Summary 2: Motion Graphs

1. Variations of the position (x) as function of time (t) or x-t graph

The x-t graph represents the variations of the abscissa as function of time.

Example 1: A particle moves on the x-axis according to the following table.

t (s)	0	1	2	3	4	5
x (m)	0	5	10	15	20	25

Table 1. Variation of x as function of t for a moving particle

The graph of x-t graph is shown in the following figure.

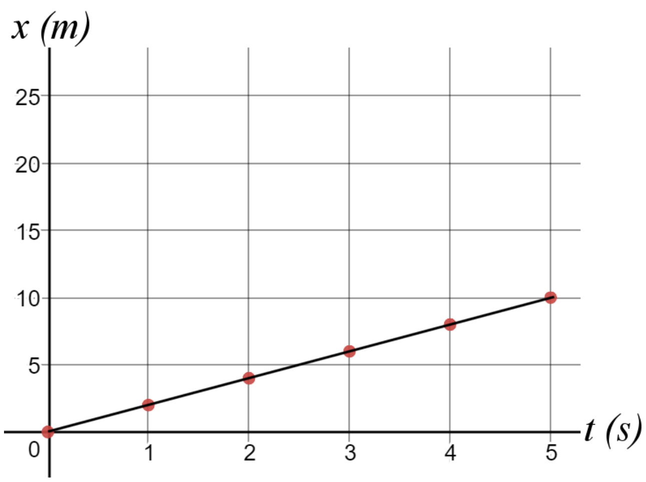

Figure 1. x-t graph drawn for Table 1

1.1. The slope of x-t graph

The slope of an x-t graph is given by

$$slope = \frac{\Delta x}{\Delta t} = \frac{x_2 - x_1}{t_2 - t_1} \tag{1}$$

The slope of x-t graph represents the velocity.

If the x-t graph is a straight line, then the slope is constant and so the velocity is constant.

Example 2: The velocity in example 1 is constant and is equal to the slope

$$v = slope = \frac{\Delta x}{\Delta t} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{20 - 5}{4 - 1} = \frac{15}{3} = 5m/s$$

Example 3: The following x-t graph has a higher slope and hence higher constant velocity than that in example 2.

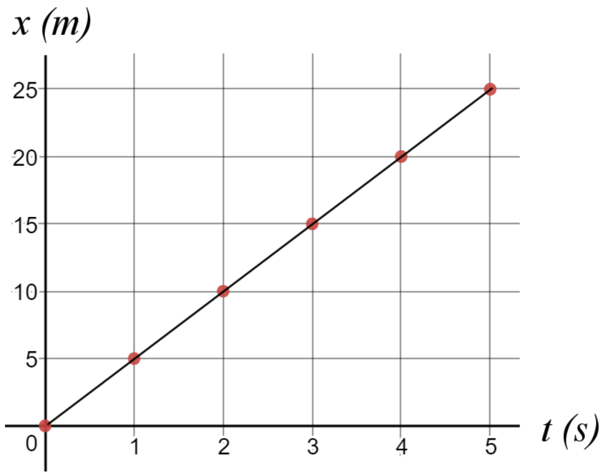

Figure 2. x-t graph of a moving particle of example 3

Example 4: The position of a particle on the x-axis is filled in the following table. Notice that the position does not vary with time so the particle is at rest.

t (s)	0	1	2	3	4	5
x (m)	5	5	5	5	5	5

Table 2. Variation of x as function of time

The corresponding x-t graph is drawn in the following figure

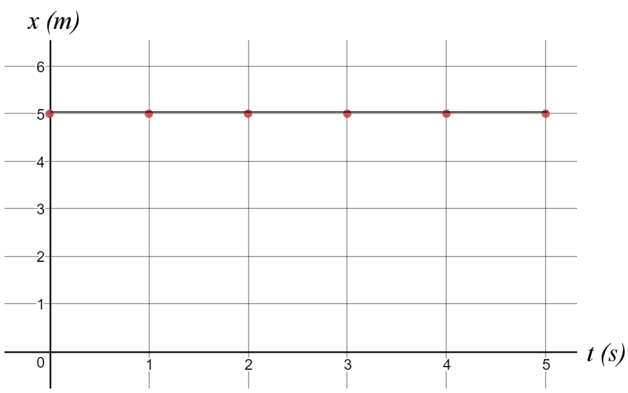

Figure 3. x-t graph of an object at rest

Example 5: The slope of following x-t graph is increasing and hence the speed is increasing so the object is accelerating.

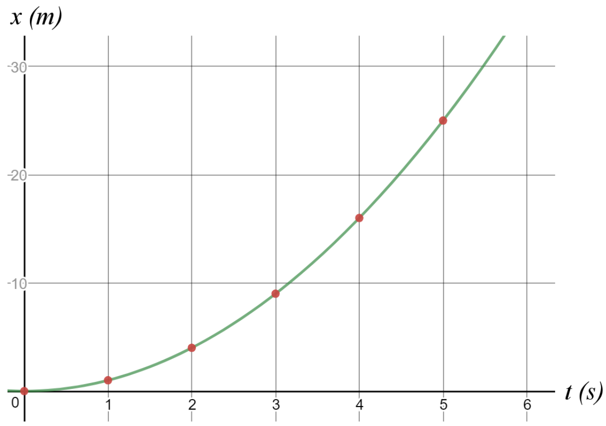

Figure 4. x-t graph of an accelerating object

2. Variations of the velocity (v) as function of time (t) or v-t graph

The v-t graph represents the variations of the velocity as function of time.

Example 6: The following table represents the variations of v as function of t of a moving object on the x-axis:

t (s)	0	1	2	3	4	5
v (m/s)	0	2	4	6	8	10

Table 3. Variations of v as function of t

The above table is plotted in the following v-t graph

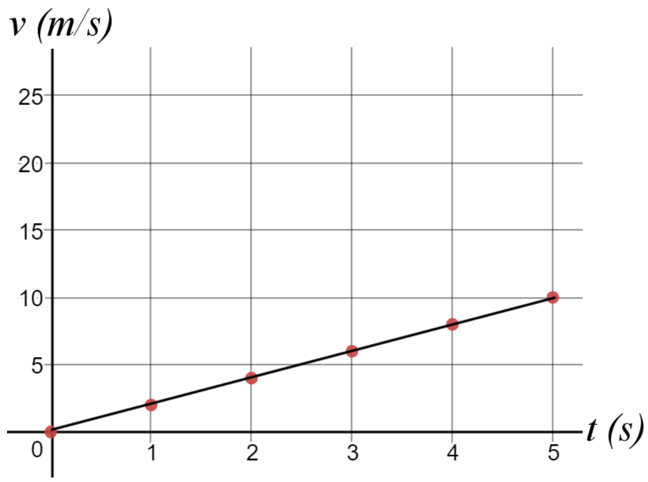

Figure 5. v-t graph of an accelerating object

2.1. The slope of v-t graph

The slope of an x-t graph is given by

$$slope = \frac{\Delta v}{\Delta t} = \frac{v_2 - v_1}{t_2 - t_1} \quad (2)$$

The slope of a v-t graph represents the acceleration.

For example, the slope in example 6 is

$$a = slope = \frac{\Delta v}{\Delta t} = \frac{v_2 - v_1}{t_2 - t_1} = \frac{8-2}{4-1} = \frac{6}{3} = 2m/s^2$$

Example 7: The following v-t graph has a higher slope than that in example 6 and hence the acceleration is higher.

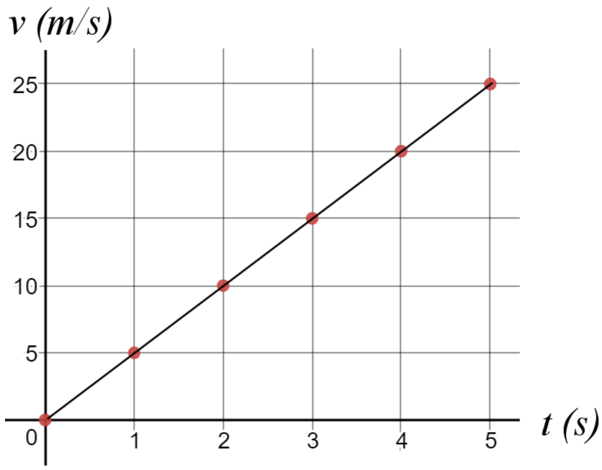

Figure 6. v-t graph of higher acceleration

2.2. Calculating the displacement from the v-t graph

In the v-t graph, the area under the line (between the line and the time axis) is numerically equal to displacement.

Note: in calculating the displacement, if the area is above the time axis, then it is considered positive. If the area is below the time axis, it is considered negative.

For example, the area under the line in graph in figure 6 from t=0s to t=5s is

$$A = \frac{base \times height}{2} = \frac{5 \times 25}{2} = 62.5$$

Then the displacement is $\Delta x = 62.5m$.

Example 8: Consider the following v-t graph.

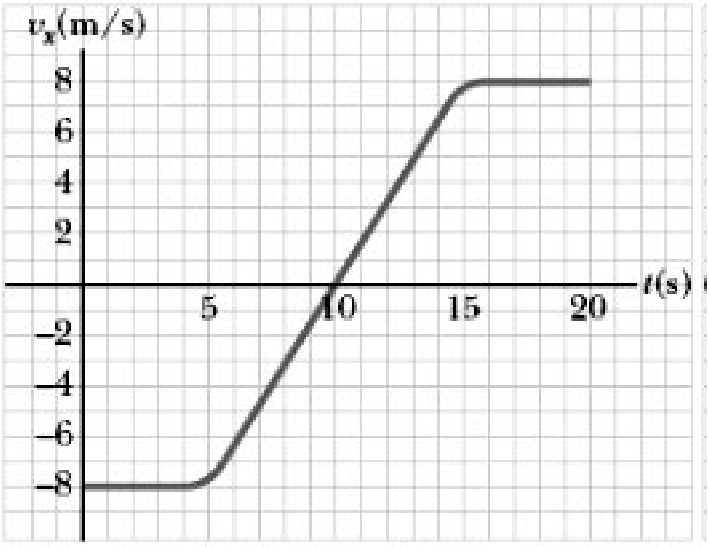

Figure 7. Example 8

The total area (taking into account the negative areas and positive areas) between the graph and the time axis from t=0s and t=20s is

$$A = 5 \times (-8) + \frac{5 \times (-8)}{2} + \frac{5 \times 8}{2} + 5 \times 8 = 0$$

So the total displacement between t=0s and t=20s is zero.

Farid Minawi's Physics Zone
www.physics-zone.com