

Gwinnett School of Math, Science, and Technology

AP Physics: Mechanics/Electricity & Magnetism Notes

Anish Goyal
3rd/4th Period

Jeffrey Burmester
Educator

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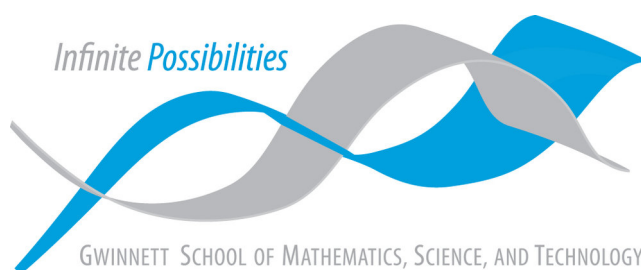


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1 Kinematics

1.1 Variables

1.1.1 Position

- Typically given by the variable x

1.1.2 Time

- Typically given by the variables t

1.1.3 Displacement

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

1.1.4 Distance

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

1.1.5 Average Velocity

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

1.1.6 Velocity

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

1.1.7 Average Acceleration

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

1.1.8 Acceleration

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

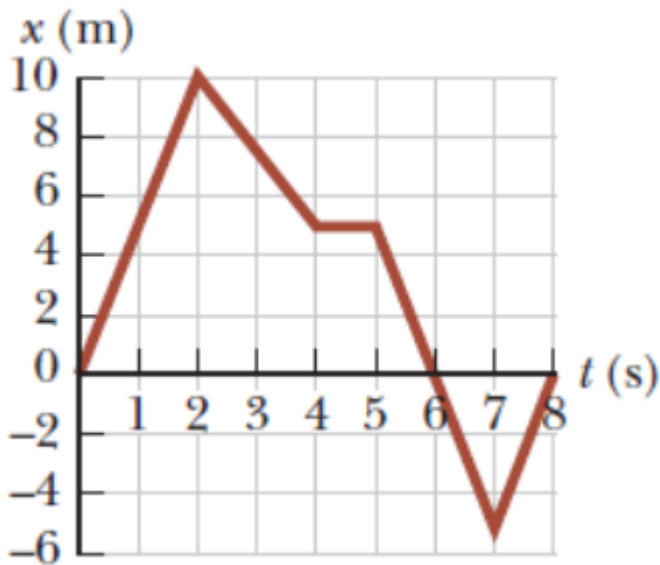
1.1.9 Speed

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

1.2 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

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

(b) 0 to 4s

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

(c) 2 to 6s

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

(d) 1 to 7s

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

(e) 0 to 7s

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

1.2.2 Problem 2

A person walks first at a constant speed of 4.80 m/s along a straight line from point (A) to point (B) and then back along the line from (B) to (A) at a constant speed of 2.90 m/s.

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

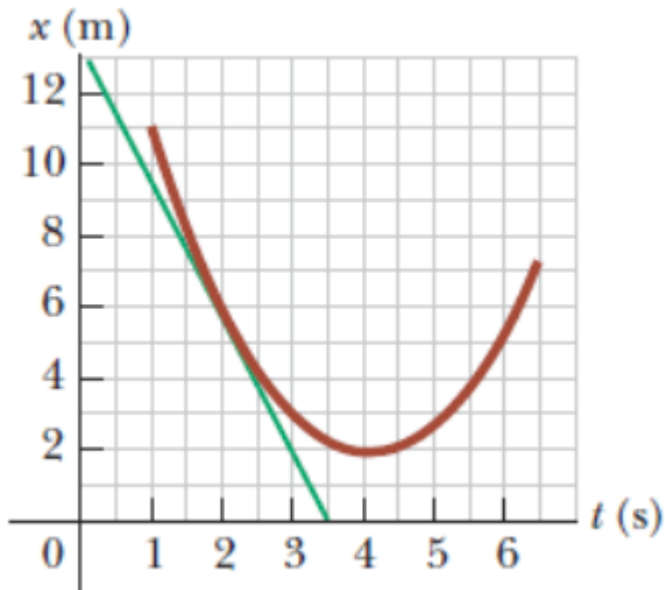
$$\begin{aligned}
 \text{Average speed} &= \frac{d_{AB} + d_{BA}}{t_{AB} + t_{BA}} \\
 d &= d_{AB} = d_{BA} \\
 t_{AB} &= \frac{d}{V_{AB}} \\
 t_{BA} &= \frac{d}{V_{BA}} \\
 \therefore \text{Average speed} &= \frac{d + d}{\frac{d}{V_{AB}} + \frac{d}{V_{BA}}} \\
 &= \frac{2d(V_{AB})(V_{BA})}{2d} \\
 &=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

(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.

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

(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.

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

(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?

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

1.3 Derivative Relationships

1.3.1 Acceleration and Velocity

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

1.3.2 Acceleration and Position

- $V = \frac{dx}{dt}$
- $\int_0^x V dt = \int_0^t at + V_0 dt$
- $x|_0^x = \frac{1}{2}at^2 + V_0t|_0^t$
- $x = \frac{1}{2}at^2 + V_0t$

If initial time or position is not zero:

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

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

$$\frac{dx}{dt} = 16t^3 - 6$$

$$\frac{d^2x}{dt^2} = 48t^2$$

$$a = 48(2)^2$$

$$a = 192$$

1.4 Practice with 1-D Kinematic Equations (moderate)

1.4.1 Problem 1

A world-class sprinter can 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 of 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 $1.00g = 9.80\text{m/s}^2$

1.4.6 Problem 6

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

- (a) for $a = -4.0 \text{ m/s}^2$
- (b) for $a = -8.0 \text{ m/s}^2$

1.5 Acceleration Definitions (08/04 Homework)

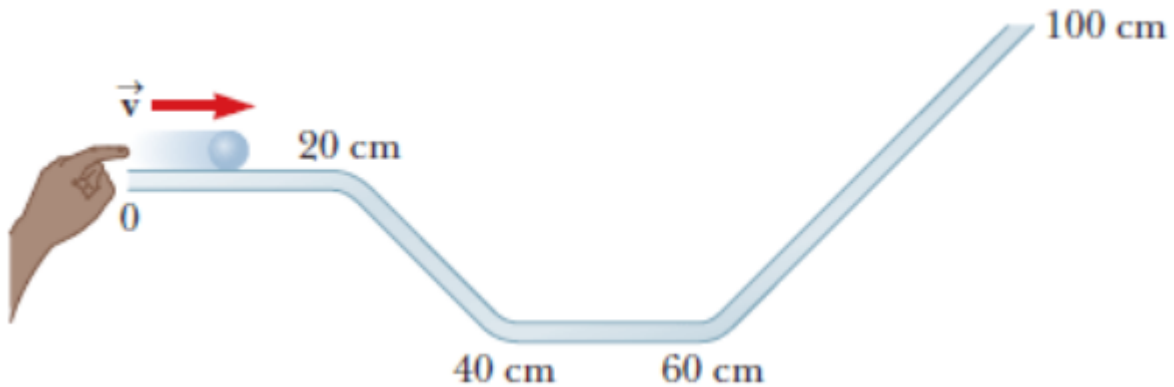
1.5.1 Problem 1

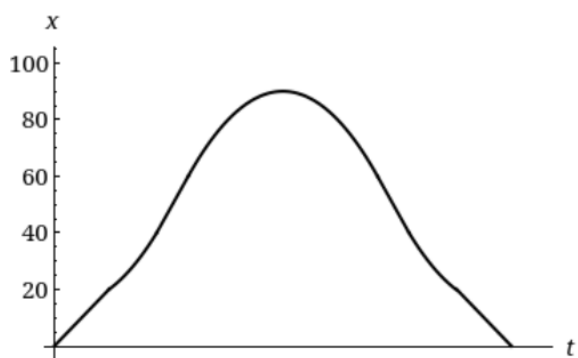
A 48.0 g Super Ball traveling at 29.0 m/s bounces off a brick wall and rebounds at 18.0 m/s. A high-speed camera records this event. If the ball is in contact with the wall for 4.05 ms, what is the magnitude of the average acceleration of the ball during this time interval?

$$\bullet a = \left| \frac{-18 - 29}{0.00405} \right| = 11604.938 \text{ m/s}^2$$

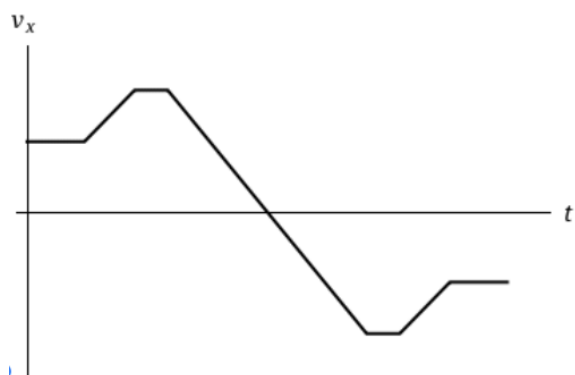
1.5.2 Problem 2

A child rolls a marble on a bent track that is 100 cm long as shown in the figure below. We use x to represent the position of the marble along the track. On the horizontal sections from $x = 0$ to $x = 20$ cm and from $x = 40$ to $x = 60$ cm, the marble rolls with constant speed. On the sloping sections, the marble's speed changes steadily. At the places where the slope changes, the marble stays on the track and does not undergo any sudden changes in speed. The child gives the marble some initial speed at $x = 0$ and $t = 0$ and then watches it roll to $x = 90$ cm, where it turns around, eventually returning to $x = 0$ with the same speed with which the child released it. Prepare graphs of x versus t , v_x versus t , and a_x versus t , with their time axes identical, to show the motion of the marble. You will not be able to place any numbers other than zero on the horizontal axis or on the velocity and acceleration axes, but show the correct graph shapes.

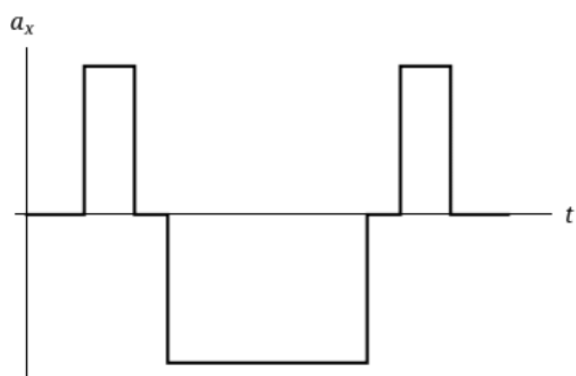




x versus t



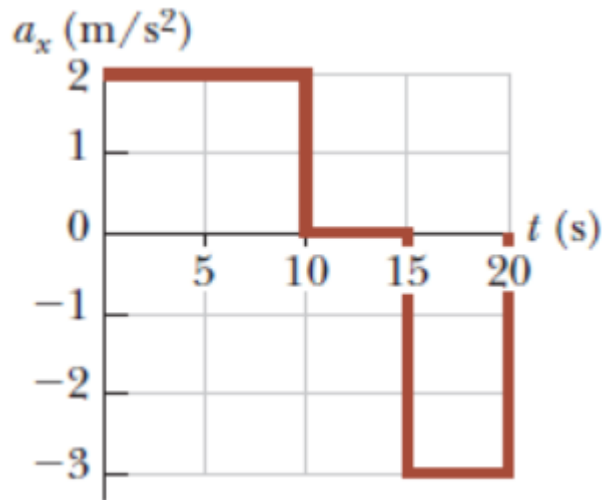
V_x versus t



a_x versus t

1.5.3 Problem 3

A particle starts from rest and accelerates as shown in the figure below.



(a) Determine the particle's speed at $t = 10.0$ s.

- $\int_0^{10} a \, dt = 10 \cdot 2 = 20 \text{ m/s}$

(b) Determine the particle's speed at $t = 20.0$ s?

- $\int_0^{20} a \, dt = 10 \cdot 2 + 5 \cdot (-3) = 20 - 15 = 5 \text{ m/s}$

(c) Determine the distance traveled in the first 20.0 s. (Enter your answer to one decimal places.)

$$\Delta x \text{ from 0-10 seconds: } \frac{1}{2} \cdot 2 \cdot 10^2 = 100$$

$$\Delta x \text{ from 10-15 seconds: } 20 \cdot 5 = 100$$

$$\Delta x \text{ from 15-20 seconds: } \frac{1}{2} \cdot -3 \cdot 5^2 + 20 \cdot 5 = 62.5$$

$$\therefore \Delta x = 262.5 \text{ m}$$

1.5.4 Problem 4

An object moves along the x axis according to the equation $x = 3.25t^2 - 2.00t + 3.00$, where x is in meters and t is in seconds.

(a) Determine the average speed between $t = 1.70$ s and $t = 3.30$ s.

$$\bullet \bar{V} = \frac{x(3.30) - x(1.70)}{t_1 - t_0} = \frac{(3.25(3.30)^2 - 2(3.30) + 3) - (3.25(1.70)^2 - 2(1.70) + 3)}{3.30 - 1.70} = 14.25 \text{ m/s}$$

(b) Determine the instantaneous speed at $t = 1.70$ s.

$$\bullet V = \frac{dx}{dt} = 6.5(1.7) - 2 = 9.05 \text{ m/s}$$

(c) Determine the instantaneous speed at $t = 3.30$ s.

$$\bullet V = \frac{dx}{dt} = 2(3.25)(3.3) - 2 = 19.45 \text{ m/s}$$

(d) Determine the average acceleration between $t = 1.70$ s and $t = 3.30$ s.

$$\bullet \bar{a} = \frac{V(3.30) - V(1.70)}{t_1 - t_0} = \frac{(2(3.25)(3.30) - 2) - (2(3.25)(1.70) - 2)}{3.30 - 1.70} = 6.5 \text{ m/s}^2$$

(e) Determine the instantaneous acceleration at $t = 1.70$ s.

$$\bullet a = \frac{dV}{dt} = 2(3.25) = 6.5 \text{ m/s}^2$$

(f) Determine the instantaneous acceleration at $t = 3.30$ s.

$$\bullet a = \frac{dV}{dt} = 2(3.25) = 6.5 \text{ m/s}^2$$

(g) At what time is the object at rest?

$$\bullet 0 = 6.5t - 2 \implies 0.308 \text{ s}$$