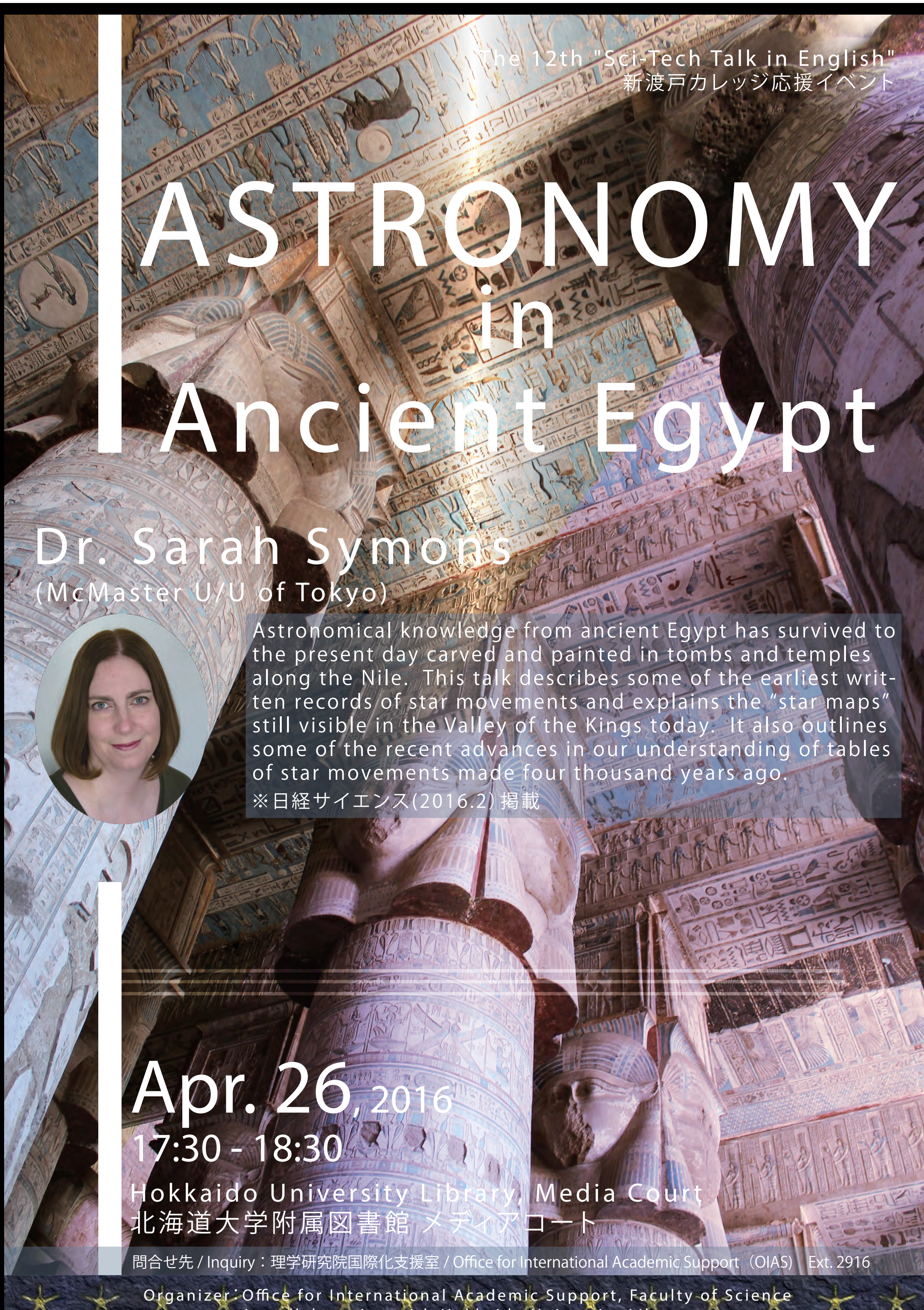
Essential Physics I

英語で物理学の

エッセンス I

Lecture 2: 25-04-16

News



Tomorrow!

Public science talk in English

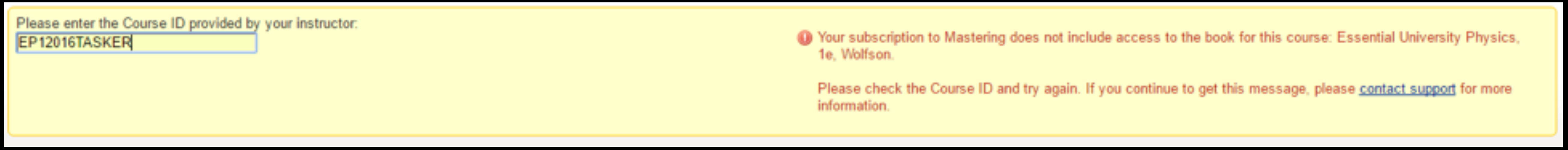
On star tables found in Egyptian coffins

Central library, media court
5:30 - 6:30 pm

http://www.sci.hokudai.ac.jp/international/project/sci-tech-talk/

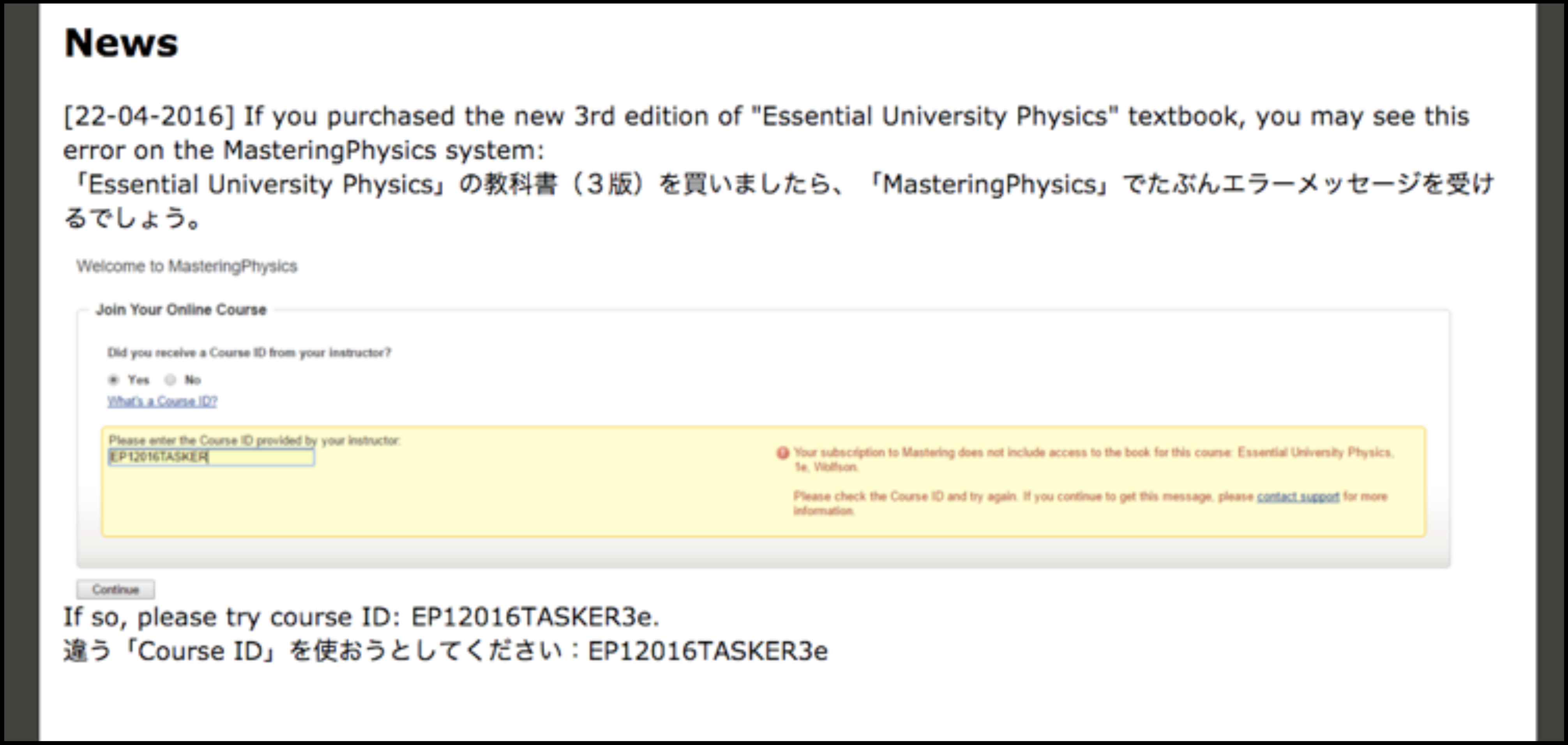
Course

If you see this…



Course ID: EP12016TASKER3e

(And check the webpage)



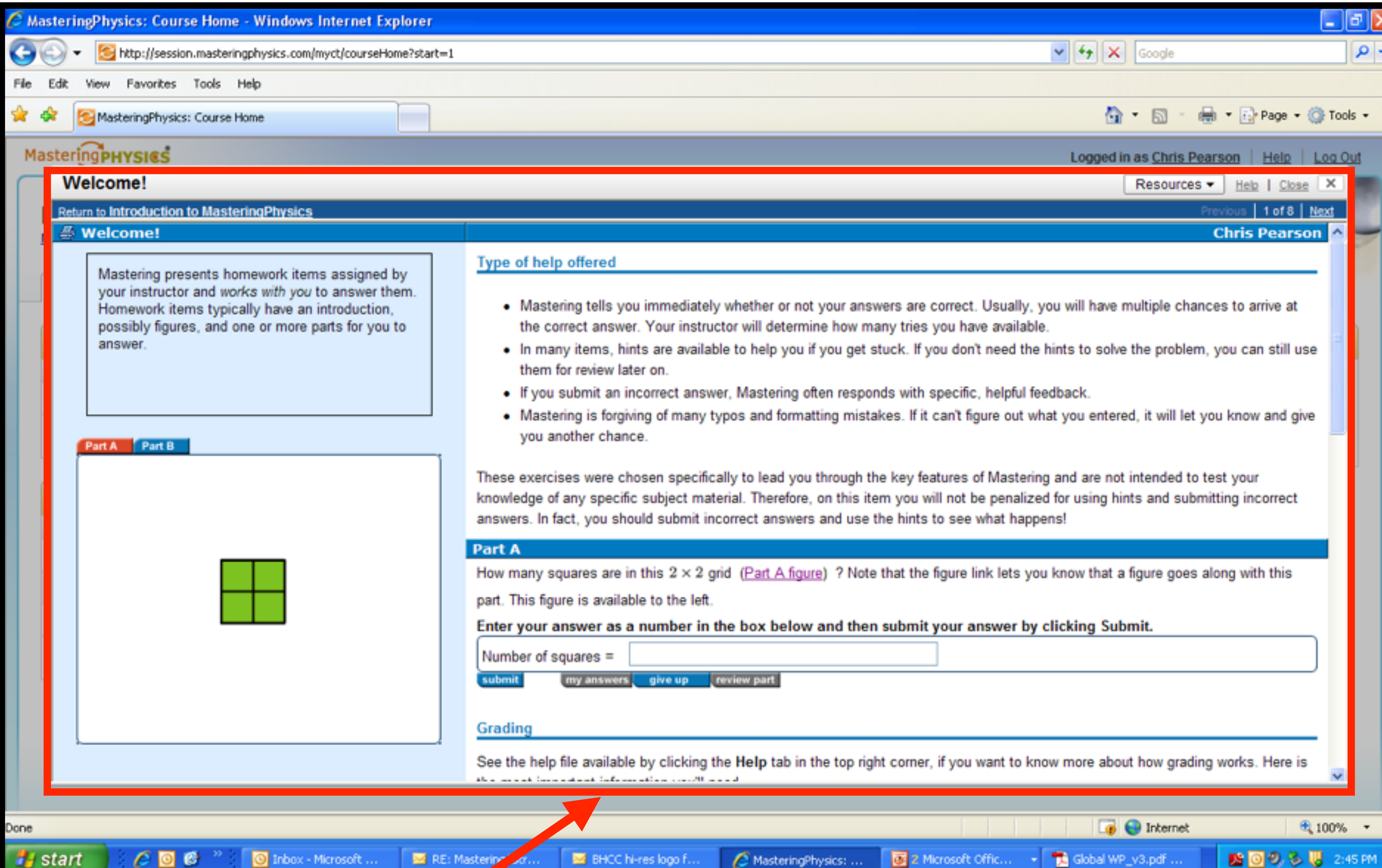
Course

On http://www.masteringphysics.com

If you see this error:

> You must configure your browser to allow popup windows for this site

Course



popup window

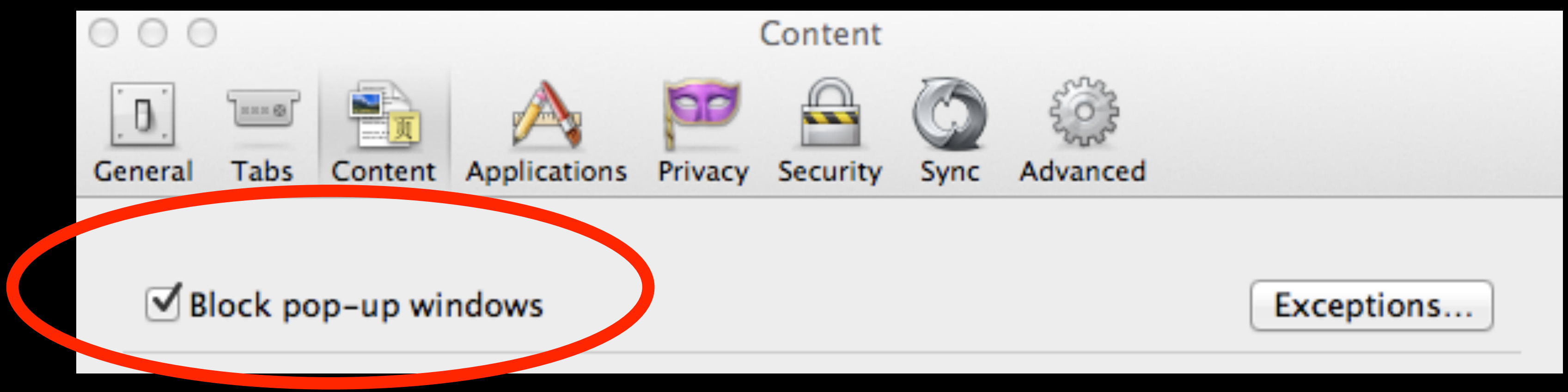
Course

On http://www.masteringphysics.com

If you see this error:

You must configure your browser to allow popup windows for this site

Look in your web browser's preferences

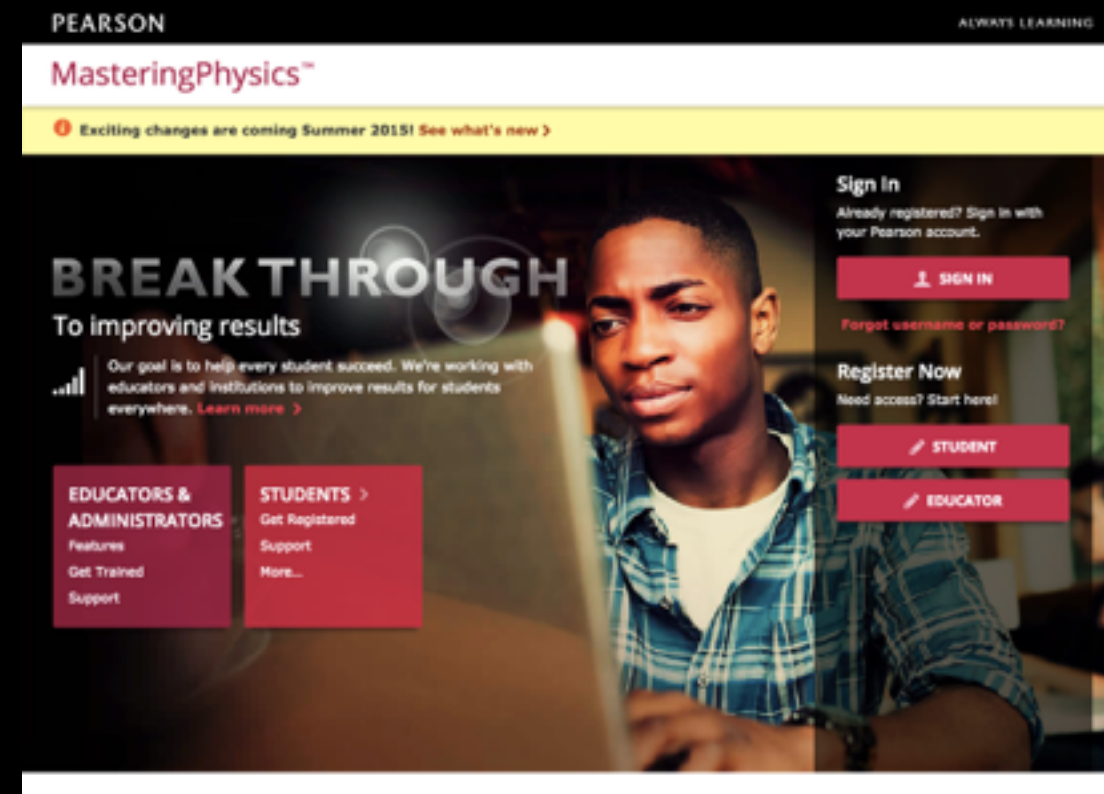


e.g. firefox

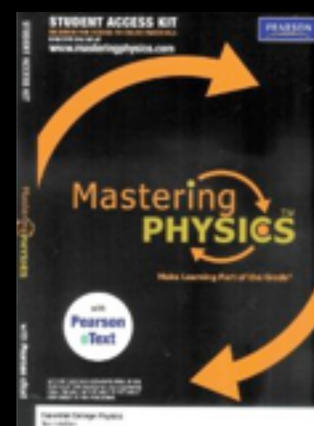
Course

Homework on

http://www.masteringphysics.com



Access code (from textbook) needed



Not here last week?

See me after class.

Course

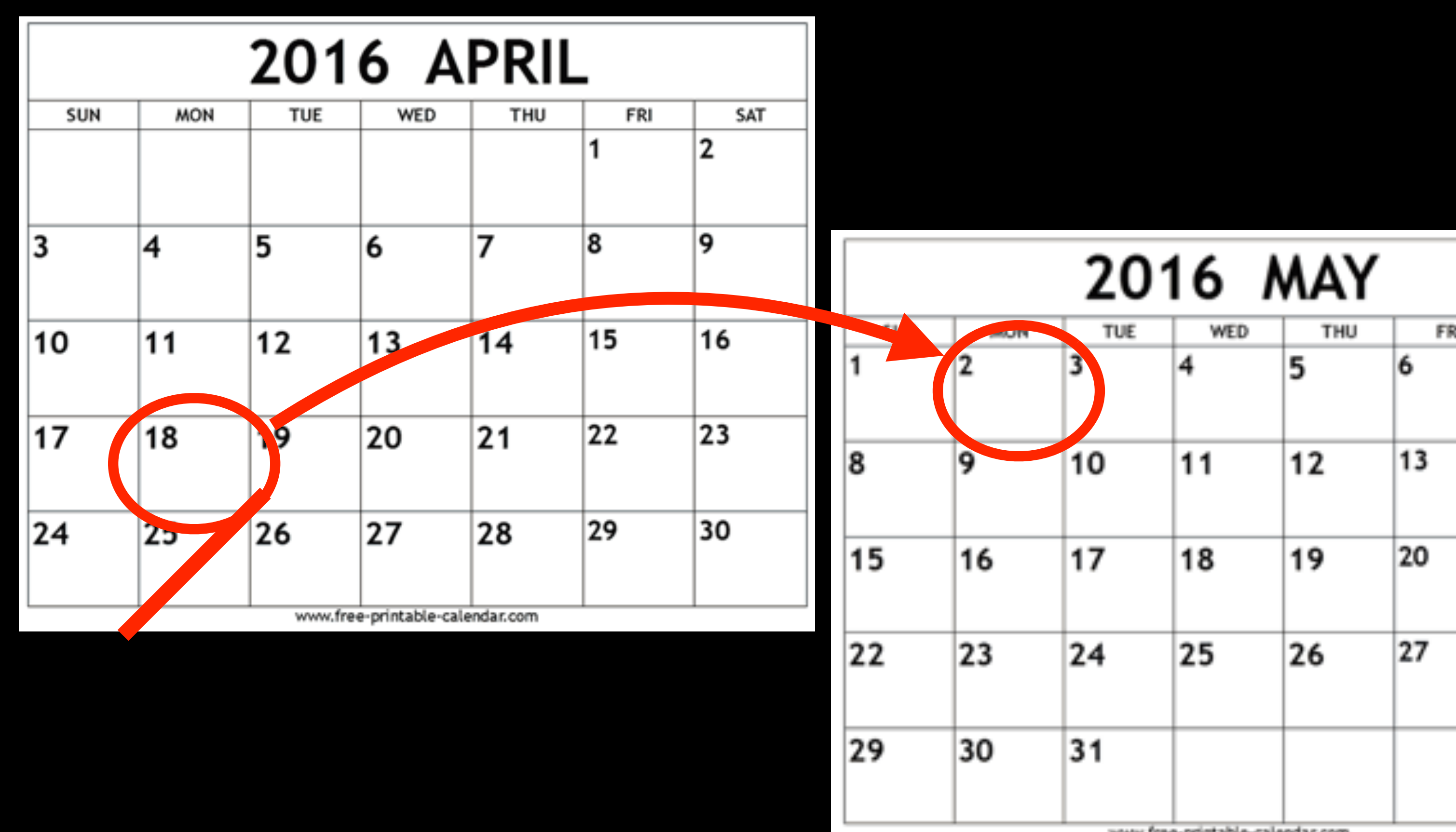
Usually,

Homework is due the following lecture.

(1 week)

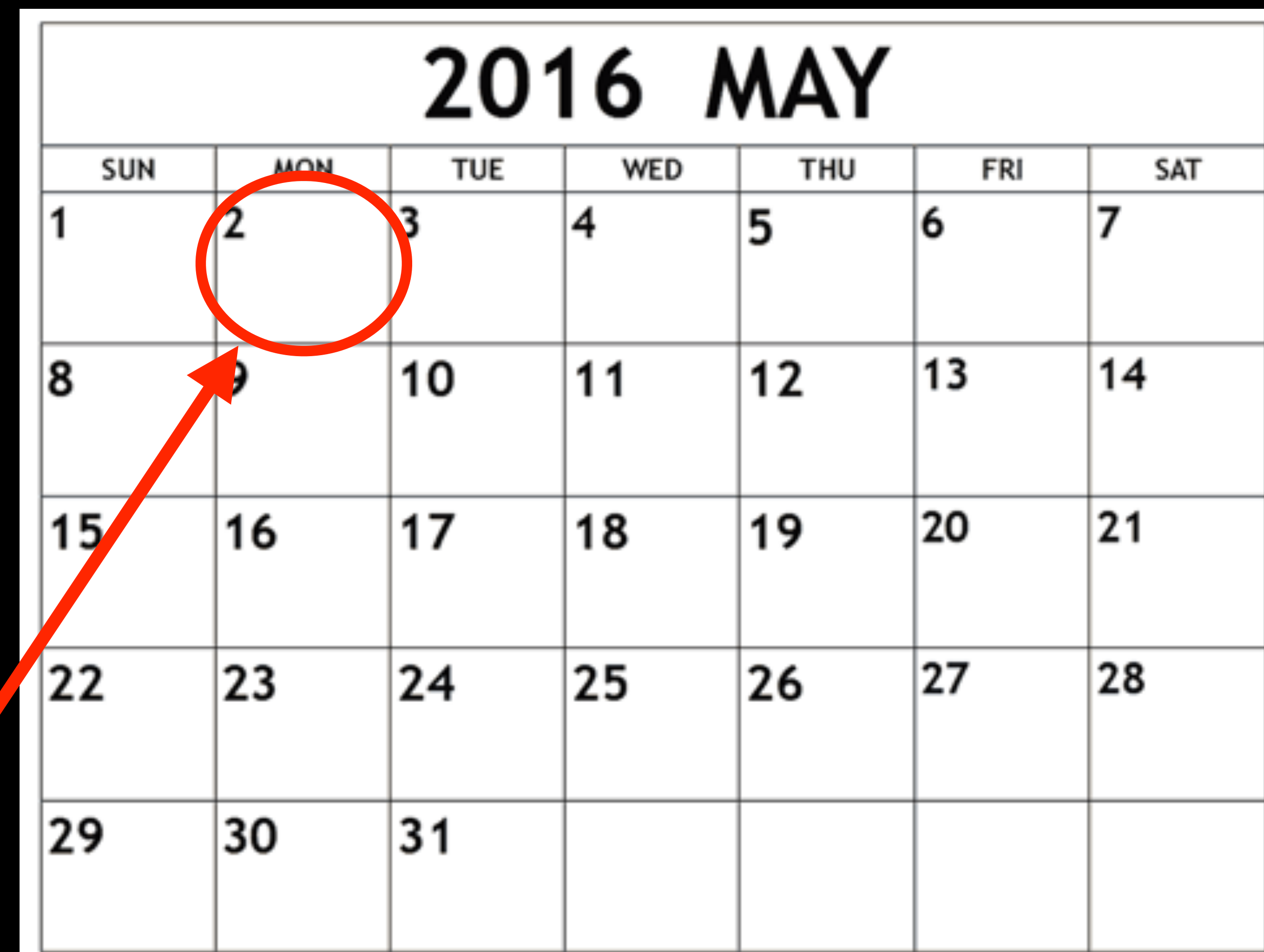
But, because last week was the 1st week...

1st homework is due 2016/05/02



Course

This week's homework is also due next lecture...



week 1 and week 2 homework due next week

来週に宿題１と宿題２を出してください。

This lecture

Units

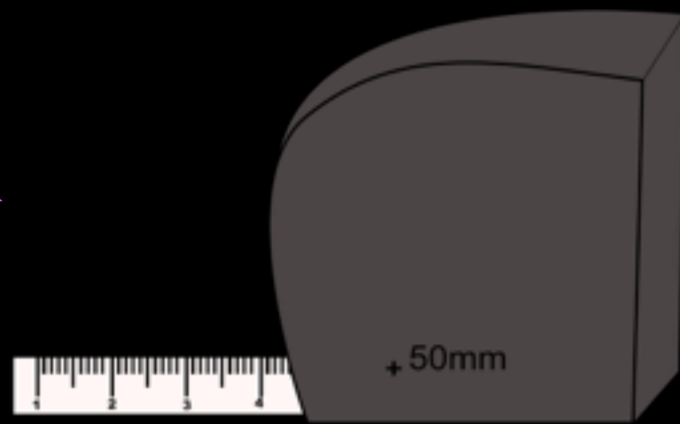
Motion in 1D

This lecture

- Know why units are important
- Convert (change) between units
- Use scientific notation for large and small numbers
- Understand the difference between speed and velocity
- Calculate average and instantaneous velocity and acceleration
- Use equations for constant acceleration

Units

K



s

m

kg

A

cm

Units

Why are units important?

If we don't use units... numbers have no meaning

e.g. This bomb will explode in…

Answer = 3

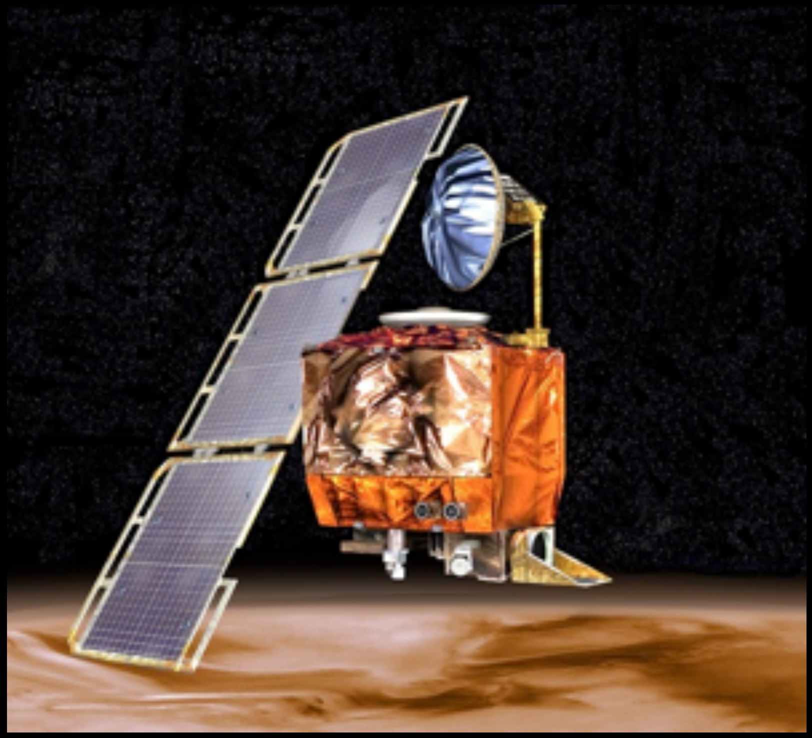
Answer = 3 seconds

and the wrong units can be a disaster!

Units

Why are units important?

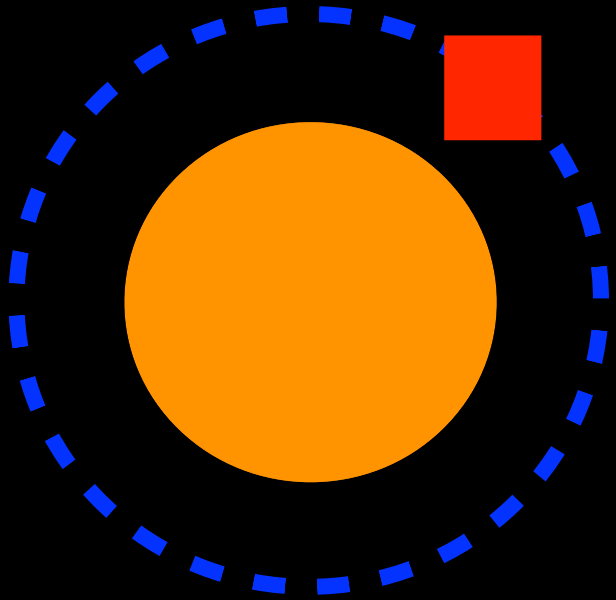
1998-12-11: NASA launched the 'The Mars Climate Orbiter'



Aim: Study Mars's climate while orbiting above the planet.

It travelled for 9 months...

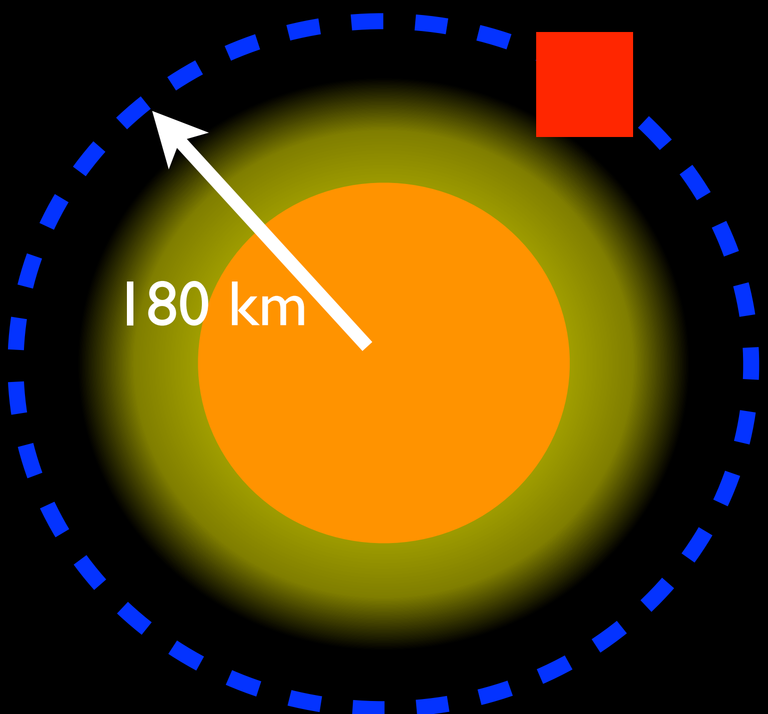
... travelled 415,000,000 miles to reach Mars.



Then, something went wrong....

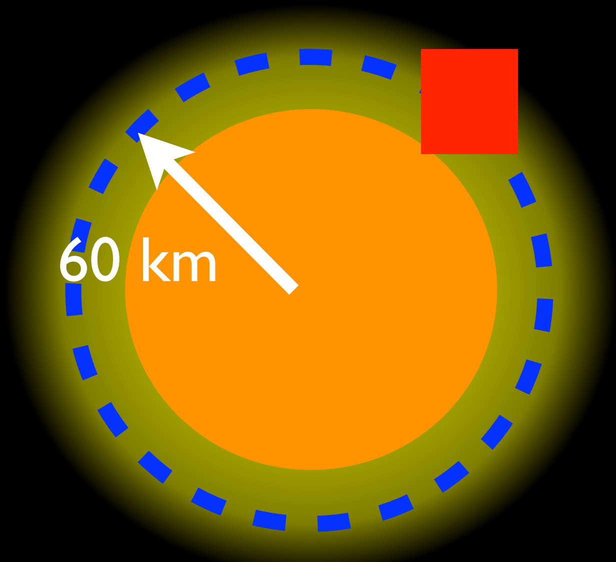
Units

Why are units important?



Instead of orbiting Mars at height of 180 km...

... it orbited at only 60 km ...



... and entered Mars's atmosphere ...

... which it wasn't built to do.

The spacecraft was burned & destroyed.

Units

Why are units important?

What went wrong?

The spacecraft's direction was changed by the force (F) from its engines.

The engineers measured this force in pounds (lb)

.... but the flight controllers measured the force in Newtons (N).

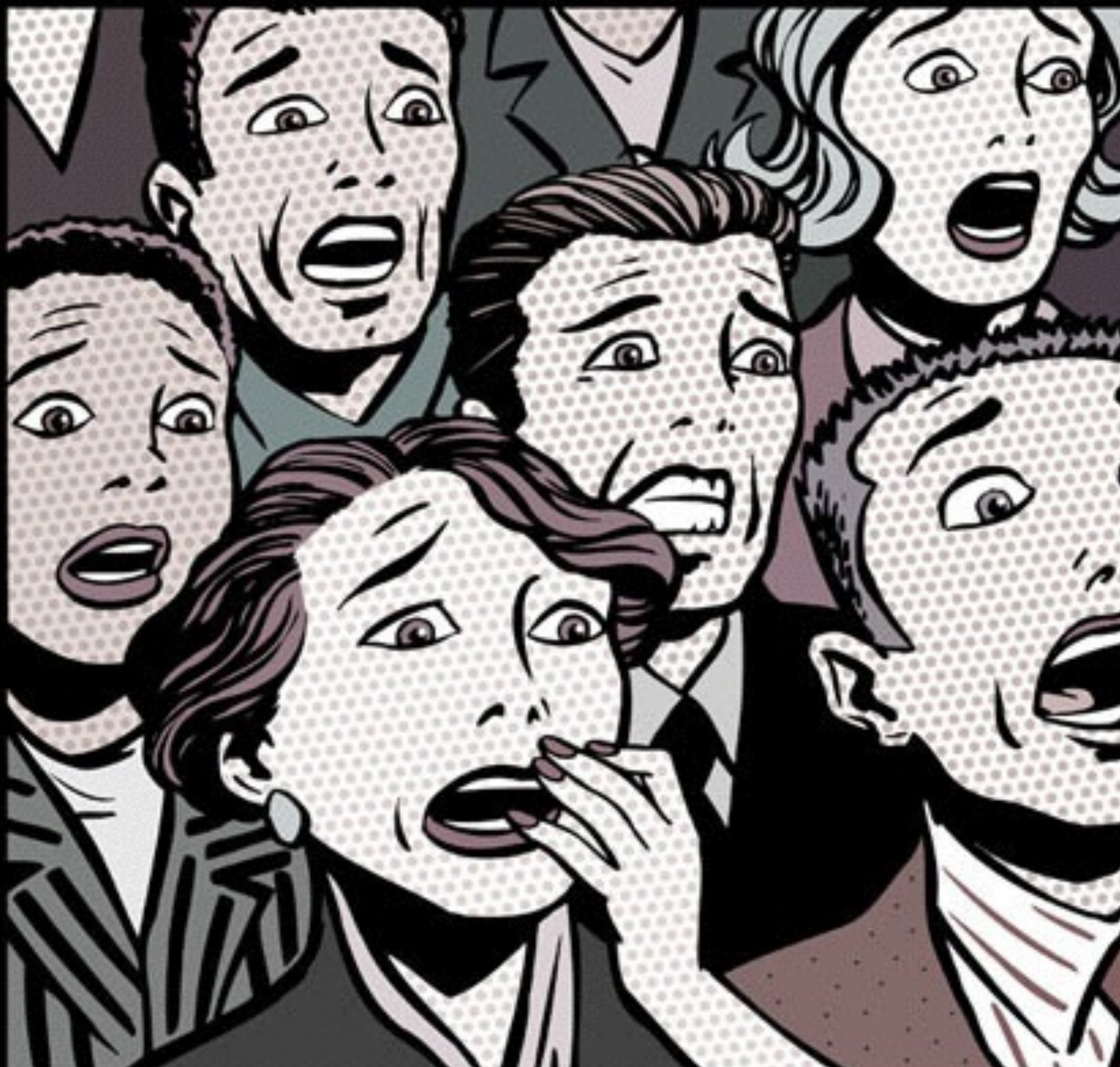
Since 1 lb = 4.45 Newtons, 4.45 x the correct force was used.

Units

W

What went

The spacec
force (F) fr



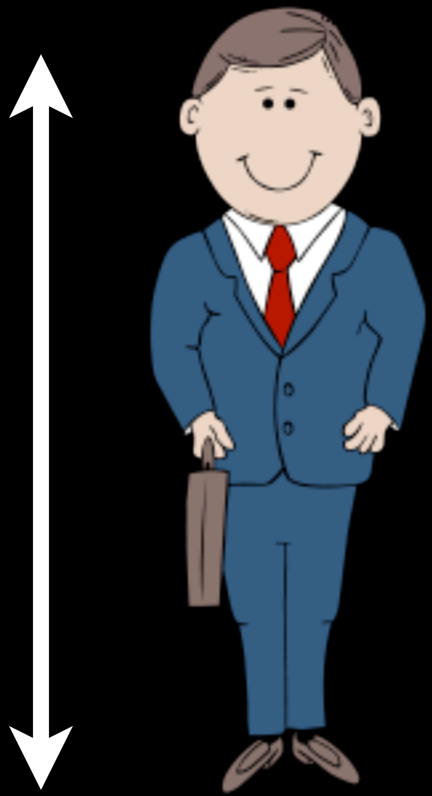
The engine

.... but the f ... tons (N).

Since 1 lb = 4.45 Newtons, 4.45 x the correct force was used.

Units

Average man's height in Japan | 67.4 inches



Tokyo Skytree | 634 metres

Units

Bacteria 2 micrometers

Average distance to the moon from Earth 238,855 miles

Whitney Mountain, USA 4418 metres

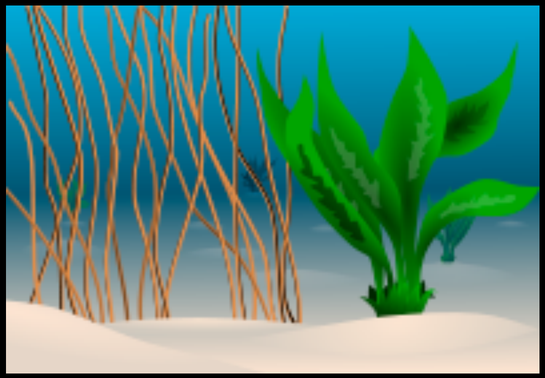
CN Tower, Toronto 1,815 feet

Radius of the Hydrogen atom 0.53 angstrom

Units

Mount Fuji 12,388 feet

Deepest point in the ocean 5966 fathom



Odori Park 1,640 yards

Units

Average man's height in Japan 67.4 inches

Tokyo Skytree 634 metres

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Deepest point in the ocean 5966 fathom

Odori Park 1,640 yards

Which is the 3rd tallest?

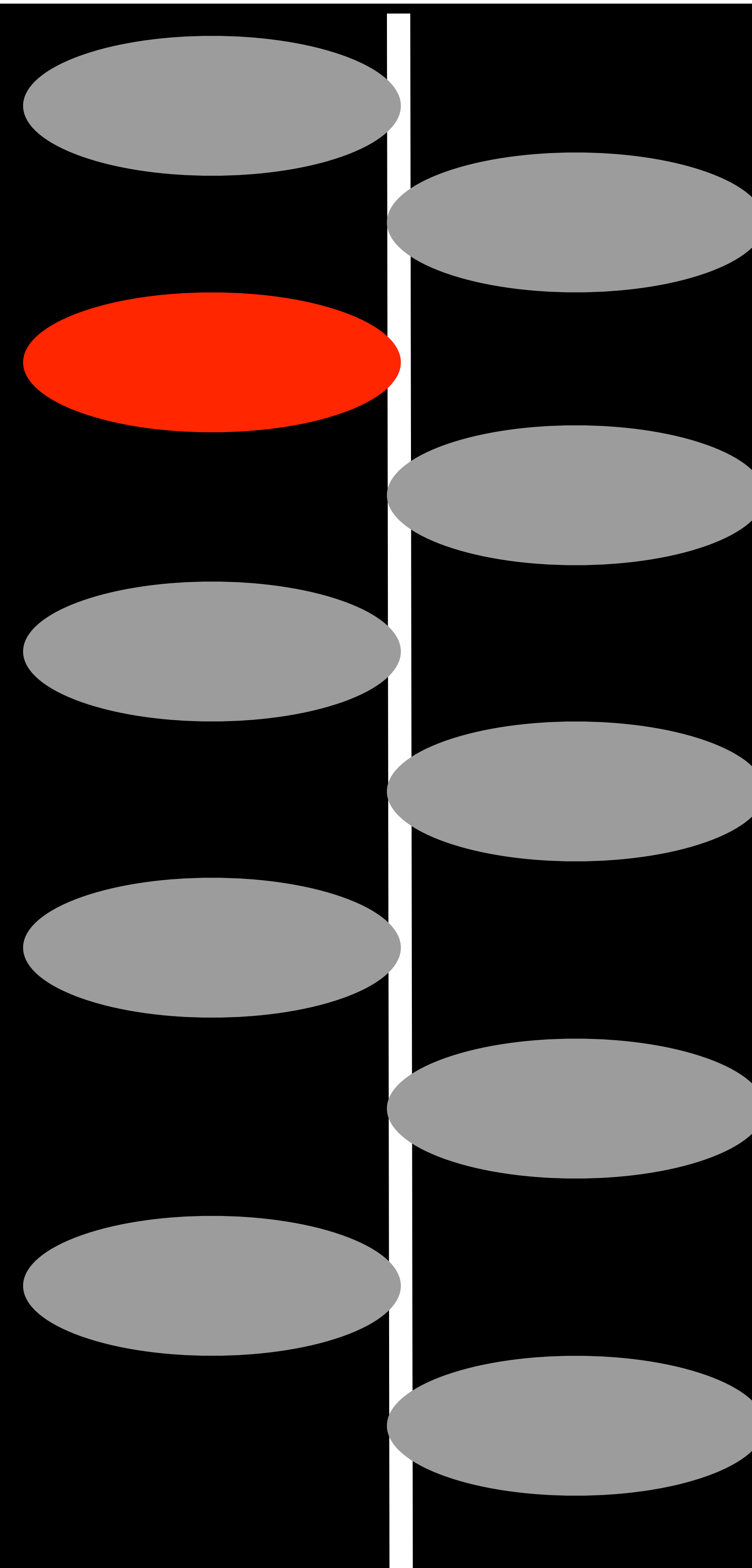
(A) Mount Fuji

(B) Deepest point in the ocean

(C) Tokyo Skytree

(D) Whitney Mountain

(E) Odori Park



Units

Average man's height in Japan 67.4 inches

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Average distance to the moon from Earth 238,855 miles

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Radius of the Hydrogen atom 0.53 angstrom

Mount Fuji 12,388 feet

Deepest point in the ocean 5966 fathom

Odori Park 1,640 yards

Units

Average distance to the moon from Earth	238,855 miles
Deepest point in the ocean	5966 fathom
Whitney Mountain, USA	4418 metres
Mount Fuji	12,388 feet
Odori Park	1,640 yards
Tokyo Skytree	634 metres
CN Tower, Toronto	1,815 feet
Average man's height in Japan	67.4 inches
Bacteria	2 micrometers
Radius of the Hydrogen atom	0.53 angstrom

Units Quiz

Which is the 3rd tallest?

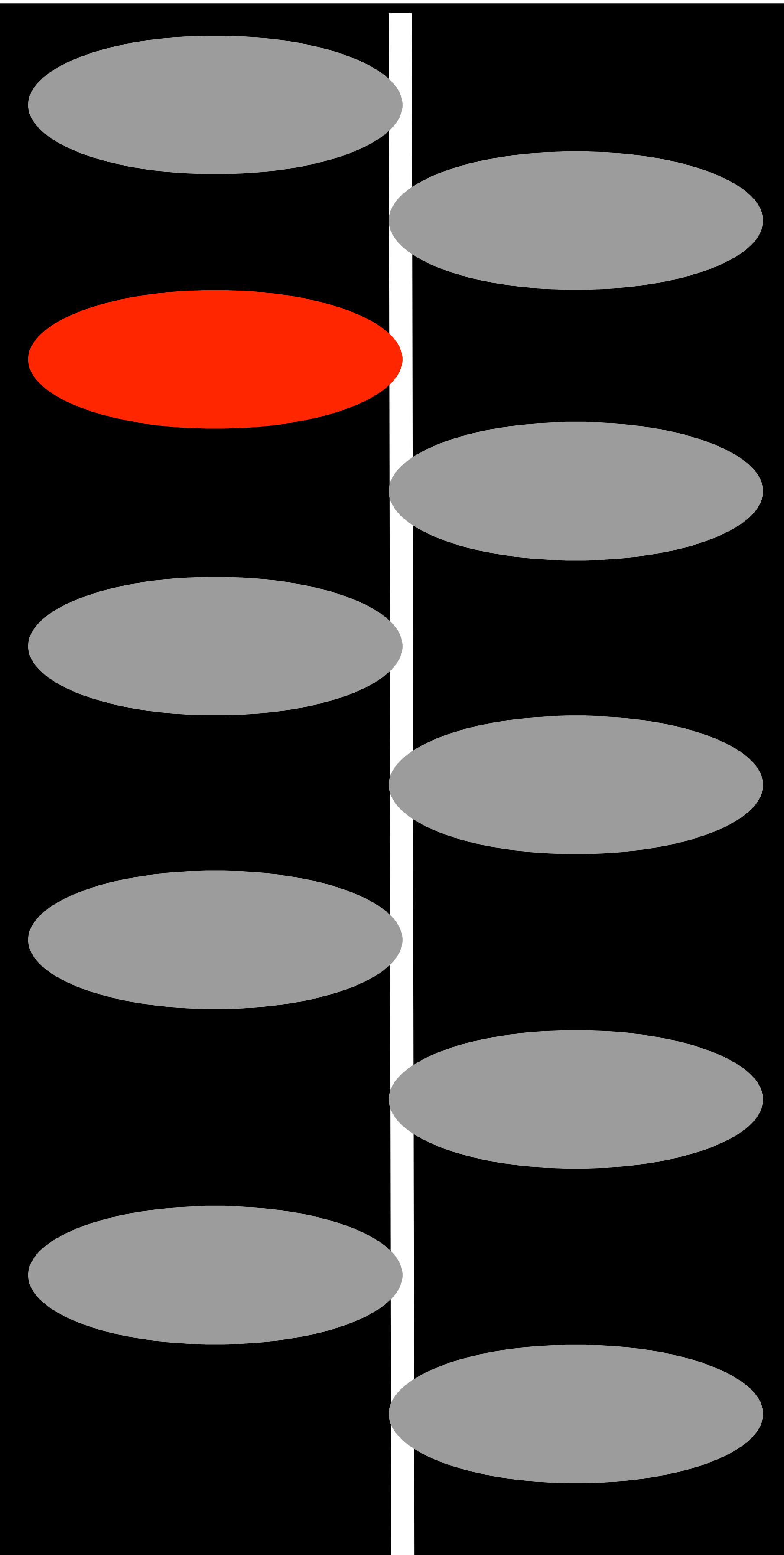
(A) Mount Fuji

(B) Deepest point in the ocean

(C) Tokyo Skytree

(D) Whitney Mountain

(E) Odori Park

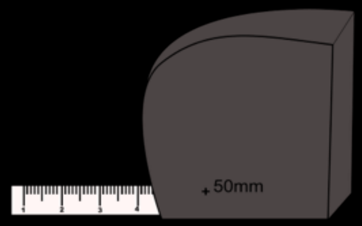


Units

MUCH easier if we all use the same units

The 'Systeme International d'Unites'
(International System of Units): SI

Length



metres [m]

Time

seconds [s]

Mass

kilograms [kg]

Temperature

kelvin [K]

Units

Average distance to the moon from Earth 238,855 miles

Deepest point in the ocean 5966 fathom

Whitney Mountain, USA 4418 metres

Mount Fuji 12,388 feet

Odori Park 1,640 yards

Tokyo Skytree 634 metres

CN Tower, Toronto 1,815 feet

Average man's height in Japan 67.4 inches

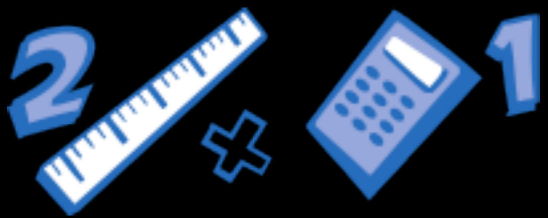
Bacteria 2 micrometers

Radius of the Hydrogen atom 0.53 angstrom

Units

Average distance to the moon from Earth	384,400,000 m
Deepest point in the ocean	10,911 m
Whitney Mountain, USA	4,418 m
Mount Fuji	3,776 m
Odori Park	1,500 m
Tokyo Skytree	634 m
CN Tower, Toronto	553 m
Average man's height in Japan	1.71 m
Bacteria	0.000002 m
Radius of the Hydrogen atom	0.000000000053 m

Units



Calculating units

Units can be calculated like algebra:

$$x = v \times t$$

distance = velocity x time

$\longrightarrow$ 80km/h

3h

$$= \left(\frac{80\text{km}}{\text{h}}\right) \times 3\text{h}$$

$$= 240 \quad ?$$

Units

Calculating units

Units can be calculated like algebra:

$$x = v \times t$$

distance = velocity x time

$\longrightarrow$ 80km/h

3h

$$= \left(\frac{80\text{km}}{\cancel{\text{h}}} \right) \times 3\cancel{\text{h}}$$

$$= 240 \ \text{km}$$

Units

Quiz

Calculating units

Calculate: $$a = \frac{v}{t}$$ for: $$v = 6\mathrm{m/s}$$ $$t = 3\mathrm{s}$$

(A) $a = 2\mathrm{m}$

(B) $a = 2\mathrm{m/s}^2$

(C) $a = 2\mathrm{m/s}$

(D) $a = 2\mathrm{s}$

$$a = \frac{6\,\mathrm{m/s}}{3\,\mathrm{s}}$$

$$= \frac{6}{3}\frac{\mathrm{m}}{\mathrm{s}\times\mathrm{s}} \qquad = 2\frac{\mathrm{m}}{\mathrm{s}^2}$$

Units — Quiz

Calculating units

Calculate: $E = \frac{1}{2}\mathrm{mv}^2$ for: $m = 10\mathrm{kg}$, $v = 2\mathrm{m/s}$

(A) $E = 20\,\mathrm{kg\,s}^2$

(B) $E = 20\,\mathrm{kg\,s}^2/\mathrm{m}^2$

(C) $E = 20\,\mathrm{kg\,m/s}$

(D) $E = 20\,\mathrm{kg\,m}^2/\mathrm{s}^2$

$$E = \frac{1}{2}\left(10\,\mathrm{kg}\right)\left(2\,\mathrm{m/s}\right)^2$$

$$= 20\,\frac{\mathrm{kgm}^2}{\mathrm{s}^2}$$

Also called the 'Joule' : J

Units

Changing units

$\longrightarrow 80\text{km/h}$

3h

$$x = v \times t = 240\,\text{km}$$

But what if we wanted miles?

$$1\text{mi} = 1.61\text{km}$$

$$\div 1.61\text{km}$$

$$\left(\frac{1\text{mi}}{1.61\text{km}}\right) = \left(\frac{1.61\text{km}}{1.61\text{km}}\right)$$

$$\left(\frac{1\text{mi}}{1.61\text{km}}\right) = 1$$

.... we can x 1 by anything

Units

Changing units

$$x = v \times t = 240\,\mathrm{km}$$

But what if we wanted miles?

$$x = v \times t$$

$$= \left(\frac{80\mathrm{km}}{\mathrm{h}}\right) \times 3\mathrm{h}$$

$$= 240\ \cancel{\mathrm{km}} \times \left(\frac{1\mathrm{mi}}{1.61\cancel{\mathrm{km}}}\right) = 1$$

Units

Changing units

$\longrightarrow$ 80km/h

3h

$$x = v \times t = 240\,\mathrm{km}$$

But what if we wanted miles?

$$x = v \times t$$

$$= \left(\frac{80\mathrm{km}}{\mathrm{h}}\right) \times 3\mathrm{h}$$

$$= 240\ \cancel{\mathrm{km}} \times \left(\frac{1\mathrm{mi}}{1.61\cancel{\mathrm{km}}}\right) = \left(\frac{240 \times 1\mathrm{mi}}{1.61}\right) = 149\ \mathrm{mi}$$

Units

Quiz

Changing units

Change 65 miles / hour to m / s

(A) $29\,\mathrm{m/s}$

(B) $104.65\,\mathrm{m/s}$

(C) $40.4\,\mathrm{m/s}$

(D) $1.74\,\mathrm{m/s}$

$1\,\mathrm{mile} = 1.61\,\mathrm{km}$

Changing units

Change 65 miles / hour to m / s

$$1\,\text{mile} = 1.61\,\text{km}$$

$\div\ 1\,\text{mile}$

$$\frac{1\,\text{mile}}{1\,\text{mile}} = \frac{1.61\,\text{km}}{1\,\text{mile}}$$

$$1 = \frac{1.61\,\text{km}}{1\,\text{mile}}$$

$$65\,\frac{\text{mile}}{\text{hour}} \times \left(\frac{1.61\,\text{km}}{1\,\text{mile}}\right) = 104.65\,\text{km}/\text{hour}$$

Changing units

Change 65 miles / hour to m / s

$$1\,\mathrm{km} = 1000\,\mathrm{m}$$

$$\frac{1\,\mathrm{km}}{1\,\mathrm{km}} = \frac{1000\,\mathrm{m}}{1\,\mathrm{km}} \qquad \div\, 1\,\mathrm{km}$$

$$1 = \frac{1000\,\mathrm{m}}{1\,\mathrm{km}}$$

$$104.65\,\frac{\cancel{\mathrm{km}}}{\mathrm{hour}} \times \left(\frac{1000\,\mathrm{m}}{1\,\cancel{\mathrm{km}}}\right) = 104650\,\mathrm{m/hour}$$

Changing units

Change 65 miles / hour to m / s

$$1\,\text{hour} = 3600\,\text{s}$$

$$\div\, 3600\text{s}$$

$$\frac{1\,\text{hour}}{3600\,\text{s}} = \frac{3600\,\text{s}}{3600\,\text{s}}$$

$$\frac{1\,\text{hour}}{3600\,\text{s}} = 1$$

$$104650\,\frac{\text{m}}{\text{hour}} \times \left(\frac{1\,\text{hour}}{3600\,\text{s}}\right) = 29\,\text{m/s}$$

Units

Scientific notation

But... if we use a single unit set, the numbers can get very big:

Radius of the observable Universe:

100,000,000,000,000,000,000,000,000 m

26 zeros

$$= 1 \times 10^{26}\mathrm{m}$$

or very small:

Size of a proton:

0.000000000000001 m

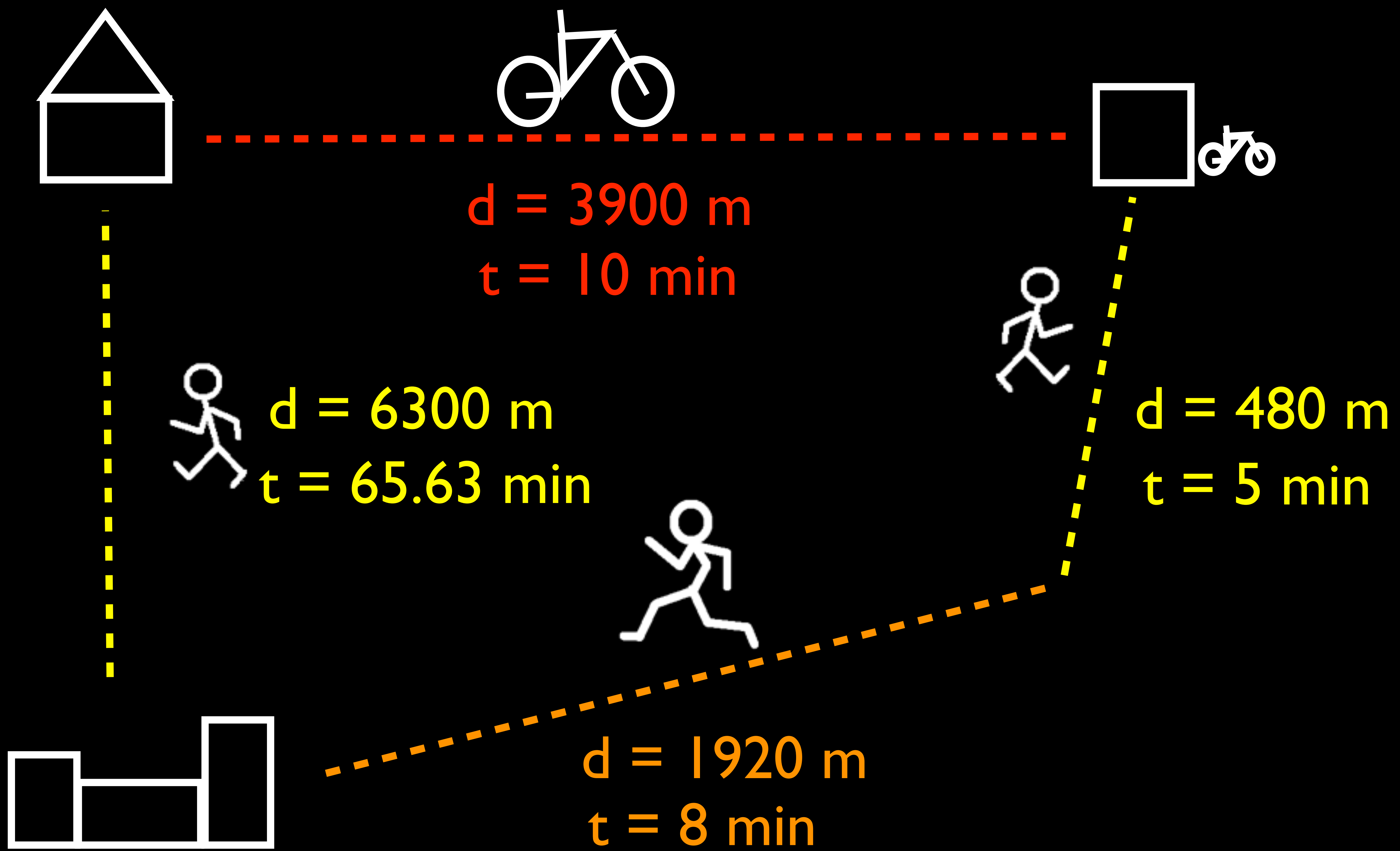
15 zeros

$$= 1 \times 10^{-15}\mathrm{m}$$

Motion in 1D

Motion in 1D

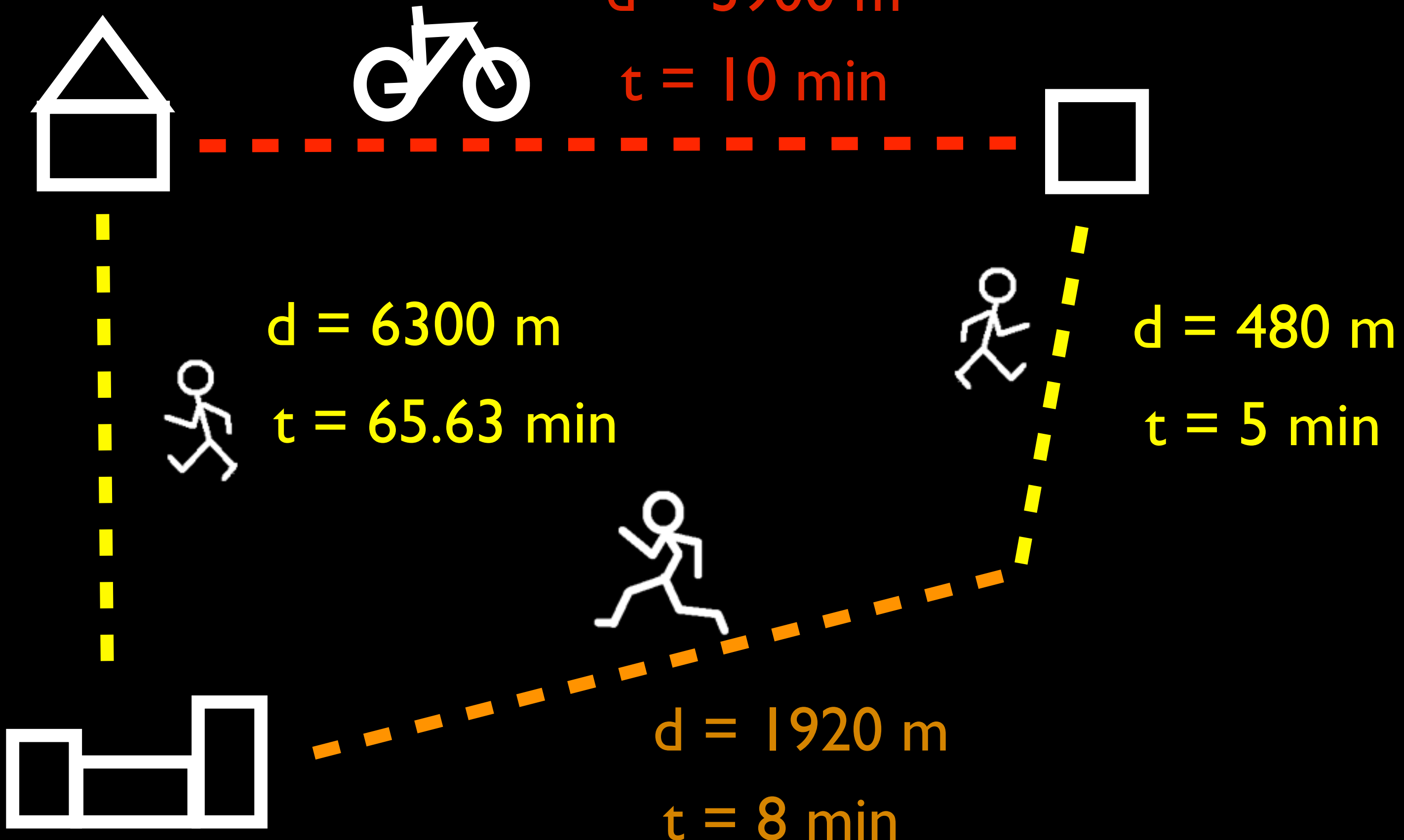
Speed & Velocity



Motion in 1D

Speed & Velocity

$$\text{Average speed} = \frac{\text{Total distance}}{\text{Total time}}$$



Total distance = 3900 m + 480 m + 1920 m + 6300 m

= 12,600 m

Total time = 10 min + 5 min + 8 min + 65.63 min

= 88.63 min

$$\text{Average speed} = \frac{12{,}600 \text{ m}}{88.63 \text{ min}} = 142 \text{ m/min} = 2.4 \text{ m/s}$$

Motion in 1D

Speed & Velocity

Speed is different to velocity which includes direction

$$\text{Average velocity} = \frac{\text{total displacement}}{\text{total time}}$$

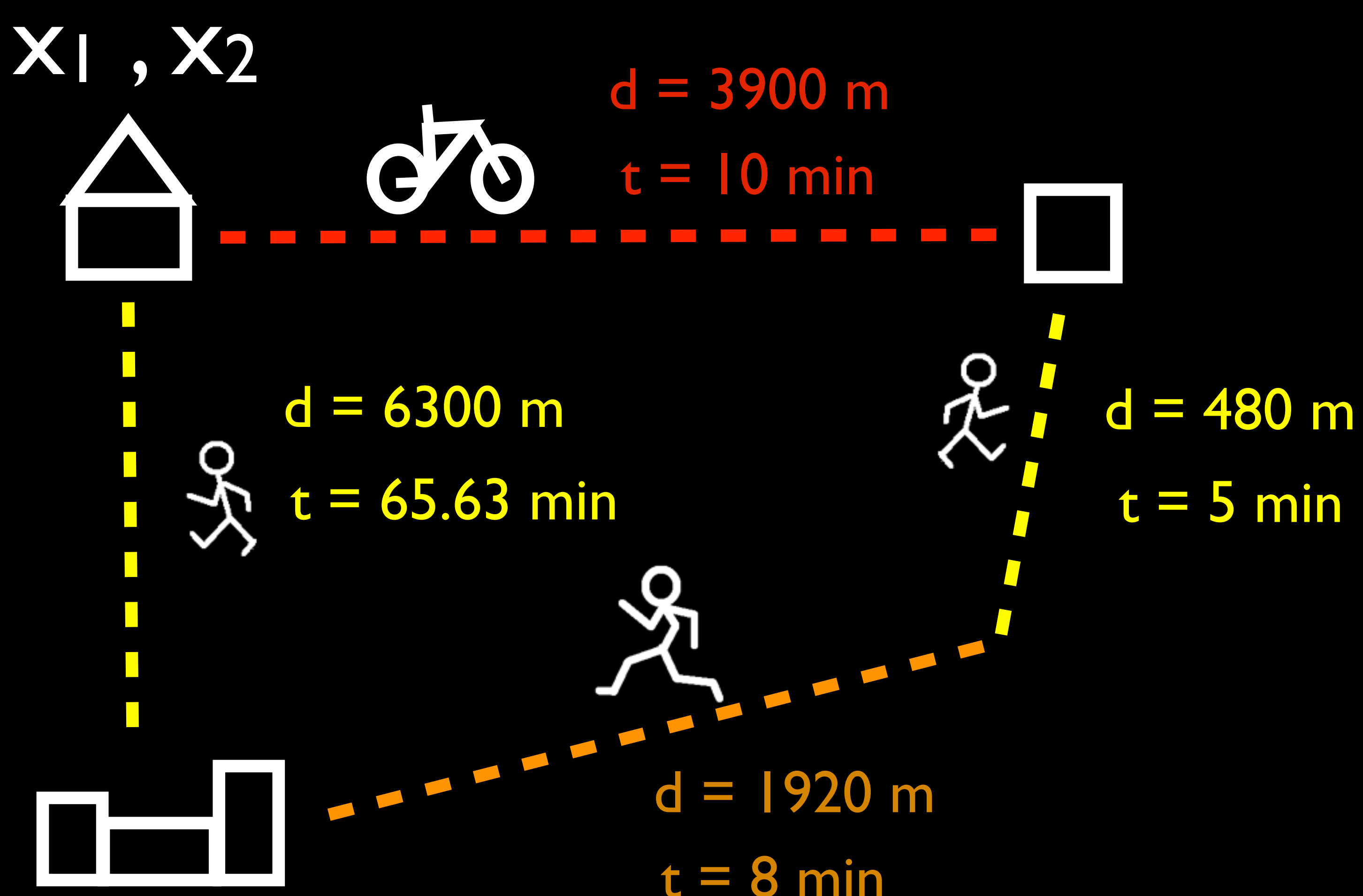
change in position

$$\text{Average velocity} = v_{av} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{\Delta x}{\Delta t}$$

Motion in 1D

Speed & Velocity

$$\text{Average velocity} = \frac{\text{total displacement}}{\text{total time}} = \frac{\Delta x}{\Delta t}$$



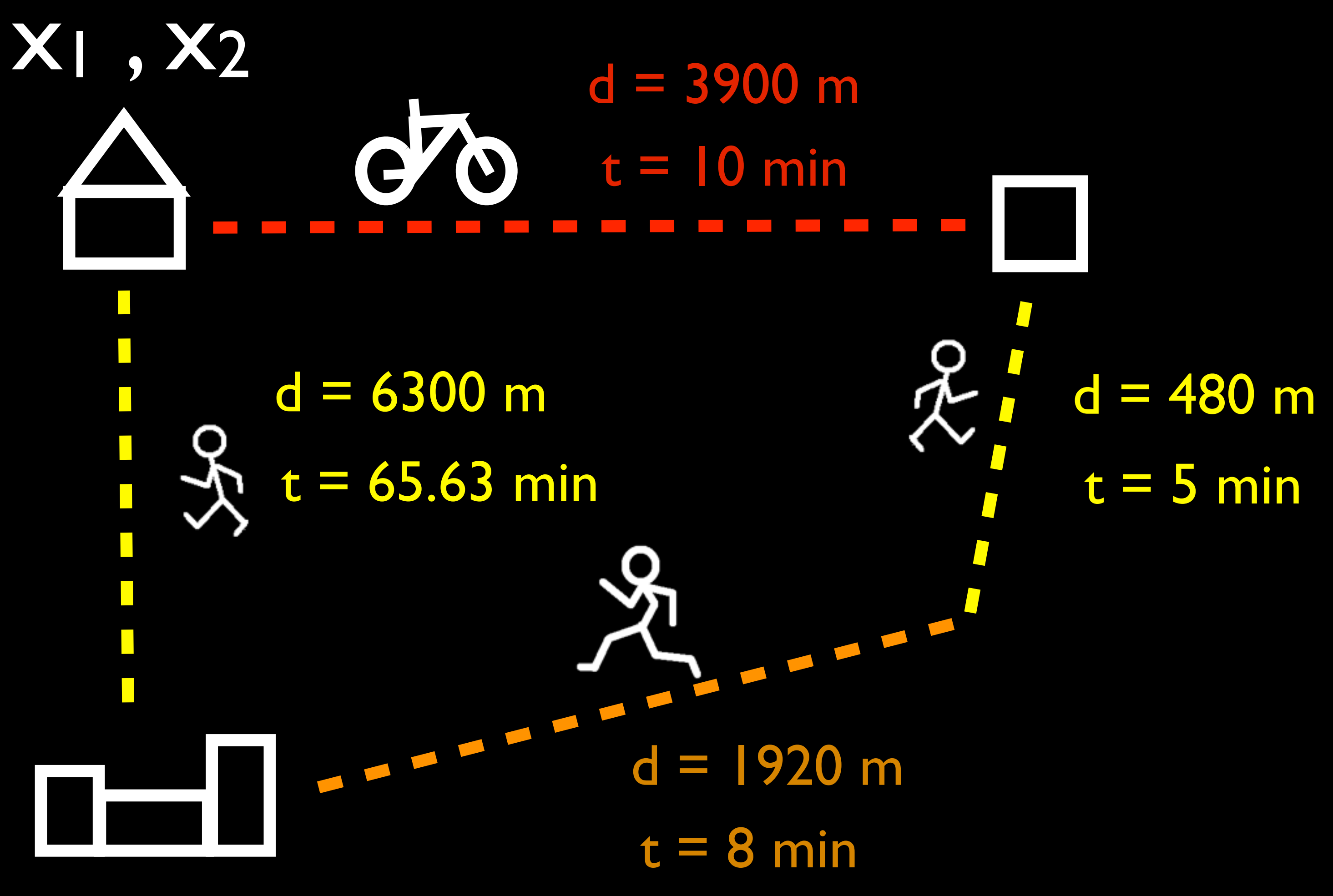
$$\text{Total displacement} = x_2 - x_1$$

$$= 0$$

$$\text{Average velocity} = v_{av} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{0}{88.63\text{ min}} = 0$$

Motion in 1D

Speed & Velocity



Total displacement = 0

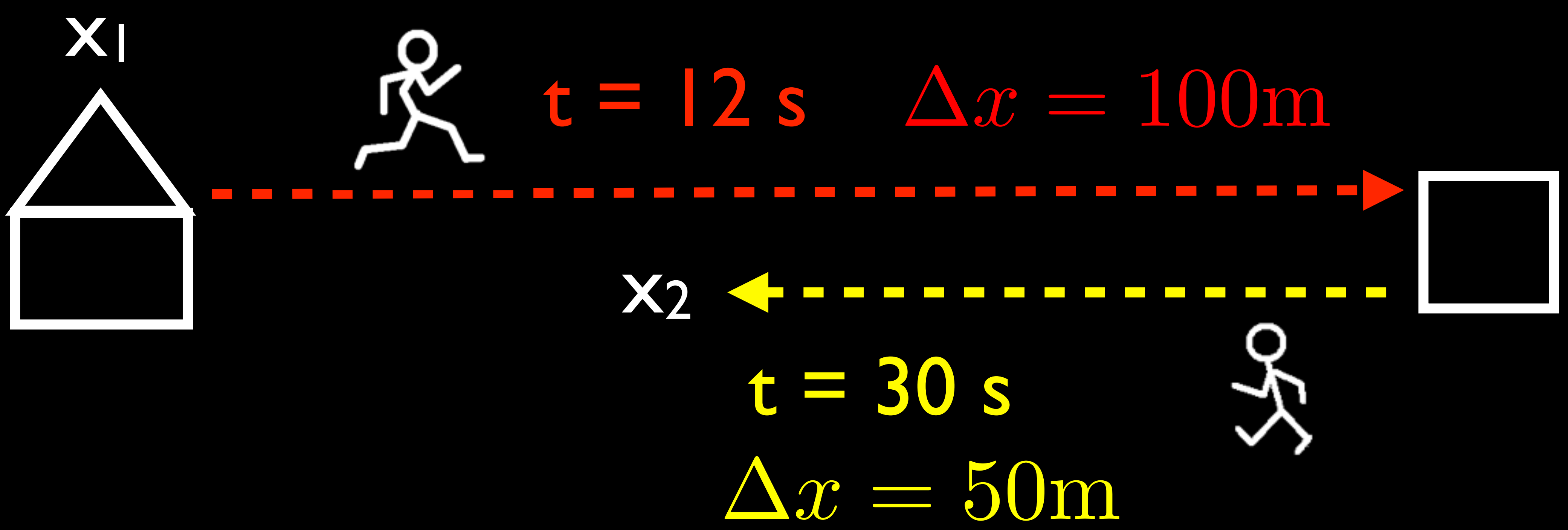
Total distance = 12,600 m

Average speed = 2.4 m/s

Average velocity = 0

Motion in 1D

Quiz



What is the average speed for the total trip?

(A) $1.2\,\text{m/s}$

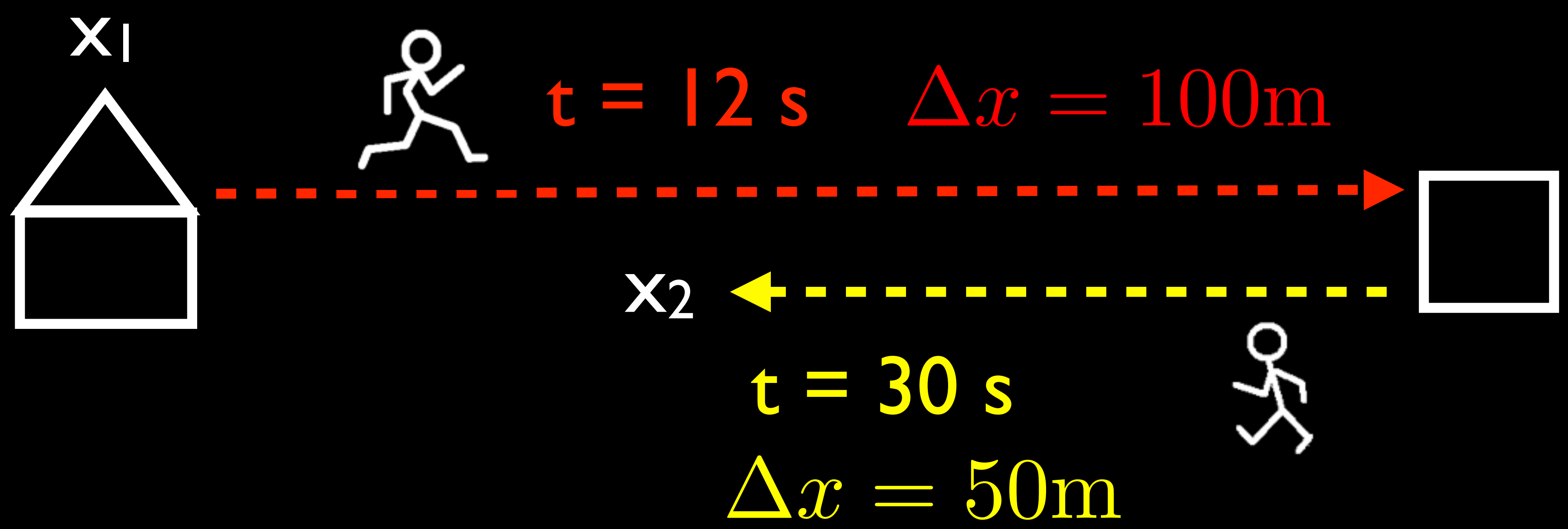
(B) $5\,\text{m/s}$

(C) $3.6\,\text{m/s}$

(D) $2.8\,\text{m/s}$

Motion in 1D

Quiz

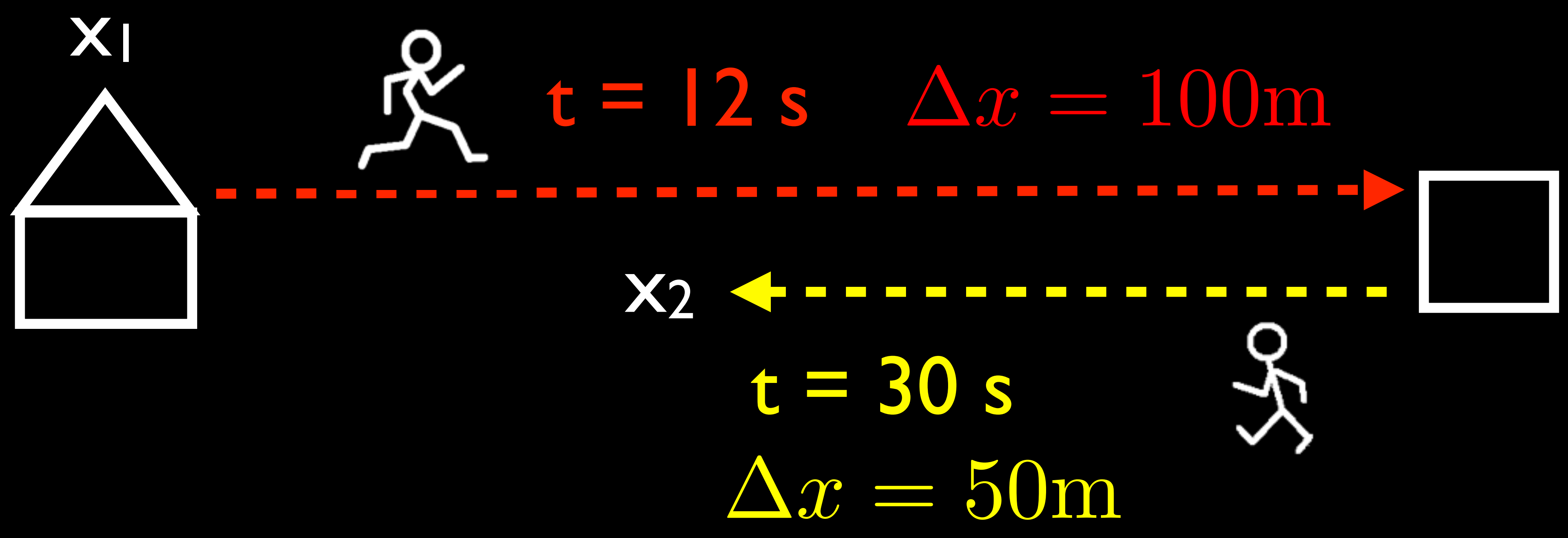


What is the average speed for the total trip?

$$\text{Average speed} = \frac{\text{Total distance}}{\text{Total time}} = \frac{100\,\mathrm{m} + 50\,\mathrm{m}}{12\,\mathrm{s} + 30\,\mathrm{s}}$$

$$= 3.6\,\mathrm{m/s}$$

Motion in 1D



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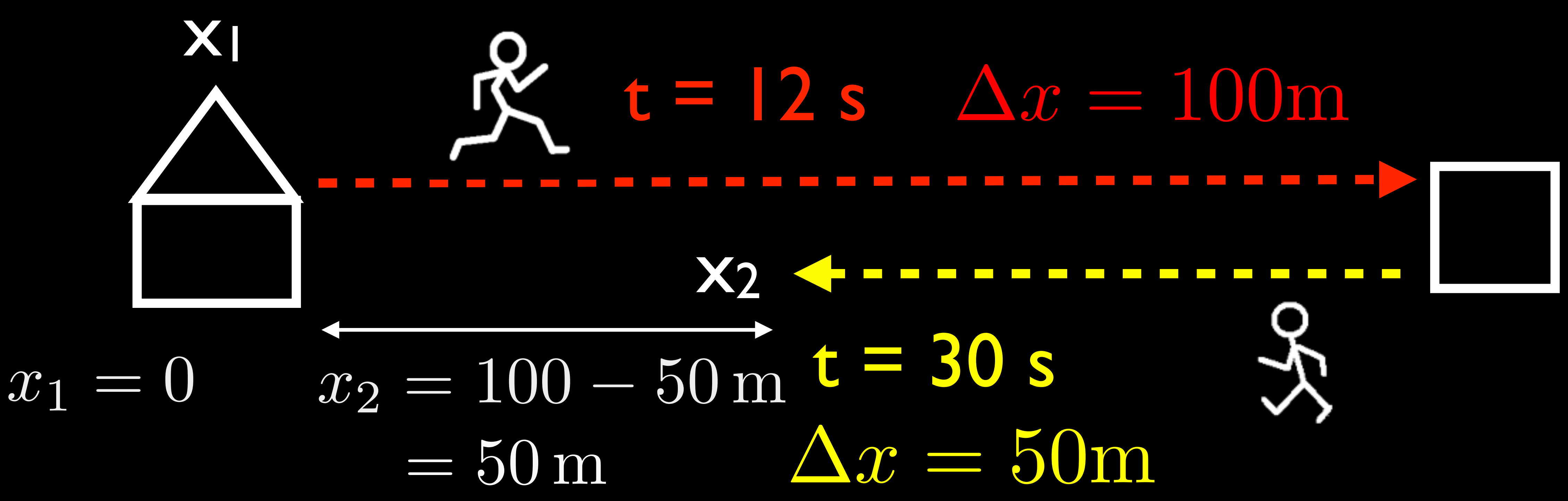
Motion in 1D

Quiz



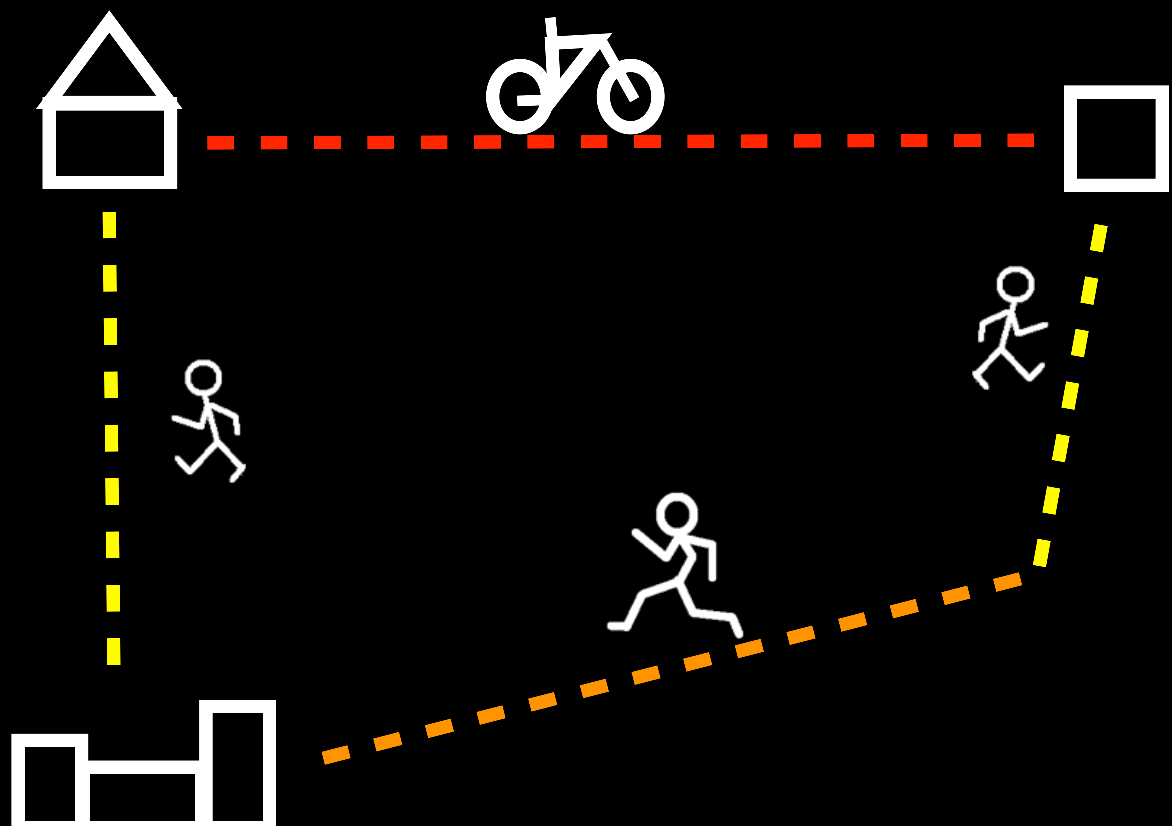
What is the average velocity for the total trip?

$$\text{Average velocity} = \frac{\text{total displacement}}{\text{total time}} = \frac{\Delta x}{\Delta t} = \frac{x_2 - x_1}{t_1 + t_2}$$

$$= \frac{50\,\text{m} - 0}{12\,\text{s} + 30\,\text{s}} = 1.2\,\text{m/s}$$

Motion in 1D

Average & Instantaneous Velocity



Problem:

Average velocity does not tell the details of a motion

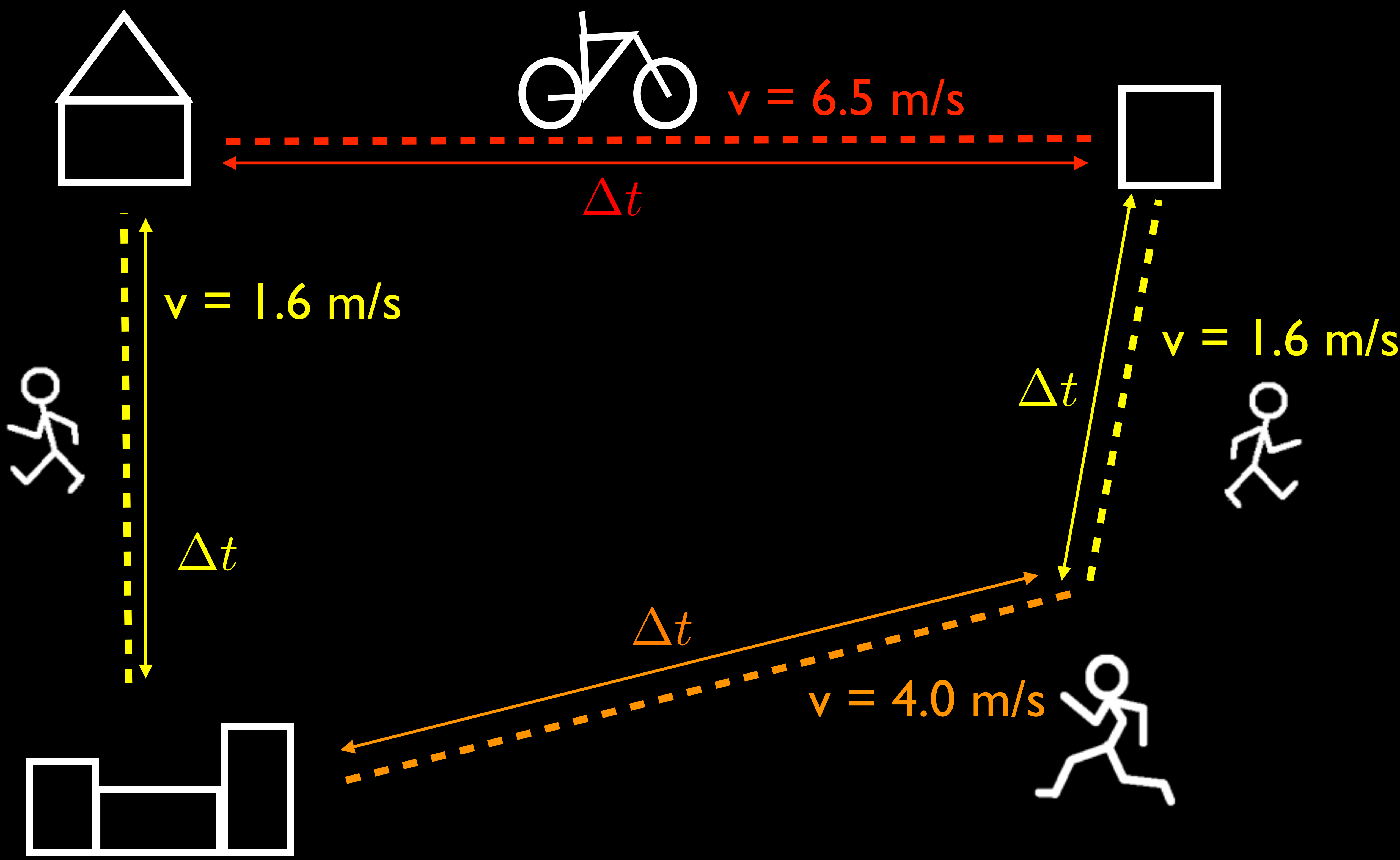
Did the person speed up?

Slow down?

Stop?

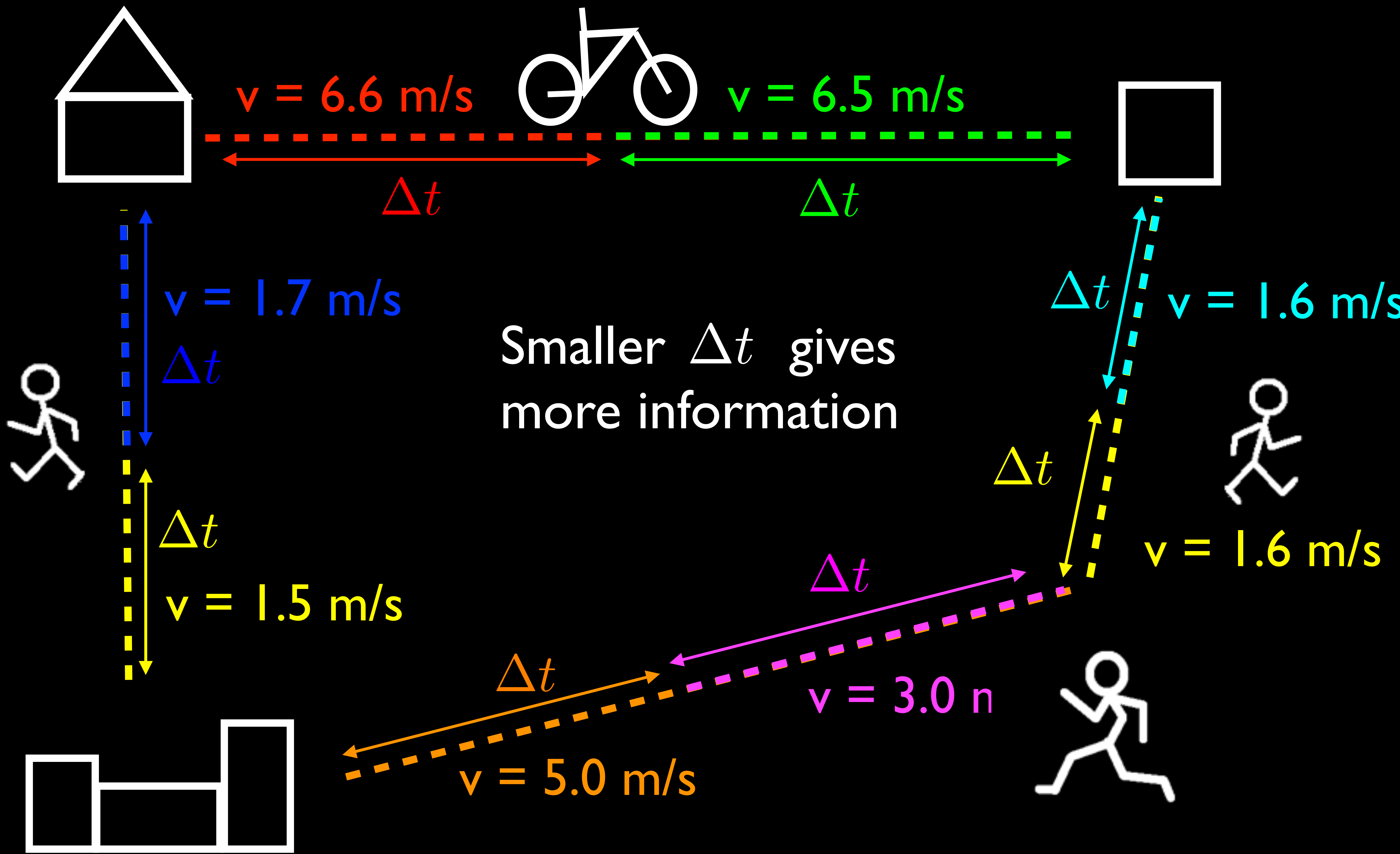
Motion in 1D

Average & Instantaneous Velocity



Motion in 1D

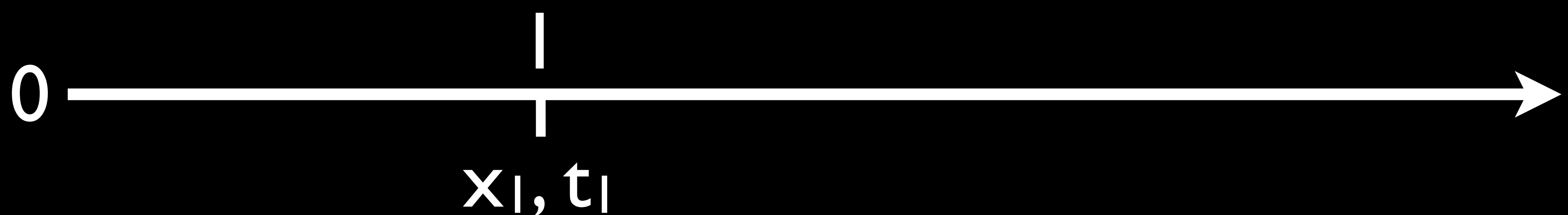
Average & Instantaneous Velocity



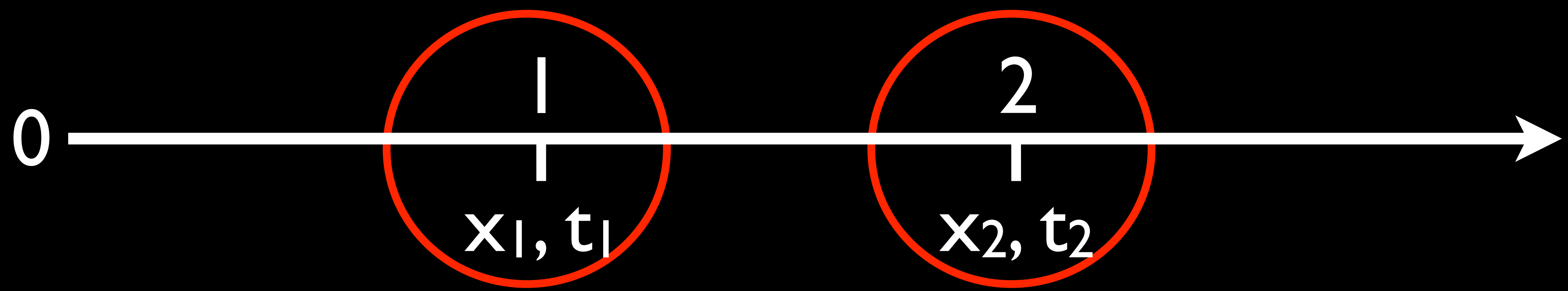
Motion in 1D

Average & Instantaneous Velocity

Can we measure velocity at only one time, t_1?

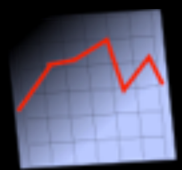


With observations, no!



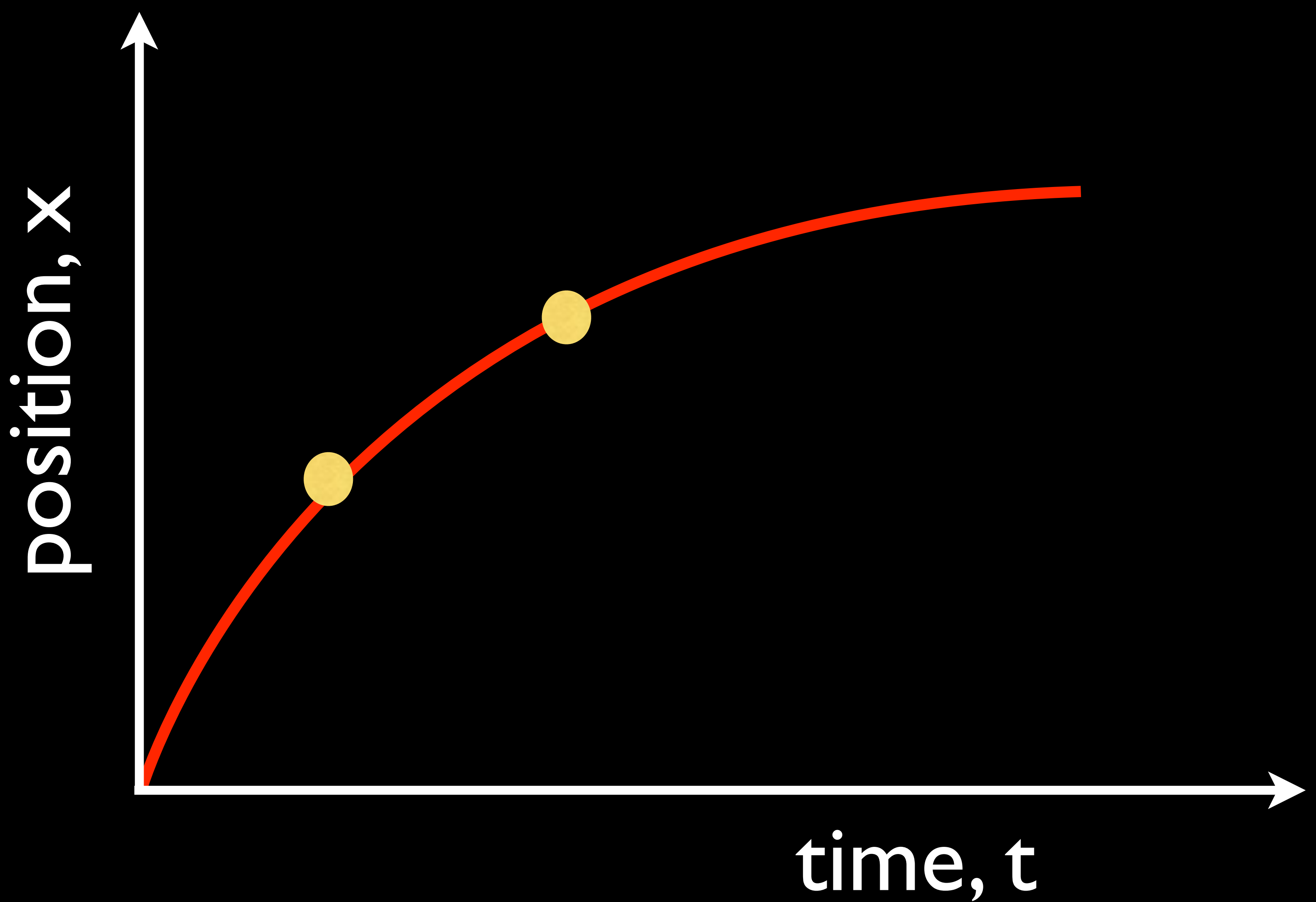
Need 2 points to get velocity

But ... let’s look at a graph...



Motion in 1D

Average & Instantaneous Velocity

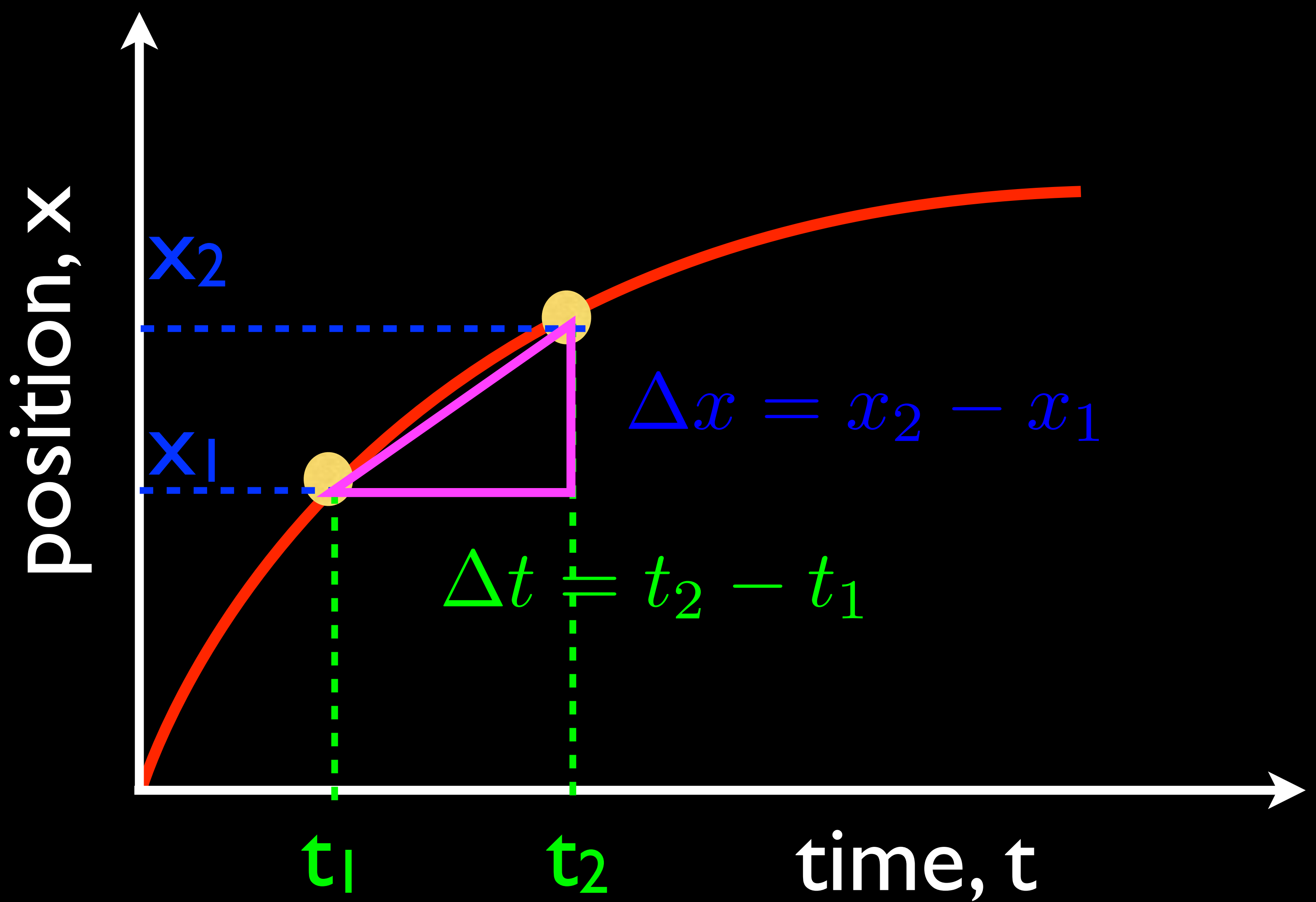


$$v_{\mathrm{av}} = \frac{\Delta x}{\Delta t}$$

Position-versus-time graph

Motion in 1D

Average & Instantaneous Velocity

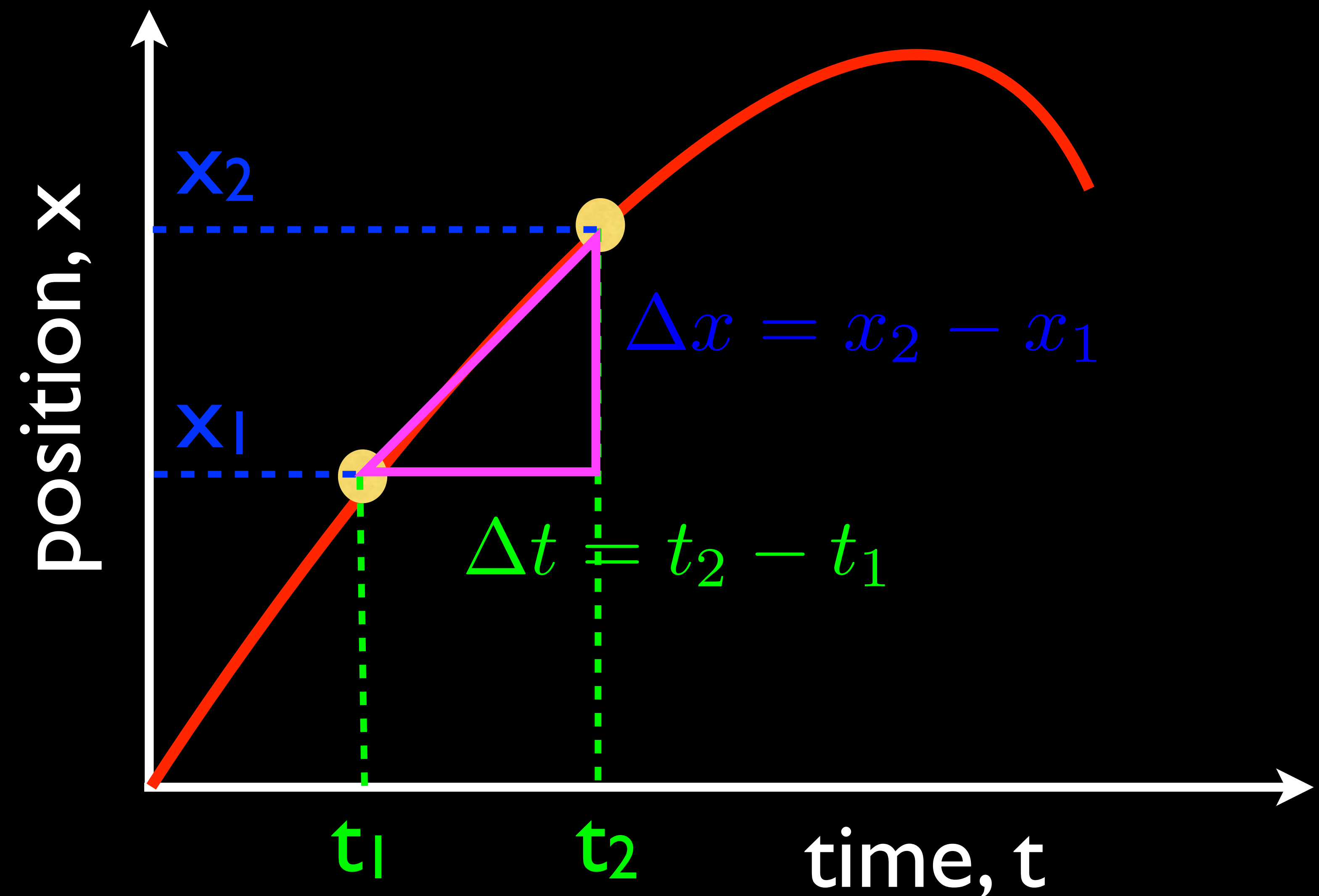


$$v_{\mathrm{av}} = \frac{\Delta x}{\Delta t}$$

Position-versus-time graph

Motion in 1D

Average & Instantaneous Velocity



$$v_{\rm av} = \frac{\Delta x}{\Delta t}$$

Δx has increased ↑

Δt is the same =

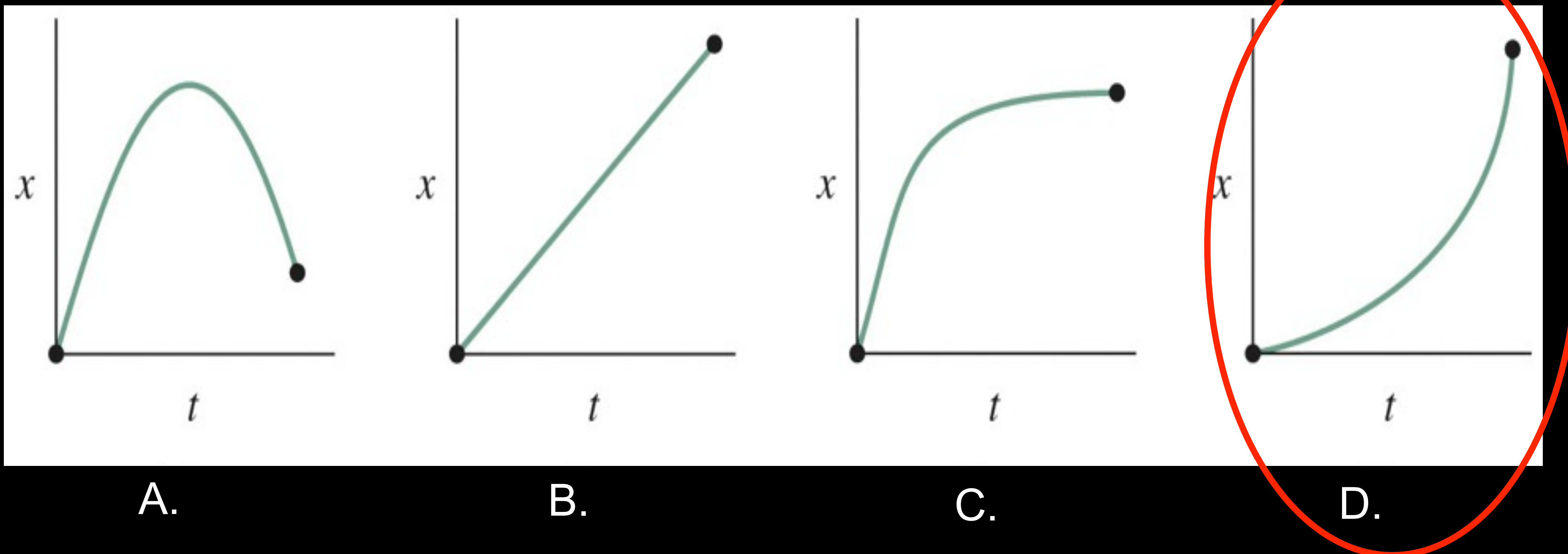
We have moved further in the same time.

- Velocity is higher.
- Gradient (slope) is steeper.

same meaning

Motion in 1D

Quiz



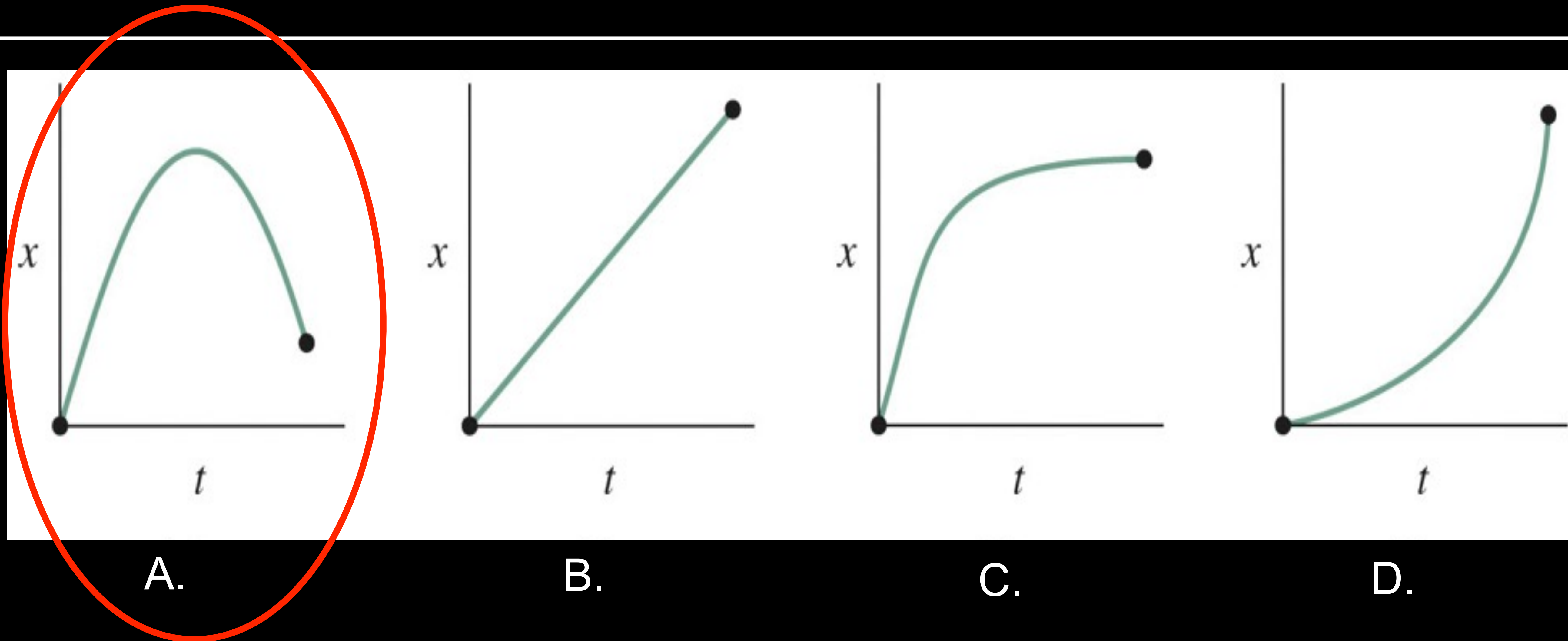
A. B. C. D.

Which graph shows an object starting slowly, then becoming faster?

Gradient increases ➡ Velocity is higher.

Motion in 1D

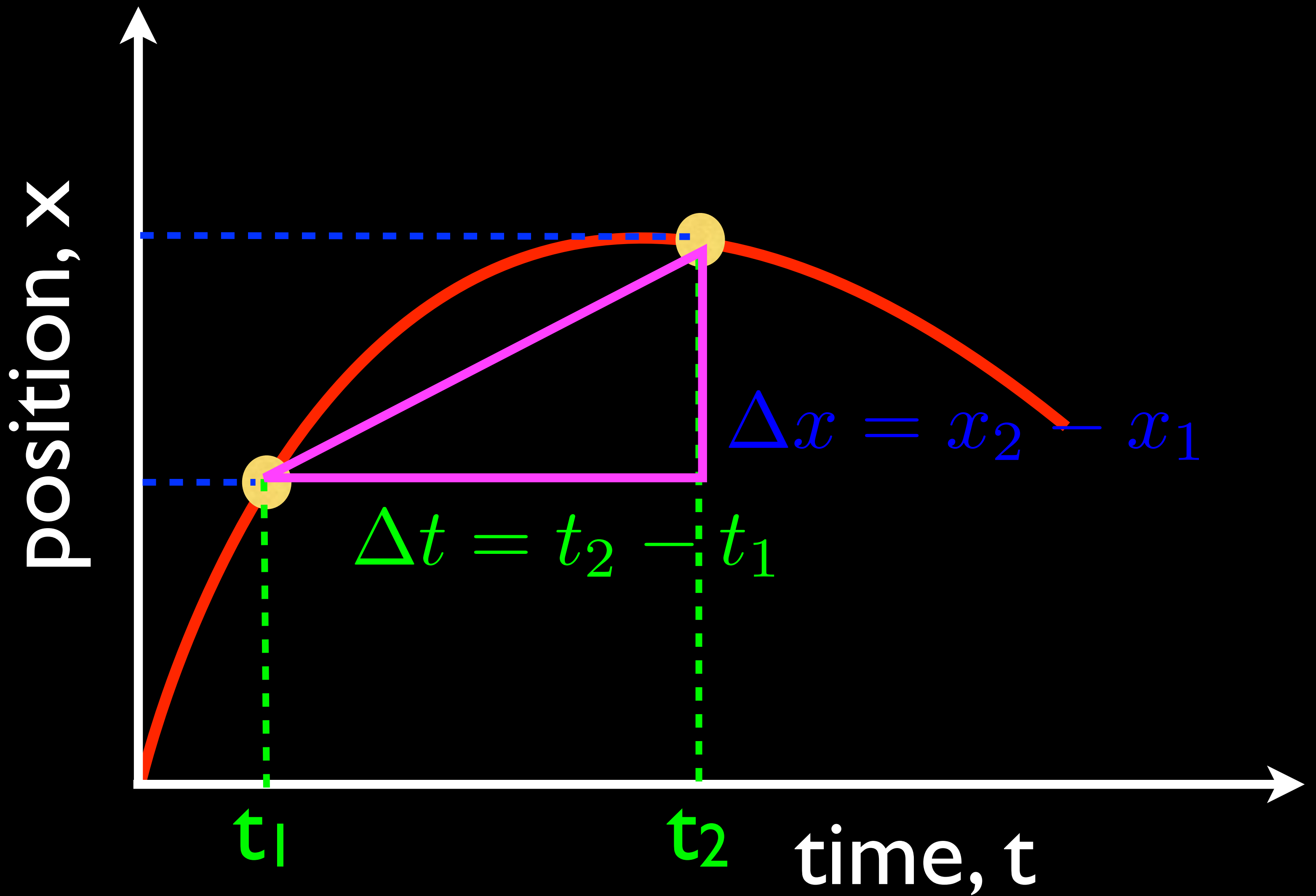
Quiz



Which graph shows an object changing direction?

Motion in 1D

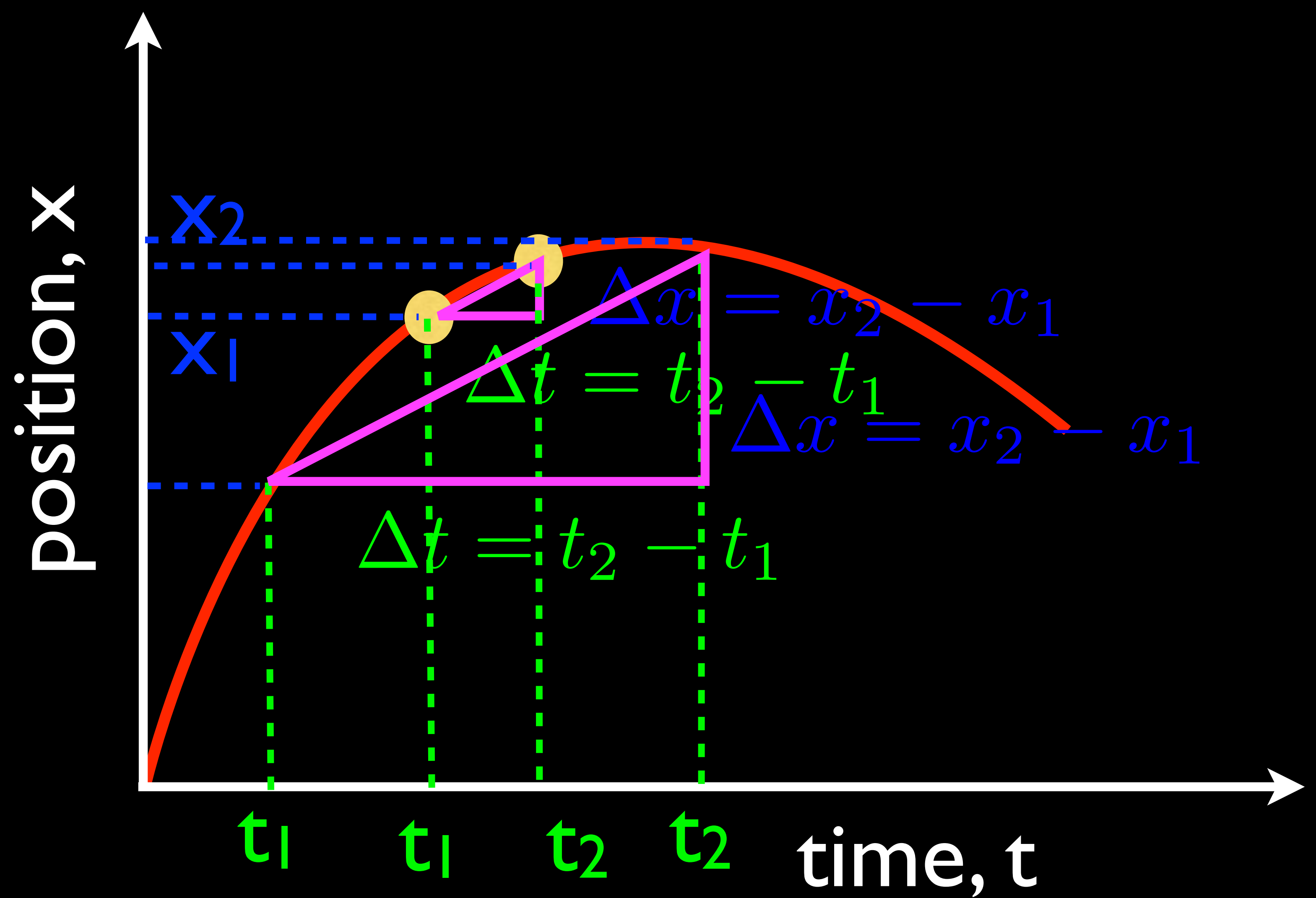
Average & Instantaneous Velocity



$$v_{\mathrm{av}} = \frac{\Delta x}{\Delta t}$$

Motion in 1D

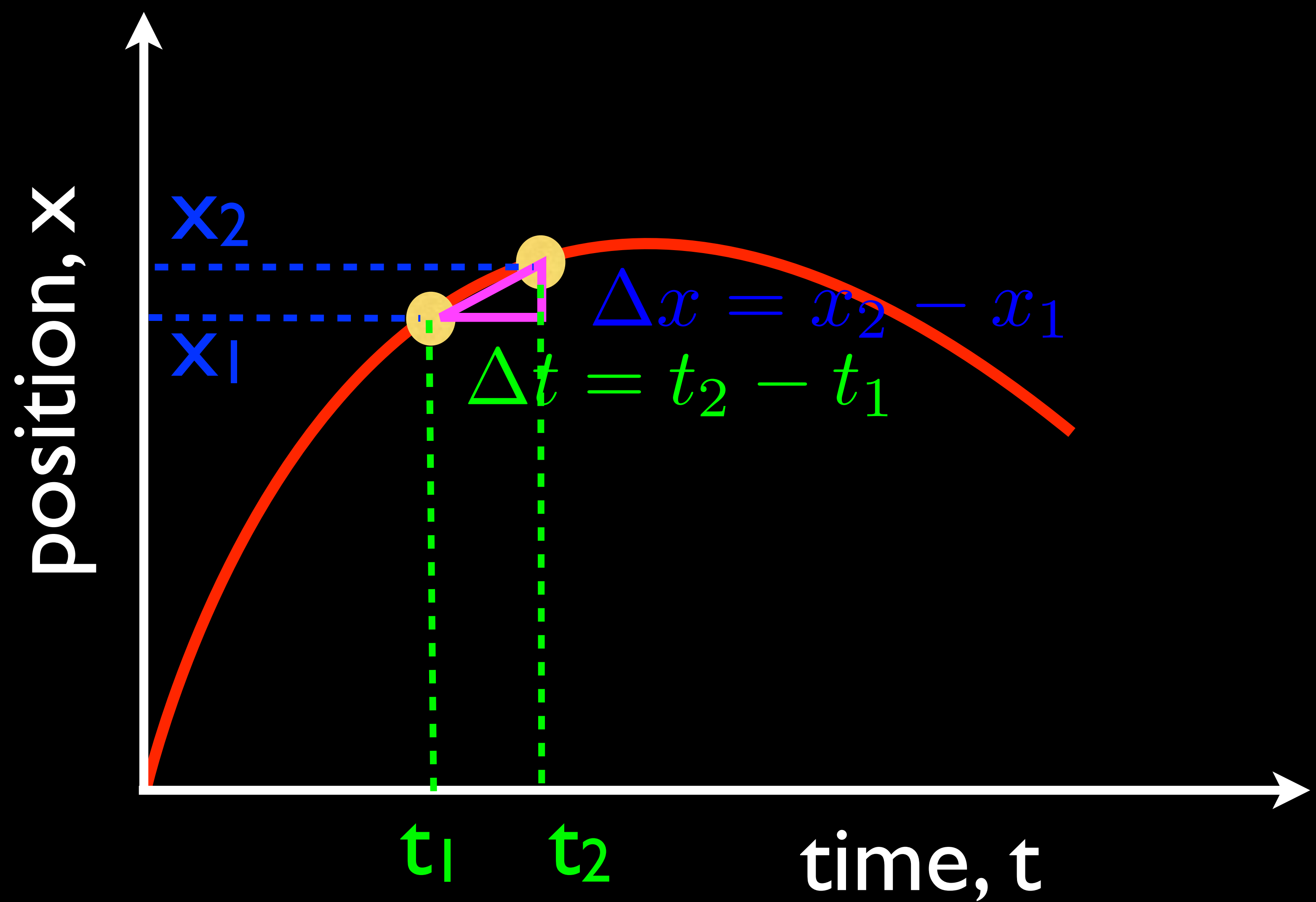
Average & Instantaneous Velocity



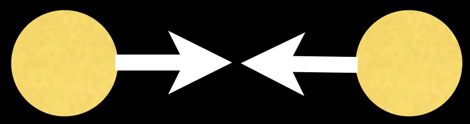
$$v_{\rm av} = \frac{\Delta x}{\Delta t}$$

Motion in 1D

Average & Instantaneous Velocity



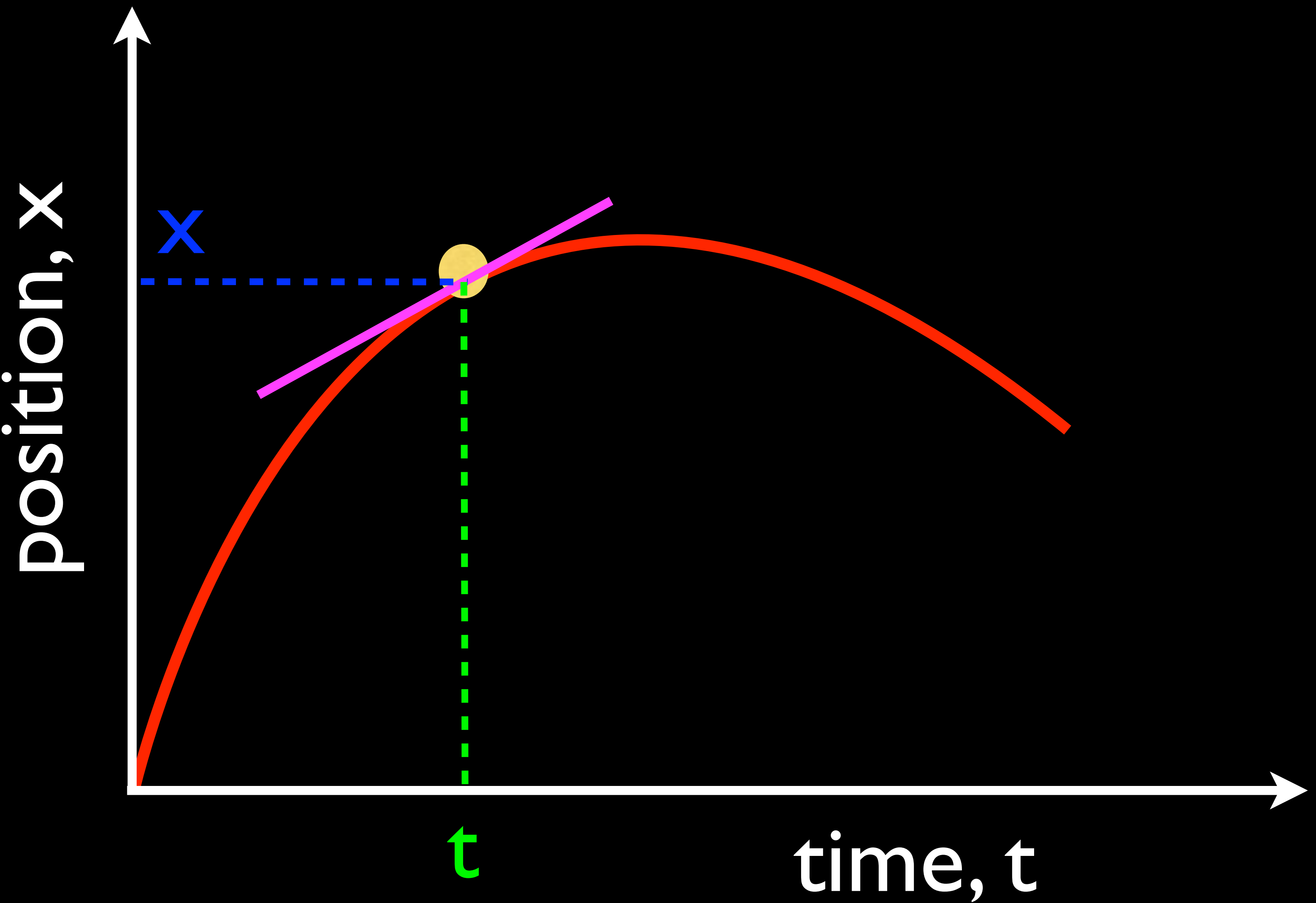
$$v_{\mathrm{av}} = \frac{\Delta x}{\Delta t}$$

As the points get closer:  Δt gets smaller

average velocity → instantaneous velocity

Motion in 1D

Average & Instantaneous Velocity



$$v = \frac{dx}{dt}$$

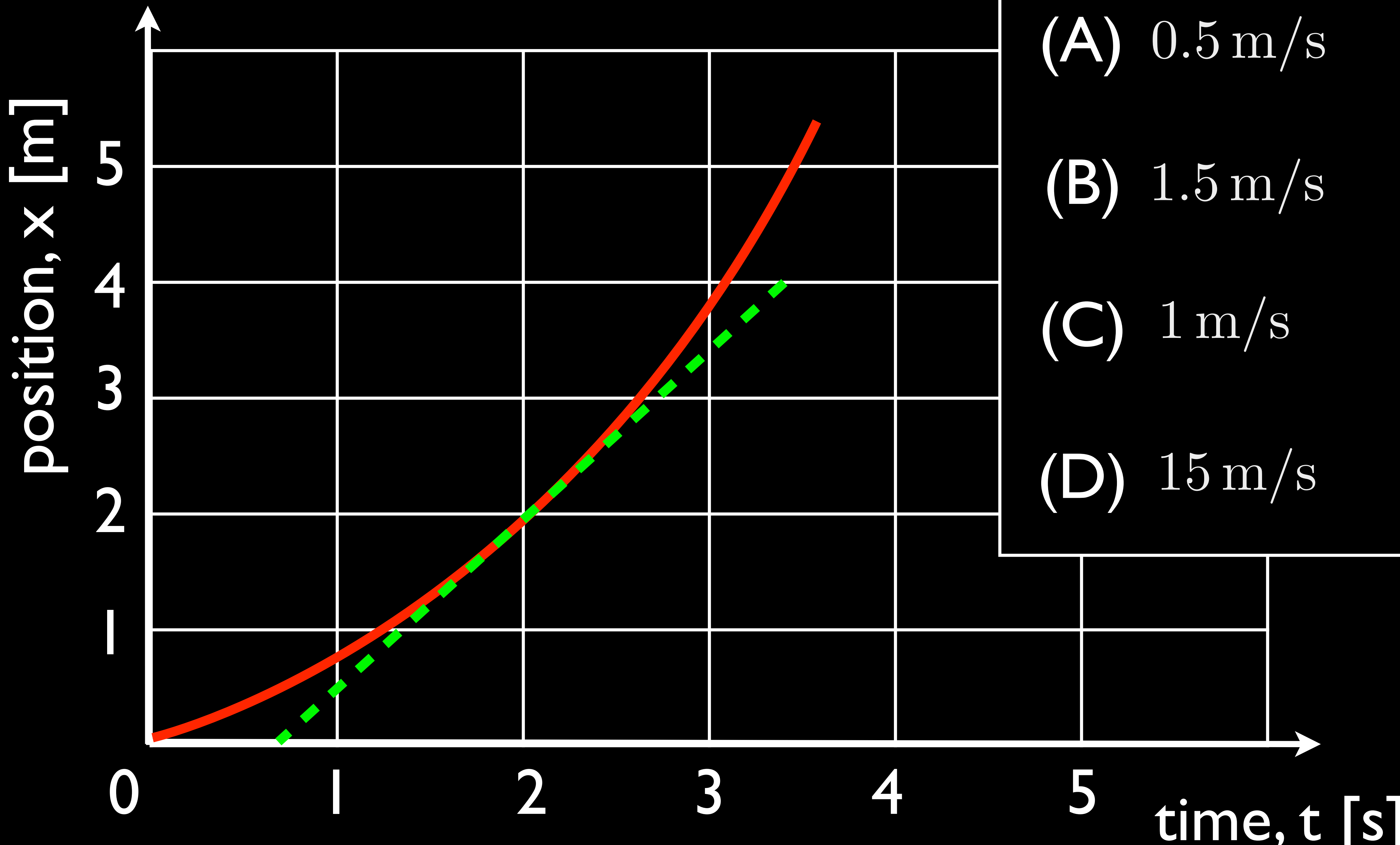
Instantaneous velocity = gradient at (x,t)

$$v = \frac{dx}{dt}$$

Motion in 1D

Quiz

Find the average velocity between t = 0 and t = 2s



(A) $0.5\,\mathrm{m/s}$

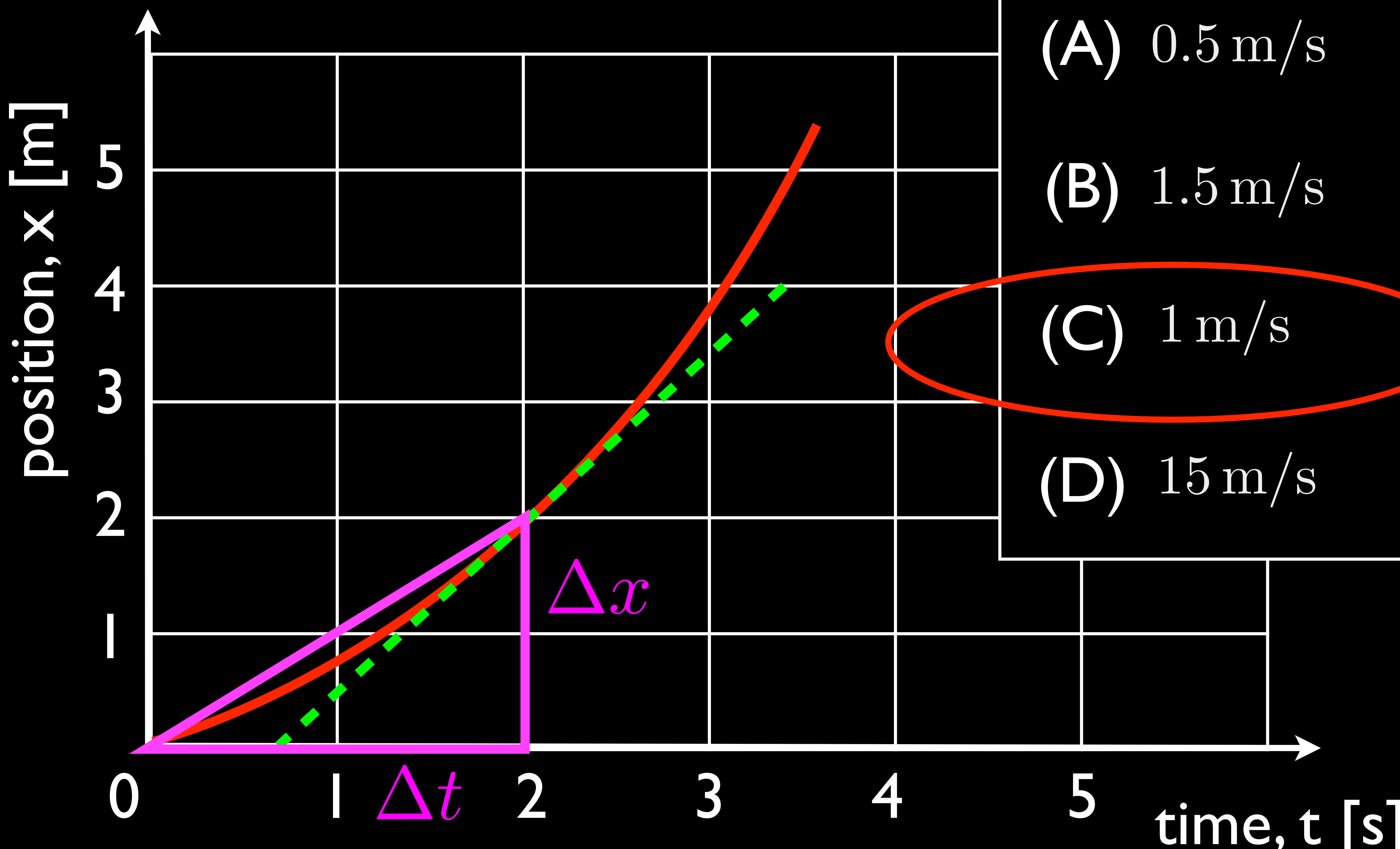
(B) $1.5\,\mathrm{m/s}$

(C) $1\,\mathrm{m/s}$

(D) $15\,\mathrm{m/s}$

Motion in 1D

Find the average velocity between t = 0 and t = 2s



(A) $0.5\,\mathrm{m/s}$

(B) $1.5\,\mathrm{m/s}$

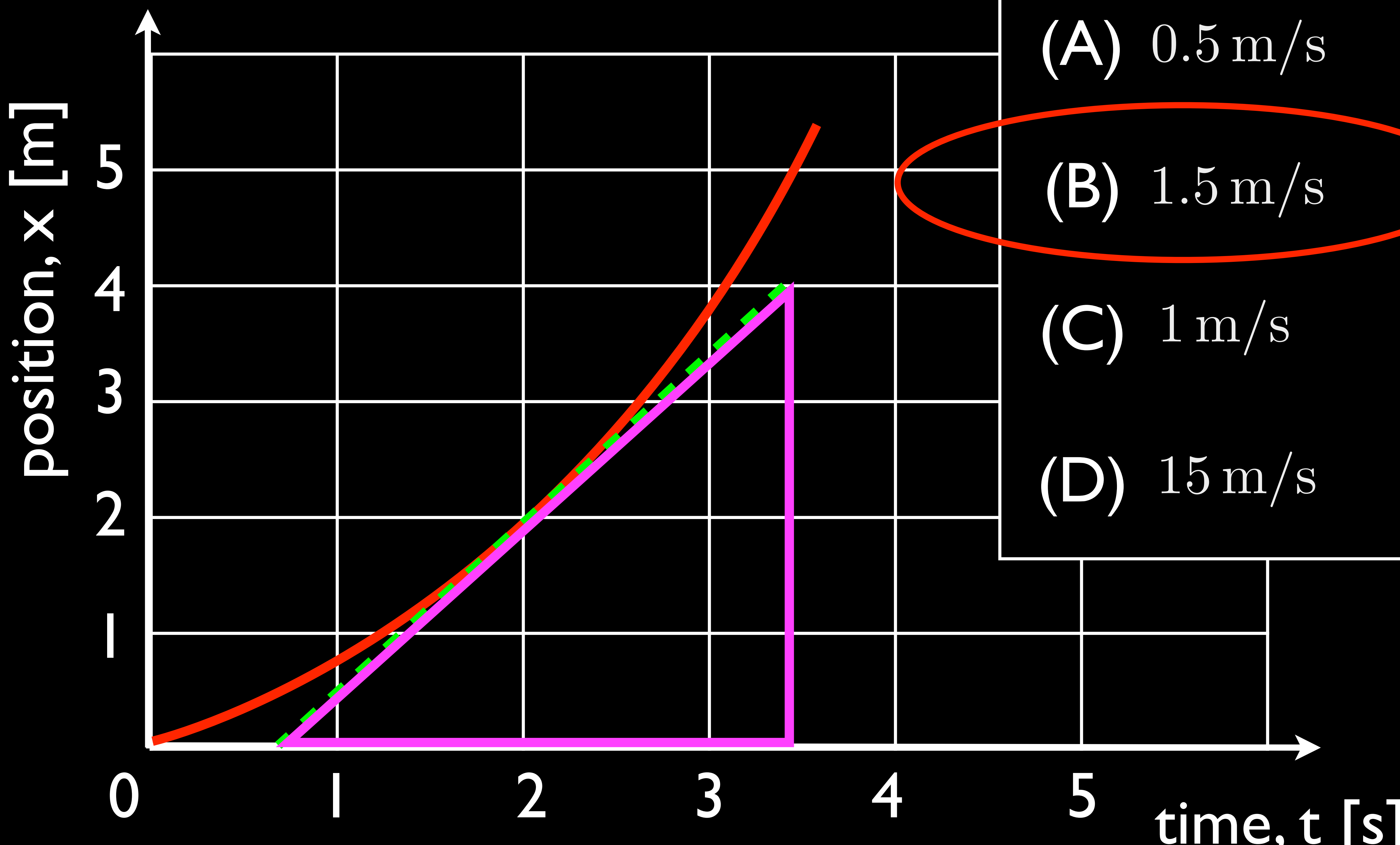
(C) $1\,\mathrm{m/s}$

(D) $15\,\mathrm{m/s}$

Motion in 1D

Quiz

Find the instantaneous velocity at t = 2s

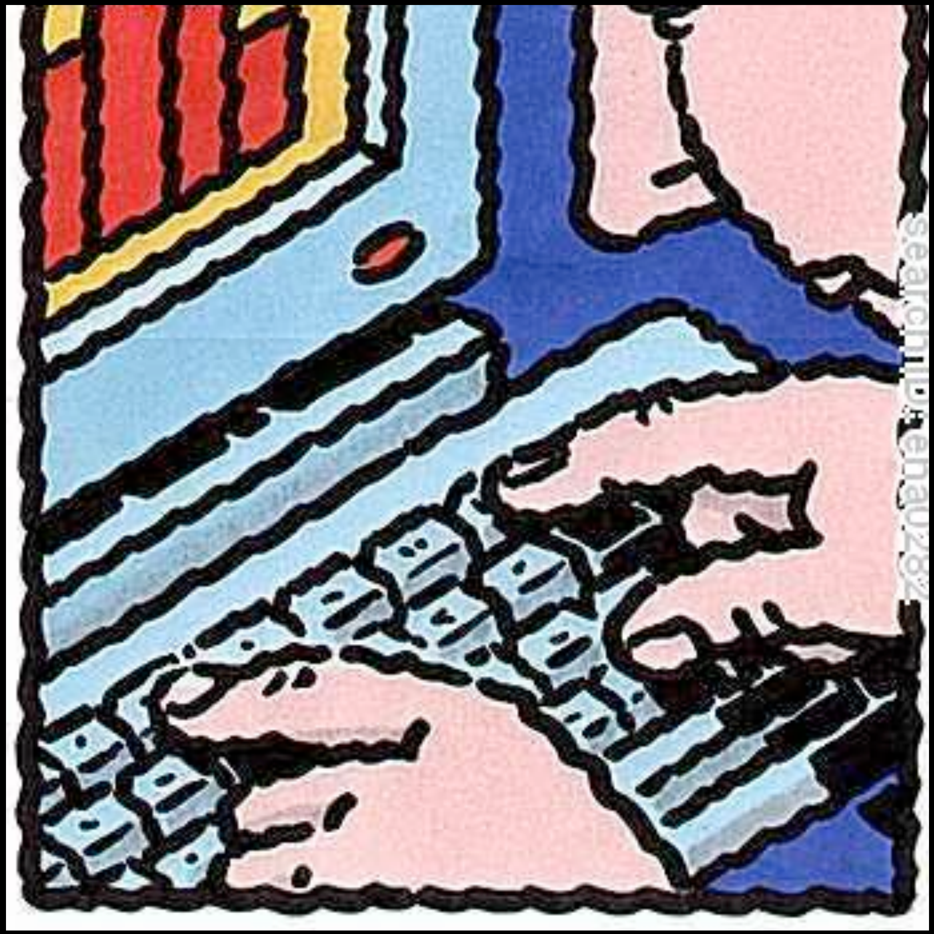


- (A) $0.5\,\mathrm{m/s}$
- (B) $1.5\,\mathrm{m/s}$
- (C) $1\,\mathrm{m/s}$
- (D) $15\,\mathrm{m/s}$

Motion in 1D

Average & Instantaneous Velocity

We can find the instantaneous velocity on a graph...

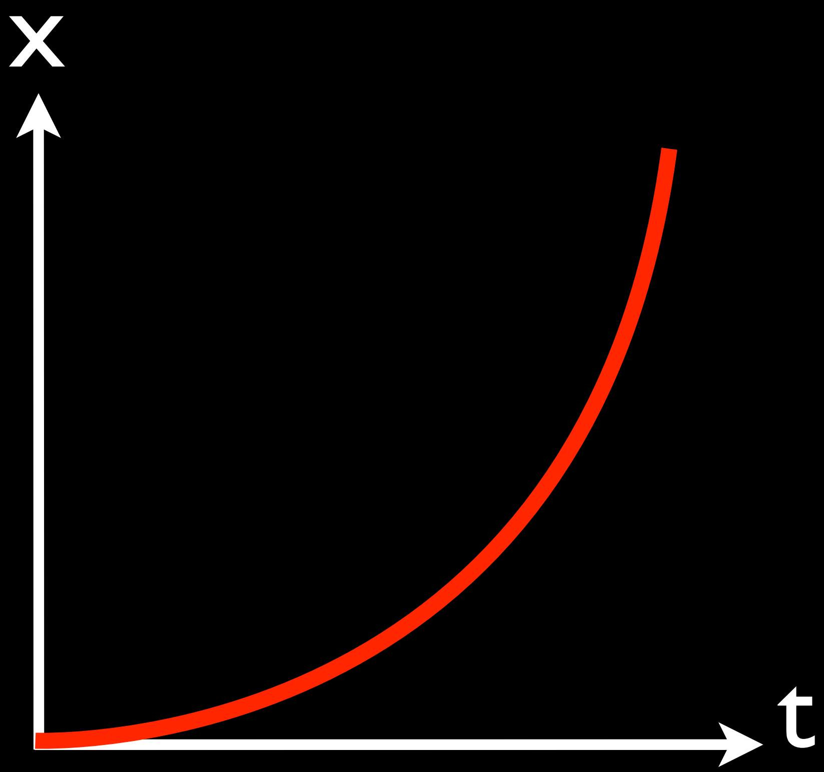


.... but this is slow.

Can we find the instantaneous velocity mathematically?

Motion in 1D

Average & Instantaneous Velocity

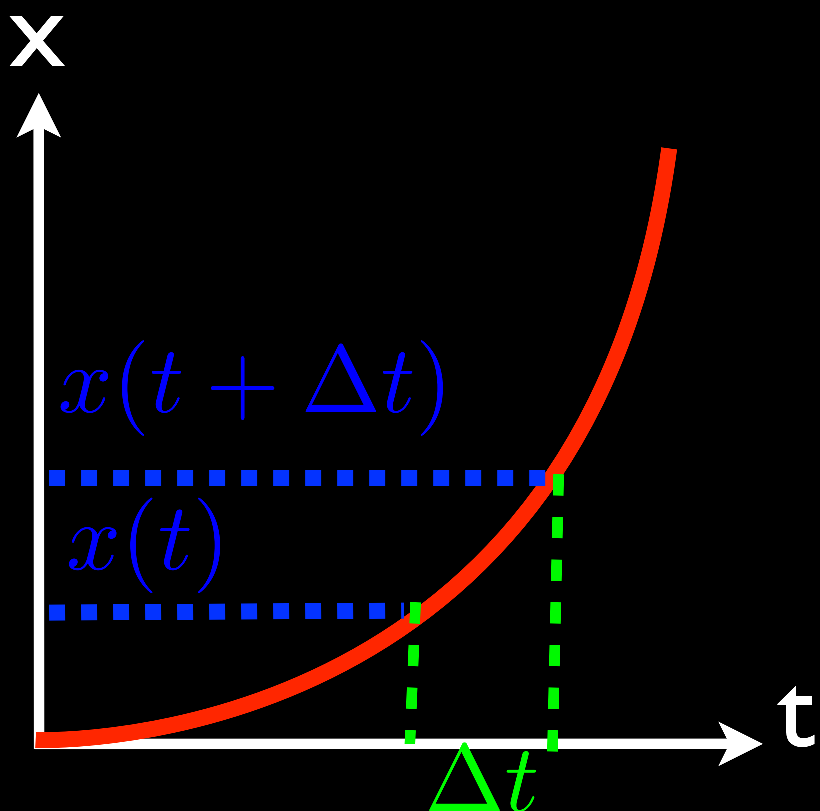


A sheep is dropped from a cliff

$$x = 5t^2$$

Motion in 1D

Average & Instantaneous Velocity



A sheep is dropped from a cliff

$$x = 5t^2$$

Find the velocity at later time

$$t + \Delta t$$

At $t + \Delta t$:

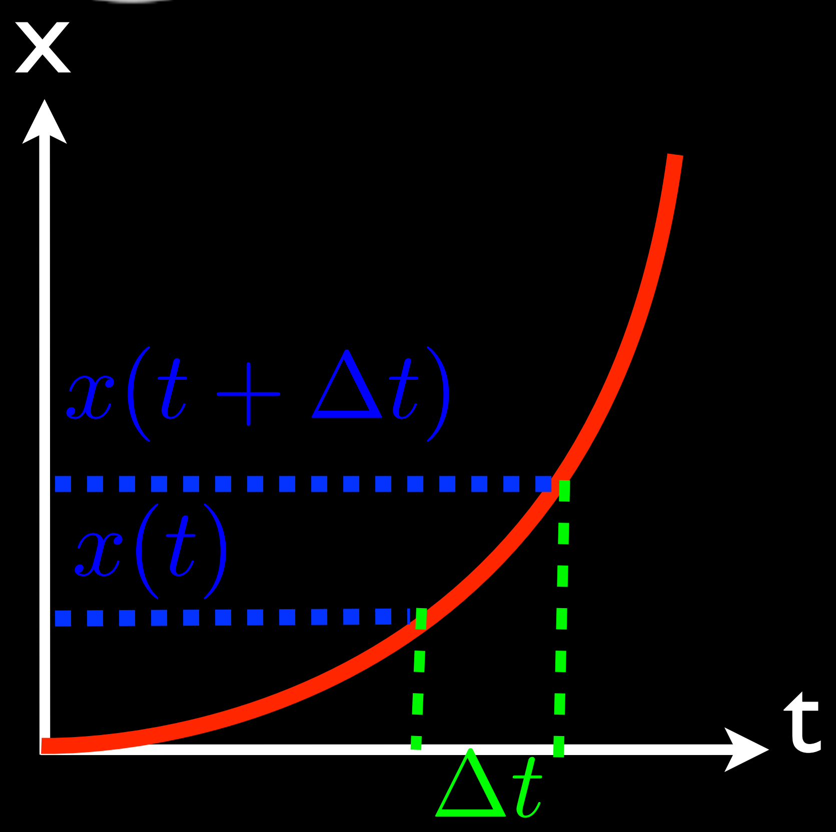
$$x(t+\Delta t) = 5(t+\Delta t)^2$$

$$= 5[t^2 + 2t\Delta t + (\Delta t)^2]$$

$$= 5t^2 + 10t\Delta t + 5(\Delta t)^2$$

Motion in 1D

Average & Instantaneous Velocity



A sheep is dropped from a cliff

$$x = 5t^2$$

Find the velocity at later time

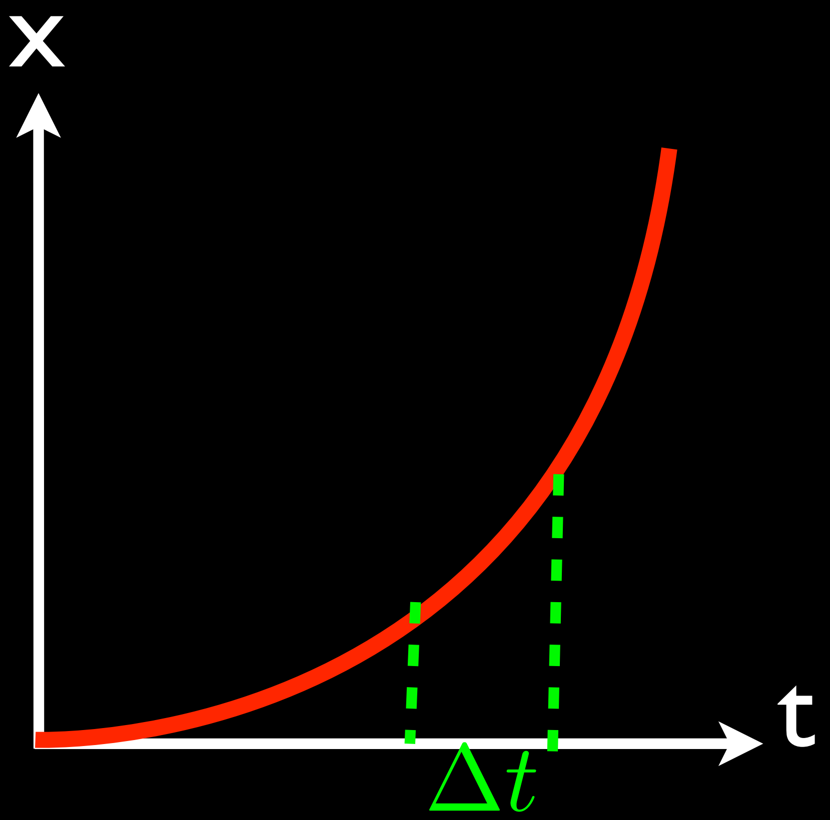
$$t + \Delta t$$

Displacement:

$$\begin{aligned}\Delta x &= x(t+\Delta t) - x(t) \\ &= [5t^2 + 10t\Delta t + 5(\Delta t)^2] - 5t^2 \\ &= 10t\Delta t + 5(\Delta t)^2\end{aligned}$$

Motion in 1D

Average & Instantaneous Velocity



A sheep is dropped from a cliff

$$x = 5t^2$$

Find the velocity at later time

$$t + \Delta t$$

Average velocity:

$$v_{av} = \frac{\Delta x}{\Delta t} = \frac{10t\Delta t + 5(\Delta t)^2}{\Delta t} = 10t + 5\Delta t$$

$\Delta t \rightarrow 0$

$$v = \lim_{\Delta t \rightarrow 0} \frac{\Delta x}{\Delta t} = 10t = \frac{dx}{dt}$$

Motion in 1D

Average & Instantaneous Velocity

Instantaneous velocity:

$$v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$$

Velocity is a rate of change

e.g. position, velocity....

The differential gives the rate of change of a quantity at a single point in time.

Motion in 1D

Average & Instantaneous Velocity

Differentiation

If: $$x = bt^n$$ b, n = constants

Then: $$\frac{dx}{dt} = nbt^{n-1}$$

Motion in 1D

Quiz

Average & Instantaneous Velocity

The height of a rocket: $x = 2.9t^2$ m

Find the (instantaneous) velocity at 20s

(A) 1160 m/s

(B) 116 m/s

(C) 58 m/s

(D) 20 m/s

Average & Instantaneous Velocity

The height of a rocket: $x = 2.9t^2$ m

Find the (instantaneous) velocity at 20s

$$v = \frac{dx}{dt} = 2.9 \times 2 \times t$$

$$v = 5.8 \times 20 = 116 \mathrm{m/s}$$

Motion in 1D

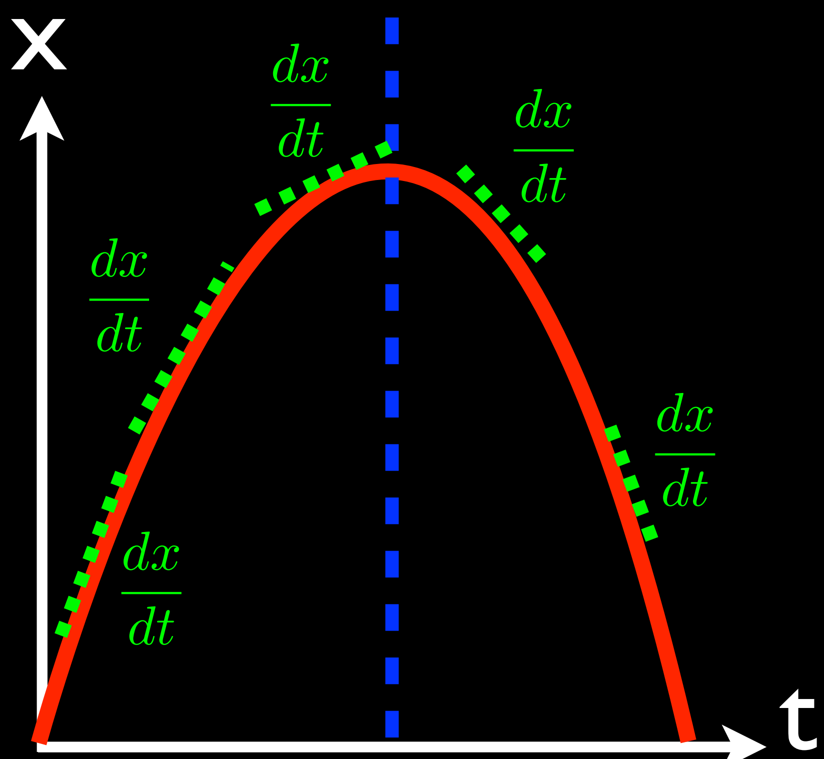
Acceleration

If $v = \dfrac{dx}{dt}$ then what is $\dfrac{dv}{dt} =$?

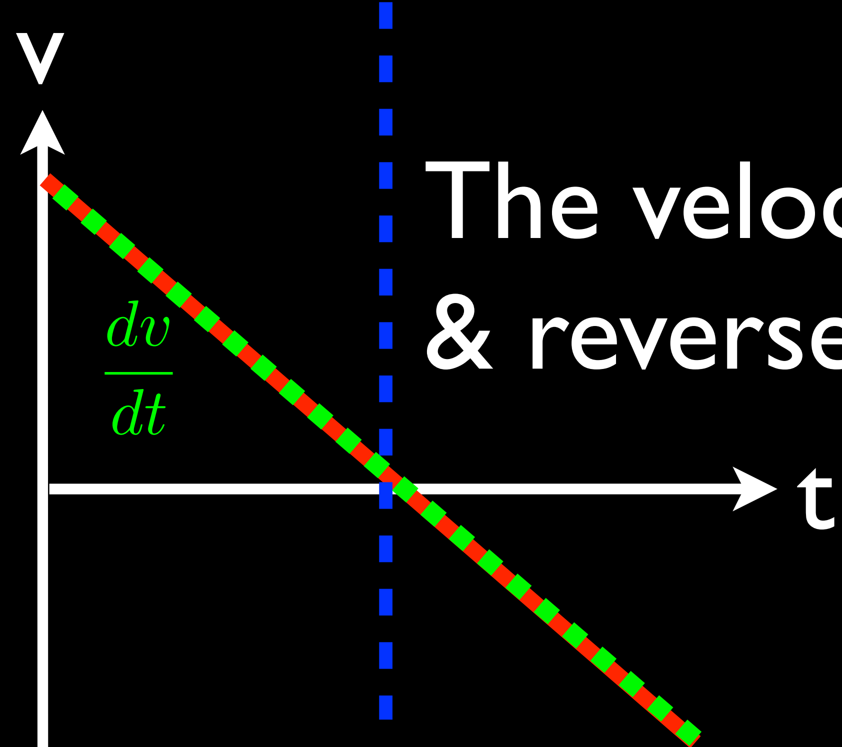
A change in velocity is acceleration

average acceleration $= \dfrac{\Delta v}{\Delta t}$

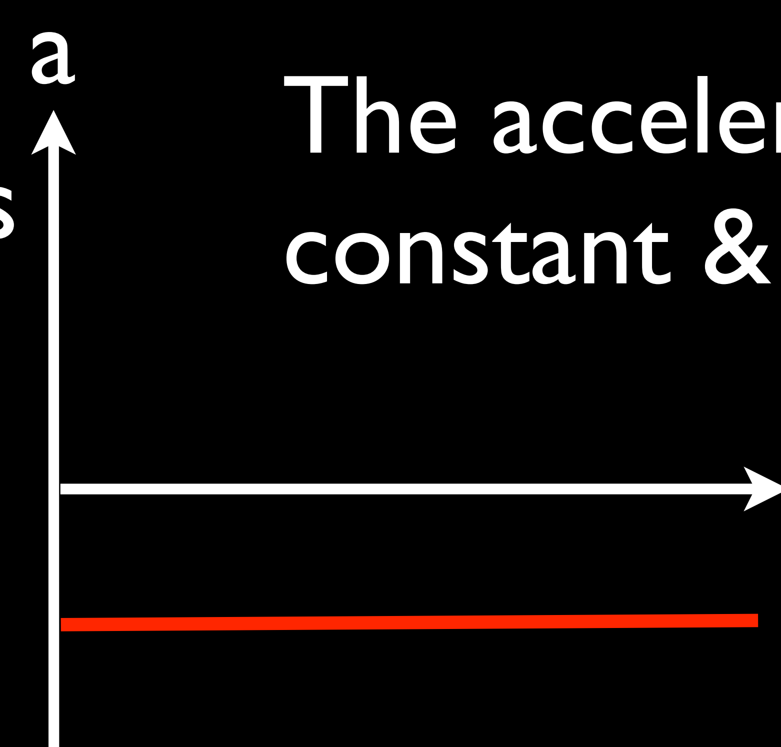
(instantaneous) acceleration $= \dfrac{dv}{dt}$



A ball is thrown vertically into the air



The velocity decreases & reverses direction



The acceleration is constant & negative

Motion in 1D

Quiz

A Subaru Impreza does 0 - 60 mph in 5.2 s

What is its average acceleration?

(60 mph = 100 km/h)

(A) $5.34\,\mathrm{m/s^2}$

(B) $19.2\,\mathrm{m/s^2}$

(C) $11.5\,\mathrm{m/s^2}$

(D) $19231\,\mathrm{m/s^2}$

Motion in 1D

Quiz

A Subaru Impreza does 0 - 60 mph in 5.2 s

What is its average acceleration?

(60 mph = 100 km/h)

$$60\,\mathrm{mph} = 100\,\mathrm{km/h} = 100\left(\frac{\mathrm{km}}{\mathrm{h}}\right)\times\left(\frac{1000\,\mathrm{m}}{\mathrm{km}}\right)\times\left(\frac{\mathrm{h}}{3600\,\mathrm{s}}\right)$$

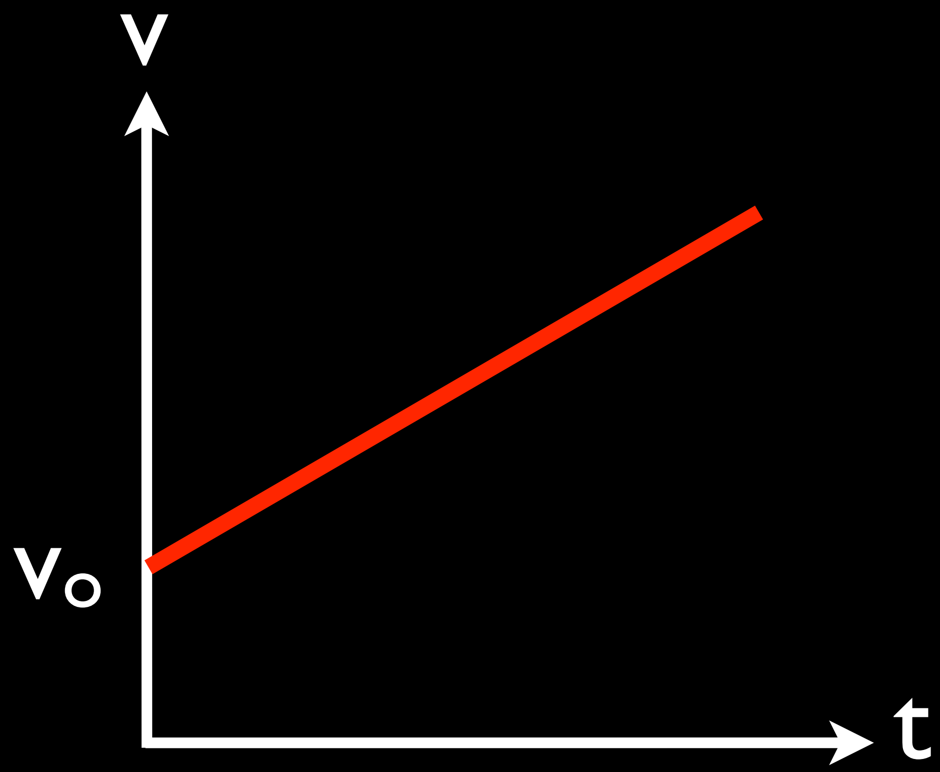
$$= 27.8\,\mathrm{m/s}$$

$$a_{\mathrm{av}} = \frac{\Delta v}{\Delta t} = \frac{27.8\,\mathrm{m/s}}{5.2\,\mathrm{s}} = 5.34\mathrm{m/s^2}$$

Motion in 1D

Acceleration

When the acceleration is constant, the equations for motion are simple

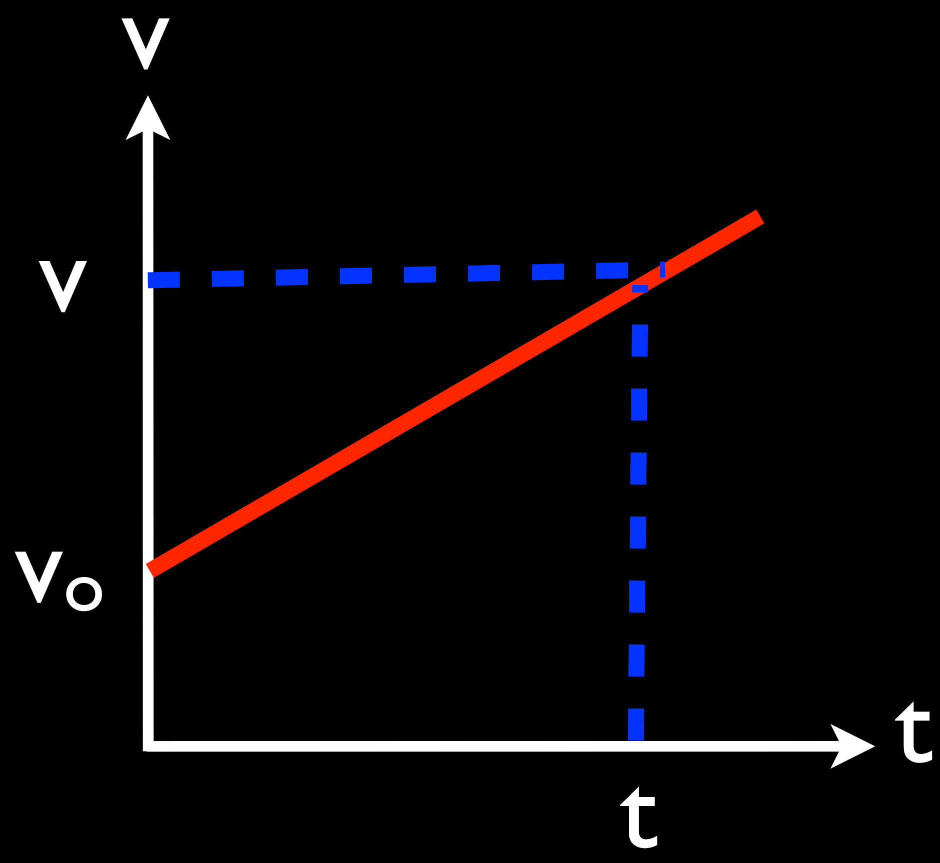


$$a = \frac{\Delta v}{\Delta t} = \frac{v - v_o}{t - 0}$$

$$v = v_o + at$$

Motion in 1D

Acceleration



Average velocity over time, t:

$$v_{\text{av}} = \frac{1}{2}(v_o + v)$$

But, we know:

$$v_{\text{av}} = \frac{\Delta x}{\Delta t} = \frac{x - x_o}{t - 0}$$

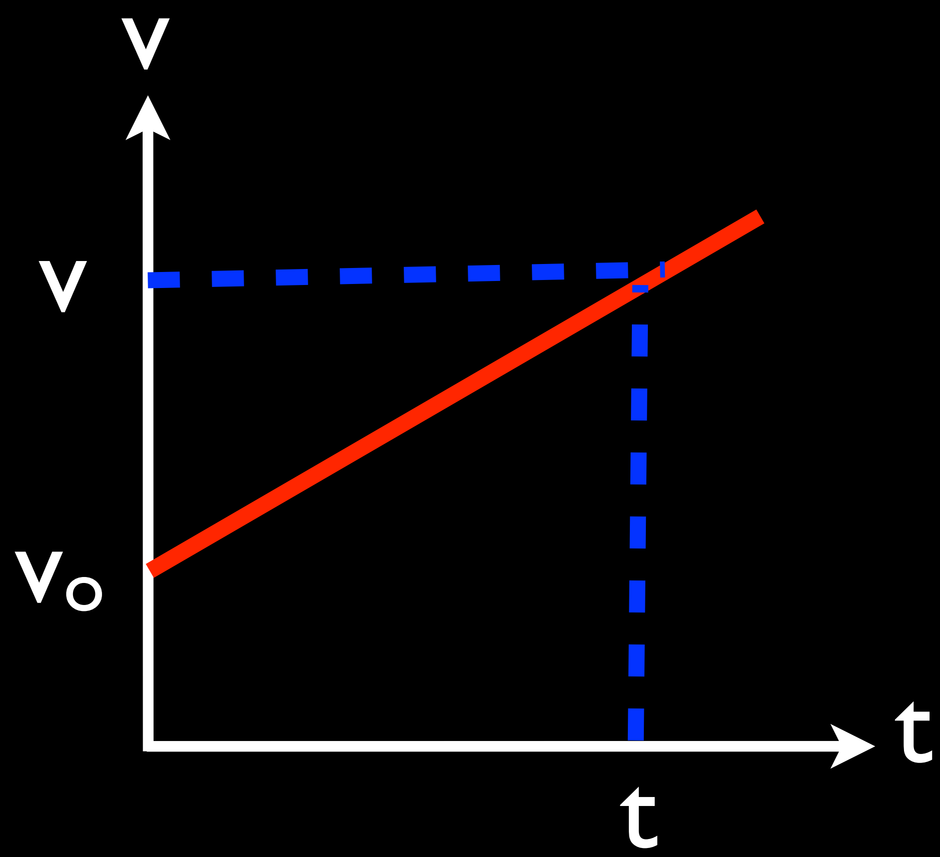
Therefore: $$x = x_o + \frac{1}{2}(v_o + v)t$$

But: $$v = v_o + at$$

So: $$x = x_o + v_o t + \frac{1}{2}at^2$$

Motion in 1D

Acceleration



Finally, since:

$$v = v_o + at$$

Then: $$t = \frac{v - v_o}{a}$$

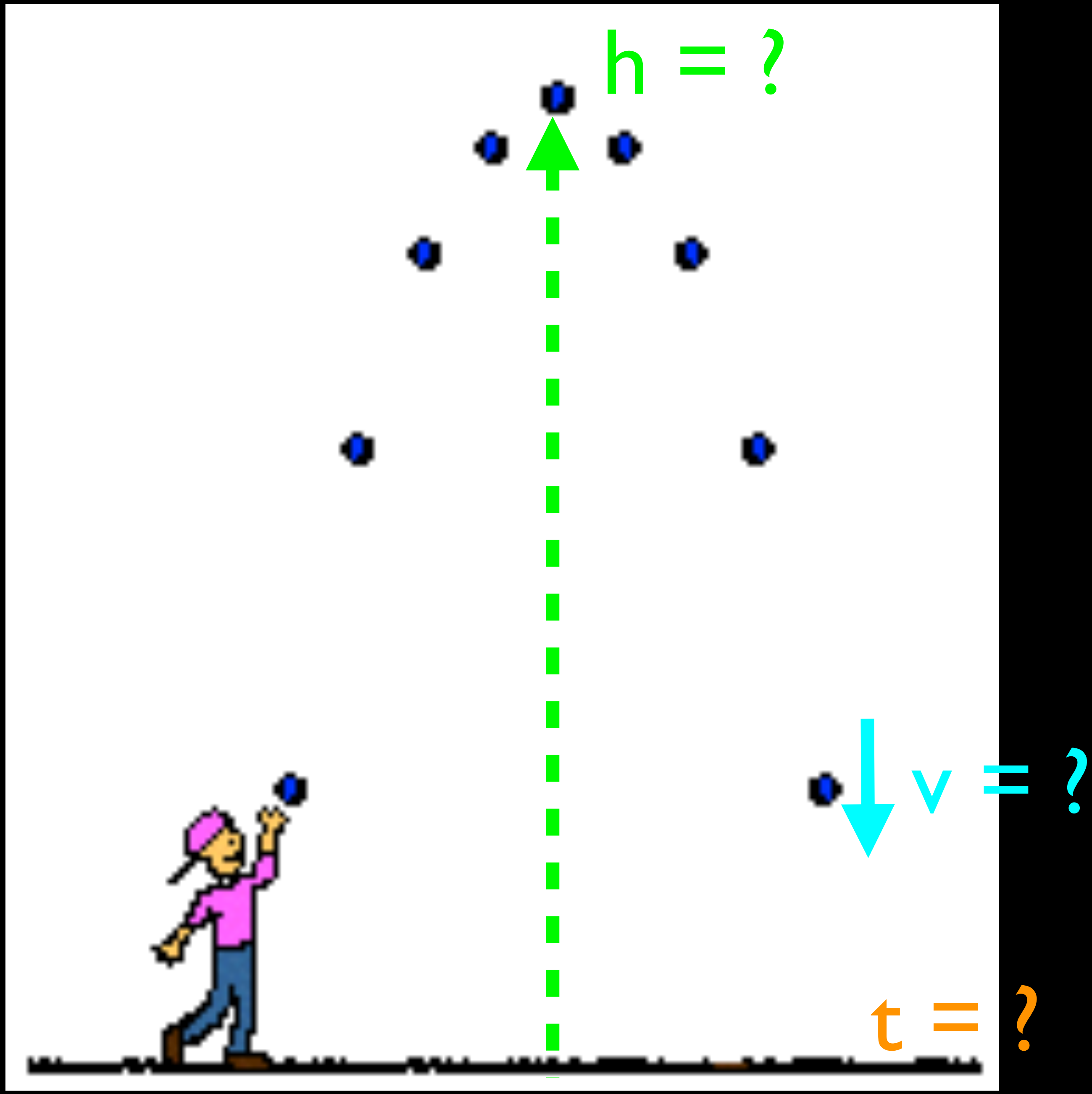
and since: $$x = x_o + v_o t + \frac{1}{2}at^2$$

So: $$v^2 = v_o^2 + 2a(x - x_o)$$

Motion in 1D

Example

You throw a ball with an initial velocity v_0 = 7.3 m/s, at a height of 1.5 m, with a = 9.8 m/s^2 (g) downward.



What is the maximum height?

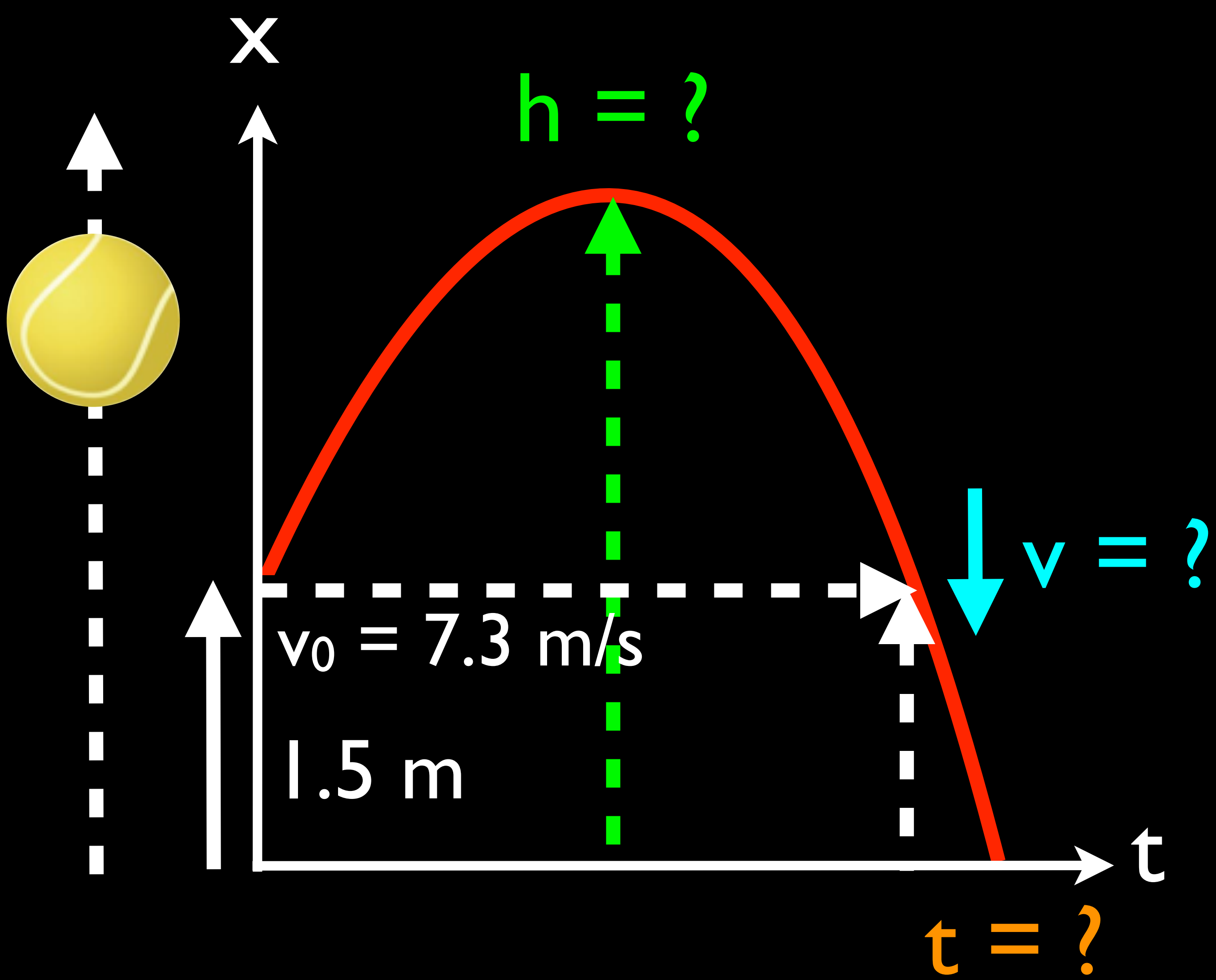
What is the speed when it passes your hand again?

When does it hit the floor?

Motion in 1D

Example

You throw a ball with an initial velocity v_0 = 7.3 m/s, at a height of 1.5 m, with a = 9.8 m/s^2 (g) downward.



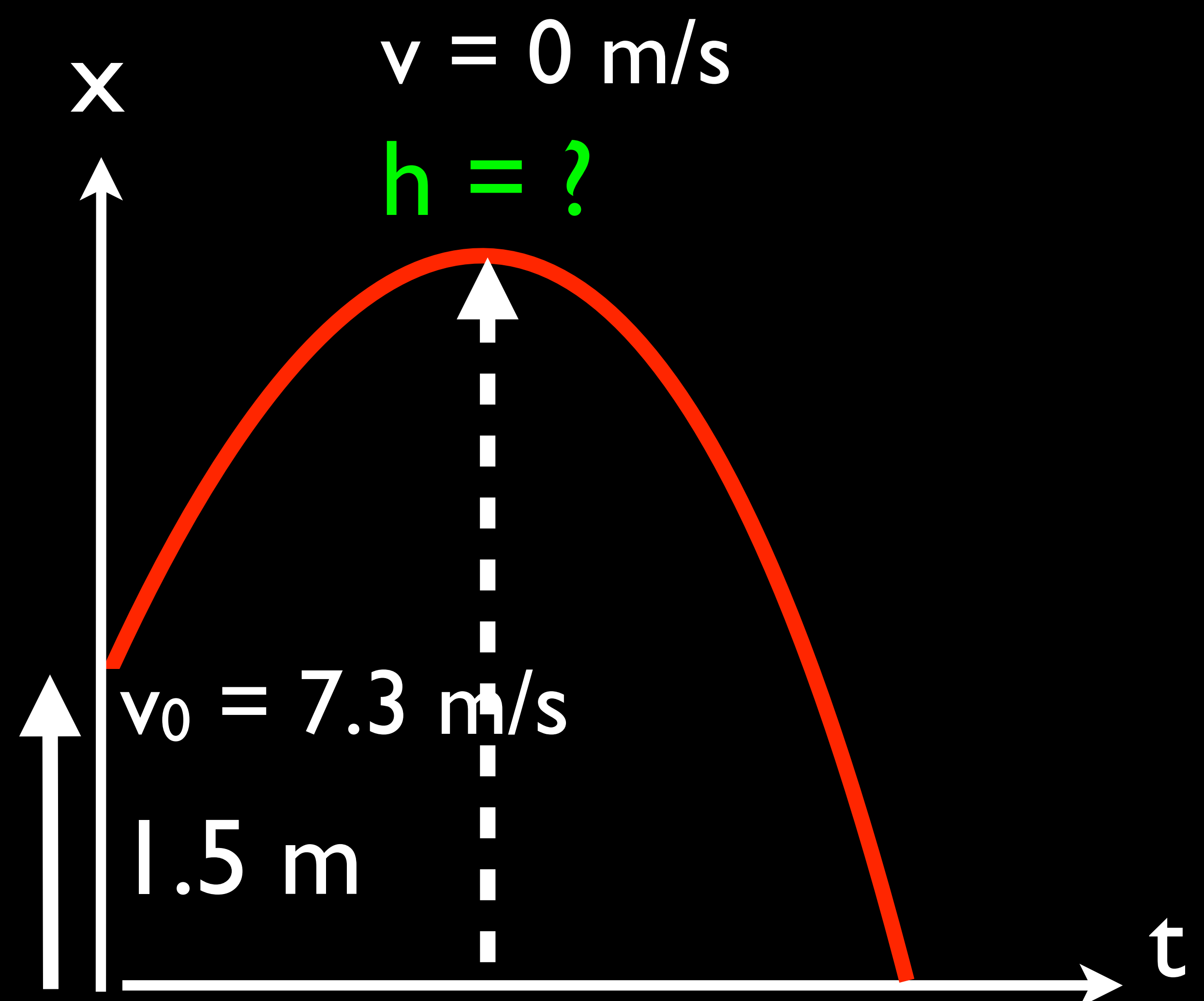
What is the maximum height?

What is the speed when it passes your hand again?

When does it hit the floor?

Motion in 1D

Example



What is the maximum height?

At maximum height, v = 0

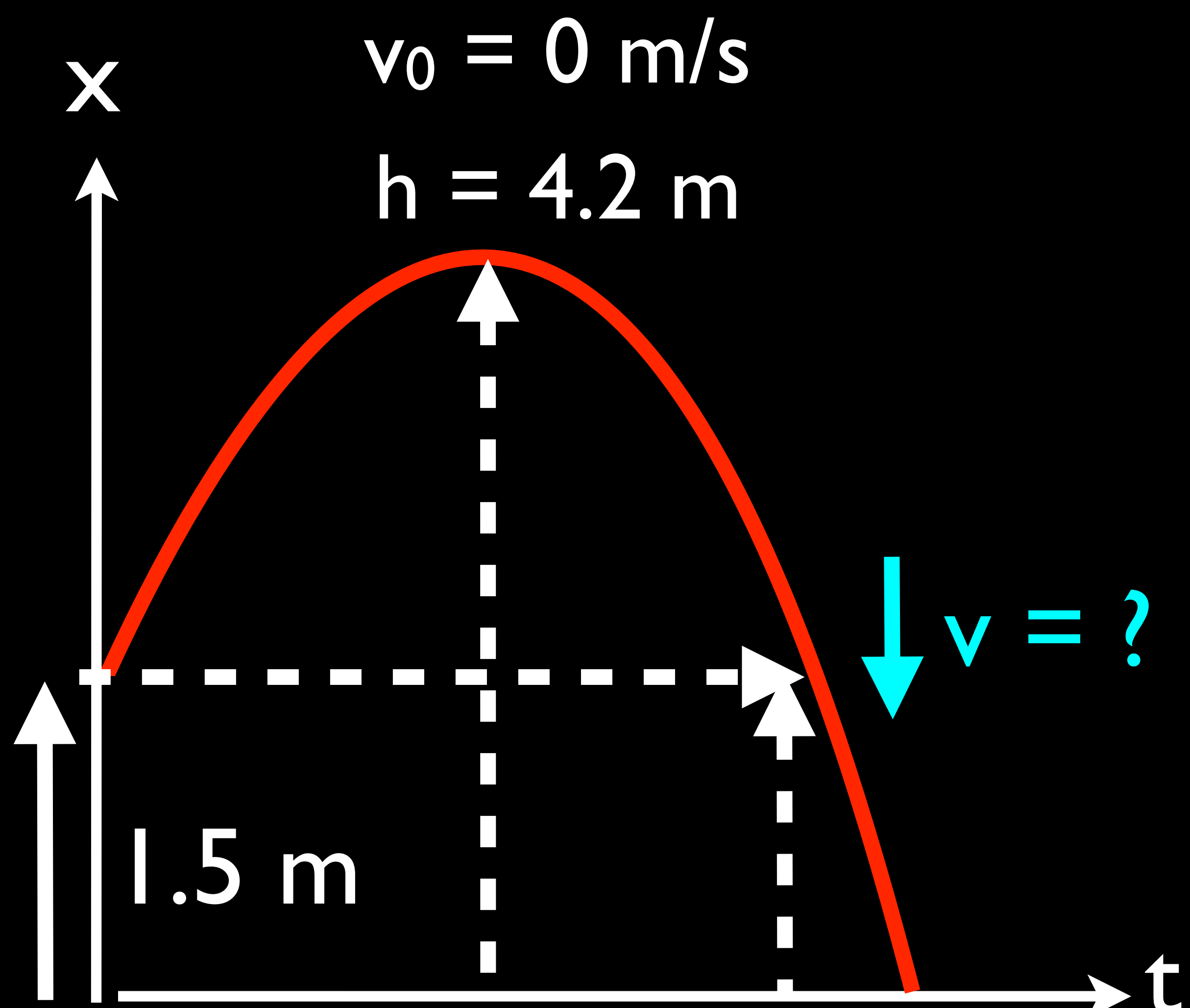
$$v^2 = v_o^2 + 2a(x - x_o)$$

$$0 = (7.3\,\mathrm{m/s})^2 + 2(-9.8\,\mathrm{m/s^2})(h - 1.5\,\mathrm{m})$$

$$h = 4.2\mathrm{m}$$

Motion in 1D

Example



What is the speed when it passes your hand again?

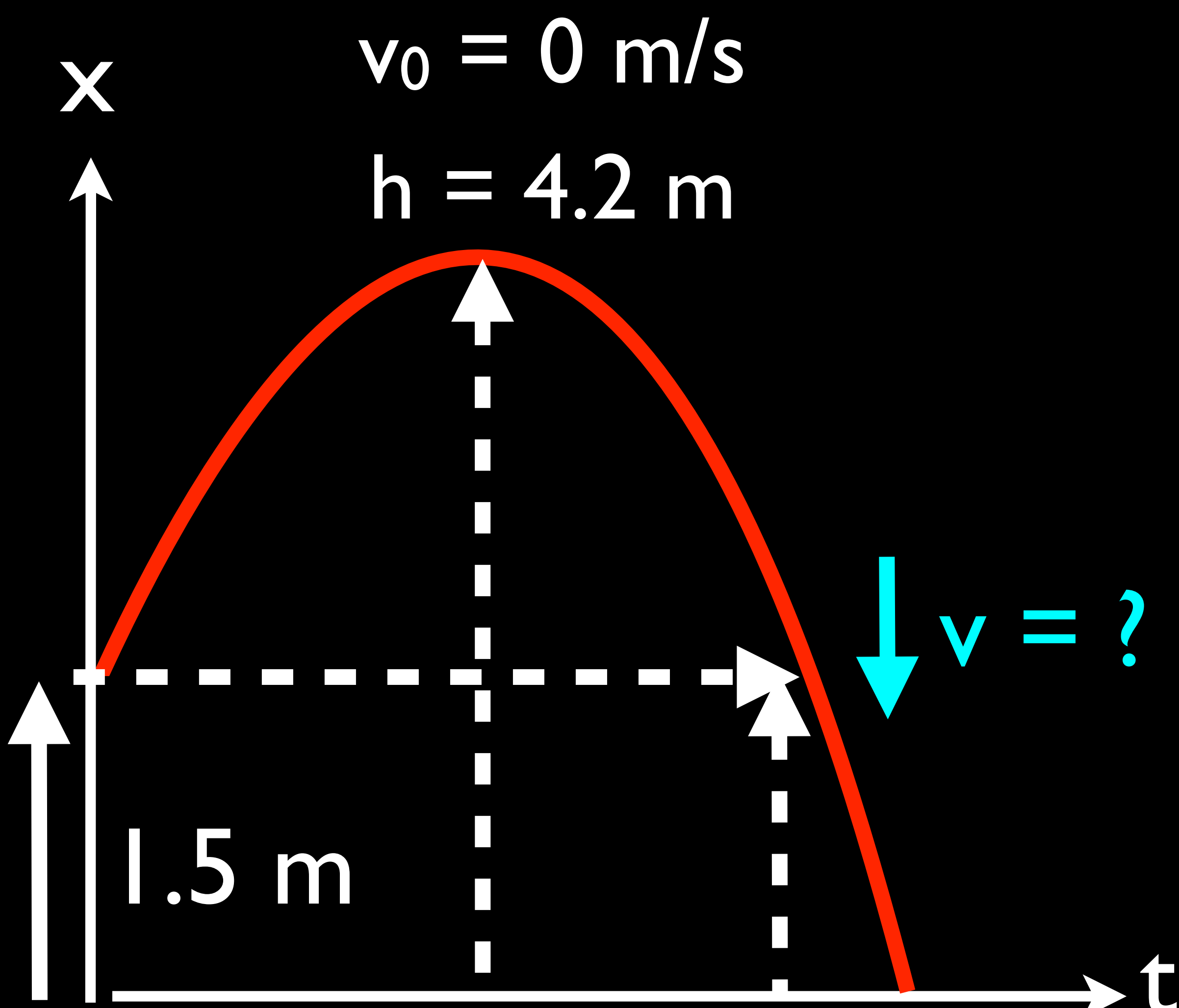
$$v^2 = v_o^2 + 2a(x - x_o)$$

$$= 2(-9.8\,\mathrm{m/s^2})(1.5\,\mathrm{m} - 4.2\,\mathrm{m})$$

$$= \pm 7.3\,\mathrm{m/s}$$

Motion in 1D

Example



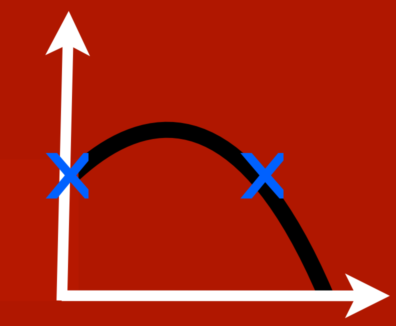
$$v^2 = v_o^2 + 2a(x - x_o)$$

$$= 2(-9.8\,\mathrm{m/s^2})(1.5\,\mathrm{m} - 4.2\,\mathrm{m})$$

$$= \pm 7.3\,\mathrm{m/s}$$

What is the speed when it passes your hand again?

Why 2 answers?



Because ball is at 1.5m twice!

Why are they the same?

Lecture 6!

Motion in 1D

Example

Quadratic equation:

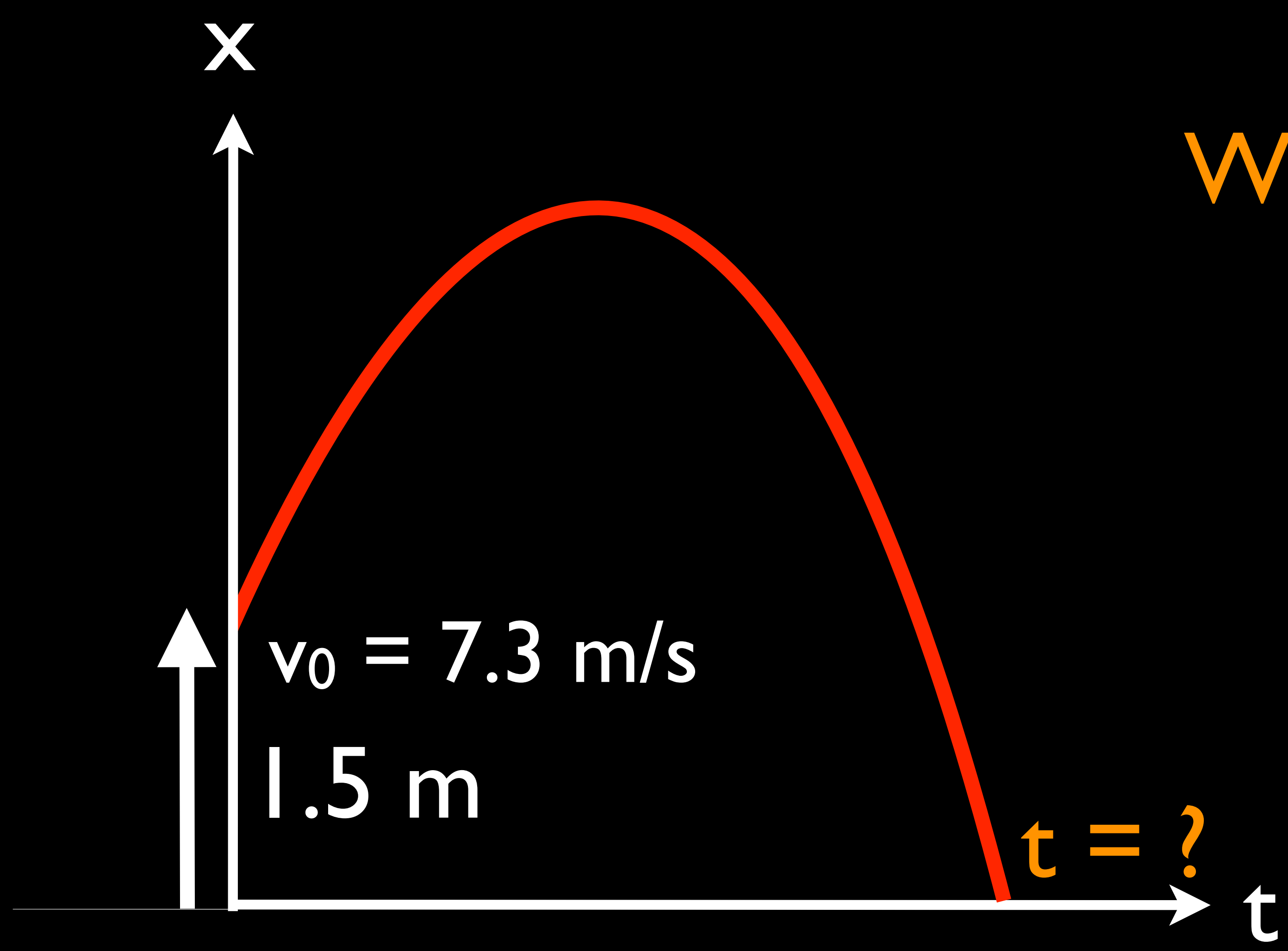
$$at^2 + bt + c = 0$$

Has 2 solutions:

$$t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Motion in 1D

Example



When does it hit the floor?

At floor, x = 0

(Quadratic equation)

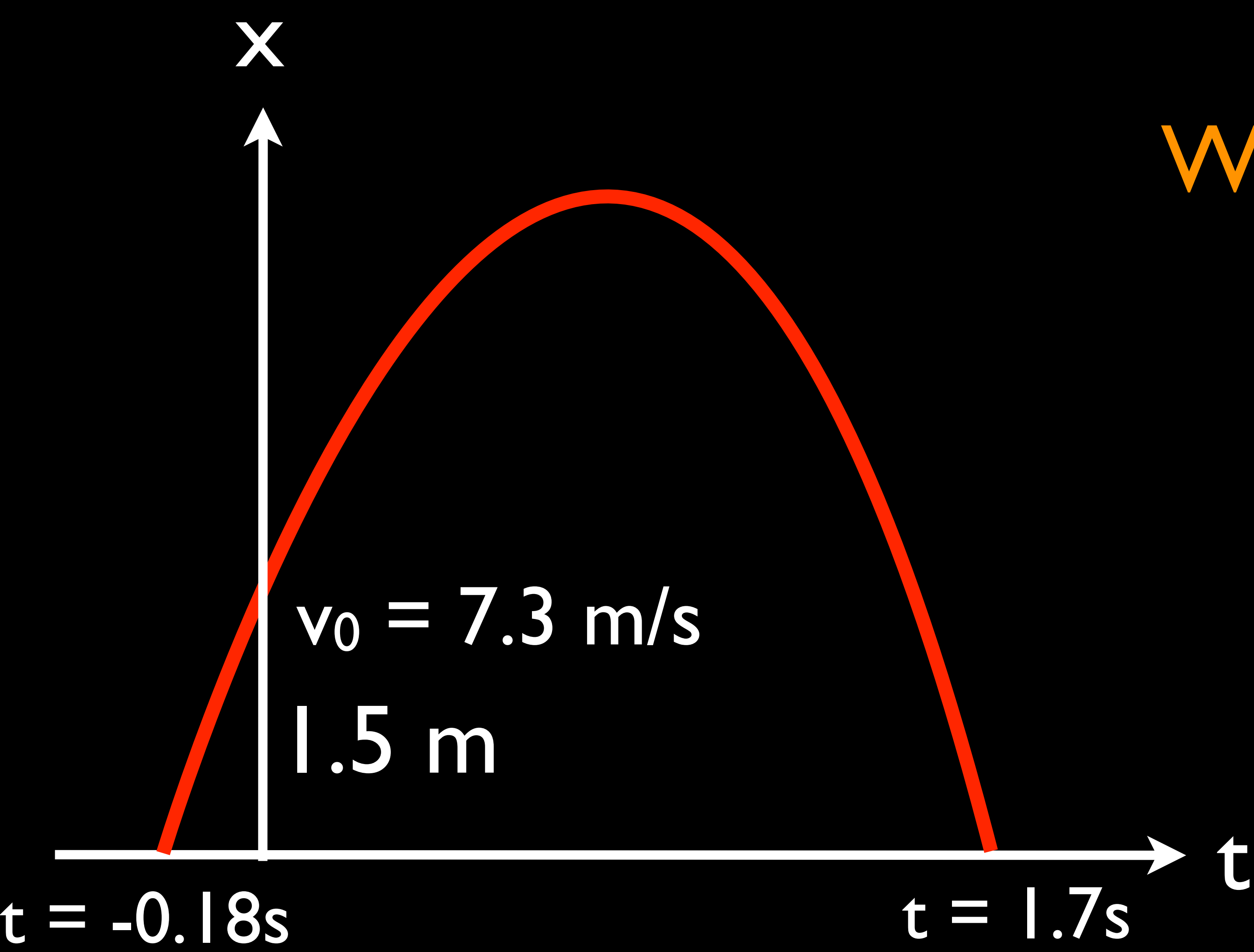
$$x = x_o + v_o t + \frac{1}{2} a t^2$$

$$t = \frac{-v_0 \pm \sqrt{v_0^2 - 4\left(\frac{1}{2}a\right) x_0}}{2\left(\frac{1}{2}a\right)}$$

$$t = \frac{7.8 \pm \sqrt{60.84 + 2(9.8)1.5}}{9.8} = 1.7\,\mathrm{s}$$

Motion in 1D

Example



When does it hit the floor?

At floor, x = 0

(Quadratic equation)

$$x = x_o + v_o t + \frac{1}{2} a t^2$$

$$t = \frac{-v_0 \pm \sqrt{v_0^2 - 4\left(\frac{1}{2}a\right)x_0}}{2\left(\frac{1}{2}a\right)}$$

$$t = \frac{7.8 \pm \sqrt{60.84 + 2(9.8)1.5}}{9.8} = 1.7\,\mathrm{s}$$

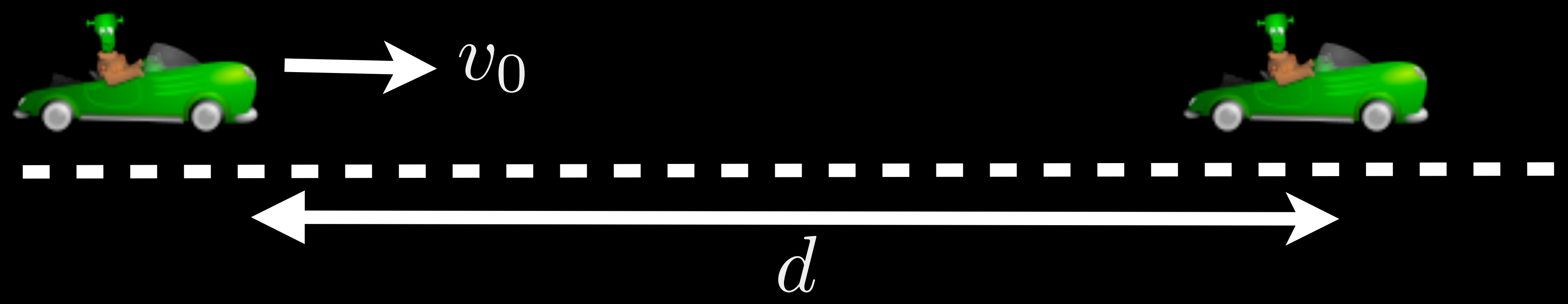
~~(or $= -0.18\,\mathrm{s}$)~~

Motion in 1D

Quiz

A car is moving at initial speed, v_0

... breaks and comes to a stop in distance d.



If the car is now moves at initial speed, $2v_0$

... what is the distance before stopping?

(breaking force the same)

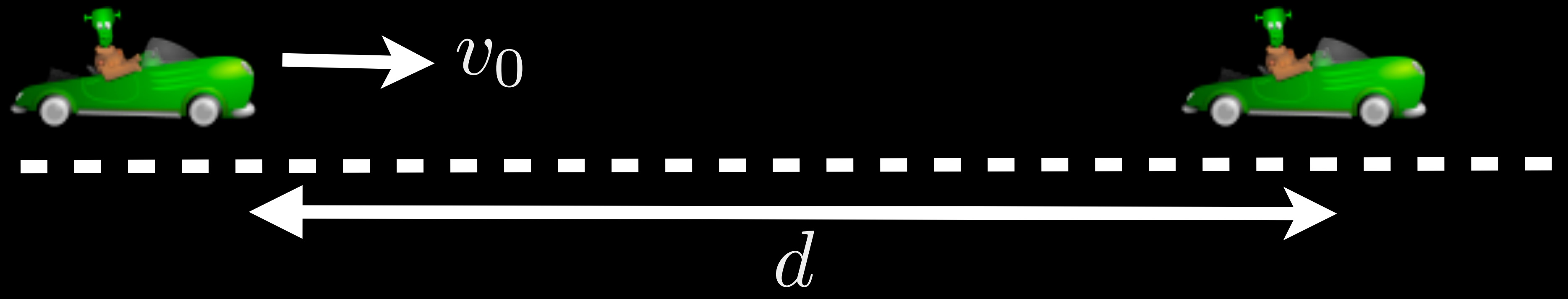
(A) 2d (B) 4d (C) d (D) d/2

Motion in 1D

Quiz

A car is moving at initial speed, v_0

... breaks and comes to a stop in distance d.



If the car is now moves at initial speed, $2v_0$

... what is the distance before stopping?

$$v^2 = v_o^2 + 2a(x - x_o) \Rightarrow 0 = (v_0)^2 + 2(-a)d \Rightarrow d = \frac{v_0^2}{2a}$$

$$0 = (2v_0)^2 + 2(-a)d_2 \Rightarrow d_2 = \frac{4v_0^2}{2a} = 4d$$

This lecture

- Know why units are important
- Convert (change) between units
- Use scientific notation for large and small numbers
- Understand the difference between speed and velocity
- Calculate average and instantaneous velocity and acceleration
- Use equations for constant acceleration