BT-204 Basic Civil Engineering & Engineering Mechanics
Unit–5 Notes Centre of Gravity and Moment of Inertia

UNIT–5 TOPICS

- Centroid and Centre of Gravity
- Moment of Inertia of Area and Mass
- Radius of Gyration
- Product of Inertia and Principal Axes
- Support Reactions
- Shear Force and Bending Moment Diagram
- Cantilever Beam
- Simply Supported Beam
- Concentrated Load
- Distributed Load
- Couple

1. CENTROID

Centroid is geometrical center of plane figure.

Properties:
- Depends only on shape of body.
- Independent of material density.

Centroid Formula:

x■ = ΣAx / ΣA
■ = ΣAy / ΣA

Where:
A = Area of section
x■, ■ = Coordinates of centroid

Applications:
- Structural design
- Beam analysis
- Engineering mechanics

2. CENTRE OF GRAVITY (C.G.)

Centre of gravity is point through which total weight of body acts.

Difference Between Centroid and C.G.

- Centroid applies to geometric shapes.
- Centre of gravity applies to physical bodies with weight.

Applications:
- Stability analysis
- Vehicle design
- Building structures

3. MOMENT OF INERTIA (M.I.)

Moment of inertia is property of body that resists rotational motion.

Types of Moment of Inertia:
- Area moment of inertia

• Mass moment of inertia

(a) AREA MOMENT OF INERTIA

Area moment of inertia is resistance offered by area against bending.

Formula:

$I = \Sigma Ar^2$

Where:
A = Area element
r = Distance from axis

Common Formulas:

Rectangle about centroidal axis:
$I = bd^3/12$

Circle about centroidal axis:
$I = \pi d■/64$

(b) MASS MOMENT OF INERTIA

Mass moment of inertia measures resistance against angular acceleration.

Formula:

$I = \Sigma mr^2$

Where:
m = Mass element
r = Distance from axis

4. RADIUS OF GYRATION

Radius of gyration is distance from axis at which whole area or mass can be assumed concentrated.

Formula:

$k = \sqrt{(I/A)}$

Where:
I = Moment of inertia
A = Area

Applications:
• Column design
• Stability calculations

5. PRODUCT OF INERTIA

Product of inertia is measure of distribution of area with respect to two perpendicular axes.

Formula:

$Ixy = \int xy\ dA$

Applications:
• Unsymmetrical sections
• Structural analysis

6. PRINCIPAL AXES

Principal axes are axes about which product of inertia becomes zero.

Importance:
• Simplifies structural calculations
• Used in beam analysis

7. SUPPORT REACTIONS

Support reactions are forces developed at supports of beams and structures.

Types of Supports:
• Roller support
• Hinged support
• Fixed support

Equilibrium Equations:

$\sum Fx = 0$
$\sum Fy = 0$
$\sum M = 0$

8. SHEAR FORCE (S.F.)

Shear force is algebraic sum of vertical forces acting on either side of section.

Positive Shear Force:
Left side moves upward.

Negative Shear Force:
Left side moves downward.

9. BENDING MOMENT (B.M.)

Bending moment is turning effect produced by external forces on beam section.

Positive Bending Moment:
Sagging of beam.

Negative Bending Moment:
Hogging of beam.

10. SHEAR FORCE DIAGRAM (SFD)

SFD shows variation of shear force along length of beam.

Uses:
• Beam design
• Structural analysis

11. BENDING MOMENT DIAGRAM (BMD)

BMD shows variation of bending moment along beam length.

Uses:
• Determination of maximum bending moment
• Beam design

12. CANTILEVER BEAM

Cantilever beam is fixed at one end and free at other end.

Applications:
• Balconies
• Bridges
• Aircraft wings

13. SIMPLY SUPPORTED BEAM

Simply supported beam is supported at both ends.

Applications:
• Building structures
• Bridges

14. TYPES OF LOADS

(a) Concentrated Load:
Load acting at single point.

(b) Distributed Load:
Load spread over length of beam.

(c) Couple:
Pair of equal and opposite forces separated by distance.

MOST IMPORTANT 14 MARK QUESTIONS

1. Explain centroid and centre of gravity with applications.

2. Explain area moment of inertia and mass moment of inertia.

3. Derive moment of inertia for rectangle and circle.

4. Explain radius of gyration with applications.

5. Explain product of inertia and principal axes.

6. Explain support reactions with equilibrium equations.

7. Explain shear force and bending moment.

8. Draw SFD and BMD for cantilever beam with concentrated load.

9. Draw SFD and BMD for simply supported beam with distributed load.

10. Explain concentrated load, distributed load and couple.

11. Differentiate cantilever beam and simply supported beam.

12. Solve support reaction numerical problems.

IMPORTANT 7 MARK QUESTIONS

1. Define centroid and centre of gravity.

2. Explain radius of gyration.

3. Explain product of inertia.

4. Explain principal axes.

5. Define shear force and bending moment.

6. Explain cantilever beam.

7. Explain simply supported beam.

8. Explain support reactions.

IMPORTANT NUMERICALS

1. Centroid calculations.

2. Moment of inertia calculations.

3. Radius of gyration numerical.

4. Support reaction problems.

5. SFD and BMD numerical problems.

EXAM TIPS

- Practice SFD and BMD diagrams regularly.
- Learn formulas of moment of inertia carefully.
- Practice support reaction numerical problems daily.
- Revise centroid and C.G. concepts properly.
- Focus on repeated PYQ questions.