(4 Hours) [Total Marks : 100

N.B. : (1) Question No. **1** is **compulsory**.
(2) Solve any **three** questions from the remaining questions.
(3) Assume **suitable** data if **necessary**.

M.E (M) M/c Design Sem I PDL Theory of Elasticity & Material Behaviour 31/1/13

1. (a) A component subjected to cyclic axial loading +25 kN to 60 kN is to be designed from a steel having $S_u = 800$ N/mm^2 and has $E = 20 \times 10^4$ N/mm^2. The component is hollow circular cylinder with inside diameter equal to half the outer diameter. The related material data is as follows :– **13**

b	=	Fatigue strength exponent	=	–0·071
k_f	=	Fatigue strength correction factor	=	1·326
e'_f	=	Fatigue ductility coefficient	=	1·05
σ'_f	=	Fatigue strength coefficient	=	1180 N/mm^2
Factor of safety	=	1·5		

Design cross-section of the component for 8×10^5 cycles.

(b) A machine component is repeatedly subjected to following axial load :– **12**
+12 kN, –10 kN, +20 kN, –7·0 kN, +10 kN, –18 kN repeated cycle. Determine the number of cycles of the above load spectrum (you may apply any method for counting cycles) and give the range of each cycle.

2. (a) Discuss the 'Griffith Theory' which gives the energy needed to create the new surfaces for crack propagation. Using this theory, establish the critical stress intensity property of the material. **10**

$KI_c = \sigma_c \cdot \sqrt{a_c}$

Where σ_c is the stress applied (or farfield stress field) and a_c is the critical crack length.

(b) An edge crack, detected on large plate, is of length 2mm under a constant amplitude cyclic load having $\sigma_{max} = 300$ MPa and $\sigma_{min} = 180$ MPa. If the plate is made of steel with following properties :– **15**

$KI_c = 160\,\text{MPa}\sqrt{m}$, values of 'c' and 'm' for Paris law equation are $6{\cdot}8 \times 10^{-12}$ and 3·0 respectively.

Determine the life of the plate if maximum crack propagation length is to be restricted to 25 mm. The geometric constant for the crack may be taken as Y = 1.

3. (a) A solid circular tension member, 1·5 meter long and 25 mm diameter is take up a tensile load of 45 kN, for 10 years at 400°C. The maximum extension of the member permitted is 3 mm. The material properties of the material, from which the tension member is to be made, are given below :– **13**
(i) Modulus of elasticity (E) = 140 GPa
(ii) Coefficient of thermal expansion (α) = $4{\cdot}7 \times 10^{-6}$ per degree centigrade.
(iii) Material constant for power law (B) = $1{\cdot}2 \times 10^{-22}$ at 400°C
(iv) Stress exponent (N) = 6·9 at 400°C $e_c = B\,t\,\sigma^N$

Where	σ_f	–	failure stress in MPa
	e_c	–	creep strain
	t	–	time in days
	B and N	–	Constants for the power law

(v) Room temperature (T) = 20°C.

Determine the extension of the member and state if the member can survive for the duration or not.

subjected to a stress of 150 MPa. The blades are required to give a life of 10,000 hours.

(i) Estimate the maximum temperature to which the turbine blades can be exposed.

(ii) What would be the reduction in design life, if the turbine ran 10°C hortter. LMP (Larson Miller Parameter) is 27500 at 150 MPa and constant 'C' = 20.

4. (a) The state of stress at a point P is given by – **8**

$$\sigma_p = \begin{pmatrix} 2 & -2 & 0 \\ -2 & \sqrt{2} & 0 \\ 0 & 0 & -\sqrt{2} \end{pmatrix}$$

With respect to the first coordinate system. A second co-ordinate system is introduced whose x', y' and z' axes are given by –

$$\begin{pmatrix} 0 \\ 1/\sqrt{2} \\ 1/\sqrt{2} \end{pmatrix}, \begin{pmatrix} 1/\sqrt{2} \\ 1/2 \\ -1/2 \end{pmatrix}, \begin{pmatrix} -1/\sqrt{2} \\ 1/2 \\ -1/2 \end{pmatrix}$$

What are the components of σ_p' (σ_p in new coordinate system) ?

(b) Determine the principal stresses and their associated directions at a point P where the state of stress is defined by the rectangular components as – **12**

$\sigma_x = 1$, $\sigma_y = 1$, $\sigma_z = 1$, $\tau_{xy} = 2$, $\tau_{yz} = 1$ and $\tau_{zx} = 1$.

(c) How are measurements performed with a resistance strain gauge ? **3**

(d) What is the main advantage of semi-conductor strain gauge ? **2**

5. (a) Eigen values of σ_{ij} are calculated from the characteristic equation det $(\sigma_{ij} - \delta_{ij}\cdot\sigma) = 0$. Show that this can be written in the form **8**

$$\sigma^3 - I_\sigma\cdot\sigma^2 + II_\sigma\cdot\sigma - III_\sigma = 0$$

Where I_σ, II_σ and III_σ are the First, Second and Third stress invariants. What are their values ?

(b) The displacement componets are given by – **8**

$$u_x = K(x^2 + 2x),\quad u_y = K(4x + 2y^2 + z),\quad u_z = 4KZ^2.$$

Where K is small quantity. Calculate the linear strain at the point (2, 2, 3) in the direction $n_x = 0$, $n_y = 1/\sqrt{2}$, $n_z = 1/\sqrt{2}$.

(c) By considering a small cubic element of a material, show that – **5**

$$\tau_{ij} = \tau_{ji}$$

(d) How many temperature compensation be performed on resistance strain gauges ? **2**

(e) How many a brittle coating be used for strain measurement ? **2**

6. (a) If the stress tensor τ_{em} is in old coordinate system x, y, z and $\tau_{i'j'}$ is stress tensor after rotation in new x', y', z' coordinate system, then prove that – **10**

$$\tau_{i'j'} = a_{ie}\cdot a_{jm}\cdot\tau_{em}$$

(b) At a point in a body the components of strain are $\epsilon_x = 0{\cdot}01$, $\epsilon_y = -0{\cdot}055$, $\epsilon_z = 0{\cdot}003$ $\gamma_{xy} = 0{\cdot}02$, $\gamma_{yz} = 0{\cdot}005$, $\gamma_{xz} = 0{\cdot}004$. Find principal strains. **8**

(c) What is strain sensitivity ?

(d) What is meant by a strain-gauge rosette ? How it is used ? **5**

(e) What is strain sensitivity ? **1**

(f) Define gauge factor for strain gauges. **1**