MOTION

IB PHYSICS | COMPLETED NOTES

Units

IB PHYSICS | MOTION

Two Types of Observations

Provide some examples of each

Quantitative	"How Many" / "How Much" Numerical
Qualitative	Description

Measurement

How can you **quantify** a measurement?

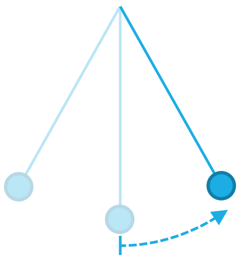
Systems and Units

Fundamental S.I. Units:

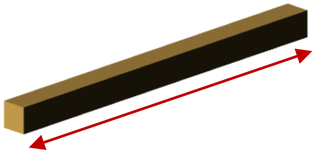
Length	Meter	m
Mass	Kilogram	kg
Time	Second	s
Electric Current	Ampere (amp)	A
Temperature	Kelvin	K
Amount of Substance	Mole	mol
Luminous Intensity	Candela	cd

Units are Arbitrary

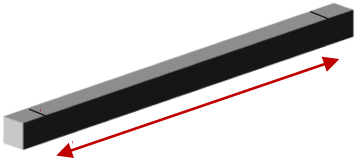
Take the history of the meter…



1790 - The length of a pendulum that swings half of its maximum distance in one second

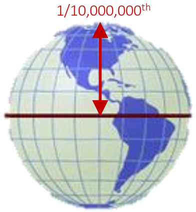


1795 - The length of an official bar of brass fabricated to be exactly one meter as determined in 1791

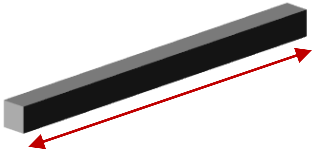


1889 – The distance between two lines on an official bar of platinum-iridium alloy, measured at 0°C

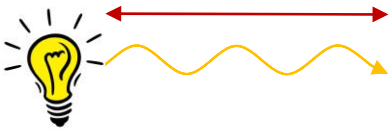
1791 - The length of one ten-millionth of the distance between the North Pole and the equator



1799 - The length of an official bar of platinum, measured from the brass bar and stored at the French National archives



1983 – The length traveled by light in a vacuum during 1/299,792,458 of a second



What’s ‘the standard’?

All of our base SI units are grounded in some “standard” that helps maintain consistency.

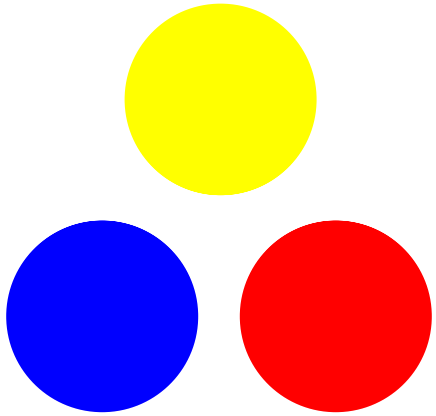
Some of these units even reference each other…

Definition of the Second

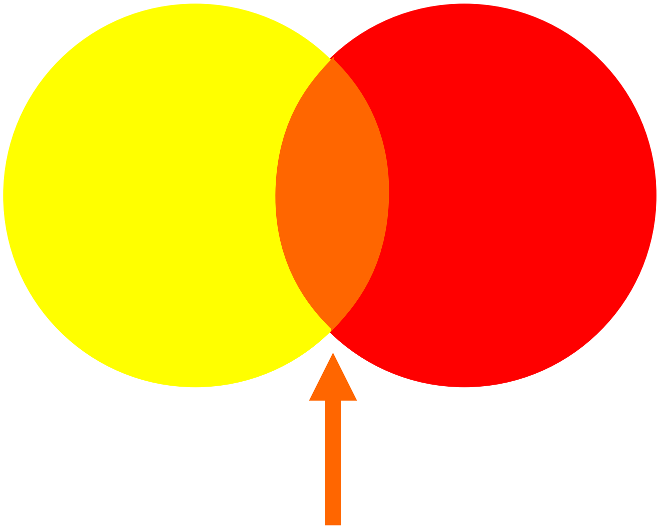
The “second” is defined as the interval required for 9,192,631,770 vibrations of the cesium-133 atom measured via an atomic beam clock

Primary and Secondary Colors

Primary Colors



Secondary Colors



Fundamental vs Derived

Fundamental S.I. Units

Length	m
Mass	kg
Time	s

Derived Units

Velocity: m/s

Acceleration: $m/s^2 = m/s/s$

Force:

$$N = kg \times m/s^2$$

Welcome to IB Land!

Since this course is *International* all of the units must be in the "European" format rather than the "American" format

This means that instead of writing units with a fraction slash, we must use negative exponents

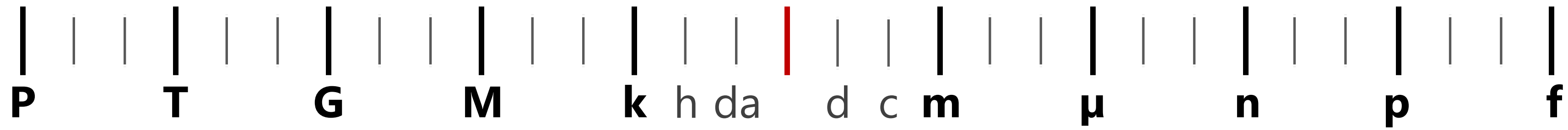
7 m/s	m s^{-1}	$6.67 \frac{Nm^2}{kg^2}$	N m^2 kg^{-2}
9.81 m/s^2	m s^{-2}	$2.2 \frac{J}{K}$	J K^{-1}
87 g/cm^3	g cm^{-3}	$8.31 \frac{J}{K \times mol}$	J K^{-1} mol^{-1}

The Metric System

*Taken directly from the IB Physics Data Booklet

Prefix	Abbreviation	Value
peta	P	10^{15}
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
hecto	h	10^{2}
deca	da	10^{1}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}

The Metric System



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kilo	k	10^{3}
hecto	h	10^{2}
deca	da	10^{1}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	µ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}

The value given is the number of places the decimal moves

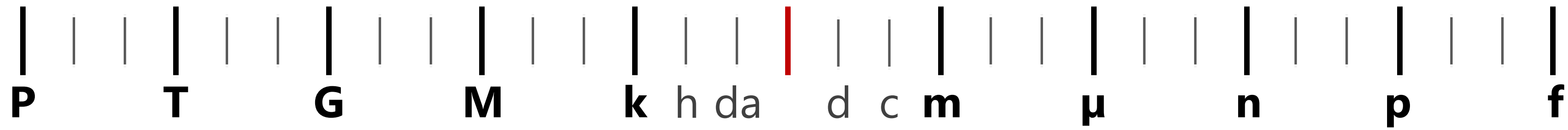
Please make sure that you go in the correct direction!

900 nm = 900,000,000,000 m

or

900 nm = 0.0000009 m

The Metric System



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deca	da	10^{1}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}

base

9

900 nm → 0.0000009 m

900×10^{-9} m

The Metric System

Prefix	Abbreviation	Power
giga-	G	10^9
mega-	M	10^6
kilo-	K	10^3
hecto-	h	10^2
deca-	da	10^1
	Base	
deci-	d	10^{-1}
centi-	c	10^{-2}
milli-	m	10^{-3}
micro-	µ	10^{-6}
nano-	n	10^{-9}

Conversions:

250 g = 0.25 kg

0.00325 kg = 3,250,000 µg

54 mm = 0.000054 km

The Metric System | Try These

Prefix	Abbreviation	Power
giga-	G	10^9
mega-	M	10^6
kilo-	K	10^3
hecto-	h	10^2
deca-	da	10^1
Base		
deci-	d	10^{-1}
centi-	c	10^{-2}
milli-	m	10^{-3}
micro-	μ	10^{-6}
nano-	n	10^{-9}

6

6

65 μC = 0.000065 C

12 MW = 12,000,000 W

The Metric System

SI prefixes

1000^n	10^n	Prefix	Symbol	Short scale	Long scale	Decimal equivalent in SI writing style
1000^8	10^{24}	yotta-	Y	Septillion	Quadrillion	1 000 000 000 000 000 000 000 000
1000^7	10^{21}	zetta-	Z	Sextillion	Trilliard (thousand trillion)	1 000 000 000 000 000 000 000
1000^6	10^{18}	exa-	E	Quintillion	Trillion	1 000 000 000 000 000 000
1000^5	10^{15}	**peta-**	P	Quadrillion	Billiard (thousand billion)	1 000 000 000 000 000
1000^4	10^{12}	tera-	T	Trillion	Billion	1 000 000 000 000
1000^3	10^9	giga-	G	Billion	Milliard (thousand million)	1 000 000 000
1000^2	10^6	mega-	M	Million		1 000 000
1000^1	10^3	kilo-	k	Thousand		1 000
$1000^{2/3}$	10^2	hecto-	h	Hundred		100
$1000^{1/3}$	10^1	deca-	da	Ten		10
1000^0	10^0	*(none)*	*(none)*	One		1
$1000^{-1/3}$	10^{-1}	deci-	d	Tenth		0.1
$1000^{-2/3}$	10^{-2}	centi-	c	Hundredth		0.01
1000^{-1}	10^{-3}	milli-	m	Thousandth		0.001
1000^{-2}	10^{-6}	micro-	µ	Millionth		0.000 001
1000^{-3}	10^{-9}	nano-	n	Billionth	Milliardth	0.000 000 001
1000^{-4}	10^{-12}	pico-	p	Trillionth	Billionth	0.000 000 000 001
1000^{-5}	10^{-15}	femto-	f	Quadrillionth	Billiardth	0.000 000 000 000 001
1000^{-6}	10^{-18}	atto-	a	Quintillionth	Trillionth	0.000 000 000 000 000 001
1000^{-7}	10^{-21}	zepto-	z	Sextillionth	Trilliardth	0.000 000 000 000 000 000 001
1000^{-8}	10^{-24}	yocto-	y	Septillionth	Quadrillionth	0.000 000 000 000 000 000 000 001

There's more…

"What about Instagram?"

Lesson Takeaways

- ❑ I can describe the difference between quantitative and qualitative observations
- ❑ I can identify the 7 Fundamental SI units
- ❑ I can define and give an example of a derived unit
- ❑ I can represent fractional units with negative exponents
- ❑ I can convert metric units between prefixes

Dimensional Analysis

IB PHYSICS | MOTION

Conversions

Convert the Following:

26.2 miles → kilometers

1 Mile = 1.609 Kilometers

$$26.2\ \cancel{\text{mi}} \times \frac{1.609\ \text{km}}{1\ \cancel{\text{mi}}} = \boxed{\mathbf{42.2\ km}}$$

Conversions with fractions

Convert the Following:

35 mi hr^{-1} → m s^{-1}

1 Mile = 1609 meters

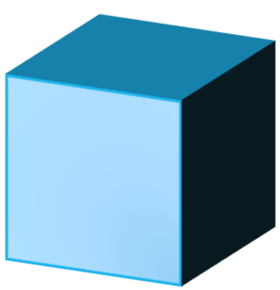
$$\frac{35\ \text{mi}}{1\ \text{hr}} \times \frac{1609\ \text{m}}{1\ \text{mi}} \times \frac{1\ \text{hr}}{60\ \text{min}} \times \frac{1\ \text{min}}{60\ \text{s}} = \mathbf{15.6\ m\ s^{-1}}$$

Conversions with Exponents

How many cm^2 are there in 1 m^2?

$$100 \times 100 = 100^2 = \mathbf{10,000\ cm^2}$$

How many cm^3 are there in 1 m^3?



$$100 \times 100 \times 100 = 100^3 = \mathbf{1,000,000\ cm^2}$$

Conversions with Exponents

Convert the Following:

$0.05\ \text{km}^2 \rightarrow \text{m}^2$

$$0.05\ \text{km}^2 \times \frac{1000\ \text{m}}{1\ \text{km}} \times \frac{1000\ \text{m}}{1\ \text{km}} = \mathbf{50,000\ m^2}$$

$$0.05\ \text{km}^2 \times \left(\frac{1000\ \text{m}}{1\ \text{km}}\right)^2 = \mathbf{50,000\ m^2}$$

Conversions with Exponents

Convert the Following:

1 meter = 3.28 feet

$5\ m^2 \rightarrow ft^2$

$$5\ \mathrm{m}^2 \times \left(\frac{3.28\ \mathrm{ft}}{1\ \mathrm{m}}\right)^2 = \mathbf{53.8\ ft^2}$$

$5\ m^3 \rightarrow ft^3$

$$5\ \mathrm{m}^3 \times \left(\frac{3.28\ \mathrm{ft}}{1\ \mathrm{m}}\right)^3 = \mathbf{176.4\ ft^3}$$

Dimensional Analysis

Start with the formula and substitute units in for variables

$$v = \frac{d}{t} \qquad \left[\frac{m}{s}\right] = \frac{[m]}{[s]}$$

Is this formula valid?

$$d = at \qquad [m] = \left[\frac{m}{s^2}\right][s]$$

not valid

$$[m] = \left[\frac{m}{s}\right]$$

Dimensional Analysis

We can use equations with units that we know to find units that we don't.

$$p = m \times v$$

$$= [\mathrm{kg}] \left[\frac{\mathrm{m}}{\mathrm{s}}\right]$$

Variable	Unit
Momentum **p**	kg m s^{-1}
Mass **m**	Kilogram [kg]
Velocity **v**	Meters per second [ms^{-1}]

Dimensional Analysis

Constants have units too! That's what makes our equation valid

$$F = G\frac{m_1 m_2}{d^2}$$

$$G = \frac{Fd^2}{m_1 m_2} = \frac{[\mathrm{N}][\mathrm{m}]^2}{[\mathrm{kg}]^2}$$

$$= \frac{[\mathrm{N}][\mathrm{m}]^2}{[\mathrm{kg}]^2}$$

Variable	Unit
Force **F**	Newton [N]
Mass $\mathbf{m_1}$ and $\mathbf{m_2}$	Kilogram [kg]
Distance **d**	Meter [m]
Universal Gravitation Constant **G**	N m^2 kg^{-2}

Normalized Scientific Notation

Helpful for very **big** numbers

89,000,000 = 8.9×10^{7} or 8.9E7

750,000,000,000 = 7.5×10^{11} or 7.5E11

8,759,000,000 = 8.759×10^{9} or 8.759E9

Normalized Scientific Notation

Helpful for very **small** numbers

0.00125 = 1.25×10^{-3} or 1.25E-3

0.0000008255 = 8.255×10^{-7} or 8.255E-7

0.00000082550 = 8.2550×10^{-7} or 8.2550E-7

Lesson Takeaways

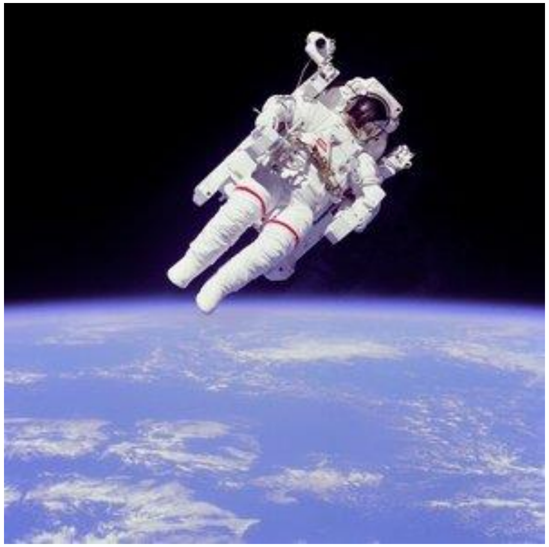
- ❑ I can convert fraction units and exponential units using Dimensional Analysis
- ❑ I can use dimensional analysis to verify a formula
- ❑ I can use dimensional analysis to determine the units for a solution
- ❑ I can represent large and small numbers using scientific notation

Displacement Graphs

IB PHYSICS | MOTION

What is Motion?

An object's change in __position______________ relative to a reference point.



Relative to the earth:
Moving 17,500 mph

Relative to the shuttle:
Not moving

Distance vs. Displacement

Distance	How far travelled
Displacement	How far from origin

Distance and Displacement in 2D

Distance as the Crow Flies : 1170.297

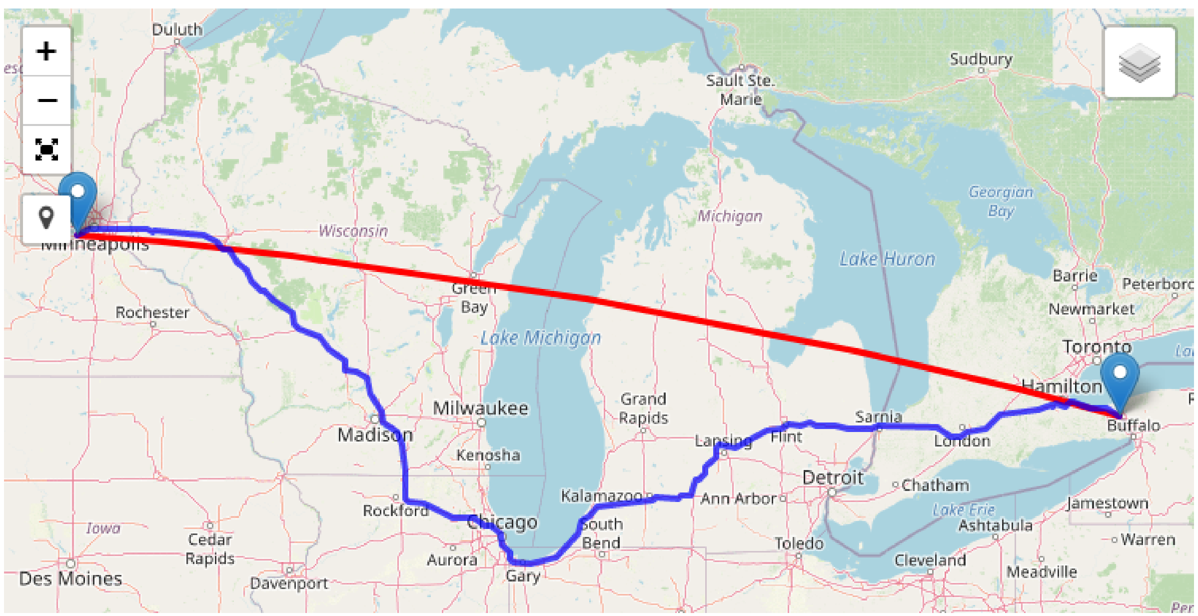
Distance by Land Transport : 1525.995

This road journey will take 21 Hours, 11 Minutes

You can **link to this result : How Far is it Between Minnetonka High School - The Cove, Minnetonka and Niagra Falls, Canada**

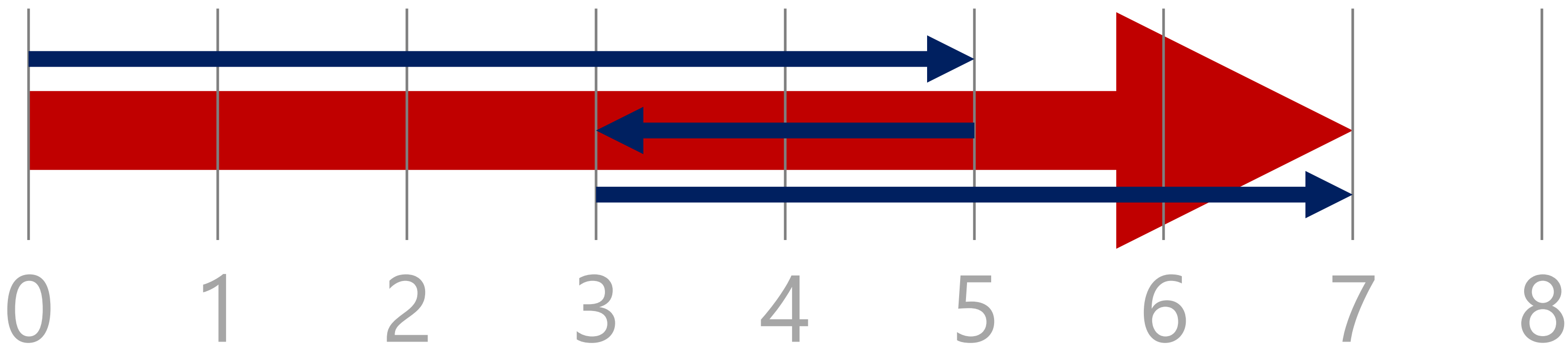
https://www.freemaptools.com/how-far-is-it-between-minnetonka-high-school---the-cove_-minnetonka-and-niagra-falls_-ca

Map Showing the Distance Between Minnetonka High School - The Cove, Minnetonka and Niagra Falls, Canada



Try this | Distance and Displacement

You walked 5 km East, turned around and walked 2 km West, turned around again and walked another 4 km East. What is your distance? What is your displacement?

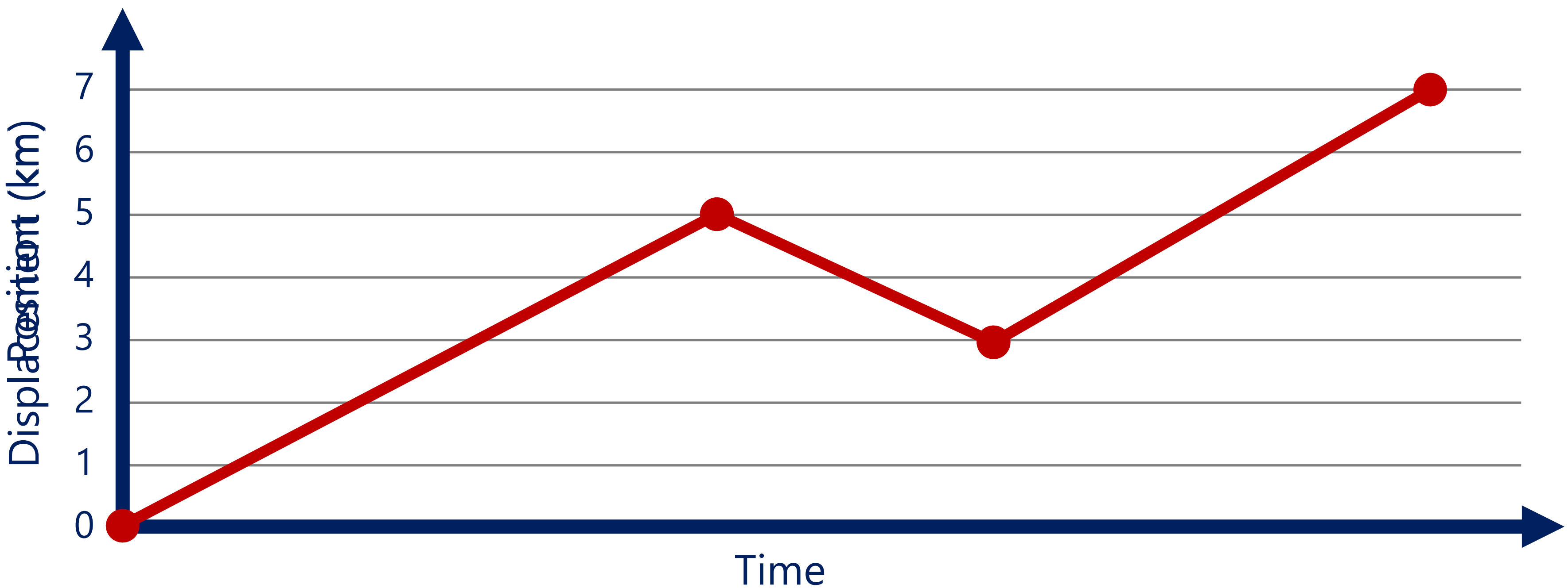


5 + 2 + 4

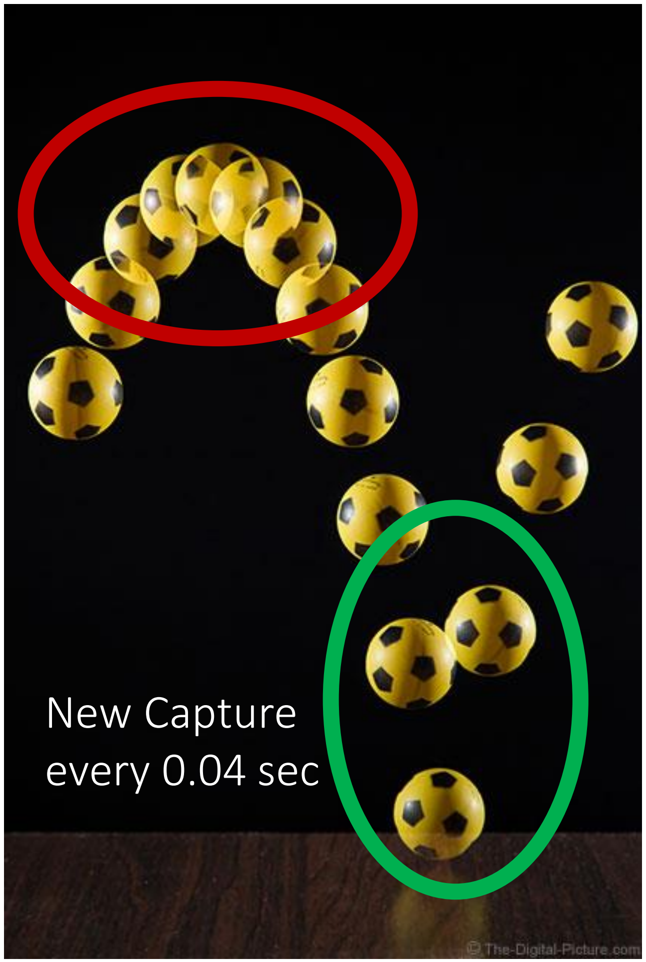
Distance	11 km
Displacement	7 km

Graphing Displacement

You walked 5 km East, turned around and walked 2 km West, turned around again and walked another 4 miles km. What is your distance? What is your displacement?



Stroboscopic Photographs



In a stroboscopic photograph, a new snapshot is captured every ___ seconds and combined to show the motion over a period of time.

Circle the part of the motion where this soccer ball is moving the FASTEST

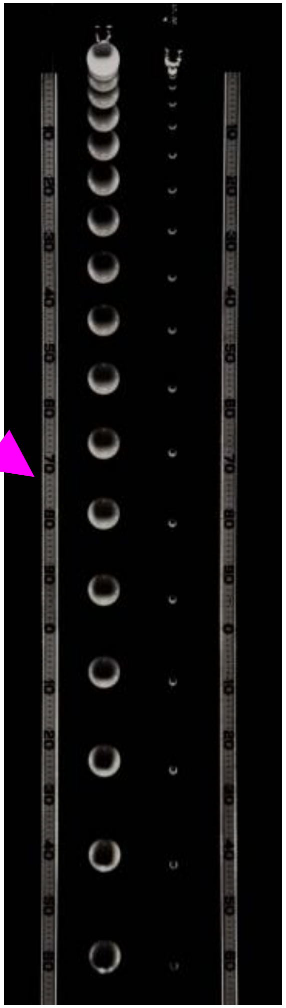
Circle the part of the motion where this soccer ball is moving the SLOWEST

Stroboscopic Photographs

Constant Velocity or Accelerating?

How do you know?

More spacing between pictures = moving faster



Predict the Motion…

Which cart do you think has the best chance of reaching the 10-meter location first?

Time	0.0 s	1.0 s	2.0 s	3.0 s
Cart A	0.0 m			
Cart B	2.0 m			
Cart C	3.0 m			

Predict the Motion...

Now which cart do you think has the best chance of reaching the 10-meter location first?

Time	0.0 s	1.0 s	2.0 s	3.0 s
Cart A	0.0 m	4.0 m		
Cart B	2.0 m	4.0 m		
Cart C	3.0 m	4.0 m		

What new information do you have about the carts now that you didn't before?

Predict the Motion…

Now which cart do you think has the best chance of reaching the 10-meter location first?

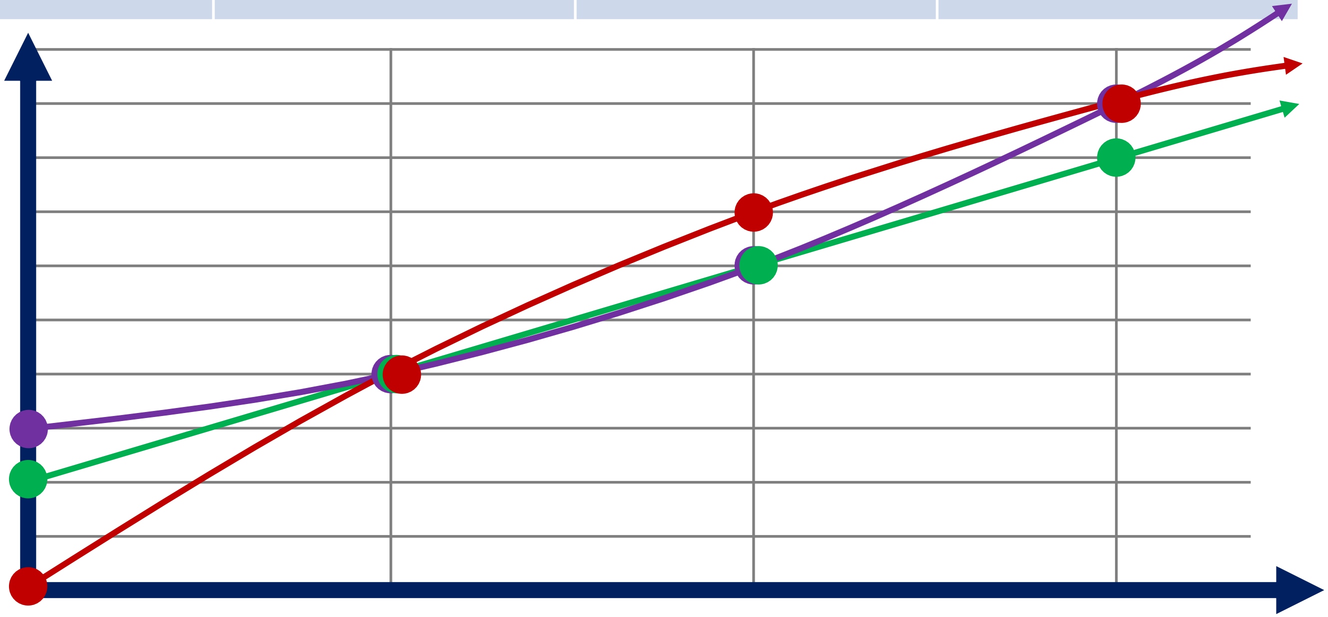
Time	0.0 s	1.0 s	2.0 s	3.0 s
Cart A	0.0 m	4.0 m	7.0 m	??
Cart B	2.0 m	4.0 m	6.0 m	??
Cart C	3.0 m	4.0 m	6.0 m	??

What patterns do you see? Can you use these to predict the next position?

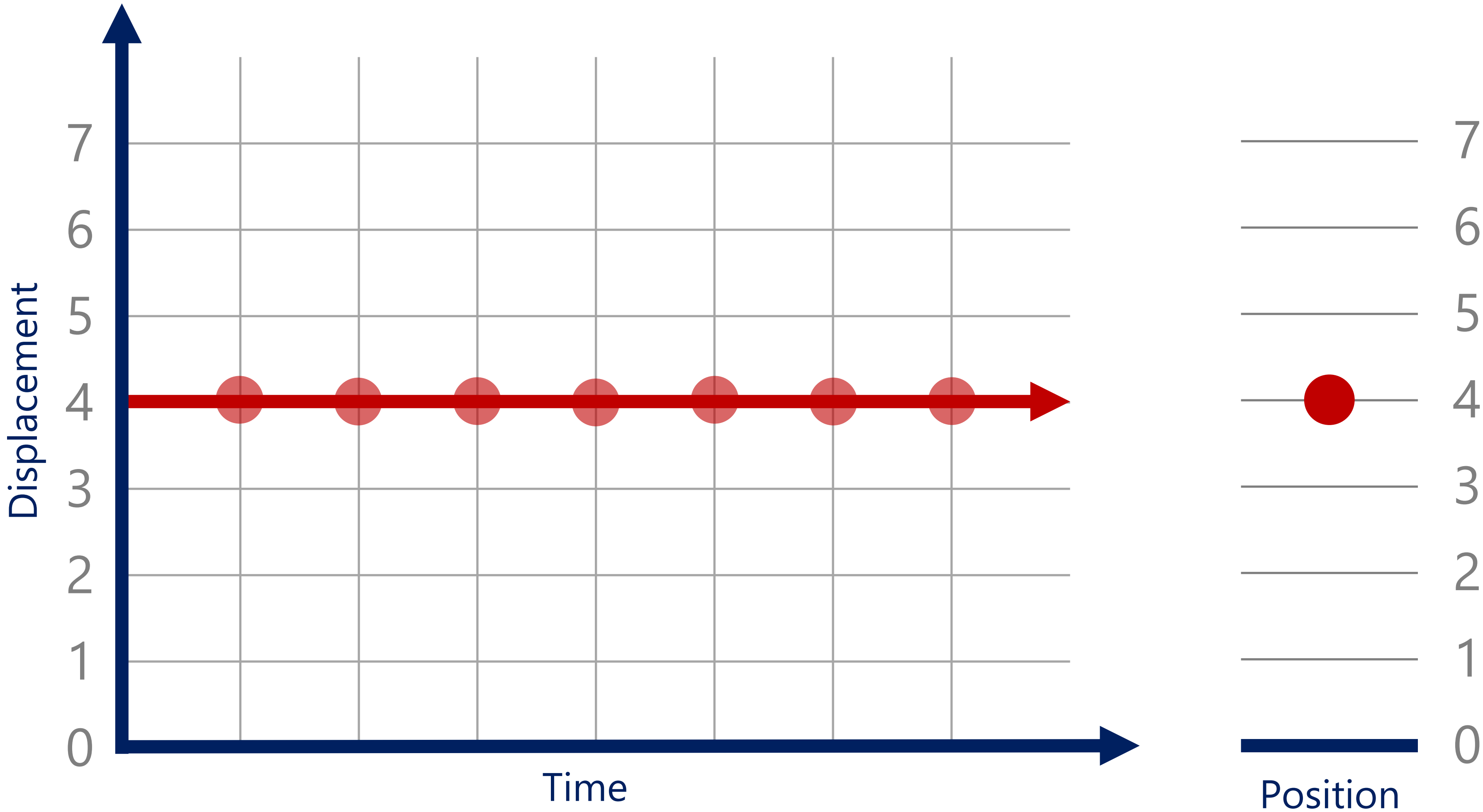
Predict the Motion…

It's more than just position, you need multiple frames to see motion

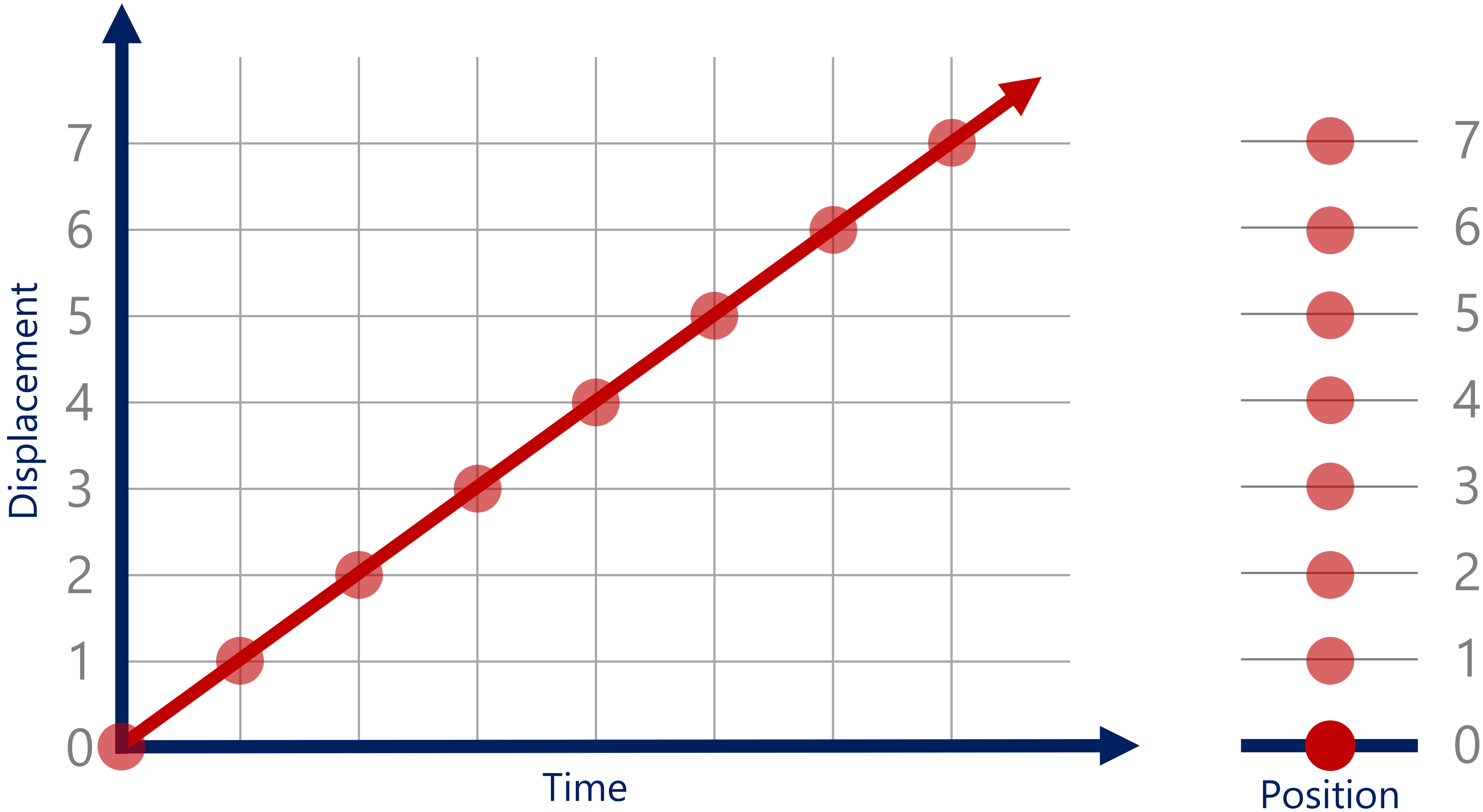
Time	0.0 s	1.0 s	2.0 s	3.0 s
Cart A	0.0 m	4.0 m	7.0 m	9.0 m
Cart B	2.0 m	4.0 m	6.0 m	8.0 m
Cart C	3.0 m	4.0 m	6.0 m	9.0 m



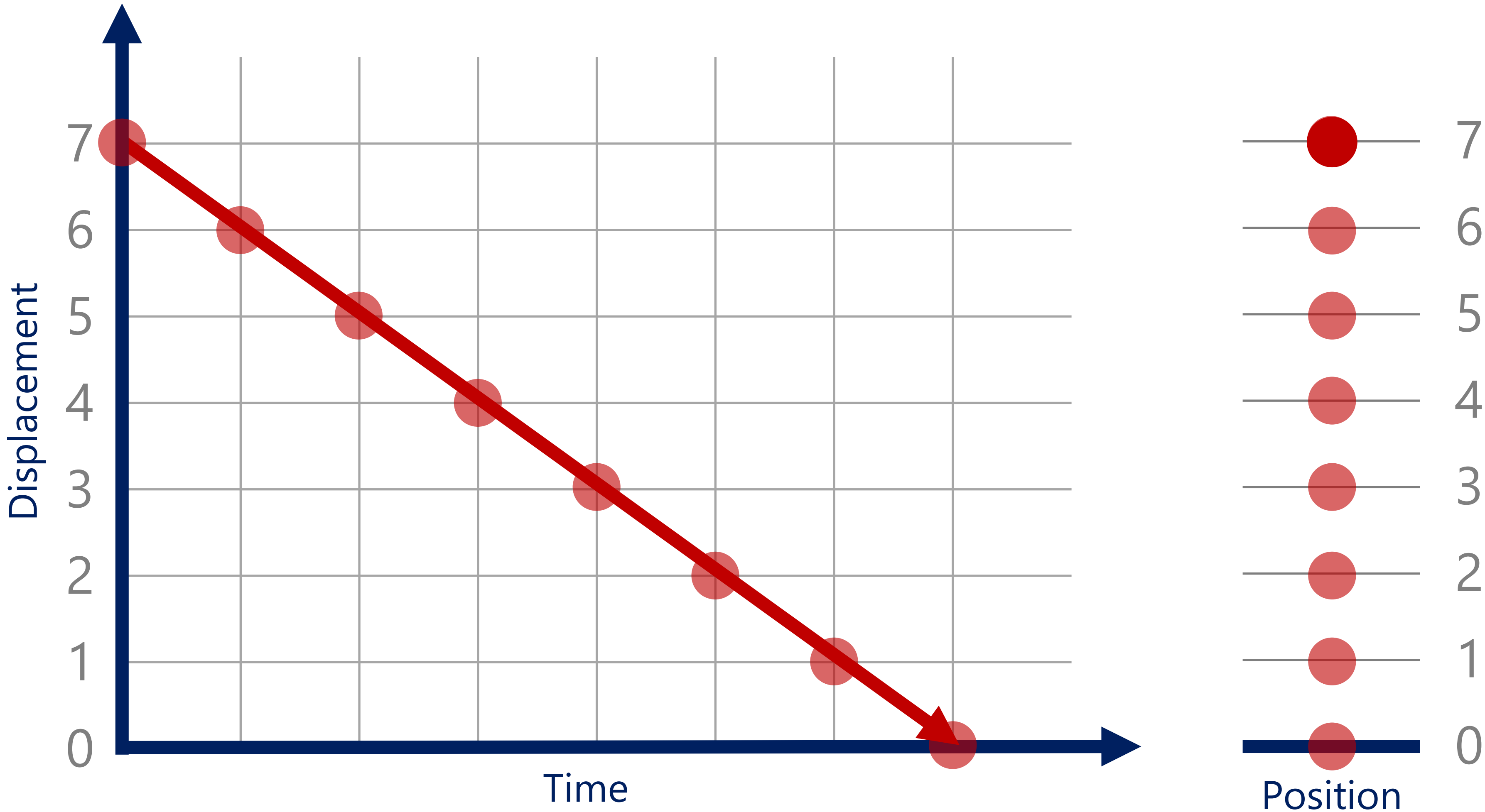
An object not moving



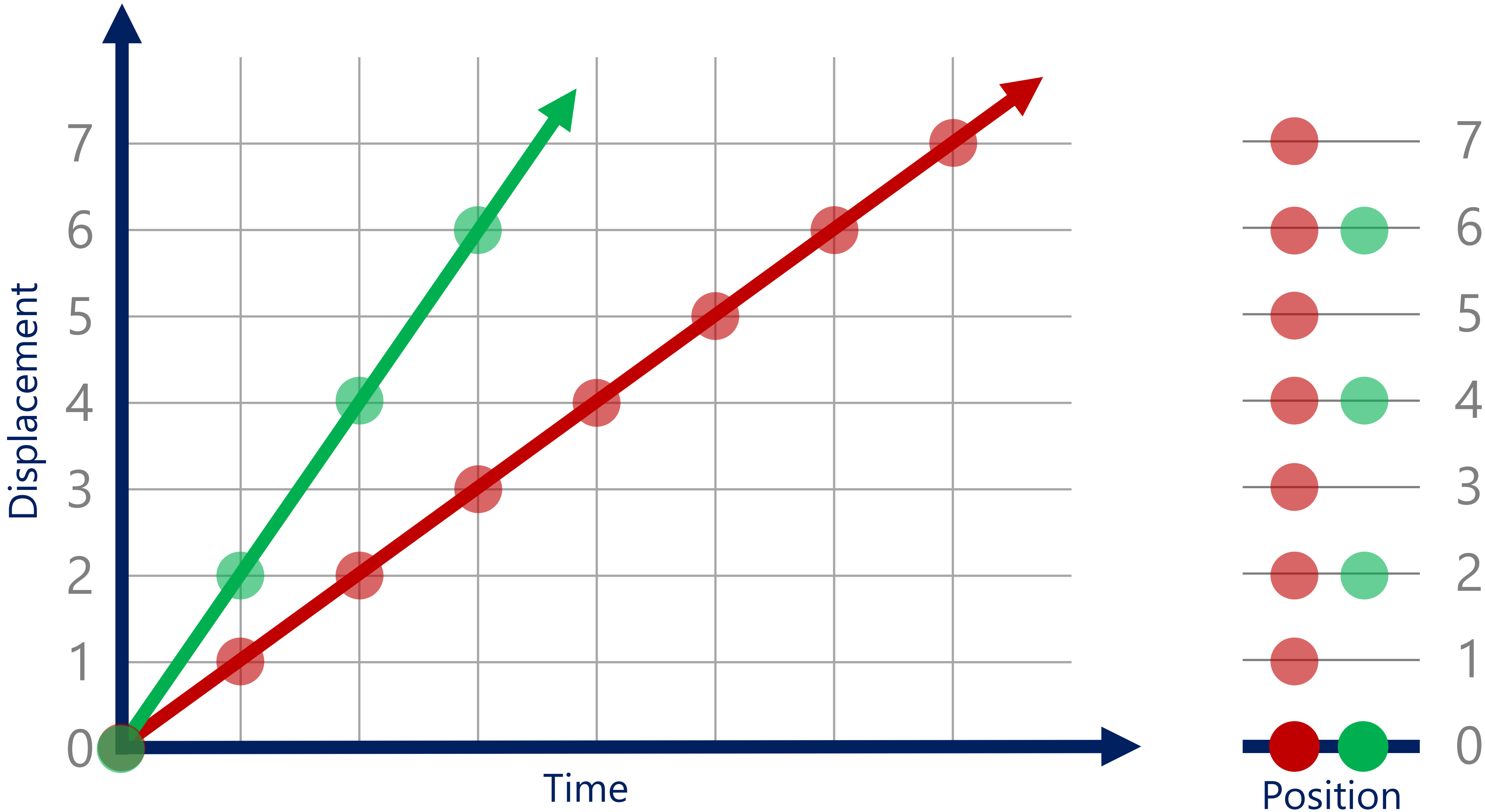
An object moving forward



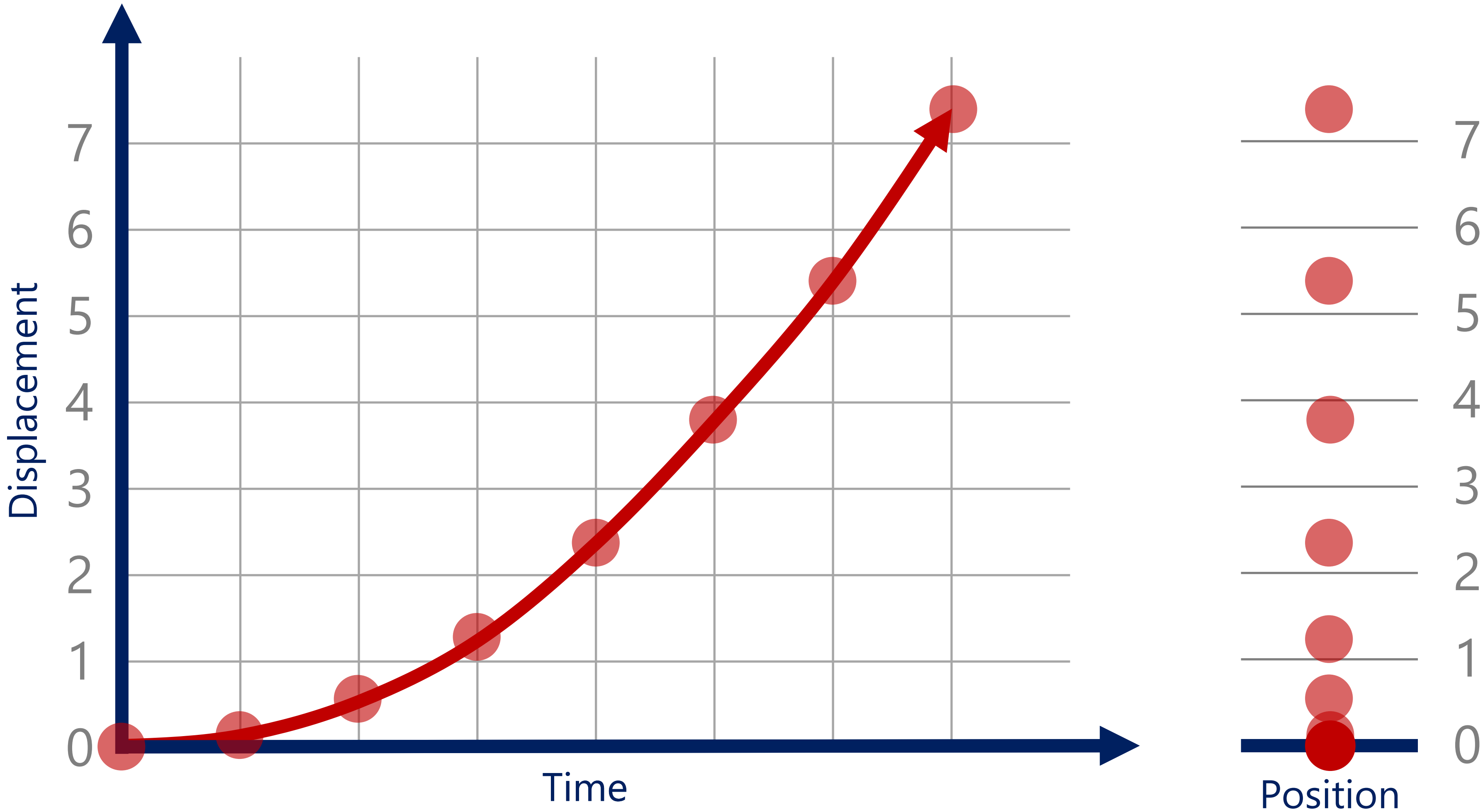
An object moving backward



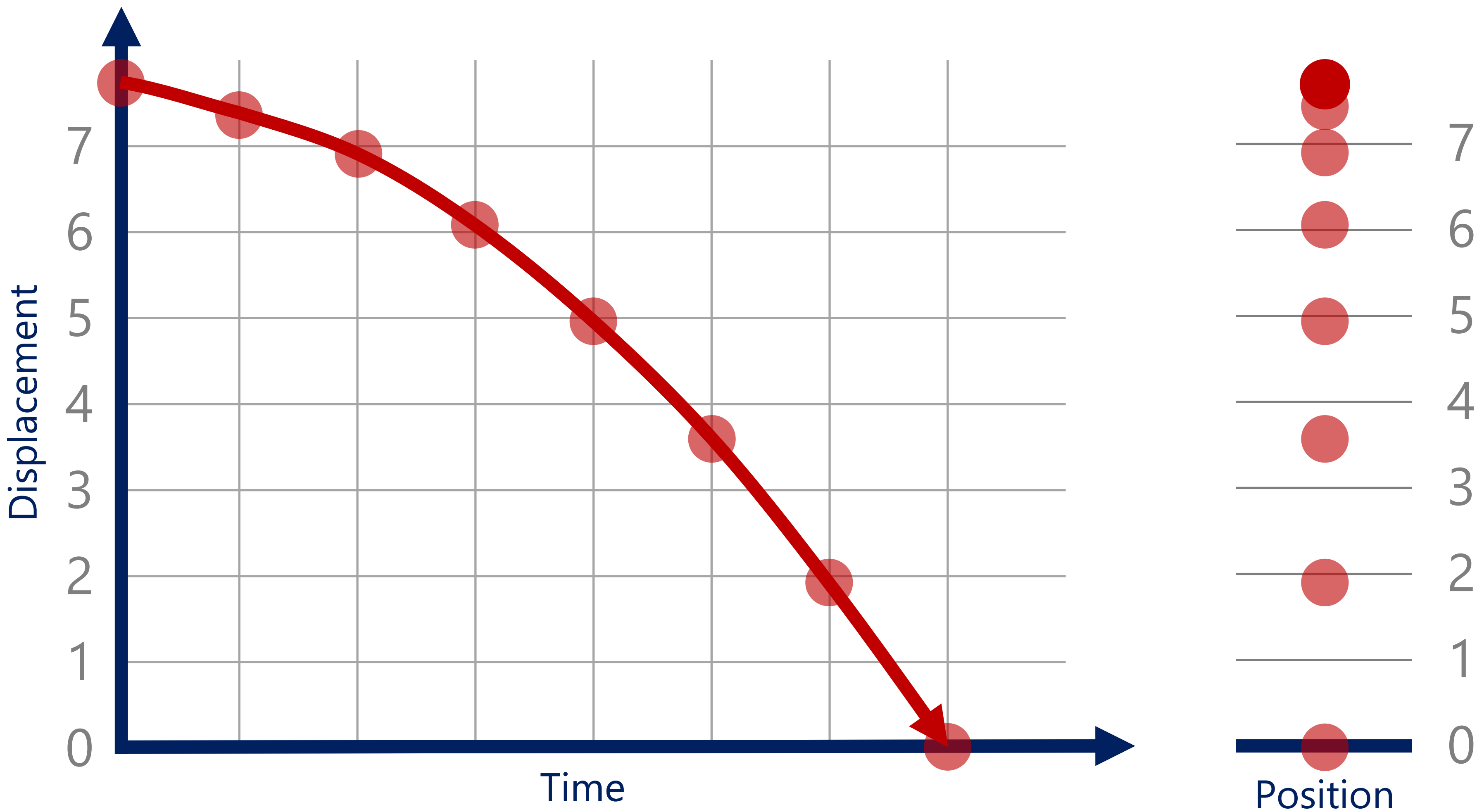
Showing Velocity



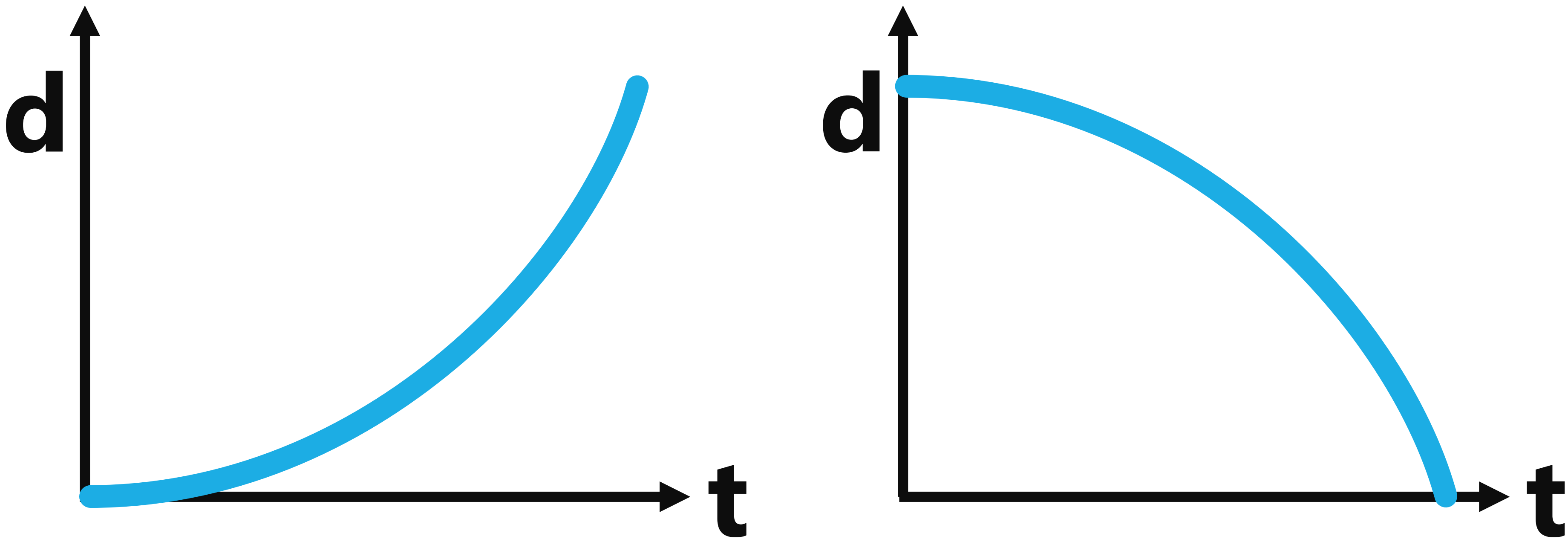
Speeding Up (moving positive)



Speeding Up (moving negative)

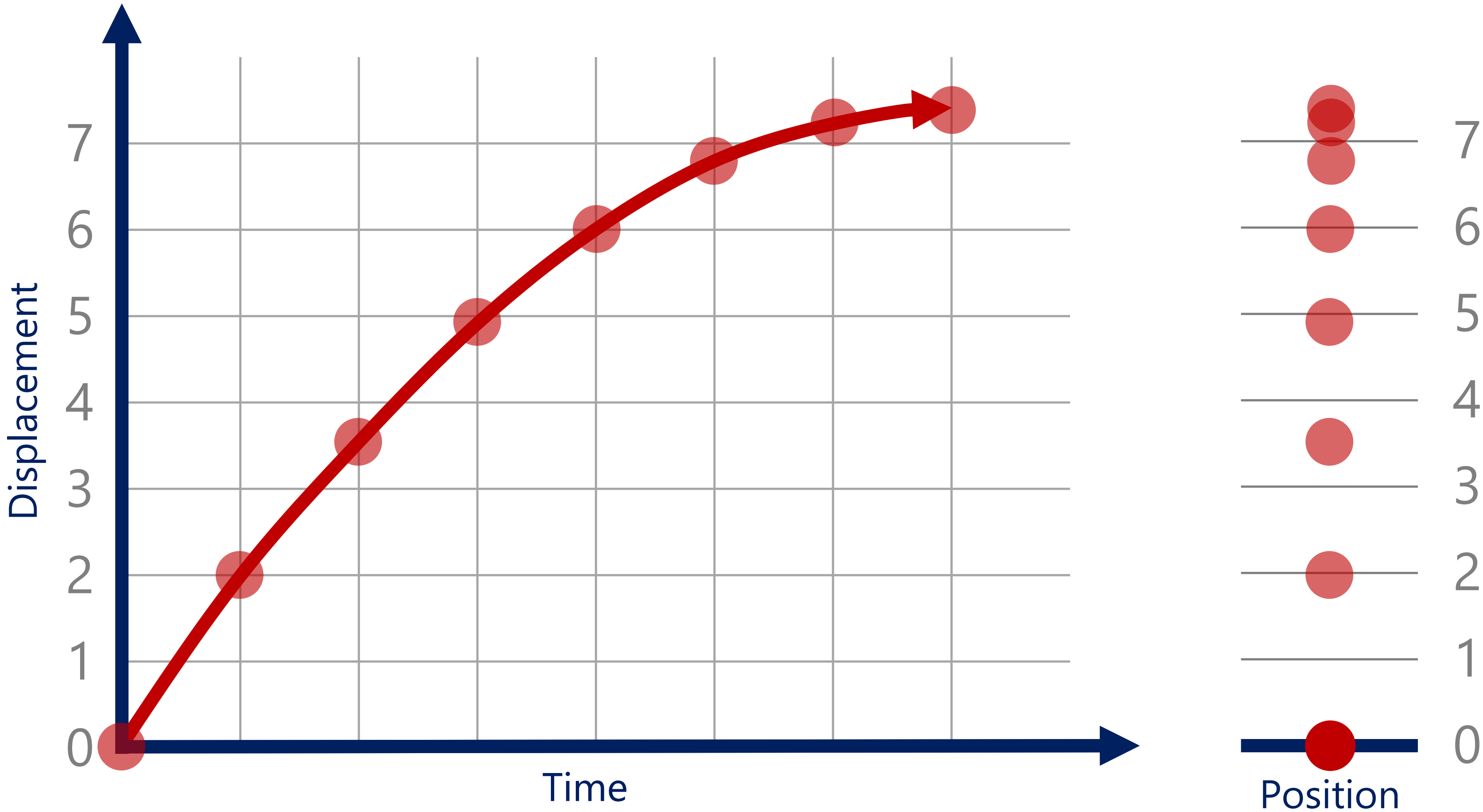


How are these Similar?

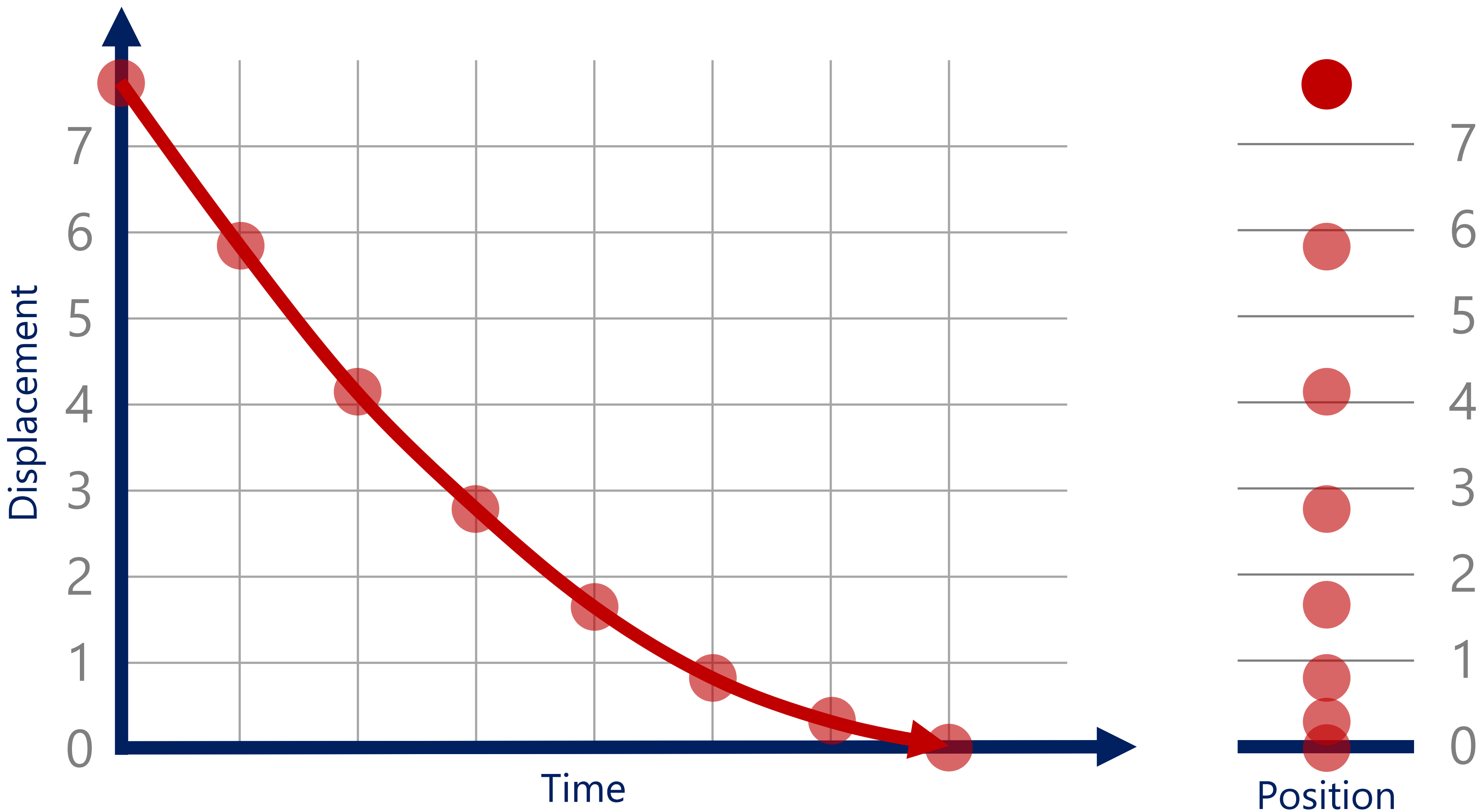


Getting faster because the graph is getting steeper (farther spacing)

Slowing Down (moving positive)



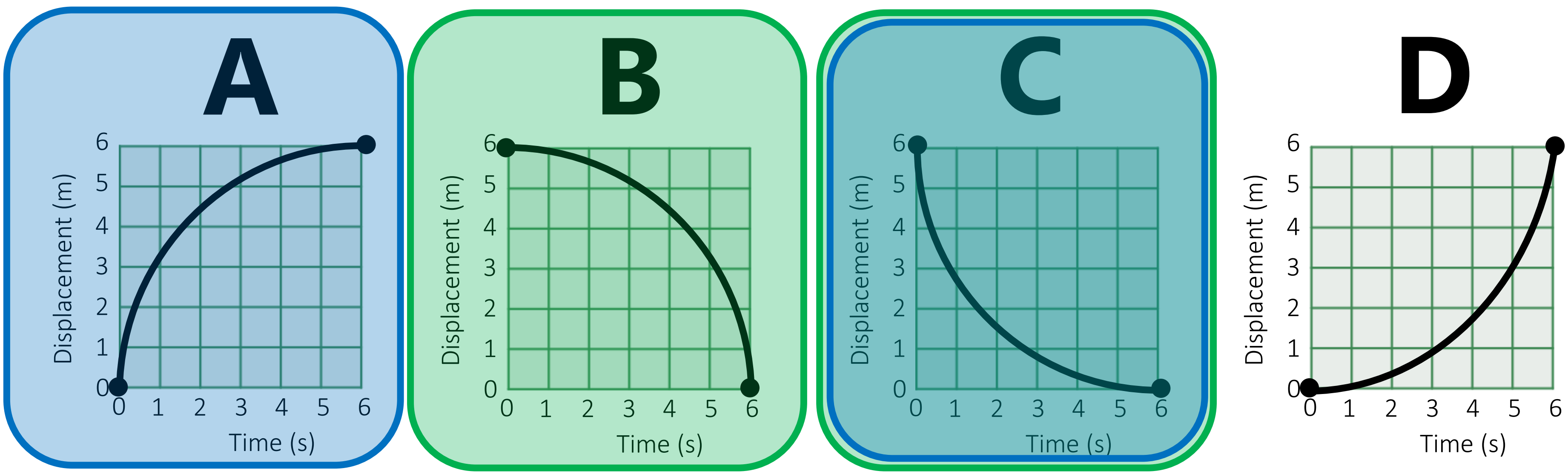
Slowing Down (moving negative)



Displacement vs Time Graphs

Which graph(s) represent an object moving in the negative direction?

Which graph(s) represent an object slowing down?



Lesson Takeaways

- ❑ I can describe the difference between distance and displacement
- ❑ I can calculate distance and displacement for 1D motion
- ❑ I can plot constant velocity on a displacement vs time graph
- ❑ I can plot changing velocity on a displacement vs time graph
- ❑ I can use a displacement vs time graph to identify if an object is moving in the positive or negative direction as well as if it is speeding up or slowing down

Velocity Graphs

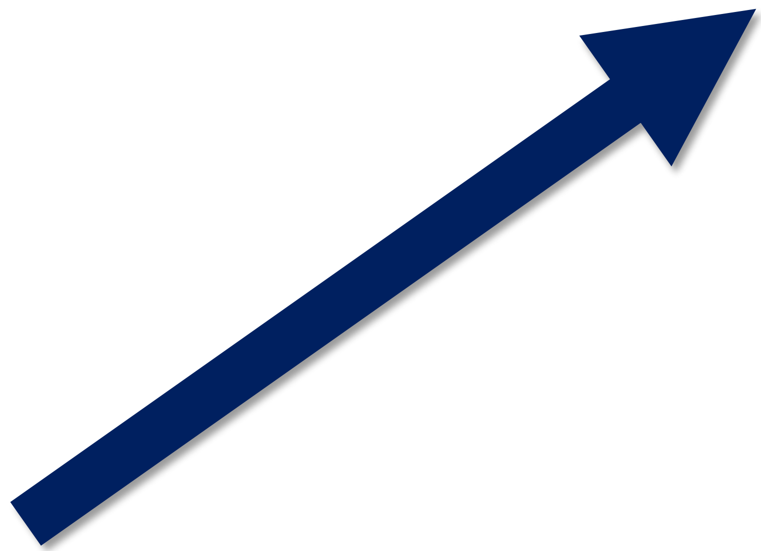
IB PHYSICS | MOTION

What is...

Speed	The rate of change of position “how fast ”
Velocity	Speed **with direction**

What is a Vector?

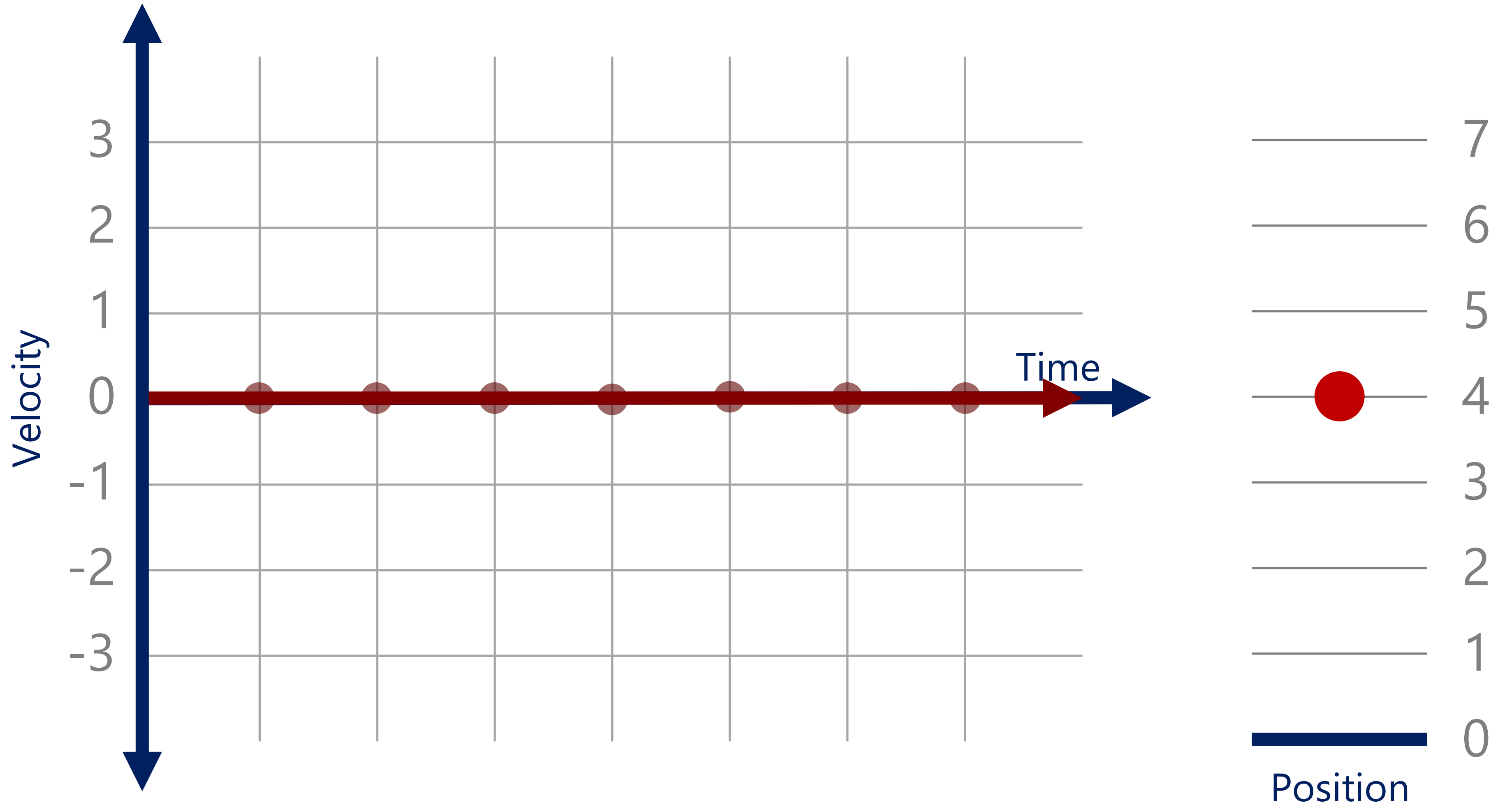
A Vector is a quantity that includes both **direction** and **magnitude**



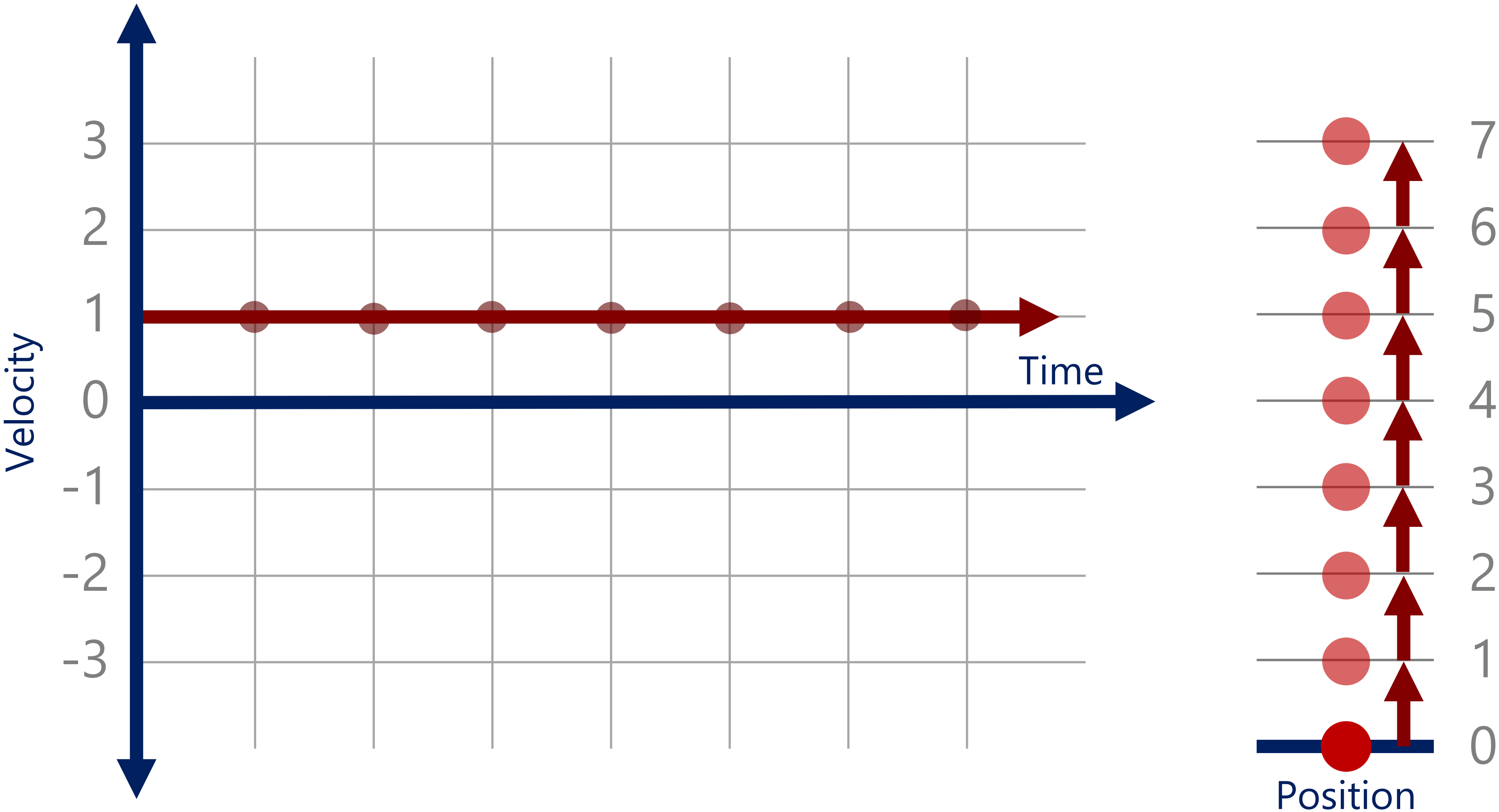
Vector vs Scalar

Vector Quantities	Scalar Quantities
Displacement	Distance
Velocity	Speed
Force	Energy
Can be negative to indicate direction	Only Positive

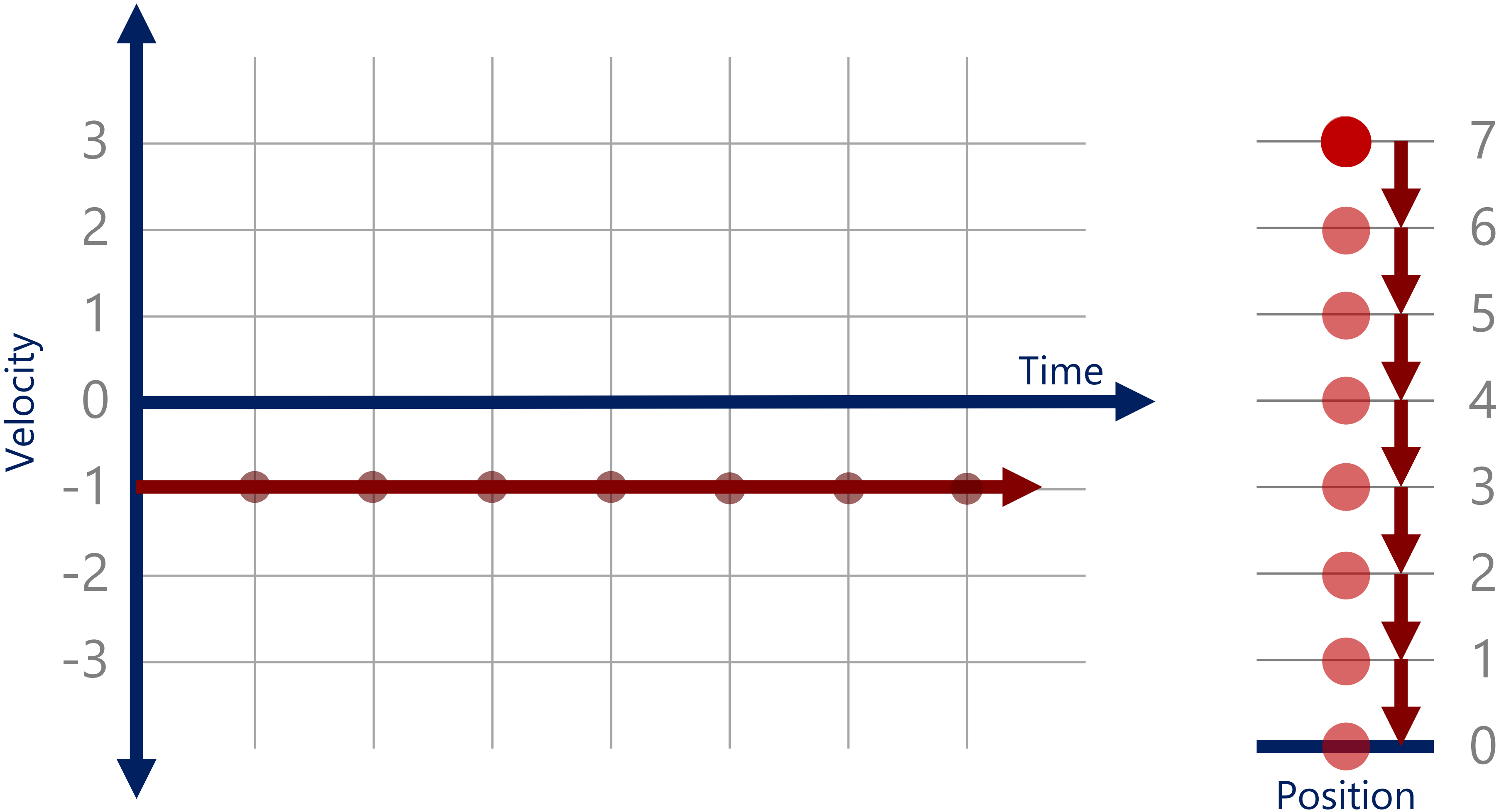
An object not moving



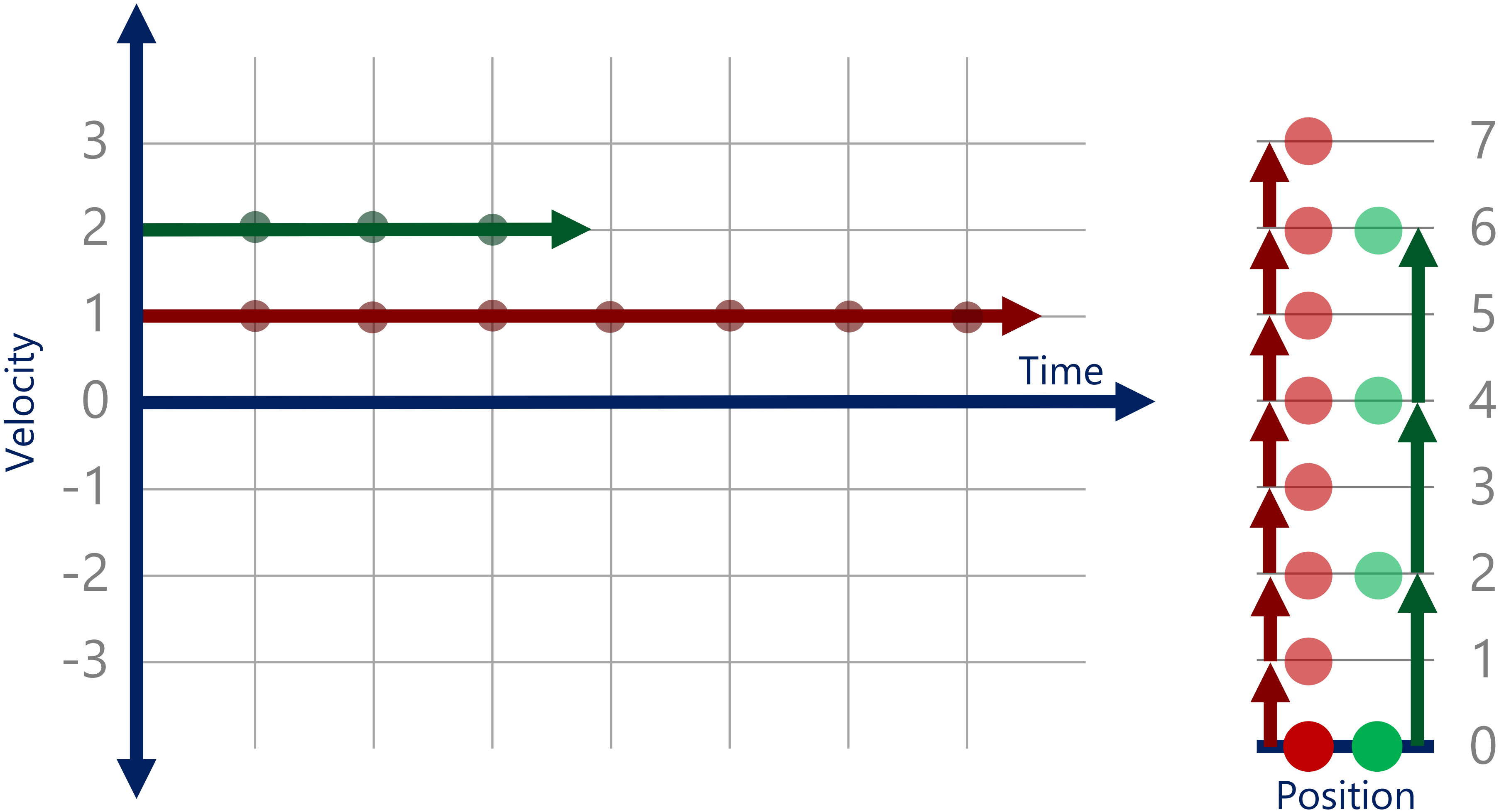
An object moving forward



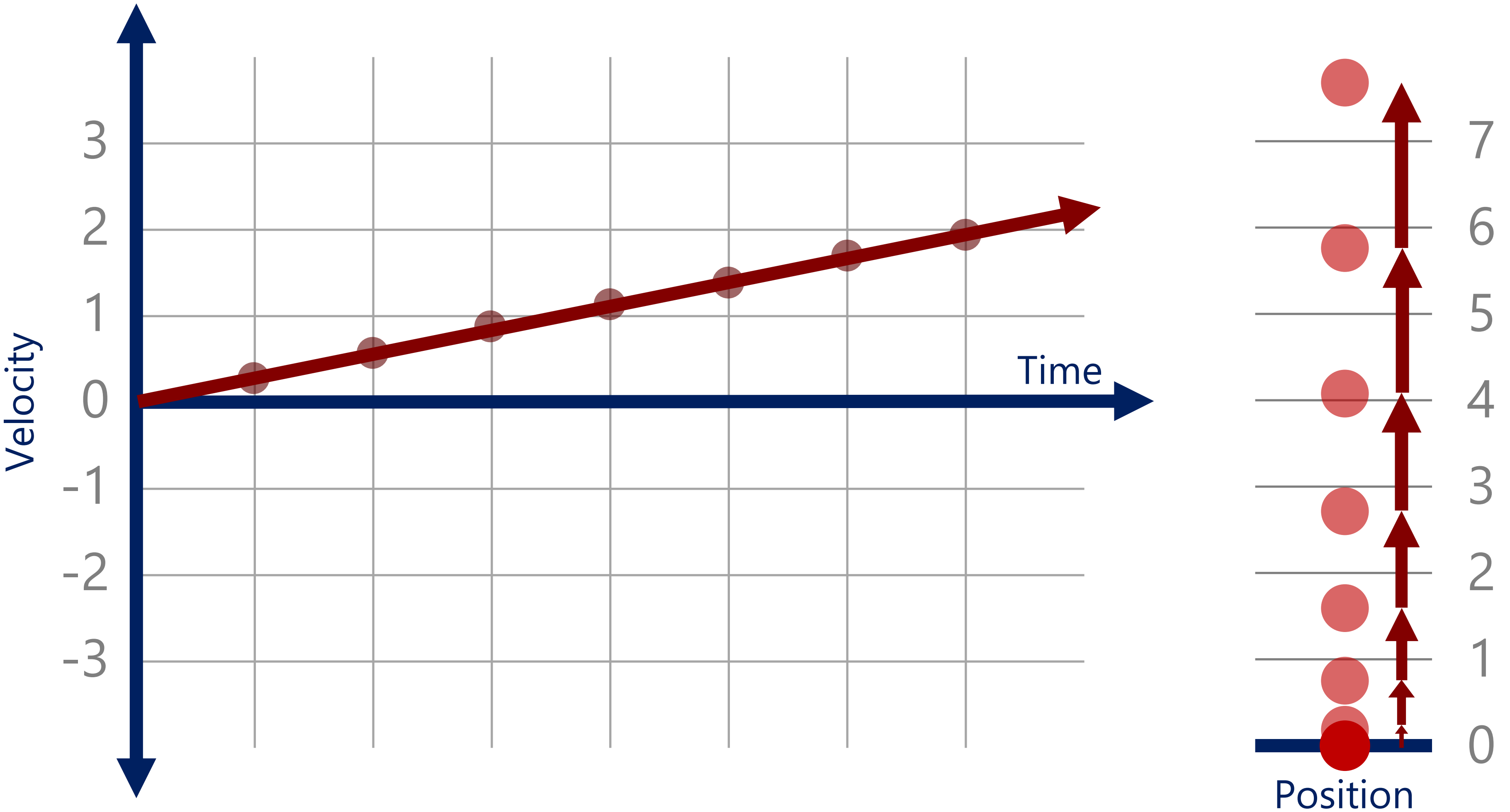
An object moving backward



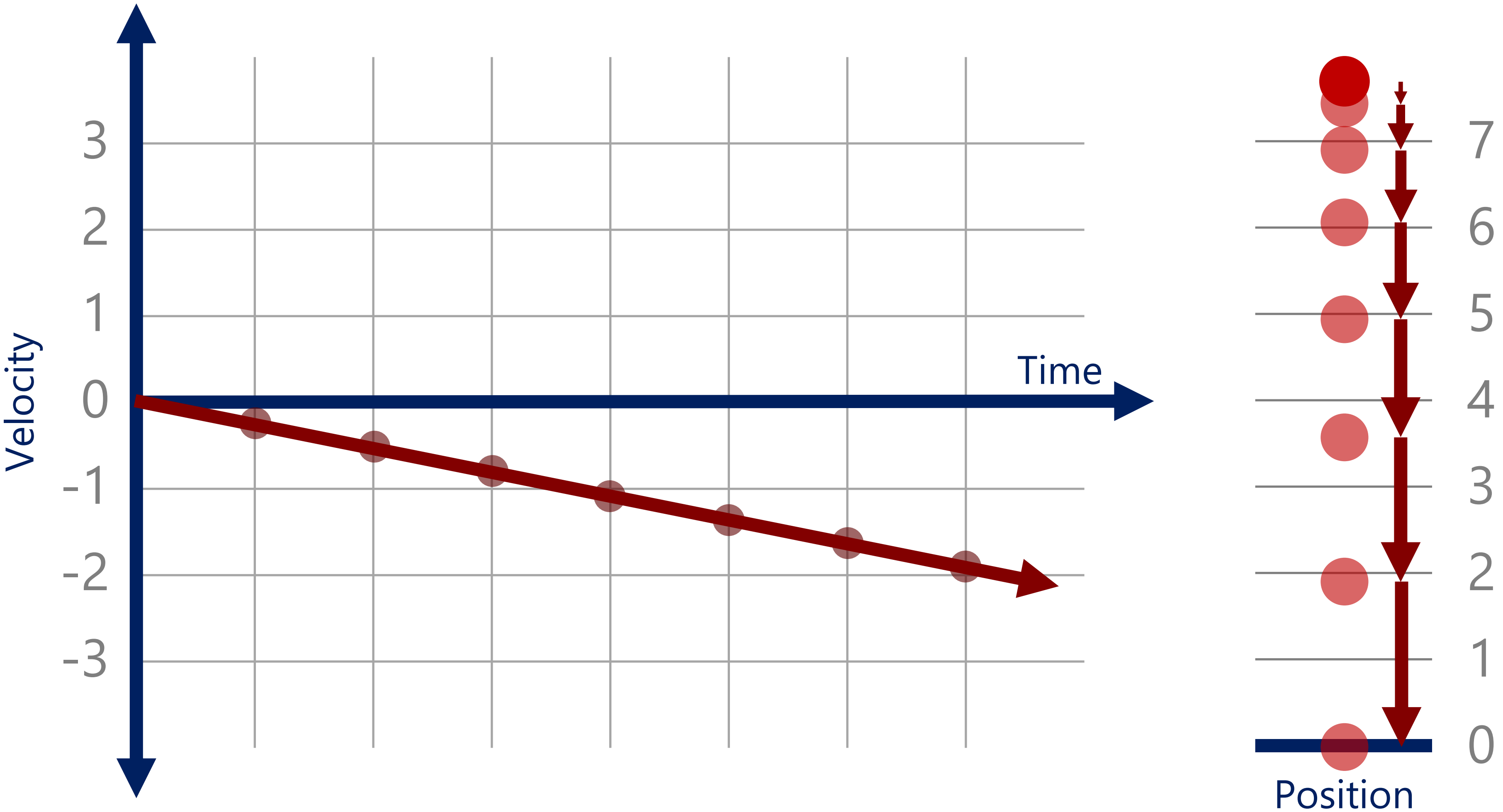
Showing Velocity



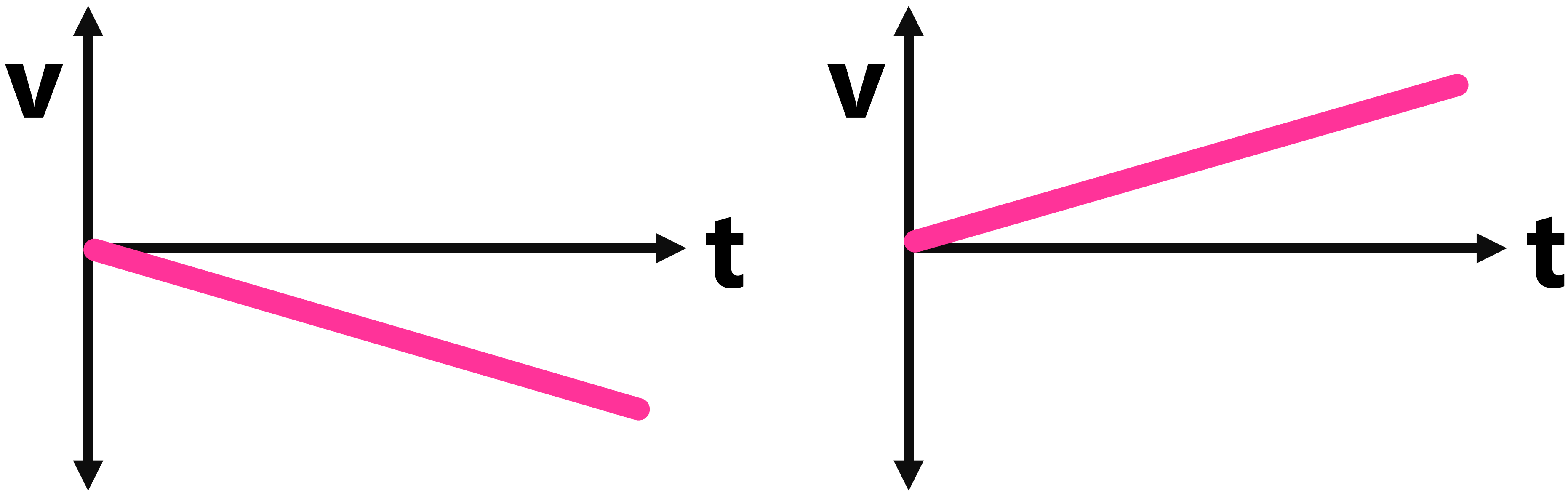
Speeding Up (moving positive)



Speeding Up (moving negative)

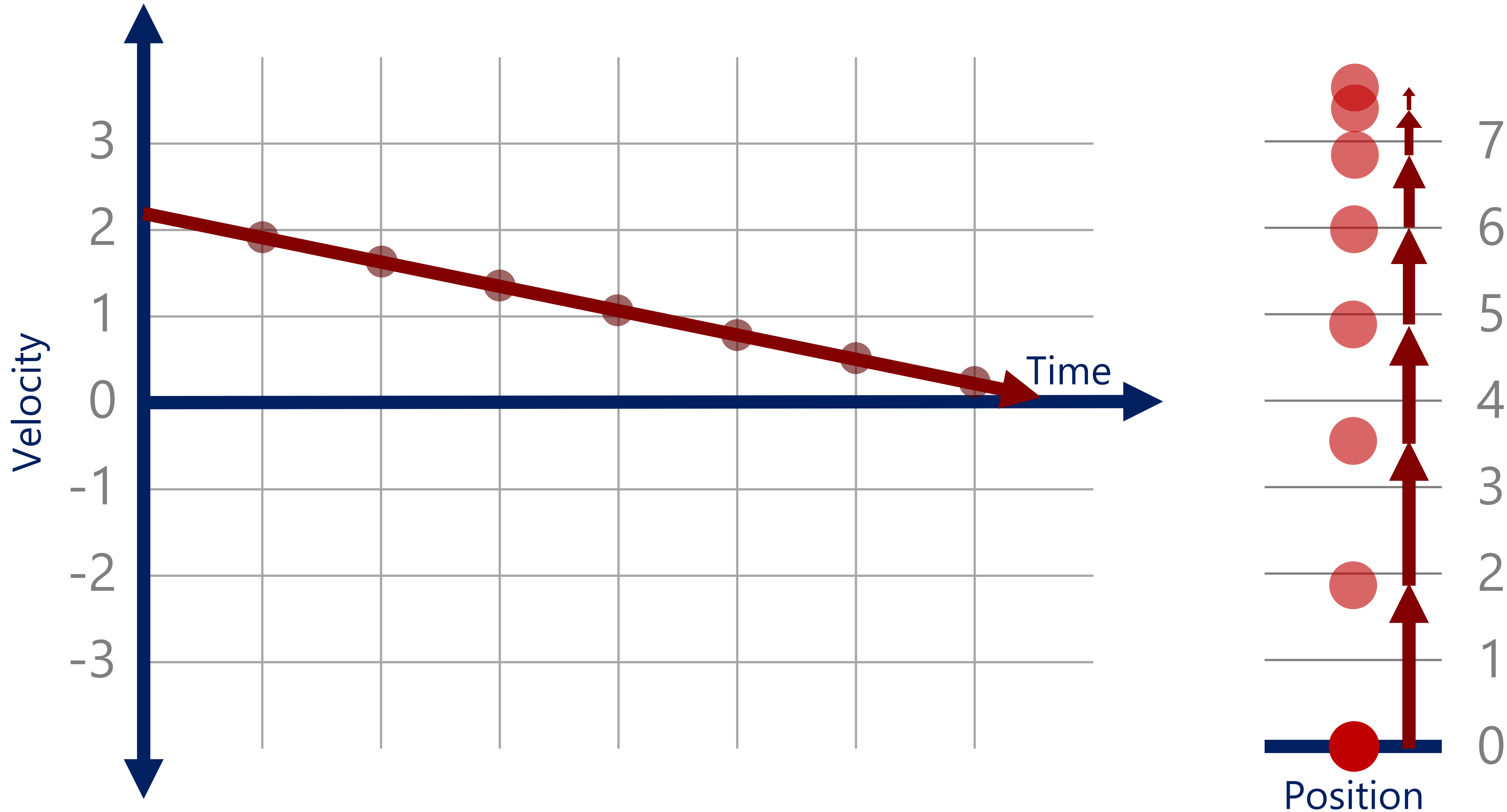


How are these Similar?

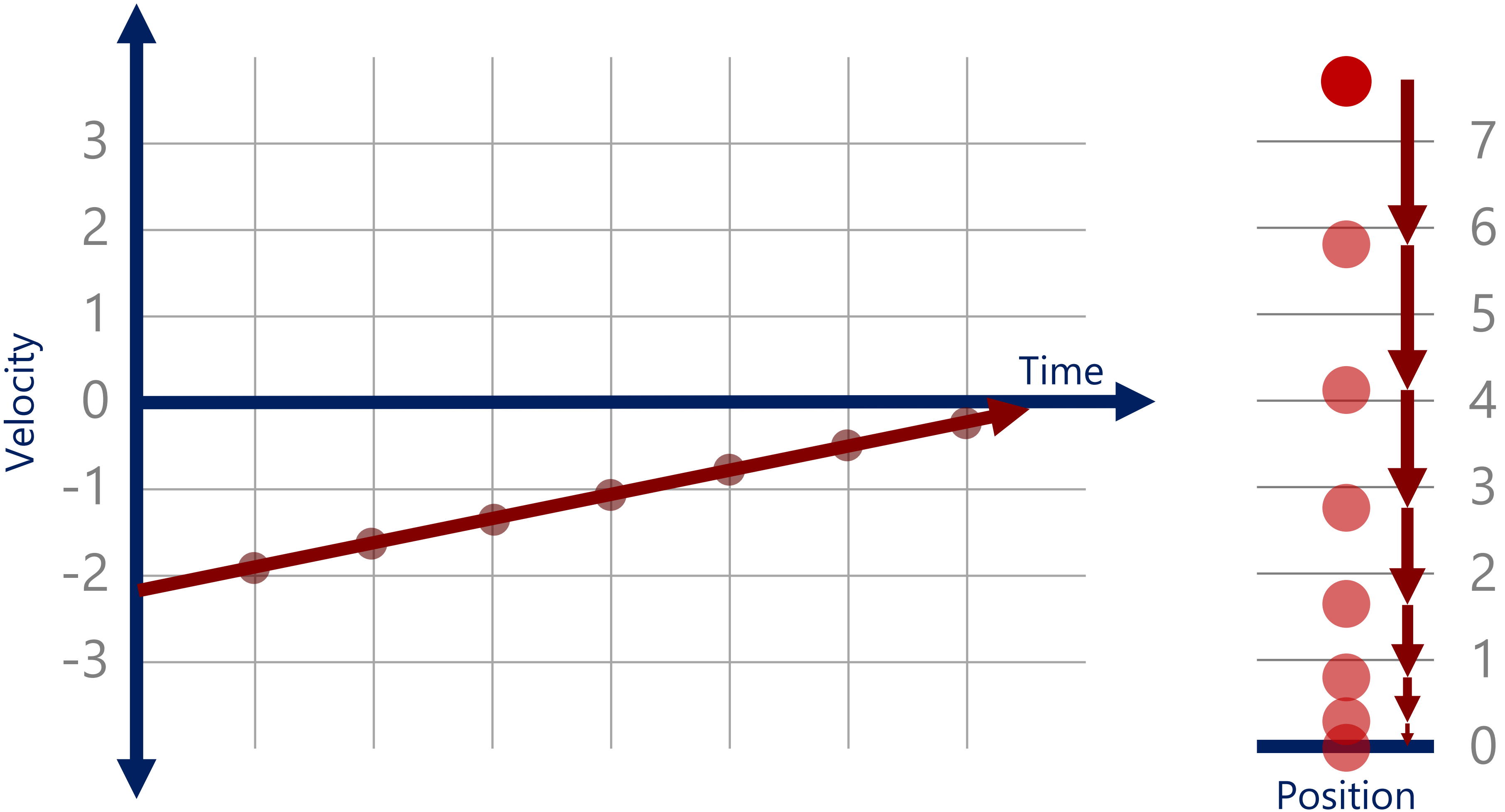


Getting faster because velocity is getting farther from zero

Slowing Down (moving positive)



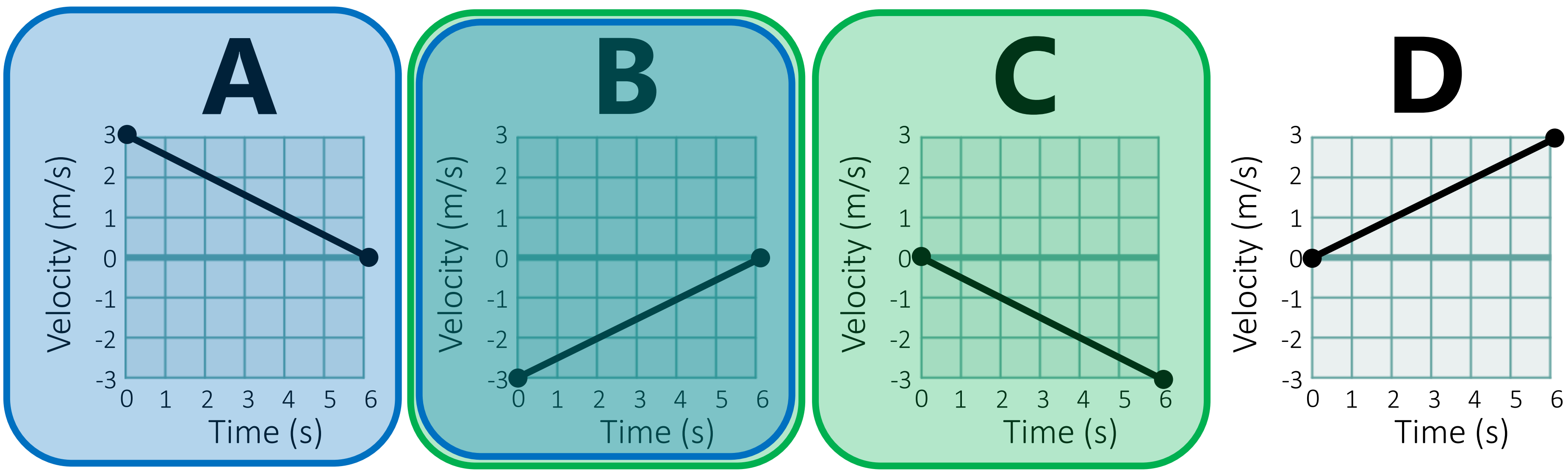
Slowing Down (moving negative)



Velocity vs Time Graphs

Which graph(s) represent an object moving in the negative direction?

Which graph(s) represent an object slowing down?

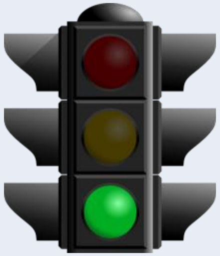


What is…

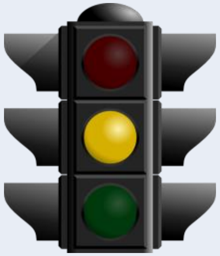
Velocity	change in **position** over time "speed *with direction*"
Acceleration	change in **velocity** over time

Types of Acceleration

Speeding Up

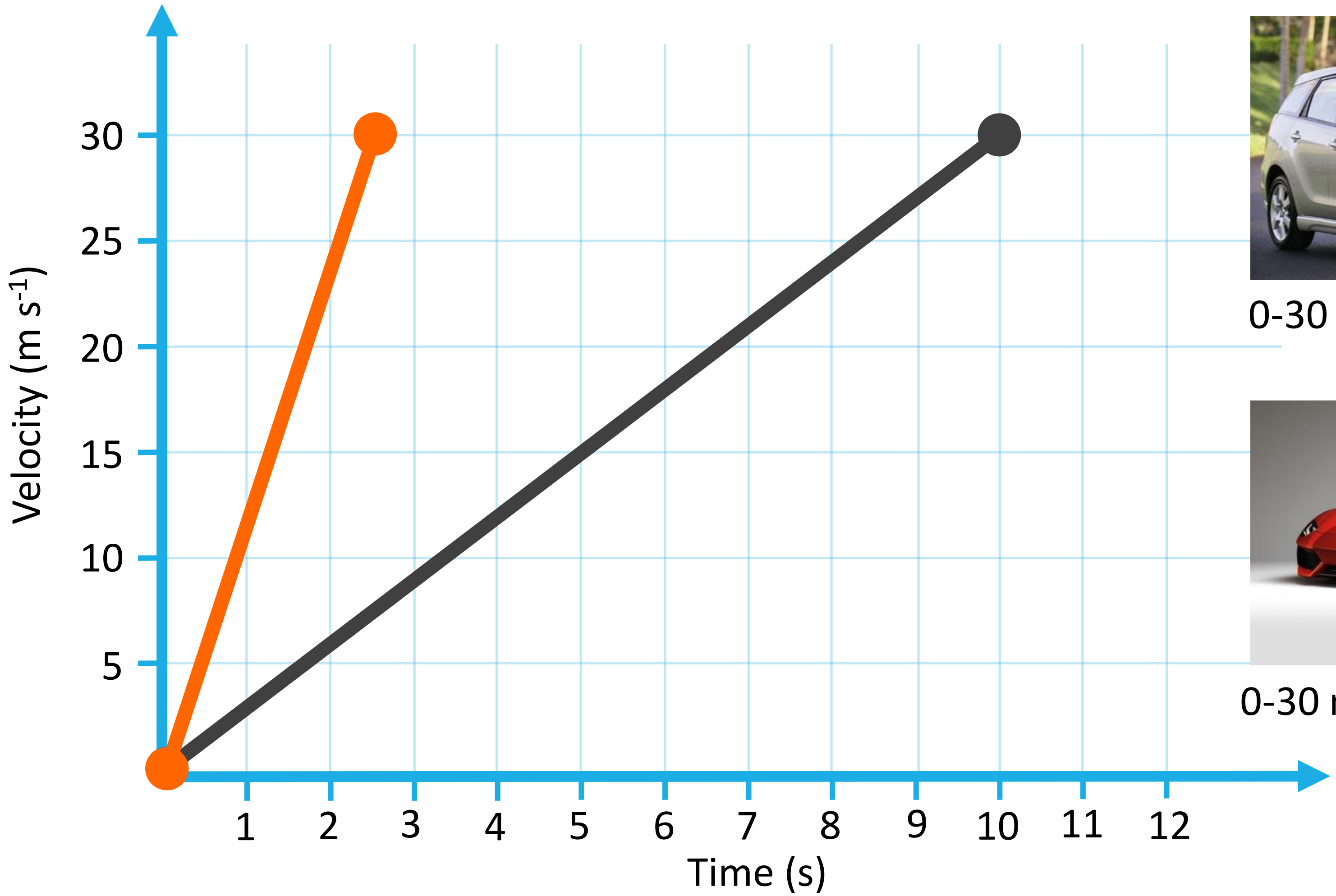


Slowing Down



Changing Direction

Acceleration is Related to Force



0-30 m s^{-1} in 10 seconds

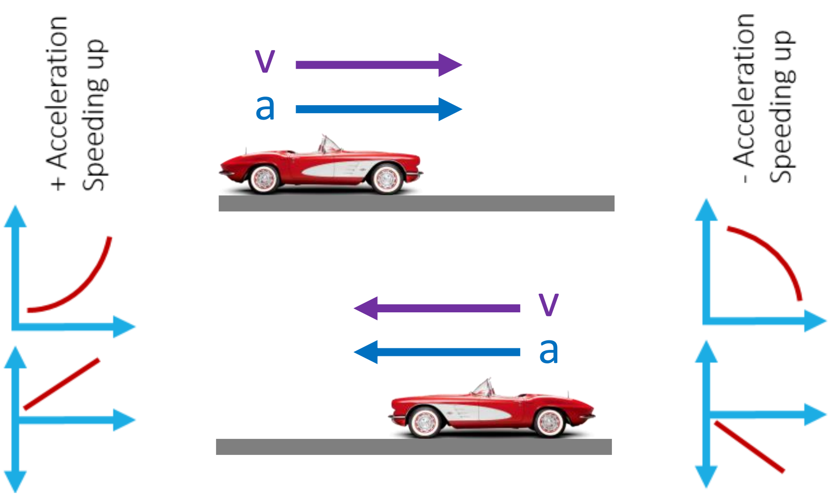
0-30 m s^{-1} in 2.5 seconds

Acceleration | Slowing or Speeding?

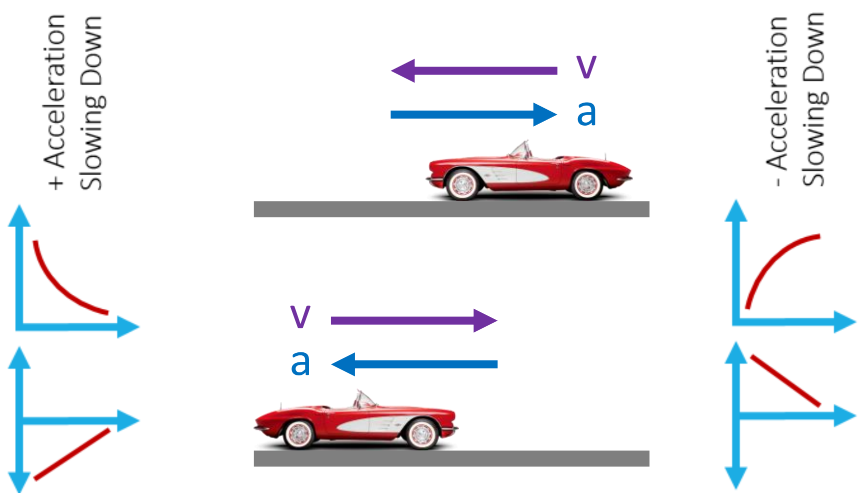
When the acceleration is in the **same** direction as the velocity the object is __speeding up__

When the acceleration is in the **opposite** direction as the velocity the object is __slowing down__

"Foot on the Gas"



"Foot on the Brake"



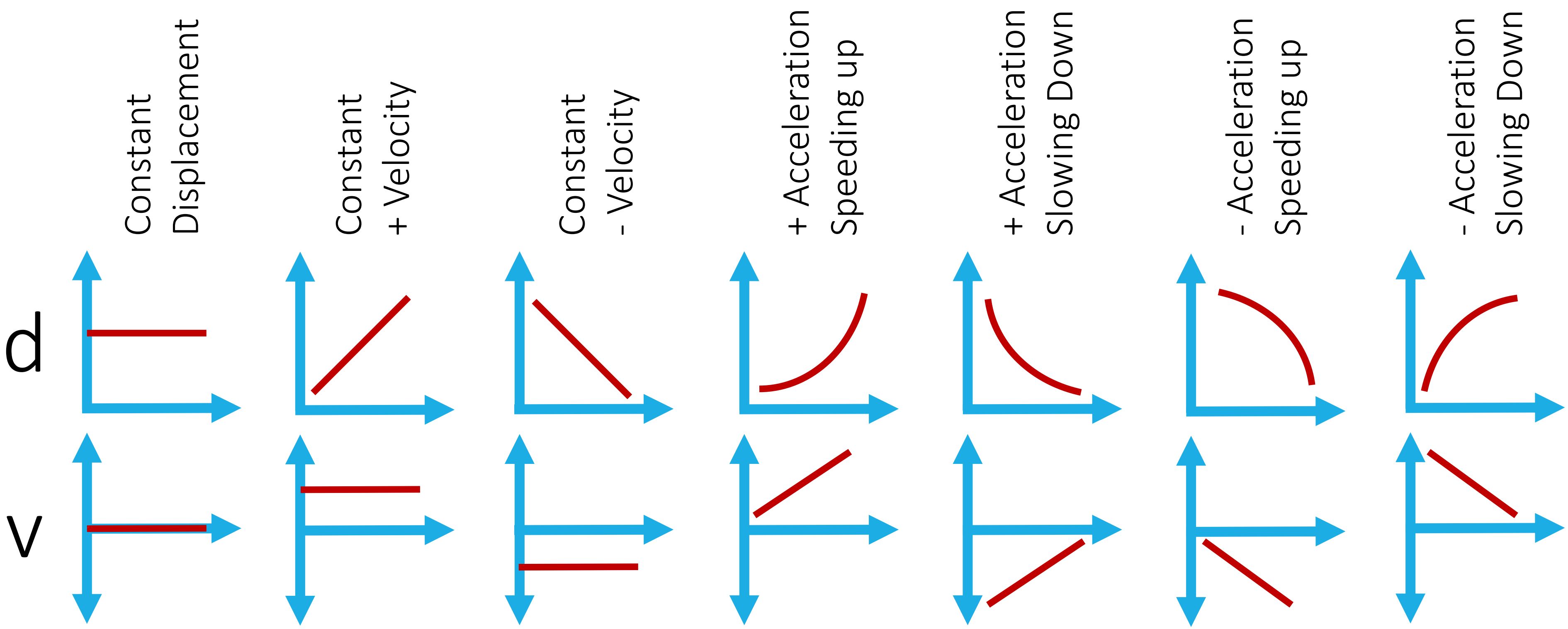
Lesson Takeaways

- ❑ I can describe the difference between speed and velocity
- ❑ I can compare the difference between a vector and scalar quantity
- ❑ I can plot constant velocity on a velocity vs time graph
- ❑ I can plot changing velocity on a velocity vs time graph
- ❑ I can use a velocity vs time graph to identify if an object is moving in the positive or negative direction as well as if it is speeding up or slowing down
- ❑ I can define acceleration in terms of velocity

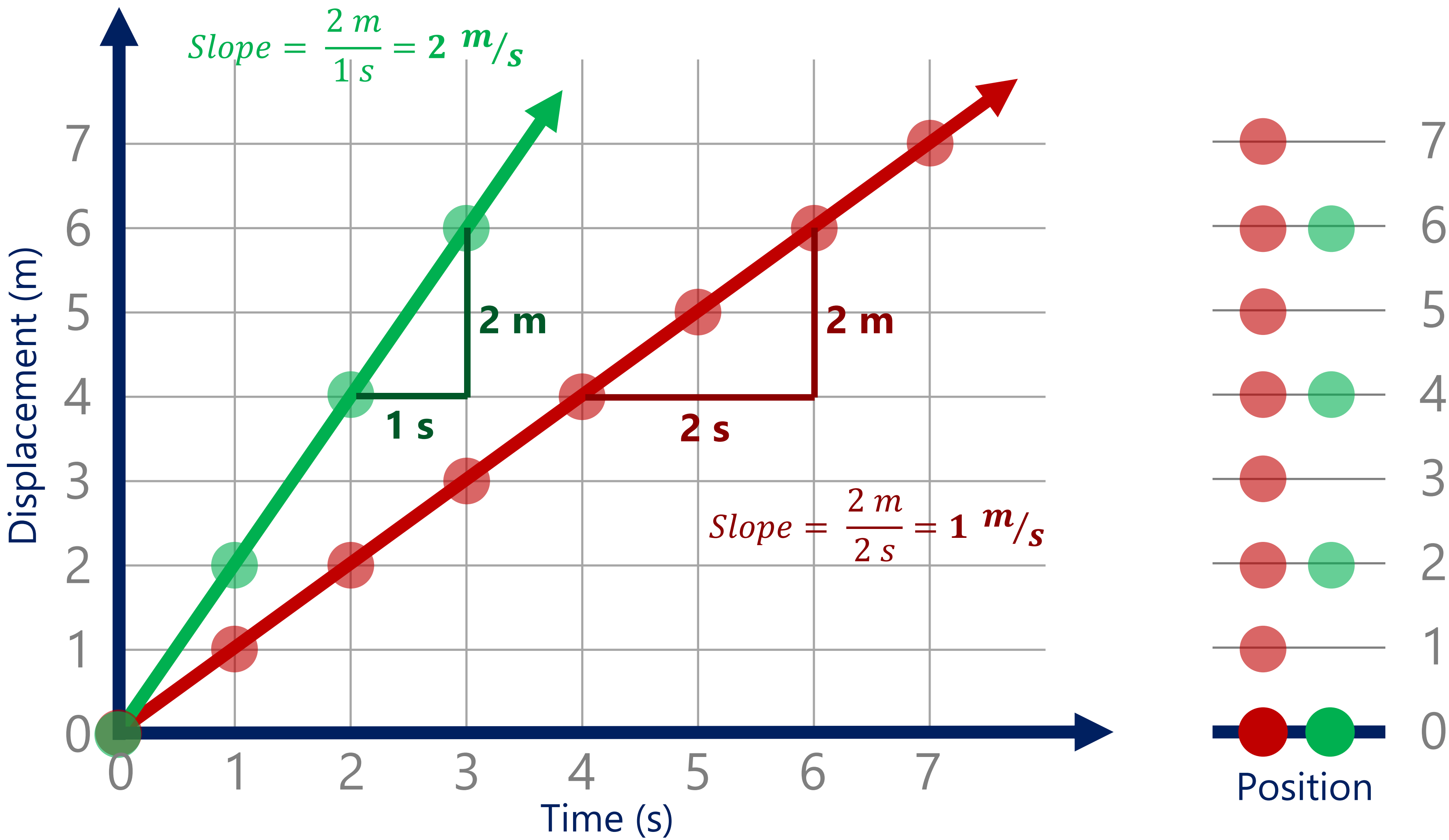
Calculating from Graphs

IB PHYSICS | MOTION

Motion Graphs Guide



Calculating Instantaneous Velocity



The power of the slope!

Displacement vs Time

Slope

Velocity

Average Speed and Velocity

$$\text{Average Speed} = \frac{Total\ Distance}{Total\ Time}$$

* Always Positive

$$\text{Average Velocity} = \frac{Total\ Displacement}{Total\ Time}$$

* Includes Direction

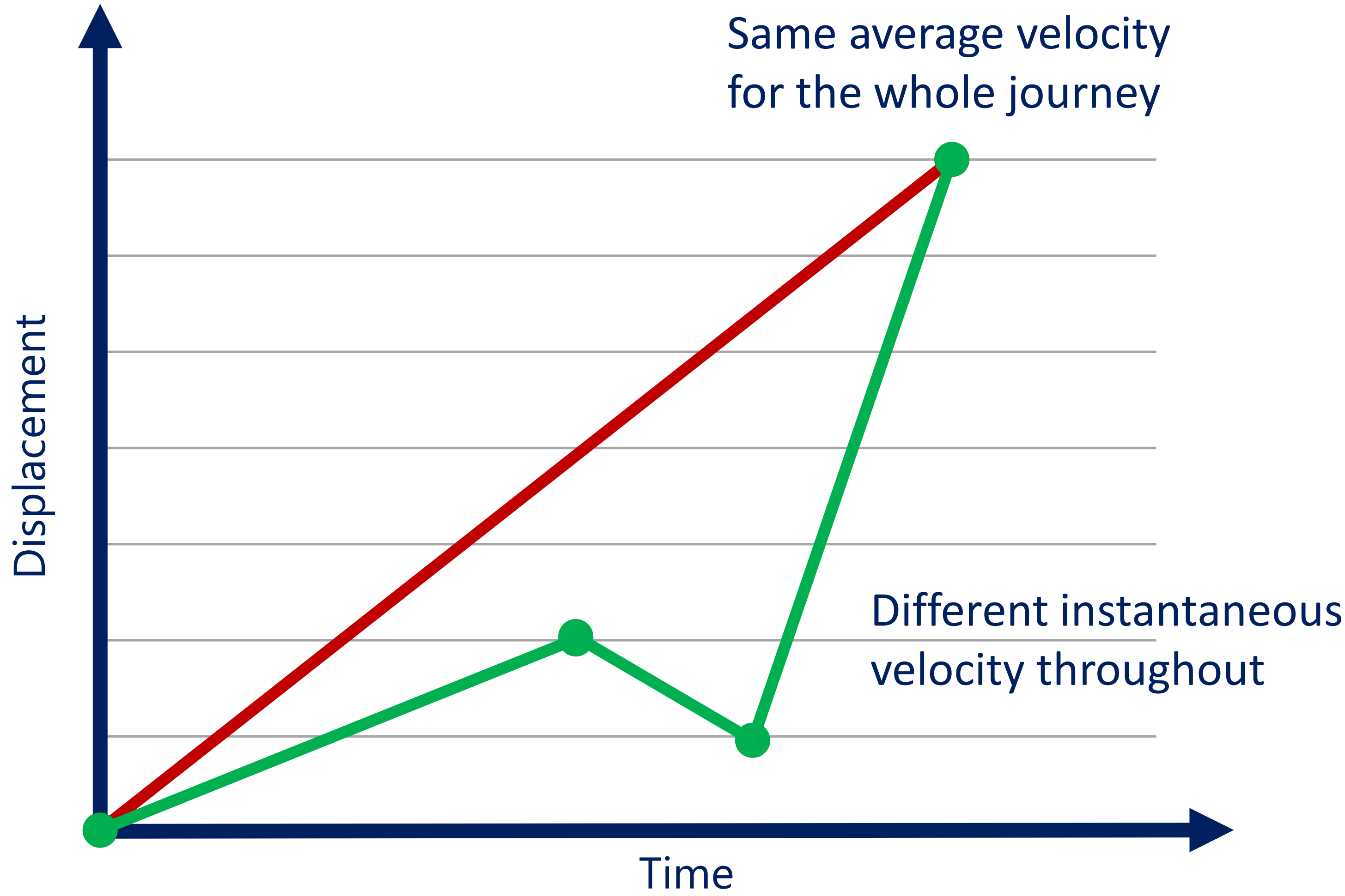
Calculating Average Speed

Eliud Kipchoge broke the 2-hour marathon (26.2 miles) in October of 2019. Kipchoge finished in 1.99 hours. What was his average speed in mph?

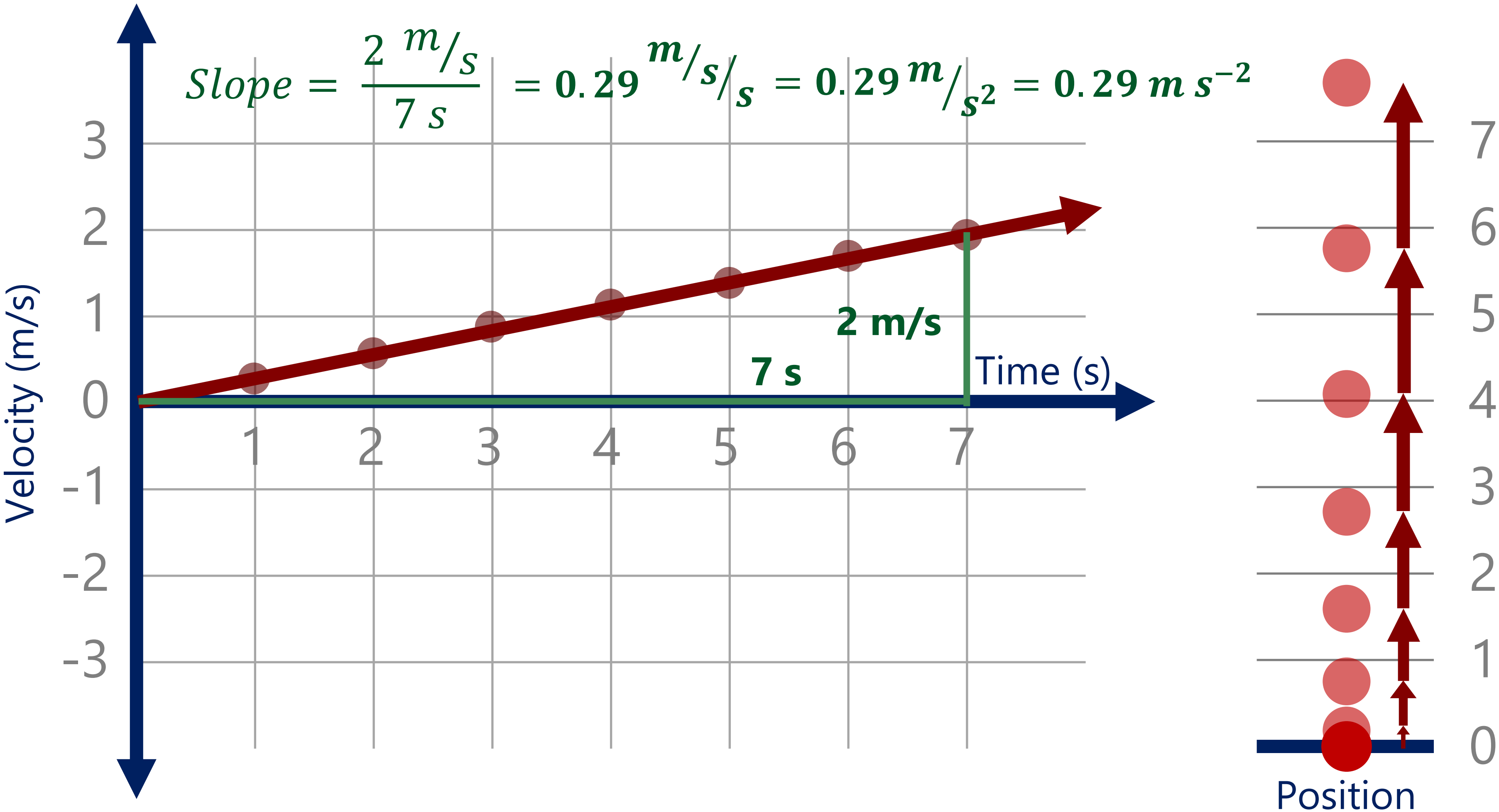
$$v = \frac{d}{t} = \frac{26.2}{1.99} =$$

$$\boxed{13.2 \text{ mi hr}^{-1}}$$

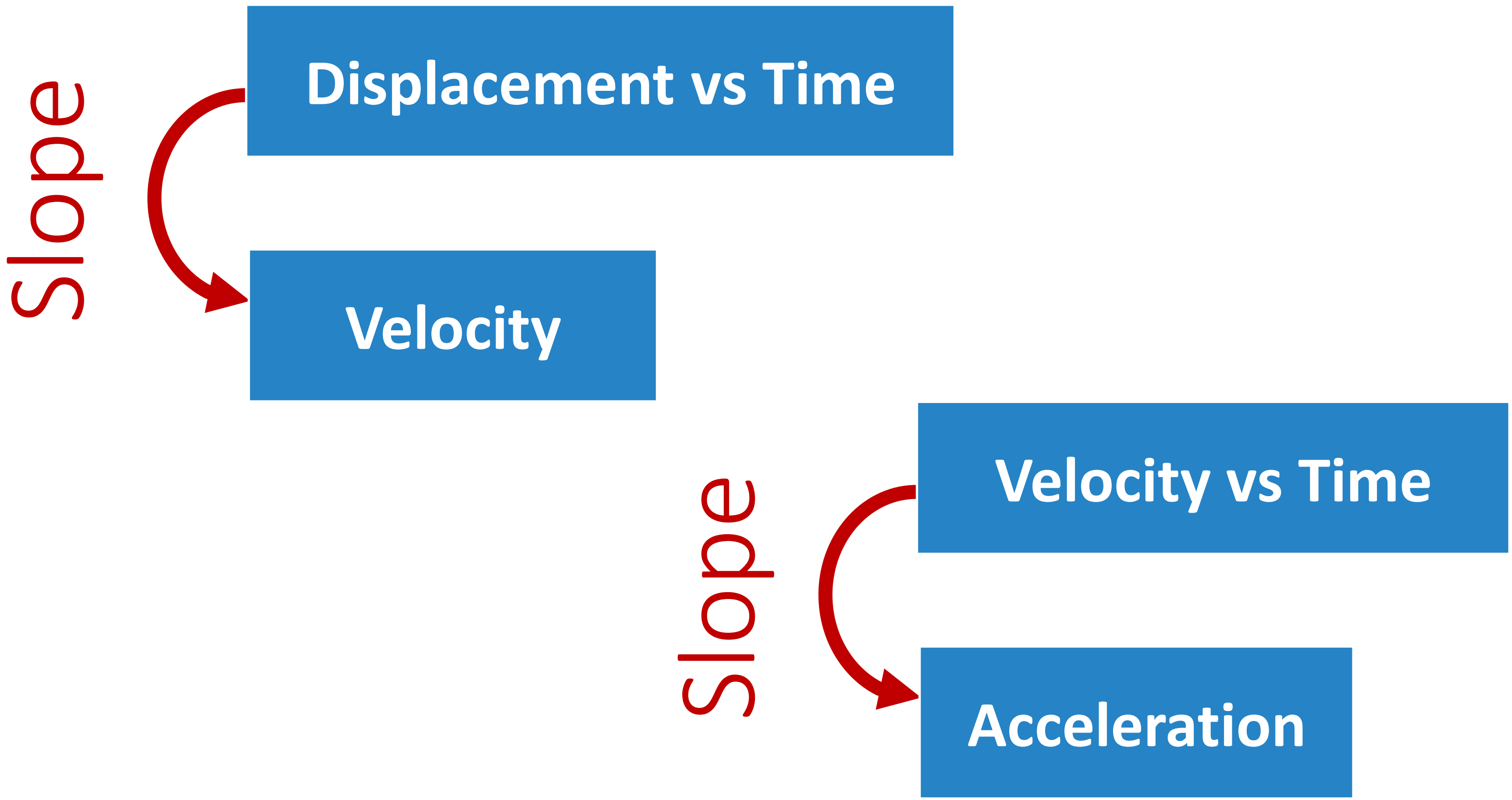
Average vs Instantaneous



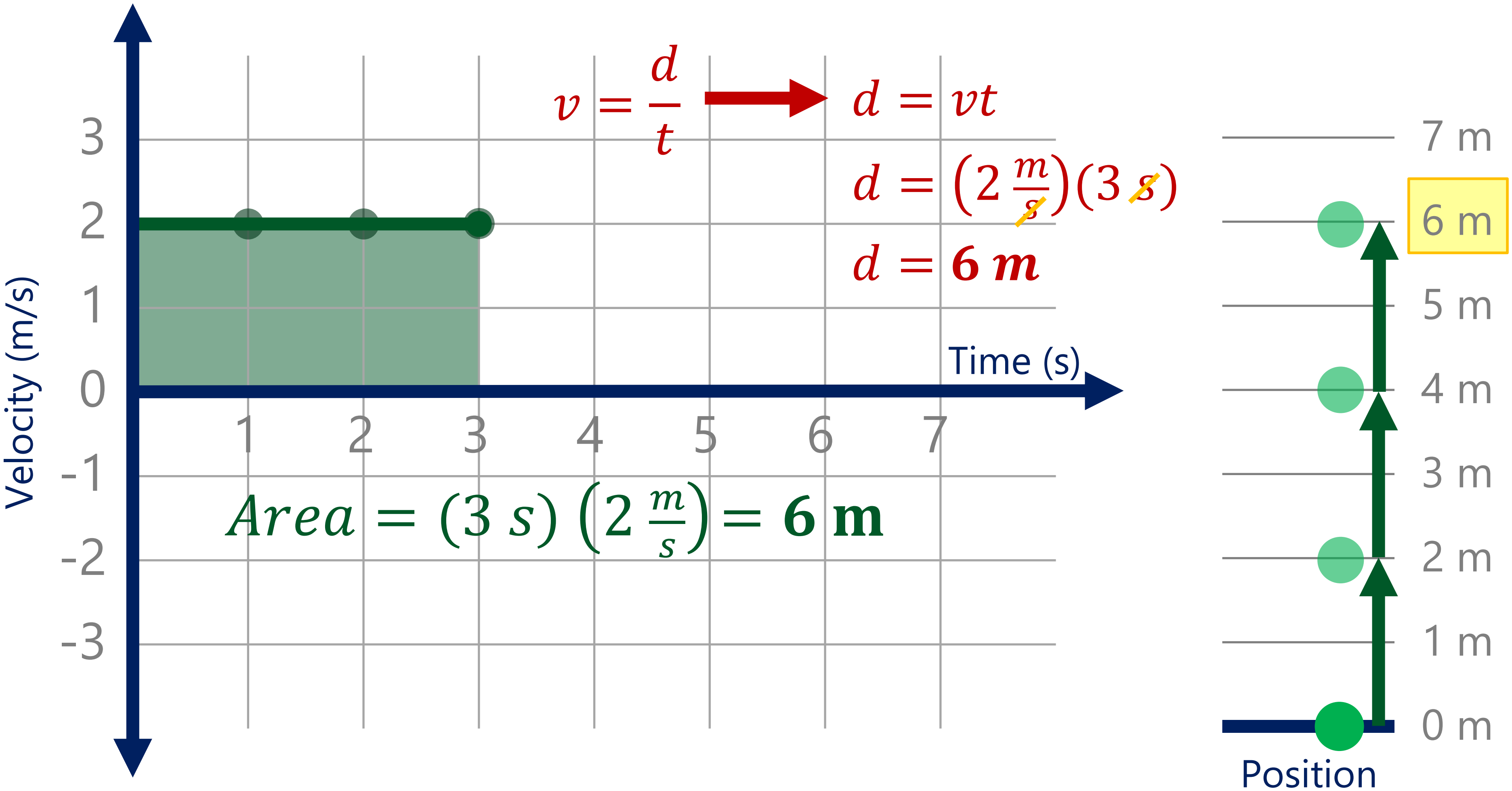
An object speeding up (positive)



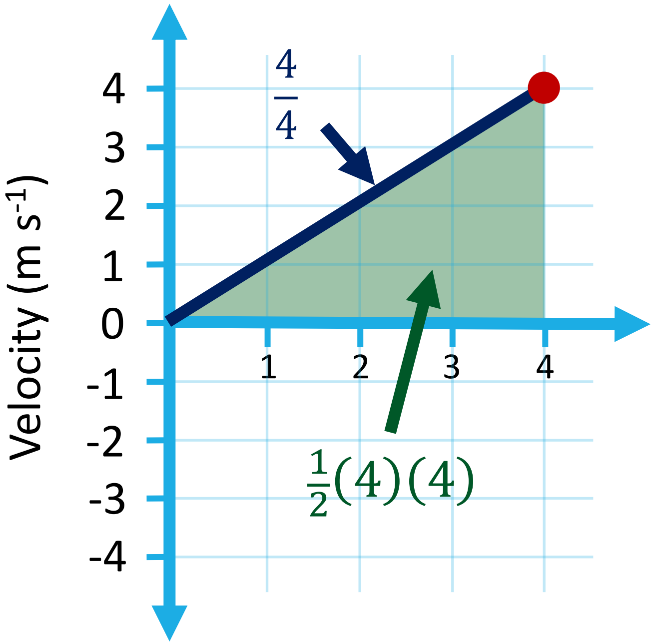
The power of the slope!



Calculating Displacement



Information from a V vs T graph



What is the velocity at 4 seconds?

$4\ m\ s^{-1}$

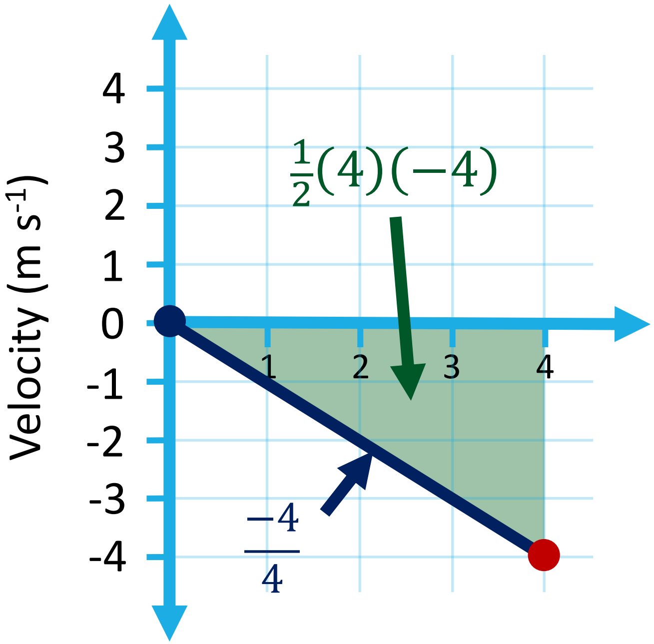
What is the acceleration from 1 s – 4 s?

Slope = $1\ m\ s^{-2}$

What is the displacement after 4 s?

Area = 8 m

Information from a V vs T graph



What is the velocity at 4 seconds?

-4 m s^{-1}

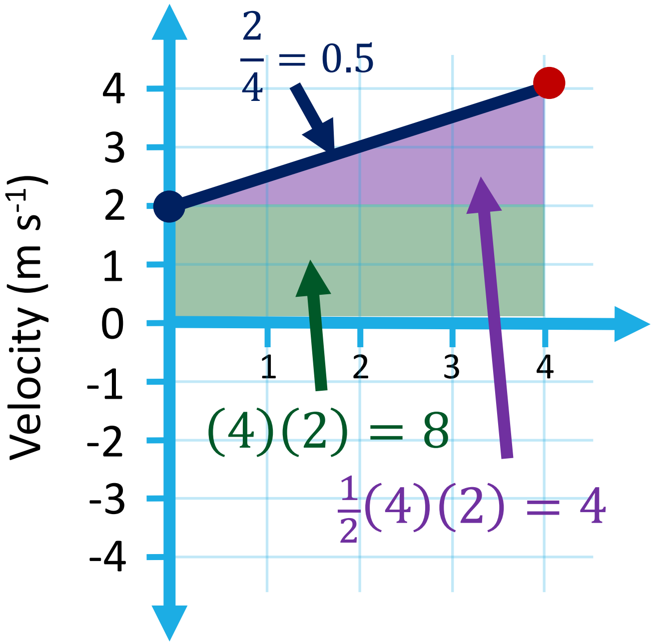
What is the acceleration from 0 s – 4 s?

Slope = -1 m s^{-2}

What is the displacement after 4 s?

Area = -8 m

Information from a V vs T graph



What is the velocity at 4 seconds?

$4\ m\ s^{-1}$

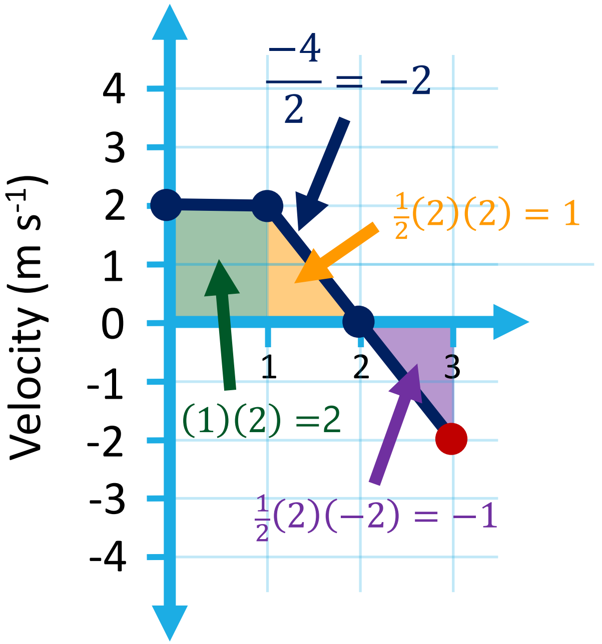
What is the acceleration from 0 s – 4 s?

Slope = $0.5\ m\ s^{-2}$

What is the displacement after 4 s?

Area = 12 m

Information from a V vs T graph



What is the velocity at 3 seconds?

-2 m s^{-1}

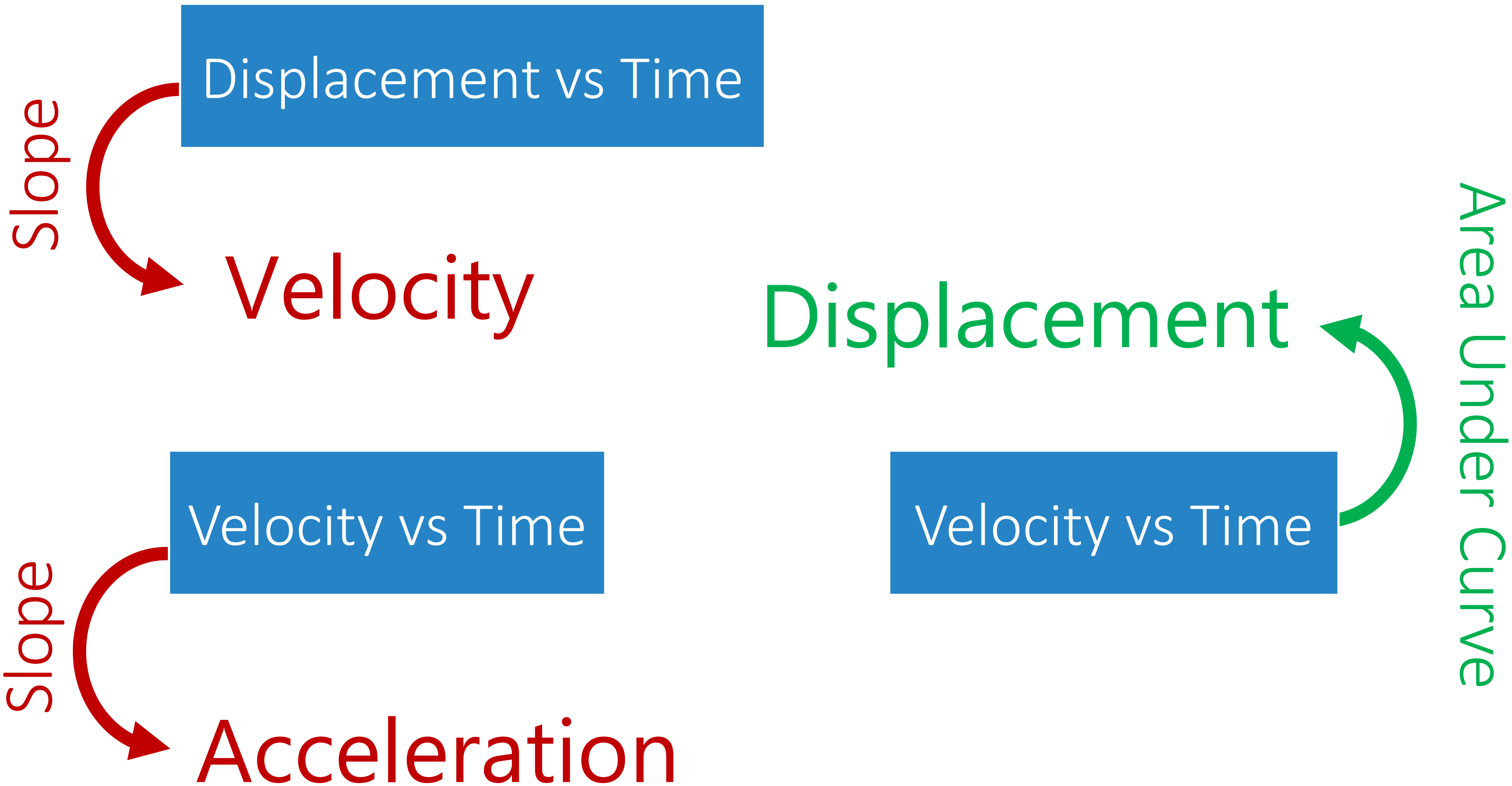
What is the acceleration from 1 s – 3 s?

Slope = -2 m s^{-2}

What is the displacement after 3 s?

(2) + (1) + (-1) = Area = 2 m

Use the graphs to tell you MORE!



Lesson Takeaways

- ❑ I can use an equation to calculate average speed/velocity
- ❑ I can calculate instantaneous velocity using the slope of a displacement vs time graph
- ❑ I can calculate instantaneous acceleration using the slope of a velocity vs time graph
- ❑ I can calculate overall displacement using the area of a velocity vs time graph

The Kinematic Equations

IB PHYSICS | MOTION

Motion Variables

Displacement	Initial Velocity	Final Velocity	Acceleration	Time
s	**u**	**v**	**a**	**t**

Whenever we are describing the motion of an accelerating object, there are five variables that we need to take into account

Note: The variables used in IB Physics vary slightly from other nomenclature standards

Calculating Acceleration

$$acceleration = \frac{final\ velocity - initial\ velocity}{change\ in\ time}$$

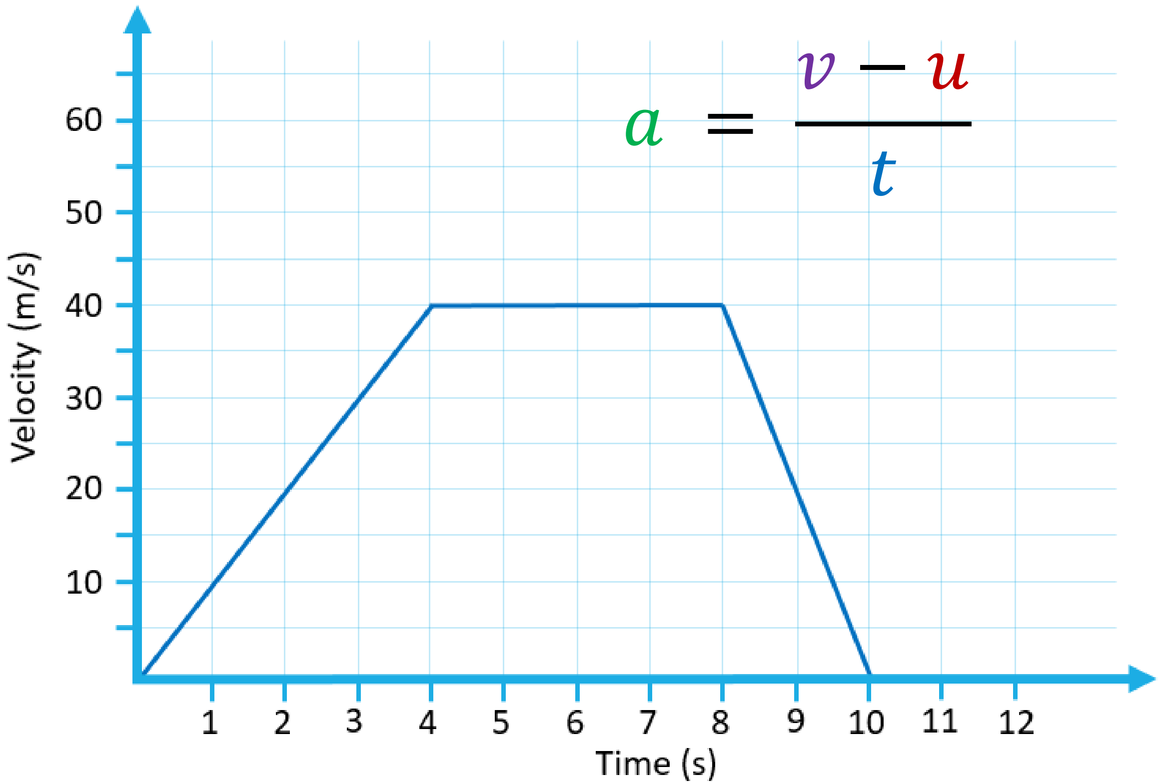
Symbols

$$a = \frac{v - u}{t}$$

Units

$$ms^{-2} = \frac{ms^{-1} - ms^{-1}}{s}$$

Think about this unit...



$$a = \frac{v - u}{t}$$

m/s/s

m/s^2

$m\ s^{-2}$

Try This | 1

What is the acceleration of a car that accelerates from 15 m s^{-1} to 35 m s^{-1} in 10 seconds?

u	15 ms^{-1}
v	35 ms^{-1}
a	?
t	10 s

$$a = \frac{v - u}{t} = \frac{35 - 15}{10}$$

$$a = \mathbf{2\ ms^{-2}}$$

Try This | 2

Find the average acceleration of a northbound train that slows down from 12 m s^{-1} to a complete stop in 8 sec

**Tip: You <u>can</u> get a negative value!*

u	12 ms^{-1}
v	0 ms^{-1}
a	?
t	8 s

$$a = \frac{v-u}{t} = \frac{0-12}{8}$$

$$a = -\mathbf{1.5\ ms^{-2}}$$

Solve for v

$$a = \frac{v - u}{t}$$

$$v = u + at$$

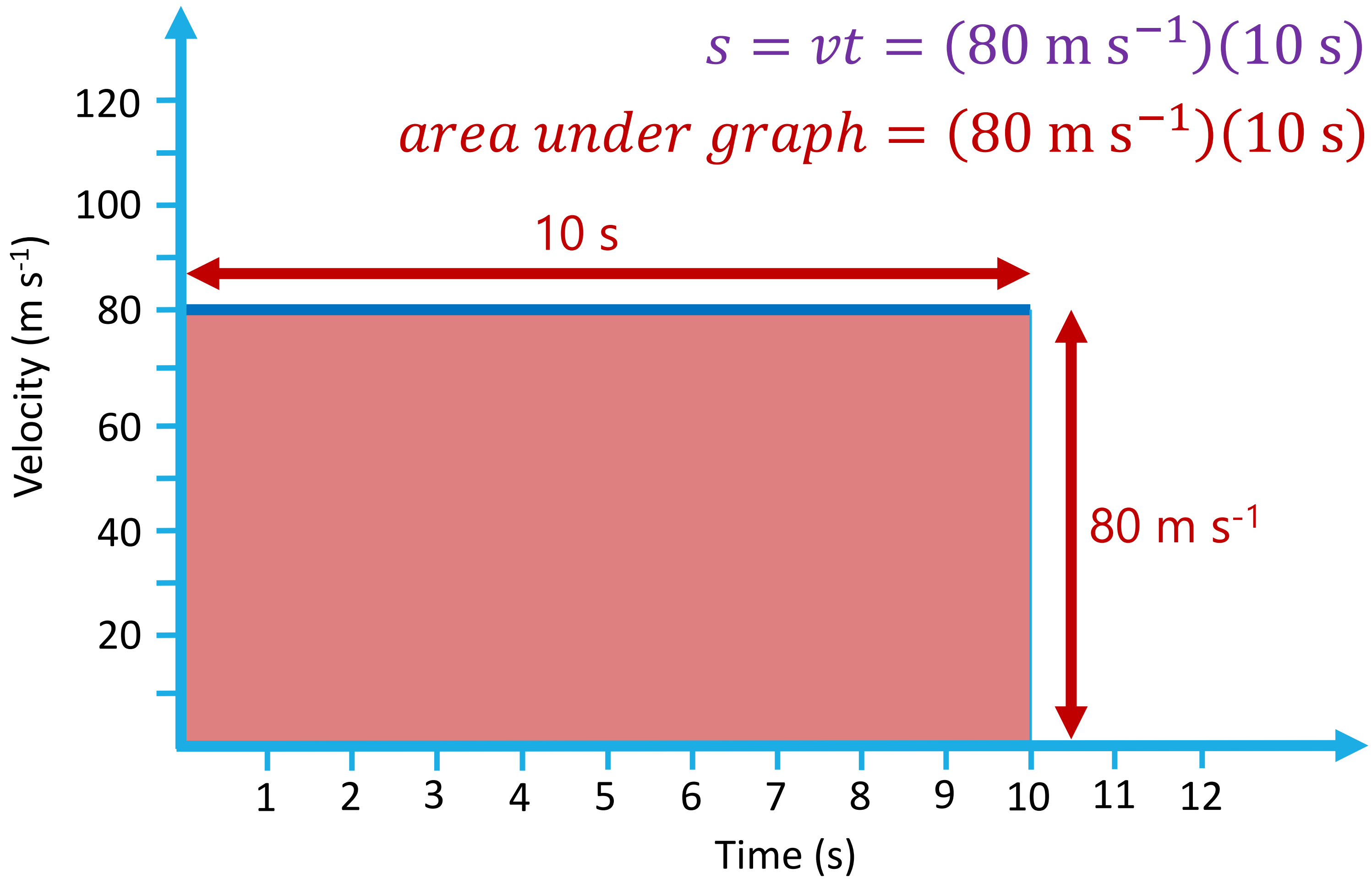
Physics Data Booklet

Sub-topic 2.1 – Motion
$v = u + at$
$s = ut + \frac{1}{2}at^2$
$v^2 = u^2 + 2as$
$s = \frac{(v+u)t}{2}$

How far have I gone?

$$s = vt = (80\ \mathrm{m\ s^{-1}})(10\ \mathrm{s}) = 800\ \mathrm{m}$$

$$area\ under\ graph = (80\ \mathrm{m\ s^{-1}})(10\ \mathrm{s}) = 800\ \mathrm{m}$$



Use the graphs to tell you MORE!

Displacement vs Time

Slope

Velocity

Displacement

Area Under Curve

Velocity vs Time

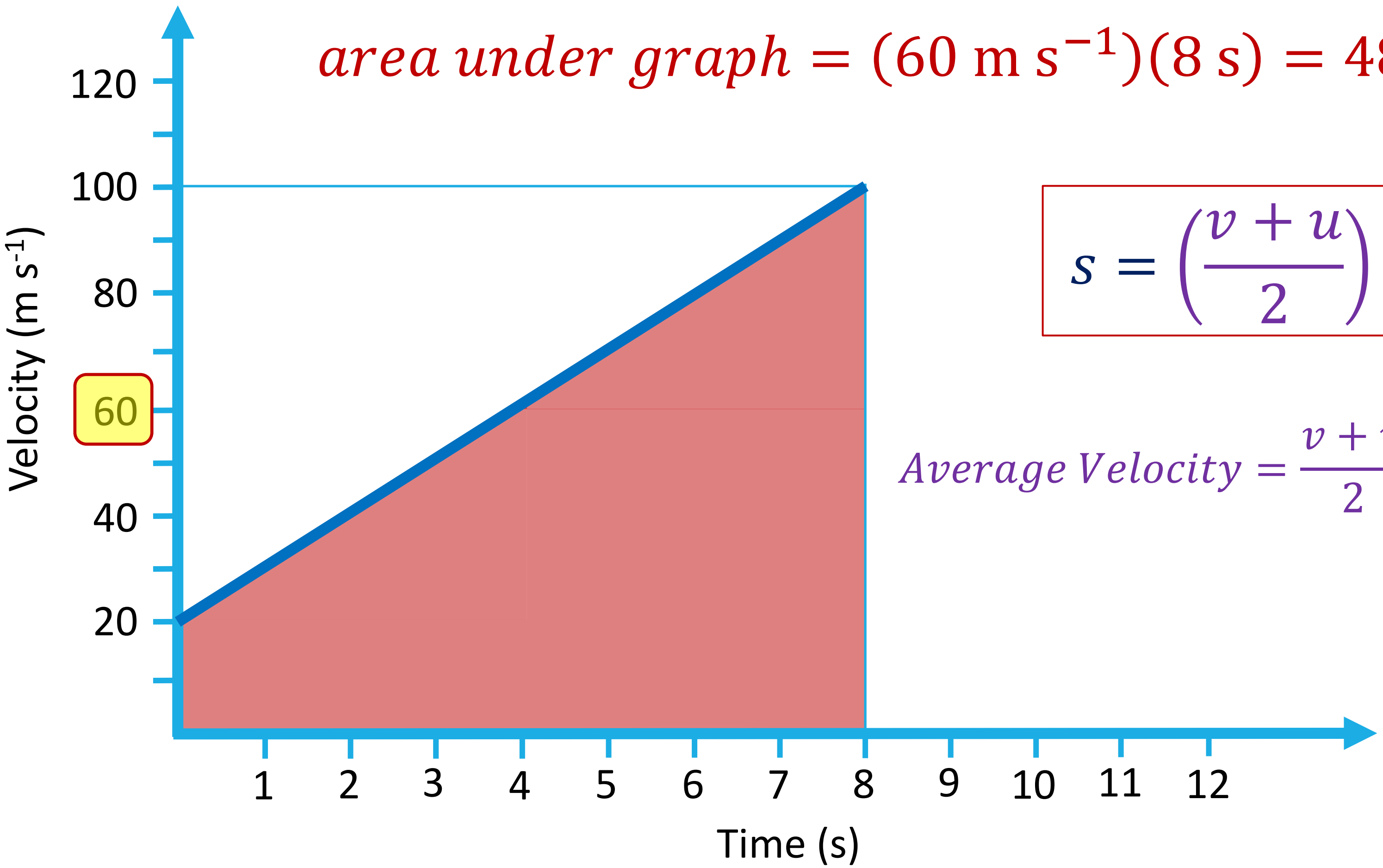
Velocity vs Time

Slope

Acceleration

How far have I gone?

$$area\ under\ graph = (60\ \mathrm{m\ s^{-1}})(8\ \mathrm{s}) = 480\ \mathrm{m}$$



$$s = \left(\frac{v+u}{2}\right) \times t$$

$$Average\ Velocity = \frac{v+u}{2}$$

Physics Data Booklet

Sub-topic 2.1 – Motion
$v = u + at$
$s = ut + \frac{1}{2}at^2$
$v^2 = u^2 + 2as$
$s = \frac{(v + u)t}{2}$

What if I don’t know v?

$$s = \frac{(v+u)t}{2} \qquad v = u + at$$

$$s = \frac{(u+at+u)t}{2} = \frac{(2u+at)t}{2}$$

$$s = \frac{2ut+at^2}{2} \rightarrow s = ut+\frac{1}{2}at^2$$

Physics Data Booklet

Sub-topic 2.1 – Motion
$v = u + at$
$s = ut + \frac{1}{2}at^2$
$v^2 = u^2 + 2as$
$s = \frac{(v+u)t}{2}$

One more equation

$$v^2 = u^2 + 2as$$

Equations

	m	$m\,s^{-1}$	$m\,s^{-1}$	$m\,s^{-2}$	s
$v = u + at$		u	v	a	t
$s = ut + \frac{1}{2}at^2$	s	u		a	t
$v^2 = u^2 + 2as$	s	u	v	a	
$s = \frac{(v+u)t}{2}$	s	u	v		t

Try This | 3

You speed up with a uniform acceleration from 0 m/s to 30 m/s in 5 seconds. How far have you gone?

$v = u + at$		u	v	a	t
$s = ut + \frac{1}{2}at^2$	s	u		a	t
$v^2 = u^2 + 2as$	s	u	v	a	
$s = \frac{(v+u)t}{2}$	s	u	v		t

$$s = \frac{(30+0)(5)}{2} = \mathbf{75\ m}$$

s	?
u	0 m s^{-1}
v	30 m s^{-1}
a	------
t	5 s

Try This | 4

If a plane on a runway is accelerating at 4.8 m s^{-2} for 15 seconds before taking off, how long should the runway be?

$$s = ut + \frac{1}{2}at^2$$

$$= (0)(15) + \frac{1}{2}(4.8)(15)^2$$

$$s = 540 \text{ m}$$

s	?
u	0 m s^{-1}
v	-------
a	4.8 m s^{-2}
t	15 s

Try This | 5

A driver slams on the brakes and skids for 3 seconds before coming to a stop. You go and measure that the skid marks show a deceleration over 9 m. What was the initial speed of the car?

$$s = \frac{(v+u)t}{2}$$

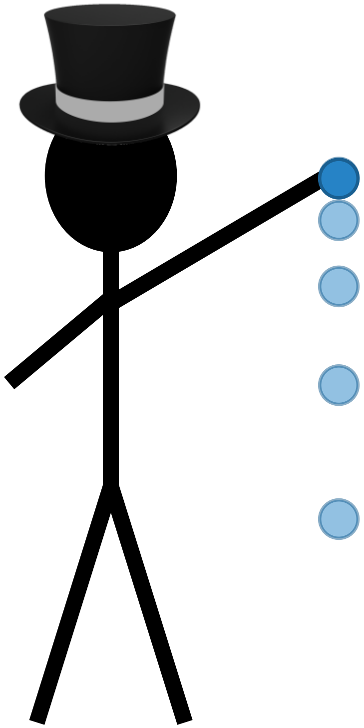
$$u = \frac{2s}{t} - v = \frac{2(9)}{(3)} - 0$$

$$u = 6 \text{ m s}^{-1}$$

s	9 m
u	?
v	0 m s^{-1}
a	-----
t	3 s

Lesson Takeaways

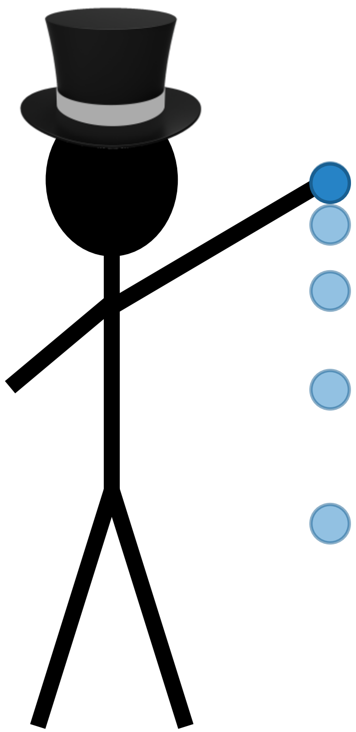
- ❑ I can identify the 5 primary variables of motion
- ❑ I can identify the proper kinematic equation to use for a problem that is presented
- ❑ I can rearrange to solve for the unknown variable
- ❑ I can calculate for an unknown



Free Fall

IB PHYSICS | MOTION

What is Free Fall?



The only force acting on the object is gravity

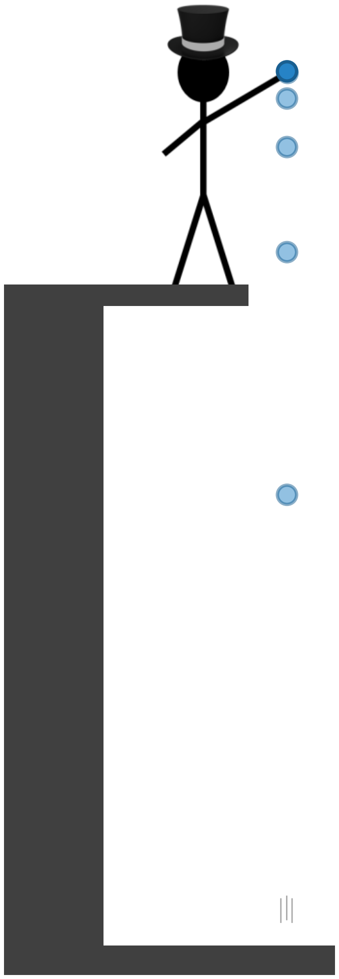
No Air Resistance

Acceleration due to Gravity

-9.81 m s^{-2}

negative

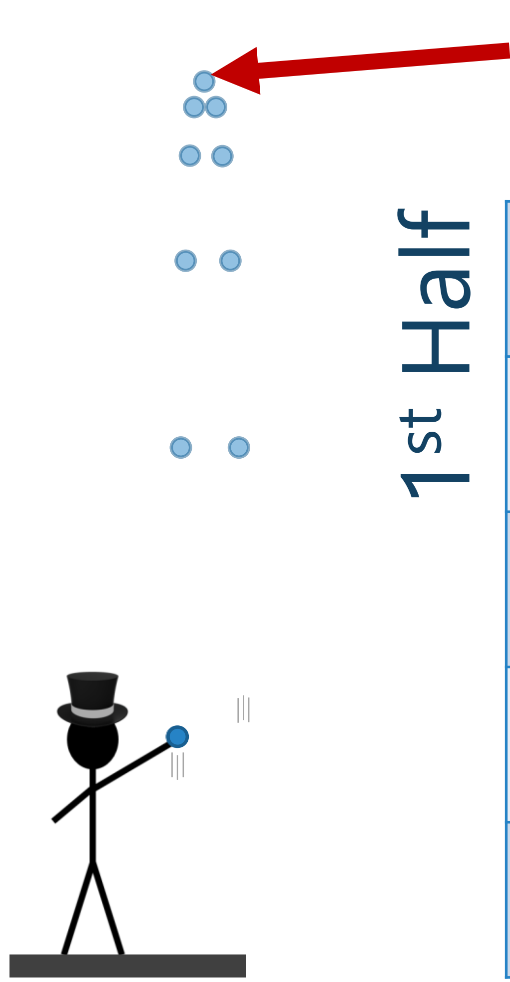
What if you drop something?



What do you know?

s	
u	0 m s^{-1}
v	
a	-9.81 m s^{-2}
t	

What if you throw something up?



What do you know?

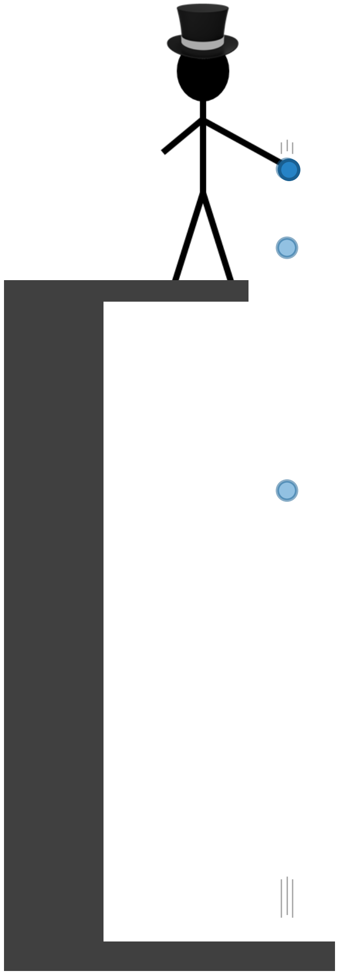
1st Half

s	
u	
v	$0\ m\ s^{-1}$
a	$-9.81\ m\ s^{-2}$
t	

2nd Half

s	
u	$0\ m\ s^{-1}$
v	
a	$-9.81\ m\ s^{-2}$
t	

What if you throw something down?



What do you know?

s	
u	
v	
a	$-9.81\ \mathrm{m\ s^{-2}}$
t	

Reminder of our Equations

Units	*m*	*m s*$^{-1}$	*m s*$^{-1}$	*m s*$^{-2}$	*s*
$v = u + at$		u	v	a	t
$s = ut + \frac{1}{2}at^2$	s	u		a	t
$v^2 = u^2 + 2as$	s	u	v	a	
$s = \frac{(v+u)t}{2}$	s	u	v		t

Dropping a marble

If you drop a marble off of the Empire State Building (~380 m), how fast will it be going once it reaches the ground?

$$v^2 = u^2 + 2as$$

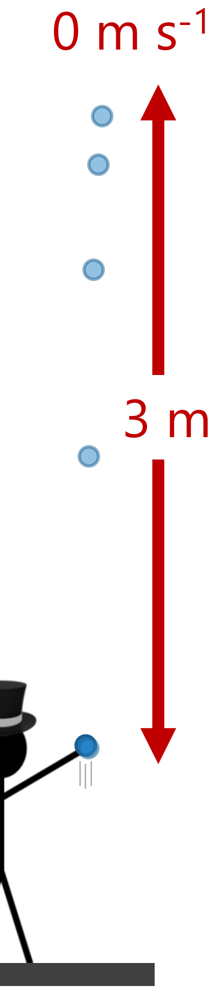
$$v = \sqrt{0^2 + 2(-9.81)(-380)}$$

$$v = -86.3 \text{ m s}^{-1}$$

*The negative indicates a downward direction

s	-380 m
u	0 m s^{-1}
v	?
a	-9.81 m s^{-2}
t	---

Shooting a Basket



What is the vertical velocity of a basketball required to reach the rim of the basketball hoop? (~3.0 m high)

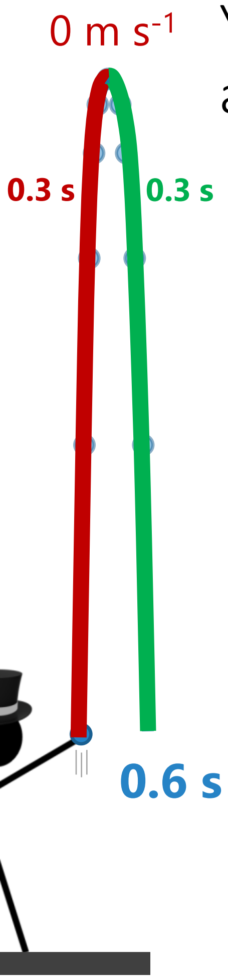
$$v^2 = u^2 + 2as$$

$$0^2 = u^2 + 2(-9.81)(3)$$

$$u = 7.67 \text{ m s}^{-1}$$

s	3 m
u	?
v	0 m s^{-1}
a	-9.81 m s^{-2}
t	---

Flipping a Coin



You flip a coin and catch it. It is in the air for a total of 0.6 seconds. How high did it go?

$$s = ut + \frac{1}{2}at^2$$

$$s = \frac{1}{2}(-9.81)(0.3)^2$$

$$s = 0.441 \text{ m}$$

s	?
u	0 m s^{-1}
v	---
a	-9.81 m s^{-2}
t	0.3 s

Half the time

Lesson Takeaways

- ❑ I can identify the constant acceleration due to gravity neglecting air resistance
- ❑ I can interpret a free fall problem to identify hidden values and understand when to look at only half of the problem
- ❑ I can use the kinematic equations to solve a free fall problems

Projectile Motion

IB PHYSICS | MOTION

Reminder of our Equations

Units	*m*	*m s*$^{-1}$	*m s*$^{-1}$	*m s*$^{-2}$	*s*
$v = u + at$		u	v	a	t
$s = ut + \frac{1}{2}at^2$	s	u		a	t
$v^2 = u^2 + 2as$	s	u	v	a	
$s = \frac{(v+u)t}{2}$	s	u	v		t

Dropping the Ball

How much time will it take this ball to hit the ground when dropped? The impact velocity?

$$s = \cancel{ut} + \frac{1}{2}at^2$$

$$-25 = \frac{1}{2}(-9.81)t^2$$

$$t = 2.26 \text{ s}$$

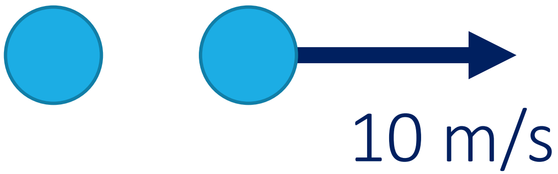
$$v^2 = \cancel{u^2} + 2as$$

$$v = \sqrt{2as} = \sqrt{2(-9.81)(-25)}$$

$$v = -22.2 \text{ m s}^{-1}$$

s	-25 m
u	0 m s^{-1}
v	?
a	-9.81 m s^{-2}
t	?

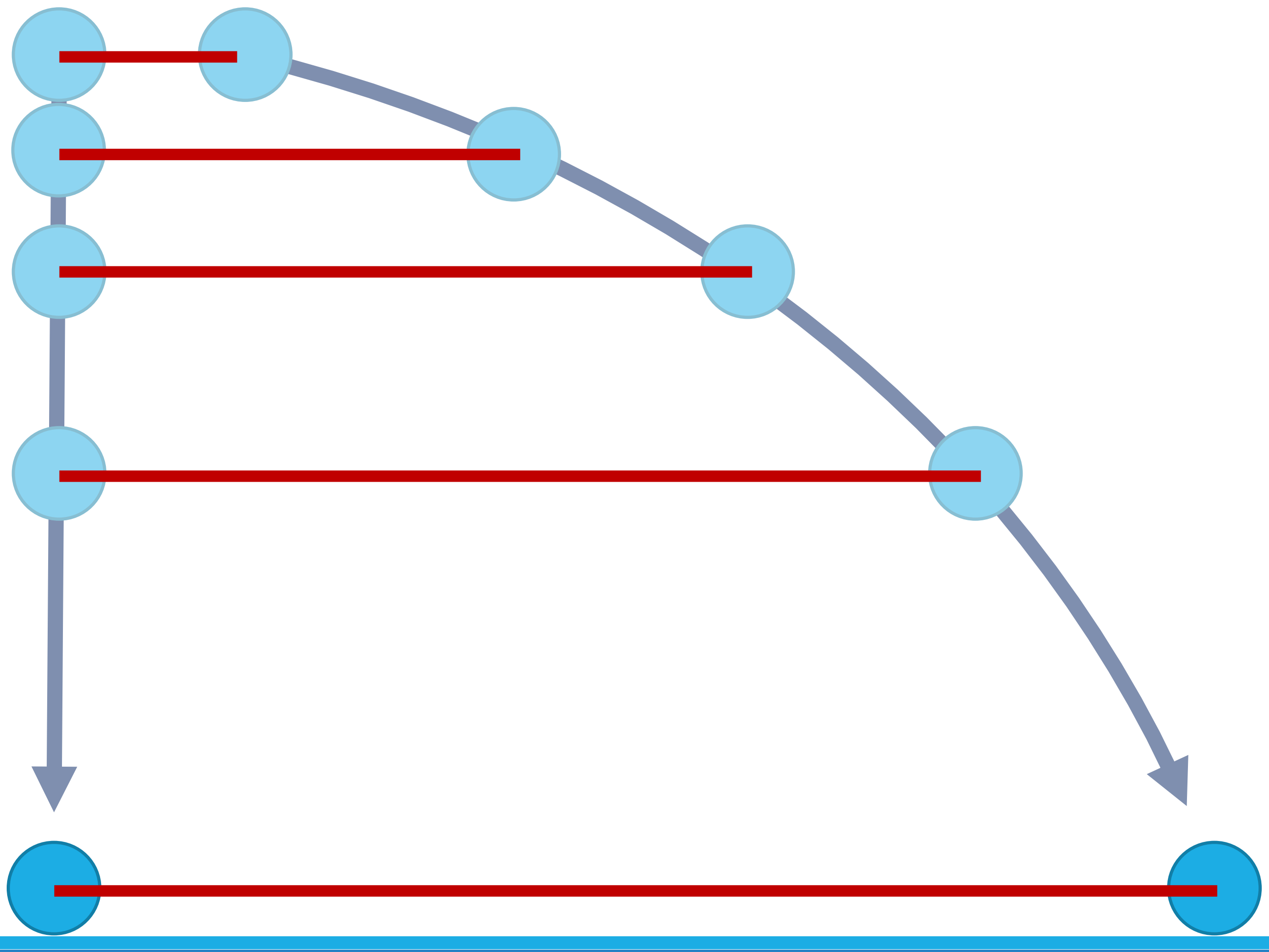
Air Time - Comparison

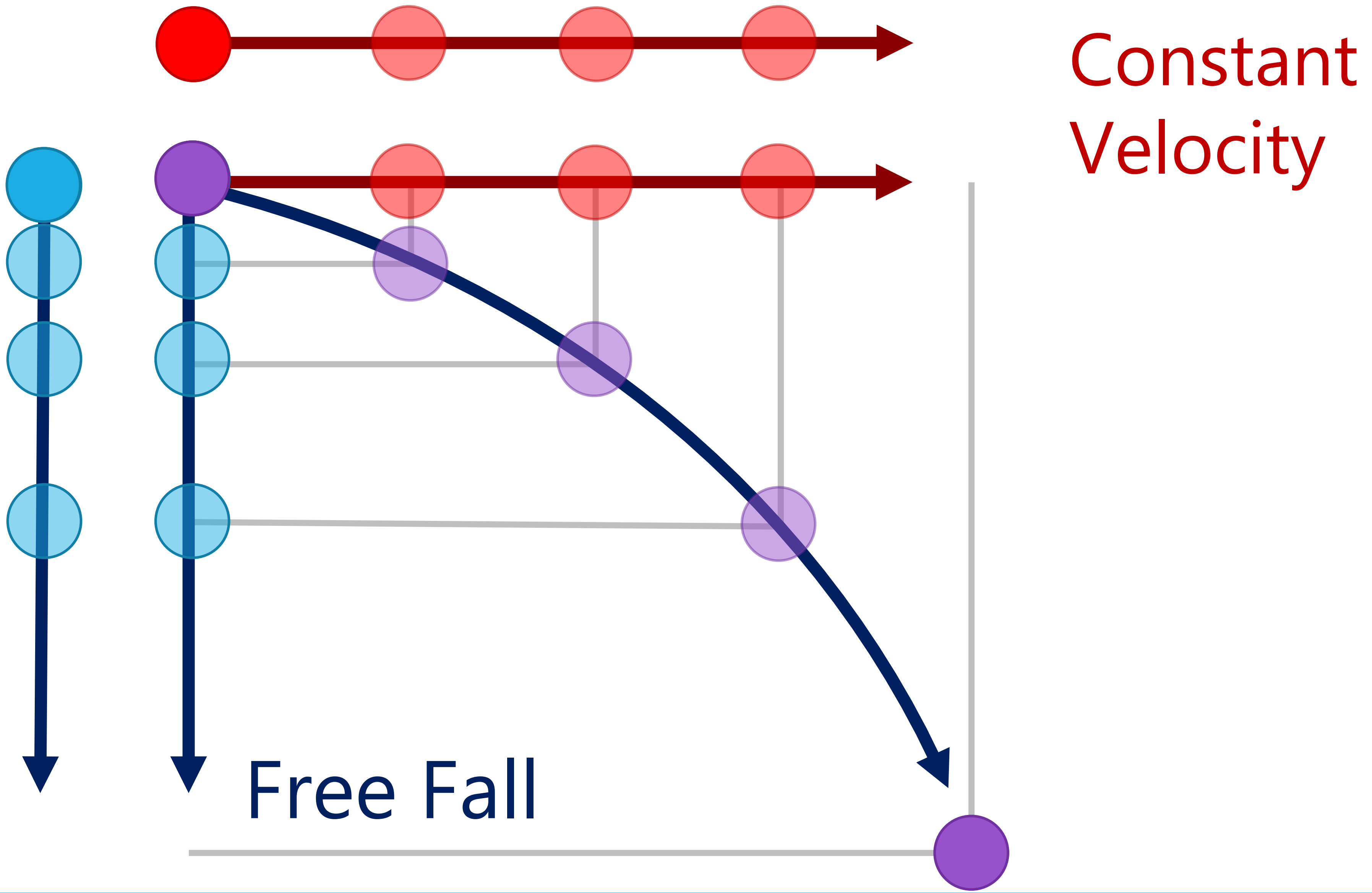


Which ball will have more air time?

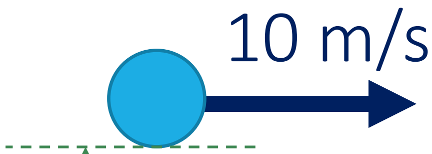
The balls hit the ground at EXACTLY the same time

Air Time - Comparison




Constant
Velocity
Free Fall

Horizontal Projectile



From Previous Problem →

Vertical Only	
s	-25 m
u	0 m s^{-1}
v	-22.2 m s^{-1}
a	-9.81 m s^{-2}
t	2.26 s

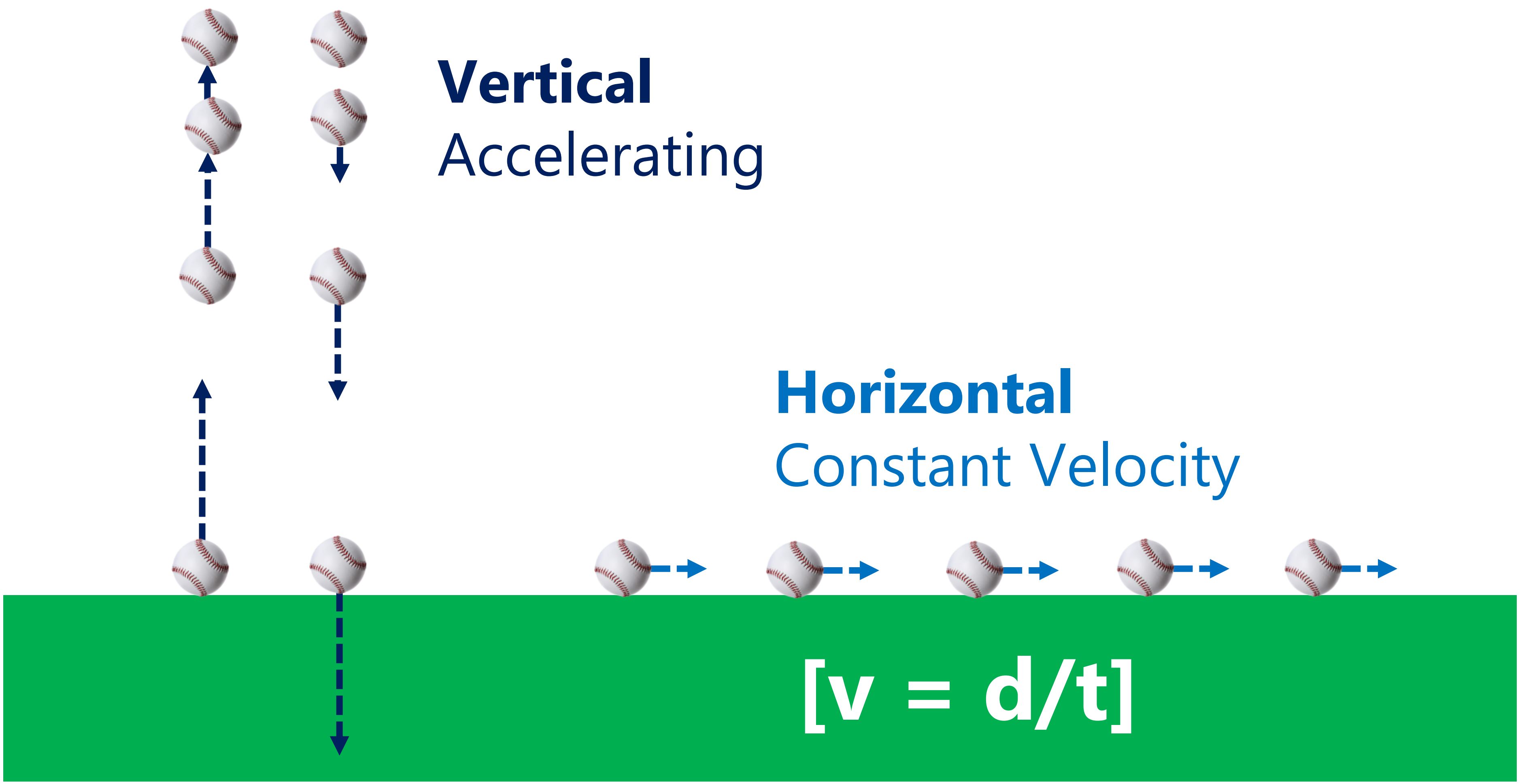
How far does the ball travel?

$$v = \frac{d}{t}$$

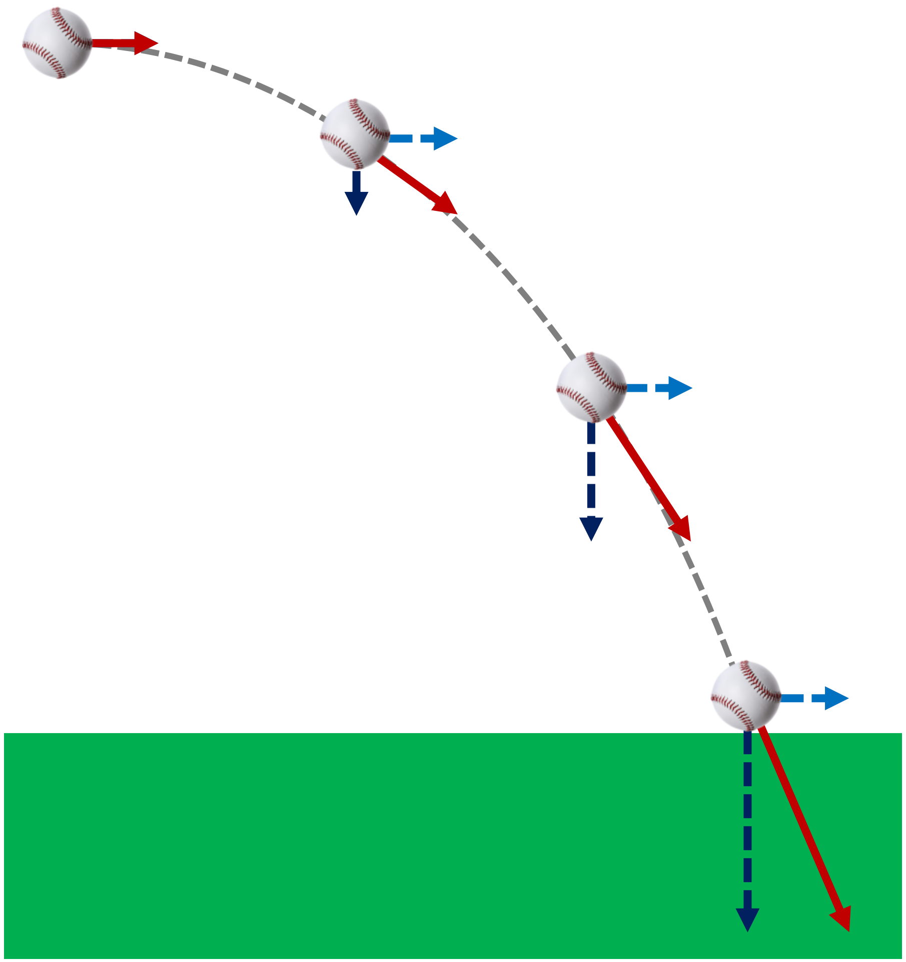
$$d = vt = (10\ \mathrm{m\ s^{-1}})(2.26\ \mathrm{s})$$

$$d = 22.6\ \mathrm{m}$$

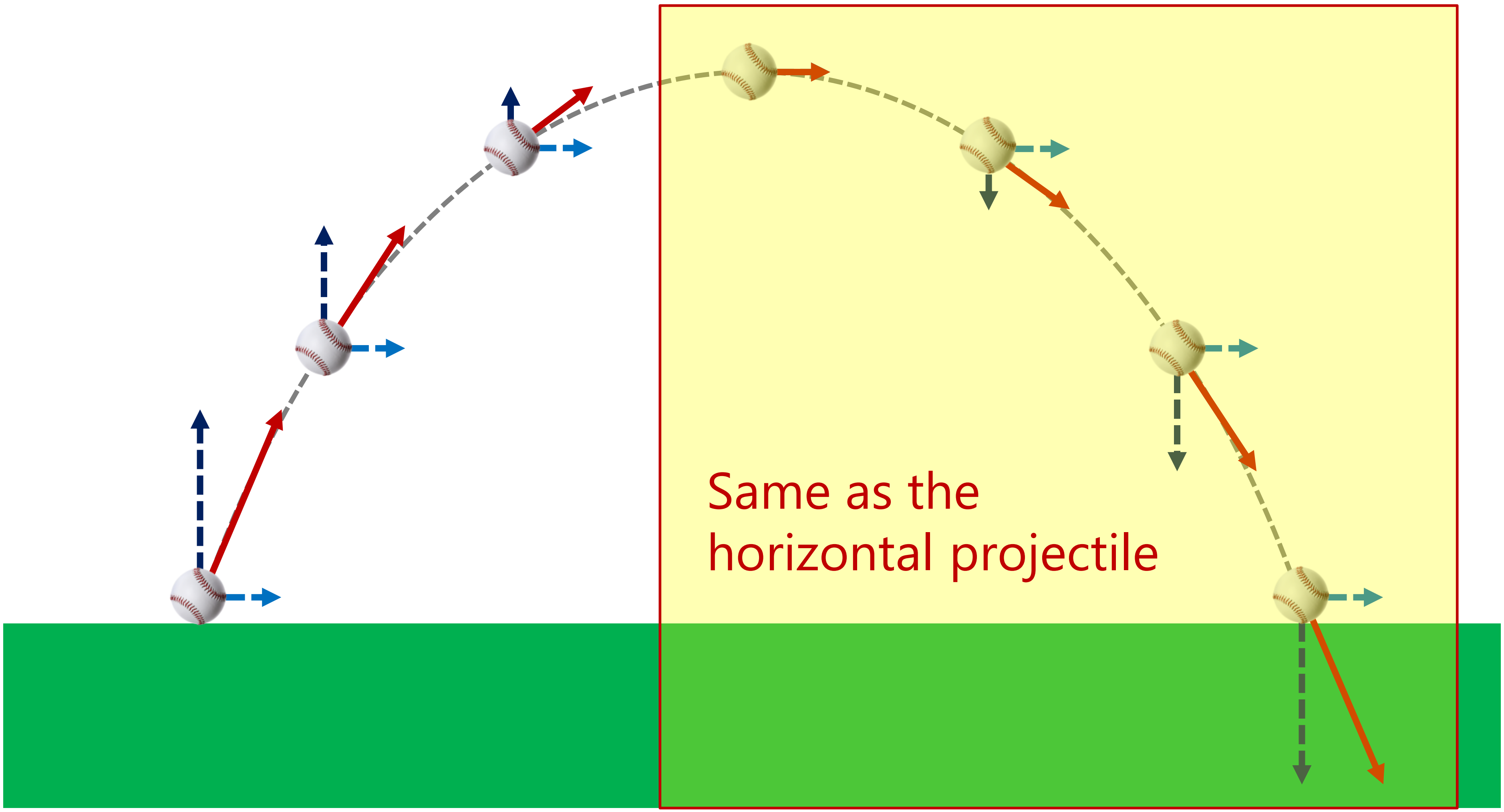
One Dimensional Motion



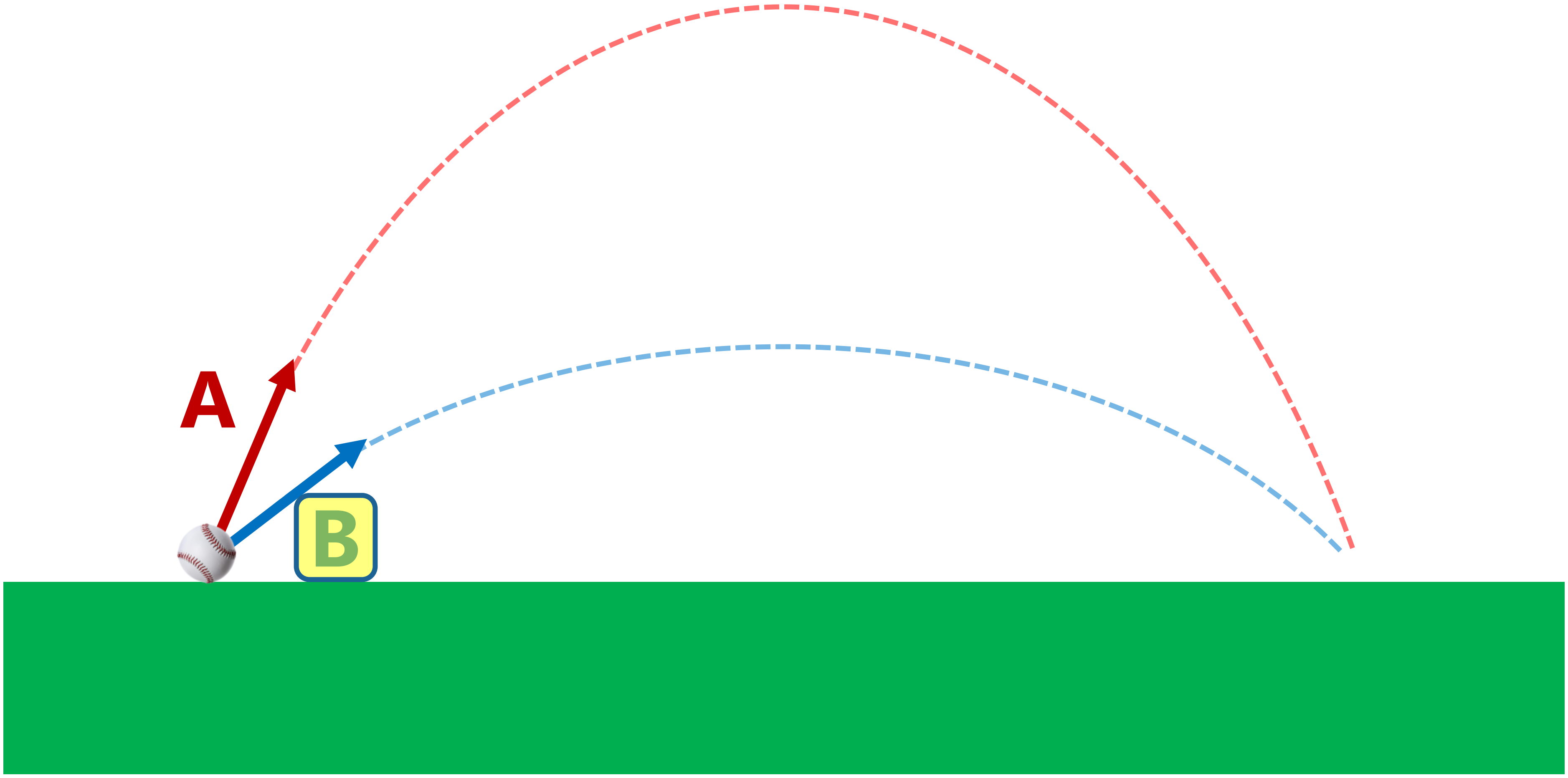
Horizontal Projectile



Two-Dimensional Projectile

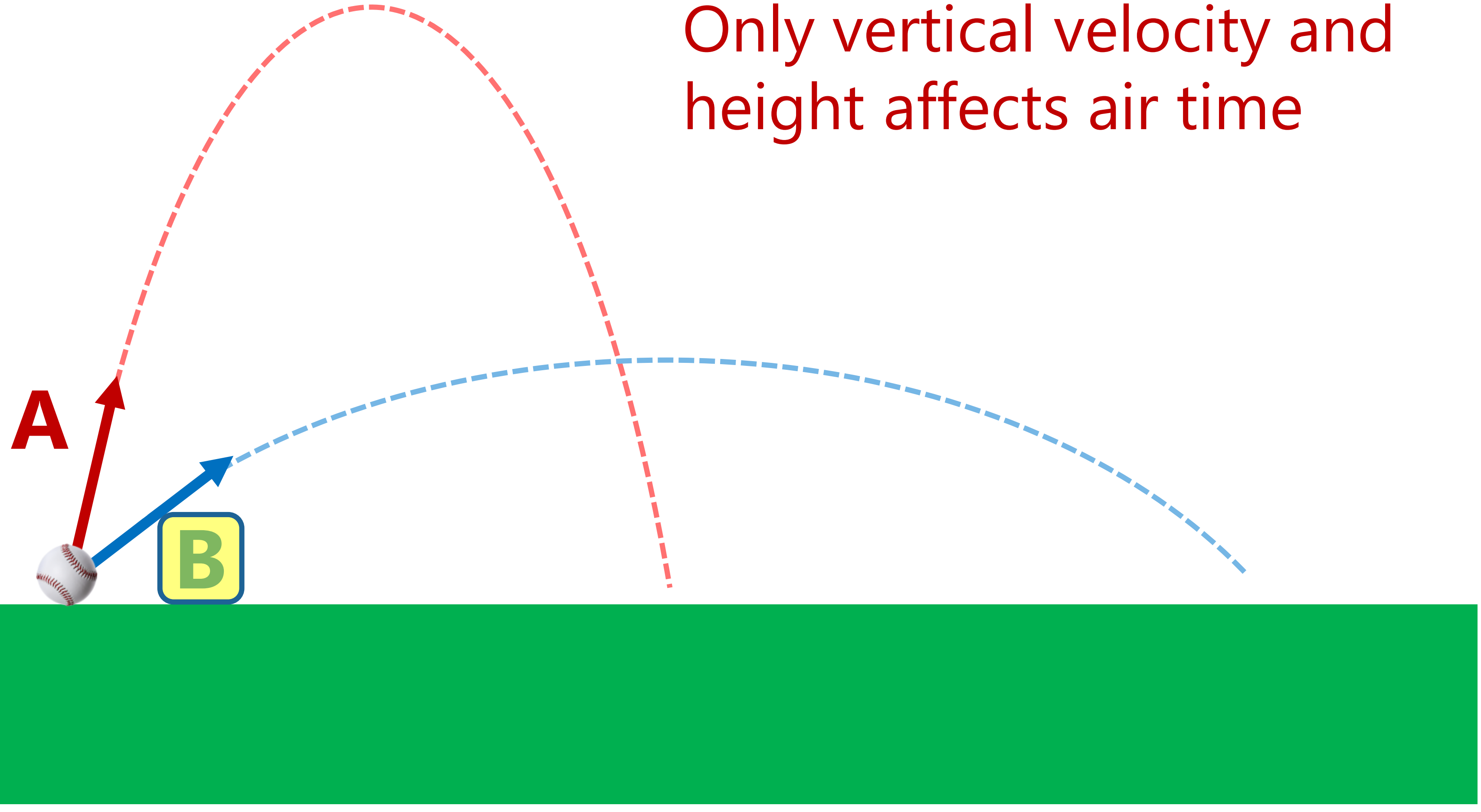


Which one lands first??



Which one lands first??

Only vertical velocity and height affects air time



Lesson Takeaways

- ❑ I can compare the motion of an object dropped from rest and an object with an initial horizontal velocity
- ❑ I can calculate the air time and speed for a horizontal projectile
- ❑ I can describe how the vertical and horizontal components are independent from each other for a projectile's motion
- ❑ I can compare the air time for two projectiles given their trajectories.