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

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

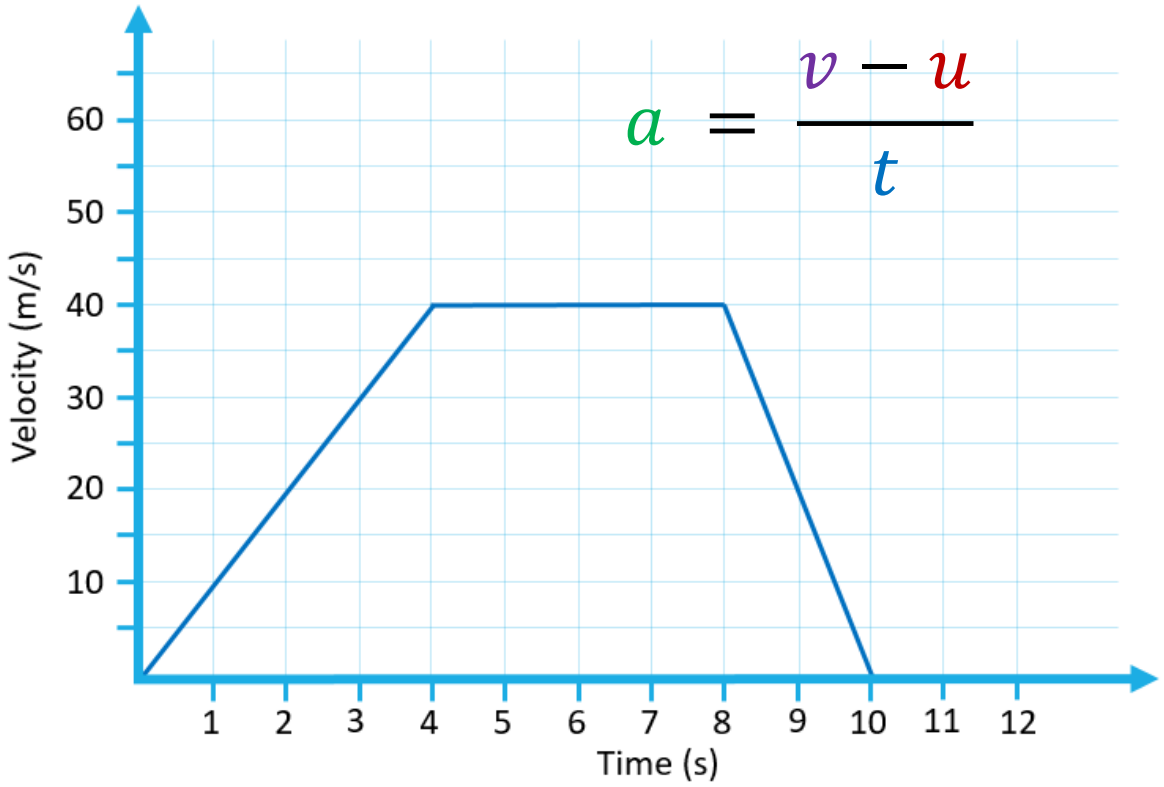
Symbols

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

Units

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

Think about this unit…



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

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

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

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 can get a negative value!*

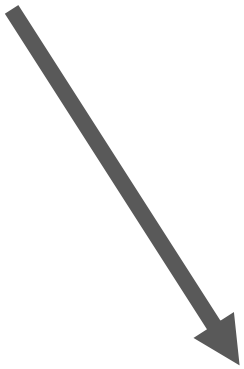
u	12 ms^{-1}
v	0 ms^{-1}
a	?
t	8 s

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

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

Solve for v

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



$$v = u + at$$

Physics Data Booklet

Sub-topic 2.1 – Motion

$$v = u + at$$

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

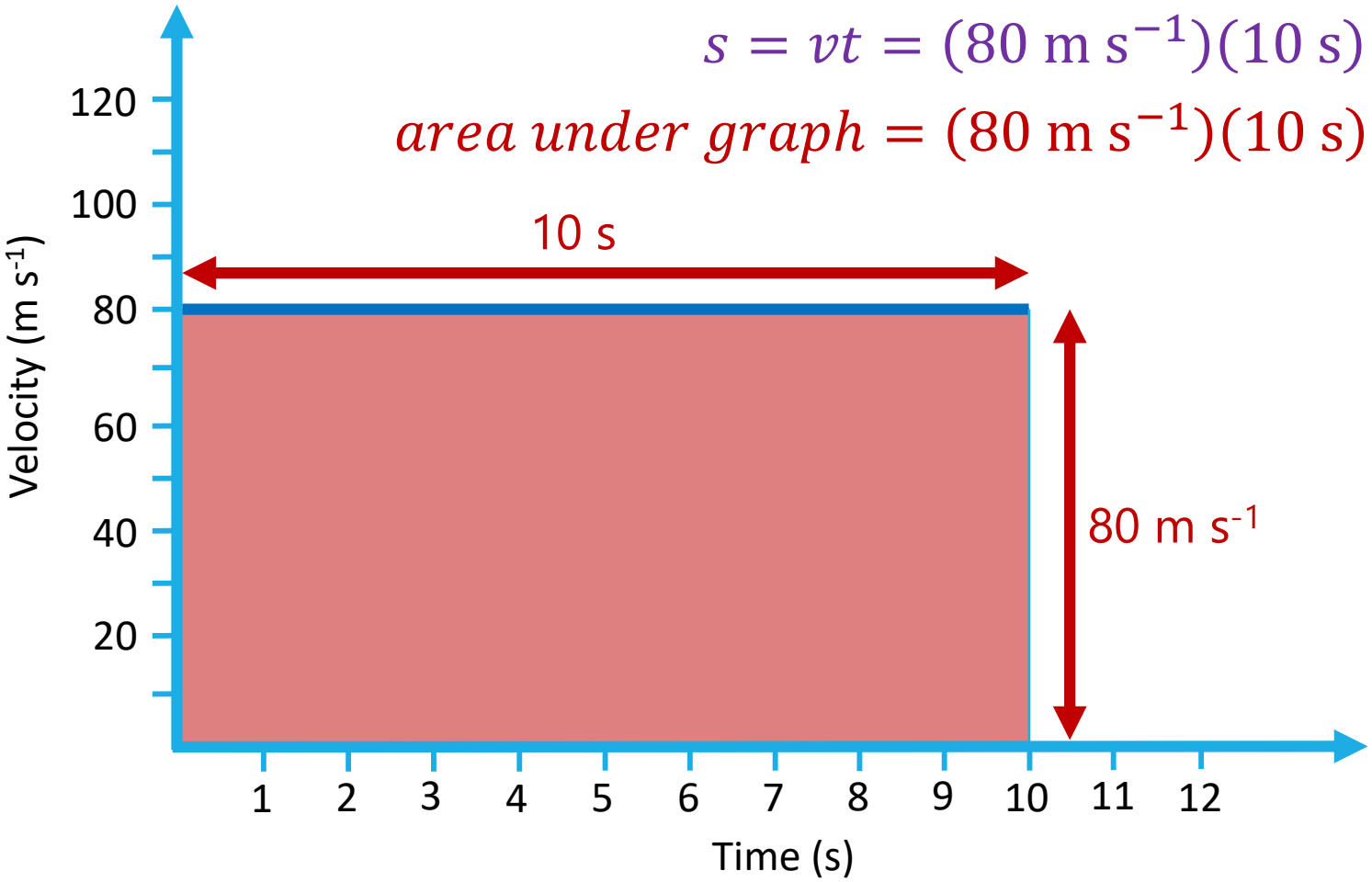
$$v^2 = u^2 + 2as$$

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

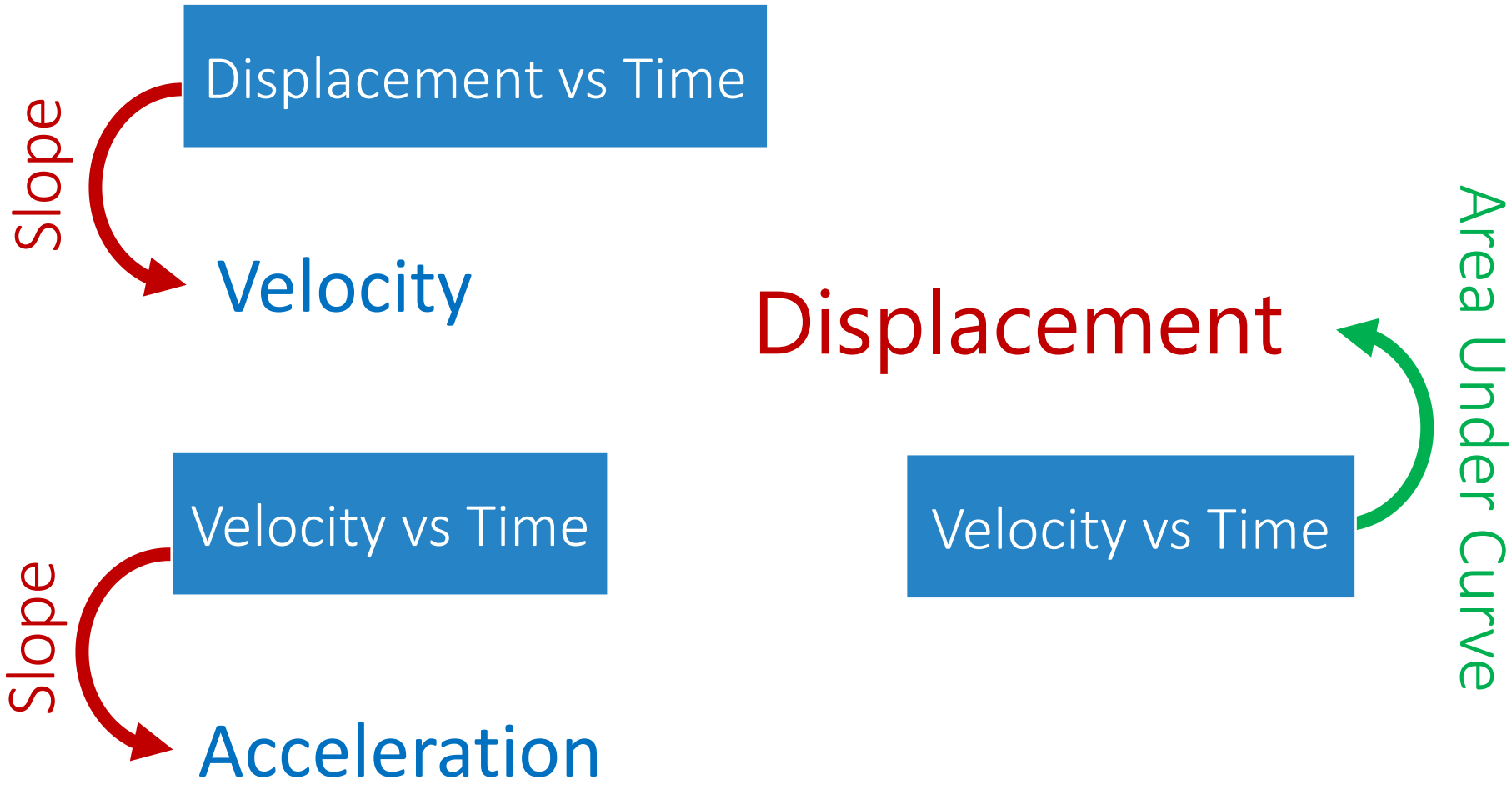
How far have I gone?

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

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

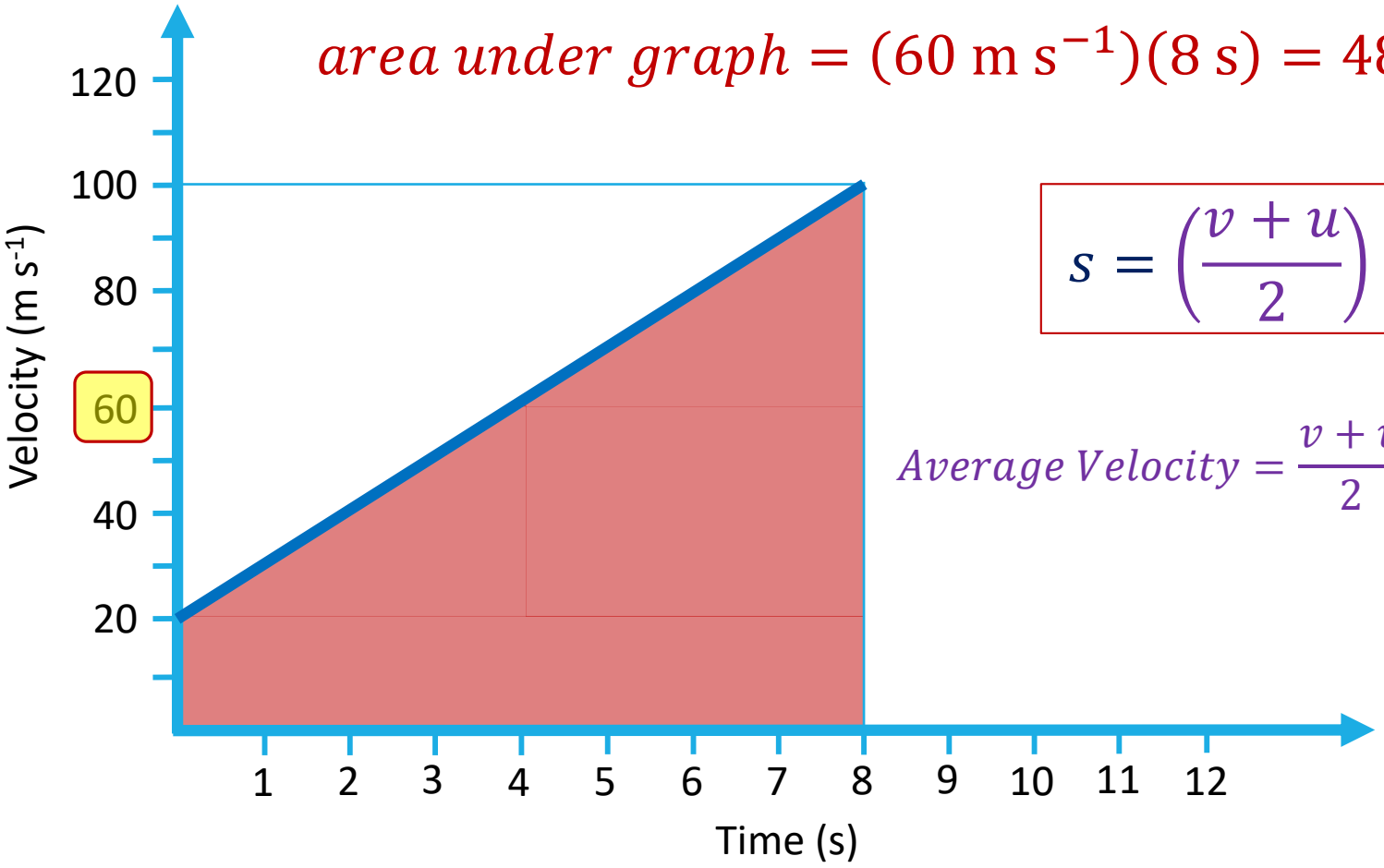


Use the graphs to tell you MORE!



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?

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

$$v = u + at$$

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

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

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?

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

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

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