CLASS 9TH PHYSICS • UNIT 2

Kinematics (Rest & Motion)

Complete Notes, Numericals & MCQs

Colorful Study Booklet

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1 Q.1. Define mechanics and also differentiate between the two main branches of mechanics.

Ans: Mechanics: Mechanics is the branch of physics that deals with the motion of objects and the forces that cause or change this motion.

i. Kinematics: The study of motion without referring to the forces that cause it. It focuses on displacement, velocity, acceleration, and time.

Example: Describing the motion of cars, buses, or motorcycles without considering what causes them to move.

ii. Dynamics: Deals with the study of forces and their effect on the motion of objects.

Example: The motion of an object falling from a table to the ground, analyzed via the force of gravity.

2 Q.2. Differentiate between scalar and vector quantities with examples.

Ans: Scalar quantities: A scalar is a physical quantity described completely by its magnitude only (a number and unit).

Examples: Mass, length, time, speed, volume, work, energy, pressure, power.

Addition of Scalars: Simple arithmetic, e.g. 5 m + 3 m = 8 m.

Vector quantities: A vector requires both magnitude and direction.

Examples: Velocity, displacement, force, momentum, torque, acceleration, weight.

Addition of Vectors: Added using head-to-tail rule, not simple arithmetic.

Importance in Kinematics: Scalars describe "how much," vectors describe "how much and in which direction" - essential for describing motion.

3 Q.3. How are vectors represented symbolically and graphically? Explain.

Ans: Symbolic Representation: Vectors are shown in boldface (A, V, F, d) or with an arrow over the letter when handwritten. Magnitude is shown without the arrow, in italics.

Graphical Representation: A straight line with an arrowhead. Length corresponds to magnitude (to scale); arrowhead indicates direction.

Reference Axes: Horizontal (x-axis, east-west) and vertical (y-axis, north-south) lines intersecting at origin O.

Drawing Vectors: Drawn from the origin, direction defined by angle theta with the x-axis, measured anti-clockwise from the positive x-axis.

4 Q.4. Define resultant vector. How vectors are added by head-to-tail rule? Explain with example.

Ans: Resultant Vector: A single vector representing the combined effect of two or more vectors.

Head-to-Tail Rule: Redraw vectors so the head of one coincides with the tail of the next; the resultant goes from the tail of the first to the head of the last.

Example: v1 = 300 N at 30 deg, v2 = 400 N at 60 deg with x-axis. Scale: 100 N = 1 cm. v1 drawn as 3 cm at 30 deg, v2 as 4 cm at 60 deg starting from head of v1. Resultant measured as 6.8 cm = 680 N at angle 49 deg with x-axis.

5 Q.5. Define and explain rest and motion with example. Show that rest and motion are relative to observer.

Ans: Rest: A body not changing position with respect to its surroundings is at rest.

Motion: A body continuously changing position with respect to surroundings is in motion.

Relativity of Rest and Motion: Rest and motion depend on the observer's frame of reference.

Example: A person standing in a moving train appears at rest to fellow passengers but in motion to an observer on the platform.

6 Q.6. Explain different types of motion and give examples. Further explain types of translatory motion.

Ans: Three main types: i. Translatory Motion ii. Rotatory motion iii. Vibratory motion

i. Translatory Motion: Every particle moves uniformly in the same direction. Examples: motion of a train/car, riders in a ferris wheel.

Types of Translatory Motion:

(a) Linear motion - along a straight line. Examples: freely falling body, aeroplane flying straight.

(b) Random motion - along an irregular path. Examples: motion of a bee, gas molecules.

(c) Circular motion - along a circle. Examples: ball tied to a string, moon around Earth.

ii. Rotatory motion: Each point moves around a fixed axis. Examples: electric fan, washing machine drum, top, cycle wheel.

iii. Vibratory motion: Repeated to-and-fro motion about a fixed position. Examples: swing, simple pendulum.

7 Q.7. Differentiate between Distance and Displacement.

Ans: Distance: The length of the actual path of motion - a scalar quantity.

Displacement: The shortest distance between initial and final position - a vector quantity, direction from initial to final position.

Example: Travel from Lahore to Multan - distance travelled 320 km (speedometer), but displacement is the shortest straight-line distance with direction Lahore to Multan.

Note: Distance is always greater than or equal to the magnitude of displacement.

8 Q.8. Explain the concepts of speed and velocity. Discuss uniform and non-uniform velocity with an example.

Ans: Speed: Distance covered in unit time. $v = S/t$. Scalar quantity, SI unit m/s or km/h.

Instantaneous Speed: Speed shown by speedometer at any instant.

Average Speed: Total distance / total time.

Velocity: Net displacement in unit time - a vector. $v = d/t$.

Example: Car moving north at 70 km/h - speed 70 km/h (scalar), velocity 70 km/h north (vector).

Uniform velocity: Speed and direction do not change.

Non-uniform velocity: Speed or direction (or both) changes.

Example: A paratrooper falling at uniform velocity once air resistance balances gravity.

9 Q.9. Explain the concept of acceleration and its types. Discuss uniform and non-uniform acceleration.

Ans: Acceleration: The time rate of change of velocity. Occurs due to change in magnitude or direction of velocity.

Positive Acceleration: Velocity increases. Example: car overtaking another.

Negative Acceleration (Deceleration): Velocity decreases. Example: applying brakes.

Formula: a = delta v / delta t. SI unit m/s2. If constant: v_f = v_i + at.

Uniform Acceleration: Rate of change of velocity is constant.

Non-uniform acceleration: Magnitude or direction (or both) changes - variable acceleration.

10 Q.10. What is a graph? How it is drawn? Explain.

Ans: A graph is a pictorial diagram (straight line or curve) showing the relationship between two physical quantities, drawn on graph paper with x-axis (independent variable, e.g. time) and y-axis (dependent variable, e.g. distance).

Steps to Draw a Distance-Time Graph: (i) Select Axes: time on x-axis, distance on y-axis. (ii) Choose a Suitable Scale. (iii) Mark Values. (iv) Plot Data Points. (v) Draw the Line or Curve.

11 Q.11. What is distance-time graph? Explain steps to draw a graph on a paper.

Ans: Distance-Time Graph: Shows the relation between distance S and time t.

Example Table: Time (min): 0,1,2,3,4,5; Distance (km): 0,1.2,2.4,3.6,4.8,6.0 - equal distance in equal time intervals, so uniform speed, straight line graph.

Steps: (i) Time on x-axis, distance on y-axis. (ii) Select suitable scales. (iii) Mark values of each division. (iv) Plot pairs of values. (v) Join points to get best straight line.

Second Example (accelerating car): Time (min): 0,1,2,3,4,5; Distance (km): 0, 0.240, 0.960, 2.160, 3.840, 6.000 - speed increases in equal intervals, graph curves upward, indicating acceleration.

12 Q.12. Explain distance time graph for an object: (i) when speed of object decreases (ii) when object is at rest

Ans: (i) When speed decreases: Distance travelled in same time interval decreases - graph curves downward - deceleration/negative acceleration.

(ii) When object is at rest: Distance does not change with time - graph is a horizontal line (slope = 0), meaning the object is not moving.

13 Q.13. Explain gradient of distance-time graph. What does the gradient represent?

Ans: The gradient is the slope of the graph line, representing speed.

Select points P and Q at times t1, t2. Distances S1, S2. ΔS = S2-S1, Δt = t2-t1.

Slope = ΔS/Δt = average speed (v_avg).

Also expressed as tan(theta) = ΔS/Δt.

Conclusion: Gradient of distance-time graph = average speed of the body.

14 Q.14. Explain speed-time graph when an object: (i) moving with uniform acceleration (ii) moving with constant speed

Ans: Speed-time graph plots speed v versus time t.

(i) Uniform acceleration: Table shows speed increasing by the same amount every second (0,8,16,24,32,40 m/s) - straight line rising upward.

(ii) Constant speed: Speed stays the same (20,20,20,20,20,20 m/s) - horizontal line parallel to time axis.

15 Q.15. Explain gradient of speed-time graph. What does it represent? Find the gradient for constant speed.

Ans: Motion with Constant Acceleration: Slope = $\Delta v/\Delta t$ = average acceleration (a).

Motion with Constant Speed: v2 = v1, so Δv = 0, acceleration = 0.

Conclusion: Gradient of speed-time graph = acceleration; zero gradient means zero acceleration (constant speed motion).

16 Q.16. Show that the area under speed-time graph is numerically equal to the distance covered by an object.

Ans: (i) Constant Speed: Graph is a horizontal line, forming a rectangle. Area = base x height = t x v = S. Distance covered = area under graph.

(ii) Uniformly Increasing Speed: Graph forms a right-angled triangle (0 to v over time t). Average speed = v/2. Distance = (v/2) x t. Area of triangle = 1/2 x t x v = distance travelled.

17 Q.17. Explain the three equations of motion and the assumptions made while applying them.

Ans: If v_i is initial velocity, v_f final velocity, t time, S distance, a acceleration:

$v_f = v_i + at$

$S = v_i t + 1/2\, at^2$

$2aS = v_f^2 - v_i^2$

Assumptions: (i) Motion along a straight line. (ii) Only magnitudes of vector quantities used. (iii) Acceleration assumed uniform. (iv) Direction of initial velocity taken as positive; opposite direction negative.

18 Q.18. Explain the concept of free fall acceleration and application of equations of motion to freely falling bodies.

Ans: Gravitational acceleration g acts downward, standard value 9.8 m/s2 (approximated as 10 m/s2). Equations become:

$v_f = v_i + gt$

$S = v_i t + 1/2\, gt^2$

$2gh = v_f^2 - v_i^2$

Important Points: (i) If released from rest, $v_i = 0$. (ii) g positive downward, all downward quantities positive, opposite negative. (iii) If thrown upward, g is negative and final velocity is zero at the highest point.

NUMERICAL PROBLEMS (Unit 2)

19 2.1 Draw the representative lines of the following vectors:

(a) A velocity of 400 m/s making an angle of 60 deg with x-axis. Scale: 1 cm = 100 m/s

(b) A force of 50 N making an angle of 120 deg with x-axis. Scale: 1 cm = 10 N

20 **2.2 A car moving at average speed 72 km/h covers 360 km. Find time.**

Solution: t = distance/speed = 360/72 = 5 hours. Result: 5 hours.

21 **2.3 A truck starts from rest and reaches 90 km/h in 50 seconds. Find average acceleration.**

Solution: v_f = 25 m/s, t = 50 s. a = (25-0)/50 = 0.5 m/s2. Result: 0.5 m/s2.

22 **2.4 A car passes a green signal at 5 m/s, accelerates at 1.5 m/s2. Find velocity after 5 s.**

Solution: v_f = v_i + at = 5 + 1.5x5 = 12.5 m/s. Result: 12.5 m/s.

23 **2.5 A motorcycle at 18 km/h accelerates at 2 m/s2. Find distance in 10 s.**

Solution: v_i = 5 m/s. S = v_i t + 1/2 at^2 = 50 + 100 = 150 m. Result: 150 m.

24 **2.6 A wagon at 54 km/h brakes and stops within 25 m. Find acceleration.**

Solution: v_i = 15 m/s. 2aS = v_f^2 - v_i^2 => 50a = -225 => a = -4.5 m/s2. Result: -4.5 m/s2 (deceleration).

25 **2.7 A stone dropped from 45 m. Find time to reach ground and final velocity.**

Solution: h = 1/2 gt^2 => 45 = 5t^2 => t = 3 s. v_f = gt = 30 m/s. Result: t = 3 s, v = 30 m/s.

26 **2.8 A car travels 10 km at 20 m/s, then 0.8 km at 4 m/s. Find average velocity.**

Solution: t1 = 10000/20 = 500 s, t2 = 800/4 = 200 s. Total distance = 10800 m, total time = 700 s. v_avg = 10800/700 = 15.4 m/s. Result: 15.4 m/s.

27 **2.9 A ball dropped from a tower reaches ground in 5 s. Find height and final velocity.**

Solution: h = 1/2 gt^2 = 5x25 = 125 m. v_f = gt = 50 m/s. Result: height 125 m, velocity 50 m/s.

28 **2.10 A cricket ball hit straight up takes 3 s to reach highest point, hit 1 m above ground. Find initial velocity and total height.**

Solution: v_f=0=v_i+gt(g=-10) => v_i = 30 m/s. h = v_i t + 1/2 gt^2 = 90-45 = 45 m. Total height = 45+1 = 46 m. Result: v_i = 30 m/s, total height = 46 m.

SHORT QUESTIONS (Exercise)

29 **2.1 Define scalar and vector quantities.**

Ans: Scalar - described completely by magnitude only (mass, length, time, speed). Vector - requires magnitude and direction (velocity, displacement, force).

30 **2.2 Give 5 examples each for scalar and vector quantities.**

Ans: Scalar: volume, work, energy, pressure, power. Vector: force, momentum, torque, acceleration, weight.

31 **2.3 State head-to-tail rule for addition of vectors.**

Ans: Redraw vectors so the head of one coincides with the tail of the next; the resultant vector runs from the tail of the first to the head of the last vector.

32 **2.4 What are distance-time graph and speed-time graph?**

Ans: Distance-Time Graph: shows how distance changes over time; slope = speed. Speed-Time Graph: shows how speed changes over time; slope = acceleration, area under curve = distance.

33 **2.5 Falling objects near Earth have the same constant acceleration. Does this imply a heavier object falls faster?**

Ans: No. Ignoring air resistance, all objects fall at the same rate (g ~ 10 m/s2) regardless of mass, since gravity acts uniformly on all objects.

34 **2.6 Vector quantities are sometimes written in scalar notation. How is direction indicated?**

Ans: Using (i) positive/negative signs, (ii) directional words (N,S,E,W), (iii) angles, (iv) unit vectors.

35 **2.7 A body moves with uniform speed. Will its velocity be uniform? Give reason.**

Ans: No. Velocity includes direction; if direction changes, velocity changes even if speed stays constant.

36 **2.8 Is it possible for a body to have acceleration when moving with (i) constant velocity (ii) constant speed?**

Ans: (i) No - zero velocity change means zero acceleration. (ii) Yes - if direction changes (e.g., circular motion), acceleration (centripetal) exists even at constant speed.

ADDITIONAL SHORT QUESTIONS

37 **2.1 The car while moving on a circular road may have constant speed, but its velocity is changing at every instant. Why?**

Ans: Velocity is a vector; direction continuously changes along the circular path even though speed is constant.

38 **2.2 Write down the equations of motion for freely falling bodies.**

Ans: v_f = v_i + gt; h = v_i t + 1/2 gt^2; 2gh = v_f^2 - v_i^2

39 **2.3 With daily life examples, explain: (i) acceleration in direction of motion (ii) acceleration against direction of motion (iii) acceleration zero, body in motion**

Ans: (i) Apple falling from tree - acceleration downward, same as motion. (ii) Cricket ball thrown upward - acceleration downward, opposite to motion. (iii) Car moving uniformly in a fixed direction - zero acceleration, body in motion.

Graphical analysis of motion

40 **2.4 (a) What does each line on the graph represent? (b) Which cyclist traveled the most distance? (c) Which traveled at greatest/lowest/constant speed?**

Ans: (a) Each line represents a cyclist's distance over time. (b) Cyclist A (highest line). (c) Greatest speed: Cyclist A (steepest slope); lowest: Cyclist C; all travelled at constant speeds (straight lines).

41 **2.5 What does the gradient of a distance-time graph represent?**

Ans: Speed of the object - steeper gradient means higher speed.

42 **2.6 What does the gradient of a speed-time graph represent?**

Ans: Acceleration - positive gradient means increasing speed, negative means decreasing speed.

43 **2.7 What does the area under a speed-time graph represent?**

Ans: The distance traveled by the object.

Distance and Displacement

44 **2.8 Is it possible that displacement is zero but not the distance? Under what condition are they equal?**

Ans: Yes - if a body returns to its initial position, displacement is zero but distance is not. They are equal when the body moves in a straight line from start to end point.

Vector

45 **2.9 Define resultant vector.**

Ans: A single vector obtained by adding two or more vectors, having the same combined effect as all vectors added.

46 **2.10 How a vector is represented graphically? Explain.**

Ans: By a straight line with an arrowhead; length represents magnitude (to scale), arrow direction represents vector direction.

Relativity

47 **2.11 What is meant by universal speed limit?**

Ans: According to Einstein's theory of special relativity (1905), the speed of light (~3x10^8 m/s) is constant and is the universal speed limit - no object with mass can reach or exceed it.