18080

BRAINWARE UNIVERSITY

Term End Examination 2025-2026
Programme – B.Tech.(ME)-2021/B.Tech.(ME)-2023
Course Name – Solid Mechanics
Course Code - PCC-ME502
(Semester V)

Full Marks : 60 **Time : 2:30 Hours**

[The figure in the margin indicates full marks. Candidates are required to give their answers in their own words as far as practicable.]

Group-A

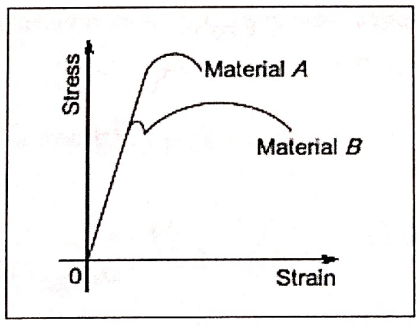
(Multiple Choice Type Question) 1 x 15=15

1. *Choose the correct alternative from the following :*

(i) Remember the number of components a 3D stress tensor have.

a) 3 b) 6
c) 9 d) 12

(ii) The stress strain diagram of two materials A and B is shown below:



The following statements are made based on this diagram:

I. Material A is more brittle than material B.

II. The ultimate strength of material B is more than that of A.

With reference to the above statements, Choose the correct option from the following

a) Both the statements are false. b) Both the statements are true.
c) I is true but II is false. d) I is false but II is true.

(iii) St. Venant's Principle is used to

a) Calculate the exact stress at a point b) Neglect localized effects of load application
c) Determine thermal expansion d) Estimate strain energy

(iv) The time-dependent elastic behavior in which a material continues to recover its shape even after immediate recovery is called

a) Plasticity
b) Creep
c) Anelasticity
d) Hardening

(v) The general form of the biharmonic equation is recorded as

a) $\nabla^4\phi=0$
b) $\nabla\phi=0$
c) $\nabla^2\phi=0$
d) None of these

(vi) The state of stress at a point in a material is given as follows:

$$[\sigma]=\begin{bmatrix}115 & 50 & 15\\ 50 & 75 & -20\\ 15 & -20 & 145\end{bmatrix}\text{MPa}$$

The hydrostatic stress tensor is determined as

a)

$$[\sigma_{Hydrostatic}]=\begin{bmatrix}111.67 & 0 & 0\\ 0 & 111.67 & 0\\ 0 & 0 & 111.67\end{bmatrix}\text{MPa}$$

b)

$$[\sigma_{Hydrostatic}]=\begin{bmatrix}111.67 & -20 & 0\\ 0 & 111.67 & 0\\ 0 & 0 & 111.67\end{bmatrix}\text{MPa}$$

c)

$$[\sigma_{Hydrostatic}]=\begin{bmatrix}111.67 & 0 & 0\\ 0 & 111.67 & 0\\ -34 & 0 & 111.67\end{bmatrix}\text{MPa}$$

d)

$$[\sigma_{Hydrostatic}]=\begin{bmatrix}111.67 & 0 & 90\\ 0 & 111.67 & 0\\ 90 & 0 & 111.67\end{bmatrix}\text{MPa}$$

(vii) The maximum stress around an elliptical hole in a plate under uniform tension is given by

a)

$$\sigma_{max}=\sigma_0\left(1+2\frac{a}{b}\right)$$

b)

$$\sigma_{max}=\sigma_0\left(1+\frac{a}{b}\right)$$

c)

$$\sigma_{max}=3\sigma_0\left(\frac{a}{b}\right)$$

d)

$$\sigma_{max}=2\sigma_0\left(\frac{a}{b}\right)$$

(viii) Identify the general equation applicable to stress distribution in axisymmetric problems, including thick cylinders, rotating cylinders, and disks.

a)

$$r\frac{d^2\sigma_r}{dr^2}+3\frac{d\sigma_r}{dr}+(3+\vartheta)\rho\omega^2r^2=0$$

b)

$$r\frac{d^2\sigma_r}{dr^2}+3\frac{d\sigma_r}{dr}\rho\omega^2r^2=0$$

c)

$$r\frac{d^2\sigma_r}{dr^2}+3\frac{d\sigma_r}{dr}=0$$

d)

None of these

(ix) The generalized Hooke's law in index notation can be expressed as

a) $\sigma_{ij} = D_{ijkl}\epsilon_{kl}$

b) $\sigma_{ij} = D_{ijkl}\epsilon_{l}$

c) $\sigma_{ij} = D_{ij}\epsilon_{l}$

d) None of these

(x) For isotropic materials, the form $\sigma_{ij} = C_{ijkl}\,\varepsilon_{kl}$ reduces to

a) $\sigma_{ij}=\lambda\delta_{ij}\epsilon_{kk}+2\mu\varepsilon_{ij}$

b) $\sigma_{ij}=E\varepsilon_{ij}$

c) $\sigma_{ij}=\mu\varepsilon_{ij}$

d) $\sigma_{ij}=\lambda\varepsilon_{kk}$

(xi) The Betti's reciprocal theorem states that

a) The work done by one force system through displacements from another force system is equal in reverse

b) The sum of all forces in a system equals zero

c) Energy is conserved in all materials

d) The displacement at one point is always zero

(xii) In index notation $\sigma_{ij,j}$, the repeated index j implies

a) Matrix transpose

b) Summation over j

c) Differentiation with respect to j without summation

d) Scalar multiplication

(xiii) The mathematical form of Cauchy's equation of motion can be expressed as

a) $(\sigma + \rho b_i) = \rho a_i$

b) $(\sigma_j + \rho b_i) = \rho a_i$

c) $(\sigma_{ij,j} + \rho b_i) = \rho a_i$

d) $(\sigma_{ij,j} + \rho b_i) = a_i$

(xiv) The elasticity tensor C_{ijkl} belongs to _____ order of tensor.

a) 4^{th}

b) 3^{rd}

c) 2^{nd}

d) 1^{st}

(xv) In Griffith's energy theory, identify the condition under which fracture occurs

a) Stress exceeds yield stress

b) Elastic strain energy released ≥ surface energy required to form new crack surfaces

c) Applied stress equals tensile strength

d) Stress intensity factor becomes zero

Group-B

(Short Answer Type Questions) 3 x 5=15

2. Categorize the following 2D stress states as general, principal, or hydrostatic. (3)

$$(a)\ \sigma = \begin{bmatrix} 1 & 2 \\ 2 & 3 \end{bmatrix} \quad (b)\ \sigma = \begin{bmatrix} -1 & 0 \\ 0 & -3 \end{bmatrix} \quad (c)\ \sigma = \begin{bmatrix} -1 & 0 \\ 0 & -1 \end{bmatrix}$$

3. Differentiate between Linear Elastic Fracture Mechanics (LEFM) and Elastic–Plastic Fracture Mechanics (EPFM). (3)
4. An alloy specimen has a modulus of elasticity (E) of 120 GPa and modulus of rigidity (G) of 45 GPa. Determine the poisson's ratio of the material. (3)
5. Define Fracture Toughness. (3)
6. "The cross product of two vectors produces another vector" - Justify your answer. (3)

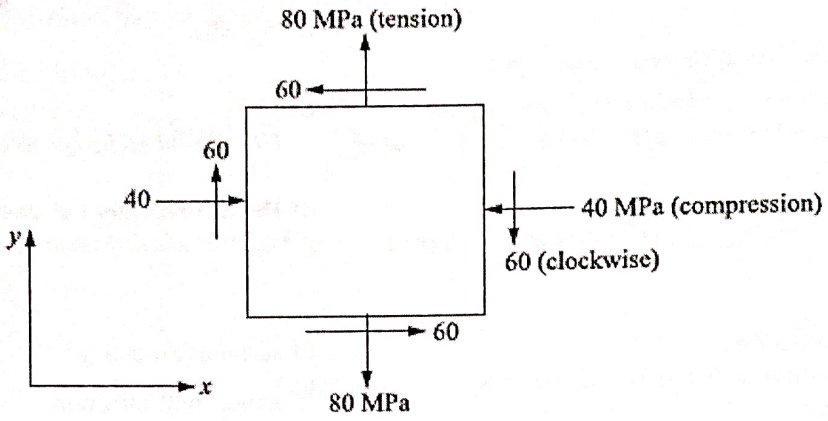
OR

"A vector is independent of the coordinate system" - Justify your answer. (3)

Group-C

(Long Answer Type Questions) 5 x 6=30

7. The state of stress is given by the figure, as shown below (5)



i) Draw Mohr's circle and determine principal stresses.

ii) Determine stresses at a plane having its normal 45° anticlockwise to the direction of y-axis.

iii) Determine the maximum shear stress.

8. The two-dimensional state of stress is given as σ_{xx} = 1 MPa, σ_{yy} = 3 MPa, and τ_{xy}= 2 MPa. Assuming the vector n is inclined at 45° with the basis vector. Compute: (5)

(i) The components of the unit vector n.

(ii) The traction vector (t_n).

(iii) The normal stress (σ_n).

(iv) The shear stress (τ_n).

9. Show that the displacement components in plane stress problems in cartesian coordinates satisfy the following equations: (5)

$$\nabla^2 u + \frac{1+v}{1-v}\frac{\partial}{\partial x}\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}\right)=0$$

$$\nabla^2 v + \frac{1+v}{1-v}\frac{\partial}{\partial y}\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}\right)=0$$

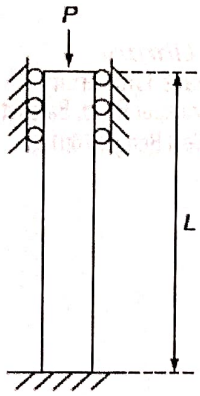
Where, $\nabla^2 = \frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}$

10. Derive the expression for the critical stress σ_c in an infinite plate of thickness t with a central crack of length 2a: (5)

$$\sigma_c = \sqrt{\frac{2E\gamma_s}{\pi a}}$$

Where, E = Young's modulus, γ_s = specific surface energy.

11. Explain Castigliano's Theorem with the help of suitable illustrations. (5)
12. Show that for a column having one end fixed and the other end guided as shown in the figure below. (5)

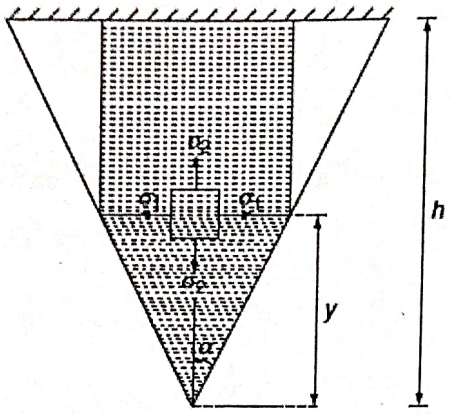


The buckling load of the column (P) must satisfy a transcendental or a non-algebraic equation

$$\sqrt{EI}\tan\left(\sqrt{\frac{PL^2}{EI}}\right) = \sqrt{PL^2}$$

OR

Formulate an expression for the maximum shear stress τ_{max} in the plane of the wall of the conical tank filled with water which is supported along its upper edge as shown in Figure. (5)



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