ENGINEERING MECHANICS

Unit VI: Motion in a Plane

Rectilinear Motion • Curvilinear Motion • Work, Power & Energy

WBSCTE Diploma — 2nd Semester | Study Notes

SECTION A — RECTILINEAR MOTION

1. Introduction to Motion in a Plane

Dynamics is the branch of Engineering Mechanics that deals with the study of bodies in motion. When a body moves, its position changes with time. The study of this motion without considering the forces causing it is called Kinematics, while the study including forces is called Kinetics. In this unit we study two important categories of planar motion: Rectilinear Motion (straight-line) and Curvilinear Motion (curved path), and also the concepts of Work, Power, and Energy.

Rectilinear Motion	Motion along a straight line path. Also called translatory or linear motion.
Curvilinear Motion	Motion along a curved path. Includes circular motion.
Plane Motion	Motion confined to a single plane (2-D motion).

2. Key Concepts — Displacement, Velocity & Acceleration

Before studying the equations of motion, it is essential to clearly understand the three primary kinematic quantities: displacement, velocity, and acceleration.

Distance (d)	Total path length covered by a body, regardless of direction. Scalar quantity. SI unit: metre (m).
Displacement (s)	Shortest straight-line distance between initial and final positions, with direction. Vector quantity. SI unit: metre (m).
Speed	Rate of change of distance. Scalar. SI unit: m/s.
Velocity (v)	Rate of change of displacement. $v = ds/dt$. Vector. SI unit: m/s.

Acceleration (a)	Rate of change of velocity. a = dv/dt. Vector. SI unit: m/s².
Uniform Acceleration	Acceleration remains constant throughout the motion.
Retardation	Negative acceleration — velocity decreasing with time.

3. Displacement–Time and Velocity–Time Diagrams

Graphical representation of motion helps visualise and analyse the behaviour of a moving body at a glance. The two most important graphs are the Displacement–Time (s-t) graph and the Velocity–Time (v-t) graph.

3.1 Displacement–Time (s–t) Graph

s–t Graph

```
           s (m)
           |  /
 | /  ← slope = velocity (v)
            |/
        O——————— t (s)
Uniform velocity: straight line
Accelerating: curve (concave up)
At rest: horizontal line
```

Key Points

```
SLOPE of s-t graph = Velocity
• Steep slope → high velocity
• Zero slope  → body at rest
• Negative slope → returning

v = Δs / Δt
= (s₂ - s₁) / (t₂ - t₁)
```

3.2 Velocity–Time (v–t) Graph

v–t Graph

```
         v (m/s)
 |   / ← slope = acceleration
           |  /
            | /
        O——————— t (s)
Uniform accel.: straight line up
Decelerating: line sloping down
Uniform velocity: horizontal line
```

Key Points

```
SLOPE of v-t graph = Acceleration
AREA under v-t graph = Displacement

a = Δv / Δt = (v - u) / t

s = Area under v-t curve
= (1/2)(u+v)t  [trapezium]
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Reading Diagrams — Quick Summary

- s–t graph: slope at any point = instantaneous velocity
- v–t graph: slope at any point = instantaneous acceleration
- Area under v–t graph between two instants = displacement in that interval
- Horizontal line in v–t graph = uniform velocity (zero acceleration)
- Straight line through origin in v–t graph = uniform acceleration from rest

4. Equations of Motion (Deduction)

For a body undergoing uniformly accelerated rectilinear motion, three fundamental equations relate the kinematic variables — initial velocity (u), final velocity (v), acceleration (a), time (t), and displacement (s). These are derived from the basic definitions of velocity and acceleration.

4.1 First Equation: $v = u + at$

Derivation of $v = u + at$

From the definition of acceleration:

$a = (v - u) / t$

$\therefore\ at = v - u$

$\therefore$ **$v = u + at$** ← **1st Equation of Motion**

4.2 Second Equation: $s = ut + \frac{1}{2}at^2$

Derivation of $s = ut + \frac{1}{2}at^2$

From v–t graph, displacement = Area of trapezium = Area of rectangle + Area of triangle

$s = u \cdot t + \frac{1}{2} \times (v - u) \times t$

Since $(v - u) = at$:

$s = ut + \frac{1}{2} \times at \times t$

$s = ut + \frac{1}{2}at^2$ ← **2nd Equation of Motion**

4.3 Third Equation: $v^2 = u^2 + 2as$

Derivation of $v^2 = u^2 + 2as$

From eq.1: $t = (v - u)/a$

Substituting in eq.2: $s = u(v-u)/a + \frac{1}{2}a[(v-u)/a]^2$

$2as = 2u(v-u) + (v-u)^2$

$2as = (v-u)[2u + (v-u)]$

$2as = (v-u)(v+u) = v^2 - u^2$

$v^2 = u^2 + 2as$ ← **3rd Equation of Motion**

① $v = u + at$ ② $s = ut + \frac{1}{2}at^2$ ③ $v^2 = u^2 + 2as$

u = initial velocity | *v = final velocity* | *a = acceleration* | *t = time* | *s = displacement*

Special Cases to Remember

- Body starts from REST: **$u = 0$ → $v = at$, $s = \frac{1}{2}at^2$, $v^2 = 2as$**
- Body brought to REST: **$v = 0$ → $0 = u + at$, i.e. $t = u/a$**
- Uniform velocity: **$a = 0$ → $s = ut$**
- Free fall (downward): **$u = 0$, $a = g = 9.81$ m/s²**
- Vertical throw (upward): **$a = -g$, at highest point $v = 0$**

5. Newton's Second Law — P = ma and Momentum

5.1 Newton's Second Law of Linear Motion

Newton's Second Law of Motion states that the rate of change of linear momentum of a body is directly proportional to the applied external force and takes place in the direction of the force.

Statement & Derivation of F = ma

Let a body of mass m have initial velocity u and, under force F, attain velocity v in time t.

Initial momentum $= mu$

Final momentum $= mv$

Rate of change of momentum $= (mv - mu)/t = m(v-u)/t = m \cdot a$

By Newton's 2nd Law: $F \propto (mv - mu)/t$

$\therefore F = k \cdot ma$ ($k = 1$ in SI units)

$\therefore F = ma$ or $P = ma$ ← Newton's 2nd Law

$$F = ma \quad \text{(or } P = ma \text{ in some notations)}$$

F = Force (N) | m = mass (kg) | a = acceleration (m/s²)

5.2 Linear Momentum

The linear momentum of a body is defined as the product of its mass and velocity. It is a vector quantity and has the same direction as the velocity of the body.

$$p = m \times v$$

p = Linear momentum (kg·m/s) | m = mass (kg) | v = velocity (m/s)

SI Unit of Momentum	kg·m/s (kilogram metre per second)

Nature	Vector quantity — direction same as velocity
Relation to Force	F = dp/dt (Newton's 2nd Law in general form)
Impulse	Change in momentum = F × t = m(v − u)

6. Conservation of Linear Momentum

The Law of Conservation of Linear Momentum is one of the most fundamental principles of physics. It is a direct consequence of Newton's Third Law of Motion.

Law of Conservation of Linear Momentum

Statement: When no external force acts on a system of bodies, the total linear momentum of the system remains constant before and after any interaction (collision).

Total momentum before collision = Total momentum after collision

For two bodies of masses m_1 and m_2:

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

u = initial velocity | *v = final velocity* | *Valid when net external force = 0*

Practical Examples of Conservation of Momentum

- Recoil of gun: **Bullet moves forward, gun recoils backward so total momentum = 0**
- Rocket propulsion: **Exhaust gases go backward, rocket moves forward**
- Ball collision: **Total momentum of two balls before and after collision is equal**
- Explosion: **Fragments fly in all directions but vector sum of momenta = initial momentum**

Example 1: Rectilinear Motion

Problem Statement

A car starts from rest and accelerates uniformly. It attains a speed of 90 km/h in 15 s. Find (a) acceleration, (b) distance covered, and (c) distance covered in the 10th second.

Solution

Given: $u = 0$, $v = 90$ km/h $= 90 \times 1000/3600 = 25$ m/s, $t = 15$ s

- Acceleration: $a = (v - u)/t = (25 - 0)/15 = 1.667$ m/s²
- Distance: $s = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2} \times 1.667 \times 15^2 = 187.5$ m
- Distance in 10th second: $s_n = u + a(n - \frac{1}{2}) = 0 + 1.667(10 - 0.5) = 1.667 \times 9.5 = 15.83$ m

Example 2: Conservation of Momentum

Problem Statement

A bullet of mass 50 g is fired with velocity 300 m/s from a rifle of mass 3 kg. Find the recoil velocity of the rifle.

Solution

Given: $m_1 = 0.05$ kg (bullet), $v_1 = 300$ m/s; $m_2 = 3$ kg (rifle), $u_1 = u_2 = 0$ (initially at rest)

- By Conservation of Momentum: $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$
- $0 + 0 = 0.05 \times 300 + 3 \times v_2$
- $0 = 15 + 3v_2$
- $v_2 = -15/3 = -5$ m/s

Recoil velocity of rifle = 5 m/s (backward direction)

SECTION B — CURVILINEAR / CIRCULAR MOTION

7. Angular Displacement, Velocity & Acceleration

When a body moves along a circular path, its position is described by an angle rather than a straight-line distance. The rotational counterparts of linear displacement, velocity, and acceleration are angular displacement, angular velocity, and angular acceleration.

7.1 Angular Displacement (θ)

Angular displacement is the angle turned by a body about its axis of rotation in a given time. It is measured in radians (rad). One complete revolution = 2π radians.

$$\theta = \text{Arc length / Radius} = s / r \quad \text{(in radians)}$$

s = arc length (m) | r = radius (m) | 1 revolution = 2π rad = 360°

7.2 Angular Velocity (ω)

Angular velocity is the rate of change of angular displacement with respect to time. It is the rotational equivalent of linear velocity.

$$\omega = d\theta/dt = \theta/t \quad \text{(for uniform rotation)}$$

ω = angular velocity (rad/s) | θ = angular displacement (rad) | t = time (s)

Relation with rpm (revolutions per minute):

$$\omega = 2\pi N/60 \quad \text{(rad/s)}$$

N = speed in rpm | ω in rad/s

7.3 Angular Acceleration (α)

Angular acceleration is the rate of change of angular velocity with respect to time. Positive α means speeding up; negative α (retardation) means slowing down.

$$\alpha = d\omega/dt = (\omega_2 - \omega_1)/t$$

α = angular acceleration (rad/s²) | ω_1, ω_2 = initial/final angular velocities

Angular Displacement θ	rad (radian)
Angular Velocity ω	rad/s
Angular Acceleration α	rad/s²
Moment of Inertia I	kg·m²

8. Relations Between Linear and Angular Quantities

8.1 Linear Velocity and Angular Velocity: v = rω

Derivation of v = rω

Consider a body moving along a circular path of radius r.

In a small time dt, the body sweeps an angle dθ and covers arc length ds.

$ds = r \cdot d\theta$

Dividing by dt: $ds/dt = r \cdot d\theta/dt$

∴ $v = r \cdot \omega$ ← Relation between linear and angular velocity

$$v = r \cdot \omega$$

v = linear (tangential) velocity (m/s) | r = radius (m) | ω = angular velocity (rad/s)

8.2 Linear Acceleration and Angular Acceleration: a = rα

Derivation of a = rα

Differentiating v = rω with respect to time t:

$dv/dt = r \cdot d\omega/dt$

$\therefore$ **$a = r \cdot \alpha$** ← **Relation between linear and angular acceleration**

$$a = r \cdot \alpha$$

a = tangential acceleration (m/s²) | r = radius (m) | α = angular acceleration (rad/s²)

Linear ↔ Angular Analogy

LINEAR		ANGULAR
s (m)	↔	θ (rad)
$v = ds/dt$	↔	$\omega = d\theta/dt$
$a = dv/dt$	↔	$\alpha = d\omega/dt$
$v = r\omega$		$a = r\alpha$
$F = ma$		$\tau = I\alpha$

Angular Equations of Motion

EQUATIONS OF ANGULAR MOTION

$$\omega_2 = \omega_1 + \alpha t$$
$$\theta = \omega_1 t + \tfrac{1}{2}\alpha t^2$$
$$\omega_2^2 = \omega_1^2 + 2\alpha\theta$$

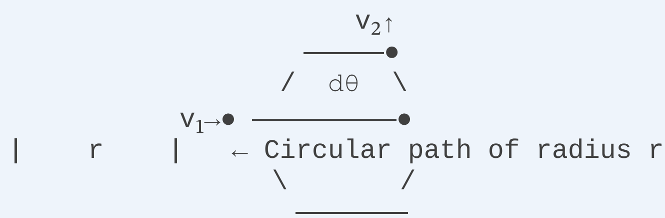
(analogous to $v=u+at$, $s=ut+\tfrac{1}{2}at^2$, $v^2=u^2+2as$)

9. Centripetal and Centrifugal Force

When a body moves along a circular path with uniform speed, although its speed is constant, its direction continuously changes. This change in direction means the velocity vector is changing, implying there is an acceleration — called centripetal acceleration — directed towards the centre of the circle.

9.1 Centripetal Acceleration — Concept & Derivation

Circular Motion — Centripetal Acceleration



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Centripetal accel. directed towards CENTRE (O)
aₒ = v²/r = ω²r
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Derivation of Centripetal Acceleration ($a_o = v^2/r$)

A particle moves along a circle of radius r with uniform speed v.

At two close instants, velocities v_1 and v_2 are tangential but their directions differ by dθ.

Change in velocity = $|\Delta v| = v \cdot d\theta$ (for small dθ, treating $v_1 \approx v_2 = v$)

Time for this change = $dt = r \cdot d\theta / v$ (since arc = $r \cdot d\theta = v \cdot dt$)

Centripetal acceleration:

$a_o = |\Delta v|/dt = (v \cdot d\theta)/(r \cdot d\theta/v) = v^2/r$

Also: since $v = r\omega$ → $a_o = (r\omega)^2/r = \omega^2 r$

∴ $a_o = v^2/r = \omega^2 r$ ← Centripetal Acceleration

$$a_o = v^2/r = \omega^2 r$$

a_o = centripetal acceleration (m/s²) | v = linear speed (m/s) | ω = angular velocity (rad/s) | r = radius (m)

9.2 Centripetal Force — Definition & Expression

The force that continuously acts on a body towards the centre of its circular path, providing the centripetal acceleration, is called Centripetal Force. Without this force, the body would fly off tangentially.

$$F_c = m \cdot a_o = mv^2/r = m\omega^2 r$$

Fc = centripetal force (N) | m = mass (kg) | v = speed (m/s) | r = radius (m) | ω = angular velocity (rad/s)

Real Examples of Centripetal Force

- Tension in a string **provides centripetal force for a ball whirled in a circle.**
- Gravitational force **provides centripetal force for planets orbiting the Sun.**
- Normal reaction **on a banked road provides centripetal force for a turning vehicle.**
- Friction **between tyres and road provides centripetal force on a flat curved road.**

9.3 Centrifugal Force — Concept

Centrifugal force is a pseudo-force (fictitious force) experienced by a body in a rotating (non-inertial) reference frame. It acts outward, away from the centre of rotation, and is equal in magnitude but opposite in direction to centripetal force.

$$F_{cf} = mv^2/r \quad \text{(outward)} \quad = \quad -F_c$$

Centrifugal force is NOT a real force — it arises only in rotating frames of reference

Centripetal vs Centrifugal Force

Centripetal Force	Centrifugal Force
Acts towards the centre	Acts away from the centre
Real force (actual physical force)	Pseudo/fictitious force
Experienced in inertial frame	Experienced in rotating (non-inertial) frame
Example: Tension in string	Example: Mud flying off spinning wheel
Formula: mv^2/r (inward)	Formula: mv^2/r (outward)

Example 3: Circular Motion

Problem Statement

A stone of mass 0.5 kg is tied to a string of length 1.2 m and whirled in a horizontal circle at 120 rpm. Find: (a) angular velocity, (b) linear velocity, (c) centripetal acceleration, (d) centripetal force.

Solution

Given: m = 0.5 kg, r = 1.2 m, N = 120 rpm

- (a) $\omega = 2\pi N/60 = 2\pi \times 120/60 = 4\pi = 12.57$ rad/s
- (b) $v = r\omega = 1.2 \times 12.57 = 15.08$ m/s
- (c) $a_c = v^2/r = (15.08)^2/1.2 = 227.4/1.2 = 189.5$ m/s² OR $a_c = \omega^2 r = (12.57)^2 \times 1.2 = 189.6$ m/s²
- (d) $F_c = m \cdot a_c = 0.5 \times 189.5 = 94.75$ N ← Centripetal Force

SECTION C — WORK, POWER & ENERGY

10. Work

In everyday language, 'work' means any kind of physical or mental effort. However, in Engineering Mechanics, work has a precise definition. Work is said to be done when a force acting on a body causes it to move through a displacement in the direction of the force (or its component).

Definition & Mathematical Expression of Work

Work done (W) = Force × Displacement in the direction of force

$W = F \times s \times \cos\theta$

where θ is the angle between the direction of force F and displacement s.

- If $\theta = 0°$ (force and displacement in same direction): $W = F \cdot s$ (maximum)
- If $\theta = 90°$ (force perpendicular to displacement): $W = 0$ (no work done)
- If $\theta = 180°$ (force opposite to displacement): $W = -F \cdot s$ (negative work)

$$W = F \cdot s \cdot \cos\theta \quad \text{(in general)}$$

SI Unit: Joule (J) = 1 Newton × 1 metre = 1 N·m

SI Unit of Work	Joule (J) = N·m
Nature	Scalar quantity (dot product of two vectors)
Positive Work	Force and displacement in same direction ($\theta < 90°$)
Negative Work	Force opposes displacement ($\theta > 90°$), e.g. friction
Zero Work	Force perpendicular to displacement ($\theta = 90°$), e.g. normal force on horizontal motion

11. Power

Power is the rate at which work is done. It tells us how quickly or slowly work is being performed. A more powerful engine can do the same work in less time. Power is a measure of the effectiveness of an energy conversion process.

$$P = W/t = F \cdot v$$

P = Power (W) | W = Work (J) | t = time (s) | F = Force (N) | v = velocity (m/s)

SI Unit of Power	Watt (W) = 1 Joule per second = 1 J/s
Other Unit	Kilowatt (kW) = 1000 W, 1 HP (Horsepower) = 746 W
Nature	Scalar quantity
Alternative form	P = F·v (Force × velocity) — useful for moving vehicles
Average Power	P_{avg} = Total work done / Total time taken

12. Energy

Energy is defined as the capacity or ability of a body to do work. A body possesses energy if it can exert a force on another body and cause displacement. Energy is a scalar quantity and has the same unit as work — the Joule (J).

12.1 Kinetic Energy (KE)

Kinetic Energy is the energy possessed by a body due to its motion. A moving body can do work by virtue of its motion. The expression for KE is derived from the work-energy theorem.

Derivation of KE = $\frac{1}{2}mv^2$

A body of mass m starts from rest (u = 0) and is accelerated by force F through distance s.

Work done = F × s = ma × s (by Newton's 2nd law)

From $v^2 = u^2 + 2as$ with u = 0: $v^2 = 2as \rightarrow as = v^2/2$

$\therefore$ KE = W = ma × s = m × ($v^2/2$)

$\therefore$ **KE = $\frac{1}{2}mv^2$** ← **Kinetic Energy**

$$KE = \frac{1}{2}mv^2$$

KE = Kinetic Energy (J) | m = mass (kg) | v = velocity (m/s)

12.2 Potential Energy (PE)

Potential Energy is the energy stored in a body due to its position or configuration. The most common form in Engineering Mechanics is gravitational potential energy — the energy a body possesses by virtue of its height above a reference level.

$$PE = mgh$$

PE = Potential Energy (J) | m = mass (kg) | g = 9.81 m/s² | h = height above reference (m)

12.3 Conservation of Energy

Law of Conservation of Energy

Statement: Energy can neither be created nor destroyed. It can only be converted from one form to another. The total mechanical energy of a body (KE + PE) remains constant if no non-conservative forces (like friction) act.

KE + PE = Constant (for conservative systems)

$$\frac{1}{2}mv_1^2 + mgh_1 = \frac{1}{2}mv_2^2 + mgh_2$$

Kinetic Energy	$\frac{1}{2}mv^2$ (J)
Potential Energy (grav.)	mgh (J)
Elastic PE (spring)	$\frac{1}{2}kx^2$ (J)
Work-Energy Theorem	$W_{net} = \Delta KE$

Energy Transformations

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ENERGY CONVERSION EXAMPLES
─────────────────────────────────────────────────
Ball thrown up:  KE  →  PE   (at highest point: all PE)
Ball falling:    PE  →  KE   (at ground: all KE)
Generator:       Mech. Energy → Electrical Energy
Motor:           Electrical Energy → Mech. Energy
Stretched spring: Elastic PE → KE when released
─────────────────────────────────────────────────
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Example 4: Work, Power & Energy

Problem Statement

A pump of mass 500 kg raises water to a height of 20 m in 5 minutes. Find (a) Work done, (b) Power developed. ($g = 9.81$ m/s²)

Solution

Given: m = 500 kg, h = 20 m, t = 5 min = 300 s, g = 9.81 m/s²

- (a) Work done = $mgh = 500 \times 9.81 \times 20 = 98{,}100$ J = 98.1 kJ
- (b) Power = $W/t = 98100/300 = 327$ W ≈ 0.327 kW

Example 5: Kinetic Energy & Braking

Problem Statement

A car of mass 1200 kg is moving at 72 km/h. Brakes are applied and it stops in 50 m. Find (a) KE before braking, (b) Braking force applied.

Solution

Given: m = 1200 kg, v = 72 km/h = 20 m/s, s = 50 m, final v = 0

- (a) KE = ½mv² = ½ × 1200 × 20² = ½ × 1200 × 400 = 240,000 J = 240 kJ
- (b) Work done by braking force = KE (all KE is used up)
- F × s = KE → F = 240000/50 = 4800 N

Braking Force = 4800 N ← Answer

13. SI Units — Quick Reference Table

The following table summarises all important quantities, their symbols, and SI units covered in Unit VI. Students must memorise these for objective questions.

Quantity	SI Unit	Symbol	Formula
Displacement (s)	metre	m	—
Velocity (v)	m/s	$m \cdot s^{-1}$	v = s/t
Acceleration (a)	m/s^2	$m \cdot s^{-2}$	a = Δv/Δt
Force / P	Newton	N	F = ma
Momentum (p)	kg·m/s	$kg \cdot m \cdot s^{-1}$	p = mv
Angular Disp. (θ)	radian	rad	θ = s/r
Angular Vel. (ω)	rad/s	$rad \cdot s^{-1}$	ω = θ/t
Angular Accel. (α)	rad/s^2	$rad \cdot s^{-2}$	α = Δω/Δt
Centripetal Force	Newton	N	$Fc = mv^2/r$
Work (W)	Joule	J	W = F·s·cosθ
Power (P)	Watt	W	P = W/t = F·v
Energy (KE)	Joule	J	$KE = ½mv^2$
Energy (PE)	Joule	J	PE = mgh

IMPORTANT EXAM QUESTIONS

Unit VI — Motion in a Plane | Engineering Mechanics | WBSCTE Diploma 2nd Semester
(Based on WBSCTE Board Previous Year Final Exam Papers & Standard Question Bank)

The following questions are compiled from WBSCTE Diploma 2nd Semester previous year papers and the official question bank for Engineering Mechanics, Unit VI — Motion in a Plane. All sub-topics — Rectilinear Motion, Newton's Laws, Momentum, Curvilinear Motion, Centripetal/Centrifugal Force, and Work-Power-Energy — are covered. Practice every question thoroughly.

Section A — Short Answer / Definitions (2–3 Marks)

These questions test conceptual clarity, definitions, and short derivations. Expect 4–6 such questions in the WBSCTE exam from Unit VI.

S.No.	Question	Type / Marks
1	Define: (a) Displacement (b) Velocity (c) Acceleration. State their SI units.	Short / 2M
2	Distinguish between uniform and non-uniform motion with examples.	Short / 2M
3	State Newton's Second Law of Motion. Derive P = ma from it.	Short / 3M
4	Define momentum. State the Law of Conservation of Momentum with one example.	Short / 3M
5	Define: (a) Angular displacement (b) Angular velocity (c) Angular acceleration.	Short / 3M
6	Write the relation between linear velocity and angular velocity. Prove $v = r\omega$.	Short / 3M
7	Define Work, Power, and Energy. State their SI units.	Short / 3M

Section B — Descriptive & Derivation Questions (5 Marks)

Full explanations, neat diagrams, and step-by-step derivations are required. Always show all steps clearly.

S.No.	Question	Type / Marks
1	Draw and explain Displacement–Time and Velocity–Time diagrams for uniformly accelerated motion.	Descriptive / 5M
2	Derive the three equations of motion for uniformly accelerated rectilinear motion.	Derivation / 5M
3	State and prove the Law of Conservation of Linear Momentum.	Derivation / 5M

4	Derive expressions for centripetal acceleration and centripetal force for a body moving in a circular path.	**Derivation / 5M**
5	What is centrifugal force? How does it differ from centripetal force? Give examples.	**Descriptive / 3M**
6	Derive v = rω and a = rα from first principles.	**Derivation / 5M**
7	Explain the work-energy theorem. State the law of conservation of energy.	**Descriptive / 5M**

Section C — Numerical Problems (5–8 Marks)

Numericals carry the highest marks. Always write Given, Find, Diagram (if applicable), Equations, and Stepwise working. Units must be shown at every step.

S.No.	Question	Type / Marks
1	A car starts from rest and attains a velocity of 72 km/h in 10 s. Find: (a) acceleration, (b) distance covered.	**Numerical / 5M**
2	A body of mass 5 kg is moving with velocity 10 m/s. A force of 20 N acts on it for 4 s. Find the final velocity and change in momentum.	**Numerical / 5M**
3	Two balls of mass 3 kg and 5 kg moving at 4 m/s and 2 m/s in opposite directions collide and stick together. Find their common velocity after collision.	**Numerical / 5M**
4	A stone of mass 2 kg is tied to a string of length 0.5 m and rotated in a horizontal circle at 120 rpm. Find: (a) angular velocity, (b) linear velocity, (c) centripetal force.	**Numerical / 8M**
5	A body of mass 10 kg is raised to a height of 5 m in 4 s. Find (a) Work done, (b) Power developed, (c) Potential energy stored. ($g = 9.81\ m/s^2$)	**Numerical / 5M**
6	A vehicle of mass 1000 kg is moving at 20 m/s. Find its kinetic energy. If a braking force of 5000 N is applied, find the distance taken to stop.	**Numerical / 5M**
7	A wheel starts from rest and reaches 300 rpm in 5 s. Find angular acceleration and angular velocity in rad/s.	**Numerical / 5M**

Exam Tips for Unit VI — Motion in a Plane

- Always write all given data clearly before starting any numerical problem.
- State the correct equation of motion BEFORE substituting values; this earns method marks.
- For v–t and s–t diagrams, label axes, slopes, and areas — each label can carry marks.
- Remember: **slope of s–t = velocity; slope of v–t = acceleration; area under v–t = displacement.**
- Key formula chain: **$v=r\omega$, $a=r\alpha$, $F_c=mv^2/r=m\omega^2r$ — these link Section A to Section B seamlessly.**

- In conservation of momentum problems, assign one direction as positive and stick to it throughout.
- For Work-Power-Energy: state the law/theorem first, then apply formula — never jump straight to substitution.
- Convert all units to SI (km/h → m/s, rpm → rad/s, min → s) BEFORE substituting.

— End of Unit VI Notes —

Prepared for WBSCTE Diploma 2nd Semester | Engineering Mechanics | Unit VI: Motion in a Plane