Chapter 2

Analyzing Motion: Enrichment Solutions

Vectors and Scalars

When measuring quantities in science, it is necessary to specify the direction for some quantities. Most quantities we measure are scalars. These are measured with a size or magnitude but without regard to direction. For example, temperature is a scalar. While it can be positive or negative, it does not have a direction like right or left, or east or west, associated with it.

Other quantities require that a direction be given along with the size or magnitude. Force is a vector. You can pull on a door handle with a force of 25 newtons east, or you can push on the door handle with a force of 25 newtons west. While these two forces have the same magnitude, they act in different directions. One force will open the door; the other force will not.

In the study of motion, two similar quantities, speed and velocity, are often confused. Speed describes how fast an object is moving, regardless of direction. The speedometer of a car measures speed. It indicates how fast the car is moving, but does not include the direction. For example, 100 km/h is a typical speed for a car on the highway.

Velocity, though, is a vector. If we start at a point and travel at 100 km/h east for one hour, we will end up 100 km east of our starting point. If we travel at 100 km/h west, starting from the same point, we will end up 100 km west of the starting point. These two velocities, 100 km/h east and 100 km/h west, are definitely different velocities. It is the direction that makes them different.

In summary, **scalars are quantities with size or magnitude only.** We give the value of such a quantity with a number for its size and a unit to tell us the type of quantity.

A vector is a quantity with both magnitude and direction. We give the value of a vector using a number for its size, a unit to tell us the type of quantity, and a direction.

For each quantity, give the unit and state whether it is a vector or scalar quantity.

Table 1

Quantity	Symbol of the Quantity	Unit	Vector or Scalar
Time Instant	t	second (s)	scalar
Time Interval	t	second (s)	scalar
Distance Traveled	d	metre (m)	scalar
Displacement	D$\vec{d}$	metre (m)	vector
Mass	m	kilogram (kg)	scalar
Length	l	metre (m)	scalar
Speed	v	metres/second (m/s)	scalar
Acceleration	$\vec{a}$	metres/second/second (m/s/s or m/s^2)	vector
Velocity	$\vec{v}$	metres/second (m/s)	vector
Force	$\vec{F}$	newtons (N)	vector
Energy	E	joules (J)	scalar

Introducing Motion: Position, Time, Distance and Speed, Displacement, and Velocity

Purpose:

To determine the position of a person moving in a straight line at different instants in time.

To interpret a Position-Time graph to obtain distance traveled, speed, displacement, and velocity.

Apparatus:

50 metres of hallway or field, stopwatches, measuring tape

Procedure:

PART A

- Using the measuring tape, mark off 5-m intervals along a crack in the floor tiles. Place a piece of masking tape at each 5-m mark. Mark these positions using small signs, like yardage markers along the sidelines of a football field.
- A student stands at each of the markers with a stopwatch.
- Have one student begin at the 0-m mark. When the student begins to move, all timers start timing with the stopwatches.
- The student walks, at a constant rate, the full length of the course. As the walking student passes each timer, the timer stops the stopwatch.
- The timers then share their times and positions with the group.

Observations:

Description of motion:

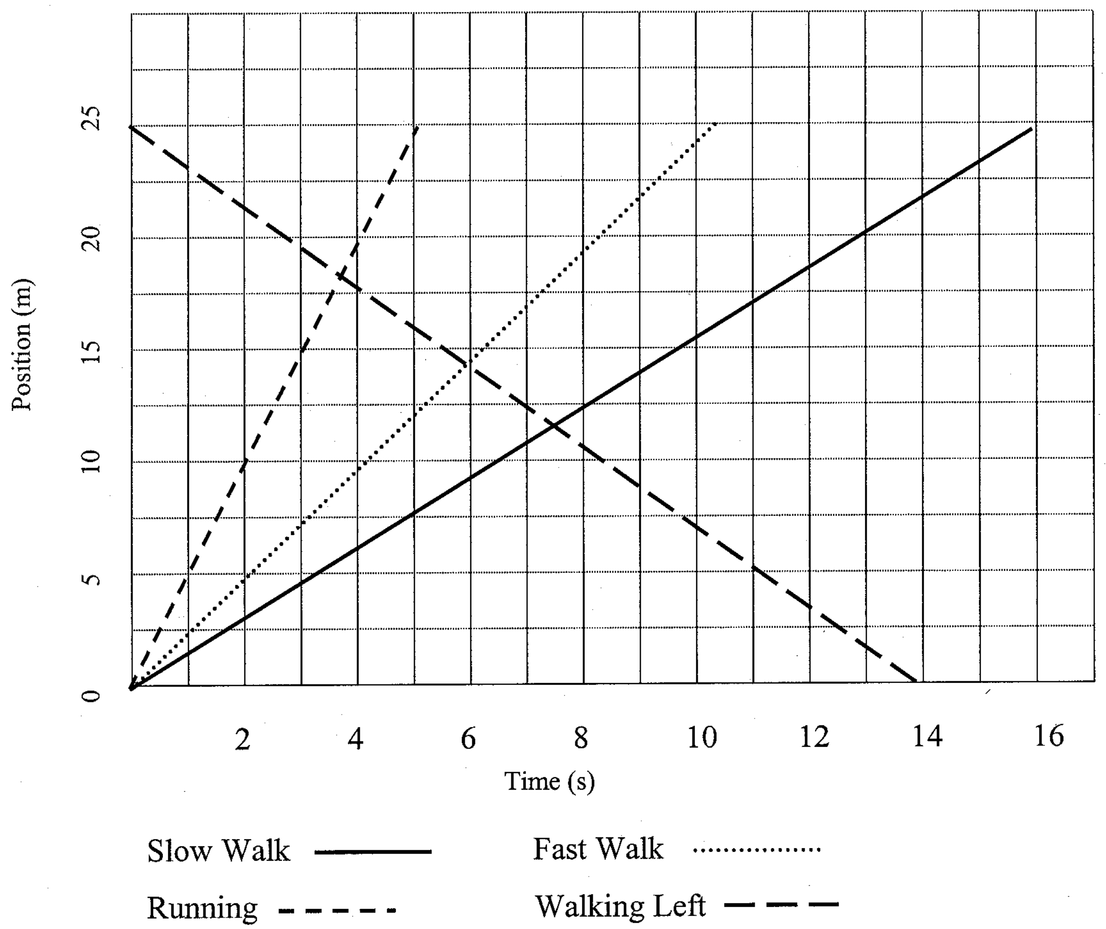
The student walks at a constant pace starting at the origin and ending at a position of 25 m to the right of the origin.

Draw a picture of the motion:

Table 2A

Time (Sec)	0	3	6	9	13	16					
Position (Metres)	0	5	10	15	20	25					

On the following graph, label time on the horizontal axis and position on the vertical axis and plot the points from the data table. Draw in the line of best fit.



Procedure:

PART B

The student will start from 0-m mark this time and walk more quickly than before but at a constant rate over the whole course. Again the timers will start timing when the student begins to move and stop timing when the student passes the timers' position.

Observations:

Description of motion:

The student started at the origin and walked at a faster but steady pace to the right, ending up at a point 25 m right of the origin.

Draw a picture of the motion:

Table 2B

Time (Sec)	0	2.0	4.0	6.5	8.3	10.4					
Position (Metres)	0	5	10	15	20	25					

Plot this information on the previous graph, using a different colour for these points. Draw in the line of best fit.

Procedure:

PART C

The student starts from 0-m mark this time and runs at a constant rate over the whole course. Again the timers start timing when the student begins to move and stop timing when the student passes the timers' position.

Observations:

Description of motion:

The student started at the origin and ran at a steady pace to the right, ending up at a point 25 m right of the origin.

Draw a picture of the motion:

Table 2C

Time (Sec)	0	1.0	2.0	2.8	4.0	5.1					
Position (Metres)	0	5	10	15	20	25					

Plot this information on the previous graph, using a third different colour for these points. Draw in the line of best fit.

1. Using the descriptions of the motion, how do the starting points compare for the three trials?

   The starting points are all the same, at 0 m.

2. From the graph, determine the starting point for each of the three trials. Compare these to the answers in part (b).

   All the lines start at 0 m at 0 s. The starting points are all the same as in #1.

3. From the description of the motions, what is the same about all three motions?

   All the motions start at the origin and end at 25 m to the right of the origin. The person moves to the right.

4. From the description of the motion, what is different about the three motions?

   The speed is different in each case. In A, it is a walk. In B, it is a faster walk. In C, it is running.

5. On the graph, what is different about the three lines?

   The slopes or steepness of the lines are all different.

Procedure:

PART D

The student will start from the last mark this time and walk quickly but at a constant rate over the whole course, ending up at 0 m. Again the timers will start timing when the student begins to move and stop timing when the student passes the timers' position.

Observations:

Description of motion:

The student begins at the 25 m mark and walks to the left, ending up at 0 m, the origin.

Draw a picture of the motion:

Table 2D

Time (Sec)	0	3	5	8	11	14					
Position (Metres)	25	20	15	10	5	0					

Plot this information on the graph, using a fourth different colour for these points. Draw in the line of best fit.

Analysis:

1. How does this fourth line differ from the other three lines on the graph?

   The fourth line begins at +25 m instead of at the origin. The line slopes to the right and down (negative slope) instead of to the right and up (positive slope) like the others.

2. From the description of the motions, can you relate something about the line to the motion it represents?

   Line 1: *The student moves steadily but slowly to the right. The slope of the line is small and positive.*

   Line 2: *The student moves steadily but more quickly to the right. The slope of the line is larger and positive.*

   Line 3: *The student moves steadily but very quickly (running) to the right. The slope of the line is still larger and positive.*

   Line 4: *The student moves steadily but slowly to the left. The slope of the line is small and negative.*

Procedure:

PART E

At the 10-m mark, station two timers. The student starts from the 0-m mark this time and walks quickly to the 10-m mark. The first timer stops the stopwatch. The student stays at the 10-m mark for a slow count of 5. At the count of 5, the second timer stops his stopwatch and the student resumes her journey, covering the whole course at a slower pace than before. Again the timers start timing when the student begins to move and stop timing when the student passes the timers' position.

Observations:

Description of motion:

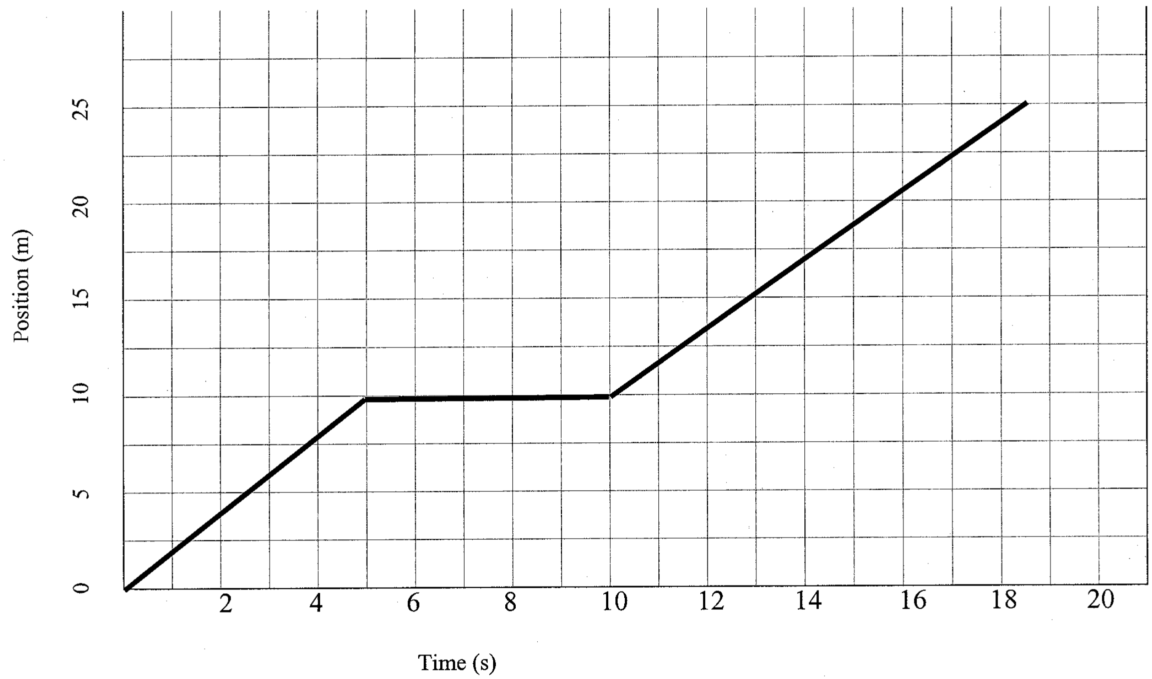
The student started at the origin, 0 m. She walked quickly to the right to the 10-m mark and stopped. She remained at the 10-m mark for a while, then walked more slowly, finishing at the 25-m mark.

Draw a picture of the motion:

Table 2E

Time (Sec)	0	2	4	10	13	16	19				
Position (Metres)	0	5	10	10	15	20	25				

Plot this information on the graph below. Plot position on the vertical axis and plot time on the horizontal axis. **Do not draw a line of best fit.** Instead, draw a line of best fit for each section.



Analysis:

1. What is different about each section of the graph drawn on page 5?

   In each section, the slope of the line is different.

2. Go back to the description of the motion. What does the graph look like when the student was moving quickly? Not moving? Moving slowly?

   In part 1, the student walked quickly. The graph is a straight line with a positive slope.

   In part 2, the student stood still. The graph is a straight line with a slope of 0.

   In part 3, the student walked more slowly than in part 1. The graph is a straight line with a positive slope, but not as steep as in part 1.

Conclusion:

Describe the information one is able to obtain **directly** from a Position-Time graph.

At a given time, the position of the object can be found directly from the graph.

We can obtain more indirect information from a Position-Time graph by looking at the line. Describe the information we can obtain **indirectly** from a Position-Time graph.

Indirectly, it seems that the speed with which the student moves gives a different slope to the line of the Position-Time graph.

When the student moves to the right, the slope is positive; and when she moves to the left, the slope is negative.

When the student moves quickly, the steepness of the line is greater.

Slope on a Position-Time graph determines the velocity of the object. The steepness gives the speed and the sign of the slope gives the direction.

Questions:

1. Distinguish between distance traveled and displacement.

   Distance traveled refers to how far an object moves regardless of its direction of motion. For example, the student walked 10 m. It is a scalar.

   Displacement refers to a change in position of an object. Displacement includes how far an object travels plus the direction of the motion. For example, the student walks 10 m to the right. Displacement is a vector.

2. Distinguish between average speed and average velocity.

   Average speed indicates how fast an object is traveling. It is found by distance traveled over time. It is a scalar.

   Average velocity is the rate of change of position with time. It is found by displacement over time interval. It is a vector.

3. For each trial (A through E), calculate the total distance traveled. Obtain the information from the graph.

   In all trials except D, the student started at the origin and ended up at +25 m from the origin, traveling a distance of 25 m.

   In trial D the student started at +25 m and finished at the origin, traveling a distance of 25 m.

4. For each trial (A through E), calculate the total time for the journey. Obtain the information from the graph

   A: $Dt = 16\ s$ *D:* $Dt = 14\ s$

   B: $Dt = 10.4\ s$ *E:* $Dt = 19\ s$

   C: $Dt = 5.1\ s$

5. For each trial (A through E), calculate the average speed. Show the equation and the work for each calculation.

   The equation used is $v_{avg} = Dd / Dt$

   A: $v_{avg} = 25\ m / 16\ s = 1.6\ m/s$

   B: $v_{avg} = 25\ m / 10.4\ s = 2.4\ m/s$

   C: $v_{avg} = 25\ m / 5.1\ s = 4.9\ m/s$

   D: $v_{avg} = 25\ m / 14\ s = 1.8\ m/s$

   E: $v_{avg} = 25\ m / 19\ s = 1.3\ m/s$

6. For each trial (A through E), calculate the displacement for the whole journey. Obtain the information from the graph.

   $$D\vec{d} = \vec{d}_2 - \vec{d}_1$$

   This equation is used for all calculations. For A, B, C, and E, the work is the same.

   $$D\vec{d} = \vec{d}_2 - \vec{d}_1 = +25\ \text{m} - 0\ \text{m} = +25\ \text{m}$$

   For D, the calculation is

   $$D\vec{d} = \vec{d}_2 - \vec{d}_1 = 0\ \text{m} - +25\ \text{m} = -25\ \text{m}$$

7. For each trial (A through E), calculate the **average velocity** for the journey. Show the equation and the work for each calculation.

   $$\vec{v}_{avg} = \frac{D\vec{d}}{Dt}$$

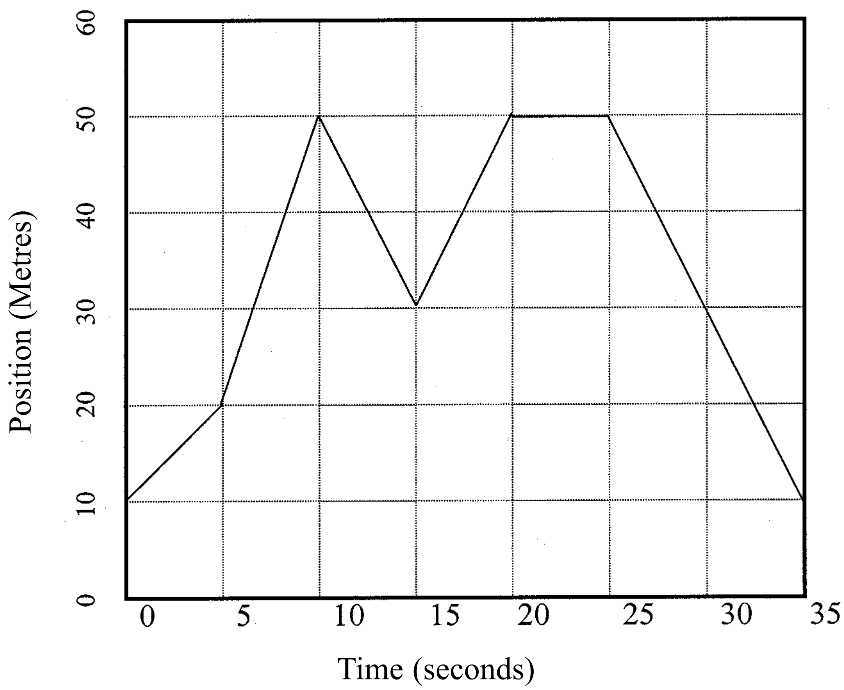
   This equation is used for all calculations.

   $$\text{A: } \vec{v}_{avg} = \frac{D\vec{d}}{Dt} = +25\ \text{m} / 16\ \text{s} = +1.6\ \text{m/s} \qquad \text{B: } \vec{v}_{avg} = \frac{D\vec{d}}{Dt} = +25\ \text{m} / 10.4\ \text{s} = +2.4\ \text{m/s}$$

   $$\text{C: } \vec{v}_{avg} = \frac{D\vec{d}}{Dt} = +25\ \text{m} / 5.1\ \text{s} = +4.9\ \text{m/s} \qquad \text{D: } \vec{v}_{avg} = \frac{D\vec{d}}{Dt} = -25\ \text{m} / 14\ \text{s} = -1.8\ \text{m/s}$$

   $$\text{E: } \vec{v}_{avg} = \frac{D\vec{d}}{Dt} = +25\ \text{m} / 19\ \text{s} = +1.3\ \text{m/s}$$

8.



The graph of Position-Time above shows the position of a soccer linesman running along the sideline of a soccer field during a soccer game.

The 0-m mark is located at the goal line at the south end of the field. All the positions are marked north of that starting point.

a. Where does the linesman start his journey?

10 m north of the south goal line.

b. During which time intervals is the linesman moving to the north?

0–10 s and 15–20 s

To the south?

10–15 s and 25–35 s

Not moving?

20–25 s

c. What is the distance traveled and the displacement for each interval listed below? Include direction with displacement.

Table 3

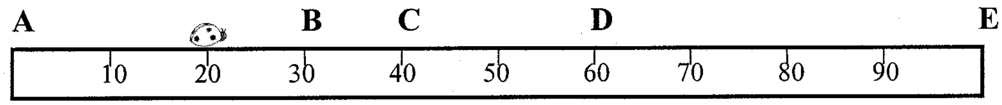
Time Interval	Distance Traveled d (m)	Displacement $D\vec{d} = \vec{d}_2 - \vec{d}_1$ (m)
0–5 seconds	10	+20 m – +10 m = +10 m =10 m [N]
5–10 seconds	30	+50 m – +20 m = +30 m = 30 m [N]
10–15 seconds	20	+30 m – +50 m = –20 m = 20 m [S]
15–20 seconds	20	+50 m – +30 m = +20 m = 20 m [N]
20–25 seconds	0	+50 m – +50 m = 0 m
25–35 seconds	40	+10 m – +50 m = –40 m = 40 m [S]

d. Calculate the average speed and the average velocity of the linesman for each time interval.

Table 4

Time Interval	Average Speed $v_{avg} = d/t$ (m/s)	Average Velocity $\vec{v}_{avg} = \frac{D\vec{d}}{Dt}$ (m/s)
0–5 seconds	10m / 5 s = 2 m/s	10m [N] / 5s = 2 m/s [N]
5–10 seconds	30m / 5 s = 6 m/s	30m [N] / 5s = 6 m/s [N]
10–15 seconds	20m / 5 s = 4 m/s	20m [S] / 5s = 4 m/s [S]
15–20 seconds	20m / 5 s = 4 m/s	20m [N] / 5s = 4 m/s [N]
20–25 seconds	0m / 5 s = 0 m/s	0m / 5s = 0 m/s
25–35 seconds	40m / 10 s = 4 m/s	40m [N] / 10s = 4 m/s [N]

Describing Motion in Various Ways



1. A somewhat confused ladybug is moving back and forth along a metrestick. Determine both the displacement and distance traveled by the ladybug as it moves from:

   a. A to B

   $\Delta\vec{d} = \vec{d}_2 - \vec{d}_1 = +30 \text{ cm} - 0 \text{ cm} = +30 \text{ cm}$

   $d = 30 \text{ cm}$

   b. C to B

   $\Delta\vec{d} = \vec{d}_2 - \vec{d}_1 = +30 \text{ cm} - +40 \text{ cm} = -10 \text{ cm}$

   $d = 10 \text{ cm}$

   c. C to D

   $\Delta\vec{d} = \vec{d}_2 - \vec{d}_1 = +60 \text{ cm} - +40 \text{ cm} = +20 \text{ cm}$

   $d = 20 \text{ cm}$

   d. C to E and then to D

   $\Delta\vec{d} = \vec{d}_2 - \vec{d}_1 = +60 \text{ cm} - +40 \text{ cm} = +20 \text{ cm}$

   $d_{CE} = 60 \text{ cm};\ d_{ED} = 40 \text{ cm};\ d_{total} = 100 \text{ cm}$

2. In the diagram above, **east** points to the **right**. During which of the intervals in #1 is the ladybug moving in the **easterly** direction?

   A to B, C to D, and C to E

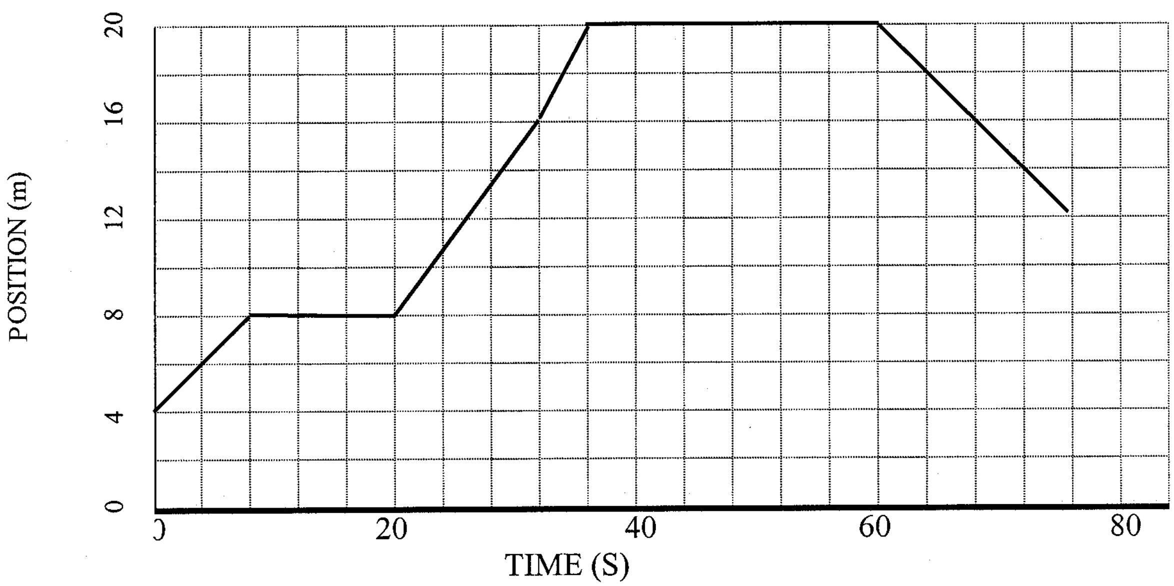
   In the **westerly** direction?

   C to B and E to D

3. Below is a table showing the position above the ground floor of an elevator at various times. On the graph below the table, plot a graph of Position-Time.

Table 5

Time (Sec)	0	4	20	32	36	60	72
Position above the ground floor (m)	4.0	8.0	8.0	16	20	20	12



4. A troubled student is waiting to see the principal. He paces back and forth in the hallway in front of the principal's office. The hallway runs north and south. The door to the office is our origin, 0 m. Here is a description of the student's motion.

   The student starts at 5.0 m N. He walks to the south for 7.0 m during 10.0 s. He stands still for 5.0 seconds. He turns around and walks 15.0 m N during 15.0 s. He stops to say "Hello" to a friend and remains still for 10.0 s. Finally, the principal calls him to the office door. It takes the student 10.0 s to reach the door.

   a. What is the total time the student spent in the hallway?

   $t_{total} = 10.0\ s + 5.0\ s + 15.0\ s + 10.0\ s + 10.0\ s = 50.0\ s$

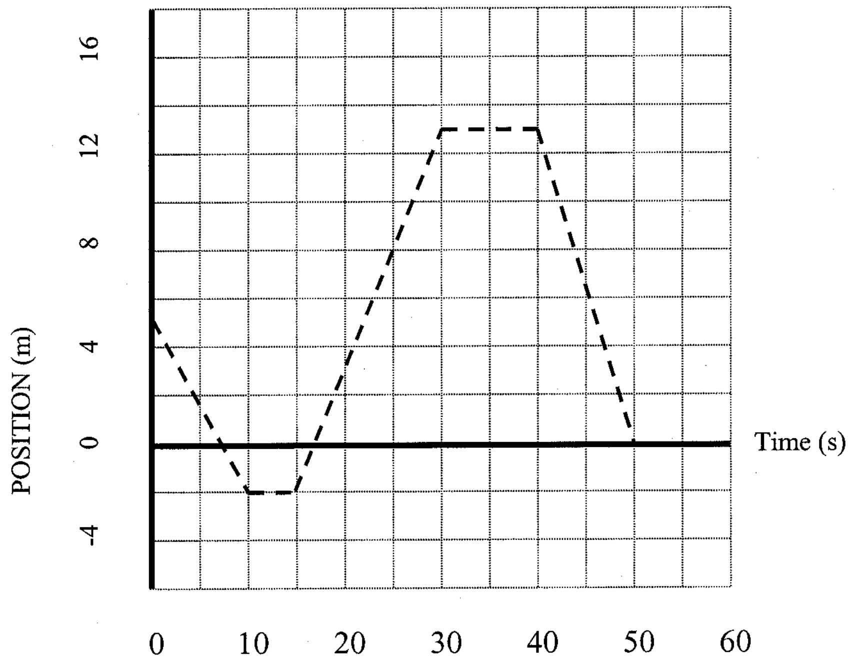
   b. What was the distance traveled by the student during his pacing?

   $d_{total} = d_1 + d_2 + d_3 = 7.0\ m + 15.0\ m + 13.0\ m = 35.0\ m$

   c. What was the average speed of the student during his pacing?

   $v_{avg} = d / t = 35.0\ m / 50.0\ s = 0.700\ m/s$

d. On the graph below, plot time on the horizontal axis and position on the vertical axis. Use straight-line segments to join the points of Position-Time that you plot.



e. What is the total displacement for the student's journey? Find this from the graph.

$$\Delta \vec{d}_{total} = \vec{d}_{50} - \vec{d}_{0} = 0\ m - +5.00\ m = -5.00\ m$$

f. What is the average velocity for the whole journey?

$$\vec{v}_{avg} = \frac{\Delta \vec{d}}{\Delta t} = -5.00\ m / 50.0\ s = -0.100\ m/s$$

Velocity, Displacement, and Time Problem Set

1. On your bicycle, you travel from A to B during 9.00 s.

   $\Delta\vec{d} = 45.0\ \text{m[S]};\ t = 9.00\ \text{s}$

   a. What is your average speed?

   $v_{avg} = ?$
   $v_{avg} = d / t = 45.0\ \text{m} / 9.00\ \text{s} = 5.00\ \text{m/s}$

   b. What is your average velocity?

   $\vec{v}_{avg} = \Delta\vec{d} / \Delta t = 45.0\ \text{m [S]} / 9.00\ \text{s} = 5.00\ \text{m/s [S]}$

2. If you travel from A to B to C to D, what is your

   a. distance traveled?

   $d_{AB} = 45.0\ \text{m};\ d_{BC} = 135\ \text{m};\ d_{CD} = 45.0\ \text{m}$
   $d_{total} = 45.0\ \text{m} + 135\ \text{m} + 45.0\ \text{m} = 225\ \text{m}$

   b. displacement?

   The displacement from A to B to C to D is the same as going directly from A to D, which is 135 m [W].

3. If the journey in #2 took 55.0 s, calculate

   a. your average speed.

   $d_{total} = 225\ \text{m};\ t = 55.0\ \text{s}$
   $v_{avg} = ?$
   $v_{avg} = d / t = 225\ \text{m} / 55.0\ \text{s} = 4.09\ \text{m/s}$

   b. your average velocity.

   $\Delta\vec{d} = 135\ \text{m [W]};\ t = 55.0\ \text{s}$
   $\vec{v}_{avg} = \Delta\vec{d} / \Delta t = 135\ \text{m [W]} / 55.0\ \text{s} = 4.09\ \text{m/s [S]}$

4. You travel around the block in 90.0 s. Calculate your average speed and your average velocity.

   a. *d_{total} = distance around the block = 45.0 m + 135 m + 45.0 m + 135 m = 360 m*

   $t = 90.0$ s

   $v_{avg} = d / t = 360$ m / 90.0 s = 4.00 m/s

   b. *The displacement for a trip around the block is 0 m. Therefore, the average velocity is 0 m/s.*

5. Fargo is located 375 km south of Winnipeg. If it takes 4.00 h to travel from Winnipeg to Fargo, calculate your average velocity.

$\Delta\vec{d} = 375 \text{ km [S]};\ t = 4.00 \text{ s}$

$\vec{v}_{avg} = \Delta\vec{d}/\Delta t = 375 \text{ km [S]}/4.00 \text{ s} = 93.75 = 93.8 \text{ km/h [S]}$

6. You make the return trip to Winnipeg from Fargo also in 4.00 h. What was your average velocity?

   On the return trip, the velocity is in the opposite direction or 98.3 km/h [N].

7. Jim lives on the same street as his school. The front of the school is located 1020 m [E] of Jim's house. If Jim walks at 3.00 m/s [E], calculate the time it takes Jim to walk from his house to the front of the school.

$\vec{v}_{avg} = 3.00 \text{ m/s [E]};\ \Delta\vec{d} = 1020 \text{ m [E]}$

$t = ?$

$\vec{v}_{avg} = \Delta\vec{d}/\Delta t$

$3.00 \text{ m/s [E]} = 1020 \text{ m [E]}/t$

$t = 1020 \text{ m [E]}/3.00 \text{ m/s [E]}$

$t = 340 \text{ s}$

8. An airplane flies at a velocity of 215 km/h [W] for 2.75 hours. What is the displacement for this journey?

$\vec{v}_{avg} = 215 \text{ km/h [W]};\ t = 2.75 \text{ h}$

$\Delta\vec{d} = ?$

$\vec{v}_{avg} = \Delta\vec{d}/\Delta t$

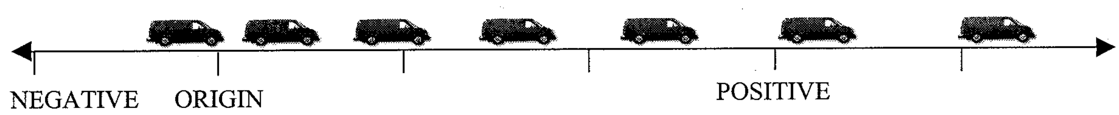
$215 \text{ km/h [W]} = \Delta\vec{d}/2.75 \text{ h}$

$\Delta\vec{d} = (215 \text{ km/h [W]})(2.75 \text{ h}) = 591.25 = 591 \text{ km [W]}$

The Meaning of the Sign of Acceleration—Student Activity

In the following graphics, the time intervals between successive images of the van are all equal. For the directions, positive is to the right, and negative is to the left.

1. For the graphic below, describe the motion of the van.



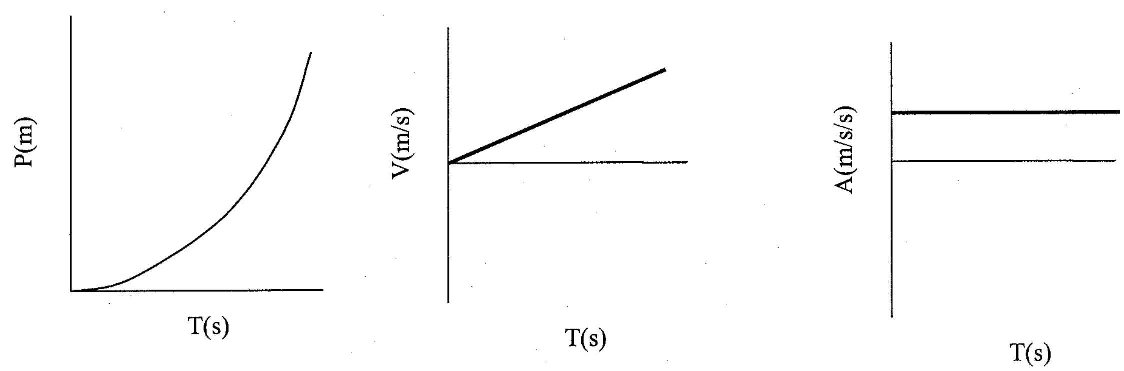
What is the sign of the velocity?

Positive

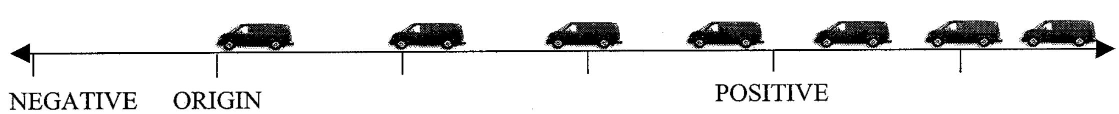
What is the sign of the acceleration?

Positive

Sketch the lines for the Position-Time graph, the Velocity-Time graph, and the Acceleration-Time graph that describe this motion.



2. For the graphic below, describe the motion of the van.



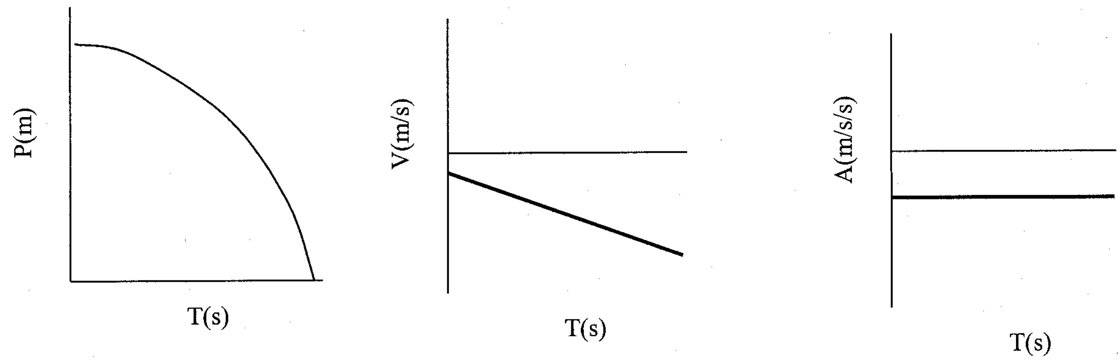
What is the sign of the velocity?

Negative

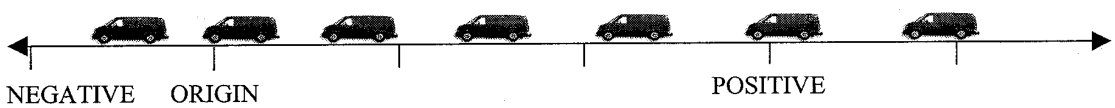
What is the sign of the acceleration?

Negative

Sketch the lines for the Position-Time graph, the Velocity-Time graph, and the Acceleration-Time graph that describe this motion.



3. For the graphic below, describe the motion of the van.



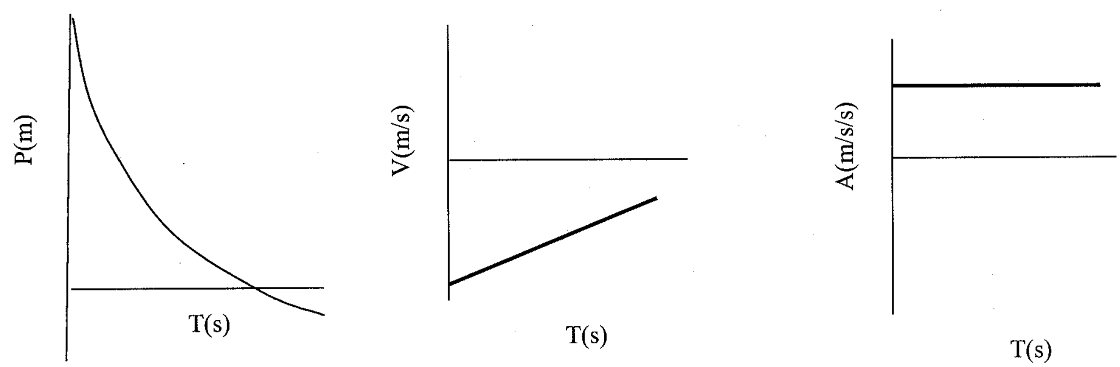
What is the sign of the velocity?

Negative

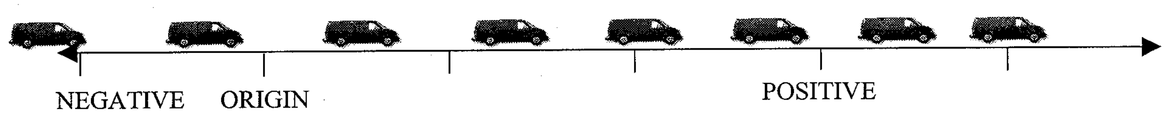
What is the sign of the acceleration?

Positive

Sketch the lines for the Position-Time graph, the Velocity-Time graph, and the Acceleration-Time graph that describe this motion.



4. For the graphic below, describe the motion of the van.



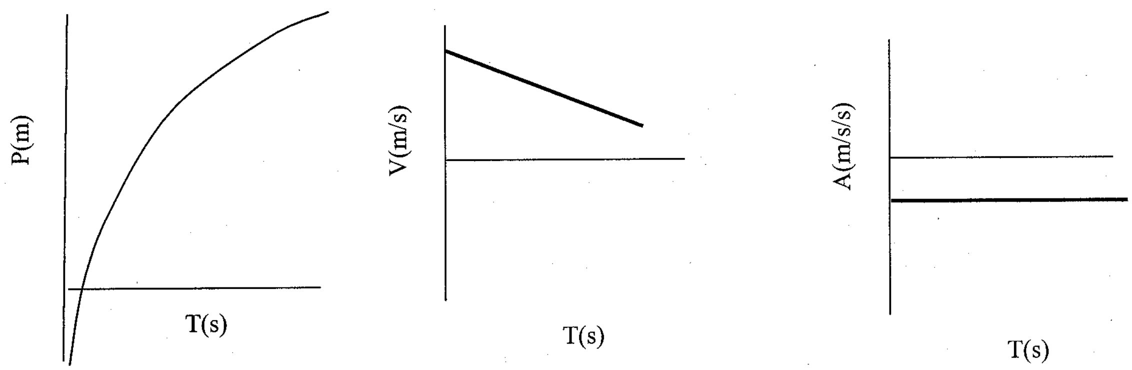
What is the sign of the velocity?

Positive

What is the sign of the acceleration?

Negative

Sketch the lines for the Position-Time graph, the Velocity-Time graph, and the Acceleration-Time graph that describe this motion.



5. From the data in the table below, describe the motion of the object.
The object is moving to the right but slowing down. There is an acceleration opposite to the direction of motion of the object.

Table 10

Time (s)	Velocity (m/s)
0	10
1	9
2	8
3	7
4	6
5	5

What is the sign of the velocity?

Positive

What is the sign of the acceleration?

Negative

6. From the data in the table below, describe the motion of the object.
   The object is moving to the left and speeding up. The velocity is increasing in the negative direction, so the acceleration acts in the direction of motion.

Table 11

Time (s)	Velocity (m/s)
0	–4
1	–8
2	–12
3	–16
4	–20
5	–24

What is the sign of the velocity?

Negative

What is the sign of the acceleration?

Negative

7. From the data in the table below, describe the motion of the object.
   The object is moving to the left but the velocity is decreasing. The acceleration acts in a direction opposite to the velocity.

Table 12

Time (s)	Velocity (m/s)
0	–11
1	–9
2	–7
3	–5
4	–3
5	–1

What is the sign of the velocity?

Negative

What is the sign of the acceleration?

Positive

8. From the data in the table below, describe the motion of the object.
   The object is moving to the right and the velocity is increasing. The acceleration of the object is in the direction of motion.

Table 13

Time (s)	Velocity (m/s)
0	0.25
1	0.50
2	0.75
3	1.00
4	1.25
5	1.50

What is the sign of the velocity?

Positive

What is the sign of the acceleration?

Negative

Acceleration, Velocity, and Time Problem Set

1. A car can accelerate from a standstill to 100 km/h [E] in 9.60 s. Calculate the average acceleration.

$$\vec{v}_1 = 0 \text{ km/h}; \ \vec{v}_2 = 100 \text{ km/h [E]}; \ t = 9.60 \text{ s}$$

$$\vec{a}_{avg} = ?$$

$$\vec{a}_{avg} = \frac{\Delta\vec{v}}{\Delta t} = \frac{100 \text{ km/h [E]} - 0 \text{ km/h}}{9.60 \text{ s}} = 10.4 \text{ km/h/s [E]}$$

2. An object is falling at –4.20 m/s. A downward motion has a negative direction. At a time 2.50 s later, the object is falling at –28.7 m/s. What was the average acceleration?

$$\vec{v}_1 = -4.20 \text{ m/s}; \ \vec{v}_2 = -28.7 \text{ m/s}; \ t = 2.50 \text{ s}$$

$$\vec{a}_{avg} = ?$$

$$\vec{a}_{avg} = \frac{\Delta\vec{v}}{\Delta t} = \frac{-28.7 \text{ m/s} - -4.20 \text{ m/s}}{2.50 \text{ s}} = \frac{-24.5 \text{ m/s}}{2.50 \text{ s}} = -9.80 \text{ m/s/s}$$

3. A curling stone is sliding at +1.72 m/s. After 2.25 s, the curling stone is sliding at +1.00 m/s. What was the average acceleration?

$$\vec{v}_1 = +1.72 \text{ m/s}; \ \vec{v}_2 = +1.00 \text{ m/s}; \ t = 2.25 \text{ s}$$

$$\vec{a}_{avg} = ?$$

$$\vec{a}_{avg} = \frac{\Delta\vec{v}}{\Delta t} = \frac{+1.00 \text{ m/s} - +1.72 \text{ m/s}}{2.25 \text{ s}} = \frac{-0.72 \text{ m/s}}{2.25 \text{ s}} = -0.32 \text{ m/s/s}$$

4. Alberto rides his bicycle on a hill with a downward slope. If Alberto coasts down the hill with an average acceleration of 1.68 m/s/s, what is his change in velocity during 5.25 s?

$$\vec{a}_{avg} = +1.68 \text{ m/s/s}; \ t = 5.25 \text{ s}$$

$$\Delta\vec{v} = ?$$

$$\vec{a}_{avg} = \frac{\Delta\vec{v}}{\Delta t} = +1.68 \text{ m/s/s} = \Delta\vec{v} / 5.25 \text{ s}$$

$$\Delta\vec{v} = (+1.68 \text{ m/s/s})(5.25 \text{ s}) = +8.82 \text{ m/s}$$

5. Alberto reaches the bottom of the hill coasting along at 9.25 m/s. He begins to coast up a second hill where the average acceleration is –1.20 m/s/s. What is the change in Alberto's velocity during 3.00 s of coasting up this hill? What is his final velocity?

$\vec{v}_1 = +9.25 \text{ m/s}; \vec{a}_{avg} = -1.20 \text{ m/s/s}; t = 3.00 \text{ s}$

$\Delta\vec{v} = ? \text{ and } \vec{v}_2 = ?$

$\vec{a}_{avg} = \frac{\Delta\vec{v}}{\Delta t} = -1.20 \text{ m/s/s} = \Delta\vec{v} / 3.00 \text{ s}$

$\Delta\vec{v} = (-1.20 \text{ m/s/s})(3.00 \text{ s}) = -3.60 \text{ m/s}$

But, $\Delta\vec{v} = \vec{v}_2 - \vec{v}_1$

$-3.60 \text{ m/s} = \vec{v}_2 - +9.25 \text{ m/s}$

$\vec{v}_2 = -3.60 \text{ m/s} + +9.25 \text{ m/s}$

$\vec{v}_2 = +5.65 \text{ m/s}$

6. A car traveling at 18.0 m/s [E] brakes for a red light and comes to a stop. The car accelerates at an average rate of –3.60 m/s/s. What is the length of the time interval over which the car is braking?

$\vec{v}_1 = 18.0 \text{ m/s [E] or } +18.0 \text{ m/s}; \vec{v}_2 = 0 \text{ m/s}; \vec{a}_{avg} = -3.60 \text{ m/s/s}$

$t = ?$

$\vec{a}_{avg} = \frac{\Delta\vec{v}}{\Delta t}$

$-3.60 \text{ m/s/s} = 0 \text{ m/s} - +18.0 \text{ m/s} \ / t$

$t = -18.0 \text{ m/s} / -3.60 \text{ m/s/s} = 5.00 \text{ s}$

7. A dragster racing on a quarter-mile track (about 400 m) has an average acceleration of 11.2 m/s/s [E] reaching a velocity of 72.0 m/s [E]. What was the time needed to race this distance?

$\vec{v}_1 = 0 \text{ m/s}; \vec{v}_2 = 72.0 \text{ m/s [E] or } +72.0 \text{ m/s}; \vec{a}_{avg} = 11.2 \text{ m/s/s [E] or } +11.2 \text{ m/s/s}$

$t = ?$

$\vec{a}_{avg} = \frac{\Delta\vec{v}}{\Delta t}$

$+11.2 \text{ m/s/s} = +72.0 \text{ m/s} - 0 \text{ m/s} \ / t$

$t = +72.0 \text{ m/s} / +11.2 \text{ m/s/s} = 6.43 \text{ s}$