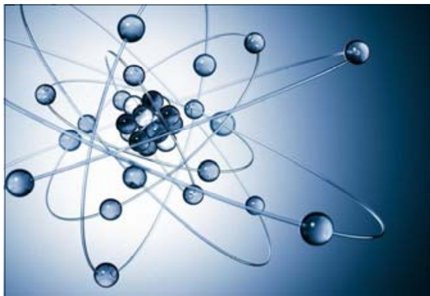
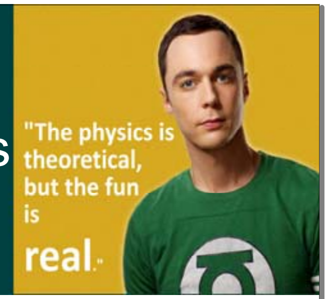


Unit 1: Kinematics



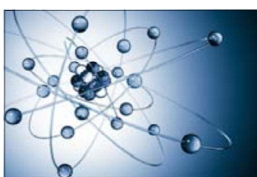
1.3 Acceleration

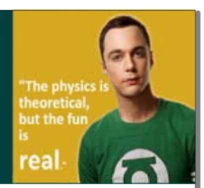
We know that Uniform Motion means you have a constant velocity. What if your velocity isn't constant? Then you have acceleration or Non-Uniform Motion. We can't sense a constant velocity but we are able to sense a change in velocity.

Acceleration is the rate of change in velocity over time.

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

Dec 15-10:28 AM





Do unit analysis to determine the units of acceleration:

$$\vec{a} = \frac{\Delta \vec{v}}{\Delta t} = \frac{m/s}{s} = \frac{m}{s} \div \frac{s}{1} = \frac{m}{s} \cdot \frac{1}{s} = \boxed{\frac{m}{s^2}}$$

3SD 2SD

Ex.) A fish begins to swim left at 5.00 m/s. 5.0 minutes later, the fish has increased its velocity to 7.00 m/s. What was the fish's acceleration over this time?

3SD

$\vec{v}_i = 5.00 \, m/s \, [left]$

$\vec{v}_f = 7.00 \, m/s \, [left]$

$t = 5.0 \, min = 3.0 \times 10^2 \, s$

$\vec{a} = ?$

$$\vec{a} = \frac{\Delta \vec{v}}{\Delta t} = \frac{\vec{v}_f - \vec{v}_i}{t}$$

$$= \frac{7.00 \, m/s \, [left] - 5.00 \, m/s \, [left]}{3.0 \times 10^2 \, s}$$

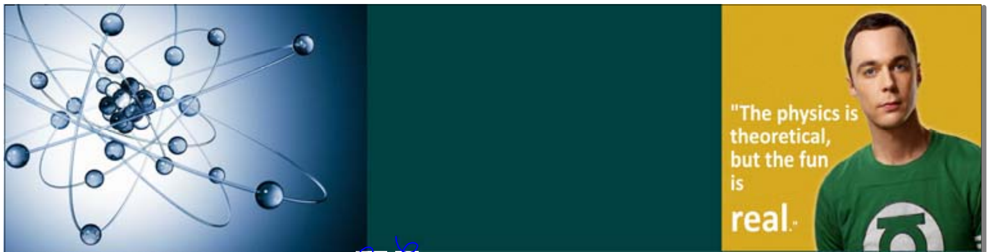
$$= \frac{2.00 \, m/s \, [left]}{3.0 \times 10^2 \, s} = \boxed{6.7 \times 10^{-3} \, m/s^2 \, [left]}$$

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t} = \frac{-7.00 \, m/s - -5.00 \, m/s}{3.0 \times 10^2 \, s}$$

$$= \frac{-2.00 \, m/s}{3.0 \times 10^2 \, s} = -6.7 \times 10^{-3} \, m/s^2$$

$$= \boxed{6.7 \times 10^{-3} \, m/s^2 \, [left]}$$

Dec 15-10:56 AM



Ex.) While driving at 100 km/h ($\div 3.6$), the driver hits the brakes. It takes 98 m to stop the car. What was the acceleration of the car?

$\vec{V_f} = 0\ m/s$

$\vec{V_i} = 27.8\ m/s$ [forwards]

$\vec{V_f} = 0\ m/s$

$\vec{d} = 98\ m$

$\vec{a} = ?$

$\vec{V} = \frac{\Delta \vec{d}}{t}$ Uniform Motion Only

$t = \frac{\vec{d}}{\vec{V}} = \frac{98\ m}{27.8\ m/s}$ $= \boxed{98 \div \boxed{ANS}}$

$= 3.5\ s$

Non-Uniform Motion $\vec{a} = \frac{\vec{V_f} - \vec{V_i}}{t} = \frac{0 - 27.8\ m/s}{3.5\ s} = \boxed{-7.9\ m/s^2}$

$\vec{a} = \frac{\vec{V_f}^2 - \vec{V_i}^2}{2\vec{d}} = \frac{(0\ m/s)^2 - (27.8\ m/s)^2}{(2 \times 98\ m)} = \boxed{-3.9\ m/s^2}$

Dec 15-10:58 AM

Negative Acceleration vs. Deceleration

The last example gave us a negative answer. What does this mean?

If $\vec{v}$ and $\vec{a}$ are in the same direction (same signs) = acceleration

If $\vec{v}$ and $\vec{a}$ are in opposite directions(opposite signs) = negative accceleration

Although you may have heard deceleration used in everyday language, it isn't necessarily proper in Physics. We say an object has negative acceleration.

Common manipulations of the acceleration formula give us the following forms:

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t}$$

$$t = \frac{\vec{V}_f - \vec{V}_i}{\vec{a}} \qquad \vec{V}_f = \vec{V}_i + \vec{a}t \qquad \vec{V}_i = \vec{V}_f - \vec{a}t$$

Dec 15-10:59 AM

2 SD 3 SD 3 SD

Ex.) A bug buzzes at 3.0 m/s [W], then accelerate for 4.75 s at 1.25 m/s^2 [W]. What is the insect's final velocity?

$\vec{v}_i = 3.0 \text{ m/s [W]}$

$t = 4.75 \text{ s}$

$\vec{a} = 1.25 \text{ m/s}^2 \text{ [W]}$

$\vec{v}_f = ?$

$\vec{v}_f = \vec{v}_i + \vec{a}t$

$= 3.0 \text{ m/s [W]} + (1.25 \text{ m/s}^2 \text{ [W]})(4.75 \text{ s})$

$= \boxed{8.9 \text{ m/s [W]}}$

Dec 15-11:24 AM

Ex.) An electron has a final velocity of 3.0 x 10^6 m/s [Forward] after accelerating for 25 s at 1.5 x 10^4 m/s^2 [Forward]. What was the electron's initial velocity?

$\vec{v}_f = 3.0 \times 10^6 \text{ m/s}$

$t = 25 \text{ s}$

$\vec{a} = 1.5 \times 10^4 \text{ m/s}^2$

$\vec{v}_i = ?$

$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t}$

$\vec{a}t = \vec{v}_f - \vec{v}_i$

$-v_f \quad -v_f$

$\frac{\vec{a}t - \vec{v}_f}{-1} = \frac{-\vec{v}_i}{-1}$

$\rightarrow -\vec{a}t + \vec{v}_f = \vec{v}_i$

$\vec{v}_i = (-1.5 \times 10^4 \frac{m}{s^2})(25 \text{ s}) + 3.0 \times 10^6 \frac{m}{s}$

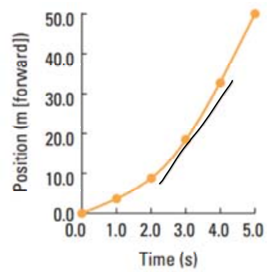
$\boxed{\vec{v}_i = 2.6 \times 10^6 \text{ m/s [forward]}}$

Dec 15-11:28 AM

Displacement vs. Time Graphs and Acceleration

It's not easy to find acceleration on a displacement-time graph. However, we can look at how velocities are changing to get a feel for acceleration.

A curve on a displacement-time graph indicates acceleration.

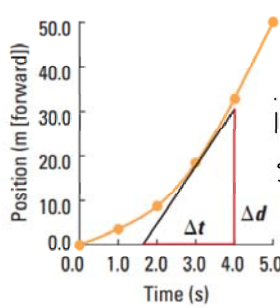


To find velocity, we need to draw a tangent line.

slope
on displacement-time

Dec 15-11:38 AM

A tangent touches a curve at one point. The slope of the tangent line will give velocity.

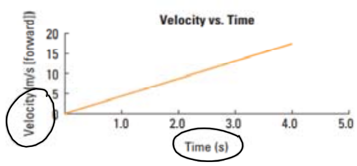


instantaneous velocity
since $\vec{v}$ is changing

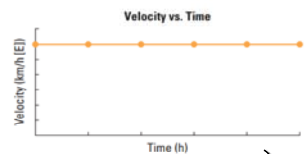
Dec 15-11:50 AM

Velocity vs. Time Graphs and Acceleration

Acceleration is the slope on a velocity-time graph.



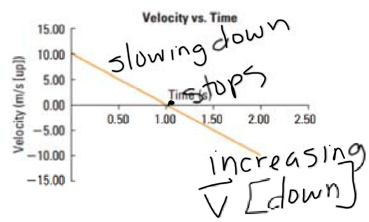
$m = \frac{m/s}{s} = m/s^2 = \vec{a}$



constant $\vec{v}$

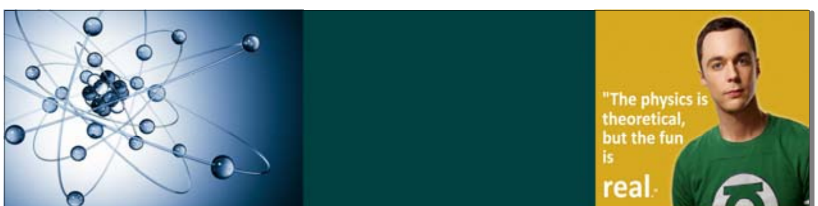
uniform motion

$\vec{a} = 0$



object thrown in the air

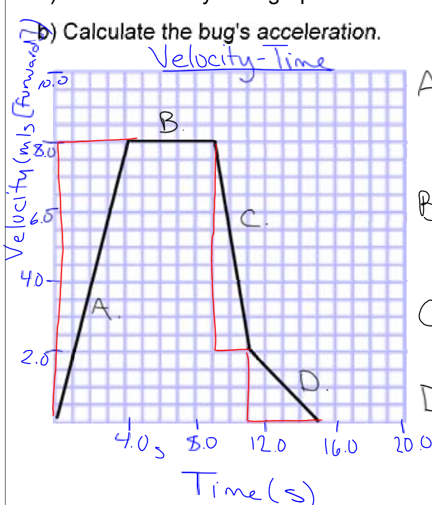
Dec 15-11:52 AM



Ex.) A bug, starting from rest, increases his speed to 8.0 m/s forwards in 4.0 s. He continues at this speed for 5.0 s, then slows down to 2.0 m/s in 2.0 s. Finally, he comes to a stop in 4.0 s.

a) Draw a velocity-time graph to model the situation.

b) Calculate the bug's acceleration.



A. $\vec{a} = \frac{\Delta v}{\Delta t} = \frac{8.0 m/s}{4.0 s} = \boxed{2.0 m/s^2}$

B. $\vec{a} = \boxed{0 m/s^2}$

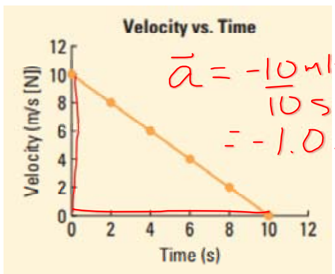
C. $\vec{a} = \frac{-6.0 m/s}{2.0 s} = \boxed{-3.0 m/s^2}$

D. $\vec{a} = \frac{-2.0 m/s}{4.0 s} = \boxed{-0.50 m/s^2}$

Dec 15-11:55 AM

Ex.) Use words to describe the motion of the objects in the following graphs:

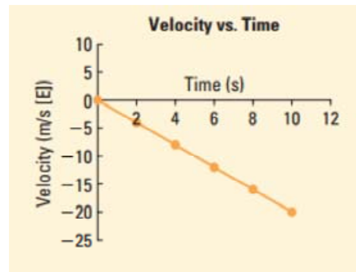
a)



$\vec{a} = \frac{-10\ m/s}{10\ s}$
$= -1.0\ m/s^2$

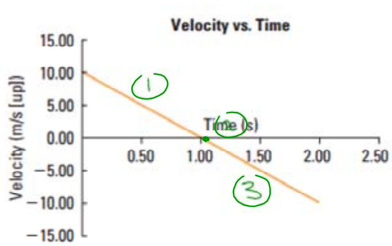
· Object slowing down ($\vec{a} = -1.0\ m/s^2$)
· non-uniform motion

b)



· Object accelerating [W]
· non-uniform motion

c)

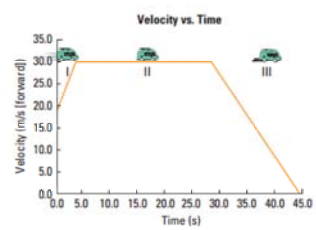


(1) negative $\vec{a}$, object slows down, non-uniform

(2) object stops & changes direction

(3) positive $\vec{a}$ but [down], speeding up, non-uniform

d)



(I) positive $\vec{a}$, van speeding up, non-uniform motion

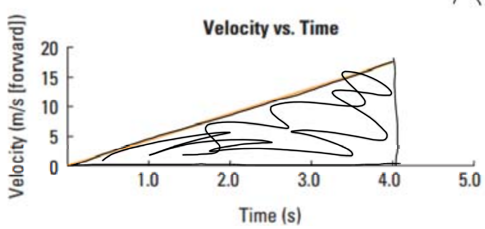
(II) $\vec{a} = 0$, uniform motion, constant $\vec{v}$, van on cruise

(III) van slows down ($\vec{a}$ neg.) & comes to a stop

*Note: We only deal with straight lines on Velocity-Time Graphs in Physics 20.

Finding Displacement from a Velocity-Time Graph

A concept from Calculus, finding the area under a curve, can be used in Physics to find displacement from a Velocity-Time Graph. Let's look at the unit analysis to see why:



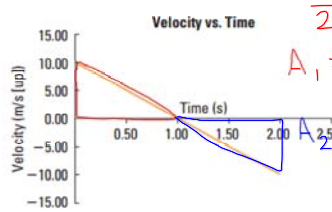
$$A = \frac{bh}{2} = \frac{\cancel{s} \cdot \frac{m}{\cancel{s}}}{2} = m$$

$$= \frac{(4.0s)(15m/s)}{2} = \boxed{30m\,[F]}$$

Dec 16-8:38 AM

Concept Check

For the velocity-time graph of a ball thrown up in the air (Figure 1.44), what is the net displacement of the ball?



▲ Figure 1.44

$$A = \frac{bh}{2} = \frac{(1.00s)(10.00m/s)}{2}$$

$A_1 = 5.0\,m$ [up]

$$A_2 = \frac{bh}{2} = \frac{(1.00s)(-10.00\,m/s)}{2}$$

$A_2 = -5.0m$
$= 5.0m$ [down]

$A_{net} = A_1 + A_2 = +5.0m + -5.0m = \boxed{0m}$

Read Pg. 31 - 40.

Pg. 30 # 1 - 3.

Dec 16-8:48 AM