Phys 131 2022

Lecture 5

Thurs: Discussion /quiz

Ex 22, 24, 26, 28, 30, 32, 37, 40

* Do before class
* Discuss in class
* One question in quiz (5pts)

Fri: Group exercise – same groups as last week

– WILL BE GRADED (5pts)

The average acceleration of an object over a time interval Δt is

$$\bar{a} = \frac{\Delta v}{\Delta t} \sim \text{rate of change of velocity}$$

A special case is motion where the average acceleration is the same regardless of the time interval. This is motion with constant acceleration.

Here we replace $\bar{a} \to a$ and get

For motion with constant acceleration

$$a = \frac{\Delta v}{\Delta t}$$

and

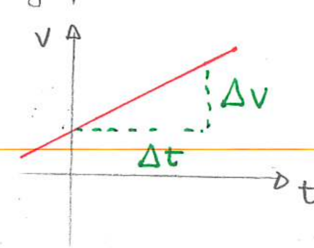
$$\Delta v = a \Delta t$$

→

For motion with constant acceleration, a graph of v vs t

1) is a straight line
2) has

$$\boxed{a = \text{slope of } v \text{ vs } t}$$



Instantaneous acceleration

We can use the same conceptual framework to arrive at a definition of acceleration. We develop the framework as:

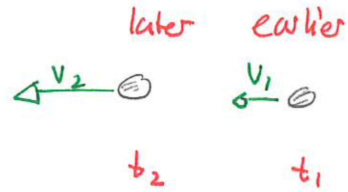
Conceptual idea

Acceleration = rate of change of velocity

Preliminary definition

Observe object at two instants and then the average acceleration over the interval is

$$\bar{a} = \frac{\Delta v}{\Delta t} = \frac{v_2 - v_1}{t_2 - t_1}$$



Exact definition

(Instantaneous) acceleration determined by letting $\Delta t \to 0$

$$a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt}$$

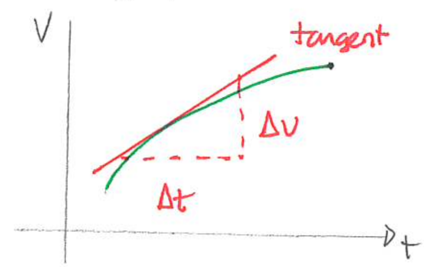
Calculation via

Given formula for v vs t

⇓

calculus

Given graph of v vs t



Acceleration = slope of v vs t graph

Quiz 1 30% → 90% } 20% − 60%

Quiz 2 50% − 90% } 30% → 70%

Motion with constant acceleration

In many situations of one-dimensional motion the acceleration is constant. We can then attempt to relate parameters for the motion at two instants.

	earlier (initial)	later (final)
time	$t = 0\,s$	t
position	x_0	x
velocity	v_0	v

For example:

Known initial data
position x_0
velocity v_0

Physics predicts
constant acceleration
a

Want information at a later time
position x
velocity v

This process can work in reverse and also with mixtures of initial and final data. We now ask how to relate the quantities. For example is

$$\Delta x = x - x_0 \overset{??}{=} v \Delta t$$

Warm Up 1

Warm Up 2

In general these are connected via the <u>kinematic equations</u>:

> If an object moving in one direction has constant acceleration, a, then with the variables as listed above:
>
> $$v = v_0 + at$$
>
> $$x = x_0 + v_0 t + \frac{1}{2} a t^2$$
>
> $$v^2 = v_0^2 + 2a\,\Delta x$$

These arise using

$$a = \frac{\Delta v}{\Delta t} \quad \text{and} \quad \Delta x = \text{area under } v \text{ vs } t$$

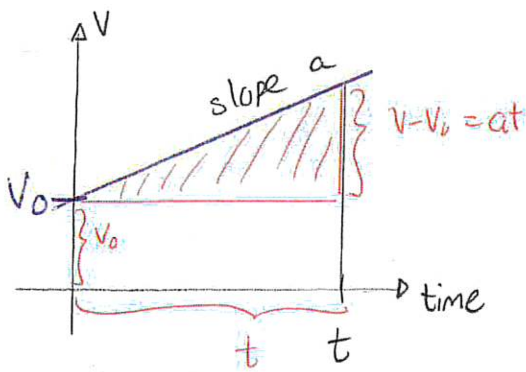
To see this:

1) For constant acceleration, $a = \frac{\Delta V}{\Delta t}$

$$\Rightarrow \Delta V = a \Delta t$$

$$\Rightarrow V - V_0 = a(t-0) \Rightarrow V = V_0 + at$$

2) The graph of V vs t is a straight line. If $a>0$ and $V_0>0$



$$\Delta x = \text{area under } V \text{ vs } t$$

$$= \text{area rectangle} + \text{area triangle}$$

$$= V_0 t + \frac{1}{2}(at)t$$

$$\Rightarrow X - X_0 = V_0 t + \frac{1}{2} a t^2$$

$$\Rightarrow X = X_0 + V_0 t + \frac{1}{2} a t^2$$

3) eliminate t using $\frac{V - V_0}{a} = t$. Then

$$(X - X_0) = V_0 \left(\frac{V-V_0}{a}\right) + \frac{1}{2} a \left(\frac{V-V_0}{a}\right)^2 = \frac{V_0(V-V_0)}{a} + \frac{1}{2a}(V-V_0)^2$$

$$\Rightarrow 2a(X-X_0) = 2V_0(V-V_0) + (V-V_0)^2 = (V-V_0)\left[2V_0 + V - V_0\right]$$

$$= (V-V_0)(V+V_0)$$

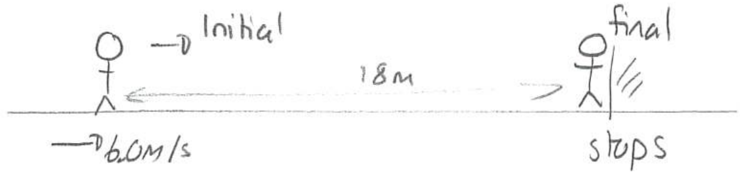
$$= V^2 - V_0^2$$

$$\Rightarrow V^2 = V_0^2 + 2a(X-X_0)$$

35 Avoid the wall!

A skateboarder slides toward a wall. Initially the skateboarder is 18 m left of the wall and moving with speed 6.0 m/s to the right. The aim of this exercise will be to determine the minimum acceleration to barely avoid hitting the wall. *(131Sp2023)*

a) Sketch the situation, illustrating the skateboarder at the initial instant and the instant just before reaching the wall.



List all relevant variables for the two instants:

$t_0 =$ 0s	$t =$
$x_0 =$ 0m	$x =$ 18m
$v_0 =$ 6.0m/s	$v =$ 0m/s.

b) Determine the acceleration by selecting one of the kinematic equations, substituting and solving for a.

$$v^2 = v_0^2 + 2a(x - x_0)$$

$$\Rightarrow \frac{v^2 - v_0^2}{2(x - x_0)} = a \Rightarrow a = \frac{(0\,\text{m/s})^2 - (6.0\,\text{m/s})^2}{2 \times 18\,\text{m}} = -1.0\,\text{m/s}^2$$

c) Use one of the kinematic equations to determine the time that it takes for the skateboarder to reach the wall.

$$v = v_0 + at \Rightarrow \frac{v - v_0}{a} = t \Rightarrow t = \frac{0\,\text{m/s} - 6\,\text{m/s}}{-1\,\text{m/s}^2} = 6\,\text{s}$$

d) Would the equation

$$v = \frac{\Delta x}{\Delta t} \quad \Rightarrow \quad 6.0\,\text{m/s} = \frac{18\,\text{m}}{\Delta t}$$

allow one to find the time taken to reach the wall correctly? Why or why not?

No, it would give 3s.

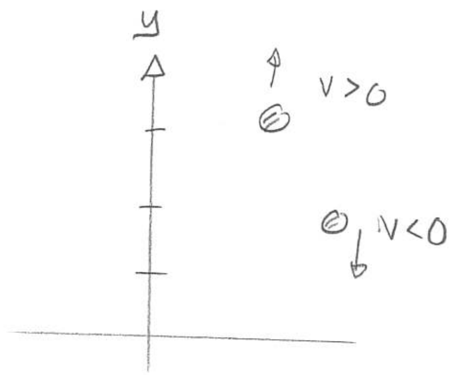
e) Set up the moving man animation at:

`http://phet.colorado.edu/en/simulation/moving-man`

and run this to check your prediction. In order to verify that you have done this, use the animation to provide the times at which the man is 10 m to the left of the wall.

Free fall motion

Now consider an object that moves vertically. This is also motion in one dimension. We use



1) position variable : y

2) velocity $V > 0 \Rightarrow$ Moves up
$V < 0 \Rightarrow$ Moves down.

One example of such motion is free fall. Free fall is motion only under Earth's gravitational field. We want to know:

1) does this motion depend on the mass of the object

2) does the object accelerate? Is the acceleration constant.

Demo: Guinea/feather demo