Motion in a Straight Line — Assignment 2

Class 11 Physics · Higher-difficulty challenge set + integrated problems + figure-based NCERT (7 questions) · Answer key included · Narayan Gurukul Academy

Instructions: (1) Attempt all questions; start with the topic-wise challenge set, then attempt the integrated (multi-topic) problems.
(2) Give all answers with correct SI units. g = 10 m/s^2 unless stated.
(3) A final answer key is provided at the end — try the full set before checking it.

Part A — Topic-wise challenge questions

Position, Distance and Displacement

2 Mark Questions

1. A man walks 5 m north, 3 m east and finally 5 m south. Find the magnitude of his displacement and the distance he walked.

3 Mark Questions

1. A cyclist rides one full round of a square park of side 100 m in 12 minutes. Find (i) the distance travelled, (ii) the magnitude of his displacement, and (iii) his average speed in m/s.

Average Speed and Average Velocity — the Two Exam Traps

2 Mark Questions

1. A train travels from station P to station Q at 40 km/h and returns along the same route at 30 km/h. Find its average speed for the round trip.

2. A particle moves at 10 m/s for 5 s and then at 20 m/s for 10 s. Find its average speed.

3 Mark Questions

1. A body covers the first half of a journey at speed v_1 and the second half at speed v_2. Show that its average speed is $2v_1v_2/(v_1 + v_2)$.

2. A man walks 2.5 km to a market at 5 km/h and returns at 7.5 km/h. Find (i) his average speed for the round trip and (ii) the magnitude of his average velocity for the whole trip.

Acceleration and Retardation

2 Mark Questions

1. A car moving at 72 km/h is brought to rest by applying brakes in 5 s. Find its retardation.

3 Mark Questions

1. A train slows uniformly from 72 km/h to 36 km/h while covering a distance of 200 m. Find its retardation and the time taken.

2. A body moving with uniform acceleration covers 20 m in the 1st second and 40 m in the 2nd second. Find its initial velocity and acceleration.

Equations of Motion and the nth-Second Formula

2 Mark Questions

1. A body starting from rest moves with a uniform acceleration of 5 m/s^2. Find its displacement in the 8th second.

3 Mark Questions

1. A particle starts from rest with a uniform acceleration of 6 m/s^2. Find the distance covered (i) in the first 5 s and (ii) in the 5th second.

2. A body starts from rest with uniform acceleration a. Show that the distances covered in successive seconds are in the ratio 1 : 3 : 5 : 7 ... .

Reading Motion Graphs

2 Mark Questions

1. The velocity of a particle increases uniformly from 10 m/s to 25 m/s in 5 s. Using the v–t graph, find the distance covered.

3 Mark Questions

1. Draw the x–t, v–t and a–t graphs for a ball thrown vertically upward until it returns to the thrower (air resistance neglected).

2. From the velocity–time graph of a uniformly accelerated body, derive all three equations of motion.

Motion Under Gravity (Free Fall)

2 Mark Questions

1. A ball is thrown upward with a speed of 30 m/s. Taking g = 10 m/s^2, find (i) the maximum height reached and (ii) the total time of flight.

2. A stone dropped from a tower reaches the ground in 3 s. Taking g = 10 m/s^2, find the height of the tower and the velocity of impact.

3 Mark Questions

1. A ball thrown vertically upward returns to its starting point in 6 s. Taking g = 10 m/s^2, find (i) its initial velocity and (ii) the maximum height reached.

2. A stone is dropped from the top of a tower 100 m high and, at the same instant, another stone is thrown vertically upward from the foot of the tower at 25 m/s. Taking g = 10 m/s^2, find when and where the two stones meet.

Non-Uniform Acceleration and Calculus

2 Mark Questions

1. A particle starts from rest with an acceleration a = 6t (m/s^2). Find its velocity and displacement as functions of time.

2. The velocity of a particle is v = $3t^2 + 4t + 2$ (m/s). Find its acceleration at t = 1 s.

3 Mark Questions

1. A particle has acceleration a = −kv (k constant) and initial velocity u. Find its velocity as a function of time.

2. A particle moving along the x-axis has acceleration a = −2x (x in metres). If it starts from rest at x = 2 m, find its speed at x = 1 m.

Frames of Reference

2 Mark Questions

1. A lift accelerates upward with acceleration a. Find the effective weight of a man of mass m standing in the lift, as observed from the ground frame.

3 Mark Questions

1. A mass m hangs from a spring balance in a lift. The lift accelerates upward at a. Show, from the lift frame and from the ground frame, that the balance reads m(g + a).

2. State the condition for a frame to be inertial, and show that any frame moving uniformly with respect to an inertial frame is itself inertial.

Relative Velocity in a Straight Line

2 Mark Questions

1. A 120 m long train moving at 10 m/s overtakes an 80 m long train moving at 6 m/s in the same direction. Find the time taken to completely pass it.

2. A police van moving at 30 km/h fires a bullet at a car speeding away in the same direction at 192 km/h. If the muzzle speed of the bullet is 150 m/s, find the speed with which the bullet hits the car.

3 Mark Questions

1. A car moving at 10 m/s is 25 m behind a scooter moving at 8 m/s in the same direction. Find the time after which the car overtakes the scooter and the distance the car covers in that time.

2. A car moving at 20 m/s is 60 m behind a bus moving at 15 m/s in the same direction. Find (i) how long the car takes to catch the bus and (ii) the distance covered by the car before catching it.

River–Boat and Rain–Man Problems

2 Mark Questions

1. Rain falls vertically at 3 m/s and a man runs horizontally at 4 m/s. Find the speed with which the rain strikes the man and the direction in which he should hold his umbrella.

2. A boy rows at 4 m/s in still water across a river 400 m wide flowing at 3 m/s, aiming perpendicular to the flow. Find how far downstream he lands and his resultant speed relative to the ground.

3 Mark Questions

1. Derive the condition for a swimmer to cross a river along the shortest possible path: the angle at which he must aim and the time taken, in terms of u, w and the width d.

2. A swimmer crosses a 200 m wide river at 4 m/s in still water aiming perpendicular to the flow, while the current is 3 m/s. Compute (i) the time to cross, (ii) the point of landing downstream, and (iii) the angle the actual path makes with the straight-across direction.

3. Rain is falling with a velocity of 10 m/s at 30° to the vertical, and a man is running horizontally at 5 m/s in the direction in which the rain has its horizontal component. Find the velocity of the rain relative to the man.

Part B — Integrated problems (multi-topic)

1. A man walks 5 km from his home to a market at 4 km/h, rests there for 30 minutes, and then walks straight back home at 6 km/h. Find (i) the total time of the round trip, (ii) his average speed, and (iii) the magnitude of his average velocity.

2. A stone is dropped from a point 45 m above the ground and, at the same instant, a second stone is thrown vertically upward from the ground at 40 m/s. Taking g = 10 m/s^2, find (i) the time at which the two stones meet and (ii) the height above the ground at which they meet.

3. A 100 m long train moving at 20 m/s crosses a bridge completely in 15 s. After crossing the bridge, the brakes are applied and the train retards uniformly at 2 m/s^2. Find (i) the length of the bridge and (ii) the distance the train travels after the brakes are applied before coming to rest.

4. A particle starts from rest and accelerates uniformly at 2 m/s^2 for 4 s, then moves with constant velocity for 6 s, and finally retards uniformly at 3 m/s^2 to rest. Find (i) the maximum velocity, (ii) the total displacement, and (iii) the total time of motion.

5. A truck passes a point at a constant speed of 10 m/s. At the same instant a car starts from rest from that point and accelerates uniformly at 2 m/s^2 in the same direction. Find (i) the time after which the car catches the truck and (ii) the distance from the point where this happens.

6. The position of a particle moving along the x-axis is x = 2t^3 − 3t^2 + 5 (x in metres, t in seconds). Find (i) the velocity at t = 2 s, (ii) the acceleration at t = 2 s, and (iii) the average velocity over the first 2 s.

Part C — Figure-based NCERT questions (answers at the end)

1. 2.2) The position–time (x–t) graphs for two children A and B returning from school O to their homes P and Q are shown in Fig. 2.9. Choose the correct entries: (a) (A/B) lives closer to the school than (B/A); (b) (A/B) starts from the school earlier than (B/A); (c) (A/B) walks faster than (B/A); (d) A and B reach home at the (same/different) time; (e) (A/B) overtakes (B/A) on the road (once/twice).

2. 2.12) Look at the graphs (a) to (d) (Fig. 2.10) carefully and state, with reasons, which of these cannot possibly represent one-dimensional motion of a particle.

3. 2.13) Figure 2.11 shows the x–t plot of one-dimensional motion of a particle. Is it correct to say from the graph that the particle moves in a straight line for t < 0 and on a parabolic path for t > 0? If not, suggest a suatable physical context for this graph.

4. 2.15) Suggest a suitable physical situation for each of the following graphs (Fig. 2.12): (a) an x–t graph that rises and then suddenly drops back to zero, (b) a v–t graph of alternating positive and negative spikes that gradually die out, (c) an a–t graph that is zero except for a short pulse.

5. 2.16) Figure 2.13 gives the x–t plot of a particle executing one-dimensional simple harmonic motion. Give the signs of position, velocity and acceleration of the particle at t = 0.3 s, 1.2 s and −1.2 s.

6. 2.17) Figure 2.14 gives the x–t plot of a particle in one-dimensional motion. Three different equal intervals of time are shown. In which interval is the average speed greatest, and in which is it the least? Give the sign of the average velocity for each interval.

7. 2.18) Figure 2.15 gives a speed–time graph of a particle in motion along a constant direction. Three equal intervals of time are shown. In which interval is the average acceleration greatest in magnitude? In which interval is the average speed greatest? Choosing the positive direction as the constant direction of motion, give the signs of v and a in the three intervals. What are the accelerations at the points A, B, C and D?

Answer Key

Position, Distance and Displacement

3M(2): 400 m; 0; about 0.56 m/s (400 m in 720 s). 2M(3): 5 km north-west — magnitude 5 m, distance 13 m.

Average Speed and Average Velocity

2M(1): 34.3 km/h (240/7 km/h). 2M(3): 16.7 m/s. 3M(0): average speed = 2.v1.v2/(v1+v2), derived from total distance / total time. 3M(1): (i) 6 km/h; (ii) zero.

Acceleration and Retardation

2M(1): retardation 4 m/s^2. 3M(1): retardation 0.75 m/s^2; time 13.3 s. 3M(2): u = 20 m/s; a = 10 m/s^2 (subtract distance of each second: s2 − s1 = a = 20 m).

Equations of Motion and nth-second

2M(2): s8 = 37.5 m. 3M(1): (i) 75 m; (ii) 27.5 m. 3M(2): successive-second distances ½a: ½a·3, ½a·5, ... → 1 : 3 : 5 : 7 ...

Reading Motion Graphs

2M(2): 87.5 m (area of trapezium = ½(10+25)·5). 3M(0): parabola for x–t, straight line of slope −g for v–t, horizontal line at −g for a–t. 3M(1): slopes and areas read off the graph.

Motion Under Gravity (Free Fall)

2M(1): H = 45 m; T = 6 s. 2M(3): tower 45 m; impact 30 m/s. 3M(0): u = 30 m/s; H = 45 m. 3M(1): t = 4 s; 20 m above ground.

Non-Uniform Acceleration and Calculus

2M(1): v = 3t^2; x = t^3. 2M(3): 10 m/s^2. 3M(1): v = u·e^(−kt). 3M(2): speed = √6 m/s at x = 1 m.

Frames of Reference

2M(2): effective weight = m(g + a). 3M(1): balance reads m(g + a) in both frames. 3M(2): frame must be non-accelerating; a frame moving uniformly w.r.t. an inertial frame has zero acceleration and is itself inertial.

Relative Velocity

2M(2): 50 s. 2M(3): 105 m/s. 3M(0): 12.5 s; 125 m. 3M(1): (i) 12 s; (ii) 240 m.

River–Boat and Rain–Man

2M(1): 5 m/s, umbrella tilted at tan^−1(4/3) = 53° to the vertical. 2M(3): 300 m downstream; 5 m/s resultant. 3M(0): aim upstream at θ = sin^−1(w/u) w.r.t. straight across; time d/√(u^2 − w^2). 3M(1): t = 50 s; 150 m downstream; tan^−1(3/4) = 36.9° to the straight-across direction. 3M(2): relative velocity ≈ 6.61 m/s at about 40.9° to the vertical.

Integrated problems

1: (i) 155 min; (ii) ≈ 3.87 km/h; (iii) 0. 2: (i) 1.125 s; (ii) ≈ 6.33 m. 3: (i) 200 m; (ii) 100 m. 4: (i) 8 m/s; (ii) ≈ 74.7 m; (iii) 13.3 s. 5: (i) 10 s; (ii) 100 m. 6: (i) 12 m/s; (ii) 18 m/s^2; (iii) 2 m/s.

Part C — figure-based NCERT questions

2.2: (a) A lives closer; (b) A starts earlier; (c) B walks faster; (d) A and B reach home at the same time; (e) B overtakes A once. 2.12: None of (a)–(d) can represent one-dimensional motion — two values of x or v at a single instant (a), (b), a negative speed (c), and a decreasing total path length (d) are all impossible. 2.13: No — the x–t plot is not the spatial

path; the particle always moves along a straight line. Context: a ball held at rest until t = 0, then released to fall freely ($x \propto t^2$). 2.15: (a) a ball thrown up and caught on its return; (b) a ball bouncing on a hard floor with shrinking rebounds; (c) a cricket ball struck by a bat — a brief large acceleration. 2.16: t = 0.3 s: $x<0$, $v<0$, $a>0$; t = 1.2 s: $x>0$, $v>0$, $a<0$; t = −1.2 s: $x<0$, $v>0$, $a>0$. 2.17: average speed greatest in interval 3 and least in interval 2; average velocity positive in intervals 1 and 2, negative in interval 3. 2.18: average acceleration greatest in magnitude in interval 2, average speed greatest in interval 3; v positive in all three intervals; a positive in interval 1, negative in interval 2 and positive in interval 3; accelerations at A, B, C and D are all zero.