EL-MANSOURA UNIVERSITY
FACULTY OF ENGINEERING
DEPT. OF PROD. & MECH. DESIGN ENG.
TIME ALLOWED: 3 HOURS

FINAL EXAM., JAN. 2010
SYSTEMS OF STRESS ANALYSIS
2nd YEAR STUDENTS
MAXIMUM GRADE: 70 POINTS

SOLVE THE FOLLOWING PROBLEMS; NEAT SKETCHES ARE REQUIRED; ALL PROBLEMS HAVE SAME POINTS; EQUATION SHEET IS PROVIDED.

PROBLEM # 1:

(a) REWRITE THE FOLLOWING STATEMENTS AND MARK EACH EITHER (√) or (×)

1. Strain gages should exhibit a linear response over a wide range of strain. ( )
2. Most electrical resistance strain gages are made of Cu-Al alloy known as Constantan (or Advance) ( )
3. Brittle coating technique is based on theory of light. ( )
4. Transmission polariscopes are used in photostress coating systems . ( )
5. If : $\sigma_{11} = 100$, $\sigma_{22} = 20$, $\sigma_{33} = 0$, the third stress invariant $I_3 = 120$ ( )
6. A wave plate is a lens which resolves light vector into two orthogonal components having different transmitting velocities ( )
7. In the case of $\sigma_{xx} = \sigma_{yy} = 100$ MPa, $\sigma_{zz} = \tau_{xy} = \tau_{yz} = \tau_{zx} = 0$, the maximum shear stress = 0 ( )
8. Strain measurements are usually confined to free surfaces of components ( )
9. Acoustical strain gages have high sensitivity ( )
10. The Whitstone bridge circuit is suitable for dynamic strain measurements ( )

(b) Show how a single-element strain gage can be used and how it should be oriented to determine σ_1, σ_2 & τ_{max} in the following plane stress states:

1. A round bar subjected to a torque T.
2. A thin-walled cylindrical pressure vessel.
3. A thin-walled spherical pressure vessel.

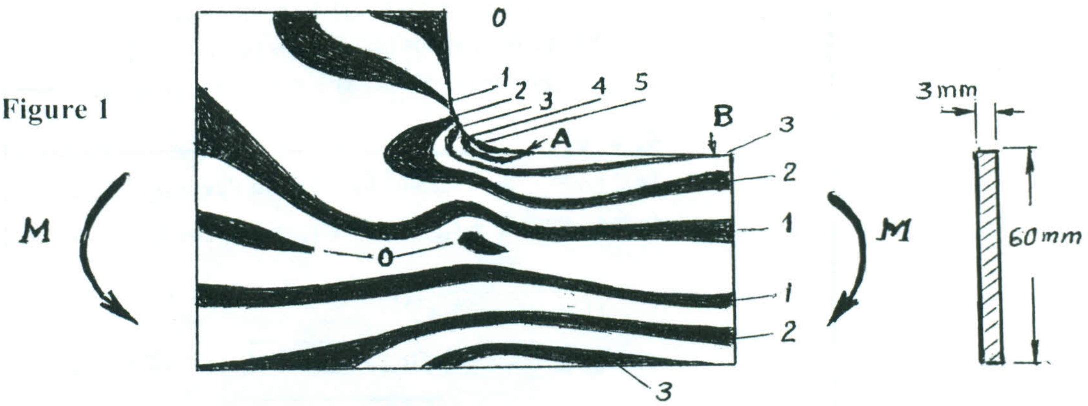
Represent each case on a sketch.

PROBLEM # 2:

(a) Explain, with the aid of accurate sketches, **three** of the following expressions:
(1) **Birefringent material**; (2) **Stress freezing**; (3) **Isoclinics**; (4) **Isochromatics**.

(b) Figure 1 shows isochromatic fringe pattern at the fillet region of a photoelastic specimen subjected to a bending moment, M. If the specimen thickness is 3 mm, and the width of the narrow section is 60 mm; and taking $f_\sigma = 20$ N/mm, it is required to determine:
(1) the maximum shear stress at point **A**
(2) the principal stress $\sigma_{11} = \sigma_{xx}$ at point **B**
(3) the magnitude of the applied bending moment, M, in Nmm

Figure 1



← P.T.O.

PROBLEM # 3:

At a particular point in a body manufactured from steel :
(E= 200 GPa and υ = 0.30), the three principal stresses are:

$\sigma_1 = \sigma_{xx} = 135$ MPa; $\sigma_2 = \sigma_{yy} = 90$ MPa ; $\sigma_3 = \sigma_{zz} = 45$ MPa,

(a) Sketch the three-dimensional Mohr's circle for stress,

(b) Determine the maximum shear stress and the minimum shear stress in MPa,

(c) Determine the six stress components, $\sigma_{x'x'}$; $\sigma_{y'y'}$; $\sigma_{z'z'}$; $\tau_{x'y'}$; $\tau_{y'z'}$; $\tau_{z'x'}$, in the new system of axes, $Ox'y'z'$, which is defined by the direction cosines shown:

	x	y	z
x'	2/3	2/3	-1/3
y'	-2/3	1/3	-2/3
z'	-1/3	2/3	2/3

PROBLEM # 4:

The following readings were taken from 3-element **equiangular strain rosette** mounted on a thin aluminum alloy specimen (E = 75 GPa; υ= 0.33):

$\varepsilon_A = 0.0014$; $\varepsilon_B = 0$; $\varepsilon_C = -0.0014$

Determine the principal strains ε_1 and ε_2 and the maximum shear strain γ_{max}.
Also calculate the corresponding stresses σ_1, σ_2, τ_{max}.

PROBLEM # 5:

Discuss theoretical and practical aspects of **three** of the following stress analysis techniques. List **advantages**, **limitations**, **sensitivity**, and **range of use** for each of the selected techniques. **Support your answers with accurate sketches:**
(a) **Mechanical gages:** (b) **Acoustical gages**; (c) **Brittle-coating technique**;
(d) **Photostress-coating technique**; (e) **Grid techniques.**

BEST WISHES,—**Examiner**: Prof. Dr. M. Shabara

EQUATION SHEET

$$\tau_{max} = \tfrac{1}{2}(\sigma_{max} - \sigma_{min}) = \tfrac{1}{2}(\sigma_1 - \sigma_3); \quad (\sigma_1 - \sigma_2) = \frac{Nf_\sigma}{h} \qquad (1)$$

$$\sigma_{nn} = \sigma_{xx}\cos^2(n,x) + \sigma_{yy}\cos^2(n,y) + \sigma_{zz}\cos^2(n,z) + 2\tau_{xy}\cos(n,x)\cos(n,y) + 2\tau_{yz}\cos(n,y)\cos(n,z) + 2\tau_{zx}\cos(n,z)\cos(n,x) \qquad (2)$$

$$\tau_{nn'} = \sigma_{xx}\cos(n,x)\cos(n',x) + \sigma_{yy}\cos(n,y)\cos(n',y) + \sigma_{zz}\cos(n,z)\cos(n',z) + \tau_{xy}[\cos(n,x)\cos(n',y) + \cos(n,y)\cos(n',x)] + \tau_{yz}[\cos(n,y)\cos(n',z) + \cos(n,z)\cos(n',y)] + \tau_{zx}[\cos(n,z)\cos(n',x) + \cos(n,x)\cos(n',z)] \qquad (3)$$

$$\epsilon_A = \epsilon_{xx} \qquad (4)$$

$$\epsilon_B = \epsilon_{xx}\cos^2\theta_B + \epsilon_{yy}\sin^2\theta_B + \gamma_{xy}\sin\theta_B\cos\theta_B \qquad (5)$$

$$\epsilon_C = \epsilon_{xx}\cos^2\theta_C + \epsilon_{yy}\sin^2\theta_C + \gamma_{xy}\sin\theta_C\cos\theta_C \qquad (6)$$

$$\sigma_{xx} = \frac{E}{(1+\nu)(1-2\nu)}[(1-\nu)\epsilon_{xx} + \nu(\epsilon_{yy} + \epsilon_{zz})]; \quad \tau_{xy} = \frac{E}{2(1+\nu)}\gamma_{xy} \qquad (7)$$

$$\epsilon_{1,2} = \tfrac{1}{2}(\epsilon_{xx} + \epsilon_{yy}) \pm \tfrac{1}{2}\sqrt{(\epsilon_{xx} - \epsilon_{yy})^2 + \gamma_{xy}^2}; \quad \epsilon_{zz} = -\frac{\nu}{1-\nu}(\epsilon_{xx} + \epsilon_{yy}) \qquad (8)$$

$$\sigma_1, \sigma_2 = \frac{\sigma_{xx} + \sigma_{yy}}{2} \pm \sqrt{\left(\frac{\sigma_{xx} - \sigma_{yy}}{2}\right)^2 + \tau_{xy}^2}; \quad \sigma_3 = 0 \qquad (9)$$