20EI604/D21

Hall Ticket Number:

III/IV B.Tech (Regular) DEGREE EXAMINATION

July/August, 2023 **Electronics and Instrumentation Engineering**

Sixth Semester **Industrial Instrumentation**

Time: Three Hours **Maximum:** 70 Marks

Answer question 1 compulsory. **(14X1 = 14Marks)**
Answer one question from each unit. **(4X14=56 Marks)**

			CO	BL	M
1	a)	What is the basic principle of electrodynamic transducer?	CO1	BL1	1M
	b)	Define Torque.	CO2	BL2	1M
	c)	Explain the principle of ultrasonic flow meter.	CO3	BL2	1M
	d)	List various head type flow meters.	CO3	BL1	1M
	e)	What is the basic principle of stroboscope?	CO1	BL1	1M
	f)	Give the principle of optical torsion meter.	CO3	BL1	1M
	g)	List different types of Viscosity measurements.	CO4	BL1	1M
	h)	What is meant by piezoelectric effect?	CO2	BL1	1M
	i)	Define Dew Point.	CO4	BL1	1M
	j)	Explain the basic principle of strain gauge Load cell	CO4	BL2	1M
	k)	Distinguish between Moisture and Humidity.	CO4	BL2	1M
	l)	Give the applications of LVDT.	CO1	BL1	1M
	m)	List two advantages of capacitive Hygrometer.	CO4	BL1	1M
	n)	Explain the principle of optical fiber based level indicator.	CO3	BL2	1M
		<u>Unit-I</u>			
2	a)	Explain the Construction and working of Doppler Transducer.	CO1	BL2	7M
	b)	Illustrate the working of Piezoelectric accelerometer with a neat diagrams.	CO1	BL3	7M
3	a)	Describe the working of AC generator tachometer with neat sketches.	CO1	BL2	7M
	b)	Explain the inductive type vibration sensor with a suitable application.	CO1	BL3	7M
		<u>Unit-II</u>			
4	a)	Compare hydraulic and Pneumatic Load cells and list their advantages.	CO2	BL4	7M
	b)	Illustrate the working principle of Strain gauge torque transducer.	CO2	BL3	7M
		(OR)			
5	a)	Outline the working of ionization gauge and also give its applications.	CO2	BL4	7M
	b)	Describe about optical torsion transducer.	CO2	BL2	7M
		<u>Unit-III</u>			
6	a)	Show that there exists a linear relationship between the volume flow rate and variable area for rotameter.	CO3	BL2	7M
	b)	Outline the radiation based level sensors with neat sketches.	CO3	BL4	7M
		(OR)			
7	a)	Illustrative the working of ultrasonic flow meter with necessary equations.	CO3	BL3	7M
	b)	Explain the construction and working of fiber optic level sensor with neat diagrams.	CO3	BL2	7M
		<u>Unit-IV</u>			
8	a)	Explain how consistency is measured by rotating vane consistency meter.	CO4	BL2	7M
	b)	Outline the working principle of gamma ray densitometer.	CO4	BL4	7M
		(OR)			
9	a)	Illustrate the working principle of Saybolt viscometer.	CO4	BL3	7M
	b)	Describe how humidity is measured by dry and wet bulb psychrometer.	CO4	BL2	7M

SCHEME AND SOLUTION

1.1x14=14MARKS

1 a) What is the basic principle of electrodynamic transducer? CO1 BL1 1M

A: Electrodynamic or Moving Coil Type Velocity Transducer :
In this type of transducer, the magnet is fixed and the coil moves in the magnetic field, thereby resulting in the generation of voltage in the coil according to the electromagnetic induction principle.

b) Define Torque. CO2 BL2 1M

A:
Torque is the time-derivative of angular momentum L,just as force is the time derivative of linear momentum.

$$\boldsymbol{\tau} = \frac{d\mathbf{L}}{dt}$$

c) Explain the principle of ultrasonic flow meter. CO3 BL2 1M

A: The basic principle of operation employs the frequency shift (Doppler Effect) of an ultrasonic signal when it is reflected by suspended particles or gas bubbles (discontinuities) in motion.

d) List various head type flow meters. CO3 BL1 1M

A: Orifice plate,Venture plate,Flow nozzle, Pilot tube.

e) What is the basic principle of stroboscope? CO1 BL1 1M

A: The stroboscope working principle uses a high intensity light which flashes at precise intervals. This light may be directed upon a rotating or vibrating object. The stroboscopic effect is apparent when the rotational or vibratory speed is in a proper ratio with the frequency of the light flashes.

f) Give the principle of optical torsion meter. CO3 BL1 1M

A: Due to torque, an angular twist (angular displacement) occurs on the shaft between its ends. This angle of twist is measured by using optical means where in angular deflection of light rays is proportional to twist and hence the torque.

g) List different types of Viscosity measurements. CO4 BL1 1M

A:
1.Flow through a capillary tube.
2.Drag experienced by a falling ball through a fluid.
3.Drag experienced by one of concentric cylinders carrying fluid between them when the other cylinder is rotating.

h) What is meant by piezoelectric effect? CO2 BL1 1M

A:Certain materials ,especially the crystalline ones,produce an emf when deformed by an application of pressure along the specific axes.the phenomenon is known as piezoelectricity or piezoelectric effect.Ex:Quartz

i) Define Dew Point. CO4 BL1 1M

A: The dew point of a given body of air is the temperature to which it must be cooled to become saturated with water vapor.

j) Explain the basic principle of strain gauge Load cell CO4 BL2 1M

A: On this cylinder, if the strain gauges are bonded, the strain gauge also is stretched or compressed, causing a change in its length and diameter.
This change in dimension of the strain gauge causes its resistance to change. This change in resistance or output voltage of the strain gauge becomes a measure of applied force.

k) Distinguish between Moisture and Humidity. CO4 BL2 1M

A: Humidity is a measurement of vapour content (water in gas state).
Moisture is a related to the content of water (water in liquid state).

l) Give the applications of LVDT. CO1 BL1 1M

A: **Applications of LVDT :**

- LVDT is used to measure the weight as a secondary transducer, this transducer can also work as a secondary transducer.

- LVDT is used in industries as well as servomechanisms.
- It can be used testing of soil strength.
- It can used robotics cleaner.
- Brain probing medical device.
- Craft shaft balancer.
- Final product infection (checking dimension).
- Electronics dial indicator.
- PILL making machine.
- Natural gas fuel valve position for a gas turbine for throttle control.
- Feedwater boiler pump valve positioning.
- Dollar bill thickness in ATM machines.
- LVDT is sensor works as the main transducer and that changes dislocation to an electrical signal straight.
- It is also used in hydraulic cylinder displacement.
- It can be used for displacement ranging from the fraction of mm to few cms.
- Some of these transducers are used to calculate the pressure and load and force.
- The other application like power turbines, automotive suspension control, hydraulics, automation, aircraft, and satellites

m) List two advantages of capacitive Hygrometer. CO4 BL1 1M

A:
1.Small size
2.Probe type packaging
3.Wide measurement range
4.Suitable for measuring moisture content in many gases including hydrocarbons
5.Being a capacitor, it can be easily incorporated in microprocessor-based electronic instrumentation.

n) Explain the principle of optical fiber based level indicator. CO3 BL2 1M

A:The fibre is kept immersed in the liquid tank. If there is no liquid in the tank, the intensity of light at the source and the detector are almost the same .As the liquid rises, some light dissipates through the liquid, bringing the intensity down at the detector. So the difference between intensities of light at the source and the detector can be calibrated against the liquid level.

Unit-I

2 a) Explain the Construction and working of Doppler Transducer. CO1 BL2 7M

A: FIG+WORKING(3+4)

Laser Doppler Velocimetery (LDV) is a technique used to measure the instantaneous velocity of a flow field. This technique, like PIV is non-intrusive and can measure all the three velocity components. The laser Doppler velocimeter sends a monochromatic laser beam toward the target and collects the reflected radiation. According to the Doppler effect, the change in wavelength of the reflected radiation is a function of the targeted object's relative velocity. Thus, the velocity of the object can be obtained by measuring the change in wavelength of the reflected laser light, which is done by forming an interference fringe pattern (i.e. superimpose the original and reflected signals).This is the basis for LDV. A flow is seeded with small, neutrally buoyant particles that scatter light. The particles are illuminated by a known frequency of laser light. The scattered light is detected by a photomultiplie tube (PMT), an instrument that generates a current in proportion to absorbed photon energy, and then amplifies that current. The difference between the incident and scattered light frequencies is called the Doppler shift. By analyzing the Doppler-equivalent frequency of the laser light scattered (intensity modulations within the crossed-beam probe volume) by the seeded particles within the flow, the local velocity of the fluid can be determined.

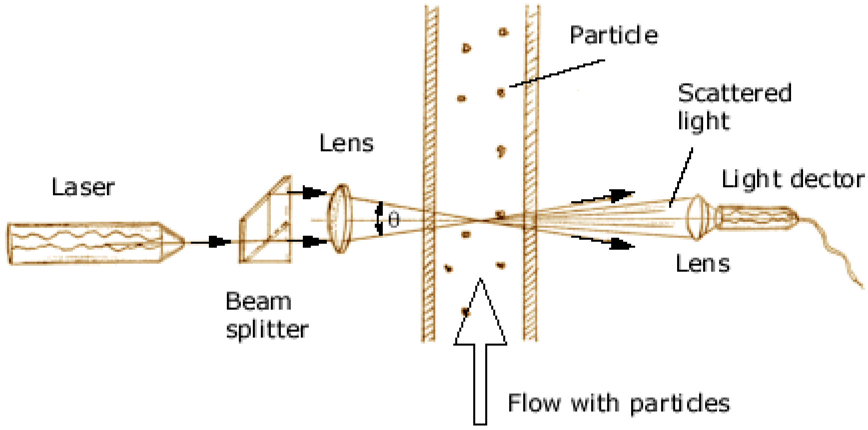


FIG.2.A. LASER DOPPLER VELOCITY METER

b) Illustrate the working of Piezoelectric accelerometer with a neat diagrams. CO1 BL3 7M

A: FIG+WORKING(3+4)

The piezoelectric accelerometers are perhaps the most practical devices for measuring accelerations caused by shock and vibration. The device includes a mass that, when accelerated, exerts an inertial force on a piezoelectric crystal. The piezoelectric effect produces an accumulation of charge on the crystal. This charge is proportional to applied force which, in turn, is proportional to the acceleration. Piezoelectric crystals have both positive and negative outputs. In Fig. 2.b the positive output electrode is connected to the mass and the negative electrode (ground) is connected to the housing. A signal conditioner converts the high impedance charge output into a usable voltage signal.

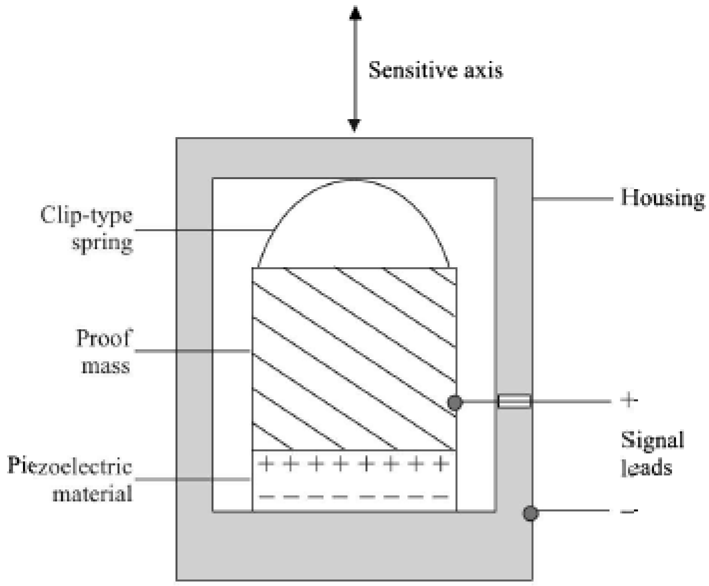


Fig. 2.b Piezoelectric accelerometer.

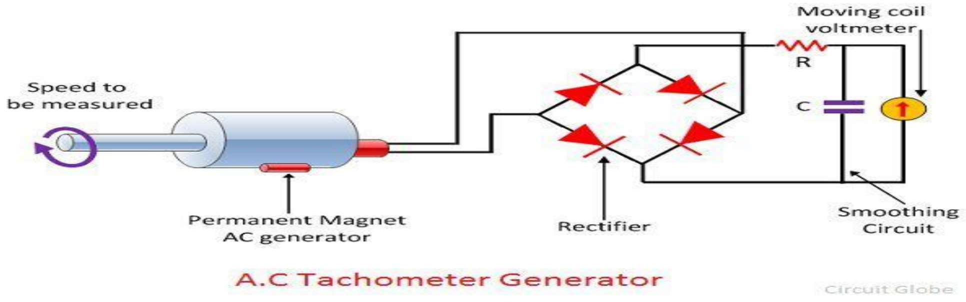
3 a) Describe the working of AC generator tachometer with neat sketches. CO1 BL2 7M

A: FIG+WORKING(3+4)

The AC tachometer has stationary armature and rotating magnetic field. Thus, the commutator and brushes are absent in AC tachometer generator.

The rotating magnetic field induces the EMF in the stationary coil of the stator. The amplitude and frequency of the induced emf are equivalent to the speed of the shaft. Thus, either amplitude or frequency is used for measuring the angular velocity.

The below mention circuit is used for measuring the speed of the rotor by considering the amplitude of the induced voltage. The induces voltages are rectified and then passes to the capacitor filter for smoothening the ripples of rectified voltages.

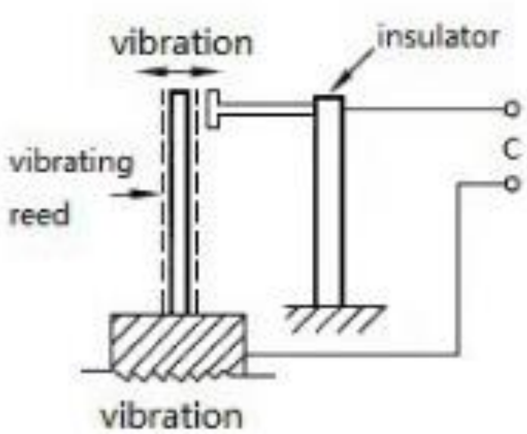


b) Explain the inductive type vibration sensor with a suitable application. CO1 BL3 7M

A: FIG+WORKING(3+4)

Inductive vibration sensor

An inductive vibration sensor is a kind of vibration sensor designed according to the principle of electromagnetic induction. Inductance-type vibration sensor is equipped with a magnet and magnetic body. When measuring the vibration of the object, the mechanical vibration parameters can be converted into electrical parameter signals. Therefore, the inductance sensor has two forms, one is the variable clearance, the other is the variable magnetic conductivity area. The inductance vibration sensor can be used to measure vibration velocity, acceleration, and other parameters.



Unit-II

4 a) Compare hydraulic and Pneumatic Load cells and list their advantages. CO2 BL4 7M

A: FIG+WORKING(3+4)

Slno	Hydraulic	Pneumatic
1	Self contained devices ,no external power	Self contained devices ,no external power
2	Suitable for potentially hazardous areas	Explosion proof
3	It operates on force balance principle	It operates on force balance principle
4	Sensitive to tem changes and facilities to adjust the zero output reading	Insensitive to temperature changes
5	The liquid has preload pressure	Need for clean,dry regulated air or nitrozen

b) Illustrate the working principle of Strain gauge torque transducer. CO2 BL3 7M

Strain gauge type. In strain gauge type torque meters, strain gauge elements are usually mounted in pairs, each subtending an angle of 45° to the shaft axis[8], on one side of the shaft. One gauge measures the increase in length (in the direction in which the surface is under tension) and the other measures the decrease in length in the other direction. Another similar pair is mounted on the opposite side of the shaft. The arrangement is shown in Fig. 9.24. In Fig. 4.b , which shows the view from a side, grey coloured strain gauges indicate that they are mounted on the opposite side of the shaft. The cross-sectional view of the arrangement is shown in Fig 4(b).

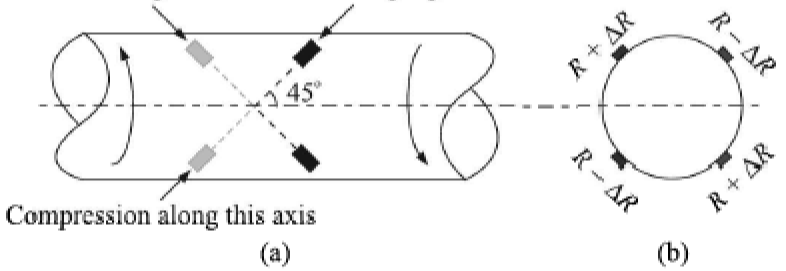


Fig. 4 Torsion measurement with strain gauge sensors: (a) side view where grey coloured gauges indicate that they are mounted on the opposite side of the shaft, and (b) the cross-sectional view of the arrangement.

Because the shaft is rotating, the torque sensor can be connected to its power source and signal conditioning electronics via a transformer. The excitation voltage for the strain gauge is inductively coupled, and the strain gauge output is converted to a modulated pulse frequency (Fig. 4.b.2).

(OR)

5 a) Outline the working of ionization gauge and also give its applications. CO2 BL4 7M

A: FIG+WORKING(3+4)

Cold cathode ionisation gauge

As the name implies, in a cold cathode ionisation gauge electrons are not produced by heating a filament. Here, a high electric field of about 4 kV is applied between the cathode and the anode to draw electrons out (Fig. 5.a).

A magnetic field of about 1500 gauss, applied around the tube, causes the electrons to spiral their way to the anode. This spiralling of electrons increases their probability of collision with the gas molecules thereby increasing the ionisation. The typical range of this gauge is from 10^{-10} to 10^{-2} Torr.

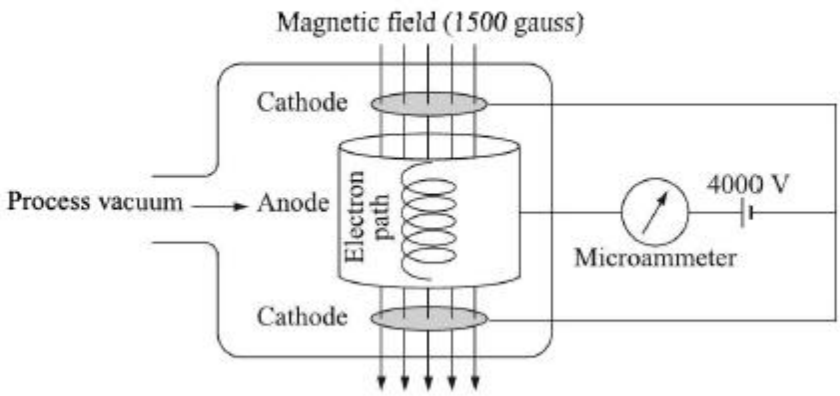


Fig. 5.a Cold cathode ionisation gauge.

Having no hot filament, the cold cathode gauge can safely be used in a decomposable gas environment and for the same reason, is unaffected by the inrush of air.

b) Describe about optical torsion transducer. CO2 BL2 7M

A: FIG+WORKING(3+4)

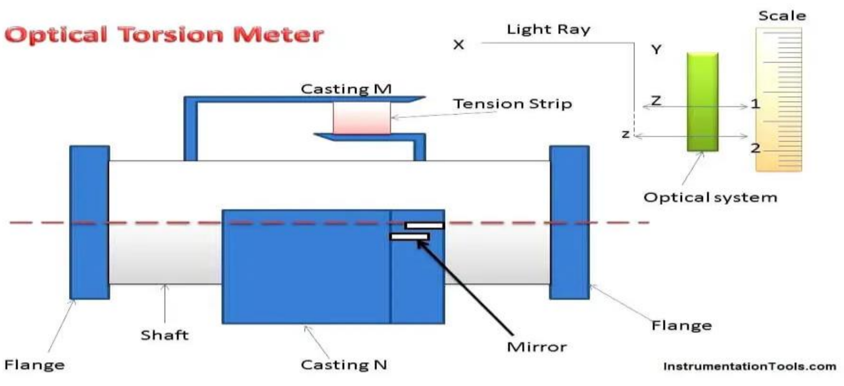
We know that the relation between the torque and the parameters of a solid cylindrical shaft under shear stress is given by[7]

$$\tau = \frac{G\pi r^4 \phi}{2l} \qquad \text{-(1)}$$

where G is the modulus of rigidity of the shaft material
r is the radius of the shaft
ϕ is the angle of deflection
l is the length of the shaft

In case of a hollow cylinder of outer radius r_1 and inner radius r_2, the relation is

$$\tau = \frac{G\pi\phi}{2l}(r_1^4 - r_2^4) \qquad \text{-(2)}$$



The main parts of an optical torsion meter as follows:

A shaft is used on which two casting M and N are connected at a known distance.
A tension strip linking the two castings.
Two mirrors which are fitted and aligned on the castings.
A light beam falling on the mirrors, an optical system and a torque calibrated scale.
Operation of optical torsion meter
When the shaft is transmitting torque, a relative movement occurs between castings M and N, and due to this, the mirrors will change position (partial inclination between the two mirrors) since they are attached to the castings.
As the mirrors are constantly made to reflect a light beam on the torque calibrated scale, due to the changed position of the mirrors, there will be an angular deflection of the light rays which is measured from the calibrated scale.
This angular deflection of the light rays is proportional to the twist on the shaft (relative movement of casting M and N) and hence the torque of the shaft.
Applications of optical torsion meter
It is used in steam turbines and I.C engines

or

Alternatively, an IR beam may be transmitted through an optical fibre to specially designed optical forks each of which can be positioned at each of the wheels such that the transmitter and receiver stay on two sides of the wheel. The IR beams passing through the air gaps get pulse modulated by the coding wheels mounted on the rotating shaft. The generated pulse pattern will depend on the shaft torque and speed.

The resulting IR light signal in the optical fibre contains the information on the torsional angle between the two toothed wheels on the rotating shaft. In addition, the IR light signal contains the information on the shaft rpm.

Unit-III

6 a) Show that there exists a linear relationship between the volume flow rate and variable area for rotameter. CO3 BL2 7M
A: FIG+WORKING(3+4)

flow rate of an incompressible fluid through a horizontal pipe is given by

$$Q_a = \frac{C_d \alpha_2}{\sqrt{1-m^2}} \sqrt{\frac{2(p_1 - p_2)}{\rho}} \qquad (1)$$

A rotameter consists of a vertical tube with a tapered bore [Fig. 6 (a)] in which a float assumes a vertical position depending on the rate of flow through the tube. The float remains at an equilibrium position because the vertical forces acting on it—differential pressure, weight, viscosity and buoyancy—are in balance.

A:

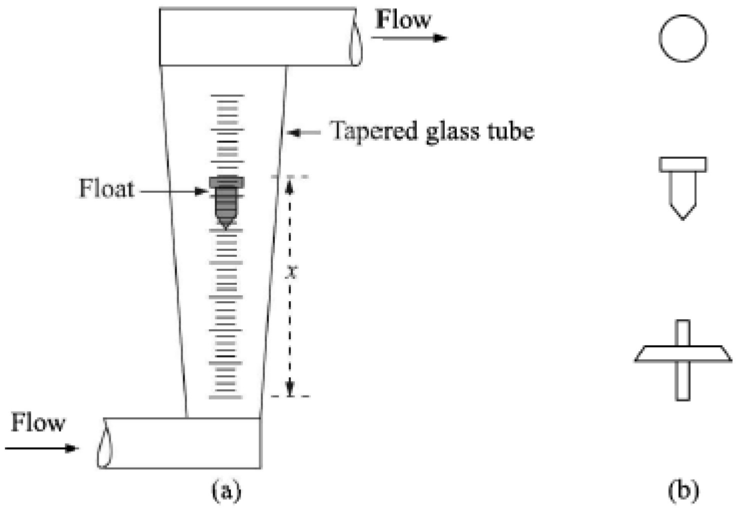


Fig. 6 (a) Rotameter, and (b) float shapes.

Seen quantitatively, the downward forces on the float are:

1. weight of the float = $V\rho g$, where V is the volume and ρ is the density of the float;
2. due to pressure on its upper surface = $p_2\alpha$, where α is the cross-sectional area of the float;

and the upward forces on it are:

1. buoyancy = $V\rho_f g$ where ρ_f is the density of the fluid;
2. due to pressure on its lower surface = $p_1\alpha$;
3. viscous drag due to fluid flow = $Kv\mu$ where v is the velocity of fluid flow, μ is the viscosity coefficient and K is a constant.

Neglecting the viscous drag which is small and equating the upward and downward forces, we get for equilibrium of the float

$$V\rho g + p_2\alpha = V\rho_f g + p_1\alpha$$

or

$$p_1 - p_2 = \frac{Vg}{\alpha}(\rho - \rho_f) \qquad (2)$$

Thus from Eqs. (1) and (2), we get

$$Q_a = \frac{C_d(\alpha_1 - \alpha)}{\sqrt{1-m^2}} \sqrt{\frac{2Vg(\rho - \rho_f)}{\alpha \rho_f}} \qquad (3)$$

where $(\alpha_1 - \alpha)$ is the difference in the cross-sectional areas of the tube and the float and which eventually is the cross-sectional area of the orifice, i.e. α_2.

If C_d is nearly constant and $m \ll 1$, then from Eq. (3)

$$Q_a = C(\alpha_1 - \alpha)$$

where C is a constant.

b) Outline the radiation based level sensors with neat sketches. CO3 BL4 7M

A: FIG+WORKING(3+4)

Two most commonly used sources of γ-rays are Cobalt-60 and Cesium-137, having half-lives of 5.3 years and 30 years respectively. The principle involved in the measurement is that when γ-ray travels through a material, its intensity is reduced according to the relation

$$I = I_0 \exp(-\mu \rho d) \qquad (12.16)$$

where I_0 is the intensity of the incident radiation
I is the intensity of the emitted radiation after passing through the material
μ is the mass absorption coefficient of the material
ρ is the density of the material
d is the distance travelled through the material.

Detectors are usually Geiger-Muller (GM) counters, ionisation chambers or scintillation
A: counters.

Gamma-ray Level Indicator

Most of the elements that are heavier than lead, are unstable. They disintegrate to form lighter elements, accompanied by α-, β- or γ-radiations. As is well known, α- and β-radiations consist of positively and negatively charged particles respectively while γ-radiation is electromagnetic wave of very high frequency. α-rays cannot penetrate even human skin and β-rays are stopped by aluminium sheet of about 6 mm thickness. γ-rays, on the other hand, have great penetrating power and therefore, can be utilised in level gauging. Apart from its penetrating power, γ-rays are not deflected by stray electric or magnetic fields while α- and β-rays are.

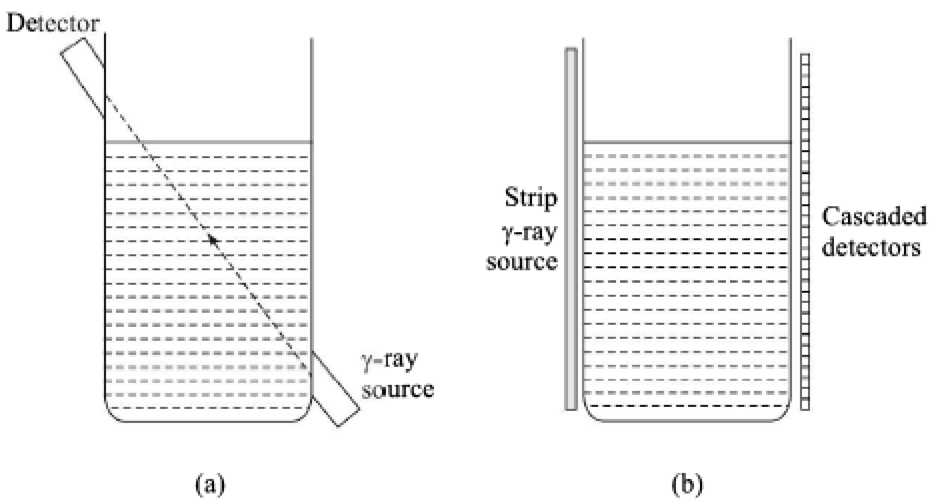


Fig. 6.B. (a) Simple arrangement for small level height, and (b) linearisation for large level heights.

(OR)

7 a) Illustrative the working of ultrasonic flow meter with necessary equations. CO3 BL3 7M

A: FIG+WORKING(3+4)

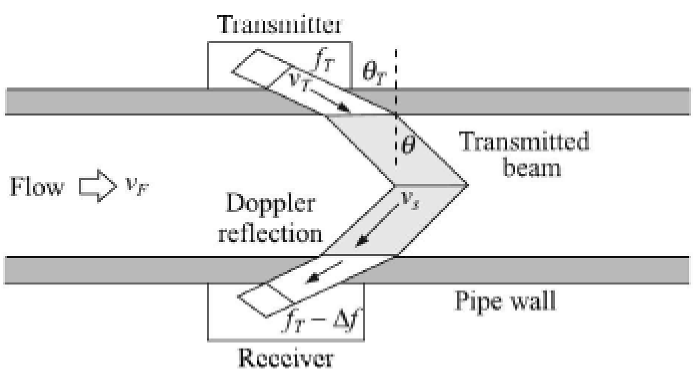


Fig. 7.A Doppler frequency shift flowmeter principle.

Equations governing phenomena in a Doppler flowmeter are

$$\Delta f = 2f_T\left(\frac{v_F}{v_s}\right)\sin\theta \quad \text{[Doppler's law of frequency shift]} \qquad (1)$$

$$\frac{\sin\theta_T}{v_T} = \frac{\sin\theta}{v_s} \quad \text{[Snell's law of refraction]} \qquad (2)$$

where v_F is the flow velocity
v_T is the sonic velocity of transmitter material
v_s is the sonic velocity of the fluid
f_T is the transmission frequency
Δf is the Doppler shift of frequency
θ_T is the angle of the transmitted sonic beam
θ is the angle of entry of the transmitted beam in the fluid

Solving Eqs. (1) and (2) simultaneously, we get

$$v_F = \frac{v_T}{f_T \sin\theta_T}\Delta f \equiv K\Delta f$$

where K is the sensitivity factor.

b) Explain the construction and working of fiber optic level sensor with neat diagrams. CO3 BL2 7M

A: FIG+WORKING(3+4)

In this method (Fig. 7.B), light of fixed intensity is sent through an unclad optical fibre to a sensor.

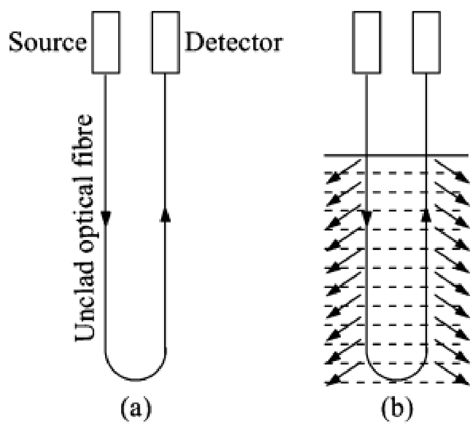


Fig. 7.B. Optical fibre-based level indicator: (a) when the fibre is in air, and (b) light dissipation when the fibre is in contact with the liquid.

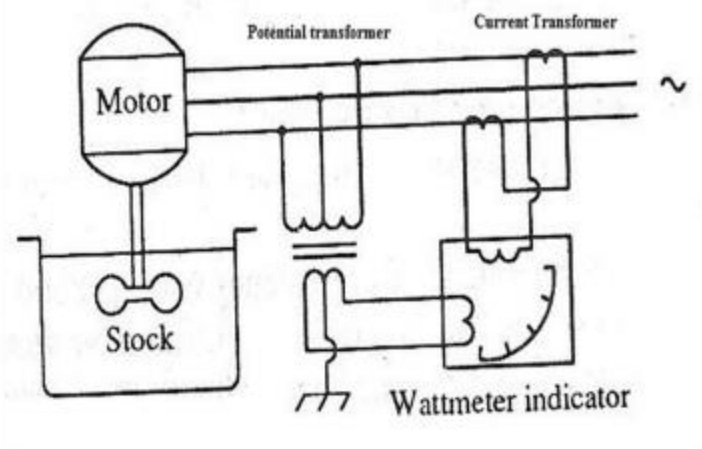
The fibre is kept immersed in the liquid tank. If there is no liquid in the tank, the intensity of light at the source and the detector are almost the same. As the liquid level rises, some light dissipates through the liquid, bringing the intensity down at the detector. So, the difference between intensities of light at the source and the detector can be calibrated against the liquid level. Of course, this calibration will not be the same for all liquids. Secondly, the measurement system is prone to error owing to the wetting of the fibre .

Unit-IV

8 a) Explain how consistency is measured by rotating vane consistency meter. CO4 BL2 7M

A: FIG+WORKING(3+4)
Rotating vane consistency meter:
 Consistency measurement is not less important in industry particularly in the manufacturing processes
 In paper or food processing industries online consistency control is done by suspending an agitator wheel in the

flow box and driving it by an electric motor.
 When the consistency of the material changes there is a change in the torque of the driving motor which can be measured by either pneumatic or elecrical methods.
 By measuring the power required to drive the agitator motor consistency can be measured. The wattmeter is empirically calibrated.



b) Outline the working principle of gamma ray densitometer. CO4 BL4 7M
A: FIG+WORKING(3+4)

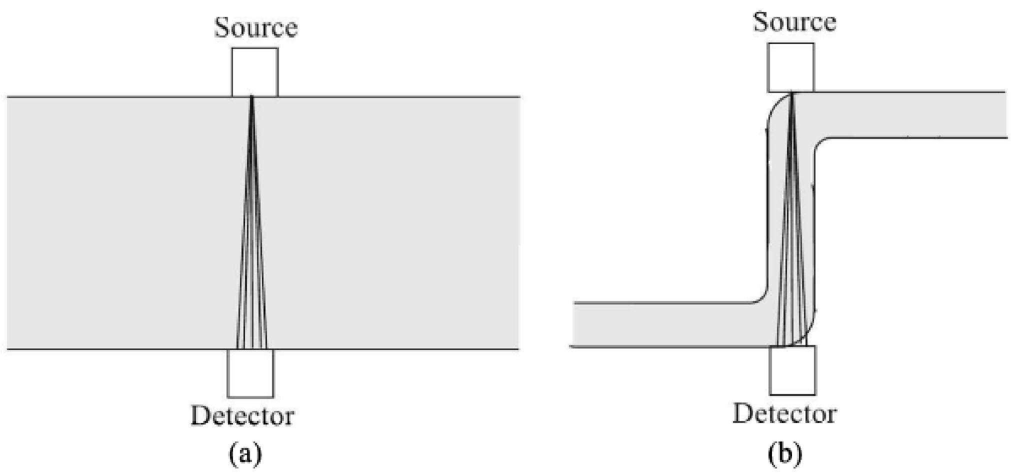


FIG 8.B. γ-ray densitometer installation: (a) for pipe diameter > 150 mm, and (b) for lesser pipe diameter.

$$I = I_0 \exp(-\mu\rho d) \quad (1)$$

where I_0 is the intensity of the incident radiation
I is the intensity of the emitted radiation after passing through the material
μ is the mass absorption coefficient of the material
ρ is the density of the material
d is the distance travelled through the material.

We know from Eq. (1) that the strength or intensity of γ-radiation depends on the density of the material through which it passes. So, it can be used to determine density of a process fluid as shown in Fig. 8.B.

(OR)

9 a) Illustrate the working principle of Saybolt viscometer. CO4 BL3 7M
A: FIG+WORKING(3+4)

Saybolt or Redwood viscometer. Used as a standard for testing petroleum products, this viscometer is known as Saybolt viscometer in USA and Redwood viscometer in UK (also in India). It consists of a cup and orifice assembly as shown in Fig. 9.A A charge of 60 cm^3 of the test fluid is taken in the cup. The stopper is opened and time t taken by the fluid to empty the cup by flowing through the capillary orifice of diameter 1.76 mm and length 12.25 mm is noted.

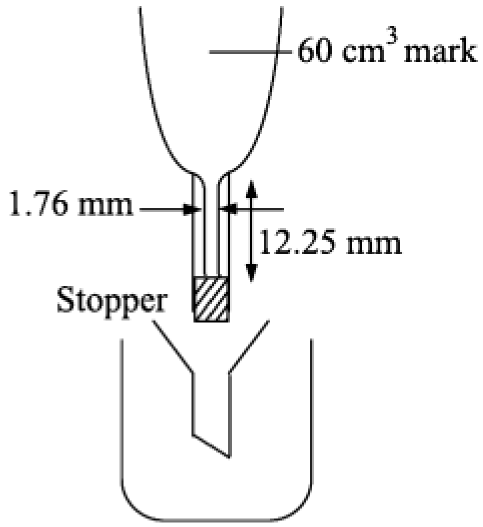


Fig. 9.A Saybolt (Redwood) viscometer.

b) Describe how humidity is measured by dry and wet bulb psychrometer. CO4 BL2 7M

A: FIG+WORKING(3+4)

Wet and Dry Bulb Hygrometer

This ubiquitous hygrometer consists of two mercury-in-glass thermometers, the bulb of one of which is covered with a wick or muslin. The wick or muslin, in turn, is always kept moist by dipping its one end into water contained in a small vessel. Continuous evaporation of water from the surface of the wet bulb keeps its temperature lower than that of the dry bulb. Temperatures indicated by the two thermometers are related to the RH of the sample atmosphere.

For a reliable measurement, the sample velocity should be well over 3 m/s. The hygrometer, therefore, should be mounted at a place where the circulation is adequate either naturally or caused by a circulating fan.

Sling psychrometer. A variant of this hygrometer, called the *sling psychrometer*[1], has a sling attached to it (Fig. 9.B) so that the unit can be whirled manually before a reading is taken.

From a knowledge of the dry-bulb temperature T_d and wet-bulb temperature T_w, RH can be calculated using psychrometric Table[2] or from theoretical formulae. At any temperature T_d, vapour pressure can be expressed by a linear relation of the type

$$p_v = A + B\Delta T$$

where A and B are empirical constants and $\Delta T = T_d - T_w$. A is not constant with temperature because it corresponds to the saturation vapour pressure when $\Delta T = 0$. B is nearly constant,

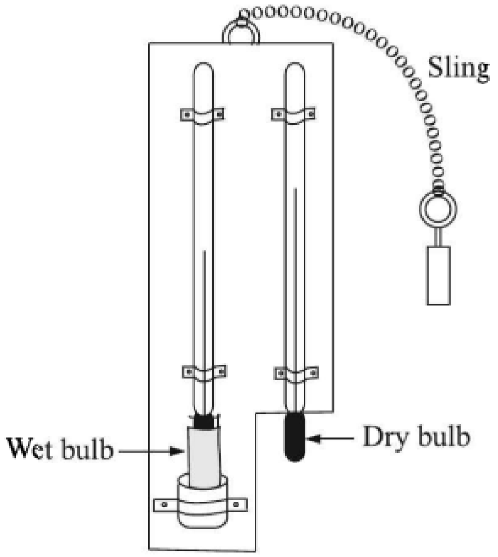


Fig. 9.B Sling psychrometer.

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