General Physics I
Classnotes

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January 22

1 Metric Prefixes

10^{12}	$= 1,000,000,000,000$	tera	T
10^{9}	$= 1,000,000,000$	giga	G
10^{6}	$= 1,000,000$	mega	M
10^{3}	$= 1,000$	kilo	k
10^{0}	$= 1$	$-$	$-$
10^{-2}	$= 0.01$	centi	c
10^{-3}	$= 0.001$	milli	m
10^{-6}	$= 0.000,001$	micro	μ
10^{-9}	$= 0.000,000,001$	nano	n
10^{-12}	$= 0.000,000,000,001$	pico	p

2 Basic Quantities

	Metric	English
Length	$m =$ meter	$ft =$ foot
Mass	$kg =$ kilogram	$sl =$ slug
Time	$s =$ second	$s =$ second

$$1\text{day} = 24 \times 60 \times 60 = 86,400\ s$$
$$1\text{day} = 10 \times 100 \times 100 = 100,000\ s$$

3 Derived Quantities

velocity/speed	mi/s	km/h	m/min	$\ldots$	$[L]/[T]$
area	cm^2	m^2	$\ldots$	$\ldots$	$[L]^2$
density	g/cm^3	kg/m^3	$\ldots$	$\ldots$	$[M]/[L]^3$

4 Conversions

$$
\begin{aligned}
1\ min &\equiv 60\ s \\
1\ h &\equiv 60\ min \\
1\ ft &\equiv 12\ in \\
1\ mi &\equiv 5280\ ft \\
1\ L &\equiv 1,000\ cm^3 \\
1\ mi^2 &\equiv 640\ acres \\
1\ in &\equiv 2.54\ cm
\end{aligned}
$$

Example:

$$
\begin{aligned}
70\ mi/h &= ?\ m/s \\
&= 70\ mi/h \times \left(\frac{5280\ ft}{1\ mi}\right) \times \left(\frac{12\ in}{1\ ft}\right) \times \left(\frac{2.54\ cm}{1\ in}\right) \times \left(\frac{1\ m}{100\ cm}\right) \\
&\quad \times \left(\frac{1\ h}{60\ min}\right) \times \left(\frac{1\ min}{60\ s}\right) \\
&= 31.2928\ m/s
\end{aligned}
$$

Example:

$$
\begin{aligned}
350 in^3 &= ?\ L \\
&= 350\ in^3 \times \left(\frac{2.54\ cm}{1\ in}\right)^3 \times \left(\frac{1\ L}{1000\ cm^3}\right) \\
&= 5.7355\ L
\end{aligned}
$$

Homework:

$$
\begin{aligned}
1acre &= \ ?\ in^2 \\
&= 1\ acre \times \left(\frac{1\ mi^2}{640\ acres}\right) \times \left(\frac{5280\ ft}{1\ mi}\right)^2 \times \left(\frac{12\ in}{1\ ft}\right)^2 \\
&= 6,272,640\ in^2
\end{aligned}
$$

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5 Position

Let

$$\begin{aligned} x &= \text{position} \\ x_i &= \text{initial position} \\ x_f &= \text{final position} \\ \Delta x &= \text{Displacement} \\ &= x_f - x_i \end{aligned}$$

Example:

$$\begin{aligned} x_i &= +3\ ft \\ x_f &= +5\ ft \\ \Delta x &= x_f - x_i \\ &= 5\ ft - 3\ ft \\ &= +2\ ft \end{aligned}$$

Example:

$$\begin{aligned} x_i &= +5\ ft \\ x_f &= -1\ ft \\ \Delta x &= x_f - x_i \\ &= -1\ ft - 5\ ft \\ &= -6\ ft \end{aligned}$$

Example:

$$\begin{aligned} x_i &= \ +3\ ft \\ x_2 &= \ +5\ ft \\ x_f &= \ -1\ ft \\ \Delta x &= x_f - x_i \\ &= \ -1\ ft - 3\ ft \\ &= \ -4\ ft \\ \text{Distance Traveled} &= 2\ ft + 6\ ft \\ &= 8\ ft \end{aligned}$$

6 Velocity

$$\begin{aligned} \bar{v} &= \text{average velocity} \\ \bar{v} &\equiv \frac{\Delta x}{\Delta t} = \frac{\text{displacement}}{\text{time elapsed}} \\ \text{average speed} &= \frac{\text{distance travelled}}{\text{time elapsed}} \end{aligned}$$

Example:

$$\begin{aligned} \text{Start at } x &= \ +3\ ft \\ \text{Move to } x &= \ +5\ ft \\ \text{End at } x &= \ -1\ ft \\ \text{Trip takes } 4\ s \\ \text{Find } a)averagevelocity \\ b)averagespeed \end{aligned}$$

$$\begin{aligned} \bar{v} &\equiv \frac{\Delta x}{\Delta t} \\ &= \frac{-1\ ft - 3\ ft}{4\ s} = \frac{-4\ ft}{4\ s} = -1\ ft/s \\ \text{average speed} &= \frac{\text{distance}}{\text{time}} = \frac{8\ ft}{4\ s} = 2\ ft/s \end{aligned}$$

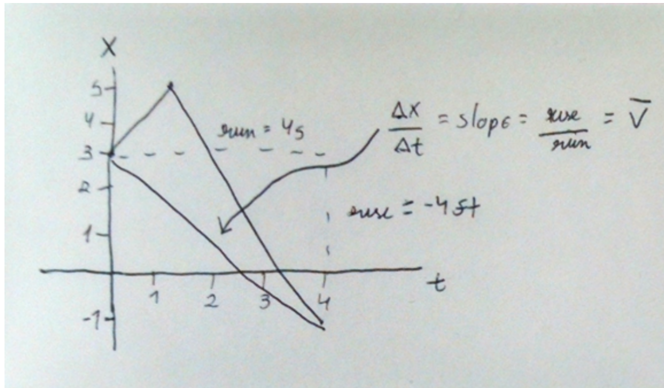

Figure 1: Graphic of the Average Speed

$$
\begin{aligned}
v &= \text{instantaneous velocity} \\
&= \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} \\
v &\equiv \frac{dx}{dt}
\end{aligned}
$$

Example:

$$
\begin{aligned}
&x = 3\ m + (17\ m/s)t + (7\ m/s^3)t^3 \\
&\text{Find} \\
&\qquad a)\text{position at } t = 2\ s \\
&\qquad b)\text{position at } t = 4\ s \\
&\qquad c)\text{average velocity from} 2\ s \to 4\ s
\end{aligned}
$$

a)

$$
\begin{aligned}
x &= 3\ m + (17\ m/s)(2\ s) + (7\ m/s^3)(2\ s)^3 \\
&= 3\ m + 34\ m + 56\ m \\
&= 93\ m
\end{aligned}
\tag{1}
$$

b)

$$\begin{aligned} x &= 3\ m + (17\ m/s)(4\ s) + (7\ m/s^3)(4\ s)^3 \\ &= 3\ m + 68\ m + 448\ m \\ &= 519\ m \end{aligned}$$

c)

$$\begin{aligned} \bar{v} &= \frac{\Delta x}{\Delta t} = \frac{519\ m - 93\ m}{4\ s - 2\ s} \\ &= \frac{426\ m}{2\ s} \\ &= 213\ m/s \end{aligned}$$

d)

$$\begin{aligned} v &= \frac{dx}{dt} \\ &= \frac{d}{dt}\left[3\ m + (17\ m/s)t + (7\ m/s^3)t^3\right] \\ &= 0 + 17\ m/s + (21\ m/s^3)t^2 \\ v(3\ s) &= 17\ m/s + (21\ m/s^3)(3\ s)^2 \\ &= 17\ m/s + 189\ m/s = 208\ m/s \end{aligned}$$

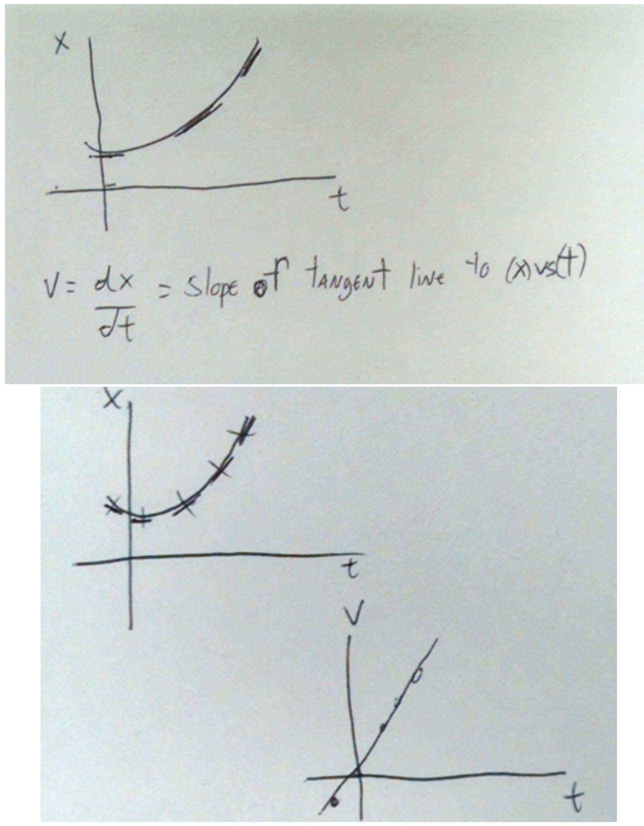

Figure 2: Graphics of Instantaneous Velocity

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7 Summary

$$\begin{aligned}
x &= \text{position} \\
\Delta x &= \text{displacement} \\
&= x_f - x_i \\
\bar{v} &= \text{average velocity} \\
&= \frac{\Delta x}{\Delta t} \\
v &= \text{instantaneous velocity} \\
&= \frac{dx}{dt} = \text{slope of x vs. t} \\
\text{Avg Speed} &= \frac{\text{distance traveled}}{\text{time elapsed}}
\end{aligned}$$

8 Acceleration

$$\begin{aligned}
\text{Let} \qquad \bar{a} &= \qquad \text{average acceleration} \\
\bar{a} &\equiv \qquad \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{\Delta t} = \frac{\text{change in velocity}}{\text{time elapsed}}
\end{aligned}$$

Example: A car goes from 20 mph to 60 mph in 8 s. What is its average acceleration?

$$
\begin{aligned}
v_i &= 20\ mi/h \\
v_f &= 60\ mi/h \\
\Delta t &= 8\ s \\
\bar{a} &= \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{\Delta t} \\
&= \frac{60\ mi/h - 20\ mi/h}{8\ s} \\
&= \frac{40\ mi/h}{8\ s} \\
&= 5\ \frac{mi}{h \times s}
\end{aligned}
$$

Example: Justin Bieber's Limo goes from 30 m/s to a stop in 0.10 s. What is its average acceleration?

$$
\begin{aligned}
v_i &= 30\ m/s \\
v_f &= 0\ m/s \\
\Delta t &= 0.10\ s \\
\bar{a} &= \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{\Delta t} \\
&= \frac{0\ m/s - 30\ m/s}{0.10\ s} \\
&= \frac{-30\ m/s}{0.10\ s} \\
&= -300\ \frac{m/s}{s} = -300 m/s^2
\end{aligned}
$$

($-$ means slowing)

Let

$$\begin{aligned} a &= \text{instantaneous acceleration} \\ &= lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} \\ a &\equiv \frac{dv}{dt} = \text{rate of change of velocity} \\ &= \text{slope of tangent line to v vs. t} \end{aligned}$$

Example:

$$\begin{aligned} x &= 3\ m + (17\ m/s)\, t + \left(7\ m/s^3\right) t^3 \\ Find &: \text{a) velocity at } 3\ s \\ & \quad \text{b) velocity at } 5\ s \\ & \quad \text{c) average acceleration from } 3\ s \to 5\ s \\ & \quad \text{c) instantaneous acceleration at } 4\ s \end{aligned}$$

a)

$$\begin{aligned} v &= \frac{dx}{dt} = 17\ m/s + \left(21\ m/s^3\right) t^2 \\ v(3\ s) &= 17\ m/s + \left(21\ m/s^3\right) (3\ s)^2 \\ &= 17\ m/s + 189\ m/s \\ &= 206\ m/s \end{aligned}$$

b)

$$\begin{aligned} v(5\ s) &= 17\ m/s + \left(21\ m/s^3\right) (5\ s)^2 \\ &= 17\ m/s + 525\ m/s \\ &= 542\ m/s \end{aligned}$$

c)

$$\begin{aligned} \bar{a} &= \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{\Delta t} = \frac{542\ m/s - 206\ m/s}{5\ s - 3\ s} \\ &= \frac{336\ m/s}{2\ s} = 168\ m/s^2 \end{aligned}$$

d)

$$
\begin{aligned}
a &= \frac{dv}{dt} \\
&= \frac{d}{dt}\left[17\ m/s + (21\ m/s^3)t^2\right] \\
&= 0 + (42\ m/s^3)t \\
a(4\ s) &= (42\ m/s^3)(4\ s) \\
&= 168\ m/s^2
\end{aligned}
$$

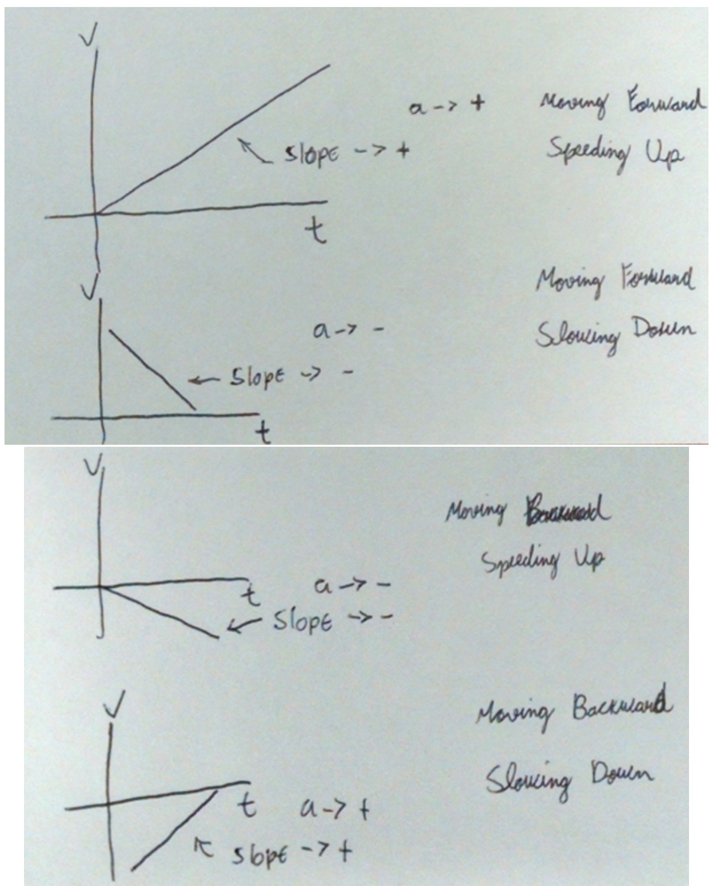

Figure 3: Graphics of Acceleration

$$
\begin{array}{lll}
t_i & \to & 0 \\
t_f & \to & t \\
x_i & \to & x_0 \\
x_f & \to & x \\
v_i & \to & v_0 \\
v_f & \to & v
\end{array}
$$

Suppose $a = \text{constant}$

$$
\begin{aligned}
\bar{a} &= a \\
\frac{v - v_0}{t} &= a \\
v - v_0 &= at \\
v &= v_0 + at : v(t) \qquad (2) \\
x &= x_0 + v_0 t + \frac{1}{2}at^2 : x(t) \qquad (3) \\
x &= x_0 + \frac{1}{2}(v_0 + v)t : \text{no } a \qquad (4) \\
2a(x - x_0) &= v^2 - v_0^2 : \text{no } t \qquad (5)
\end{aligned}
$$