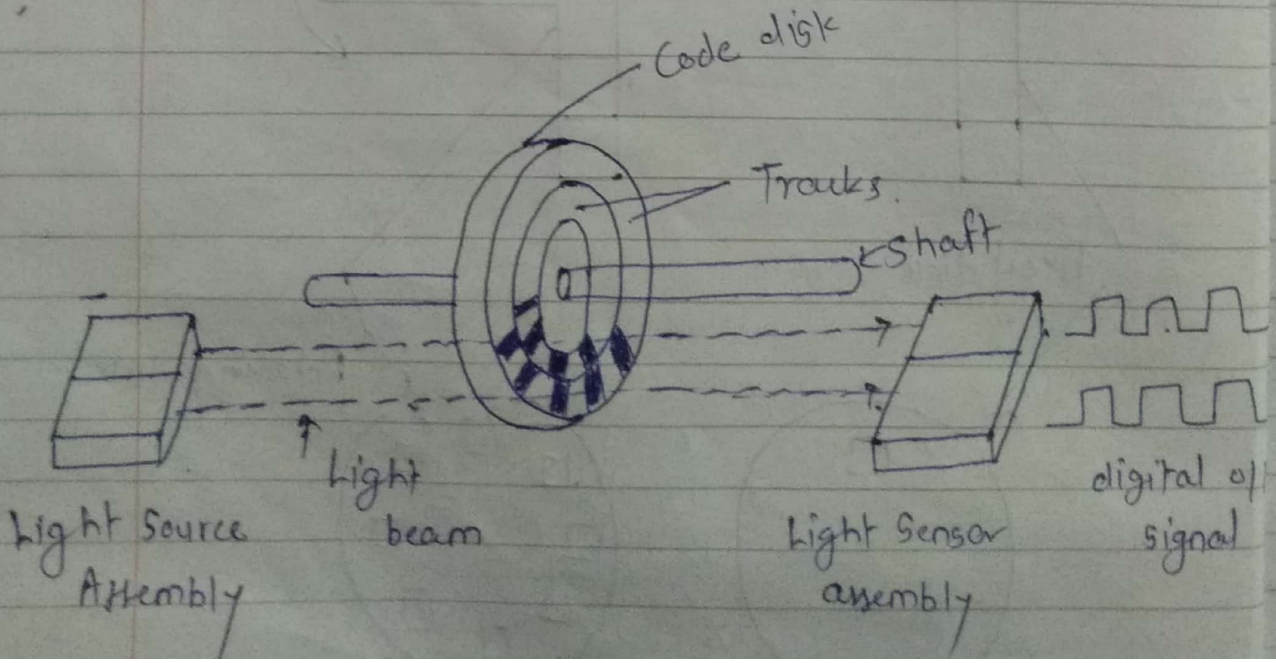
- It produces equally spaced pulses from one or more concentric tracks on the code disk.
- Each track has its own code disk



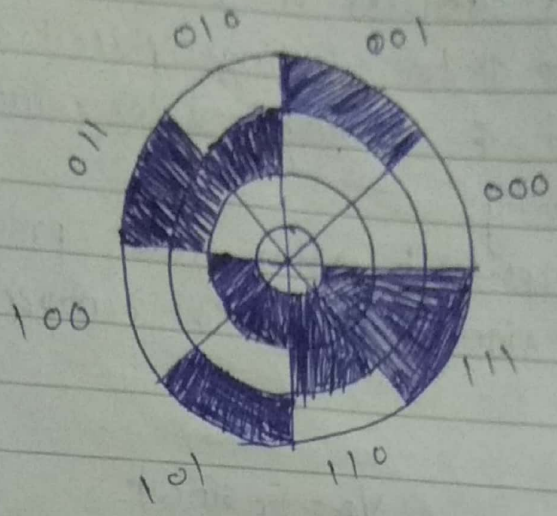
- Basic form of incremental encoder is as shown in above fig.
- It consists of pair of disk, one is fixed and other is rotating
- The rotating disk is attached to the shaft, whose angular speed is tobe measured.
- Fixed disk has only one window and beam of optical light is passes continuously through this window.
- Rotating disk consists of pattern of windows which are placed equidistantly around the disk
- When disk rotates, the light beam is alternatively transmitted and sensed by detector and produces digital o/p pulses

ii) Absolute Optical Encoder

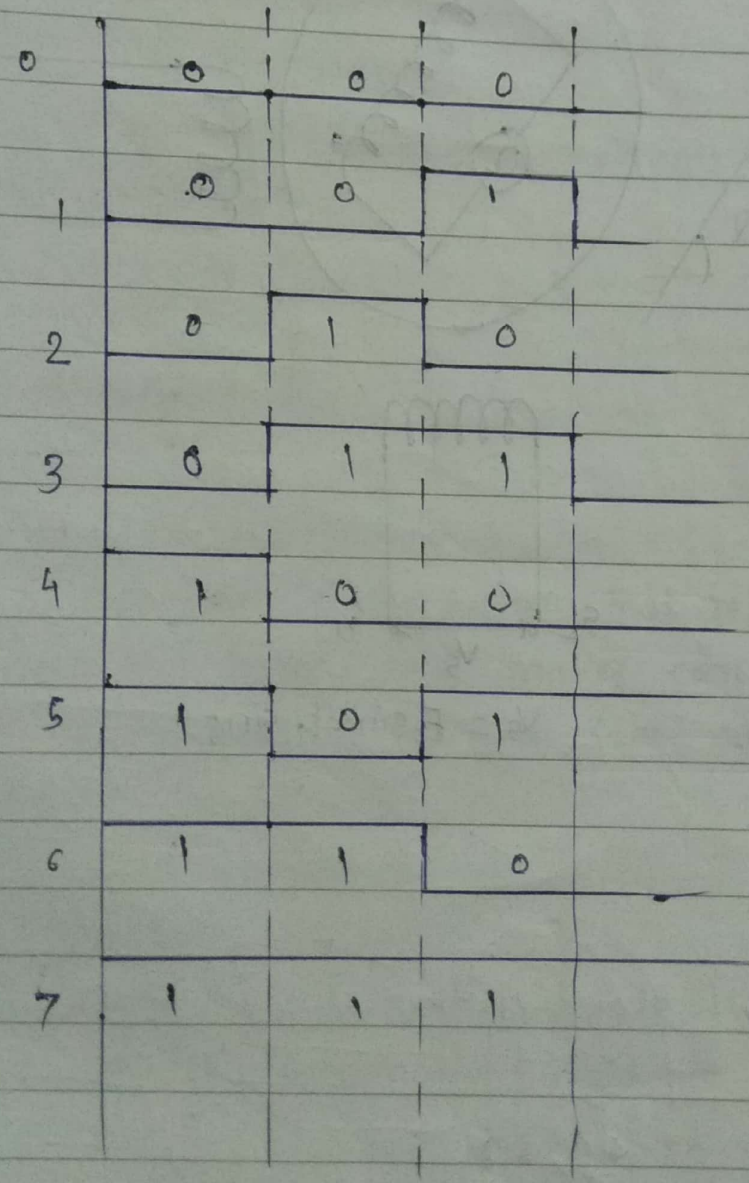
- The rotating disk has four concentric circular tracks with coded slots.
- The arrangement has four light source & four light sensor as shown in fig.
- Slots are coded in such a way that, o/p forms a binary code which can be decoded to give measured value of angle of rotation of the disk



for 3 disk

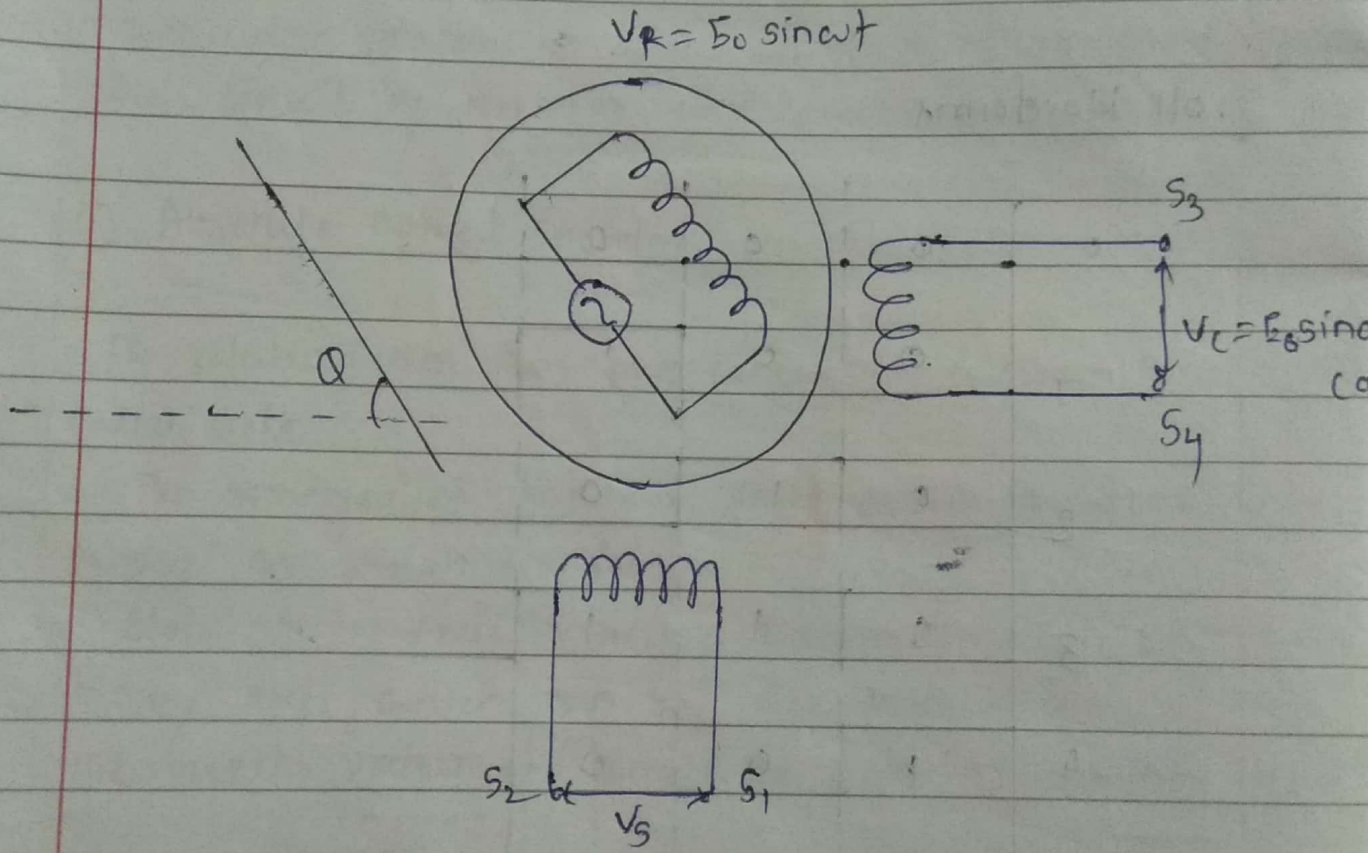


o/p waveforms



Resolvers:

- It is a type of rotary electrical transformer used for measuring degrees of rotation.
- It has two stator windings placed at right angle to each other & a single rotor winding which is as shown in fig.
- Angle input to rotar shaft produces sinθ & i/p voltage signal has cosθ components.



$V_S = E_0 \sin\omega t . \sin\theta$

MEMS (Microelectromechanical Systems)

- MEMS are a process technology utilized to make small, integrated devices or arrangements.
- MEMS systems combines mechanical and electrical elements.
- These devices / systems have the ability to sense, control the system and generates effects on the macro scale.
- Microsensors observes changes within the systems environment by activity, mechanical, thermal, magnetic, chemical or electromagnetic data or phenomena.
- Then microelectronics process this data and signals the micro-actuator to react them.

Components of MEMS

MEMS system has following components

i) Microelectronics
ii) Microsensors
iii) Microactuator
iv) Microstructure

i) Microelectronics:

- It is the Brain of the system that receives all the signals, processes the signal and makes conclusion.
- It accept/receives ~~that~~ of data which is coming from all the sensors.

ii) Microsensors:

- It collects the information / data from the surroundings.
- Then pass this information/ data to microelectronics for process
- It can monitor mechanical, thermal, biological, chemical and magnetic versions.

iii) Microactuator
- It acts as a trigger to activate external device

iv) Microstructure:
- Extremely tiny structures designed onto the surface of the chip.

Application of MEMS

- MEMS pressure sensors for medical application
- MEMS blood pressure sensor
- MEMS RF switches
- MEMS microphone
- MEMS gyroscope
-

***

Assignment Questions:

1) Write a short note on Nano-Sensor
2) What is film sensor & what are the applications of film sensor
3) Explain IR temperature Sensor
4) Explain
   i) Mos. gas sensor
   ii) Electrochemical gas sensor
5) Write a short note on smart Sensor
6) ~~What is optical fiber & What is it.~~
6) Explain the use of optical fiber in temperature measurement
7) ~~I~~ (7) Write a short note on MEMS system.
8) Two problems (Home work)

Bonus (x)

9) Static & Dynamic Characteristics of Transducer
10) Selection Criteria