1D MOTION (LINEAR MOTION)

Position and Displacement

1. What variable do we typically use to represent the horizontal position of an object?
   - A v_x
   - B y
   - C x
   - D a_x

2. The SI unit for position is
   - A ft
   - B km
   - C m
   - D m/s

3. True or false: when an object moves it can have a negative displacement.

4. True or false: an object’s position must be a whole number value.

5. The SI unit for displacement is
   - A m^2
   - B m
   - C m/s
   - D km

6. True or false: an object’s position can have a negative value.

7. What variable do we typically use to represent the vertical position of an object?
   - A a_y
   - B x
   - C v_y
   - D y

8. Fill in the blanks: The symbol Δ is called _____ and represents _____ .
   - A greater than, one value is greater than another value
   - B delta, displacement
   - C alpha, the sum of several values
   - D delta, the change in some quantity

9. The displacement of an object is
   - A the scalar quantity of the total distance an object travels along any path
   - B the final position of an object
   - C the vector quantity of the final position minus the initial position
   - D the length of an object

10. Which of the following do we typically use to represent vertical displacement?
    - A y
    - B Δx
    - C x
    - D Δy

11. A person goes for a walk around a park. They walk for 8 minutes and return to the exact position where they started. Which of the following is true? (Select all that apply)
    - A Their total distance traveled is zero
    - B Their total distance traveled is non-zero
    - C Their total displacement is zero
    - D Their total displacement is non-zero

12. A person is walking down a straight hallway and their motion is shown in Figure 1. Which of the following could describe their motion?
    - A They walk forwards and then immediately walk backwards
    - B They stop, then walk forwards, then stop, then walk backwards
    - C They walk backwards, then stop, then walk forwards
    - D They stop and then immediately walk backwards

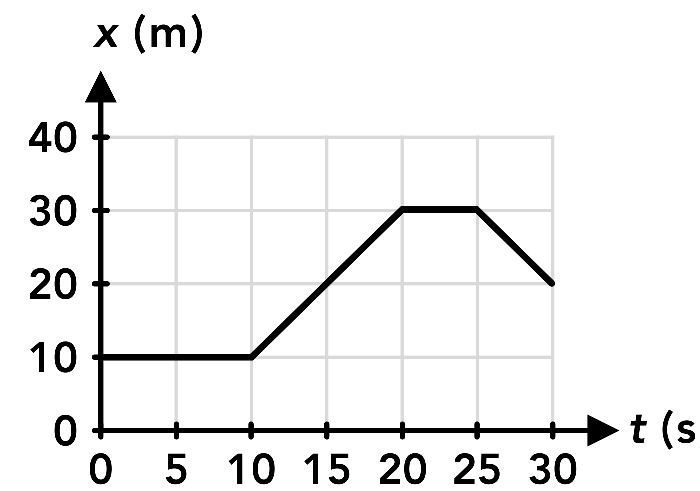

Figure 1

13. For the person's motion shown in Figure 1, what is their displacement between 15 seconds and 30 seconds?

14. For the person's motion shown in Figure 1, what is their displacement between 10 seconds and 20 seconds?

15. For the person's motion shown in Figure 1, what is their displacement between 25 seconds and 30 seconds?

16. A car drives 1.3 km along a straight road. What is the car's displacement in m?

17. A train is traveling west. At time t_1 the train is at a position of 0.4 km. At time t_2 the train is at a position of 0.1 km. What is the displacement of the train from time t_1 to t_2?

18. A person is riding their bike along a straight path. Over a period of 1.5 seconds they travel a displacement of 6 m and end up at a position of 34 m. What was their position at the beginning of the 1.5 second period?

19. A person is running along a straight race track. During a period of time, they run from a position of 17 m to a position of -4 m. What was their displacement during that time?

20. A person is walking on a straight sidewalk. They walk in the positive direction for 12 m. Then they turn around and walk in the negative direction for 3 m. Then they turn around and walk in the positive direction for 15 m. What is their total displacement?

Velocity

21. The SI unit for velocity is
    - A km/h
    - B m/s
    - C km/s
    - D m/s^2

22. What variable do we use to represent the velocity of an object?
    - A y
    - B x
    - C v
    - D a

23. If an object is said to be "at rest" then which of the following is true?
    - A The object's position is zero
    - B The object has no energy
    - C The object is sitting on the ground
    - D The object's speed is zero

24. What is the difference between “speed” and “velocity”? (Select all that apply)
    - A Speed is a scalar quantity and velocity is a vector quantity
    - B Velocity is a scalar quantity and speed is a vector quantity
    - C Speed is the magnitude of the velocity
    - D Velocity has a direction and speed does not

25. A ball is thrown directly upwards and falls to the ground. Which of the following is used to represent the initial vertical velocity of the ball?
    - A v_{yf}
    - B v_y
    - C v_{yi}
    - D v_f

26. The speedometer in a car (which measures how fast the car is moving) describes which of the following?

A The average speed of the car

B The total distance traveled by the car

C The instantaneous speed of the car

D The average velocity of the car

27. A person is running on a straight road. It takes them a duration of Δt to run from a position of x_i to a position of x_f . If we were given each of those values, which of the following could we determine? (Select all that apply)

A The average speed of the runner during that time period

B The instantaneous speed of the runner at any moment during that time period

C The instantaneous speed of the runner at the start of that time period

D The displacement of the runner during that time period

28. True or false: speed can have a positive or a negative value.

29. Which of the following are valid equations relating velocity, position (or displacement) and time? (Select all that apply)

A $v_x = \frac{\Delta x}{\Delta t}$

B $x_f = x_i + v_x \Delta t$

C $v_x = \frac{x_f - x_i}{t_f - t_i}$

D $\Delta x = v_x \Delta t$

30. A train's motion is shown in Figure 2. The positive direction is east and the negative direction is west. Which of the following is true at t = 1 min?

A The train is not moving

B The train is moving in the east direction

C The train is moving in the west direction

D None of the above

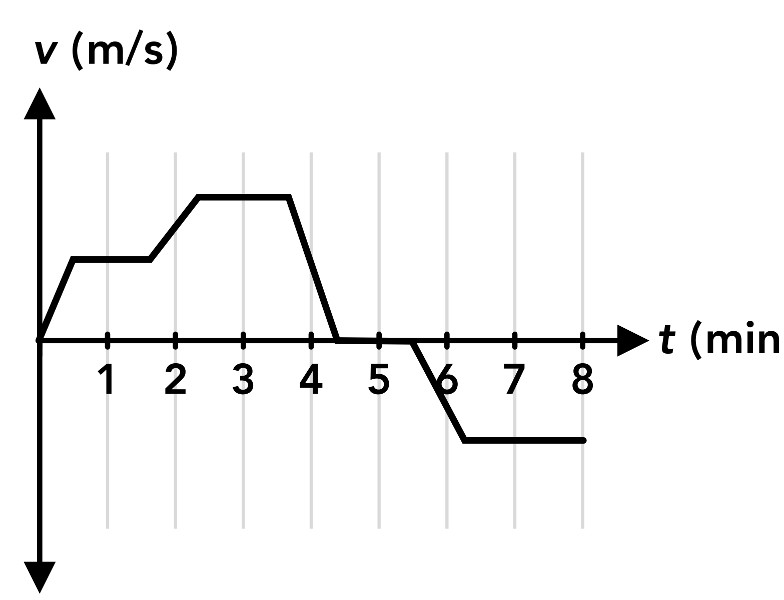

Figure 2

31. For the train's motion shown in Figure 2, which of the following is true? (Select all that apply)

A The train is moving faster at t = 3 min than it is at t = 1 min

B The train is stopped at t = 3 min

C The train is moving in the east direction at t = 2 min

D The train is moving in the west direction at t = 4 min

32. An elevator's motion is shown in Figure 3. Which of the following best describes its motion?

    A It moves up, stops, and moves down
    B It moves up, stops, and moves up
    C It moves up, stops, moves up, stops, and moves down
    D It moves down, stops, moves up, stops, and moves down

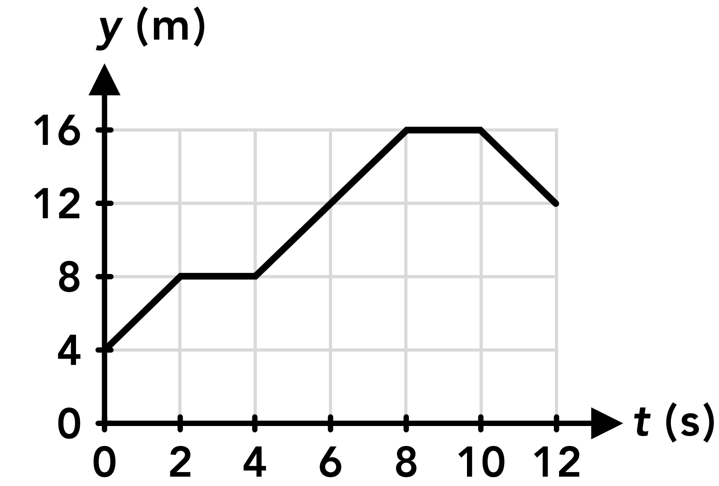

Figure 3

33. For the elevator's motion shown in Figure 3, what is its velocity at 3 s?

34. For the elevator's motion shown in Figure 3, what is its velocity at 5 s?

35. For the elevator's motion shown in Figure 3, what is its velocity at 11 s?

36. For the elevator's motion shown in Figure 3, what is its average velocity between 0 s and 12 s?

37. If it takes a train 6 seconds to travel 162 m, what is the average speed of the train?

38. An elevator is moving at a constant 3 m/s. How far does it travel during a period of 7.5 seconds?

39. A bus is driving on a straight road. Over a period of 3 minutes it travels a displacement of 3.5 km. What is the average speed of the bus during that time in m/s?

40. During a race, a coach records a runner's position at two times. At $t = 4$ seconds the runner is at a position of x. At $t = 12$ seconds the runner is at a position of 35 m. The coach calculates the runner's average speed to be 2.5 m/s. What was the position of the runner at $t = 4$ seconds?

41. A subway makes its way through a city on a straight track. During the first part of its trip it travels 1.5 km in a period of 0.8 hours. During the second part, it travels 2.3 km in a period of 1 hour. What is the average speed of the subway over the entire trip (in km/h)?

42. A car's motion is shown in Figure 4. What is the displacement of the car during the period between 0 s and 6 s?

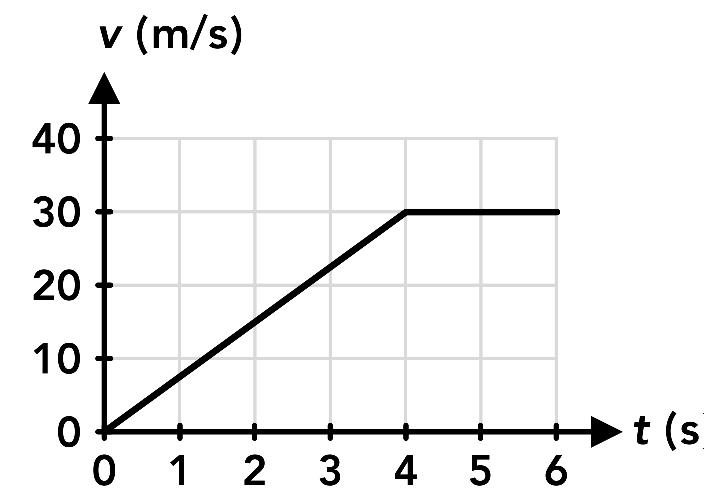

Figure 4

Acceleration

43. What variable do we use to represent the acceleration of an object?
   - A y
   - B x
   - C a
   - D v

44. The SI unit for acceleration is
   - A m/s
   - B m
   - C m/s^2
   - D km/h

45. Fill in the blank: Acceleration is defined as the change in ____ over time.
   - A position
   - B speed
   - C displacement
   - D velocity

46. Which of the following describes an object that is accelerating? (Select all that apply)

A. A race car speeding up at the start of a race
B. A bike slowing down at an intersection
C. A pen falling through the air after being knocked off a desk
D. A moving elevator slowing down to a stop

47. True or false: if an object is accelerating it must be speeding up.

48. Which of the following are valid equations relating acceleration, velocity and time? (Select all that apply)

A. $a = \frac{\Delta v}{\Delta t}$
B. $v_f = v_i + a\Delta t$
C. $a = \frac{v_f - v_i}{t_f - t_i}$
D. $\Delta v = a\Delta t$

49. A car's motion is shown in Figure 5. Which of the following describes the motion of the car from $t = 0$ s to $t = 4$ s?

A. The car is moving at a constant velocity
B. The car has a positive acceleration
C. The car is not moving
D. The car has a negative acceleration

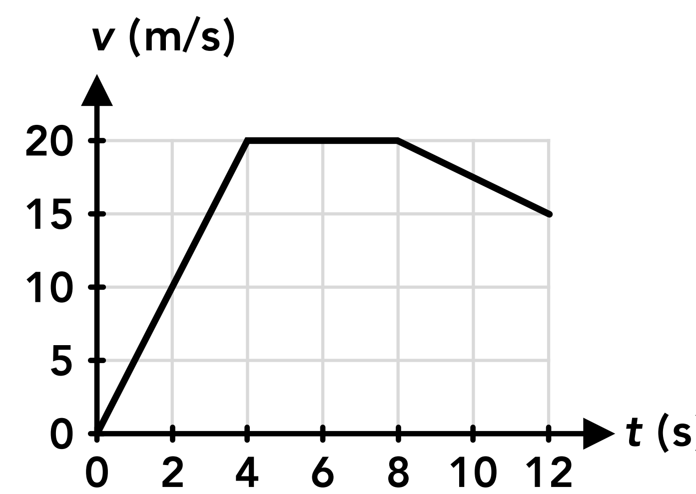

Figure 5

50. For the car's motion shown in Figure 5, which of the following describes the motion from $t = 4$ s to $t = 8$ s?

A. The car is not moving
B. The car has a positive acceleration
C. The car's acceleration is 0 m/s²
D. The car has a negative acceleration

51. For the car's motion shown in Figure 5, which of the following describes the motion from $t = 8$ s to $t = 12$ s?

A. The car has a negative velocity
B. The car has a negative acceleration
C. The car's acceleration is 0 m/s²
D. The car has a positive acceleration

52. The motion of two cars, car A and car B, is shown in Figure 6. Which of the following is true about the motion of the cars?

A. Car A and car B are moving at the same speed at t_1
B. Car B is always moving faster than car A before t_1
C. Car A is moving faster than car B at t_1
D. Car A and car B are never moving at the same speed

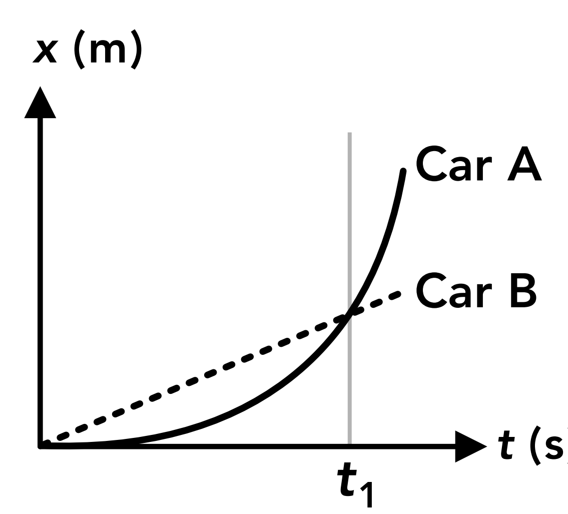

Figure 6

53. A biker is moving in the positive direction and their motion is shown in Figure 7. Which of the following describes the motion of the biker?

- A They are moving at a constant speed
- B They are slowing down
- C They are speeding up
- D The are not moving

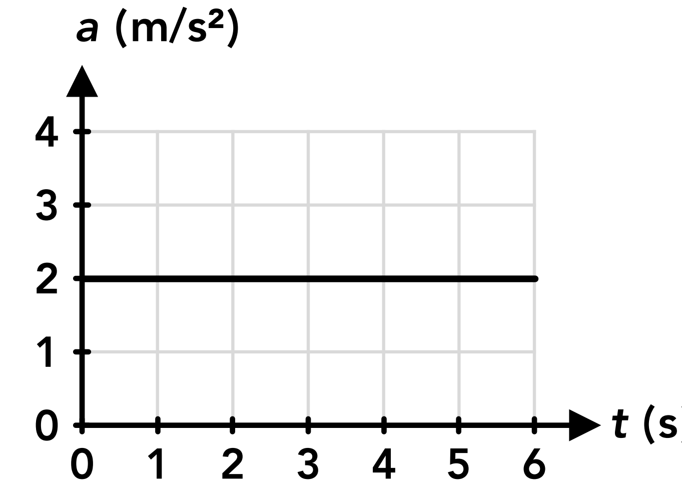

Figure 7

54. For the biker's motion shown in Figure 7, if their velocity is 3 m/s at t = 1 s, what is their velocity at t = 4 s?

55. A boat is traveling in a straight line when it speeds up from 5 m/s to 9 m/s over a period of 5 seconds. What is the acceleration of the boat?

56. At the start of a race, a runner accelerates from rest to a speed of 18 km/h in 4.5 seconds. What is their acceleration in m/s^2 ?

57. A person is riding their bike at 4 m/s when they speed up with a constant acceleration of 0.6 m/s^2. What is their speed after accelerating for 3 seconds?

58. A book is dropped from rest off a balcony. If the book accelerates downwards at 9.8 m/s^2, how long does it take the book to reach a speed of 15 m/s?

59. A car is stopped at a red light. When the light turns green, the car accelerates at 4 m/s^2. How far does the car travel in 3 seconds?

60. An ice skater is moving in a straight line at 6 m/s when they begin to slow down at -0.8 m/s^2. How long does it take them to come to a stop?

61. A coconut falls from a tree and accelerates down at 9.8 m/s². How fast is the coconut moving after it falls 4 m?

62. A train is moving at 36 km/h when it begins to slow down at -2 m/s² before reaching a station. While slowing down, how far does the train move over a period of 5 seconds?

63. A train's motion is shown in Figure 8. What is the train's acceleration at t = 1.5 s?

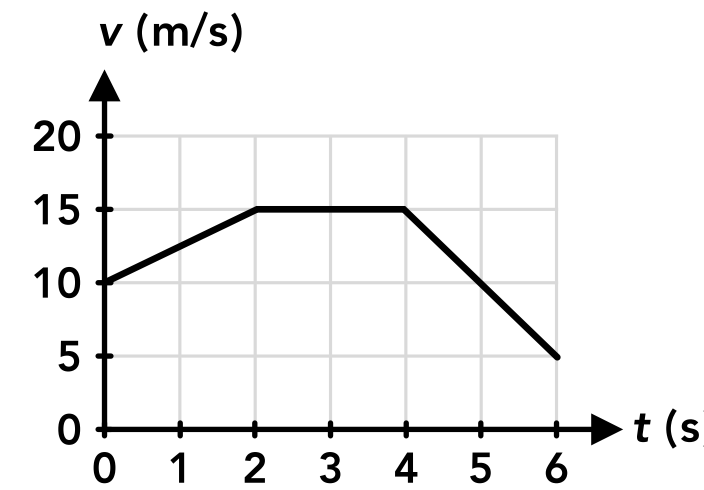

Figure 8

64. For the train's motion shown in Figure 8, what is the train's acceleration at t = 5 s?

Answers

1. C	11. B, C	21. B	31. A, C	41. 2.1 km/h	51. B	61. 8.9 m/s
2. C	12. B	22. C	32. C	42. 120 m	52. C	62. 25 m
3. True	13. 0 m	23. D	33. 0 m/s	43. C	53. C	63. 2.5 m/s²
4. False	14. 20 m	24. A, C, D	34. 2 m/s	44. C	54. 9 m/s	64. -5 m/s²
5. B	15. -10 m	25. C	35. -2 m/s	45. D	55. 0.8 m/s	
6. True	16. 1,300 m	26. C	36. 0.67 m/s	46. A, B, C, D	56. 1.1 m/s²	
7. D	17. -0.3 km	27. A, D	37. 27 m/s	47. False	57. 5.8 m/s	
8. D	18. 28 m	28. False	38. 22.5 m	48. A, B, C, D	58. 1.5 s	
9. C	19. -21 m	29. A, B, C, D	39. 19.4 m/s	49. B	59. 18 m	
10. D	20. 24 m	30. B	40. 15 m	50. C	60. 7.5 s	

Answers - Position and Displacement

1. **Answer: C**
   We typically use the variable $\boldsymbol{x}$ to represent the horizontal position of an object. The variable $\boldsymbol{y}$ would represent the vertical position of an object, $\boldsymbol{v}_x$ would represent the horizontal velocity of an object and $\boldsymbol{a}_x$ would represent the horizontal acceleration of an object.

2. **Answer: C**
   Meters (m) is the SI unit for position. Feet (ft) and kilometers (km) are valid units of position but are not the SI unit. Meters per second (m/s) is the SI unit for velocity.

3. **Answer: True**
   Once we establish the origin (where the position is defined as 0) and which directions are positive and negative, displacement can be in the positive or negative direction. If the value of the final position is less than the value of the initial position, the displacement is negative.

4. **Answer: False**
   The value of an object's position can be any real number, not just integers.

5. **Answer: B**
   Meters (m) is the SI unit for displacement (and position). Square meters (m^2) is the SI unit for area, meters per second (m/s) is the SI unit for velocity and kilometers (km) is a valid unit for displacement but is not the SI unit.

6. **Answer: True**
   Once we establish the origin (where the position is defined as 0) and which directions are positive and negative, position can have a positive or negative value.

7. **Answer: D**
   We typically use the variable $\boldsymbol{y}$ to represent the vertical position of an object. The variable $\boldsymbol{x}$ would represent the horizontal position of an object, $\boldsymbol{v}_y$ would represent the vertical velocity of an object and $\boldsymbol{a}_y$ would represent the vertical acceleration of an object.

8. **Answer: D**
   The symbol is the Greek letter "delta" and it represents the change in some quantity. By itself it does not represent displacement. $\Delta \boldsymbol{x}$ or $\Delta \boldsymbol{y}$ would represent displacement or change in position, but $\Delta \boldsymbol{v}$ would represent change in velocity.

9. **Answer: C**
   Displacement is a vector quantity (it has a magnitude and a direction) whereas distance is a scalar quantity and only has a magnitude. The displacement and can be calculated as the final position minus the initial position. Option A describes distance, not displacement.

10. **Answer: D**
    We typically use Δy to represent vertical displacement. y represents vertical position, Δx represents horizontal displacement and x represents horizontal position.

11. **Answer: B, C**
    The distance traveled would be the total length of their path during the walk and would be non-zero. Displacement is defined as the difference between the initial position and the final position, so if the initial and final positions are the same, the displacement would be zero.

12. **Answer: B**
    During 0-10 seconds they don't move. During 10-20 seconds they walk forwards (assuming the positive direction is forwards). During 20-25 seconds they don't move. During 25-30 seconds they walk backwards.

13. **Answer: 0 m**
    Their displacement is their final position minus their initial position during that period. They are at a position of 20 m at both times so their displacement during that period is 0 m (their distance traveled is not 0 m).
    $\Delta x = x_f - x_i = (20\text{ m}) - (20\text{ m}) = 0\text{ m}$

14. **Answer: 20 m**
    Their displacement is their final position minus their initial position during that period.
    $\Delta x = x_f - x_i = (30\text{ m}) - (10\text{ m}) = 20\text{ m}$

15. **Answer: -10 m**
    Their displacement is their final position minus their initial position during that period.
    $\Delta x = x_f - x_i = (20\text{ m}) - (30\text{ m}) = -10\text{ m}$

16. **Answer: 1,300 m**
    $$\frac{1.3\text{ km}}{} \times \frac{1000\text{ m}}{1\text{ km}} = 1{,}300\text{ km}$$

17. **Answer: -0.3 km**
    The displacement of the train is the final position (at time t_2) minus the initial position (at time t_1).
    $\Delta x = x_f - x_i = (0.1\text{ km}) - (0.4\text{ km}) = -0.3\text{ km}$

18. **Answer: 28 m**
    Their displacement is equal to the final position minus the initial position. The time value of 1.5 seconds is not needed to answer this question.
    $\Delta x = x_f - x_i \qquad (6\text{ m}) = (34\text{ m}) - x_i \qquad x_i = 28\text{ m}$

19. **Answer: -21 m**
    Their displacement is their final position minus their initial position.
    $\Delta x = x_f - x_i = (-4\text{ m}) - (17\text{ m}) = -21\text{ m}$

20. **Answer: 24 m**
    Their total displacement can be found by adding the individual displacements (including the positive and negative signs because displacement is a vector and includes direction).
    $\Delta x = (12\text{ m}) + (-3\text{ m}) + (15\text{ m}) = 24\text{ m}$

21. **Answer: B**
Meters per second (m/s) is the SI unit for velocity and speed. Kilometers per hour (km/h) and kilometers per second (km/s) are valid units for velocity but are not the SI unit. Meters per second squared (m/s^2) is the SI unit for acceleration.

22. **Answer: C**
The variable $\boldsymbol{v}$ represents velocity. $\boldsymbol{x}$ represents horizontal position, $\boldsymbol{y}$ represents vertical position and $\boldsymbol{a}$ represents acceleration.

23. **Answer: D**
The phrase "at rest" means an object is not moving and its speed or velocity is zero. It does not refer to an object's position, energy, or any other quantity.

24. **Answer: A, C, D**
Speed is a scalar quantity which means it only includes a magnitude or a value, while velocity is a vector quantity and includes a magnitude and a direction. Speed is the magnitude of the velocity. For example, if the velocity of a car is 80 km/h west, 80 km/h is the magnitude of the velocity (which is the speed) and west is the direction of the velocity.

25. **Answer: C**
$\boldsymbol{v}_{yi}$ represents initial vertical velocity (the variable $\boldsymbol{v}$ represents velocity, the subscript "y" represents the vertical direction and the subscript "i" represents the initial value). You may also see this written as $\boldsymbol{v}_{y0}$ where the subscript "0" represents the initial value, or the value at time 0.

26. **Answer: C**
The speedometer describes the instantaneous speed of the car, which is the speed at any moment in time.

27. **Answer: A, D**
We cannot determine the instantaneous speed of the runner, only the average speed.

The average speed of the runner is: $\boldsymbol{v}_{avg} = \dfrac{\boldsymbol{x}_f - \boldsymbol{x}_i}{\Delta \boldsymbol{t}}$

The displacement of the runner is: $\Delta \boldsymbol{x} = \boldsymbol{x}_f - \boldsymbol{x}_i$

28. **Answer: False**
Speed is a scalar (the magnitude of velocity) and can only have a positive value. Velocity is a vector and can have a negative value, where the negative tells us the velocity is in the negative direction.

29. **Answer: A, B, C, D**
These are all the same equation rearranged algebraically in different ways.

30. **Answer: B**
This is a graph of the train's velocity vs time and up is the positive direction. At $\boldsymbol{t} = 1$ min the train has a positive velocity so the train is moving in the east (positive) direction.

31. **Answer: A, C**
The train is moving faster at 3 min than it is at 1 min because the velocity is greater at 3 min. The train is moving in the east direction at 2 min because the velocity is positive and the previous question stated that east is the positive direction. The train is not stopped at 7 min, it has a constant negative velocity. The train is moving in the east direction at 4 min because the velocity is positive.

32. **Answer: C**
This is a graph of the elevator's vertical position or height vs time. The elevator is moving up from 0-2 seconds, stopped from 2-4 seconds, moving up from 4-8 seconds, stopped from 8-10 seconds and moving down from 10-12 seconds.

33. **Answer: 0 m/s**
The velocity is the slope of the position-time graph. The slope of the line at 3 s is 0 so the velocity is 0 m/s.

34. **Answer: 2 m/s**
The velocity is the slope of the position-time graph. The slope of the line at 5 s can be found using two points on the graph, such as the points at 4 s and 8 s.

Velocity (slope) at 5 s: $v_y = \frac{\Delta y}{\Delta t} = \frac{(16\text{ m}) - (8\text{ m})}{(8\text{ s}) - (4\text{ s})} = 2\text{ m/s}$

35. **Answer: -2 m/s**
The velocity is the slope of the position-time graph. The slope of the line at 11 s can be found using two points on the graph, such as the points at 10 s and 12 s.

Velocity (slope) at 11 s: $v_y = \frac{\Delta y}{\Delta t} = \frac{(12\text{ m}) - (16\text{ m})}{(12\text{ s}) - (10\text{ s})} = -2\text{ m/s}$

36. **Answer: 0.67 m/s**
The average velocity of the elevator over that period of time would be its displacement during that period divided by the amount of time.

$$v_y = \frac{\Delta y}{\Delta t} = \frac{(12\text{ m}) - (4\text{ m})}{(12\text{ s})} = 0.67\text{ m/s}$$

37. **Answer: 27 m/s**
The average speed of the train is equal to the distance traveled divided by the period of time.

$$v = \frac{\Delta x}{\Delta t} = \frac{162\text{ m}}{6\text{ s}} = 27\text{ m/s}$$

38. **Answer: 22.5 m**
The distance traveled is equal to the speed multiplied by the period of time, which can be found by rearranging the equation for speed.

$$v = \frac{\Delta y}{\Delta t} \qquad (3\text{ m/s}) = \frac{\Delta y}{(7.5\text{ s})} \qquad \Delta y = (3\text{ m/s})(7.5\text{ s}) = 22.5\text{ m}$$

39. **Answer: 19.4 m/s**
The question is asking for a speed in units of m/s so the time must be converted from minutes to seconds and the displacement must be converted from km to m. The average speed is the displacement divided by the time.

$$\frac{3\text{ min}}{} \times \frac{60\text{ s}}{1\text{ min}} = 180\text{ s}$$

$$\frac{3.5\text{ km}}{} \times \frac{1000\text{ m}}{1\text{ km}} = 3500\text{ m}$$

$$v = \frac{\Delta x}{\Delta t} = \frac{3500\text{ m}}{180\text{ s}} = 19.4\text{ m/s}$$

40. **Answer: 15 m**
The position of the runner at 4 seconds can be treated as the initial position x_i and solved for using the equation for average speed.

$$v = \frac{x_f - x_i}{t_f - t_i} \qquad 2.5 \text{ m/s} = \frac{(35 \text{ m}) - x_i}{(12 \text{ s}) - (4 \text{ s})} \qquad x_i = 15 \text{ m}$$

41. **Answer: 2.1 km/h**
The average speed is equal to the total distance traveled divided by the total time.

$$v_{avg} = \frac{\text{total distance}}{\text{total time}} = \frac{(1.5 \text{ km}) + (2.3 \text{ km})}{(0.8 \text{ h}) + (1 \text{ h})} = \frac{3.8 \text{ km}}{1.8 \text{ h}} = 2.1 \text{ km/h}$$

42. **Answer: 120 m**
This is a graph of the car's velocity vs time. The displacement of the car is equal to the area under the curve (the area between the graph line and the horizontal axis). This can be found by dividing the area into a triangular area from 0-4 seconds and a rectangular area from 4-6 seconds and adding them together.

Displacement from 0-4 seconds: area $= \frac{1}{2}bh = \frac{1}{2}(4 \text{ s} - 0 \text{ s})(30 \text{ m/s}) = 60 \text{ m}$

Displacement from 4-6 seconds: area $= bh = (6 \text{ s} - 4 \text{ s})(30 \text{ m/s}) = 60 \text{ m}$

Total displacement from 0-6 seconds: area $= 60 \text{ m} + 60 \text{ m} = 120 \text{ m}$

Answers - Acceleration

43. **Answer: C**
The variable a represents acceleration. x represents horizontal position, y represents vertical position, and v represents velocity.

44. **Answer: C**
The SI unit for acceleration is meters per second squared (m/s^2) which is equal to a change in velocity (m/s) per unit of time (s). Meters per second (m/s) is the SI unit for velocity, meters (m) is the SI unit for position and displacement and kilometers per hour (km/h) is a valid unit for velocity but is not the SI unit.

45. **Answer: D**
Acceleration is defined as the change in velocity (a vector) over time, not the change in speed (a scalar) over time. Speed is the magnitude of velocity and a change in speed is considered acceleration because the velocity is changing. However, a change in the direction of the velocity only (where the speed does not change) is also considered acceleration.

46. **Answer: A, B, C, D**
The race car is accelerating because its speed (the magnitude of the velocity) is changing. The bike is accelerating because its speed is changing (a decrease in speed is still a change in speed). The pen is accelerating as it falls because all object accelerate as they fall due to gravity. The elevator is accelerating because its speed is changing (it's slowing down).

47. **Answer: False**
Acceleration is defined as the change in velocity, which could be a change in the direction or the magnitude (the speed) of the velocity. A decrease in speed (an object that is slowing down) is still considered acceleration. An object is also considered to be accelerating if the speed remains the same and only the direction changes.

48. **Answer: A, B, C, D**
These are all the same equation rearranged algebraically in different ways.

49. **Answer: B**
This is a graph of the car's velocity vs time. The slope of the velocity-time graph is equal to the acceleration of the car. During the period from 0-4 s the graph has a constant, positive slope so the car has a positive acceleration.

50. **Answer: C**
This is a graph of the car's velocity vs time. The slope of the velocity-time graph is equal to the acceleration of the car. During the period from 4-8 s the slope of the graph is zero so the car has zero acceleration.

51. **Answer: B**
This is a graph of the car's velocity vs time. The slope of the velocity-time graph is equal to the acceleration of the car. During the period from 8-12 s the slope of the graph is negative so the car has a negative acceleration.

52. **Answer: C**
This is a position vs time graph and the slope of each line is equal to the velocity of each car, and speed is the magnitude of the velocity. At time t_1 the slope of the line for car A is greater than the slope of the line for car B so the speed of car A is greater than the speed of car B at time t_1. Car B is moving faster than car A at 0 s, and the cars are moving at the same speed at some time between 0 s and t_1 (at a time when the slopes are equal).

53. **Answer: C**
The biker is moving in the positive direction and they have a positive acceleration. The velocity and acceleration are in the same direction (the positive direction) so the biker is speeding up (the magnitude of the velocity is increasing over time).

54. **Answer: 9 m/s**
The change in velocity during a period of time is given by the area under the curve of the acceleration-time graph during that period (the area between the line and the horizontal axis). This change in velocity is added to the initial velocity at 1 s to find the final velocity at 4 s.
Change in velocity from 1 s to 4 s: $\Delta v = \text{area} = bh = (4\text{ s} - 1\text{ s})(2\text{ m/s}^2) = 6\text{ m/s}$
Final velocity at 4 s: $v_f = v_i + \Delta v = (3\text{ m/s}) + (6\text{ m/s}) = 9\text{ m/s}$

55. **Answer: 0.8 m/s**
The acceleration of the boat is equal to the change in velocity divided by the period of time.

$$a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{\Delta t} = \frac{(9\text{ m/s}) - (5\text{ m/s})}{(5\text{ s})} = 0.8\text{ m/s}^2$$

56. **Answer: 1.1 m/s²**
The final speed of 18 km/h must be converted into m/s. The initial speed is 0 m/s becuase they start at rest. The acceleration of the runner is equal to the change in speed divided by the period of time.

$$\frac{18\text{ km}}{\text{h}} \times \frac{1000\text{ m}}{1\text{ km}} \times \frac{1\text{ h}}{60\text{ min}} \times \frac{1\text{ min}}{60\text{ s}} = 5\text{ m/s}$$

$$a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{\Delta t} = \frac{(5\text{ m/s}) - (0\text{ m/s})}{(4.5\text{ s})} = 1.1\text{ m/s}^2$$

57. **Answer: 5.8 m/s**
Their final speed can be found using the equation for acceleration.

$$a = \frac{v_f - v_i}{\Delta t} \qquad (0.6\text{ m/s}^2) = \frac{v_f - (4\text{ m/s})}{(3\text{ s})} \qquad v_f = 5.8\text{ m/s}$$

58. **Answer: 1.5 s**
The period of time can be found using the equation for acceleration. The initial speed is 0 m/s (at rest).

$$a = \frac{v_f - v_i}{\Delta t} \qquad (9.8\ \text{m/s}^2) = \frac{(15\ \text{m/s}) - (0\ \text{m/s})}{\Delta t} \qquad \Delta t = 1.5\ \text{s}$$

59. **Answer: 18 m**
The final position of the car can be found using the kinematic equation below, using 0 m for the initial position and 0 m/s for the initial velocity (since the car is initially stopped).

$$x_f = x_i + v_i t + \frac{1}{2}at^2 = (0\ \text{m}) + (0\ \text{m/s})(3\ \text{s}) + \frac{1}{2}(4\ \text{m/s}^2)(3\ \text{s})^2 = 18\ \text{m}$$

60. **Answer: 7.5 s**
The period of time can be found using the equation for acceleration. The final speed is 0 m/s (they come to a stop) and the acceleration given is negative.

$$a = \frac{v_f - v_i}{\Delta t} \qquad (-0.8\ \text{m/s}^2) = \frac{(0\ \text{m/s}) - (6\ \text{m/s})}{\Delta t} \qquad \Delta t = 7.5\ \text{s}$$

61. **Answer: 8.9 m/s**
The final speed can be found using the kinematic equation below. The initial speed is 0 m/s. If we choose up to be the positive direction then the acceleration is -9.8 m/s², the initial position is 4 m and the final position is 0 m (or the initial position is 0 m and the final position is -4 m, as long as the displacement is negative):

$$v_{yf}^2 = v_{yi}^2 + 2a_y(y_f - y_i) \qquad v_{yf}^2 = (0\ \text{m/s})^2 + 2(-9.8\ \text{m/s}^2)(0\ \text{m} - 4\ \text{m}) \qquad v_f = 8.9\ \text{m/s}$$

62. **Answer: 25 m**
The initial speed of 36 km/h must be converted into m/s. The final position of the train can be found using the kinematic equation below. The initial position is 0 m and the acceleration is negative.

$$\frac{36\ \text{km}}{\text{h}} \times \frac{1000\ \text{m}}{1\ \text{km}} \times \frac{1\ \text{h}}{60\ \text{min}} \times \frac{1\ \text{min}}{60\ \text{s}} = 10\ \text{m/s}$$

$$x_f = x_i + v_i t + \frac{1}{2}at^2 = (0\ \text{m}) + (10\ \text{m/s})(5\ \text{s}) + \frac{1}{2}(-2\ \text{m/s}^2)(5\ \text{s})^2 = 25\ \text{m}$$

63. **Answer: 2.5 m/s²**
This is a graph of the train's velocity vs time. The acceleration of the train is equal to the slope of the graph. The slope of the line at 1.5 s can be found using the two points at 0 s and 2 s.

Acceleration at 1.5 s: $\text{slope} = a = \frac{\Delta v}{\Delta t} = \frac{(15\ \text{m/s}) - (10\ \text{m/s})}{(2\ \text{s}) - (0\ \text{s})} = 2.5\ \text{m/s}^2$

64. **Answer: -5 m/s²**
The acceleration of the trian is equal to the slope of the graph. The slope of the line at 5 s can be found using the two points at 4 s and 6 s, and the slope is negative so the acceleration is negative.

Acceleration at 5 s: $\text{slope} = a = \frac{\Delta v}{\Delta t} = \frac{(5\ \text{m/s}) - (15\ \text{m/s})}{(6\ \text{s}) - (4\ \text{s})} = -5\ \text{m/s}^2$