#1. A homogeneous, isotropic, linear elastic bar has rectangular cross sectional area $A$, modulus of elasticity $E$ and Poisson’s ratio $\nu$. The bar is subjected to an axial load $P$ along the $x$ direction as shown. Three strain gages are attached to the bar as shown so that gage #1 is oriented at 0°, gage #2 is oriented at 45°, gage #3 is oriented at 90° and all angles are measured from the $x$ axis. Each gage measures the normal strain along the axis defined by the angle of the gage. For example, gage #1 measures the normal strain along the $x$ axis, etc. Find the equations for the three normal strains $\varepsilon_1$, $\varepsilon_2$, and $\varepsilon_3$ in terms of the given parameters $P$, $A$, $E$ and $\nu$. 

![Diagram of the bar with gages and forces](image-url)
This is one of five problems. You are required to work four of the five problems. Clearly indicate which problems you are choosing. Show all work on the exam sheets provided and write your student personal identification (PID) number on each sheet. Do not write your name on any sheet. Your PID number:____________________________

#2. A thin walled spherical pressure vessel having mean diameter $D$ and wall thickness $t$ is subjected to an internal pressure $p$. If the vessel wall material is homogeneous and isotropic with a tensile yield strength $Y$, and the Factor of Safety against failure by yielding is $F_s$, derive the equation for the maximum allowable internal pressure in the vessel according to the Maximum Shear Stress yield criterion.
This is one of five problems. You are required to work four of the five problems. Clearly indicate which problems you are choosing. Show all work on the exam sheets provided and write your student personal identification (PID) number on each sheet. Do not write your name on any sheet. Your PID number:____________________________

#3. A homogeneous, isotropic and linear elastic rod has cross sectional area A, length L, modulus of elasticity E, coefficient of thermal expansion $\alpha$ and the rod is securely fixed between two rigid supports as shown below. The rod has been repaired by using a glue joint whose normal $x'$ is oriented at an angle $\theta$ with respect to the x axis. If the temperature of the rod is increased by the amount $\Delta T = T_f - T_i$, where $T_f$ = final temperature and $T_i$ = initial temperature, derive the expression for the shear stress $\tau_{x'y'}$ which acts parallel to the glue joint. Your answer should be expressed in terms of the given parameters.

![Diagram of the rod with glue joint and rigid supports](image_url)
#4. You are requested to design an annular ring, which fits the inner radius $r_2$ of the tube to the outer diameter $r_1$ of the shaft as shown. Assuming that the shaft, tube, and the ring are all made of the same isotropic material with a shear modulus $G$ and no slip occurs at the interface between the shaft, ring, and the tube. Let the relative rotation angle of the end C of the tube with respect to the end B of the shaft is $\theta$ (see the top view for respective positions) when a torsional torque $T$ is applied. Show that the thickness $t$ is:

$$t = \frac{T}{4\pi G \theta} \left( \frac{1}{r_1^2} - \frac{1}{r_2^2} \right)$$

Top View
#5. A cantilever beam of length $L$ and a circular cross-section with a diameter $D$ is loaded at the free end by a force $P$. Assuming this beam is made of an idealized isotropic elastoplastic material having the stress-strain curve ($\sigma_o$ indicates the yield stress) and moment-curvature curve as shown. Show that the maximum bending moment ($M_o$) this beam can support is 1.7 times that of the maximum elastic moment ($M_y$), defined as the largest moment for which the deformation remains fully elastic.