Phys 111: General Physics I

"The Great Fairies Three"

University of Idaho

September 03, 2019

Today's Announcments

Homework Wk #2 Due Thursday

Starting This Week

- Physics labs
- Tutoring (Library & EP 309)
- Recitation & Office Hours

Recomendation: Read Open Stax College Physcis 1.3 and 1.4 as prep for lab.

Today's Topics

1. Acceleration
2. Free-Fall
3. Using Graphs & Data

Acceleration is the rate of change of the velocity of an object. This can be a change in the magnitude (speed) or direction of the velocity. Denoted $\vec{\mathbf{a}}$, magnitude of $\vec{\mathbf{a}}$ denoted a.

Average Acceleration = (Final Velocity - Initial Velocity) / Elapsed Time

- Trip to store and back takes 25 min: $< \vec{\mathbf{a}} >= 0\ m/s^2$.
- 0 to 60 mph in 8.0 s: $\vec{\mathbf{a}}_{ave} = 27000 mi/h^2$.
- Sprinting 0 to 7.00 m/s in 7.0 s: $a = 1.0 m/s/s$.

$$\vec{\mathbf{a}}_{ave} = \frac{\vec{\mathbf{v}}_f - \vec{\mathbf{v}}_o}{\Delta t}$$

Instantaneous Acceleration Wait hold up! What about instantaneous velocity?

Instantaneous (Top Ramen)

Instantaneous quantities indicate that quantity at each instant of time. In physics we say this means Δt gets really darn small. To be mathematically consistent we write dt for such small amounts of time:

$$\lim_{t \to 0} \Delta t = dt$$

Instantaneous Velocity of an object is the velocity at each instant of time:

$$\vec{\mathbf{v}} = \lim_{t \to 0} \frac{\Delta \vec{\mathbf{x}}}{\Delta t} = \frac{d\vec{\mathbf{x}}}{dt}$$

Instantaneous Acceleration of an object is the acceleration at each instant of time:

$$\vec{\mathbf{a}} = \lim_{t \to 0} \frac{\Delta \vec{\mathbf{v}}}{\Delta t} = \frac{d\vec{\mathbf{v}}}{dt}$$

Acceleration Check/Clarification

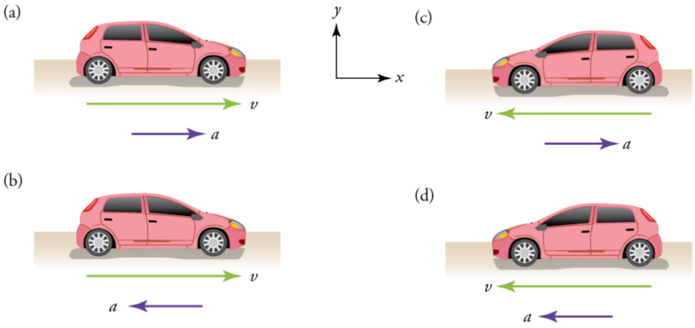
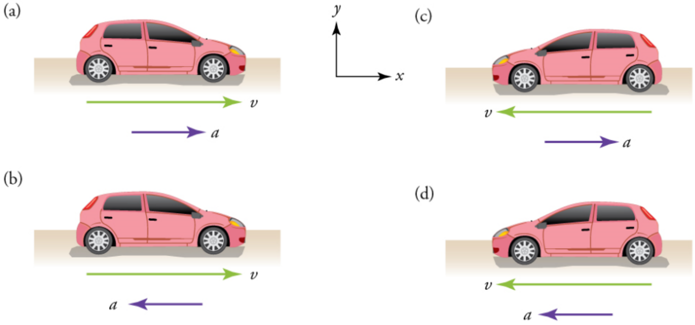


Figure: 3.1 Negative Acceleration vs Deceleration

Acceleration Check/Clarification



Answers

a. $\vec{\mathbf{a}}_a = +a\ \hat{\mathbf{i}}$

b. $\vec{\mathbf{a}}_c = +a\ \hat{\mathbf{i}}$

c. $\vec{\mathbf{a}}_c = +a\ \hat{\mathbf{i}}$

d. $\vec{\mathbf{a}}_d = -a\ \hat{\mathbf{i}}$

C&J Example 1

C&J 2.3.16 Over a time interval of 2.16 years, the velocity of a planet orbiting a distant star reverses direction, changing from +20.9 km/s to -18.5 km/s. Find

a. the total change in the planet's velocity (in m/s) and
b. its average acceleration (in m/s^2) during this interval. Include the correct algebraic sign with your answers to convey the directions of the velocity and the acceleration.

C&J 2.3.17 A motorcycle has a constant acceleration of 2.5 m/s^2. Both the velocity and acceleration of the motorcycle point in the same direction. How much time is required for the motorcycle to change its speed from

a. 21 to 31 m/s, and
b. 51 to 61 m/s?

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C&J 2.3.17 A motorcycle has a constant acceleration of **2.5** $\mathbf{m/s^2}$. Both the velocity and acceleration of the motorcycle point in the *same* direction. **How much time** is required for the motorcycle to change its speed from

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C&J 2.3.16 Over a time interval of 2.16 years, the velocity of a planet orbiting a distant star reverses direction, changing from +20.9 km/s to -18.5 km/s. Find

a. the total change in the planet's velocity (in m/s). $\mathbf{-39.4 \times 10^3\ m/s}$

b. its average acceleration (in m/s^2) during this interval. $\mathbf{-5.80 \times 10^{-7}\ m/s^2}$

C&J 2.3.17 A motorcycle has a constant acceleration of 2.5 m/s^2. Both the velocity and acceleration of the motorcycle point in the same direction. How much time is required for the motorcycle to change its speed from

a. 21 to 31 m/s? $\mathbf{4\ m/s^2}$

b. 51 to 61 m/s? $\mathbf{4\ m/s^2}$

Two General Categories

1. Constant Acceleration
2. Nonconstant Accleration

Acceleration is the rate at which velocity is changing... Always.

You need prior knowledge of the physical phenomena in question or you need to collect data for velocities over enough time measurements to have accurate information for your design and application.

Either data tables, plots, or equations will be given and using them will be discussed in class or in the book.

Definition: The instantaneous acceleration of an object at every moment is equal to the average acceleration for the whole motion.

Mathematically: $\vec{\mathbf{a}}(t) = \vec{\mathbf{a}}_{ave} = \overline{a}$ (in given direction)

Example

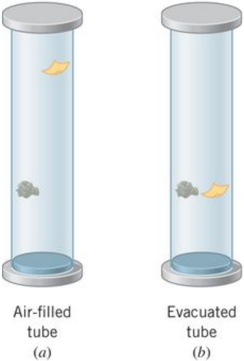


Figure: 3.2 Air Resistance vs No Air Resistance

Derivation from

$$v(t) = at + v_o$$

$$\overline{v} = \frac{v_f + v_o}{2} = \frac{y_f - y_o}{t}$$

Properties of Constant Acceleration

$$v(t) = at + v_o$$

$$\overline{v} = \frac{v_f + v_o}{2} = \frac{y_f - y_o}{t}$$

$$\frac{(\mathbf{at} + \mathbf{v_o}) + v_o}{2} = \frac{y_f - y_o}{t}$$

$$y_f - y_o = \frac{t}{2}(at + 2v_o)$$

$$y_f - y_o = \frac{1}{2}at^2 + v_o t$$

$$y_f = \frac{1}{2}at^2 + v_o t + y_o$$

$$\mathbf{y_f} = \mathbf{y_o} + \mathbf{v_o t} + \mathbf{\frac{1}{2} at^2}$$

Let's look at some data! Times (± 0.2 s) for dropping a steel ball:[1]

From 1.00 (± 0.01) m

1. 0.41 s
2. 0.46 s
3. 0.45 s
4. 0.50 s

$$\bar{t}_1 = 0.46\ s$$

From 1.50 (± 0.01) m

1. 0.59 s
2. 0.59 s
3. 0.54 s
4. 0.59 s

$$\bar{t}_2 = 0.58\ s$$

$$\overline{a} \approx 9.4\ (\pm 0.5)\ m/s^2$$

[1] Usually hundreds, if not more, data points are necessary for true significance.

Modeling Practice

From Theory

$$\textbf{Acceleration} = \textbf{2(height)/(time)}^2$$

From Experiment

measured time (s)	calculated acceleration (m/s/s)
0.41	11.90
0.46	9.45
0.45	9.88
0.50	8.00
0.59	8.62
0.59	8.62
0.54	10.29
0.59	8.62

$$\overline{a} \approx 9.4\ (\pm 0.5)\ m/s^2$$

Predictions from Known Acceleration Due to Gravity

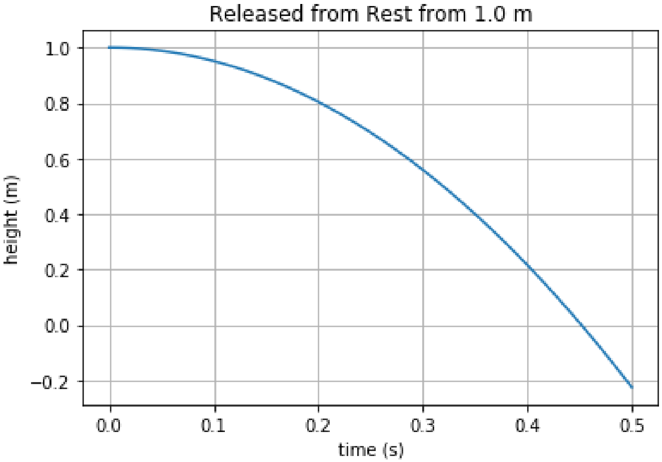


Figure: 3.3 Predicted drop time of t $= 0.452$ s vs $t_{xp} = 0.46$ s

Predictions from Known Acceleration Due to Gravity

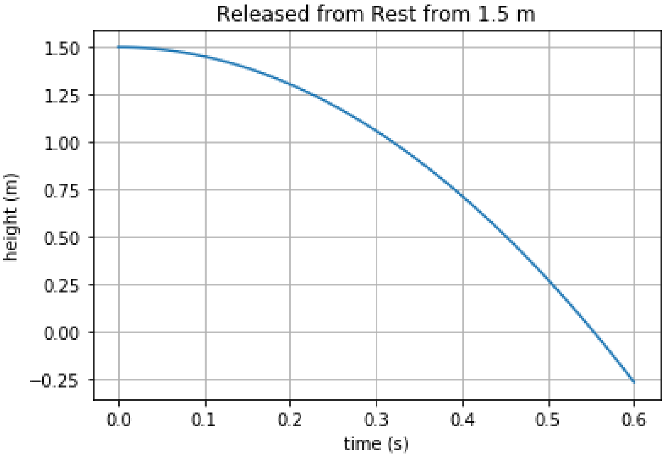


Figure: 3.4 Predicted drop time of t $= 0.553$ s vs $t_{xp} = 0.58$ s

Acceleration due to the Earth

$$a_{ui} \approx 9.805m/s^2$$

$$\overline{a} = g \approx 10.0m/s^2$$

$$g = 9.80m/s^2 \ or \ 32.2ft/s^2$$

Constant Acceleration

$$y(t) = y_o + v_o t + \frac{1}{2}at^2$$

$$v(t) = v_o + at$$

$$v_f^2 = v_o^2 + 2a\Delta y$$

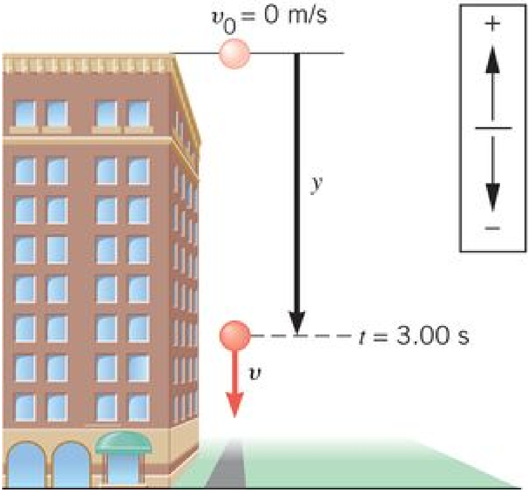


Figure: 3.5 Drop a stone from the top of a building. $a_y = -g$

Free-Fall Solution (Collecting)

$$y_f = y_o + v_o t + \frac{1}{2} a t^2$$

$$y_f = y_o - \frac{1}{2} g t^2$$

$$\Delta y = -y = -\frac{1}{2} g t^2$$

$$-y = -\left(\frac{9.80\ m/s^2}{2} \right) (3.00\ s)^2$$

$$y = (4.90)(9.00)\ m$$

$$y = 44.1\ m \approx 145\ ft$$

Rates & Amounts
How is your paycheck calculated for an hourly job?

You take how many hours you worked and you multiply that by your hourly rate.

$$\mathbf{\$11.50/h \times 34.75\ h \approx \$400}$$

$$\mathbf{\$7.25/h \times 34.75\ h \approx \$252}$$

For us velocity is the rate for displacement and *acceleration* is the *rate for velocity.*

In general we write:

$$\textbf{Amount} = \textbf{Rate} \times \textbf{Time}$$

$$\textbf{Rate} = \textbf{Amount}/\textbf{Time}$$

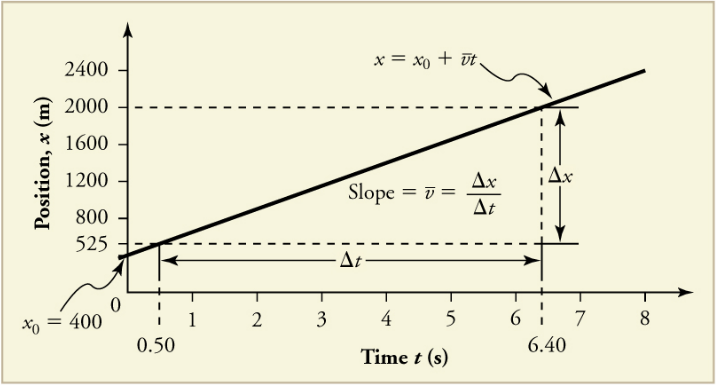
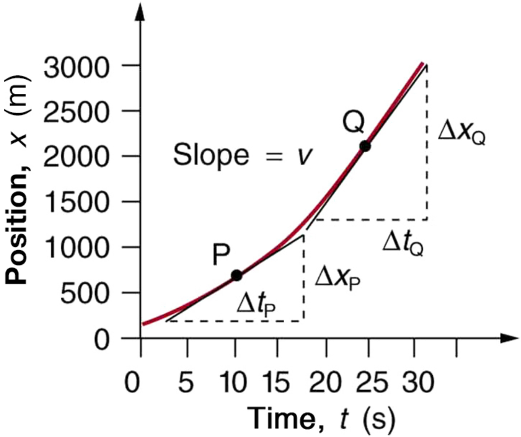


Figure: 3.6 Position vs Time for Constant Velocity $\overline{v} = 250\ m/s$



t (s)	x (m)
0	200
5	338
10	600
15	988
20	1500
25	2138
30	2900

Figure: 3.7 Position vs Time for Constant Acceleration; $v_Q = 140\ m/s$

Approximating Instantaneous Velocities

time(s)	**velocity(m/s)**
0	NA
2.5	37.6
5	40
10	65
12.5	77.6
15	90
17.5	102.4
20	115
22.5	127.6
25	**140**
27.5	152.4
30	NA

C&J 2.7.67 What is the average acceleration during each of the segments A, B, and C?

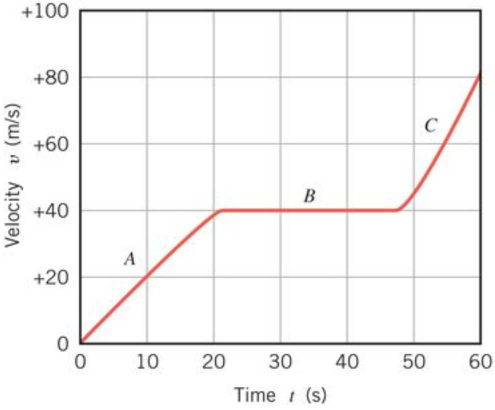
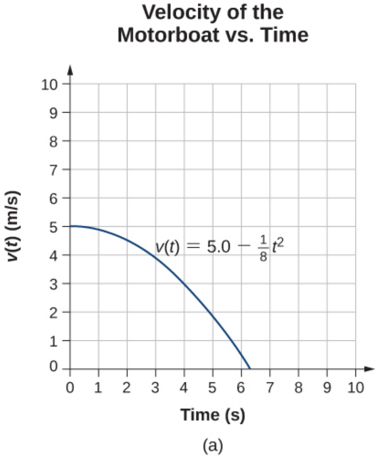


Figure: 3.8 Velocity vs Time for Non-Constant Acceleration

$$v_o = 5.00\ m/s \qquad a(t) = -(\frac{1}{4}m/s^3)t$$



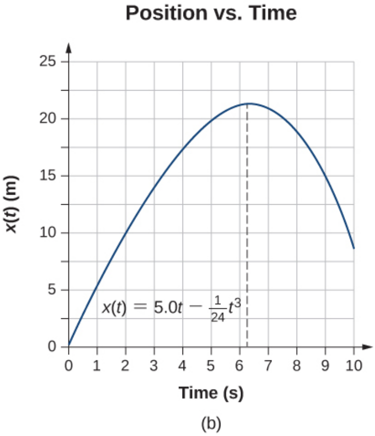


Figure: 3.9 Changing Velocity of a Motor Boat

The End

Thank you for your time and attention!

C&J 2.7.68 What is the average velocity (magnitude and direction) during each of the segments A, B, and C? Express your answers in km/h.

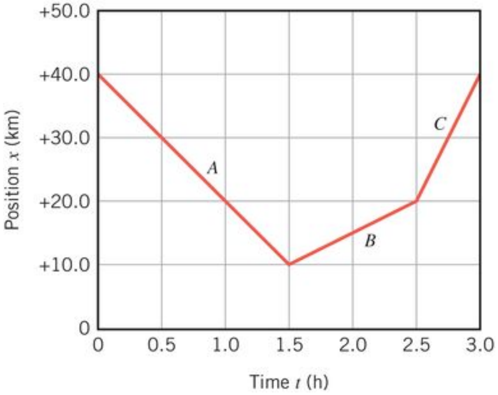


Figure: 3.10 Bus Trip Data for C&J 2.7.68

C&J 2.7.69 What is the average acceleration (in km/h^2) of the bus for the entire 3.5 h period shown in the graph?

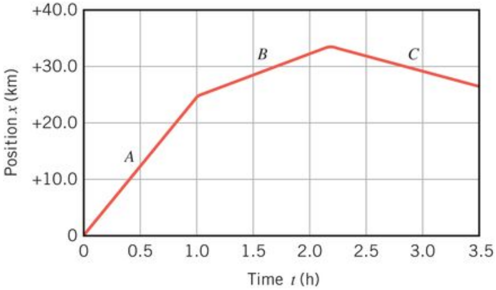


Figure: 3.11 Bus Trip Data for C&J 2.7.69