Vidyavardhini's College of Engineering and Technology, Vasai (West)

First Year Engineering

Academic Year: 2024−2025

Solutions: Internal Assessment Test-I (IAT-I)

Subject/Code: Elective Physics/BSC2023 **NEP−2020** **Semester: II**
Max. Marks / Duration: 15 / 1 Hr **Date: 28/02/2025**

Q1 Solve any three (2 Marks) [CO1]

(a) Define the following terms: (i) Calibration (ii) Sensitivity.

- **Calibration:** Calibration is the process of adjusting and verifying the accuracy of a measuring instrument by comparing it with a standard reference. (1 Mark)
- **Sensitivity:** Sensitivity is the ratio of the change in the output of a measuring instrument to the corresponding change in the input quantity being measured. (1 Mark)

(b) A researcher measures the following data (x, y): (1, 1), (9, 3), (36, 6). Find the equation of the best-fit line $y = mx + c$ using the least squares method.

The equation of the best-fit line is given by:

$$y = mx + c \tag{1}$$

Using the least squares method, we compute the slope m and intercept c using:

$$m = \frac{n\sum xy - \sum x \sum y}{n\sum x^2 - (\sum x)^2} = 0.135 \approx 0.1 (1\text{ Mark}) \tag{2}$$

$$c = \frac{\sum y - m\sum x}{n} = 1.26 \approx 1.3 \quad (1\text{ Mark}) \tag{3}$$

After calculations, we obtain: $y = 0.1x + 1.2 \quad to \quad 1.3$ all are correct.

(c) What is the sample mean and sample standard deviation of the measurement: 10.2, 10.4, 10.3 and 10.5.

Sample mean ($\bar{x}$) is given by:

$$\bar{x} = \frac{\sum x_i}{n} = \frac{10.2 + 10.4 + 10.3 + 10.5}{4} = 10.35 \qquad (1\text{ Mark}) \tag{4}$$

Sample standard deviation (s) is given by:

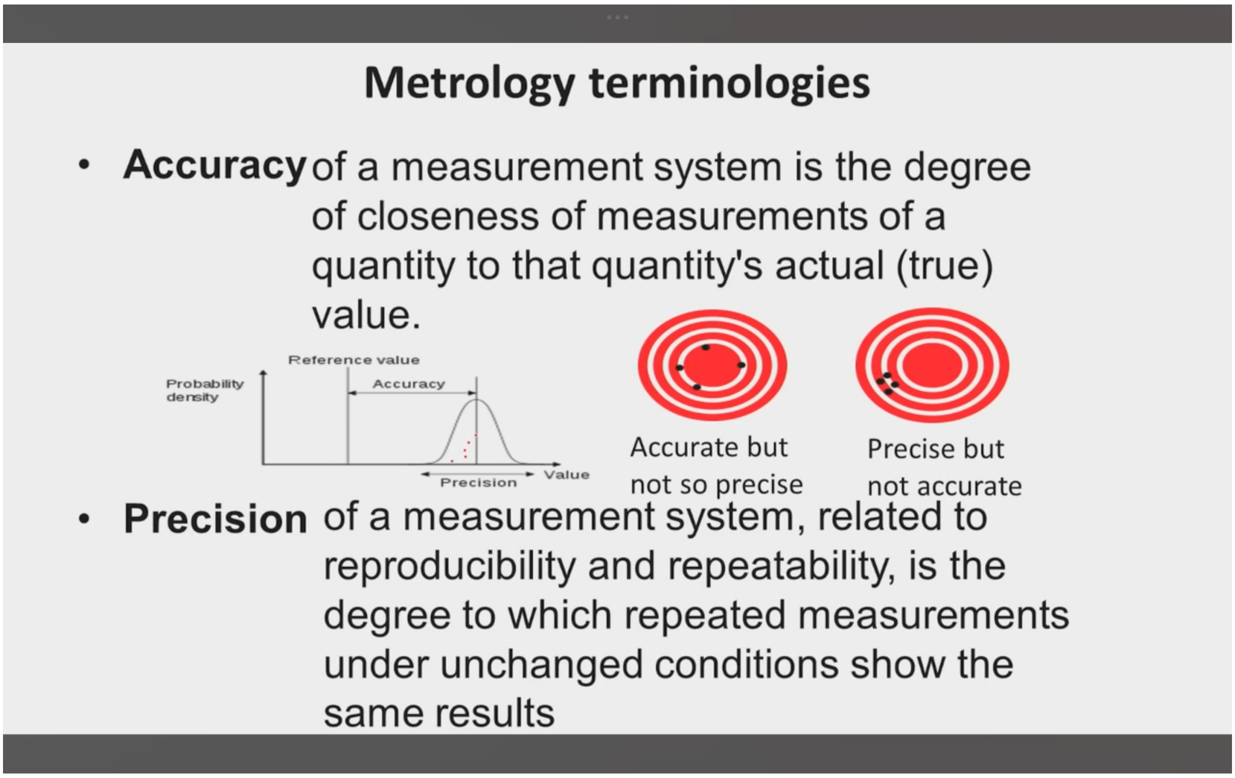
$$s = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}} \qquad \text{(1 Mark)} \tag{5}$$

After calculations:

$$Variance : s^2 = 0.0166 \qquad s \approx 0.126 \approx 0.12 \tag{6}$$

(d) Differentiate between accuracy and precision.

- **Accuracy:** Refers to how close a measurement is to the true or accepted value.
- **Precision:** Refers to how close repeated measurements are to each other, regardless of how close they are to the true value.



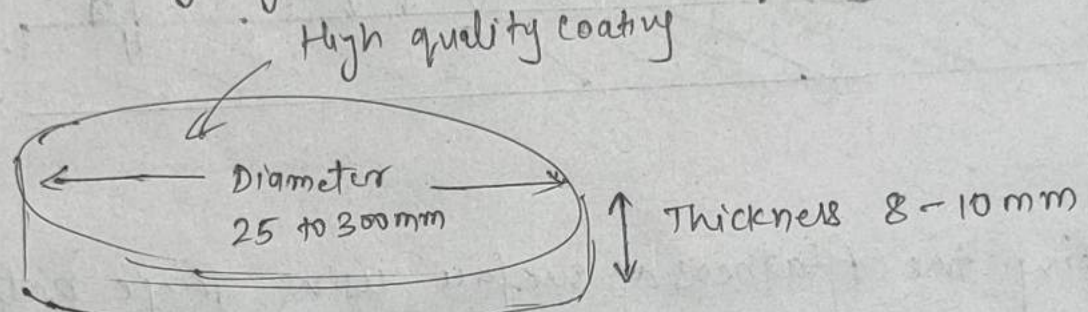
Q2 Solve any one (4 Marks) [CO2]

(a) What is an optical flat? Describe its application in checking the flatness of a surface using fringe patterns.

Interferometry Applied to flatness testing.

Optical flats: (i) A circular piece of optical glass or fused quartz with highly finished flat surfaces.

(ii) The cylindrical surface of the optical flats are finished by grinding / lapping and polishing process.



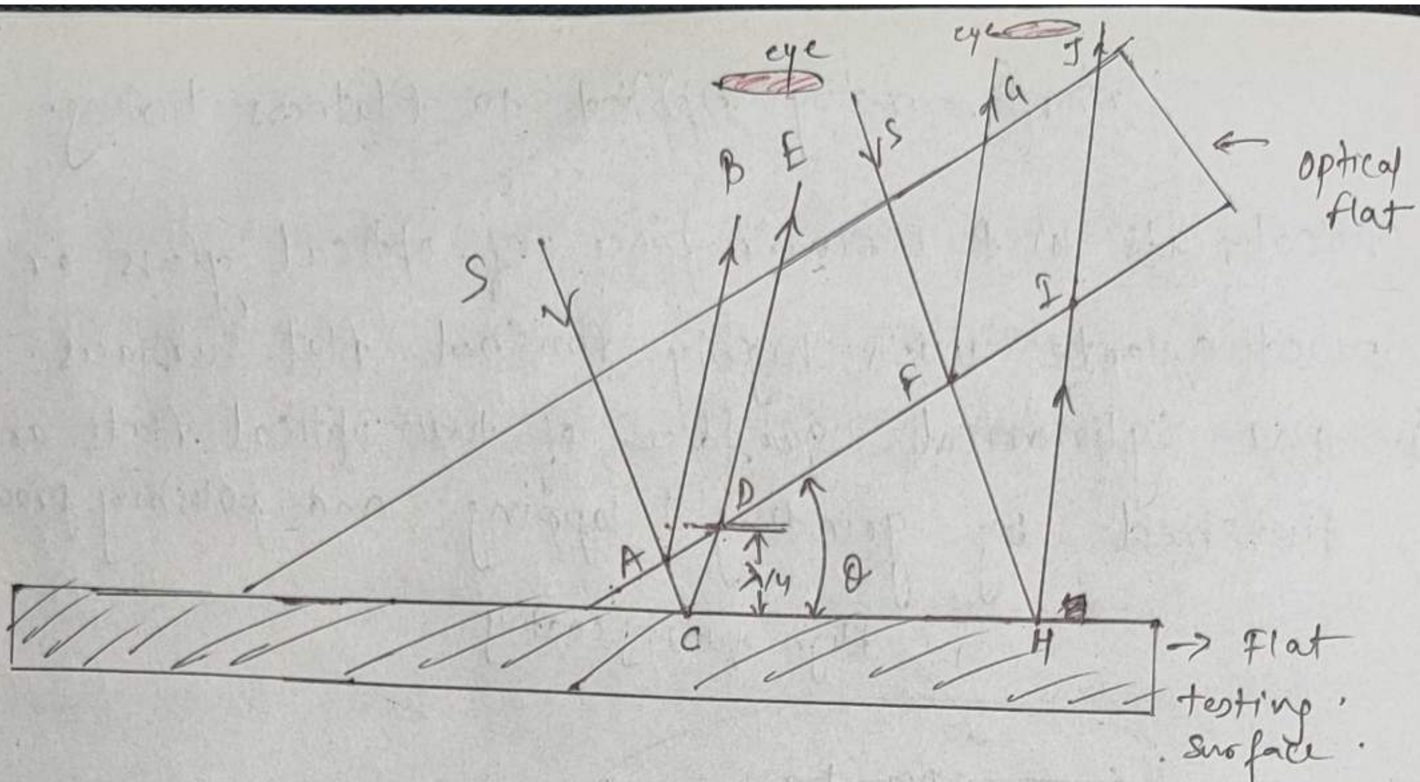
(iii) Optical flats are used to inspect surface flatness by analysing interference patterns created by reflected light (Similar interference what we learned in thin films)

Principle of operation:

i) when an optical flat is placed over a surface with a small air gap, monochromatic light creates an interference pattern due to reflection from the top and bottom surfaces of the air gap.

ii) The interference depends on the path difference of the reflected ray

(iii) If the surface is perfectly flat, straight line fringes are observed; Any deviation from the flatness result in curved or irregular fringes



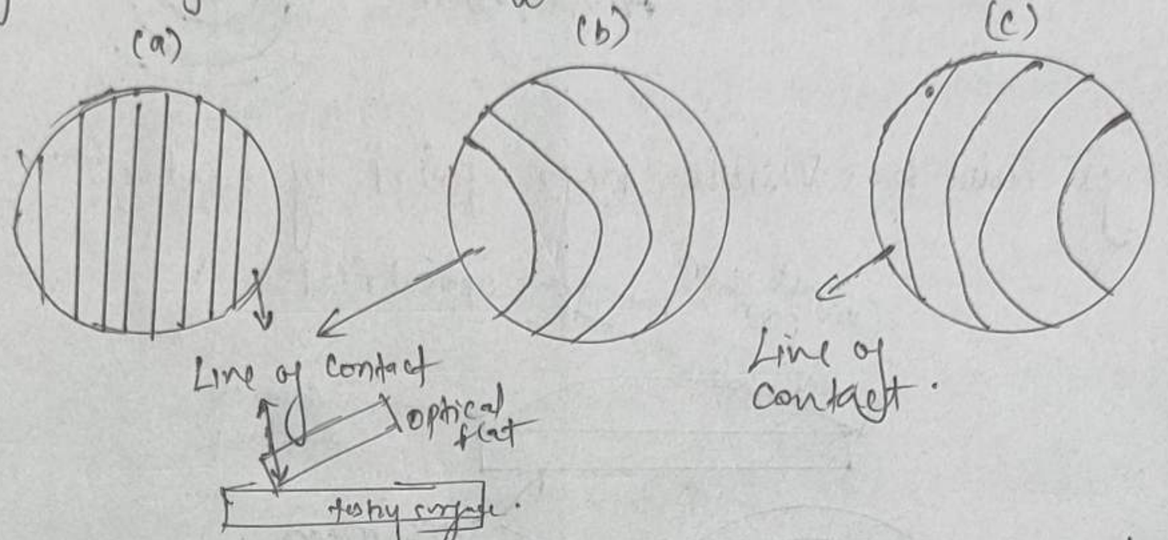
Checking the flatness of surface using fringe pattern.

i) Consider an optical flat placed upon another flat reflecting surface (whose flatness is to be tested) without applying any pressure. making an inclined plane with small angle 'θ'

ii) If the monochromatic light is illuminated as discussed before we can observe number of bands produced due to interfernce ~~form~~ due to partially reflected light along 'AB' and partially transmitted across the gap 'AC'
At point 'C' again the ray is reflected along 'CD'
The two reflected components at point 'A' and 'C' combine and we observe interference pattern due to the path difference by amount 'ACD'.

iii) We know that if ACD = odd multiple of $\frac{\lambda}{2}$ then we observe a dark band. (Let say $ACD = \frac{\lambda}{2}$)
Similarly, if $FHI = \frac{3\lambda}{2}$ then again we see a dark band.

Interference fringes: Based on the level of flatness of the test surfaces, the orientation of these dark and bright fringes will differ.



The above figure shows different fringes for different test surface. When the test surface is

(a) <u>Perfectly flat</u>: A regular fringes are form as shown in fig (a)

(b) <u>Convex and high at centre</u>: fringes are curved and away from line of contact as shown in fig (b)

(c) <u>Concave and low in the centre</u>: fringes are curved and towards the line of contact as shown in fig (c)

*Imp: If the optical flat is resting on curved surface a concentric bright and dark fringe appears (similar what you see in Newton's ring experiment)

Note: Ideally the line of sight should be perpendicular to the optical flat.

(b) Explain the surface contour test. A scratched surface is tested using an optical flat using a light of wavelength 5893 A°. If the distance between two fringes is 1 mm and the distance due to scratch is 0.5μm. Determine the depth of the scratch.

(5)

Surface Contour Test:

The surface contour test is used to study the surface irregularities of a material by analyzing the interference fringes produced when an optical flat is placed at an inclined angle over the surface.

Procedure:

i) For studying various surface contours, an optical flat is inclined over the surface to be tested

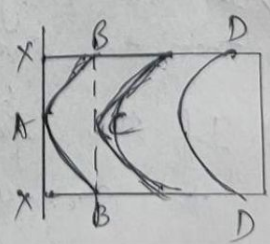
ii) Day light with wavelength $\simeq$ 500 nm is commonly used and the each fringe interval corresponds to an elevation change of 2.5 μm (high precision)

iii) Fringes represent contours of equal height relative to the optical flat, allowing surface mapping

iv) It is important to know where is the optical flat is in contact with surface being tested (The point / Line of contact) under day light the point of contact can be identified by colour changes in the surface being tested.

Here XX: Line of contact

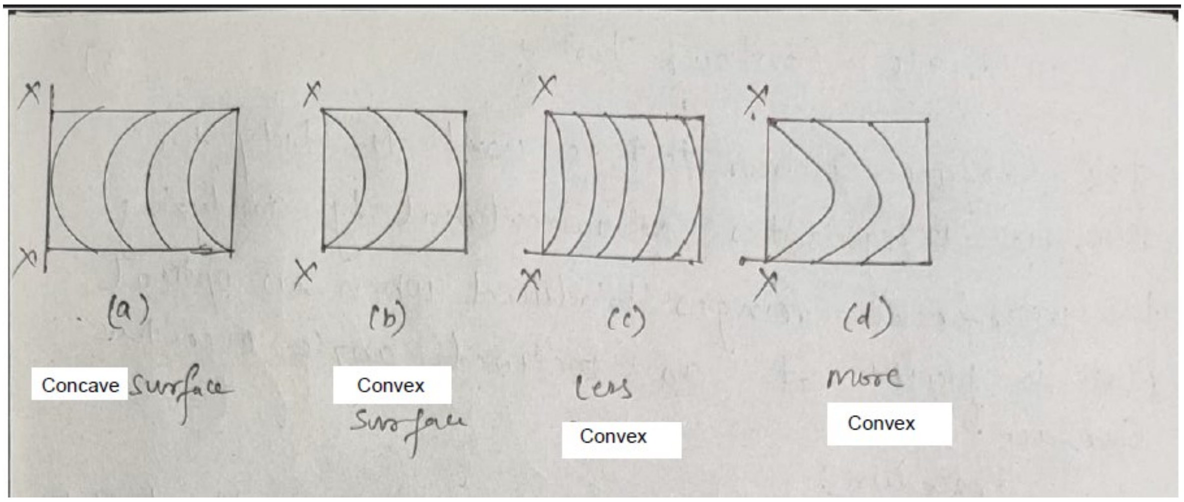
Contour BAB: points at equal height



A Similar phenomenon also observed for Newton's ring experiment

Note: Please do not get confused with fringe pattern shown in reference. R.K. Jain

Concave Surface



Given:

- Wavelength of light: $\lambda = 5893\text{Å}$
- Distance between two fringes: $d = 1$ mm $= 10^{-3}$ m
- Distance due to scratch: $x = 0.5\mu$m

Depth of the scratch (h) is given by:

$$depth = \frac{\lambda d}{2D} \tag{7}$$

Substituting values:

$$depth = \frac{5893 \times 10^{-10} \times 0.5 \times 10^{-6}}{2 \times 1 \times 10^{-3}} = 1.47 \times 10^{-10} = \text{A}^{\circ} \tag{8}$$

Thus, the depth of the scratch is approximately 1.47A°.

Q3 Solve any one (5 Marks) [CO3]

(a)Explain the construction and working of an optical transducer. Give two examples of an optical transducers.

- An optical transducer is a device that converts an optical signal (light) into an electrical signal or converts an electrical signal into an optical signal. They rely on the interaction of light with certain materials, such as semiconductors, photonic crystals, or other light-sensitive substances, to perform the conversion

- **Construction** Optical transducers consist of the following components:

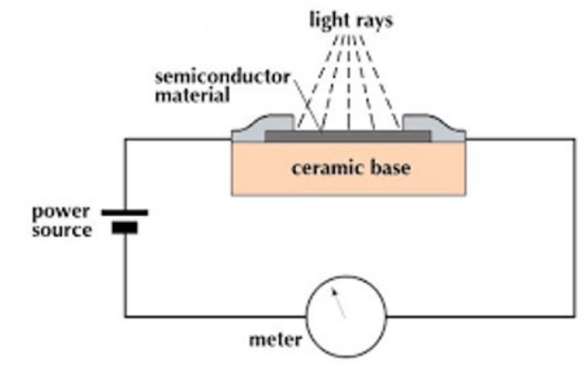
  1. Sensing Element: It could be a photodiode, a photomultiplier tube (PMT), a phototransistor, or any other light-sensitive device. For example, in a photodiode, a semiconductor material like silicon is used to detect light and generate an electrical current based on the intensity of the incident light.

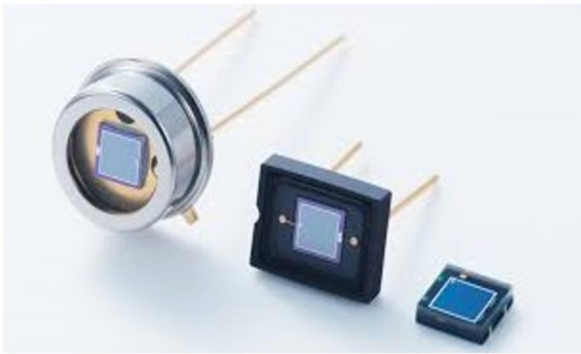
  2. Optical System: Optical lenses, mirrors, or fibers may be used to focus, direct, or collect light from the environment or from a specific source.

3. Power Supply: Some optical transducers may require a power supply to operate their internal components, such as amplifiers or sensors.

4. Output Interface: The electrical signal produced by the transducer is output via appropriate connectors for measurement, recording, or processing.

- **Working**





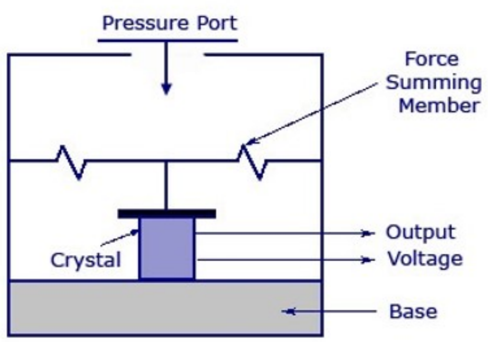
1. Some optical transducers use the phenomenon of photoelectric effect, when light strikes the semiconductor, it generates an electron-hole pair, which produces an electrical current proportional to the light intensity.

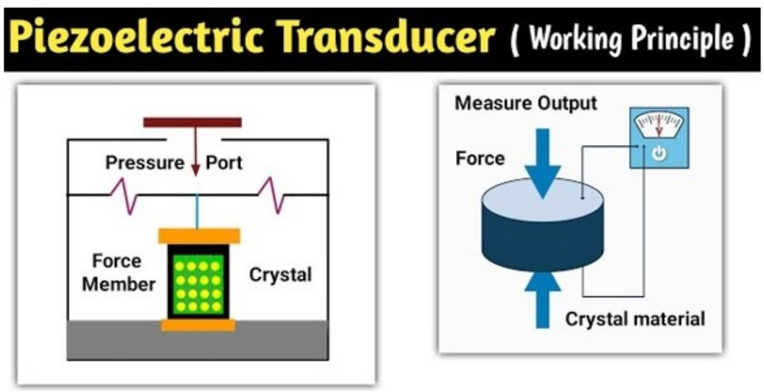
2. Some optical transducers use the principle of total internal reflection, such as in fiber-optic sensors, where changes in the refractive index of the material due to environmental conditions cause changes in the transmitted light signal.

3. Some optical transducers, like photoconductive detectors, rely on the change in the electrical conductivity of a material when exposed to light. This principle is commonly used in devices like light-dependent resistors (LDRs).

- Two examples of optical transducers are a photodiode and a CCD image sensor (Charge-Coupled Device image sensor), both of which convert light energy into electrical signals.

(b) What is piezoelectric effect? Explain the construction and working of piezoelectric transducer.





- Piezoelectric transducers are devices that convert mechanical energy (such as pressure, force, or vibration) into electrical energy, or vice versa, based on the piezoelectric effect. The piezoelectric effect refers to the ability of certain materials (like quartz, lead zirconate titanate (PZT), and others) to generate an electrical charge in response to mechanical stress.

- **Construction**

  1. The core of a piezoelectric transducer is the piezoelectric material. This material is typically a crystal (e.g., quartz) or a ceramic (e.g., lead zirconate titanate (PZT)). These materials exhibit the piezoelectric effect, where the application of mechanical stress induces an electrical charge, and the application of an electrical field induces mechanical deformation.

  2. Electrodes are attached to the surface of the piezoelectric material to collect the electrical charge generated by mechanical stress. These electrodes are usually made of conductive materials such as silver, copper, or gold.

  3. The piezoelectric element is often encapsulated in protective housing to prevent damage from external environmental factors such as moisture or temperature changes. The housing also ensures the correct mechanical alignment of the piezoelectric material.

  4. An electrical circuit is typically connected to the transducer to condition the electrical signal produced by the piezoelectric element. This may involve amplification or signal filtering, depending on the application.

- **Working**

  1. When mechanical stress (such as pressure or vibration) is applied to the piezoelectric material, the material undergoes a deformation. This deformation causes a displacement of charged particles within the material, leading to an electric dipole moment.

  2. The electrodes attached to the material collect the generated charge, which can then be measured as a voltage or current, depending on the application.

  3. In the reverse mode, when an electrical field is applied to a piezoelectric material, it causes the material to undergo mechanical deformation (strain). This phenomenon is known as the inverse piezoelectric effect.

  4. The amount of strain produced is proportional to the applied electric field, which allows piezoelectric transducers to be used as actuators for precise control of movement, such as in micro-positioning systems or ultrasonic transducers.