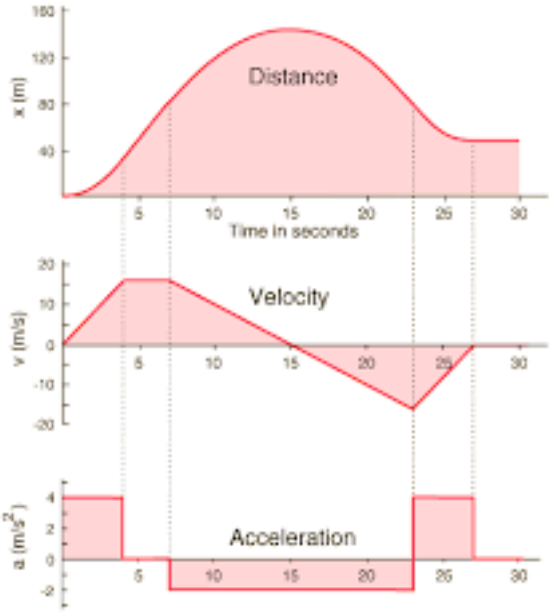
Physics 30S
Unit 2 – Motion Graphs



Mrs. Kornelsen
Teulon Collegiate Institute

Grade 11 Physics – Graphing Properties

Property	d-t Graph	v-t Graph	a-t Graph
Not Moving			Does Not Apply
Constant Velocity			
Change in Direction			Does Not Apply
Slowing Down			
Speeding Up			
Acceleration			
Calculate Distance		Does Not Apply	Does Not Apply
Calculate Displacement			Does Not Apply
Calculate Velocity			
Calculate Average Velocity		Does Not Apply	Does Not Apply
Calculate Average Speed		Does Not Apply	Does Not Apply
Calculate Acceleration	Does Not Apply		

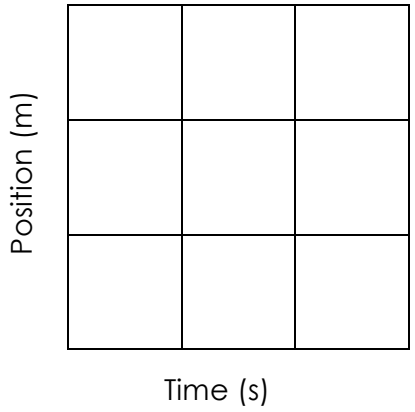
Grade 11 Physics – Position-time Graphs (d-t graphs)

A position-time graph represents the location of an object with respect to time.

Example: A plane is moving away from the airport at a uniform velocity of 300m/s [North].

(a) Plot this motion on the following d-t graph.

Time (s)	Position (m)
0	
1	
2	
3	

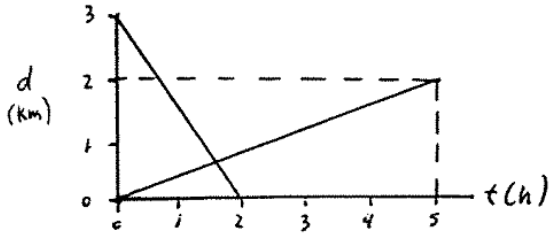


(b) Calculate the slope of the line.

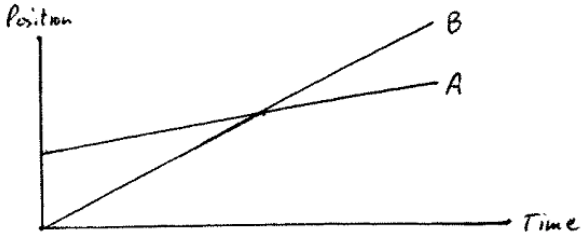
(c) How are the velocity and the slope of the line on the position-time graph related?

Grade 11 Physics – Position-time Graphs

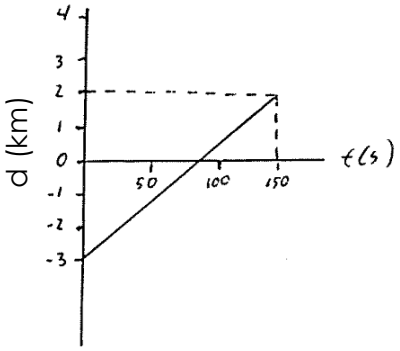
1. The graph at the right shows the positions of two hikers at various times. Determine the velocity of each. (Note the units involved).



2. Consider the d-t graph at the right. It was made by two objects (A and B).
   a. Which object is moving faster?
   b. Which starts ahead of the other?
   c. What does the intersection mean?

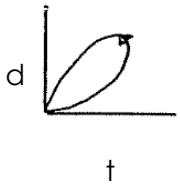


3. A commuter falls asleep on the New York subway and misses their stop. The graph shows part of the journey. The reference point is the station and negative means north and positive means south.
   a. What is the position of the station?
   b. Did the train stop at the station?
   c. Describe in words where the journey started.

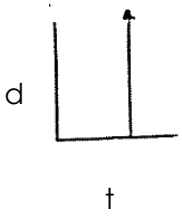


4. Below are two different position-time graphs. Tell what is impossible about each.

(a)

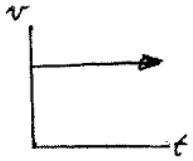


(b)

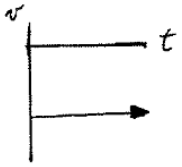


5. Below are three velocity-time graphs (we will talk about these more soon) made by three different objects. For each one, sketch the position-time graph that each object would produce. You only have to show the general shape of each d-t graph. Assume that each object starts at the origin.

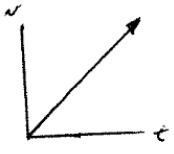
(a)



(b)



(c)



Grade 11 Physics – d-t Graphs and Non-uniform Motion

Review

On a d-t graph, a straight line means there is _____ motion, so the velocity is constant. Calculating the _____ of a straight line on a d-t graph gives you the velocity.

Non-Uniform Motion

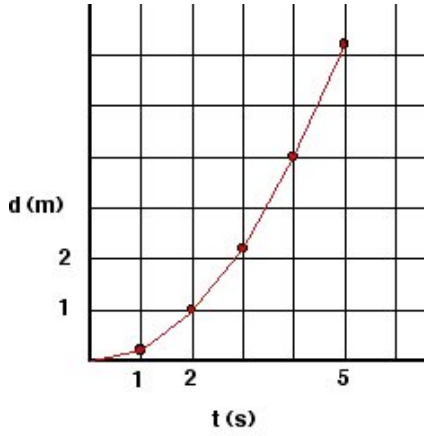
Non-uniform motion means that the velocity of an object is _____, this means there is an _____. On a d-t graph, acceleration of an object is shown by a curved line or a straight line whose slope changes. When we have an acceleration, we can either calculate the velocity at one time or the average velocity over a length of time.

Instantaneous Velocity

Instantaneous velocity is the velocity at one _____. The velocity will be different at every point in time while it's accelerating, so the instantaneous velocity will be different at every moment in time.

Instantaneous velocity is found by drawing a _____ at the exact time you want to know the velocity. Once you have a tangent line drawn, you can calculate the _____ of that tangent line to find the velocity at exactly that time.

Example: What is the velocity at 2s?



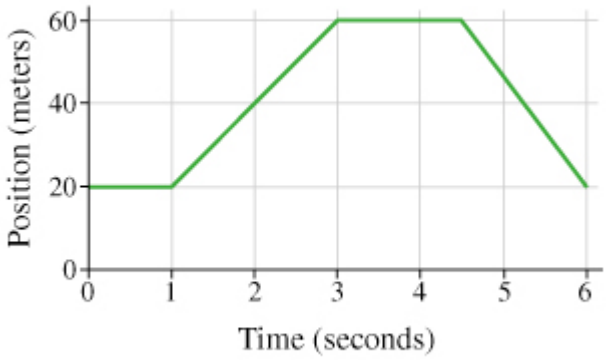
Average Velocity

The average velocity is a number that best summarizes all the data. When there is an acceleration (a change in velocity), we can calculate the average velocity to best summarize the data.

The average velocity is found by drawing a _____ (which is a line that joins two points on the curve) from the beginning to the end of the time interval and calculating the slope of that line.

Example: Calculate the average velocity between the following time intervals:

(a) 0 – 4s



(b) 0 – 6s

Drawing the chord and calculating the slope works because the slope is equal to using the formula $\vec{v}_{avg} = \frac{\Delta \vec{d}}{\Delta t}$. The rise of the chord is your displacement and the run is the time.

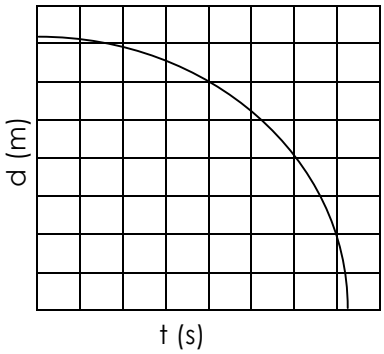
Average Speed

The average speed for a graph is calculated slightly different than average velocity, because it is not a vector. Average speed uses the formula $v_{avg} = \frac{d}{\Delta t}$ that we learned previously. You **cannot** draw the chord on the graph and calculate the slope because the rise of that chord will not be equal to the _____ the object travels.

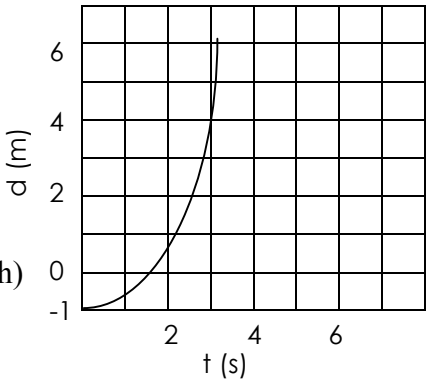
Example: use the previous graph to calculate the average speed from 0 – 6s.

Grade 11 Physics – d-t Graphs and Non-uniform Motion

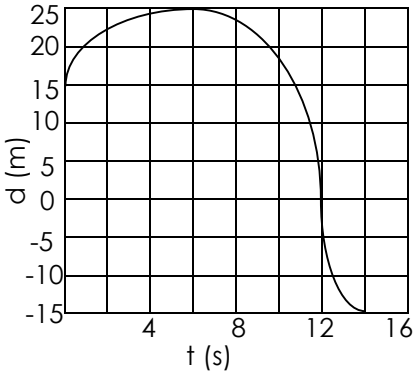
1. Look at the d-t graph at the right and answer the following questions:
    a. Is the velocity of the object increasing, decreasing or constant?
    b. Is the velocity ever positive?



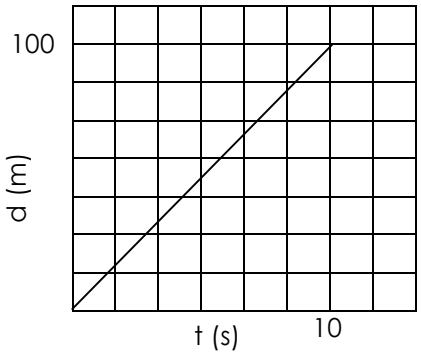
2. Consider the d-t graph at the right.
    a. Calculate the instantaneous velocity at 2.0s.
    b. What is the average velocity between 0 and 3.0s?

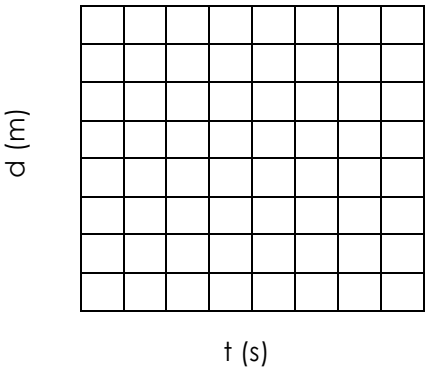


3. From the graph at the right, find: (assume positive is North)
    a. The time when velocity is equal to zero.
    b. The time when the maximum velocity occurs.
    c. The time intervals when the velocity is decreasing
    d. The time interval when the velocity is increasing.
    e. The velocity when t = 8.0s.
    f. The average speed from the beginning to the end of the journey.
    g. The average velocity from the beginning to the end of the journey.
    h. If the average speed and average velocity are equal between 0 and 5.0s?
    i. If the average speed and average velocity are equal between 0 and 12.0s?



4. A world class sprinter runs the 100m in 10s as shown below. Why is this graph not a true representation of the race? Sketch a graph (on the right) that would more accurately reflect how the race was run. Be sure to include the decrease in velocity after the finish line is crossed at the 10s mark.

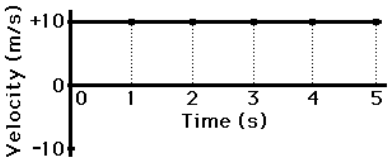




Grade 11 Physics – v-t Graphs and Acceleration

Uniform Velocity

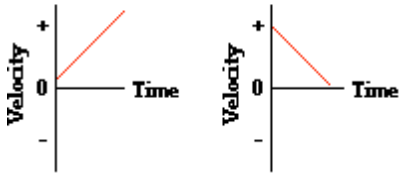
A _____ is shown on a velocity time graph with a horizontal line, as shown below.



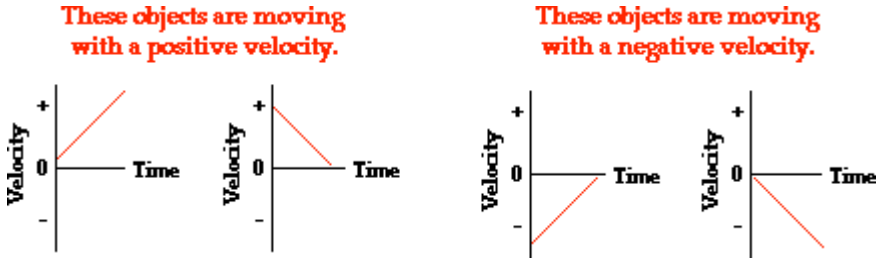
An object is _____ when the line is at zero.

Non-Uniform Velocity

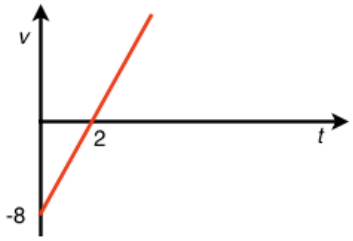
A uniform _____ on a velocity-time graph is represented by a straight, angled line. A line moving _____ from the origin means the object is speeding up, and a line moving _____ the origin means the object is slowing down. Acceleration can be calculated by determining the _____ of the line.



A **positive velocity** means the object is moving in the positive direction and a **negative velocity** means the object is moving in the negative direction.



An object _____ when the line on the graph crosses from the positive side to the negative side, or from the negative side to the positive side.



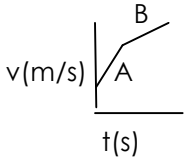
Example: Describe a situation that would produce the following velocity-time graph. Calculate the acceleration of the object that creates the graph

graph from p. 63

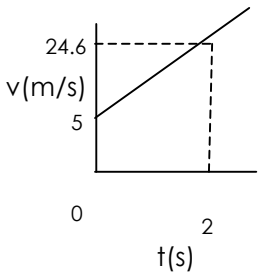
Example: The acceleration test results for a new vehicle are displayed below. Find the time the vehicle needs to reach 22m/s.

Grade 11 Physics – v-t Graphs and Acceleration

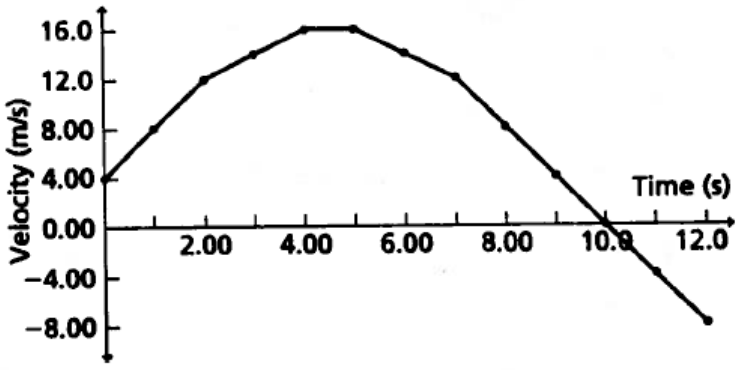
1. A distance runner increases their velocity from 2.0m/s [East] to 8.0m/s [East] in 3.0s. What is their acceleration?
2. A rocket accelerates at 40.0m/s^2 [up] for 3.0s. What is its change in velocity?
3. A motorcycle stunt rider accelerates from rest to 35m/s [North] before jumping over 20 cars. If they accelerate at 7.0m/s^2 [North], how long would it take them to reach this velocity?
4. Look at the v-t graph to the right. In which interval is the acceleration the greatest?



5. An oil tanker is moving with a velocity of 4.0m/s [South] when the captain realizes they are running late and accelerates the tanker at 0.050m/s^2 [South] for a full minute. What is the velocity of the tanker after that minute?
6. A falling object produces the v-t graph to the right. Find the time needed to reach a velocity of 10m/s.



7. Look at the graph below and answer the questions after. Assume positive is North.



   a. During what time interval(s) is the object speeding up?
   b. During what time interval(s) is the object slowing down?
   c. At what time does the object change directions?
   d. What is the velocity at 6.00s?
   e. What is the acceleration from 0 – 2.0s?
   f. What is the acceleration from 7.0 – 12.0s?

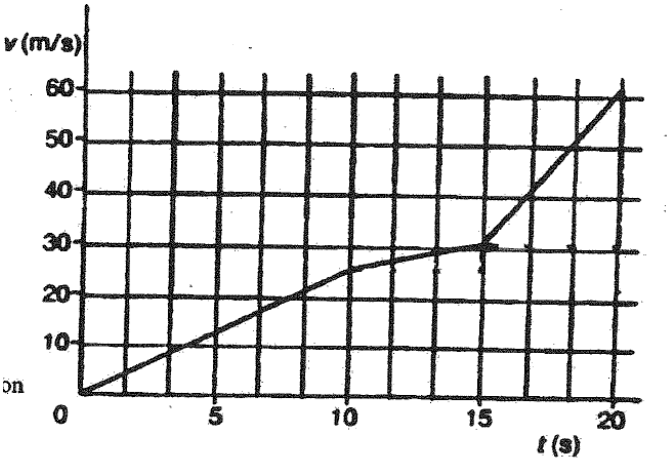
Grade 11 Physics – Displacement on a v-t Graph

Review: on a v-t graph, we know that the acceleration of an object can be found by calculating the slope of the line. A straight line means there is uniform acceleration and a curved line means there in non-uniform acceleration.

Practice #1: Look at the data table below. Graph the data on **Page 2** and calculate the acceleration of the object in the space below.

Time (s)	Velocity (m/s)
0	0
5	4
10	8
15	12
20	16
25	20
30	24

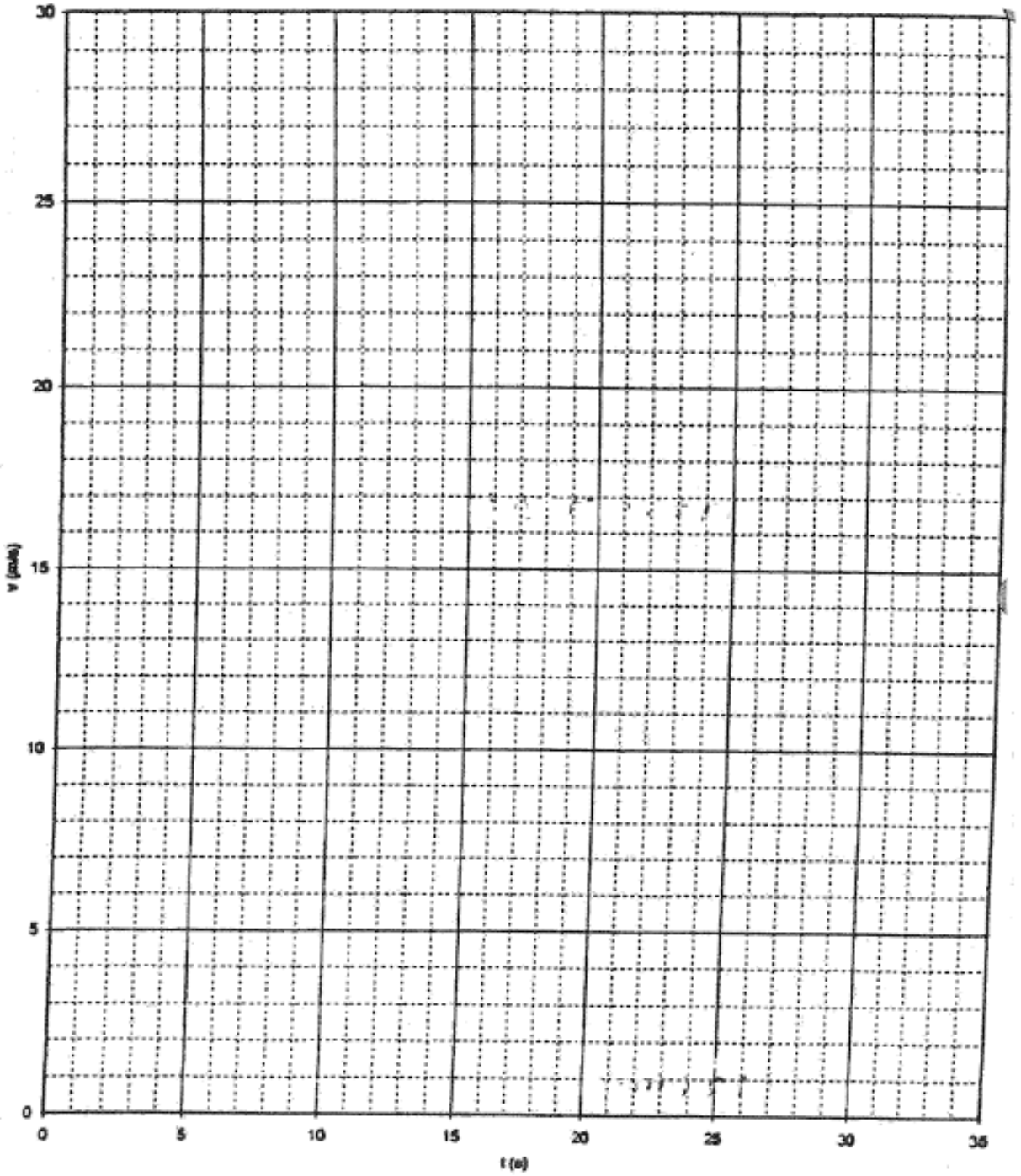
Practice #2: Use the velocity-time graph below to determine the acceleration of the object for:



(a) the first 10s of its motion

(b) between 10s and 15s.

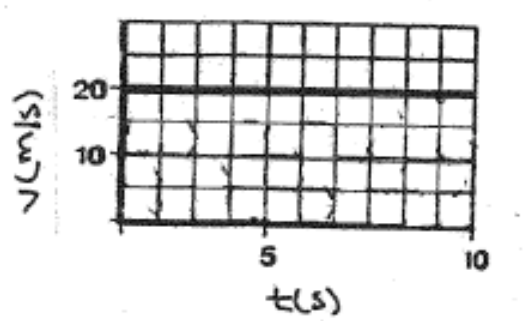
v-t Graph for Practice #1



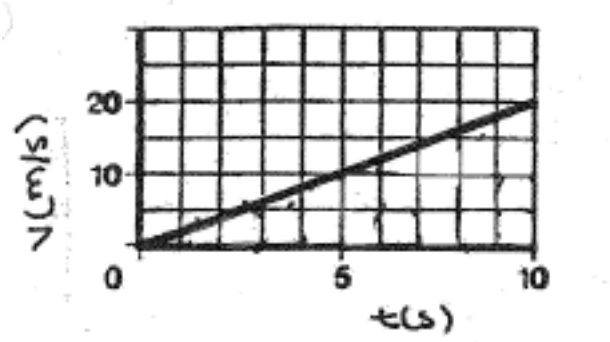
Displacement and v-t Graphs

On a v-t graph, the **displacement** can be determined by calculating the **area** under the graph

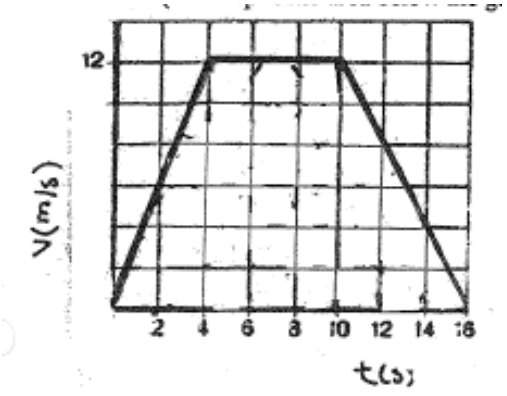
Example #1: The graph below shows the motion of a car for a 10s time interval. What is the displacement of the car during this time?



Example: #2: The graph below shows the velocity of a ball that starts at rest and rolls down a long hill. What is the ball's displacement after 10s?

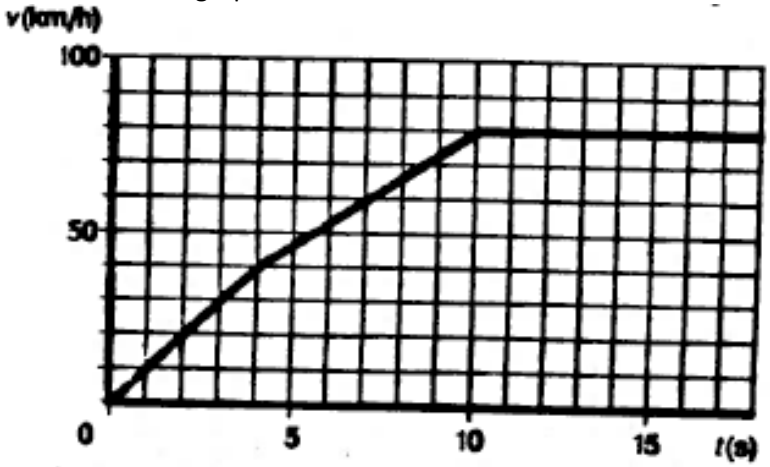


Example: #3: The graph below shows the motion of a dog running along the side of a straight road for a 16s time interval. What is its displacement for that time?
(Hint: split the area below the graph into easier shapes)



Grade 11 Physics – Displacement on a v-t Graph

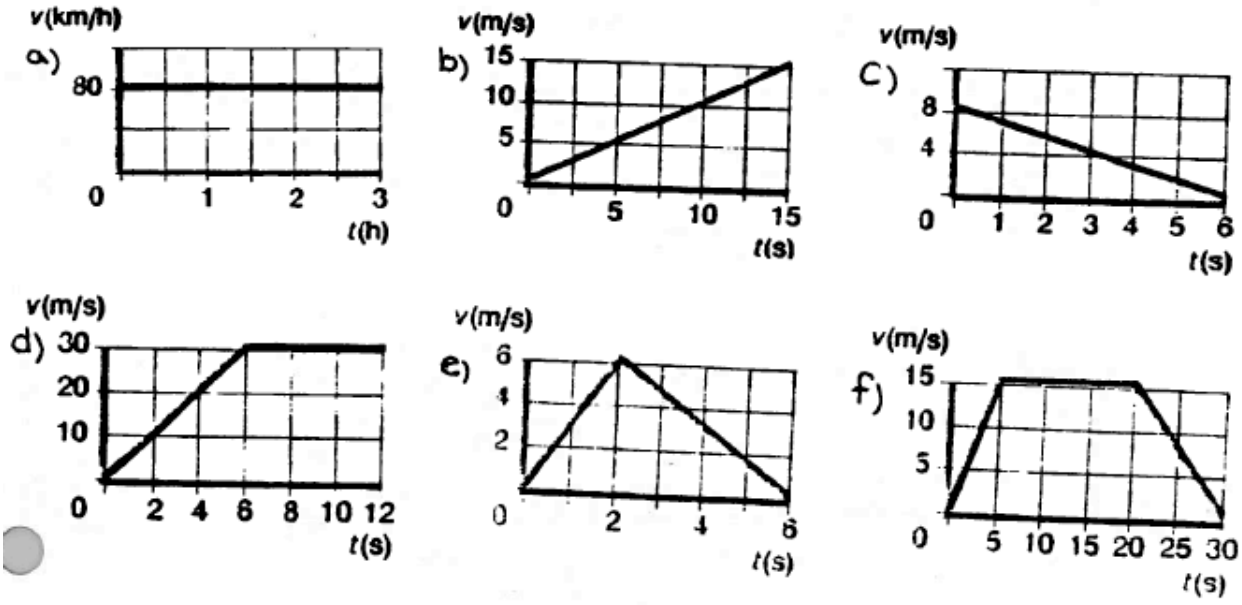
1. The graph below shows the motion of a car accelerating from a stop at an intersection.



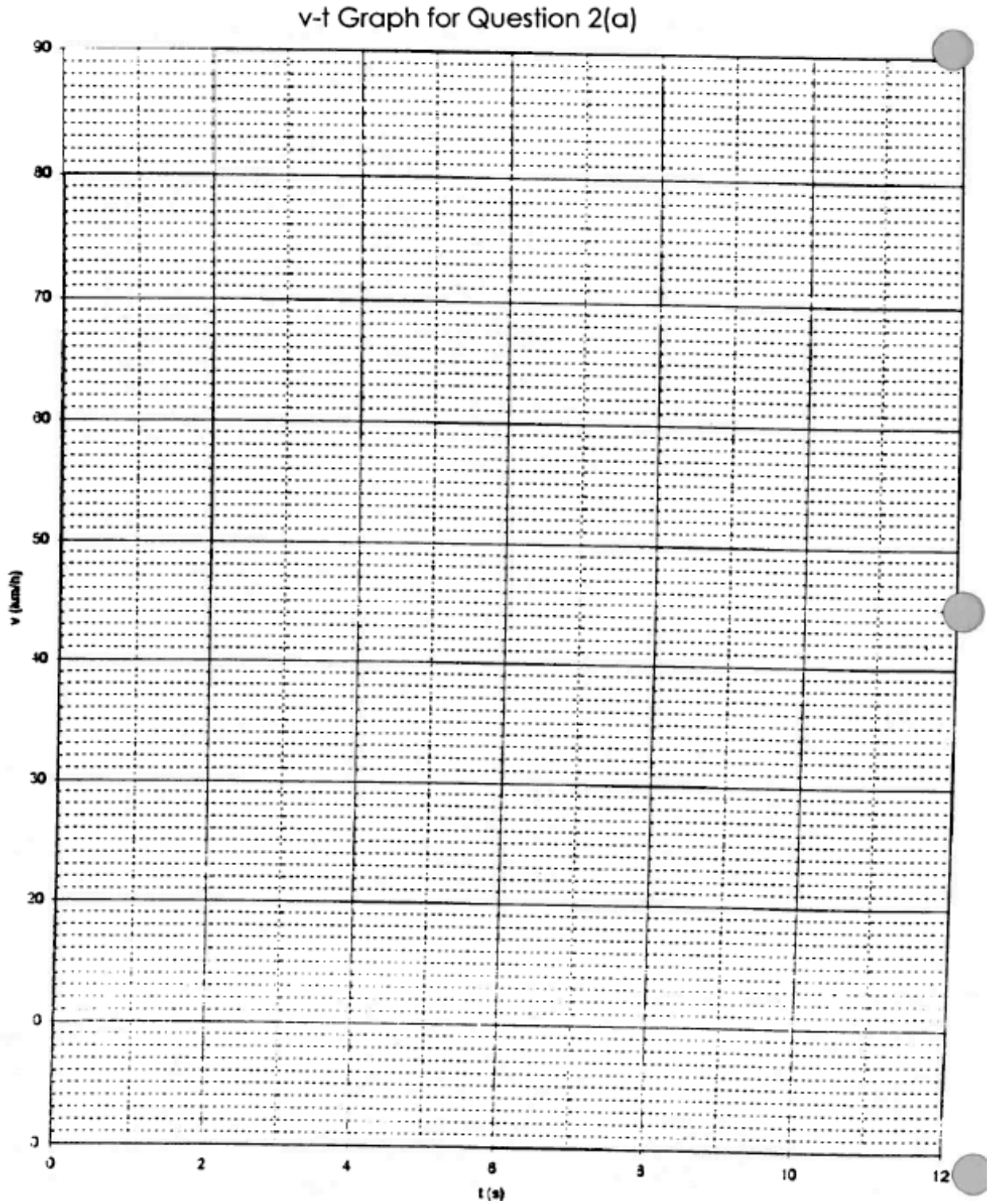
   a. How fast was the car moving at the following times: 2.0s, 4.0s, 15.0s?
   b. Determine the acceleration during the following time intervals: 0s – 4.0s, 4.0s – 10.0s, 10.0s – 15.0s.

2. Construct a velocity-time graph for the following. **Use the graphs on the following pages**
   a. A car starts from rest and accelerates at 8(km/h)/s for 10s.
   b. A runner is running at a constant velocity of 8.0m/s for 5.0s, then slows down at a uniform rate and stops in 2.0s.

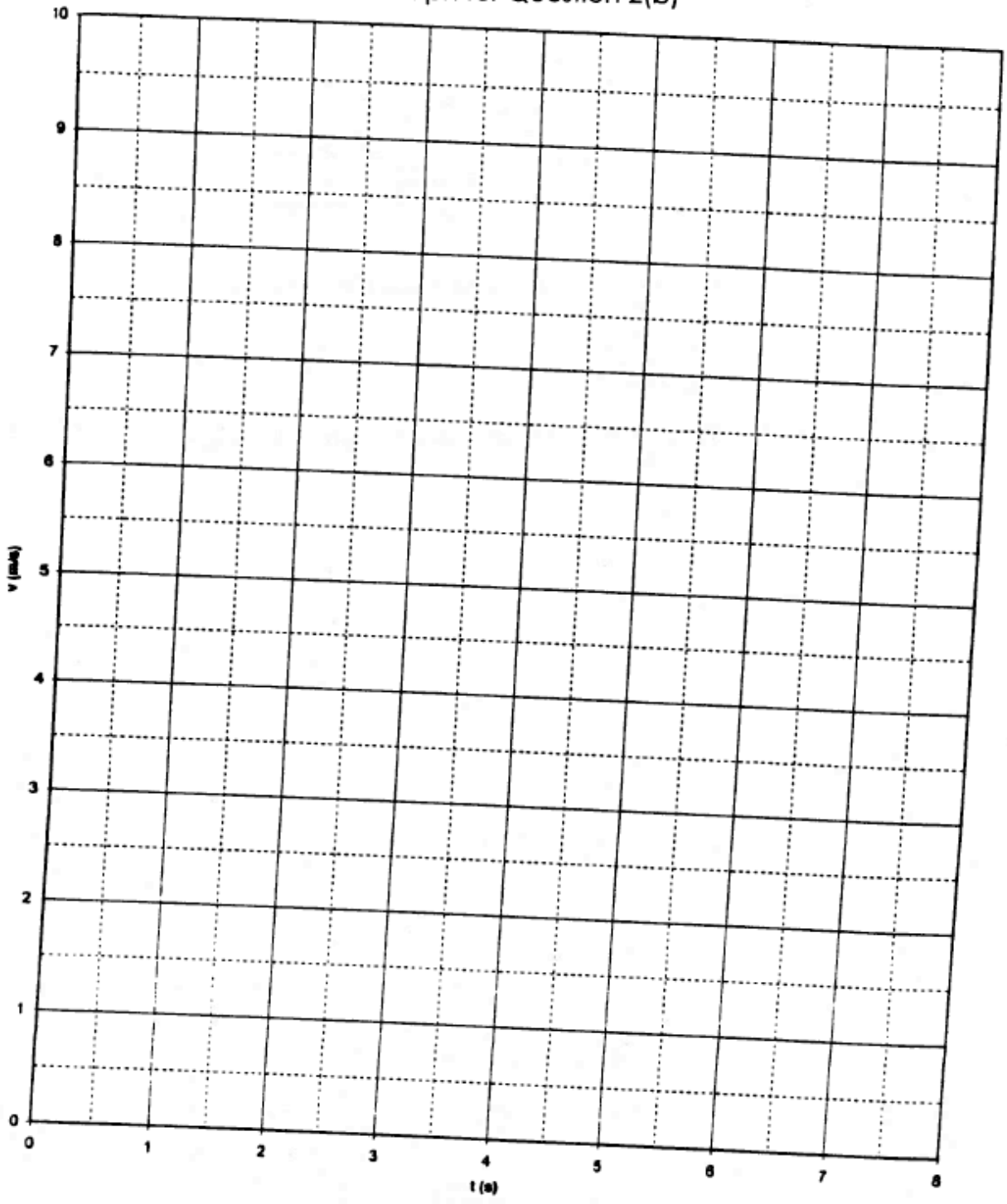
3. For each of the graphs below, calculate the displacement of the objects that would have created the v-t graph.



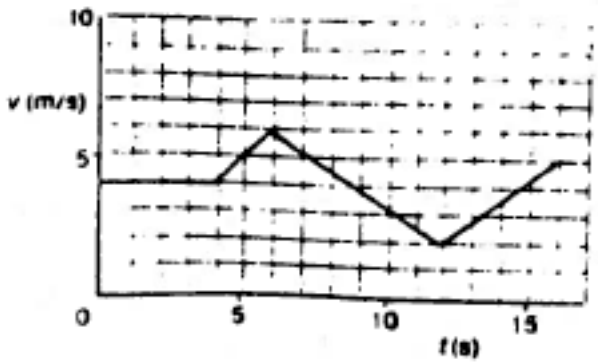
v-t Graph for Question 2(a)



v-t Graph for Question 2(b)



4. Below is a v-t graph for a bicycle trip.

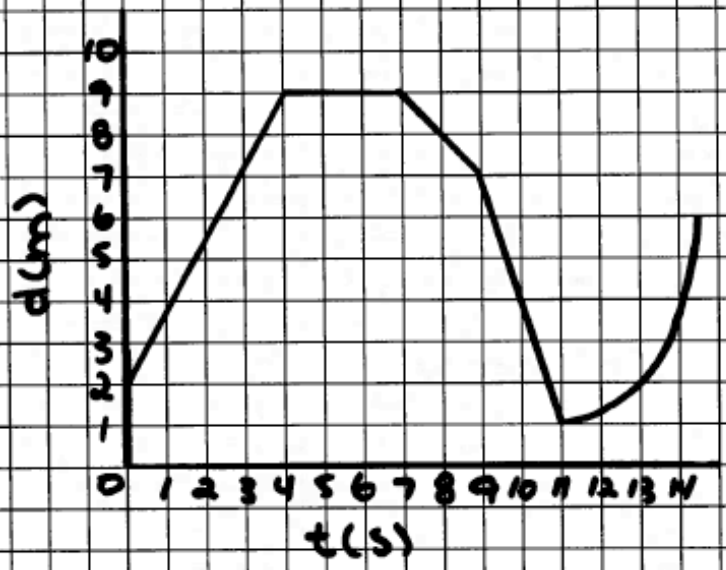


a. How fast is the bicycle moving at each of the following times:
   i. 4.0s
   ii. 6.0s
   iii. 10.0s
   iv. 12.0s

b. What is the acceleration of the bicycle at each of these times?
   i. 2.0s
   ii. 5.0s
   iii. 7.0s
   iv. 14.0 s

Practice with d-t and v-t Graphs

1)



(a) what is the speed at 2s?

(b) what is the displacement

(c) what is the distance travelled?

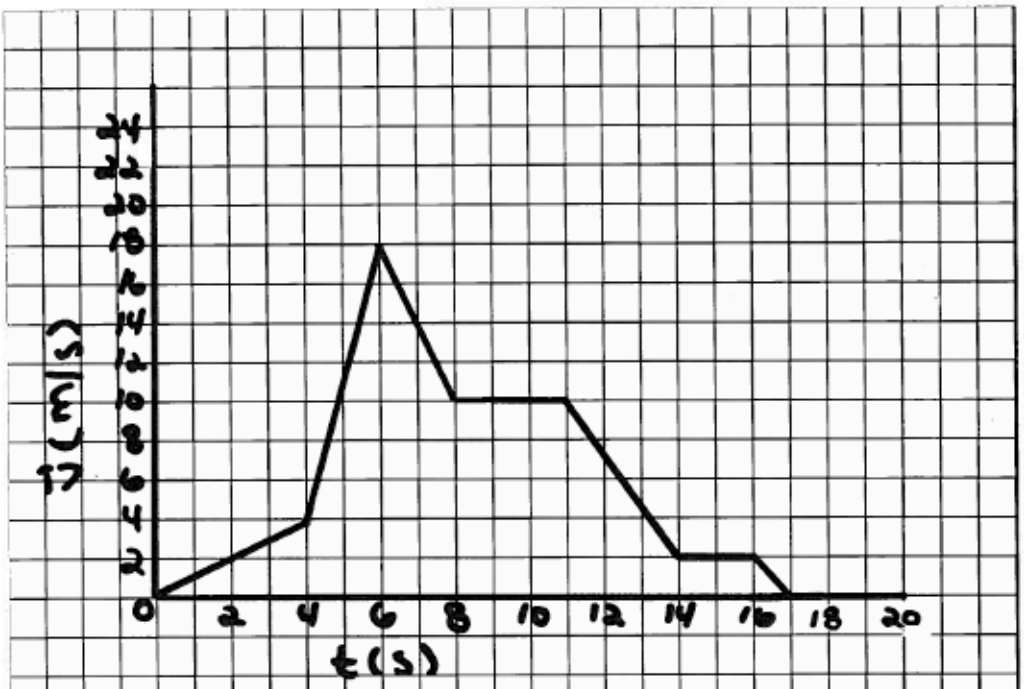
(d) what is the speed at 5s?

(e) what is the speed at 13s?

(f) from 0-4s, is the velocity increasing, decreasing or staying the same?

(g) from 11-14s, is the velocity increasing, decreasing or staying the same?

2)



(a) what is the speed at 5s?

(b) when is the acceleration the greatest?

(c) what is the displacement between 0 and 4s?

(d) when is it not moving?

(e) what is the acceleration between 8-11s?

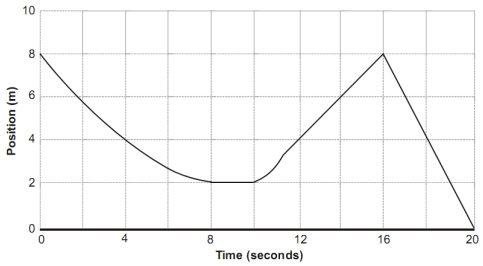
(f) what is the acceleration at 12s?

(g) what is the displacement between 11-14s?

Grade 11 Physics – Acceleration-time Graphs

Review: d-t and v-t Graphs

1. Look at the following position-time graph below and answer the questions. Assume positive means north and negative means south.



   a. When is the object moving north?

   b. When is the object moving south?

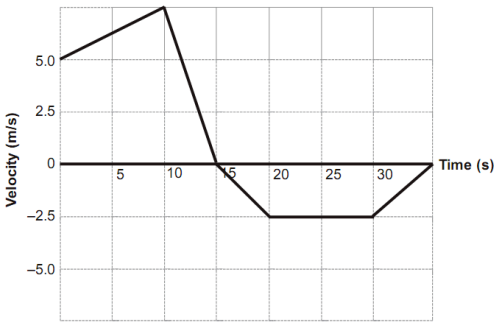
   c. What was the displacement over the 20s trip?

   d. What is the velocity at 4s?

   e. What is the average velocity over the 20s trip?

   f. What is the average speed over the 20s trip?

2. Use the following velocity-time graph to answer the questions below, assume positive is east and negative is west.



   a. When is the object moving west?

   b. When is the object slowing down?

   c. What was the acceleration at 5s?

   d. What is the displacement from 0 – 10s?

a-t Graphs

Grade 11 and 12 physics only deals with problems that have a uniform acceleration. This makes a-t graphs the least complicated. Acceleration-time graphs show how acceleration changes with respect to time.

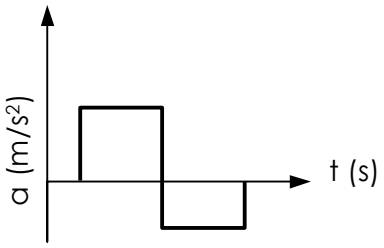
Uniform acceleration is shown on an a-t graph by a _____ line. We will deal with changes in acceleration, but they will happen instantly.

Calculating the Change in Velocity

The _____ under an a-t graph gives the change in velocity ($\Delta\vec{v}$) of an object. If the area is on the positive side of the graph, then the velocity changes in the positive direction, this could result in the object speeding up or slowing down, depending on what the initial velocity was.

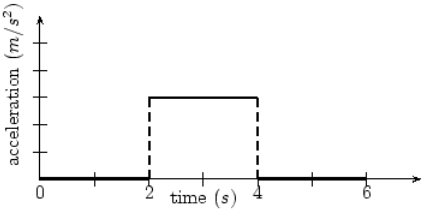
Once the change in velocity is known, the final velocity (after the acceleration) can be found by:

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



Example: At t = 0, a car is driving 10m/s [East]. The graph shows the acceleration after that time. East is positive and west is negative.

(a) What happens between 0 – 2s?



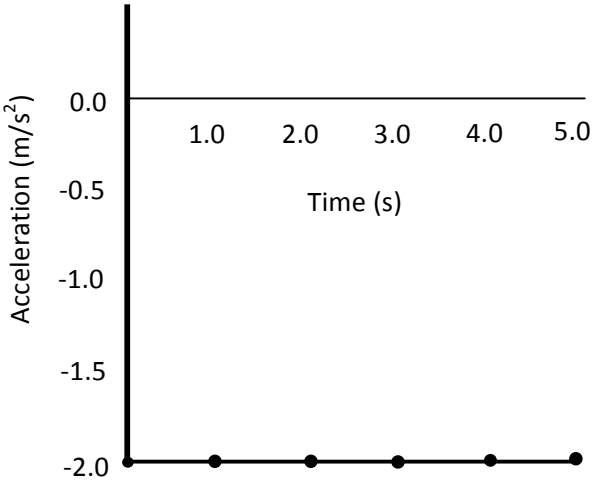
(b) What happens between 2 – 4s?

(c) What is the velocity after 4s?

(d) What happens between 4 – 6s?

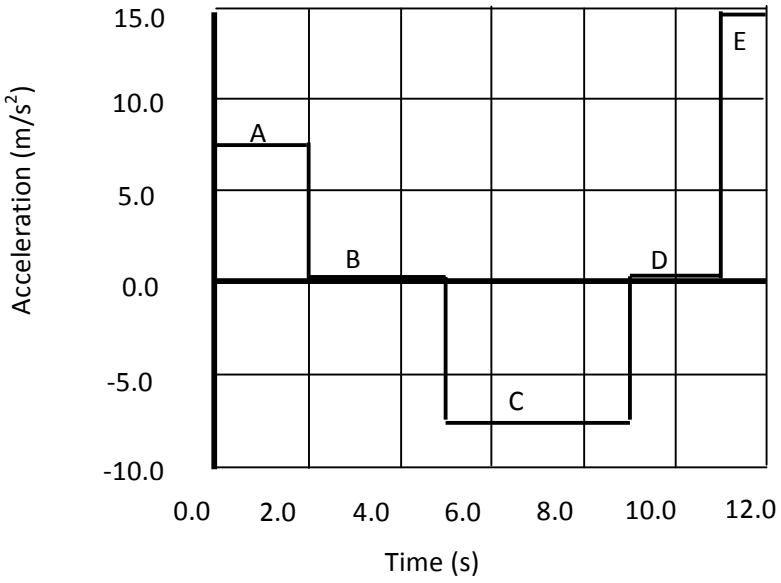
Grade 11 Physics – Acceleration-time Graphs

1. The following a-t graph is for a car travelling down the highway. Its initial velocity is 12m/s [South].



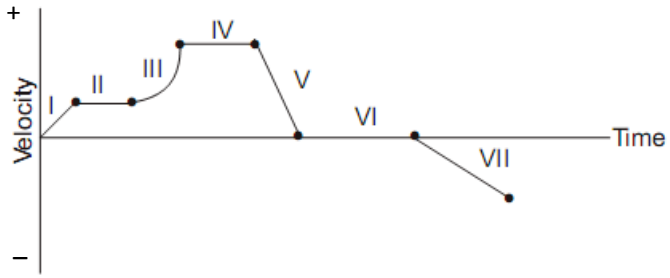
   a. If south is negative on the graph, is the car speeding up or slowing down? What is the velocity of the car after the 5.0s has passed?
   b. If north is negative on the graph, is the car speeding up or slowing down? What is the velocity of the car after the 5.0s has passed?

2. Use the following graph to answers the questions below. Assume that north is positive and south is negative.



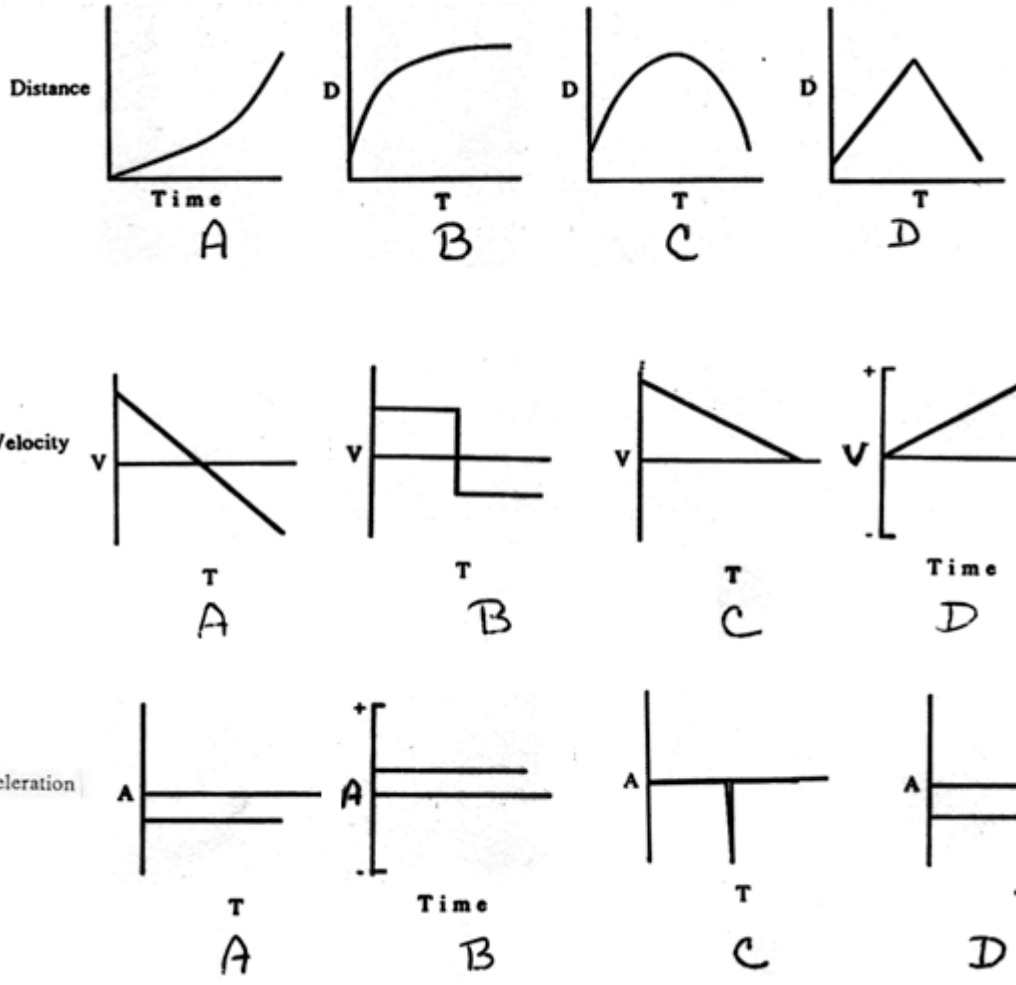
   a. What happens during section B?
   b. What happens during section C?
   c. What is the change in velocity during section A?
   d. If the object is initially travelling at 45m/s [South], what is the velocity after 9.0s?

3. Answer the questions about the following **v-t graph**.

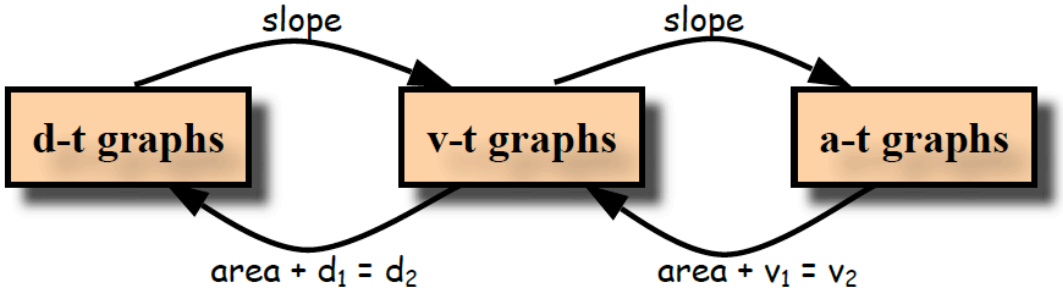


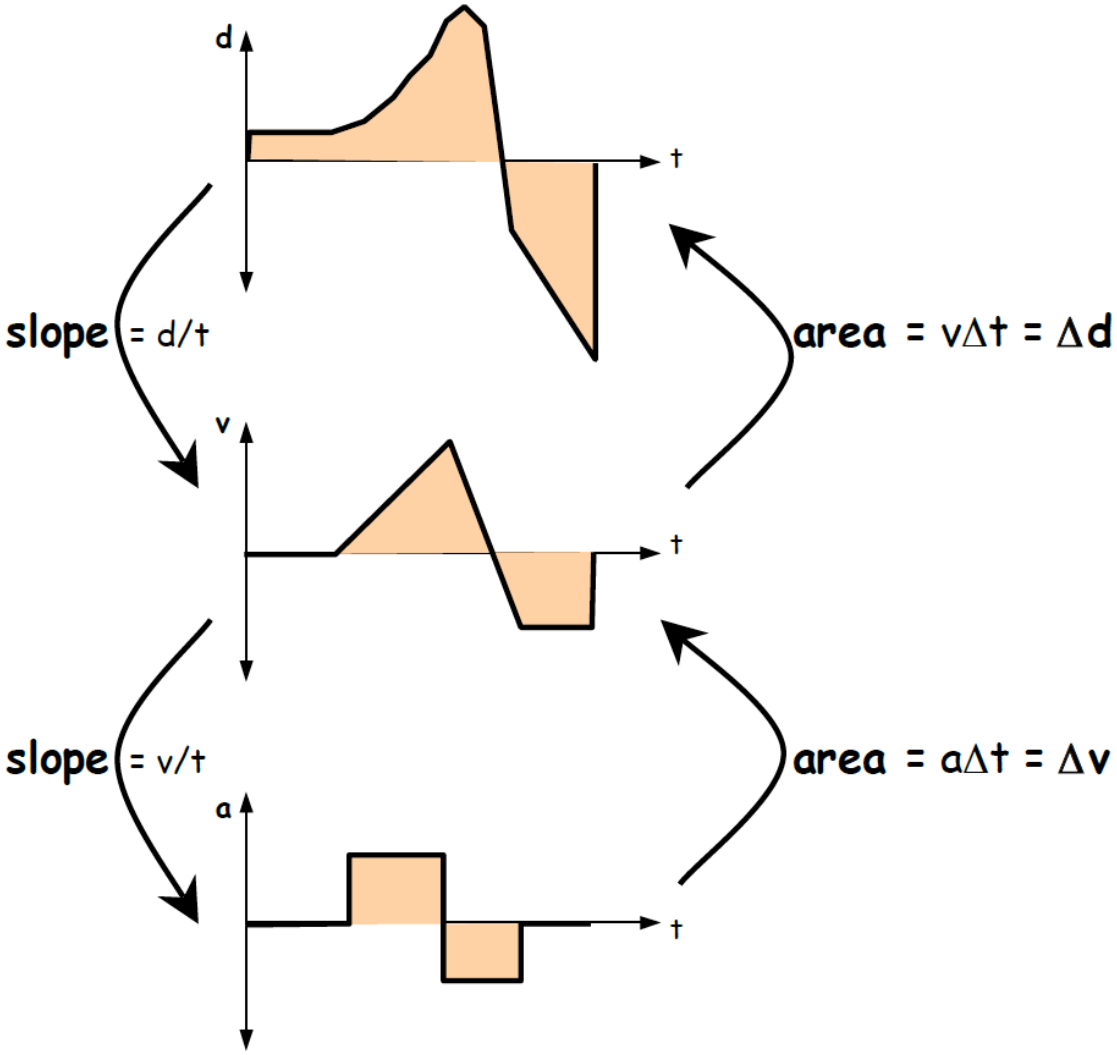
a. For which sections is the velocity positive?
b. For which sections is the velocity zero?
c. For which sections is the velocity negative?
d. When is the velocity decreasing?
e. When is the object stopped?
f. For section V, is the acceleration positive or negative?
g. For section VII, is the acceleration positive or negative?

4. Look at the following d-t, v-t and a-t graphs. Match each d-t graph to the proper v-t and a-t graph.



Summary - Motion Graphs

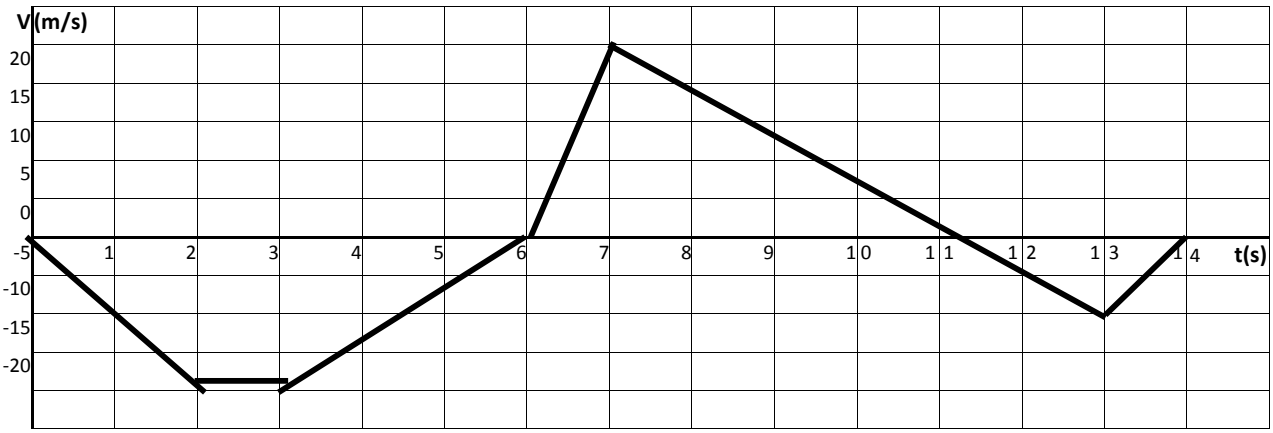




Converting Graphs

Example: From this v-t graph draw the d-t and a-t graphs. Assume the initial position to be d = 5.0 m

d
(m)

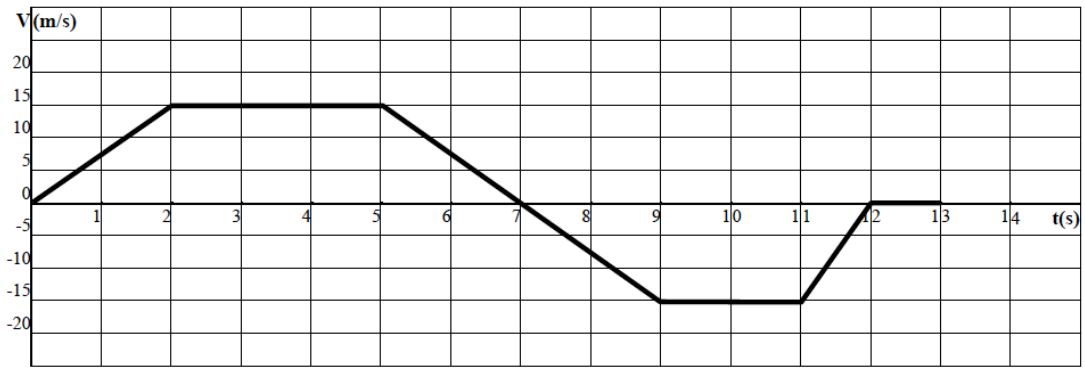


a
(m/s^2)

Grade 11 Physics – Converting Graphs

1) From this v-t graph draw the d-t and a-t graphs. Assume the initial position to be d = 0.0 m

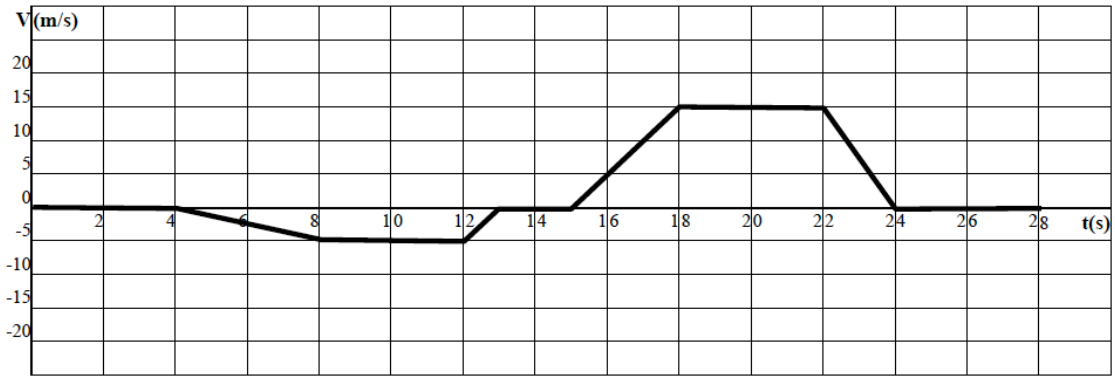
d
(m)



a
(m/s^2)

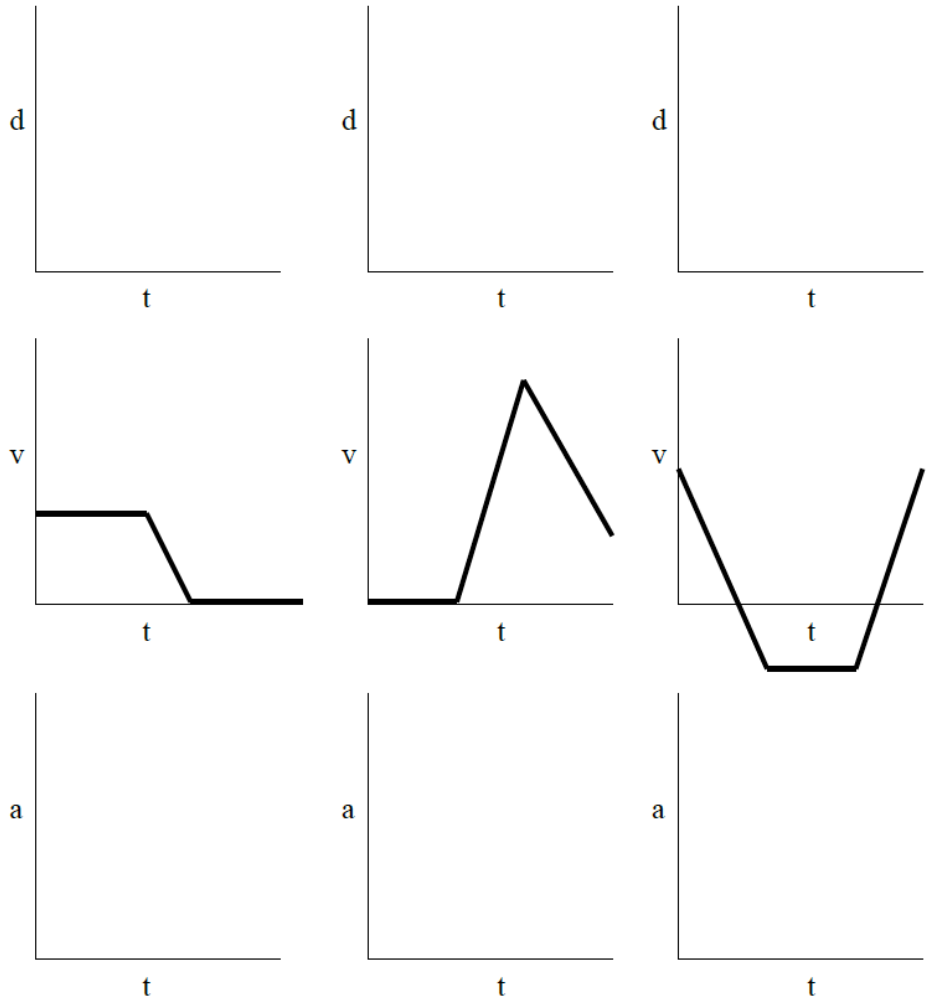
2) From this v-t graph draw the d-t and a-t graphs. Assume the *initial position* to be d =10.0 m

d
(m)



a
(m/s^2)

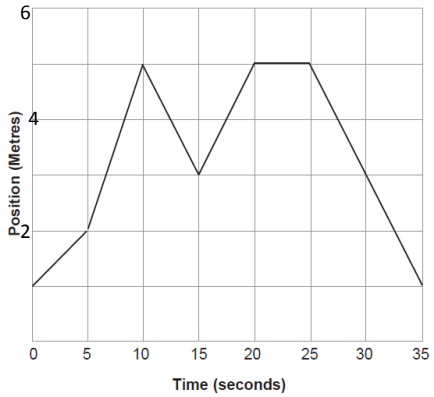
3) Sketch the following graphs from the v-t graphs given. You may assume the object creating the graph begins at d = 0m.



Grade 11 Physics – Motion Graphs Test Review

d-t Graphs

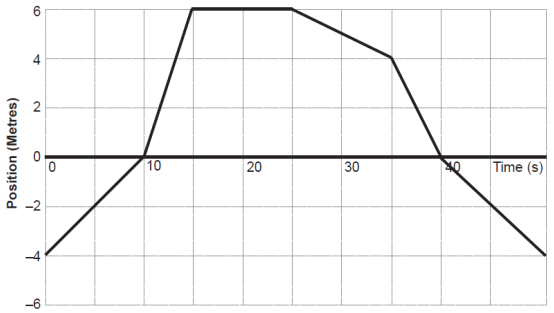
1. The graph to the right shows the position of a soccer linesman running along the sideline of a soccer field during a soccer game. The 0m mark is located at the goal line at the south end of the field. All the positions are marked North of that starting point.



   a. Where does the linesman start his journey?
   b. During which time intervals is the linesman moving:
      i. North
      ii. South
      iii. Not moving
   c. Complete the table below:

Time	Distance	Displacement	Average Speed	Average Velocity
0 – 5s				
0 – 15s				
10 – 35s				
0 – 35s				

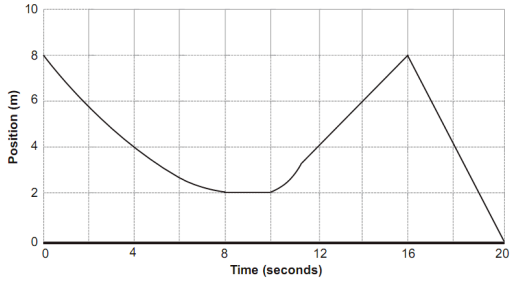
2. The graph to the right represents the motion of a remote controlled truck as it moves. The child controlling the toy is standing at the origin. Assume positive means East.



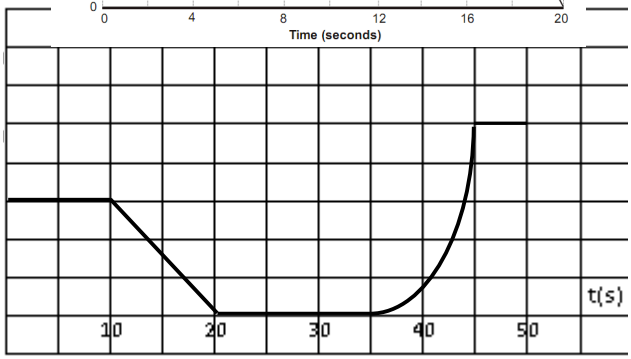
   a. What time is the truck:
      i. moving East
      ii. moving West
      iii. East of the child
      iv. West of the child
      v. Not moving
   b. What is the position of the truck at 20 seconds?
   c. Complete the table below:

Time	Distance	Displacement	Average Speed	Average Velocity
0 – 15s				
0 – 35s				
10 – 35s				
0 – 50s				

3. Use the graph to answer the following questions, assume positive is North.
    a. When is the object moving South?
    b. What is the displacement between 0 – 20s?
    c. What is the velocity at 4s?
    d. What is happening between 0 – 8s?
    e. What is happening at 8.5s?

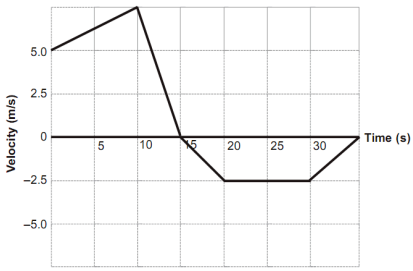


4. Use the position time graph to answer the following questions. East is positive.
    a. When was the object:
        i. stopped
        ii. going fastest
        iii. going West
    b. What was the velocity at:
        i. t = 15s?
        ii. t = 40s?
    c. What was the average velocity for:
        i. the first 25s?
        ii. the entire 50s trip?
        iii. What was the average speed from 0 – 50s?

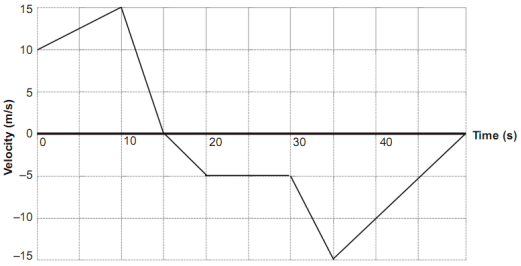


v-t Graphs

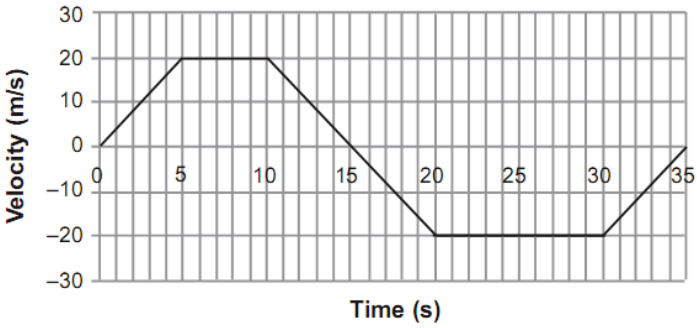
5. For the graph to the right, determine the following. East is positive.
    a. The acceleration at 5s.
    b. The acceleration at 12s
    c. The time the speed is the largest.
    d. The time interval(s) during which the object is moving West.



6. For the graph at the right, answer the following questions, assume positive is North.
    a. What was the velocity at 5s?
    b. During what time interval(s) is there a uniform velocity?
    c. At what time(s) does the object change directions?
    d. During what time interval(s) is the object slowing down?
    e. During what time interval(s) is the object speeding up?
    f. What is the displacement between 0 – 15s?



7. The graph to the right shows the motion of a car driving along a road. Answer the following questions, assume North is positive.



   a. At what time does the car first reach its maximum velocity in the Northern direction?

   b. At what time does the car first begin to slow down?

   c. At what time does the car reach its maximum distance North of its starting point?

   d. At what time does the car first start heading back South?

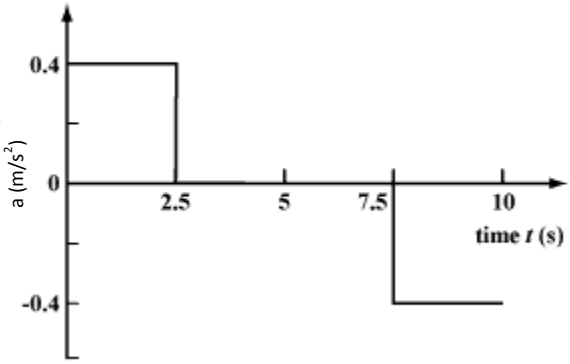
   e. Des the car ever come to rest after it has begun to head South? If so, at what time?

   f. At the 35s mark, is the car at it starting point, North if its starting point, or South of its starting point?

   g. What is the car's displacement in the Northern direction?

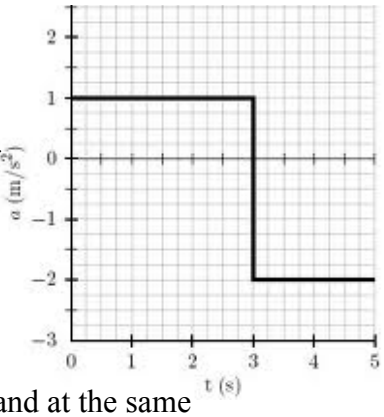
a-t Graphs

8. Use the graph to the right to answer the following questions, East is positive.
   At t = 0, the object was moving 10m/s [West].



   a. Is the object speeding up or slowing down between 0 – 2.5s?
   b. What is happening between 2.5 – 7.5s?
   c. What is the velocity after 2.5s?
   d. What is the velocity after 10s?

9. The graph to the right shows an acceleration, where North is positive.
   At t = 0, the object is moving 5m/s [North].



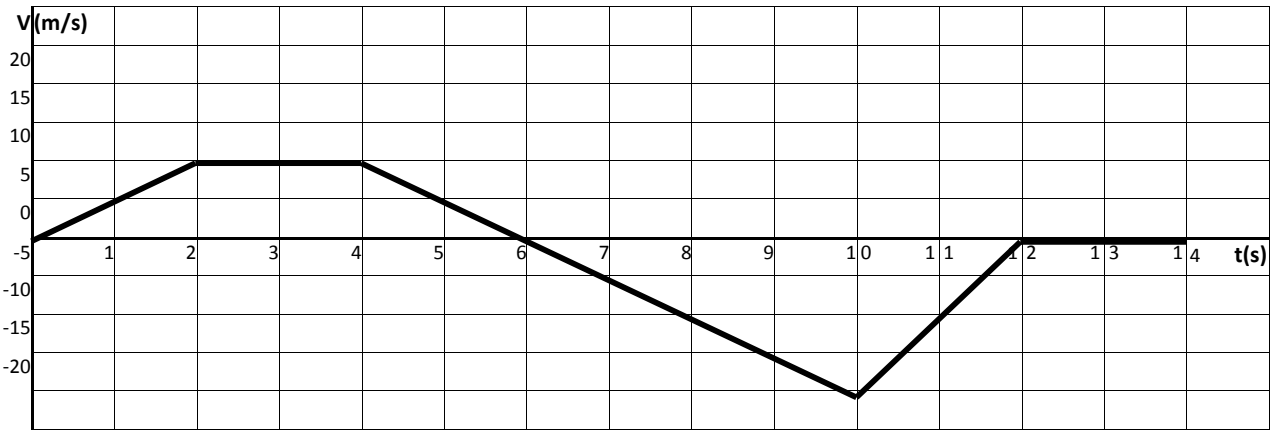
   a. Is the car speeding up or slowing down between 0 – 3s?
   b. What is the velocity of the car after 3s?

Converting Graphs

10. A basketball is thrown straight upwards and returns to the person's hand at the same speed and height it was thrown. Draw a position-time, velocity-time and acceleration-time graph of this motion.

11. From this v-t graph draw the d-t and a-t graphs. Assume the initial position is d = 5.0 m.

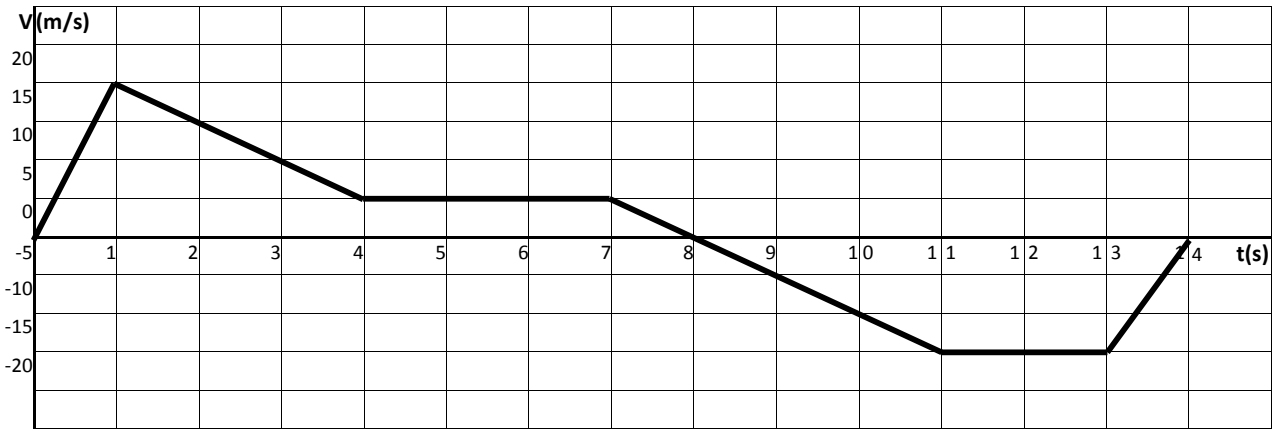
d
(m)



a
(m/s^2)

12. From this v-t graph draw the d-t and a-t graphs. Assume the initial position is d = -15 m.

d
(m)



a
(m/s^2)

Grade 11 Physics – Motion Graphs Test Review Answers

1. a. 1m North of the goal line
   b. i. 0 – 10s, 15 – 20s ii. 10 – 15s, 25 – 35s iii. 20 – 25s
   c.

Time	Distance	Displacement	Average Speed	Average Velocity
0 – 5s	1m	1m [North]	0.2m/s	0.2m/s [North]
0 – 15s	6m	2m [North]	0.4m/s	0.13m/s [North]
10 – 35s	8m	4m [South]	0.32m/s	0.16m/s[South]
0 – 35s	12m	0m	0.34m/s	0m/s

2. a. i. 0 – 15s ii. 25 – 50s iii. 10 – 40s
   iv. 0 – 10s, 40 – 50s v. 15 – 25s
   b. 6m East of the child
   c.

Time	Distance	Displacement	Average Speed	Average Velocity
0 – 15s	10m	10m [East]	0.67m/s	0.67m/s [East]
0 – 35s	12m	8m [East]	0.34m/s	0.23m/s [East]
10 – 35s	8m	4m [East]	0.32m/s	0.16m/s [East]
0 – 40s	20m	0m	0.4m/s	0m/s

3. a. 0 – 8s, 16 – 20s
   b. 8m [South]
   c. approximately 0.75m/s [South] – depending on how you draw your tangent line
   d. slowing down while moving South
   e. not moving
4. a. i. 0 – 10s, 20 – 35s, 45 – 50s ii. around 44s iii. 10 – 20s
   b. i. 7.5m/s [West] ii. around 10m/s [East]
   c. i. 3m/s [West] ii. 1m/s [East] iii. 4m/s
5. a. 0.25m/s^2 [East]
   b. 1.5m/s^2 [West]
   c. 10s
   d. 15 – 35s
6. a. 12.5m/s [North]
   b. 20 – 30s
   c. 15s
   d. 10 – 15s, 35 – 50s
   e. 0 – 102, 15 – 20s, 30 – 35s
   f. 162.5m [North]
7. a. 5s
   b. 10s
   c. 15s
   d. 15s
   e. 35s

f. South
g. 200m [North]

8. a. slowing down
   b. moving at a constant velocity
   c. 9m/s [West]
   d. 10m/s [West]
9. a. speeding up
   b. 8m/s [North]
10. if up is positive: