Acceleration

When the velocity of an object changes, we say that the object is accelerating. This acceleration can take one of three forms:

1. Speeding Up
   - occurs when the object's velocity and acceleration are in the same direction (parallel)
2. Slowing Down
   - occurs when the object's velocity and acceleration are in opposite directions (anti-parallel)
3. Changing Direction
   - occurs when the velocity and acceleration are neither parallel nor anti-parallel

We define acceleration as the rate of change of velocity. It can be calculated by taking the change in velocity and dividing by time:

$$a = \frac{\Delta v}{\Delta t} \qquad \text{or} \qquad a = \frac{v_f - v_i}{t}$$

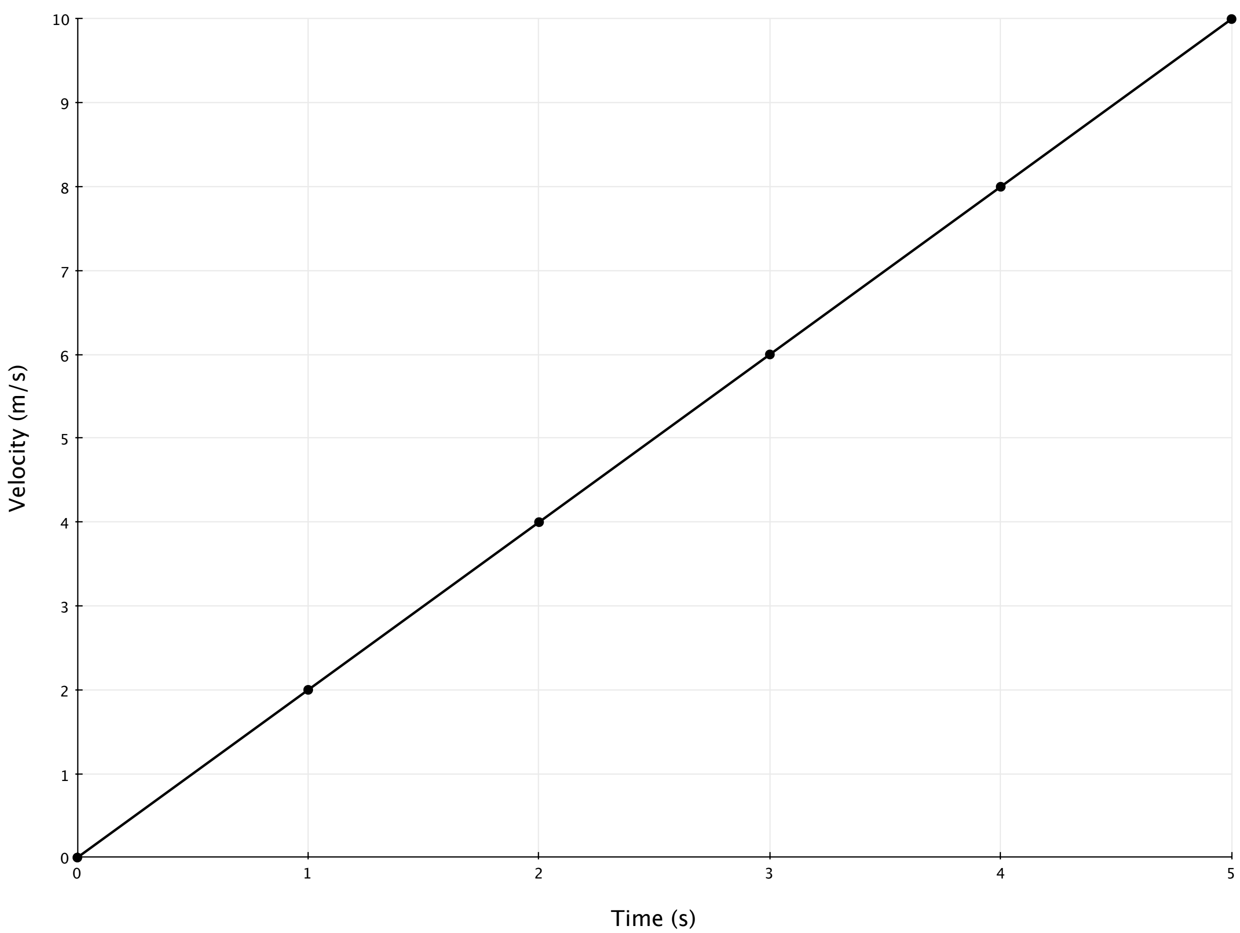
Example 1
A person is running. The runner changes velocity, going from $+5.0\ m/s$ to $+7.0\ m/s$ in a time of $1.0\ s$. What is the runner's acceleration?

Velocity-Time Graphs

Assume the runner in Example 1 starts at rest $\left(v_i = 0.0\ m/s\right)$ at a time of $t = 0.0\ s$. Given the acceleration that we calculated above, the following data table describes the motion of the runner over a $5.0\ s$ interval:

Time (s)	**Velocity** (m/s)
0.0	0.0
1.0	2.0
2.0	4.0
3.0	6.0
4.0	8.0
5.0	10.0

This data can be plotted on a graph of velocity versus time.



As was the case with a position-time graph, there is a great deal of information that can be determined from a velocity-time graph.

Some of the things you can determine directly from a graph of velocity versus time include:

- describing the motion of the object

- determining the velocity of the object at a given time
    - by reading the graph

- determine the time when the object was moving with a given velocity
    - by reading the graph

Some of the things you can determine indirectly — that is, by doing some calculations — from a velocity-time graph include:

- determine the distance traveled for an interval of time
    - area between the graph and the *x*-axis

- determine the displacement for an interval of time
    - area between the graph and the *x*-axis (area above axis is positive, below axis is negative)

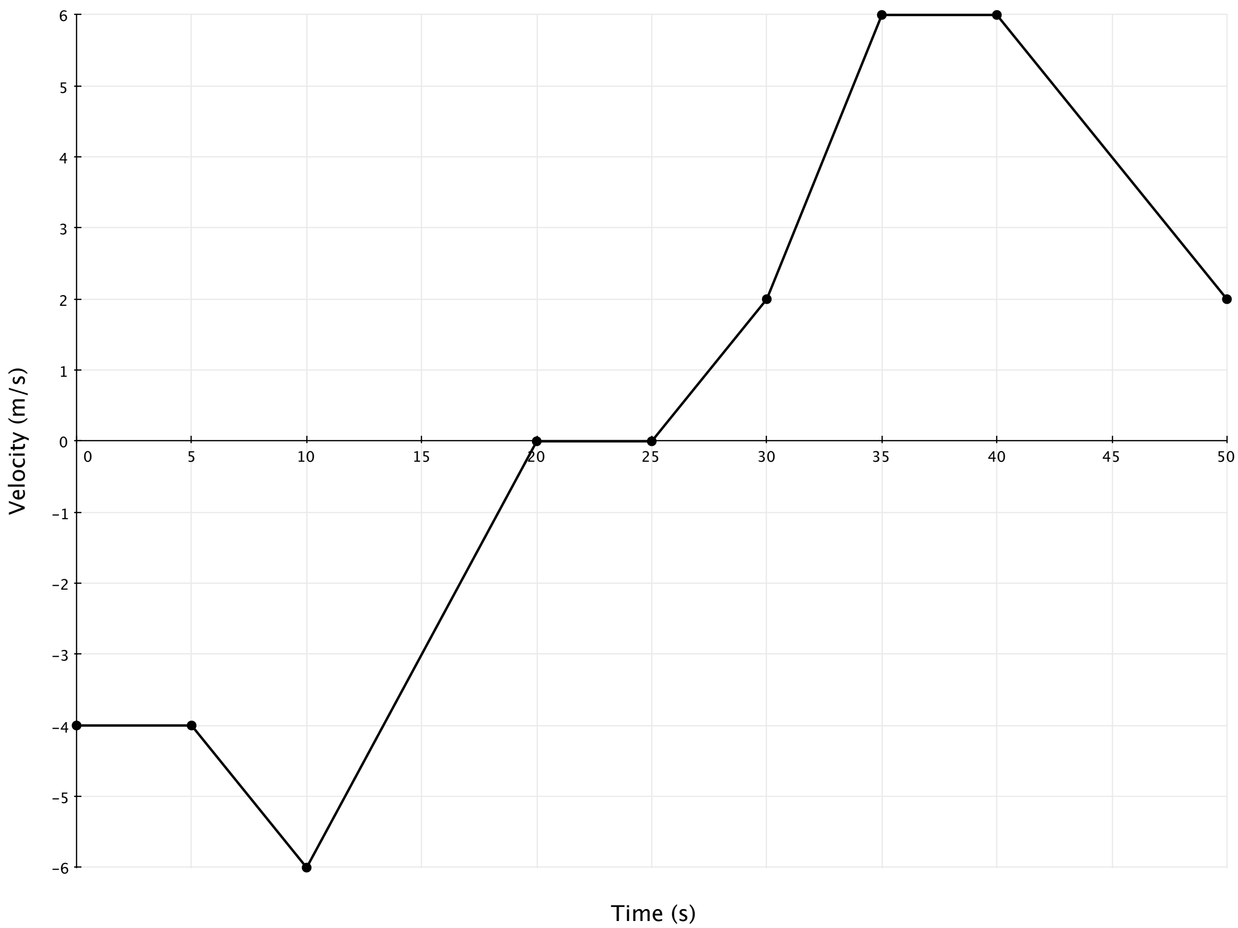
- determine the speed of the object over a given time interval (average speed)
    - total distance (area) divided by time

- determining the velocity of the object over a given time interval (average velocity)
    - total displacement (area) divided by time

- determining the acceleration of the object at a given instant (instantaneous acceleration)
    - slope of the graph at that instant
    - if the line is curved, use a tangent line

- determining the acceleration of the object over a given time interval (average acceleration)
    - slope of a line joining the point on the graph at the start of the interval to the point on the graph at the end of the interval

Example 2
Use the velocity-time graph below to answer the questions. **Note**: Right is the positive direction.



1. Describe the motion of the object.

2. What is the velocity of the object at $t = 30\ s$?

3. At what time is the object's velocity $6\ m/s\ [Left]$?

4. Determine the distance traveled by the object for the entire trip $t = 0\ s$ to $t = 50\ s$.

5. Determine the average speed of the object for the entire trip.

6. Determine the displacement of the object for the entire trip.

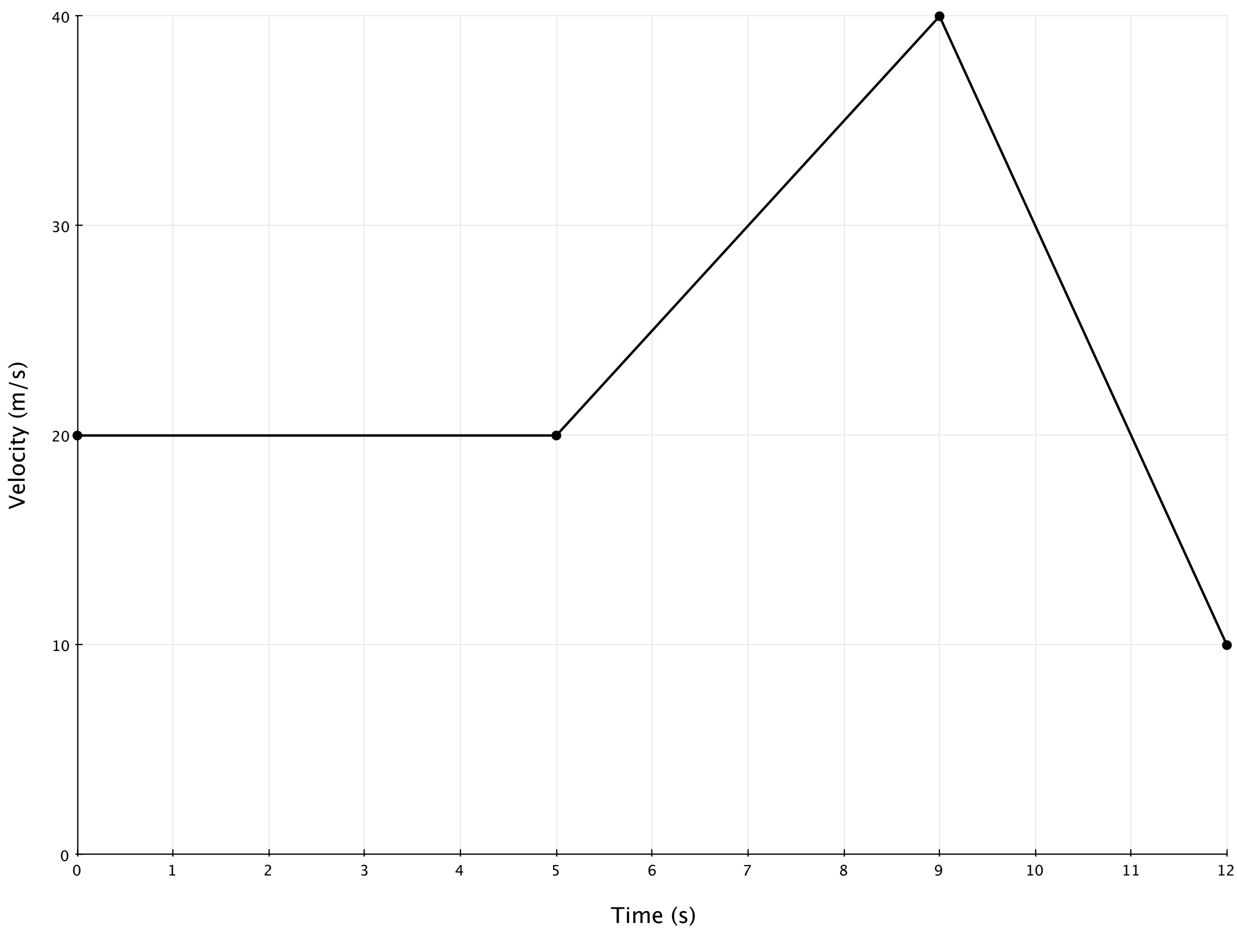
7. Determine the average velocity of the object for the entire trip.

8. Determine the acceleration of the object at $t = 15\ s$ and at $t = 45\ s$.

9. Determine the average acceleration of the object for the entire trip.

Velocity-Time Graphs

The following graph describes the motion of a car.



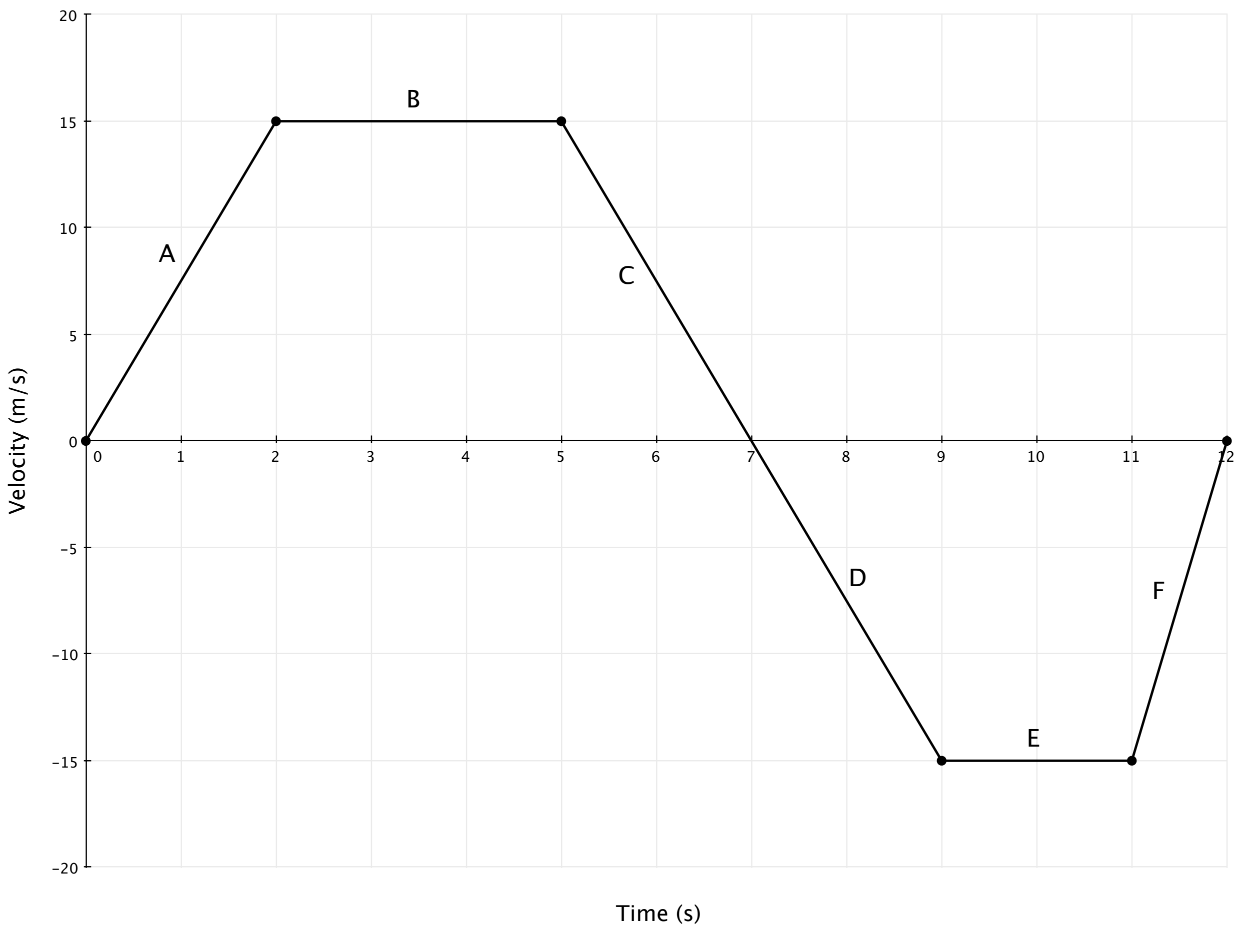
1. Complete the data table below showing time intervals and position.

Time (s)	0.0	5.0	9.0	12.0
Position (m)	0.0			

2. Complete the data table below showing time intervals and acceleration.

Time (s)	0.0 to 5.0	5.0 to 9.0	9.0 to 12.0
Acceleration $\left(m / s^2\right)$			

The following velocity-time graph shows the possible motion of a bicycle.



3. Complete the table showing time and position. Assume the bicycle starts at $0.0\ m$ and $0.0\ s$.

Section	Time (s)	Displacement (m)	Position at the End of the Interval
	0.0		0.0
A	0.0–2.0		
B	2.0–5.0		
C	5.0–7.0		
D	7.0–9.0		
E	9.0–11.0		
F	11.0–12.0		

4. Complete the table showing time and acceleration.

Section	Time (s)	Change in Velocity (m/s)	Acceleration (m/s^2)
A	0.0–2.0		
B	2.0–5.0		
C	5.0–7.0		
D	7.0–9.0		
E	9.0–11.0		
F	11.0–12.0		