Phys 131 2024

Lecture 5

GROUP EXERCISE

Fri: HW by 5pm

THURS: Seminar

EX 51, 53, 55, 56, 57, 58, 59, 61

Mon: Warm Up 3 (p24)

Acceleration

Acceleration quantifies the rate at which velocity changes. The framework is:

Conceptual Idea

Acceleration ~ rate of change of velocity

Preliminary definition

Observe object at two instants. The average acceleration over the interval between the instants is

$$a_{avg} = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i}$$

	later	earlier
		
	v_f	v_i
time	t_f	t_i
velocity	v_f	v_i

Exact definition

(Instantaneous) acceleration is the limit of average acceleration over a very small interval

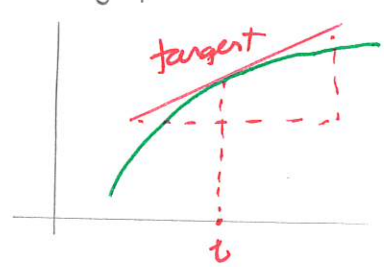
$$a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt}$$

Calculation

Given formula for v versus t

calculus

Given graph of v versus t



acceleration = slope of tangent of v vs t

Quiz 1 - 70% - 90% } 50% - 50%

Quiz 2 90% } 40% - 96%

Quiz 3 90% } 80%

Motion with constant acceleration

We will often consider a situation where the acceleration of an object is constant. We can relate kinematical quantities (position, velocity) at an earlier moment to a later moment. One version of this is:

	initial (earlier)	final (later)
time	t_i	t_f
position	x_i	x_f
velocity	v_i	v_f

Known initial situation
position x_i
velocity v_i

Physics states acceleration is constant and gives value a

Want information at a later time
position x_f
velocity v_f

The process can also work:

* in reverse – know final data want initial
* in mixed situations – have some final + initial data want rest

Let the time elapsed be

$$\Delta t = t_f - t_i$$

We want to know is $\Delta x \overset{??}{=} v \Delta t$

Warm, Up 1

Warm Up 2

In general these quantities are related by the kinematic equations

> If an object moving along one dimension has constant acceleration, then
>
> $$v_f = v_i + a\Delta t$$
>
> $$x_f = x_i + v_i \Delta t + \frac{1}{2} a \Delta t^2$$
>
> $$v_f^2 = v_i^2 + 2a\Delta x = v_i^2 + 2a(x_f - x_i)$$

Proofs: First, consider $v_f = v_i + a\Delta t$.

If the acceleration is constant then $a = \frac{\Delta v}{\Delta t}$

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

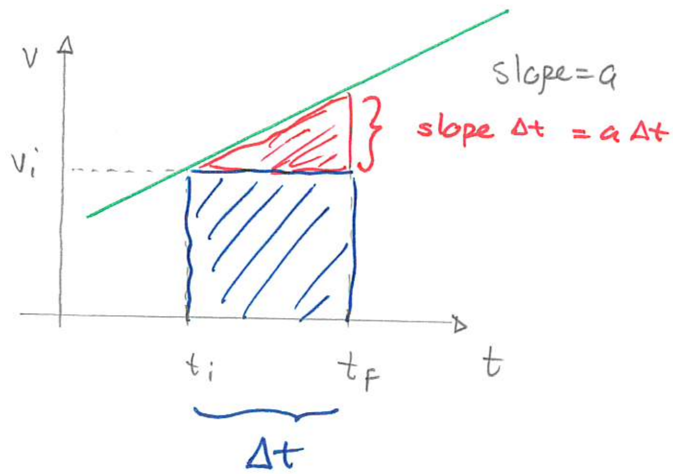
$$\Rightarrow v_f - v_i = a\Delta t \Rightarrow v_f = v_i + a\Delta t \checkmark\checkmark$$

Second, consider $x_f = x_i + \ldots$ We can use a graphical proof

Then Δx = area under v vs t

= area blue rectangle

+ area triangle



Area blue rectangle $= v_i(t_f - t_i)$

$= v_i \Delta t$

Area red triangle $= \frac{1}{2} bh$

$$= \frac{1}{2}\Delta t(a\Delta t) = \frac{1}{2}a(\Delta t)^2$$

Thus $\Delta x = v_i\Delta t + \frac{1}{2}a(\Delta t)^2$

$$\Rightarrow x_f - x_i = v_i\Delta t + \frac{1}{2}a(\Delta t)^2 \Rightarrow x_f = x_i + v_i\Delta t + \frac{1}{2}a(\Delta t)^2 \checkmark\checkmark$$

Third $v_f^2 = v_i^2 \ldots$

From $v_f - v_i = a\Delta t \Rightarrow \Delta t = \frac{v_f - v_i}{a}$

Then $\Delta x = v_i\Delta t + \frac{1}{2}a(\Delta t)^2$

$$= v_i\left(\frac{v_f - v_i}{a}\right) + \frac{1}{2}a\frac{(v_f - v_i)^2}{a^2}$$

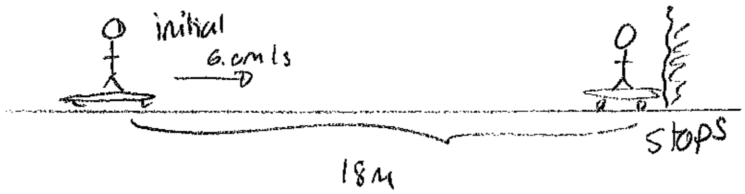
$$\Rightarrow a\Delta x = v_i(v_f - v_i) + \frac{1}{2}(v_f - v_i)^2$$

$$\Rightarrow 2a\Delta x = 2v_iv_f - 2v_i^2 + v_f^2 + v_i^2 - 2v_fv_i = v_f^2 - v_i^2 \checkmark\checkmark$$

49 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. *(131F2024)*

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:

$t_i =$ 0s	$t_f =$
$x_i =$ 0m	$x_f =$ 18m
$v_i =$ 6.0m/s	$v_f =$ 0m/s

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

$$v_f^2 = v_i^2 + 2a\Delta x$$

$$\frac{v_f^2 - v_i^2}{2\Delta x} = a \Rightarrow a = \frac{(0\,m/s)^2 - (6.0\,m/s)^2}{2 \times 18\,m}$$

$$= \frac{-36\,m^2/s^2}{36\,m} \Rightarrow a = -1.0\,m/s^2$$

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

$$v_f = v_i + a\Delta t \Rightarrow \frac{v_f - v_i}{a} = \Delta t \Rightarrow \Delta t = \frac{0\,m/s - 6.0\,m/s}{1.0\,m/s^2}$$

$$\Rightarrow \Delta t = 6.0s$$

d) Would the equation

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

not; it would give $\Delta t = 3.0s$

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

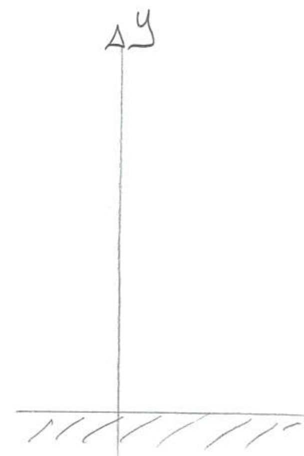
e) Set up the moving man animation at:

`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. We use:



1) position variable : y
2) velocity $v > 0 \Rightarrow$ moves up

   $v < 0 \Rightarrow$ moves down

An example of this is

Free fall $\Rightarrow$ vertical motion (up or down) only under the influence of Earth's gravity

We ask:

1) Does a freely falling object accelerate? If so is the acceleration constant?
2) Does the acceleration depend on the state of motion? Or the mass of the object.

Experiments indicate:

Acceleration (near Earth's surface) is constant and $a = -g$ where $g = 9.80\,m/s^2$

g ALWAYS positive