D : SOLID MECHANICS

Q. 1 – Q. 9 carry one mark each.

Q.1 Find the force (in kN) in the member BH of the truss shown.

Q.2 Consider the forces of magnitude F acting on the sides of the regular hexagon having side length a. At point B, the equivalent force and couple are, respectively,

(A) \( F(\leftarrow) \) and \( 3\sqrt{3}Fa \) (clockwise)
(B) \( F(\rightarrow) \) and \( \sqrt{3}Fa \) (clockwise)
(C) \( F(\leftarrow) \) and \( \sqrt{3}Fa \) (counter clockwise)
(D) \( F(\rightarrow) \) and \( 3\sqrt{3}Fa \) (counter clockwise)

Q.3 Bar-1 has a diameter \( d \), length \( L \), and elastic modulus \( E \) and subjected to tensile load \( P \), resulting in an elongation of \( \Delta_1 \). Bar-2 has diameter, \( 2d \), length \( 2L \), an elastic modulus \( 2E \) and subjected to tensile load \( 2P \), resulting in an elongation of \( \Delta_2 \). Find the ratio \( \Delta_1 / \Delta_2 \).

Q.4 In a plane stress problem, the principal stresses at a point are 30MPa and -15MPa. At the same point, on an element whose sides make an angle of 45° with respect to the principal axes, the normal stresses (in MPa) are

(A) 15/2 and 15/2  (B) 30/2 and 30/2  (C) 15/2 and -15/2  (D) 30/2 and -30/2
Q.5 Two systems shown below start from rest. For the system shown on the left, two 50N blocks are connected by a cord. For the system shown on the right, the 50N block is pulled by a 50N downward force. Neglect friction. Which of the following is true?

(A) Blocks A and C have the same acceleration.
(B) Block C will have a larger acceleration than block A.
(C) Block A will have a larger acceleration than block C.
(D) Block A will not move.

\[ \begin{align*}
\text{A} & \quad 50 \text{N} \\
\text{B} & \quad 50 \text{N} \\
\text{C} & \quad 50 \text{N}
\end{align*} \]

Q.6 Two massless rigid bars, each of length \( a = 0.5 \text{m} \), are connected by a rotational spring having stiffness \( k = 1000 \text{ N.m/rad} \). Find the buckling load \( P \) (in kN).

\[ \begin{align*}
P & \quad \text{bar}
\end{align*} \]

Q.7 A simply supported beam having a rectangular cross-section of depth \( d \) is subjected to a vertical concentrated load \( P \) at the mid-span. The maximum shear stress in a section occurs at

(A) \( d/2 \) from the top of the cross-section
(B) \( d/3 \) from the top of the cross-section
(C) \( 2d/3 \) from the top of the cross-section
(D) Top of the cross-section

Q.8 A steel block of size \( 100\times 50\times 25 \text{ mm}^3 \) is subjected to a uniform pressure on all faces. The dimension of the \( 100\text{mm} \) edge reduces by \( 25\mu\text{m} \) (note \( 1 \mu\text{m} = 10^{-6}\text{m} \)). Find the applied pressure (in GPa). Use \( E = 240 \text{ GPa} \) and \( v = 0.3 \).
Q.9 Which one of the following statements is true?

(A) In a tensile test on a rod made of ductile material, failure occurs along a plane making $45^\circ$ with respect to the axis of the rod

(B) In a tensile test on a rod made of brittle material, failure occurs along a plane making $45^\circ$ with respect to the axis of the rod

(C) In a torsion test on a rod made of ductile material, failure occurs along a plane making $45^\circ$ with respect to the axis of the rod

(D) In a torsion test on a rod made of brittle material, failure occurs along a plane making $0^\circ$ with respect to the axis of the rod
Q. 10 – Q. 22 carry two marks each.

Q.10 A block is travelling with a constant speed $v_o$ on a smooth surface when the surface suddenly becomes rough with a coefficient of friction $\mu$, which causes the block to stop after a distance $d$. When the block travels twice as fast, i.e. at a speed $2v_o$, it travels a distance $D$ on the rough surface before stopping. Find the ratio $D/d$.

Q.11 The beam shown below is loaded with a concentrated clockwise moment of $80\text{kN-m}$ at point B. The bending moment diagram (in $\text{kN-m}$) is

(A)  
(B)  
(C)  
(D)  

$E I =$ constant
Q.12 The beam shown has an internal hinge at B. A vertical load $P = 25\text{kN}$ is applied at B. Use $L = 2\text{m}$. Magnitude of the reactions (i.e. forces and moments) at A and C are

(A) Vertical reaction force at C is $12.5\text{kN}$, vertical reaction force at A is $12.5\text{kN}$, moment reaction at A is $0\text{kN-m}$.

(B) Vertical reaction force at C is $0\text{kN}$, vertical reaction force at A is $25\text{kN}$, moment reaction at A is $50\text{kN-m}$.

(C) Vertical reaction force at C is $25\text{kN}$, vertical reaction force at A is $0\text{kN}$, moment reaction at A is $50\text{kN-m}$.

(D) Vertical reaction force at C is $0\text{kN}$, vertical reaction force at A is $25\text{kN}$, moment reaction at A is $25\text{kN-m}$.

Q.13 Blocks P and Q are released from rest in the positions shown. Neglect friction between all surfaces, i.e., both blocks can translate freely. Then the direction of the acceleration of block Q (i.e. $a_Q$) is

(A) 

(B) 

(C) 

(D) 

Q.14 The acceleration, $a$, of a particle as a function of its position, $x$, is given by the relation $a = 0.1 + \sin \frac{x}{b}$, where $a$ and $x$ are expressed in $\text{m/s}^2$ and $\text{meters}$, respectively. Consider $b = 1\text{m}$. When $x = 0$, velocity is $v = 1\text{m/s}$. Find $v$ (in $\text{m/s}$) when $x = \pi\text{ meters}$. 
Q.15 The 30kg block B shown below is suspended by a 2m cord attached to the 60kg cart A. Friction is negligible. If the system is released from rest in the position shown, find the ratio of the velocity magnitudes $|v_A|/|v_B|$ when the cord is vertical.

![Diagram of the system with a 30kg block B suspended by a 2m cord attached to a 60kg cart A.]

Q.16 The plane frame shown has an internal hinge at C. Find the magnitude of axial force (in kN) in member BC.

![Diagram of the plane frame with an axial force of 200 kN at node C.]

Q.17 Two 50mm diameter solid steel rods are rigidly connected together at right angles and loaded as shown. Use $P = 1000\pi$ kN. At point A, located at the top of the cross-section at the fixed end, the magnitude of bending stress ($\sigma$) and shear stress ($\tau$) are

- (A) $\sigma = 256$ MPa, $\tau = 512$ MPa
- (B) $\sigma = 512$ MPa, $\tau = 256$ MPa
- (C) $\sigma = 512$ MPa, $\tau = 128$ MPa
- (D) $\sigma = 128$ MPa, $\tau = 512$ MPa

Q.18 At a temperature of 40°C, a rod tightly fits between two rigid walls such that the compressive stress in the rod is 60MPa. Given $E = 200$ GPa and $\alpha = 20 \times 10^{-6}/\degree C$, find the temperature at which the rod will just lose contact with the walls.
Q.19 A massless rigid rod \( AB \) of length \( h \) is pinned at end \( A \) and carries mass \( m \) at end \( B \). The rod is also supported by two linear springs of stiffness \( k \) at a height \( d \) from the end \( A \). Use \( m = 4 \text{kg}, h = 0.5 \text{m}, d = 0.2 \text{m}, k = 600 \text{N/m} \) and \( g = 10 \text{ m/s}^2 \). For small oscillations about the position shown, find the frequency of free vibration (in \( \text{rad/s} \)).

![Diagram](image)

Q.20 Find the maximum force \( P \) (in kN) that can be applied to the planar structure \( ABC \) so as to prevent buckling in any of the members. Consider buckling only in the plane of the structure. Joint \( B \) is a pin connection. Use \( E = 200 \text{GPa} \) for both members. The diameter of member \( AB \) is 10 mm and the diameter of member \( BC \) is 15 mm.

![Diagram](image)

Q.21 The plane frame shown is analyzed by neglecting axial and shear deformations. The horizontal displacement of joint \( B \) is

(A) \( \frac{2PL^3}{3EIL} \)  
(B) \( \frac{PL^3}{EI} \)  
(C) \( \frac{3PL^3}{2EI} \)  
(D) \( \frac{PL^3}{2EI} \)
Q.22  A thin walled cylindrical pressure vessel having mean radius 100mm and wall thickness 5mm, is subjected to internal pressure $p$. If the factor of safety is 2 and the yield stress in shear is 100MPa, find the maximum value of $p$ (in MPa).

END OF THE QUESTION PAPER