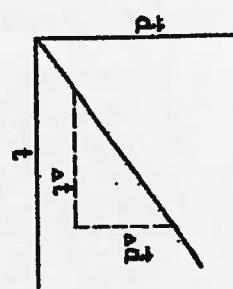


MOTION IN A STRAIGHT LINE

Displacement-time (\vec{d} - t) Graphs:

Displacement (\vec{d}) is the change in position of an object.
It is a vector quantity and has units in the form m [E], km [W], etc.

Slope of the Displacement-time Graph:



The slope of the line in a displacement-time graph represents velocity.

Velocity (\vec{v}) is the rate of change of displacement. It is a vector quantity with units in the form m/s (NW), km/h (SE), m/s (S 60° W), etc.

$$\vec{v} = \frac{\Delta \vec{d}}{\Delta t}$$

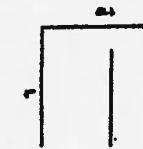
Simple \vec{d} - t Graphs:

Note: The slope of the line in a \vec{d} - t graph represents \vec{v} .

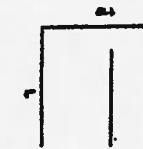


$d = \text{displacement}$

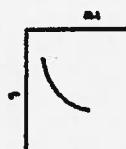
Slope is zero.
Velocity is zero.
Object is at rest.



Slope is constant.
Velocity is constant.



Slope is increasing.
Velocity is increasing.



Slope is decreasing.
Velocity is decreasing.

Note:
1. The unit of the slope of a line on the displacement-time graph is that of the velocity.

2. A straight displacement-time graph with a negative slope indicates that the velocity is in the opposite direction.

3. The slope of the position-time graph is the same as the slope of the displacement-time graph.
The position-time graph is just shifted up or down.



Example 2:

Displacement-time Graphs

22.0

18.0

14.0

10.0

6.0

2.0

-2.0

displacement (km [N])

-10

-20

-30

-40

-50

-60

-70

-80

-90

-100

-110

-120

-130

-140

-150

-160

-170

-180

-190

-200

-210

-220

-230

-240

-250

-260

-270

-280

-290

-300

-310

-320

-330

-340

-350

-360

-370

-380

-390

-400

-410

-420

-430

-440

-450

-460

-470

-480

-490

-500

-510

-520

-530

-540

-550

-560

-570

-580

-590

-600

-610

-620

-630

-640

-650

-660

-670

-680

-690

-700

-710

-720

-730

-740

-750

-760

-770

-780

-790

-800

-810

-820

-830

-840

-850

-860

-880

-900

-920

-940

-960

-980

-1000

-1020

-1040

-1060

-1080

-1100

-1120

-1140

-1160

-1180

-1200

-1220

-1240

-1260

-1280

-1300

-1320

-1340

-1360

-1380

-1400

-1420

-1440

-1460

-1480

-1500

-1520

-1540

-1560

-1580

-1600

-1620

-1640

-1660

-1680

-1700

-1720

-1740

-1760

-1780

-1800

-1820

-1840

-1860

-1880

-1900

-1920

-1940

-1960

-1980

-2000

-2020

-2040

-2060

-2080

-2100

-2120

-2140

-2160

-2180

-2200

-2220

-2240

-2260

-2280

-2300

-2320

-2340

-2360

-2380

-2400

-2420

-2440

-2460

-2480

-2500

-2520

-2540

-2560

-2580

-2600

-2620

-2640

-2660

-2680

-2700

-2720

-2740

-2760

-2780

-2800

-2820

-2840

-2860

-2880

-2900

-2920

-2940

-2960

-2980

-3000

-3020

-3040

-3060

-3080

-3100

-3120

-3140

-3160

-3180

-3200

-3220

-3240

-3260

-3280

-3300

-3320

-3340

-3360

-3380

-3400

-3420

-3440

-3460

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-3900

-3920

-3940

-3960

-3980

-4000

-4020

-4040

-4060

-4080

-4100

-4120

-4140

-4160

-4180

-4200

-4220

-4240

-4260

-4280

-4300

-4320

-4340

-4360

-4380

-4400

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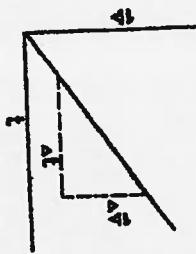
-4980

Velocity-time (\vec{v} - t) Graphs:

Velocity (\vec{v}) is the rate of change of displacement.

It is a vector quantity and has units in the form m/s [NE], km/h [ISCPW], etc.

Slope of the Velocity-time Graph:



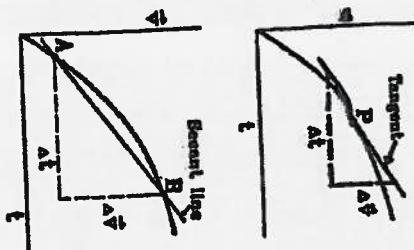
The slope of the line in a velocity-time graph represents acceleration.

$$\text{Acceleration is the rate of change of velocity. It is a vector quantity with units in the form } m/s^2 \text{ [SW].}$$

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

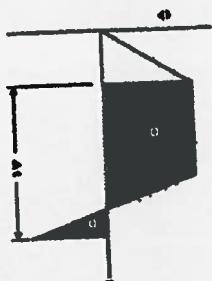
Instantaneous Acceleration:

Any instantaneous acceleration is still given at point P by determining the slope of the tangent drawn at point P.



Average Acceleration:

The average acceleration during the segment AB is found by calculating the slope of the secant line through AB.



- Note:
1. The units of the slope of a line on the velocity-time graph is that of acceleration.

The absolute sum of the areas under the velocity-time graph represents the displacement, (Δd) .

Areas above the time axis are positive.
Areas below the time axis are negative.

For any given time interval (Δt) , the average velocity can be determined by using the formula

$$\bar{v}_a = \frac{\Delta d}{\Delta t}$$

Note: The slope of the line in a \vec{v} - t graph represents 2.

Slope is zero.

Acceleration is zero.

Velocity is constant.

Slope is constant and positive.

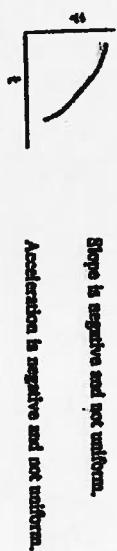
Acceleration is constant and positive.

Slope is constant and negative.

Acceleration is constant and negative.

Slope is negative and not uniform.

Acceleration is negative and not uniform.



Relationships between \overline{v} -t, \overline{d} -t, and \overline{a} -t Graphs

Observation 1-t graph from \overline{d} -t graph

The slope of the \overline{d} -t graph at various times gives the velocities at those instants. Plotting these values versus time yields the \overline{v} -t graph.

Observation 1-t graph from \overline{v} -t graph

The acceleration at any instant is found by calculating the slope of the \overline{v} -t graph. Plotting the values of these slopes versus time yields the \overline{a} -t graph.

Observation \overline{d} -t graph from \overline{v} -t graph (initial position is zero)

The total displacement at any time is equal to the algebraic sum of the areas under the \overline{v} -t graph. Areas above the time axis are positive and areas below the time axis are negative. Plotting the sum of these areas versus time yields the \overline{d} -t graph.

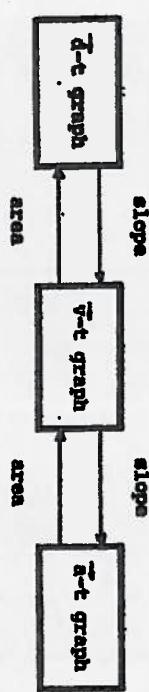
Note: If the initial position is not zero, then the area under the graph represents the change in displacement.

Observation \overline{d} -t graph from \overline{v} -t graph (initial velocity is zero)

The velocity at any instant is found by calculating the algebraic sum of the areas under the $\overline{1}$ -t graph. Areas above the time axis are positive and areas below the time axis are negative. Plotting the sum of these areas versus time yields the \overline{v} -t graph.

Note: If the initial velocity is not zero, then the area under the graph represents the change in velocity.

These transitions may be summarized as follows:



Example

For the velocity-time graph shown on the right, draw the corresponding displacement-time and acceleration-time graphs.

Find the average velocity for the 25 seconds time interval.

Solution

Calculation of areas for \overline{d} -t graph

$$\overline{d}_{1-4} = -\frac{1}{2}(40. \text{ m/s [E]} \times 4.0 \text{ s}) = 80. \text{ m [E]}$$

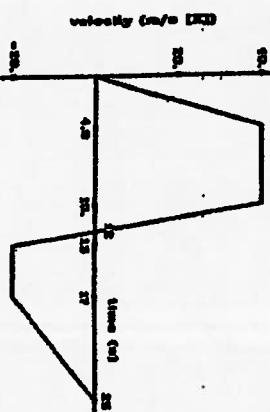
$$\overline{d}_{4-12} = 80. \text{ m [E]} + \frac{1}{2}(40. \text{ m/s [E]} \times 6.0 \text{ s}) = 320 \text{ m [E]}$$

$$\overline{d}_{12-18} = 320 \text{ m [E]} + \frac{1}{2}(40. \text{ m/s [E]} \times 2.0 \text{ s}) = 360 \text{ m [E]}$$

$$\overline{d}_{18-25} = 360 \text{ m [E]} - \frac{1}{2}(20. \text{ m/s [E]} \times 1.0 \text{ s}) = 350 \text{ m [E]}$$

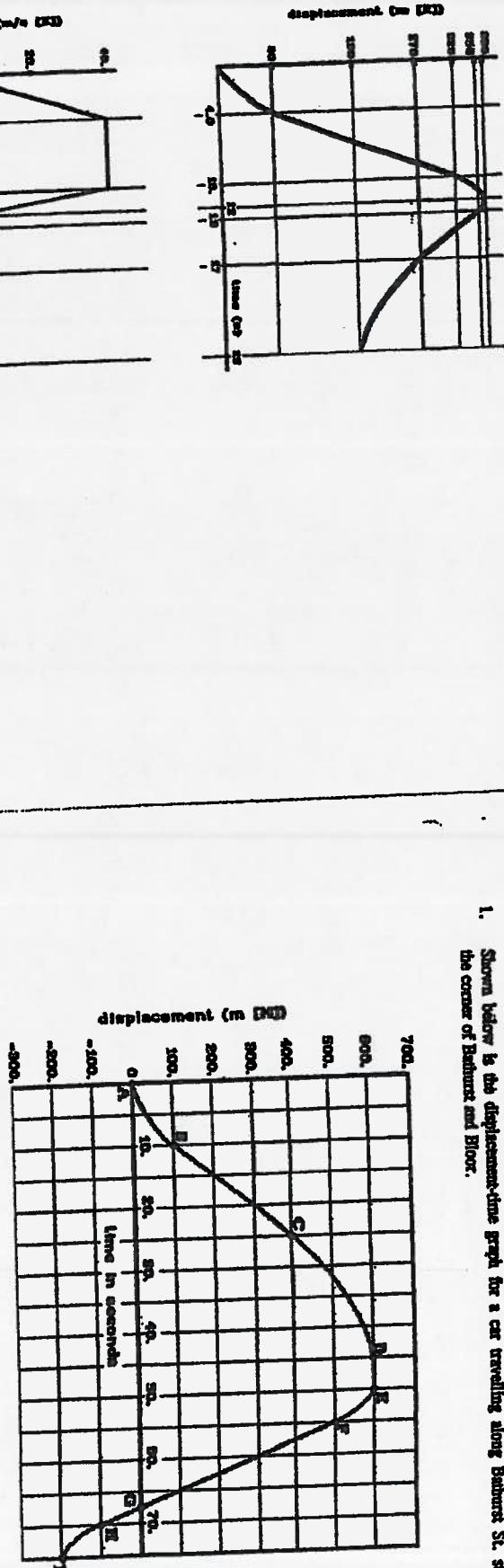
$$\overline{d}_{25-} = 350 \text{ m [E]} - (20. \text{ m/s [E]} \times 4.0 \text{ s}) = 270 \text{ m [E]}$$

$$\overline{d}_{-25} = 270 \text{ m [E]} - \frac{1}{2}(20. \text{ m/s [E]} \times 8.0 \text{ s}) = 190 \text{ m [E]}$$



PROBLEMS ON DISPLACEMENT-TIME GRAPHS

1. Shown below is the displacement-time graph for a car travelling along Bathurst St. starting from the corner of Bathurst and Bloor.



- What was the final displacement of the car?
- During which segment(s) was the car stopped?
- When it stopped, what was its displacement from the corner of Bloor and Bathurst?
- What direction was the car travelling during the segment EG?
- What direction was the car travelling during the segment GH?
- What was the velocity of the car during the segment CF?
- What was the average velocity of the car during the segment CE?
- What was the instantaneous velocity at 35 s?
- What was the velocity of the car during the segment FJ?
- During which segment(s) was the car travelling south with increasing velocity?
- During which segment(s) was the car travelling south with decreasing velocity?
- During which segment(s) was the car travelling north with decreasing velocity?
- During which segment(s) was the car travelling south with decreasing velocity?
- What was the car's acceleration during the segment BC?

(Answers on Page 31)

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