Chapter 4: Describing Motion Around Us

Exercises — Revise, Reflect, Refine

Q1 My father went to a shop from home which is located at a distance of 250 m on a straight road. On reaching there, he discovered that he forgot to carry a cloth bag. He came home to take it, went to the shop again, bought provisions and came back home. How much was the total distance travelled by him? What was his displacement from home?

SOLUTION

Let home be the starting point (origin).
My father first walks 250 m to the shop, then returns 250 m home to collect the bag, then walks 250 m to the shop again, and finally walks 250 m back home.
Total distance = 250 + 250 + 250 + 250 = 1000 m.

Displacement = final position − initial position = home − home = 0 m.
He started and ended at the same point (home), so his displacement is zero.

Answer: Total distance travelled = 1000 m. Displacement = 0 m (he returned to the starting point).

Q2 A student runs from the ground floor to the fourth floor of a school building to collect a book and then comes down to their classroom on the second floor. If the height of each floor is 3 m, find:
(i) the total vertical distance travelled, and
(ii) their displacement from the starting point.

SOLUTION

Take the ground floor as the origin (height = 0 m). Height of each floor = 3 m.
Path: Ground floor (0 m) → 4th floor (up) → 2nd floor (down, the classroom).

Height of the 4th floor above the ground = 4 × 3 = 12 m.
Height of the 2nd floor above the ground = 2 × 3 = 6 m.

(i) Vertical distance going up (ground → 4th floor) = 12 − 0 = 12 m.
Vertical distance coming down (4th floor → 2nd floor) = 12 − 6 = 6 m.
Total vertical distance travelled = 12 + 6 = 18 m.

(ii) The student's final position is the 2nd floor, 6 m above the ground floor (the start).

Displacement = final position − initial position = 6 − 0 = 6 m, directed vertically upward.

The distance (18 m) is greater than the displacement (6 m) because the student first went up past the classroom and then came back down.

Answer: (i) Total vertical distance = 18 m. (ii) Displacement = 6 m, directed vertically upward from the ground floor (to the second floor).

Q3 A girl is riding her scooter and finds that its speedometer reading is constant. Is it possible for her scooter to be accelerating and if so, how?

SOLUTION

The speedometer measures speed, which is the magnitude of velocity — it does not indicate direction.
Constant speedometer reading means constant speed, but not necessarily constant velocity.
Velocity is a vector quantity that has both magnitude (speed) and direction.

If the girl takes a turn while riding at constant speed, the direction of her velocity changes even though the magnitude (speed) stays the same.
A change in velocity (even only in direction) constitutes acceleration.

Yes, it is possible. If the scooter is moving along a curved path — for example, going around a bend or a roundabout — the direction of motion changes continuously. This means the velocity changes, so the scooter is accelerating (centripetal acceleration), even though the speedometer reading is constant.

Answer: Yes. If the scooter moves along a curved path at constant speed, its direction of velocity changes, which means it is accelerating (centripetal acceleration) even though the speedometer reads a constant value.

Q4 A car starts from rest and its velocity reaches 24 m s^{-1} in 6 s. Find the average acceleration and the distance travelled in 6 s.

SOLUTION

Given: initial velocity u = 0 (starts from rest), final velocity v = 24 m s^{-1}, time t = 6 s.

Average acceleration a = (v − u) / t = (24 − 0) / 6 = 4 m s^{-2}.

Distance travelled using $s = ut + \frac{1}{2}at^2$:
$s = 0 \times 6 + \frac{1}{2} \times 4 \times 6^2$
$s = 0 + \frac{1}{2} \times 4 \times 36$
$s = 72$ m.

Verification using $v^2 = u^2 + 2as$: $24^2 = 0 + 2 \times 4 \times 72 = 576$. ✓

Answer: Average acceleration = 4 m s^{-2}. Distance travelled in 6 s = 72 m.

Q5 A motorbike moving with initial velocity 28 m s^{-1} and constant acceleration stops after travelling 98 m. Find the acceleration of the motorbike and the time taken to come to a stop.

SOLUTION

Given: initial velocity u = 28 m s^{-1}, final velocity v = 0 (stops), distance s = 98 m.

Using $v^2 = u^2 + 2as$:
$0 = 28^2 + 2 \times a \times 98$
$0 = 784 + 196a$
$196a = -784$
$a = -784 / 196 = -4$ m s^{-2}.
The negative sign shows the motorbike decelerates (retardation).

Time to stop using $v = u + at$:
$0 = 28 + (-4) \times t$
$4t = 28$
$t = 7$ s.

Verification: $s = ut + \frac{1}{2}at^2 = 28 \times 7 + \frac{1}{2} \times (-4) \times 49 = 196 - 98 = 98$ m. ✓

Answer: Acceleration = −4 m s^{-2} (retardation of 4 m s^{-2}). Time to stop = 7 s.

Q6 Fig. 4.27 shows a position-time graph of two objects A and B that are moving along the parallel tracks in the same direction. Do objects A and B ever have equal velocity? Justify your answer.

SOLUTION

In a position-time graph, the slope of the line at any instant gives the velocity of the object at that instant.

From Fig. 4.27, both A and B are straight lines, so each object moves with its own

constant velocity. But the two lines are NOT parallel: line A starts from the origin and is steeper, while line B starts at a positive position (a head start) and is less steep. The two lines cross at t = 5 s.

Because line A is steeper than line B, the slope of A is greater than the slope of B at every instant. So the velocity of A is always greater than the velocity of B — their velocities are never equal.

The crossing point at t = 5 s means A and B are at the same POSITION at that instant (A overtakes B), not that they have the same velocity.

Therefore, objects A and B never have equal velocity. A moves faster than B throughout; at t = 5 s they merely occupy the same position.

Answer: No. In Fig. 4.27 the lines for A and B have different slopes — A (from the origin) is steeper than B (which starts ahead), so A's velocity is always greater than B's. They cross at t = 5 s, which means they are at the same position then, but their velocities are never equal.

Q7 A graph in Fig. 4.28 shows the change in position with time for two objects A and B moving in a straight line from 0 to 10 seconds. Choose the correct option(s):
(i) The average velocity of both over the 10 s time interval is equal since they have the same initial and final positions.
(ii) The average speeds of both over the 10 s time interval are equal since both cover equal distance in equal time.
(iii) The average speed of A over the 10 s time interval is lower than that of B since it covers a shorter distance than B in 10 seconds.
(iv) The average speed of A over the 10 s time interval is greater than that of B since B's speed is lower than A's in some segments.

SOLUTION

In a position-time graph, average velocity = (final position − initial position) / time, while average speed = (total path length covered) / time.

From Fig. 4.28, both objects A and B start at the same initial position (origin at t = 0) and reach the same final position at t = 10 s.
=> The displacement (change in position) is the same for both objects.
=> Average velocity of A = average velocity of B = same displacement / same time. So option (i) is CORRECT.

Both curves rise steadily from start to finish — the position of each object only

increases and never decreases (neither object turns back). When motion is along a straight line without any reversal of direction, the total distance covered equals the magnitude of the displacement.
=> Distance covered by A = distance covered by B = the same displacement.
=> Average speed of A = average speed of B. So option (ii) is also CORRECT.

Since both objects cover equal distances in equal time, neither covers a shorter (option iii) or greater (option iv) distance than the other. So options (iii) and (iv) are INCORRECT. (A is the straight line and B is curved, so their instantaneous speeds differ segment by segment, but their total distances — and hence average speeds — are equal.)

Answer: (i) and (ii). Both objects start and end at the same positions and move without reversing direction, so their displacements are equal (equal average velocity) and, since distance equals displacement here, their total distances are also equal (equal average speed). Options (iii) and (iv) are wrong because A and B cover equal distances.

Q8 A truck driver driving at the speed of 54 km h^{-1} notices a road sign with a speed limit of 40 km h^{-1} for trucks (Fig. 4.29). He slows down to 36 km h^{-1} in 36 s. What was the distance travelled by him during this time? Assume the acceleration is uniform while slowing down.

SOLUTION

Given: initial speed u = 54 km h^{-1} = 54 × (1000/3600) = 15 m s^{-1}.
Final speed v = 36 km h^{-1} = 36 × (1000/3600) = 10 m s^{-1}.
Time t = 36 s. Motion is uniformly decelerated.

Distance = average speed × time = (u + v)/2 × t
s = (15 + 10)/2 × 36
s = 12.5 × 36
s = 450 m.

Verification: a = (v − u)/t = (10 − 15)/36 = −5/36 m s^{-2}.
s = ut + ½at^2 = 15 × 36 + ½ × (−5/36) × 36^2 = 540 + ½ × (−5/36) × 1296 = 540 − 90 = 450 m. ✓

Answer: Distance travelled = 450 m.

Q9 A car starts from rest and accelerates uniformly to 20 m s^{-1} in 5 seconds. It then travels at 20 m s^{-1} for 10 seconds and finally applies the brake (with uniform acceleration) to stop in 6 seconds. Find the total distance travelled.

SOLUTION

Phase 1: Uniform acceleration from rest (u = 0) to v = 20 m s^{-1} in t_1 = 5 s.
Distance $s_1 = (u + v)/2 \times t_1 = (0 + 20)/2 \times 5 = 50$ m.

Phase 2: Constant velocity of 20 m s^{-1} for t_2 = 10 s.
Distance $s_2 = 20 \times 10 = 200$ m.

Phase 3: Uniform deceleration from u = 20 m s^{-1} to rest (v = 0) in t_3 = 6 s.
Distance $s_3 = (u + v)/2 \times t_3 = (20 + 0)/2 \times 6 = 60$ m.

Total distance = $s_1 + s_2 + s_3 = 50 + 200 + 60 = 310$ m.

Answer: Total distance travelled = 310 m.

Q10 A bus is travelling at 36 km h^{-1} when the driver sees an obstacle 30 m ahead. The driver takes 0.5 seconds to react before pressing the brake. Once the brake is applied, the velocity of the bus reduces with constant deceleration of 2.5 m s^{-2}. Will the bus be able to stop before reaching the obstacle?

SOLUTION

Given: initial speed u = 36 km h^{-1} = 36 × (1000/3600) = 10 m s^{-1}.
Reaction time = 0.5 s. Deceleration after braking = 2.5 m s^{-2}.
Obstacle distance = 30 m.

Distance covered during reaction time (constant speed 10 m s^{-1} for 0.5 s):
$d_1 = 10 \times 0.5 = 5$ m.

Braking distance (from $v^2 = u^2 + 2as$, with v = 0, a = −2.5 m s^{-2}):
$0 = 10^2 + 2 \times (-2.5) \times d_2$
$5\, d_2 = 100$
$d_2 = 20$ m.

Total stopping distance = $d_1 + d_2 = 5 + 20 = 25$ m.

25 m < 30 m (the obstacle distance), so the bus stops safely before reaching the obstacle.

Answer: Total stopping distance = 25 m, which is less than 30 m. Yes, the bus will stop safely before reaching the obstacle.

Q11 A student said, 'The Earth moves around the Sun'. In this context, discuss whether an object kept on the Earth can be considered to be at rest.

SOLUTION

Whether an object is at rest or in motion depends on the reference frame (reference point) chosen to describe the motion.

In the Earth's reference frame: A book placed on a table is at rest with respect to the table and the Earth. Its position does not change relative to objects on Earth. So, it is at rest in the Earth's reference frame.

In the Sun's reference frame: Since the Earth moves around the Sun, every object on Earth is also moving with the Earth. A book on the table is therefore in motion relative to the Sun.

Both statements are correct — rest and motion are relative concepts. The same object can be at rest with respect to one observer and in motion with respect to another.

Conclusion: A book kept on a table is at rest relative to the Earth (and any other observer on Earth) but is moving relative to the Sun.

Answer: Yes. The book is at rest relative to the Earth (its position does not change with respect to objects on Earth), but it is in motion relative to the Sun. Rest and motion are relative — they depend on the chosen reference frame.

Q12 The velocity-time graph from 0 s to 120 s for a cyclist is shown in Fig. 4.30. Shade the areas (in different colours) representing the displacement of the cyclist:
(i) while the cyclist is moving with constant velocity, and
(ii) when the velocity of the cyclist is decreasing.
Also, calculate the displacement and average acceleration in the 120 s time interval.

SOLUTION

From Fig. 4.30 the velocity-time graph has three parts:
Phase 1: t = 0 to 20 s — velocity increases uniformly from 0 to 6 m s^{-1} (rising line: the cyclist is accelerating).
Phase 2: t = 20 s to 100 s — constant velocity of 6 m s^{-1} (flat horizontal line).
Phase 3: t = 100 s to 120 s — velocity decreases uniformly from 6 m s^{-1} to 2 m s^{-1} (falling line).

(i) Shade the region under the flat part, t = 20 s to 100 s, in one colour — this is

the displacement while moving with constant velocity.
(ii) Shade the region under the falling part, t = 100 s to 120 s, in a different colour — this is the displacement while the velocity is decreasing.

Displacement = total area under the v-t graph:
Phase 1 (triangle, 0→6 over 20 s): $s_1 = ½ \times 20 \times 6 = 60$ m.
Phase 2 (rectangle, 6 m s^{-1} for 80 s): $s_2 = 6 \times 80 = 480$ m.
Phase 3 (trapezium, 6→2 over 20 s): $s_3 = (6 + 2)/2 \times 20 = 80$ m.
Total displacement = 60 + 480 + 80 = 620 m.

Average acceleration = (final velocity − initial velocity) / total time
= (2 − 0) / 120 = 0.017 m s^{-2} (approximately +1/60 m s^{-2}).
It is positive because the cyclist's velocity is higher at t = 120 s (2 m s^{-1}) than at t = 0 (0 m s^{-1}).

Answer: Shade the flat part t = 20–100 s (constant velocity) in one colour and the falling part t = 100–120 s (decreasing velocity) in another. Total displacement = 620 m. Average acceleration = (2 − 0)/120 ≈ 0.017 m s^{-2} (positive).

Q13 A girl is preparing for her first marathon by running on a straight road. She uses a smartwatch to calculate her running speed at different intervals. The graph (Fig. 4.31) depicts her velocity versus time. Estimate the distance she ran based on the graph.

SOLUTION

Distance = area under the velocity-time graph. Estimate this area from Fig. 4.31 by reading the velocity (km h^{-1}) at each hour and adding up the strip areas.

Reading Fig. 4.31 (the velocity stays between about 6.5 and 7.5 km h^{-1} throughout — it does NOT drop steeply):
t = 0 h: about 7.0 km h^{-1}
t = 1 h: about 7.25 km h^{-1}
t = 2 h: about 7.5 km h^{-1} (peak)
t = 3 h: about 7.25 km h^{-1}
t = 4 h: about 7.0 km h^{-1}
t = 5 h: about 6.5 km h^{-1}
t = 6 h: about 6.5 km h^{-1}

Estimate the area as a sum of 1-hour strips (using the average velocity in each 1 h interval):

0–1 h: (7.0 + 7.25)/2 × 1 ≈ 7.1 km
1–2 h: (7.25 + 7.5)/2 × 1 ≈ 7.4 km
2–3 h: (7.5 + 7.25)/2 × 1 ≈ 7.4 km
3–4 h: (7.0 + 7.25)/2 × 1 ≈ 7.1 km
4–5 h: (7.0 + 6.5)/2 × 1 ≈ 6.75 km
5–6 h: (6.5 + 6.5)/2 × 1 = 6.5 km

Total distance ≈ 7.1 + 7.4 + 7.4 + 7.1 + 6.75 + 6.5 ≈ 42 km.
(Since this is a read-off-the-graph estimate, an answer of roughly 40–43 km is acceptable.)

Answer: The distance is the area under the graph. Since the velocity stays roughly between 6.5 and 7.5 km h^{-1} over the 6 hours, the distance run is approximately 42 km (about 40–43 km, read off the graph).

Q14 On entering a state highway, a car continues to move with a constant velocity of 6 m s^{-1} for 2 minutes and then accelerates with a constant acceleration of 1 m s^{-2} for 6 seconds. Find the displacement of the car on the state highway in the 2 min 6 s time interval by drawing a velocity-time graph for its motion.

SOLUTION

Phase 1: Car moves at constant velocity 6 m s^{-1} for 2 minutes = 120 s.
Displacement $s_1 = 6 \times 120 = 720$ m.

Phase 2: Car accelerates from 6 m s^{-1} with acceleration 1 m s^{-2} for 6 s.
$s_2 = u_2t + \frac{1}{2}a_2t^2$
$s_2 = 6 \times 6 + \frac{1}{2} \times 1 \times 6^2$
$s_2 = 36 + \frac{1}{2} \times 36$
$s_2 = 36 + 18 = 54$ m.

Total displacement = $s_1 + s_2 = 720 + 54 = 774$ m.

Final velocity at end of phase 2: $v = 6 + 1 \times 6 = 12$ m s^{-1}.

Answer: Total displacement of the car on the state highway in 2 min 6 s = 774 m.

Q15 Two cars A and B start moving with a constant acceleration from rest, in a straight line. Car A attains a velocity of 5 m s^{-1} in 5 s. Car B attains a velocity of 3 m s^{-1} in 10 s. Using the graph, calculate the displacement in the two time intervals mentioned. (Hint: Calculate the acceleration in both cases. Then calculate their velocities at five instants of time to plot the graph.)

SOLUTION

Acceleration of Car A: $a_A = (5 - 0)/5 = 1$ m s^{-2}.
Acceleration of Car B: $a_B = (3 - 0)/10 = 0.3$ m s^{-2}.

Velocities at five instants (t = 0, 2, 4, 6, 8, 10 s) to plot the v-t graph:
t = 0 s: $v_A = 0$, $v_B = 0$
t = 2 s: $v_A = 2.0$ m s^{-1}, $v_B = 0.6$ m s^{-1}
t = 4 s: $v_A = 4.0$ m s^{-1}, $v_B = 1.2$ m s^{-1}
t = 6 s: $v_A = 6.0$ m s^{-1}, $v_B = 1.8$ m s^{-1}
t = 8 s: $v_A = 8.0$ m s^{-1}, $v_B = 2.4$ m s^{-1}
t = 10 s: $v_A = 10.0$ m s^{-1}, $v_B = 3.0$ m s^{-1}

Both are straight lines through the origin (uniform acceleration from rest).
Car A's line is steeper (higher acceleration).

Displacement in 5 s (using $s = \frac{1}{2}at^2$):
Car A: $s_A = \frac{1}{2} \times 1 \times 5^2 = 12.5$ m.
Car B: $s_B = \frac{1}{2} \times 0.3 \times 5^2 = 3.75$ m.

Displacement in 10 s:
Car A: $s_A = \frac{1}{2} \times 1 \times 10^2 = 50$ m.
Car B: $s_B = \frac{1}{2} \times 0.3 \times 10^2 = 15$ m.

Answer: Car A: acceleration = 1 m s^{-2}, displacement in 5 s = 12.5 m, in 10 s = 50 m. Car B: acceleration = 0.3 m s^{-2}, displacement in 5 s = 3.75 m, in 10 s = 15 m.

Q16 Rohan studies science from 6 PM to 7:30 PM at home. Consider the tip of the minute hand is 7 cm from the centre of the clock (Fig. 4.32). During the given time interval, what is:
(i) distance travelled,
(ii) displacement,
(iii) speed, and
(iv) velocity.

SOLUTION

Time interval: 6 PM to 7:30 PM = 90 minutes = 90 × 60 = 5400 s.
Radius of minute hand = r = 7 cm.

In 60 minutes the minute hand completes one full revolution.
In 90 minutes it completes 90/60 = 1.5 revolutions.

(i) Distance travelled by the tip = 1.5 × circumference = 1.5 × 2πr
= 1.5 × 2 × π × 7 = 21π ≈ 65.97 cm ≈ 66.0 cm.

(ii) At 6:00 PM the minute hand points to 12 (top of clock).
At 7:30 PM the minute hand again points to 6 (bottom of clock).
The tip has moved from the 12-o'clock position to the 6-o'clock position.
Displacement = straight-line distance from 12 to 6 = diameter = 2r = 2 × 7 = 14 cm.
Direction: from the 12-o'clock position straight down to the 6-o'clock position.

(iii) Speed = distance / time = 21π / 5400 = 7π/1800 ≈ 0.0122 cm s^{-1}.

(iv) Average velocity = displacement / time = 14 / 5400 = 7/2700 ≈ 0.0026 cm s^{-1}.
Direction: from the 12-o'clock position towards the 6-o'clock position (straight down).

Answer: (i) Distance = 21π ≈ 66 cm. (ii) Displacement = 14 cm (from 12-o'clock to 6-o'clock position, directed downward). (iii) Speed = 7π/1800 ≈ 0.0122 cm s^{-1}. (iv) Average velocity = 7/2700 ≈ 0.0026 cm s^{-1}, directed from the 12 to the 6 position.