Gwinnett School of Math, Science, and Technology

AP Physics: Mechanics/Electricity & Magnetism Notes

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2023-2024

Infinite Possibilities

Gwinnett School of Mathematics, Science, and Technology

Table of Contents

1 Kinematics

1.1 Variables

Position

- Typically given by the variable x

Time

- Typically given by the variables t

Displacement

- Defined as the change in position ($X_f - X_i$)
- Given by the variable Δx

Distance

- You have to take the magnitude of vectors for every time you change position
- $S = |x_2 - x_1| + |x_1 - x_0| + ...$

Average Velocity

- Defined as the change in displacement over time
- $\frac{\Delta x}{\Delta t} = V_{\text{avg}} = \bar{V}$

Velocity

- Defined as the change in displacement as time approaches 0
- $\lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt} = V$

Average Acceleration

- Defined as the change in velocity over time
- $\frac{\Delta V}{\Delta t} = A_{\text{avg}} = \bar{A}$

Acceleration

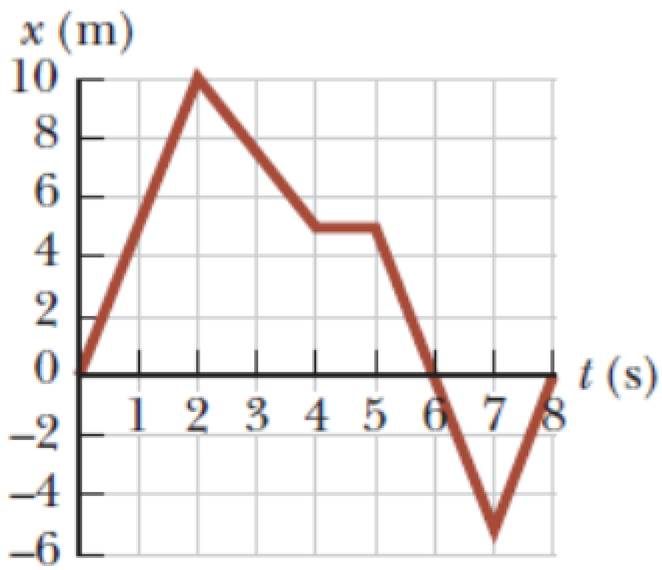
- Defined as the change in velocity as time approaches 0
- $a = \lim_{\Delta t \to 0} \frac{\Delta V}{\Delta t} = \frac{dV}{dt} = \frac{d^2 x}{dt^2}$

Speed - Speed $= \frac{S}{t}$ - Alternatively, when referring to vectors: Speed $= ||\vec{V}||$

1.2 Kinematics: Velocity and Position Definitions (08/03 Homework)

1.2.1 Problem 1

The position versus time for a certain particle moving along the x axis is shown in the figure below. Find the average velocity in the following time intervals.



(a) 0 to 2s

- $\frac{10-0}{2-0} = \frac{10}{2} = 5.000$ m/s

(b) 0 to 4s

- $\frac{5-0}{4-0} = \frac{5}{4} = 1.250$ m/s

(c) 2 to 6s

- $\frac{0-10}{6-2} = \frac{-10}{4} = -2.500$ m/s

(d) 1 to 7s

- $\frac{-5-5}{7-1} = \frac{-10}{6} = -1.667$ m/s

(e) 0 to 7s

- $\frac{-5-0}{7-0} = \frac{-5}{7} = -0.714$ s

1.2.2 Problem 2

A person walks first at a constant speed of 4.80 m/s along a straight line from point $\textcircled{A}$ to point $\textcircled{B}$ and then back along the line from $\textcircled{B}$ to $\textcircled{A}$ at a constant speed of 2.90 m/s.

(a) What is her average speed over the entire trip?

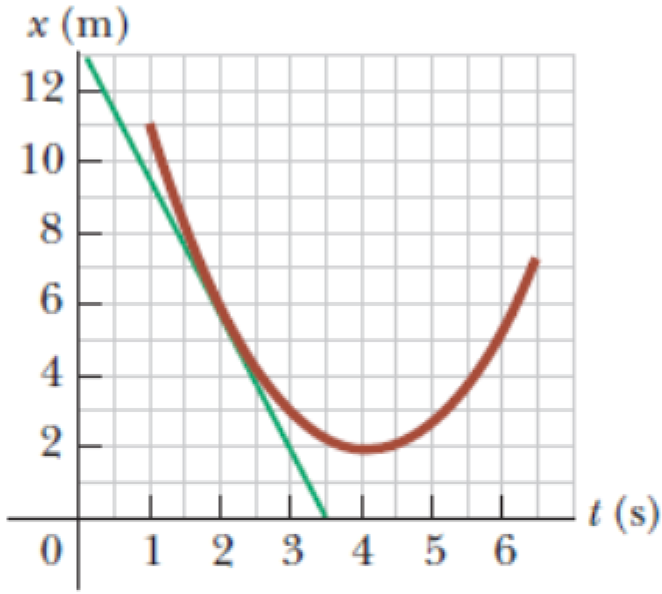
$$\begin{aligned}
\text{Average speed} &= \frac{d_{AB} + d_{BA}}{t_{AB} + t_{BA}} \\
d &= d_{AB} = d_{BA} \\
t_{AB} &= \frac{d}{V_{AB}} \\
tBA &= \frac{d}{V_{BA}} \\
\therefore \text{Average speed} &= \frac{d + d}{\frac{d}{V_{AB}} + \frac{d}{V_{BA}}} \\
&= \frac{2d(V_{AB})(V_{BA})}{2d} \\
&= \frac{2(V_{AB})(V_{BA})}{V_{AB} + V_{BA}} \\
&= 2\left[\frac{(4.80)(2.90)}{4.80 + 2.90}\right] \\
&= 3.615
\end{aligned}$$

(b) What is her average velocity over the entire trip?

- Since her displacement is 0, her average velocity is also 0.

1.2.3 Problem 3

A position-time graph for a particle moving along the x axis is shown in the figure below.



(a) Find the average velocity in the time interval $t = 2.00$ s to $t = 3.50$ s.

- $\frac{2-6}{3.5-2} = \frac{-4}{1.5} = -2.667$ m/s

(b) Determine the instantaneous velocity at $t = 2$ s (where the tangent line touches the curve) by measuring the slope of the tangent line shown in the graph.

- $\frac{2-12}{3.5-0} = \frac{-10}{3.5} = -3.714$ m/s

(c) At what value of t is the velocity zero?

- 4.000 s

1.2.4 Problem 4

A person takes a trip, driving with a constant speed of 91.5 km/h, except for a 24.0-min rest stop. The person's average speed is 71.6 km/h.

(a) How much time is spent on the trip?

$$
\begin{aligned}
\bar{V} &= \frac{(\text{Time driving}) * V_{\text{driving}}}{\text{Total time}} \\
71.6 &= \frac{(t - \frac{24}{60}) \cdot 91.5}{t} \\
71.6t &= (t - \frac{24}{60}) \cdot 91.5 \\
\frac{71.6}{91.5}t &= t - \frac{24}{60} \\
\frac{71.6}{91.5}t - t &= -\frac{24}{60} \\
\frac{71.6}{91.5}t - \frac{91.5}{91.5}t &= -\frac{24}{60} \\
-\frac{19.9}{91.5}t &= -\frac{24}{60} \\
t &= -\frac{24}{60} \cdot -\frac{91.5}{19.9} \\
t &= 1.839 \text{ hours}
\end{aligned}
$$

(b) How far does the person travel?

- $d = \bar{V} \cdot t = (71.6)(1.839) = 131.6$ km

1.3 Derivative Relationships

Acceleration and Velocity

- $a = \frac{dV}{dt}$
- $V = \frac{dx}{dt}$
- $\int V_0 V dV = \int_0^t a dt$
- $V|_{V_0}^{V} = a|_0^t$
- $V - V_0 = at$
- $V = at + V_0$

Acceleration and Position

- $V = \frac{dx}{dt}$
- $\int_0^x V dt = \int_0^t at + V_0 dt$
- $x|_0^x = \frac{1}{2}at^2 + V_0 t|_0^t$
- $x = \frac{1}{2}at^2 + V_0 t$

If initial time or position is not zero:

- $x - x_0 = V_0(t - t_0) + \frac{1}{2}a(t - t_0)^2$

1.3.1 Given $x = 4t^4 - 6t$, find a when $t = 2$.

$$\begin{aligned} \frac{dx}{dt} &= 16t^3 - 6 \\ \frac{d^2x}{dt^2} &= 48t^2 \\ a &= 48(2)^2 \\ a &= 192 \end{aligned}$$

1.4 Practice with 1-D Kinematic Equations (moderate)

1.4.1 Problem 1

A world-class sprinte rcan burst out of the blocks to essentially top speed (of about 11.5 m/s) in the first 15.0m of the race. What is the average acceleration f this sprinter and how long does it take her to reach that speed (she accelerates uniformly)?

1.4.2 Problem 2

A car slows down from a speed of 25.0m/s to rest in 5.0s. How far did it travel in that time?

1.4.3 Problem 3

In coming to a stop, a car leaves skid marks 80m long on the highway. Assuming a deceleration of 7.00m/s^2, estimate the speed of the car just before braking.

1.4.4 Problem 4

A car traveling 45km/h slows down at a constant 0.50m/s^2 just by "letting up on the gas." Calculate:

(a) the distance the car coasts before it stops
(b) the time it takes to stop
(c) the distance it travels during the first and fifth seconds

1.4.5 Problem 5

A car traveling at 90km/h strikes a tree. The front end of the car compresses and the driver comes to rest after traveling 0.80m. What was the average acceleration of the driver during the collision? Express the answer in terms of "g's," where 1.00g $=$ 9.80m/s^2

1.4.6 Problem 6

Determine the stopping distances for an automobile with ana initial speed of 90km/h and human reaction time of 1.0s:

(a) for $a = -4.0$m/s^2
(b) for $a = -8.0$m/s^2