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CMR INSTITUTE OF TECHNOLOGY, BENGALURU.

Internal Assessment Test 2 – Nov. 2017

Sub:	EXPERIMENTAL STRESS ANALYSIS				Sub Code:	10ME761	Branch:	MECH
Date:	09/11/2017	Duration:	90 min's	Max Marks: 50	Sem/Sec:	VII		OBE

Answer any FIVE FULL Questions

		MARKS	CO	RBT
1.	What is brittle coating technique? How it is useful for stress analysis?	[10]	CO6	L2
2.	Explain procedure for measurement of fractional fringe order by Tardy's method of compensation.	[10]	CO5	L4
3 (a)	Write short notes on Birefringent coating materials.	[05]	CO6	L2
(b)	Write short note on model to prototype scaling.	[05]	CO5	L2
4.	Explain the stress freezing technique for three-dimensional photo-elasticity.	[10]	CO5	L4
5.	What are the various methods of calibration of a photoelastic model material? Explain any two methods.	[10]	CO4	L4
6.	Explain the shear difference method for the separation of principal stresses in 2-D photo elasticity.	[10]	CO4	L4
7.	Describe plane polariscope. Identify all its components and derive expression for the intensity of the light wave in a dark field arrangement.	[10]	CO4	L1

Course :	Experimental Stress Analysis	**Course Code:**	10ME761

COURSE OUTCOMES		MODULES COVERED	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO's	DESCRIPTION																	
CO1	**Describe** variety of strain gauges, mounting techniques and strain gauge circuits	1	2	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
CO2	**Calculate** strain using strain gauge rosettes	2	2	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-
CO3	**Explain** the nature of light and the process of polarization	3	2	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
CO4	**Explain** different methods of 2 D photo-elasticity along with properties of different materials for strain measurement	4	2	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
CO5	**Describe** the different methods of 3D photo elasticity for strain measurement viz, stress freezing , and Moirés method	5,8	2	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
CO6	**Explain** different types of coatings, test strain data using brittle coating and bi-refringent coating	6,7	2	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-

COGNITIVE LEVEL	REVISED BLOOMS TAXONOMY KEYWORDS
L1	List, define, tell, describe, identify, show, label, collect, examine, tabulate, quote, name, who, when, where, etc.
L2	summarize, describe, interpret, contrast, predict, associate, distinguish, estimate, differentiate, discuss, extend
L3	Apply, demonstrate, calculate, complete, illustrate, show, solve, examine, modify, relate, change, classify, experiment, discover.
L4	Analyze, separate, order, explain, connect, classify, arrange, divide, compare, select, explain, infer.
L5	Assess, decide, rank, grade, test, measure, recommend, convince, select, judge, explain, discriminate, support, conclude, compare, summarize.

PROGRAM OUTCOMES (PO), PROGRAM SPECIFIC OUTCOMES (PSO)				CORRELATION LEVELS	
PO1	Engineering knowledge	PO7	Environment and sustainability	0	No Correlation
PO2	Problem analysis	PO8	Ethics	1	Slight/Low
PO3	Design/development of solutions	PO9	Individual and team work	2	Moderate/ Medium
PO4	Conduct investigations of complex problems	PO10	Communication	3	Substantial/ High
PO5	Modern tool usage	PO11	Project management and finance		
PO6	The Engineer and society	PO12	Life-long learning		
PSO1	Design, implement and maintain business applications in a variety of languages using libraries and frameworks.				
PSO2	Develop and simulate wired and wireless network protocols for various network applications using modern tools.				
PSO3	Apply the knowledge of software and design of hardware to develop embedded systems for real world applications.				
PSO4	Apply knowledge of web programming and design to develop web based applications using database and other technologies				

MARKING SCHEME

1. What is Brittle Coating Technique? How it is useful for stress analysis?

⇒ a. Explain the Brittle Coating Technique
- Draw figure [2 mrks]
- Explain methods of Coating [3 mrks]

b. Explain uses of Brittle Coating [5 mrks]

2. Explain the procedure for measurement of fractional fringe order by Tardy method of compensation?

⇒ a. Draw figure [2 mrks]

b. Write formulae derived from the Circular polariscope [3 mrks]

c. Derive Tardy method by fractional fringe order [5 mrks]

3.

(a) Write short note on Birefringent Coating material?
- Draw figure [2 mrks]
- Explain the method of coating [3 mrks]

(b) Write a short note on model to prototype scaling?
- Write equation for scaling [2 mrks]
- Explain model to prototype scaling with formulae [3 mrks]

4. Explain the stress freezing technique for 3-dimensional photo elasticity?
- Draw bond structure for model [2 mrks]
- Explain procedure for stress freezing [5 mrks]
- Diagram with detailed explanation for stress freezing technique. [3 mrks]

5. What are the various methods of calibration of a photoelastic model material? Explain any two methods?

- Name all the calibration method [4 mrks]
- Explain any two with diagram [3+3 mrks]

6. Explain shear difference method for the seperation of principal stress in 2 D photo elasticity?

- Draw diagram for shear diff. method [2 mrk]
- write all explanation for shear diff. method including all formolae [8 mrks]

7. Describe plane polariscope. Identify all its components and derive expression for the intensity of the light wave in a dark field arrangement?

- Draw fig for plane polariscope [2 mrks]
- Describe eqn for intensity of light in dark field arrangement [8 mrks]

1. What is Brittle Coating technique? How is it useful for Stress Analysis?

⇒ A technique where suitable material which is brittle in nature is sprayed on the specimen under test, gives crack pattern upon loading, which can be used for quantitative surface strain analysis is called brittle coating technique.

- Compound specimen is brittle coated allow to dry, which fractures on crack in response to strain produced, indicating the magnitude and direction of surface strains in the model.
- When the surface strains are within the elastic limit the resulting crack particles provide an overall graphical picture of the strain distribution, sequence and direction of surface strains.
- The state of the strain in the coating thus indicates qualitatively and quantitatively, the state of strain in the model and hence, the state of stress.
- The technique do not require the construction of photo elastic specimen, tests with brittle coatings can be conducted with ease and it lesser costs as compared to other techniques. It highlights the area of stress concentration, it can be applied to any material.
- Accuracy of measurements is dependent on temperature, humidity variations and thickness of the coatings.

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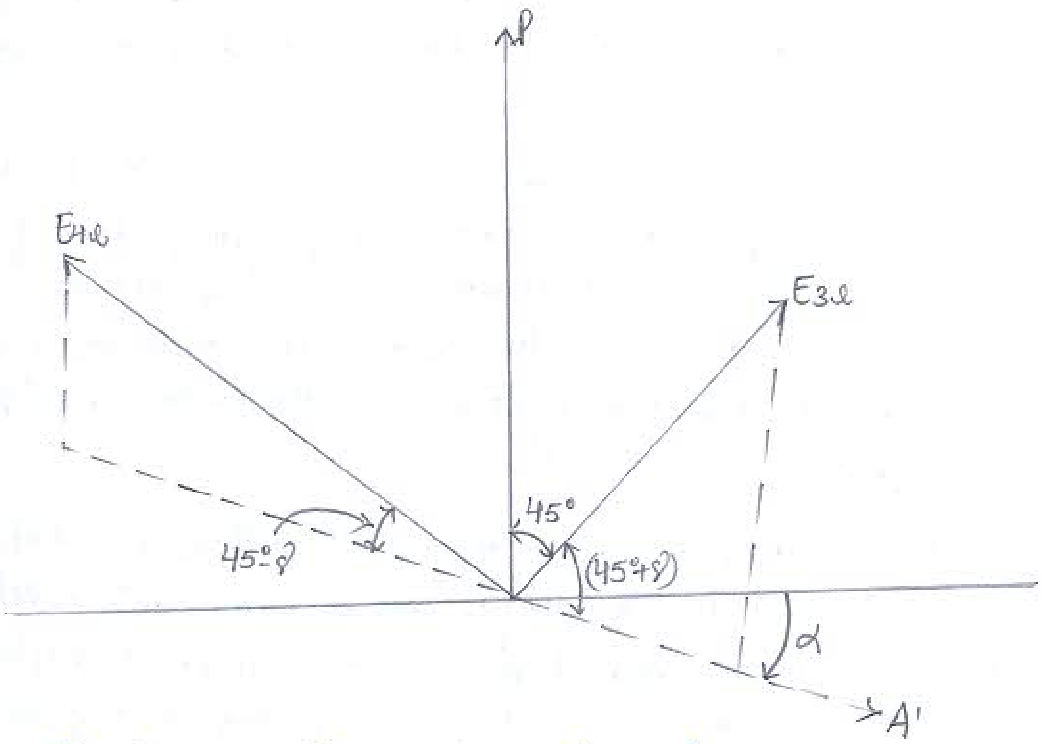
2. Explain procedure for measurements of fractional fringes order by Tardy method of Compensation?

⇒ The Tardy method of compensation is generally preferred over the other techniques since no auxiliary equipment is required and the analyzer of the polariscope serves as the compensator. In this method, the polariser of the polariscope is aligned with the dirn. of the principal stress σ_1 at the point of interest and all the other elements of the polariscope are rotated relative to the polarizer so that a standard dark field polariscope exists. Then the analyzer alone is rotated to obtain extinction. The rotation of the analyzer gives the fractional fringe order.

- As shown in fig, here $\theta = -\pi/4$ and the light vector emerging out from the second QWP becomes,



- $$E_{3e} = \frac{-a}{\sqrt{2}}\left[\sin\left(\omega t + \Delta - \frac{\pi}{4}\right)\cos\left(-\frac{\pi}{4}\right) - \cos\left(\omega t - \frac{\pi}{4}\right)\sin\left(-\frac{\pi}{4}\right)\right.$$
$$= \frac{-a}{2}\left[\sin\left(\omega t + \Delta - \frac{\pi}{4}\right) + \cos\left(\omega t - \frac{\pi}{4}\right)\right]$$

- Hly,
$$E_{4e} = \frac{a}{2}\left[-\sin\left(\omega t - \frac{\pi}{4}\right) - \cos\left(\omega t + \Delta - \frac{\pi}{4}\right)\right]$$

- let δ be the angle through which the analyzer should be rotated to obtain extinction, ie $E_t = 0$, then

- $$E_t = E_{4e}\cos\left(\frac{\pi}{4} - \delta\right) - E_{3e}\cos\left(\frac{\pi}{4} + \delta\right)$$
$$= \frac{-a}{2}\left[\sin\left(\omega t + \Delta - \frac{\pi}{4}\right) + \cos\left(\omega t - \frac{\pi}{4}\right)\right]\cos\left(\frac{\pi}{4} - \delta\right) -$$
$$\frac{a}{2}\left[-\sin\left(\omega t + \left(-\frac{\pi}{4}\right)\right) - \cos\left(\omega t + \Delta - \frac{\pi}{4}\right)\right]\cos\left(\frac{\pi}{4} + \delta\right)$$

Simplifying above eqn, we have

$$E_t = a\sin\left(\omega t + \frac{\Delta}{2}\right)\left\{\sin\left(\frac{\Delta}{2} - \theta\right)\right\} = 0$$

Hence $\sin\left(\frac{\Delta}{2} - \theta\right) = 0$

or $\left(\frac{\Delta}{2} - \theta\right) = n\pi$, $n = 0, 1, 2, 3 \ldots$

or $\frac{\Delta}{2} = n\pi + \theta$

or $N = \frac{\Delta}{2\pi} = n + \frac{\theta}{\pi}$

3.
(a) Write a short note on Birefringent Coating material?

- The method of photoelastic coatings also called the method of birefringent coatings or photostress, extends the well known photoelastic method to the measurements of surface strains in opaque materials like steel, rock etc. It is one of the whole field experimental method that is suitable for two and three dimensional models. The coating is a thin layer of birefringent material, usually a polymer that is in stress. When a prototype is loaded, the surface strains are transmitted to the coating, reproducing the producing strain field in the coating. To provide light reflection at the interface, the coating is bonded to the structure with a reflective cement. When viewed through a light polariscope, the strain coating exhibits black isoclinic and coloured isochromatic fringes. Isoclinic fringes provide direction of principal strain whereas isochromatic fringes, when viewed in normal incidence light, they permitt the determination of the difference in the principal strains, whereas when viewed in oblique incidence light, they permit the determination of the magnitude and sign of the individual principal strains.

(b) Write a short note on model of Prototype Scaling?

- Photoelastic model is fabricated from polymeric material and it is used in the place of actual prototype which is usually a metal, obviously the elastic constants of the model are greatly different from those of the metallic prototype.
- The compatibility equations in terms of stress components for 2D plane stress and plane strain cases are given by,

$$\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right)(\sigma_x + \sigma_y) = -(1+\nu)\left(\frac{\partial F_x}{\partial x} + \frac{\partial F_y}{\partial y}\right) \Rightarrow \text{Plane stress}$$

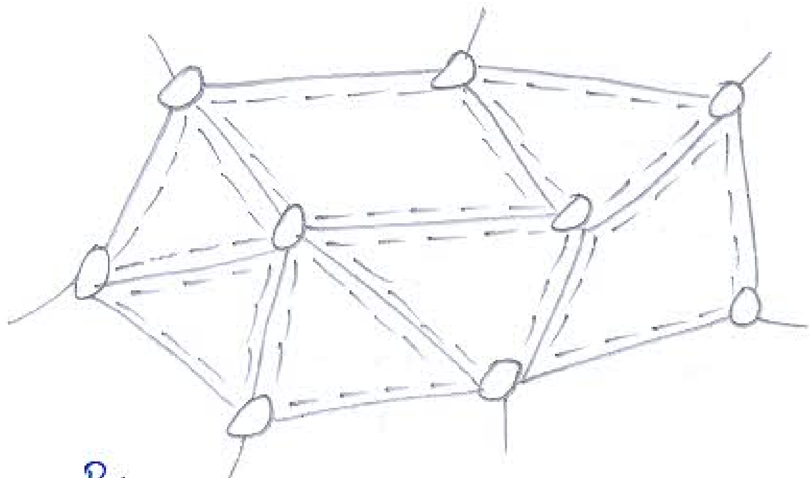
$$\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right)(\sigma_x + \sigma_y) = \frac{-1}{(1-\nu)}\left(\frac{\partial F_x}{\partial x} + \frac{\partial F_y}{\partial y}\right) \Rightarrow \text{Plane strain}$$

where ν = poison's ratio. F_x and F_y are the body forces in x and y directions.

- It can be seen from the above relations that the stress distributions are independent of elastic constants in general ie the stress results for an elastic analysis are applicable to a prototype constructed from any material.
- But we cannot apply the same magnitude of load as applied in prototype, because the deformations and strains induced are more in case of plastic materials.
- The model may differ from prototype in scale, thickness, applied load and elastic constants. Hence, scaling relationships are required to relate the results.

4. Explain the stress freezing technique for three dimensional photo-elasticity?

⇒ In this method, the model deformations caused by the applied loads are locked in the model. This is made possible by the diphase behaviour of many polymeric materials when they are heated. Polymeric materials are composed of hydrocarbon molecular chains. These molecular chain exists in the material in two essential forms. One form is well bonded, form three dimensional network called primary bonds, the second are called the secondary bonds, occur in form which is less solidly bondly and are shorter than primary bonds. At room both bonds are firm and resist deformation when load is applied. However, as the temp is increased, the secondary bond looses their ability to resist deformation. At a particular temp called as the critical temp, the secondary bonds breakdown completely and the applied load is carried completely by the primary bonds.



Primary and secondary bonds

- Consider a model made of such a diphase polymeric material and subjected to a given system of loading. Initially at room temp, the load is carried by the primary bonds and the secondary bonds together. Let the temperature be raised gradually until the critical temperature for the particular material is reached. At this temperature, the secondary bonds breakdown, becoming a soft jelly like material. The load is taken now entirely by the primary bond. With the load still on, the temp is gradually reduced to the room temperature. During the process, the process, the secondary bond gradually solidifies and lock the primary bond in their deformed configuration. If the load is now removed, primary bonds tends to regain their original configuration, but it is however prevented by the secondary bonds is reached which doesnot differ appreciably from the deformed configuration. Hence, the deformations are locked inside the model.

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5. What are the various methods of calibration of a photo-elastic model material? Explain any two methods?

- The various methods of calibration of a photo elastic model material are as follows:-

i) Simple tensile specimen
ii) Beam under pure bending
iii) Circular disc under diametrical compression.

i) Simple Tensile Specimen:-

- If we prepare a simple tensile specimen as shown below, whose width is w, thickness h, under the load P, the uniform stress in the test specimen is,

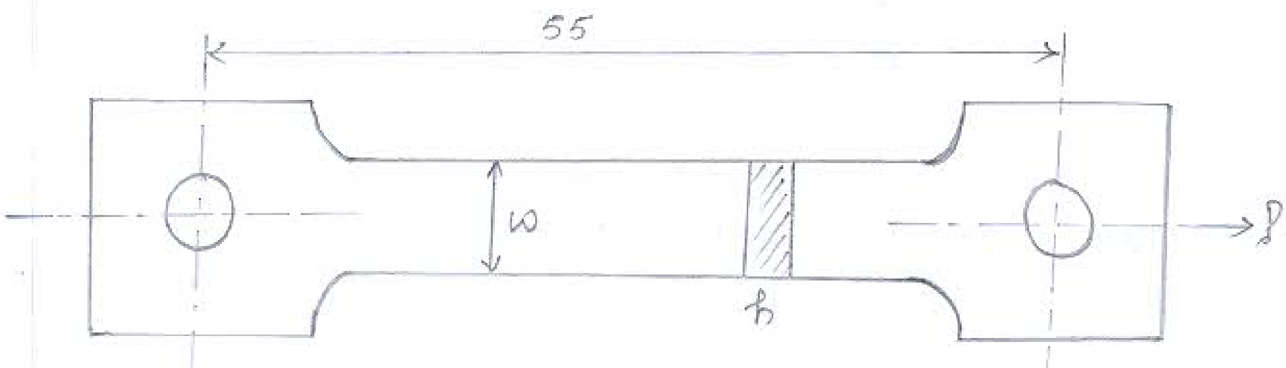
$$\sigma_1 - \sigma_2 = P/wh \;, \quad \sigma_2 = 0$$

Applying stress optic law, we get

$$\sigma_1 - \sigma_2 = \frac{N f_\sigma}{h}$$

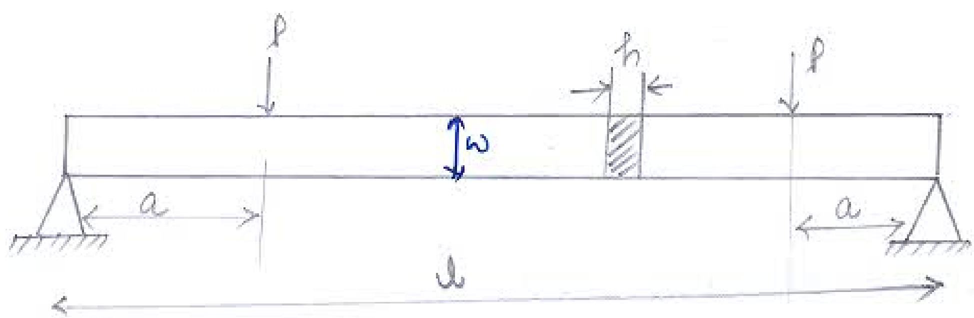
$$\frac{P}{wh} = \frac{N f_\sigma}{h}$$

Hence, $f_\sigma = \left(\frac{P}{N}\right)\frac{1}{w}$



- In the tensile specimen, we get escaping type of fringes ie as the load is increased from zero, successive fringes appear in the field of view and dissappear as the load is increased, Generally a graph is plotted between the load applied P and fringe order N and its slope is determined, which is substituted in the above formula, to determine f_σ.

ii) Beam under pure bending :-



- A rectangular beam of thickness 'h' and depth 'w' is as shown, may be used and subjected to pure bending to determine f_σ. Pure bending in the beam may be produced by applying equal loads 'P' at a distance 'a' from the ends of the beam of length 'l' as shown. The uniform bending moment M in the middle of the beam is,

$$\sigma_1 = \frac{M}{I} \cdot y = \frac{Pa}{\left(\frac{hw^3}{12}\right)} \cdot \frac{w}{2} = \frac{Pa}{\left(\frac{hw^2}{6}\right)}$$

$$\sigma_2 = 0$$

Hence, $\frac{6Pa}{hw^2} = \frac{nf_\sigma}{h}$

or $f_\sigma = \left(\frac{P}{N}\right)\cdot\frac{6a}{w^2}$

- A graph is plotted between P and N, and slope of the graph is substituted in above eqn to determine f_σ. Here, we get non-escaping type of fringes.

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6. Explain the shear difference method for the seperation of principal stresses in 2-D photo elasticity?

⇒ This is a step by step integration process along a starting line starting from a point where one of the normal stresses is known. Generally, the initial point lies on the boundary where the individual values of σ_1 and σ_2 are known. The method makes use of one of the differential equations of equilibirium, in the absence of the body forces.

$$\frac{\partial \sigma_x}{\partial x} + \frac{\partial \tau_{xy}}{\partial y} = 0$$

$$\frac{\partial \sigma_y}{\partial y} + \frac{\partial \tau_{yx}}{\partial x} = 0$$

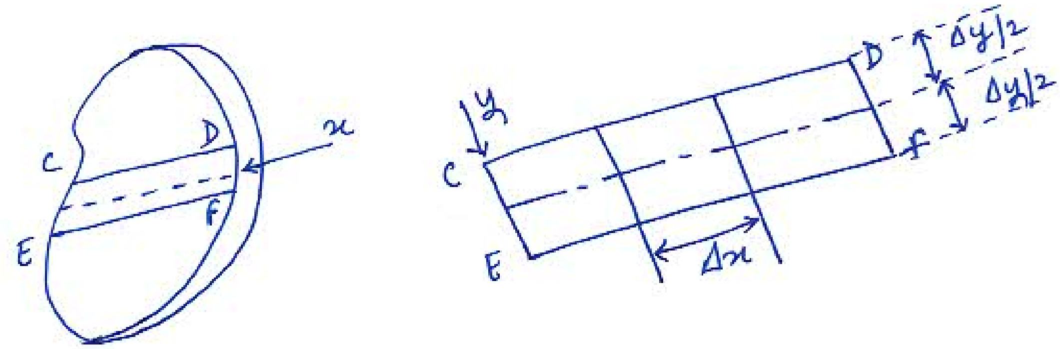
- The line of integration called the x and axis, joins the point of interest where the individual values of σ_x and σ_y are known. Assuming that this line is called the x axis, the first equation above can be integrated from the initial point 'i' to the desired point 'j'. Thus

$$\int_i^j \frac{\partial \sigma_x}{\partial x}\,dx = -\int_i^j \frac{\partial \tau_{xy}}{\partial y}\,dx$$

$$(\sigma_x)_j = (\sigma_x)_i - \int_i^j \frac{\partial \tau_{xy}}{\partial y}\,dx$$

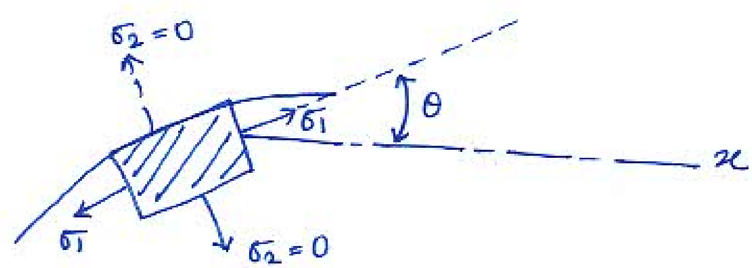
$$\text{or } (\sigma_x)_j = (\sigma_x)_i - \sum_i^j \frac{\Delta \tau_{xy}}{\Delta y}\,\Delta x$$

- The values of $\frac{\Delta \tau_{xy}}{\Delta x}$ are calculated from the values of τ_{xy} determined along the two line CD and EF, which are $\Delta y/2$ paths from the line of integration ie x axis,



- Let θ be the angle between the tangent to the boundary and the x axis. At the boundary, one of the principal stresses is zero and other stress tangential to the boundary can be evaluated from the isochromatics.

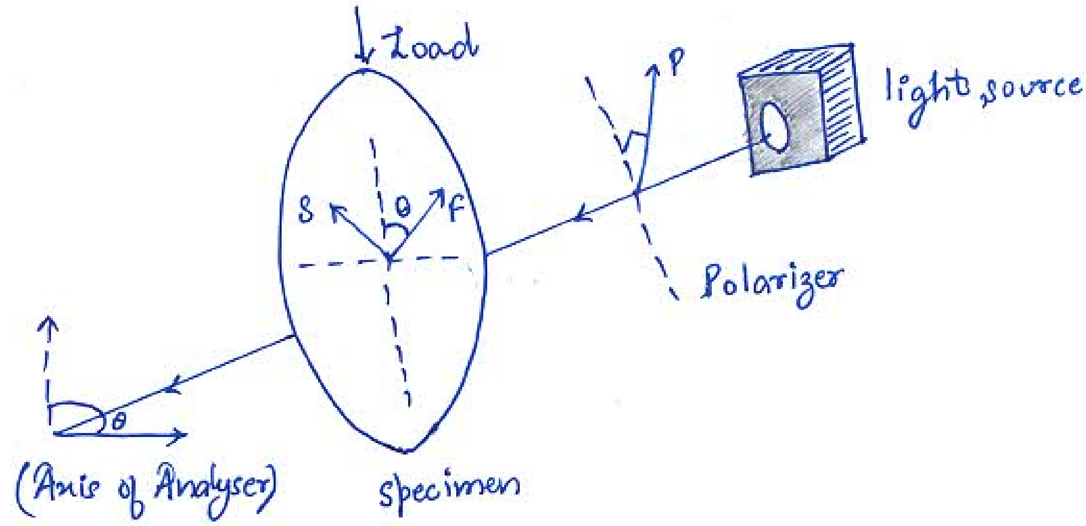
Then from the equation is given as,

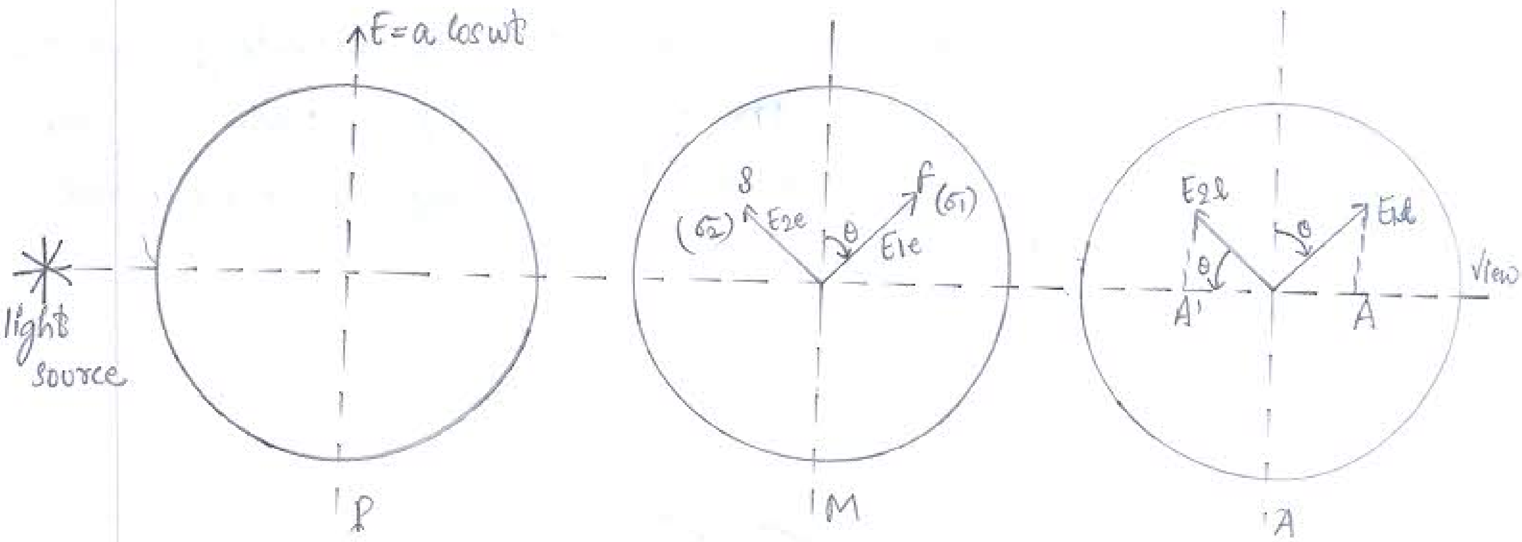


$$\therefore \; (\sigma_x)_j = (\sigma_1)_i \cos^2\theta$$

7. Describe the Plane polariscope. Identify all its components and derive expression for the intensity of the light wave in a dark field arrangement.

- The polariscope is an optical instrument containing polaroids that uses the properties of polarized light for its operation.





⇒ <u>Expression for dark field arrangement.</u>

$E = a \cos \omega t$

- light along the fast and slow axis at entry,

$E_{1e} = a \cos\theta \cos \omega t$

$E_{2e} = a \sin\theta \cos \omega t$

- light vector along the fast and slow axis at exit, we have

$E_{1l} = a \cos(\omega t + \Delta)\cos\theta$

$E_{2l} = a \cos \omega t \sin\theta$

- Light vector transmitted,

$$E_t = E_{1e}\sin\theta - E_{2e}\cos\theta$$

$$= (a\cos(\omega t+\Delta)\cos\theta)\sin\theta - (a\cos\omega t\sin\theta)\cos\theta$$

$$= a\cos(\omega t+\Delta)\sin\theta\cos\theta - (a\cos\omega t\sin\theta\cos\theta)$$

$$= a\sin\theta\cos\theta\left(\cos(\omega t+\Delta) - \cos\omega t\right)$$

$$= -2a\sin\theta\cos\theta\left[\sin\left(\frac{2\omega t+\Delta}{2}\right)\sin\left(\frac{\Delta}{2}\right)\right]$$

$$E_t = -\sin 2\theta\left[a\sin\left(\omega t+\frac{\Delta}{2}\right)\sin\frac{\Delta}{2}\right]$$

$$I \propto E^2$$

$$\therefore I = a^2\sin^2 2\theta\sin^2\frac{\Delta}{2}\sin^2\left(\omega t+\frac{\Delta}{2}\right)$$

$$I = I_0\sin^2 2\theta\sin^2\frac{\Delta}{2}\sin^2\left(\omega t+\frac{\Delta}{2}\right)$$

where I_0 = max. Intensity of light