Lesson 9: d-t & v-t Graphs

Graphing the motion of objects gives us a way to interpret the motion that would otherwise be difficult.

- Graphs will also allow you to show a large amount of information in a compact way.

Essentially you need to be able to sketch and interpret two main kinds of graphs in kinematics:

1. Displacement – Time Graphs
   - Sometimes called d-t graphs, or position – time graphs.
2. Velocity – Time Graphs
   - Sometimes called v-t graphs.

Displacement - Time (d-t) Graphs

This type of graph is based on the most basic things we need to know about the motion of an object (position and time).

- Typically you will be given a table of values that show the displacement of the object over a particular period of time.
- If the graph shows complex motion (such as Illustration 1 below), you do not just draw a single best fit line. Instead, you need to look at each section of motion and determine what kind of line best fits the data.
  - Don't worry too much about sketching these complex situations... it is much more likely that you will draw an object moving in one way only.
- For the example graph shown below, imagine that you are running in a marathon, and we have decided to graph your movement.

![Displacement vs Time Graph](image)

*Illustration 1: d-t graph of a person running a marathon.*
Now let's look at a description of the person's movement in each of the major sections.

**Zero to 90s**

Look at how you are running in those first 90 seconds.
- Every 30 seconds you have moved about another 150m away from the starting point... you must be moving at a constant positive velocity!
- A constant positive velocity is shown on a d-t graph as a straight line that slopes upwards. It is a linear relationship.
  - In fact, if you found the slope of the line in this section, it will be the velocity that you were running at.

\[
slope = \frac{\text{rise}}{\text{run}} = \frac{d}{t} = v
\]

**90s to 150s**

Yikes! You ran too fast at the start and now you’re out of breath!
- During this time period, your position on the graph has stayed the same...450m.
- This just means that you are standing in the same spot, exactly 450m away from where you started.
- A flat horizontal line means you are stopped.

**150s to 240s**

You must have started running forward again, since a positively sloped line means a positive velocity.
- Notice that this section of line is a little steeper than the first section. You are now running about 200m every 30s.
- A steeper line (which has a bigger slope) means that you are moving at a faster constant velocity.

**240s to 300s**

In this section the line slopes down, which means it has a negative slope.
- Since slope is equal to velocity, this must mean that you are running backwards.
- A negative slope means a constant negative velocity.
  - You must have forgotten to pass a check point, so you ran back to it.

**300s to 360s**

Again, we have a horizontal line. You must be stopped.

**360s to 510s**

You know that you have only one chance to still win the race... run as fast as you can!
- During this time period, the line curves upwards.
- The line becomes steeper and steeper as it continues. This means that the slope of the line is getting bigger and bigger.
Since slope is related to velocity, your velocity must be increasing. You are accelerating!

A curved line on a d-t graph means acceleration.

Here’s how you can remember if it was positive or negative acceleration on a d-t graph.

- If you see any part of the happy clown's face on a graph, it is positive acceleration.
- If you see any part of the sad clown's face, it is negative acceleration.

**Velocity-Time (v-t) Graphs**

You need to remember that the rules you learned above for d-t graphs do not apply to v-t graphs.

- A common mistake by Physics 20 students is when they assume that all types of graphs work the exact same way.
- The graphs can be related to each other, but that doesn’t mean you look at them the same way.
- The following v-t graph is based on the same data as we used for the d-t graph, but we will need to look at what’s different.
Zero to 90s

Remember that in the first 90 seconds you were running at a positive constant velocity.

- On this graph we see a horizontal line that reads “5 m/s” for those same first 90 seconds.
- On a v-t graph a flat line means constant velocity.

90s to 150s

This is the section of time when you stopped because you were out of breath.

- Notice that "stopped" is shown by a horizontal line at exactly 0 m/s.
- It's a flat line which means constant velocity. It just so happens that your constant velocity is 0 m/s.

150 to 240 seconds

You are running forward again.

- To show a faster velocity than earlier, we have a flat line that is higher than the previous one.

240 to 300 seconds

This is when you are running back to the check point.

- You are running at -3.3 m/s.
A negative velocity is shown as a negative slope.

**300 to 360 seconds**

Again, we have a horizontal line at zero. You must be stopped.

**360 to 510 seconds**

This is the section in which we already figured out you must be accelerating; you run faster and faster.

On a \( d\)-\( t \) graph the line curves upwards, but not on a \( v\)-\( t \) graph.

- On a \( v\)-\( t \) graph the line is straight and has a positive slope.
- A straight sloped line on a \( v\)-\( t \) graph means acceleration.
- The slope of the line is equal to the acceleration; a **positive slope is a positive acceleration**, and a **negative slope is a negative acceleration**.

\[
slope = \frac{\text{rise}}{\text{run}} = \frac{\Delta v}{t} = a
\]

There is one other trick you need to know about \( v\)-\( t \) graphs.

- If you multiply velocity by time, what do you get? According to our formula...

\[
v = \frac{d}{t} \text{ manipulated to } d = v\ t
\]

..displacement!

- So, if I have a \( v\)-\( t \) graph and I calculate the area under the line (which means I’m calculating velocity multiplied by time), I will know the object's displacement.

**Homework**

p.15 #1
p.20 #3, 6, 10
p.27 # 1, 2
p.45 #11, 16, 17