Phys 131 2025

Lecture 5

Fri: HW by 5pm

Ex: 40, 41, 42, 44, 47, 48, 52, 56

Group Exercise for credit 3pts

Mon: Warm Up 3 D2L

Fri: SPS noon

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 is

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

	later	earlier
time	t_f	t_i
velocity	v_f	v_i

(Close to) Exact definition: The (instantaneous) acceleration is the limit of average acceleration over a vanishingly small interval

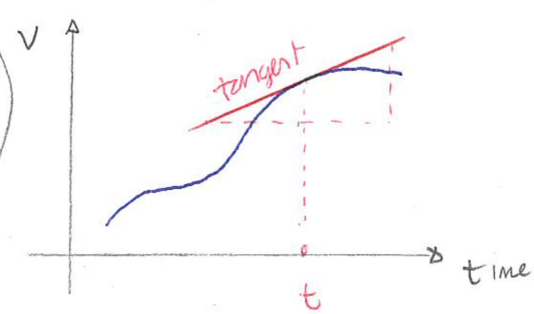
$$a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt}$$

units m/s^2

Given a formula for v vs t

acceleration = derivative of v w.r.t t

Given a graph of v vs t



acceleration = slope of tangent to v vs t

Quiz 1 30% – 70%

Quiz 2 60% — 100%

Quiz 3 85% – 90%

Quiz 4

Motion with constant acceleration

In many situations the acceleration of an object is constant. Examples include objects in free fall or objects sliding down a ramp. In these cases we can relate kinematical quantities at one moment to those at another.

For example

Suppose the details about the initial situation are known

t_i, x_i, v_i

Physics with provide acceleration

a

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

Want information at a later moment: x_f, v_f

The process can also:

* take information at a later instant and determine information at an earlier instant
* mix data from initial and final instants.

In general, only the elapsed time

$$\Delta t = t_f - t_i$$

matters

Quiz 5

In general $\Delta x \neq v_i \Delta t$. More correctly these quantities are related by the kinematic equations.

If an object moving in 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 $a = \frac{\Delta v}{\Delta t}$

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

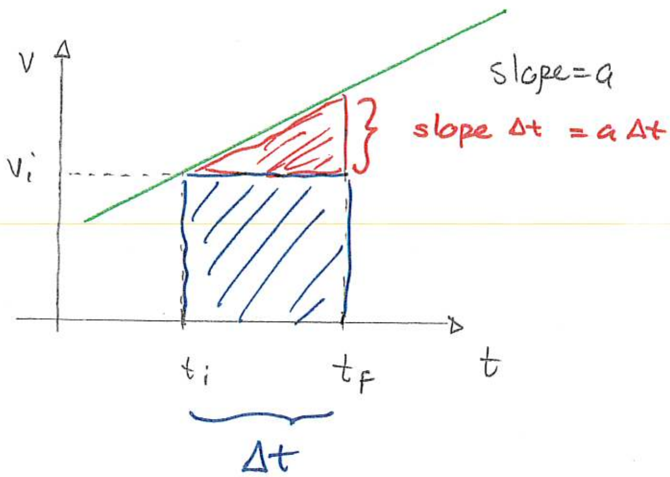
$$\Rightarrow v_f - v_i = a\Delta t \Rightarrow v_f = v_i + a\Delta t$$ ✓✓

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

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

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

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

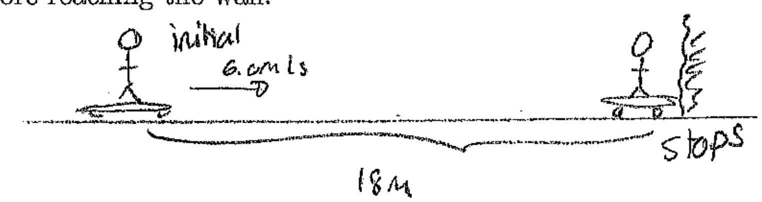
$$\Rightarrow a\Delta x = v_i(v_f - v_i) + \frac{1}{2}(v_f - v_i)^2$$

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

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.

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

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

d) Would the equation

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

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:

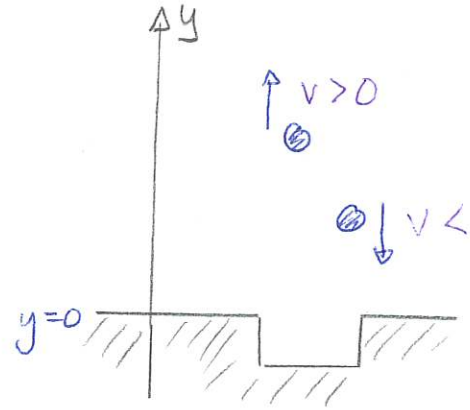
`http://phet.colorado.edu/en/simulation/moving-man`

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.

Vertical motion

Although we described kinematics for horizontal motion, the same system applies for vertical motion with these modifications:

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



The kinematic equations then apply with x replaced by y

Free fall

An example of vertical motion is

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

Longstanding questions about this are:

1) Does the motion depend on the mass of the object?
2) Does the object accelerate constantly or not?
3) Does the acceleration depend on the state of motion (up/down / faster/slower)?

DEMO: Free fall demo