A.2

Newton's 2nd Law & Kinematics

IB PHYSICS | MOTION

Newton's Second Law

A.2

The rate of change of momentum of a body is directly proportional to the unbalanced force acting on that body and takes place in same direction.

$$F = \frac{\Delta p}{\Delta t}$$

What is…

A.1

Velocity

change in **position** over time

"speed *with direction*"

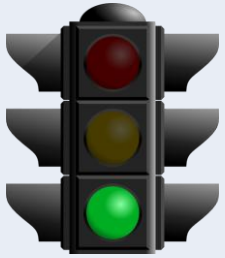
Acceleration

change in **velocity** over time

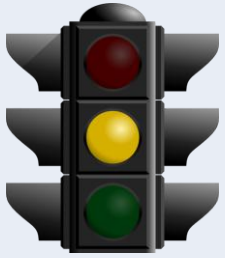
Types of Acceleration

A.1

Speeding Up



Slowing Down

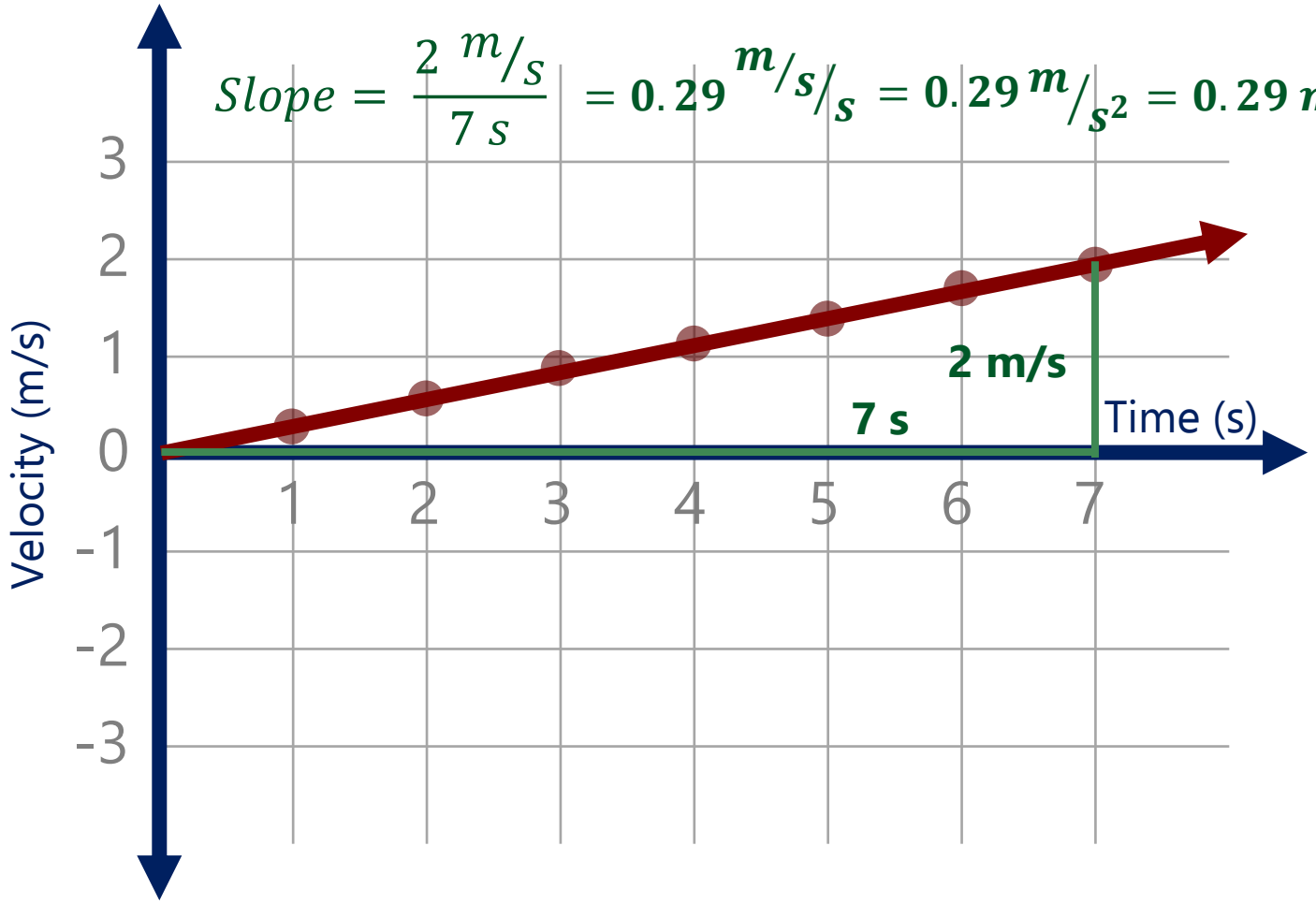


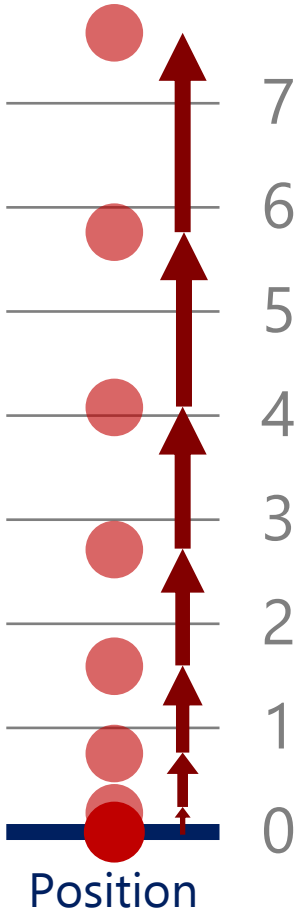
Changing Direction

An object speeding up (positive)

A.1

$$Slope = \frac{2\ {}^{m}/_{s}}{7\ s} = 0.29\ {}^{m/s}/_{s} = 0.29\ {}^{m}/_{s^2} = 0.29\ m\ s^{-2}$$





Calculating Acceleration

A.1

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

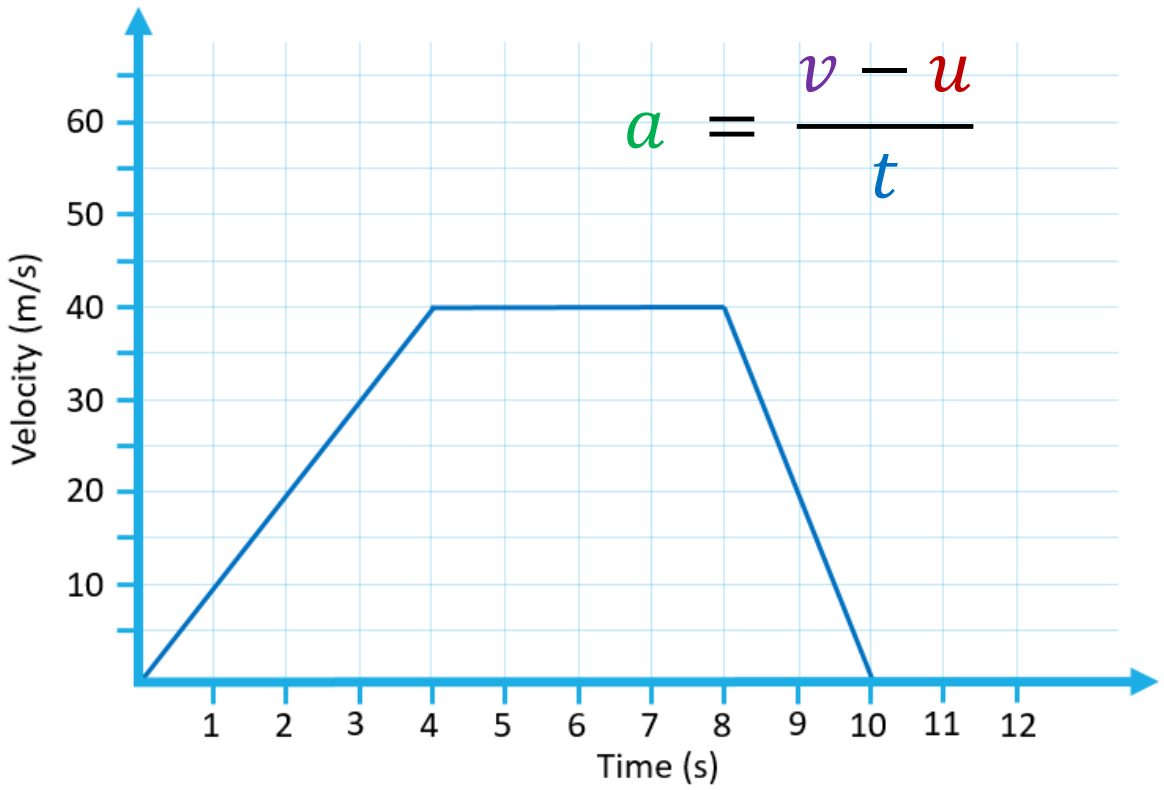
Symbols

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

Units

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

Think about this unit…

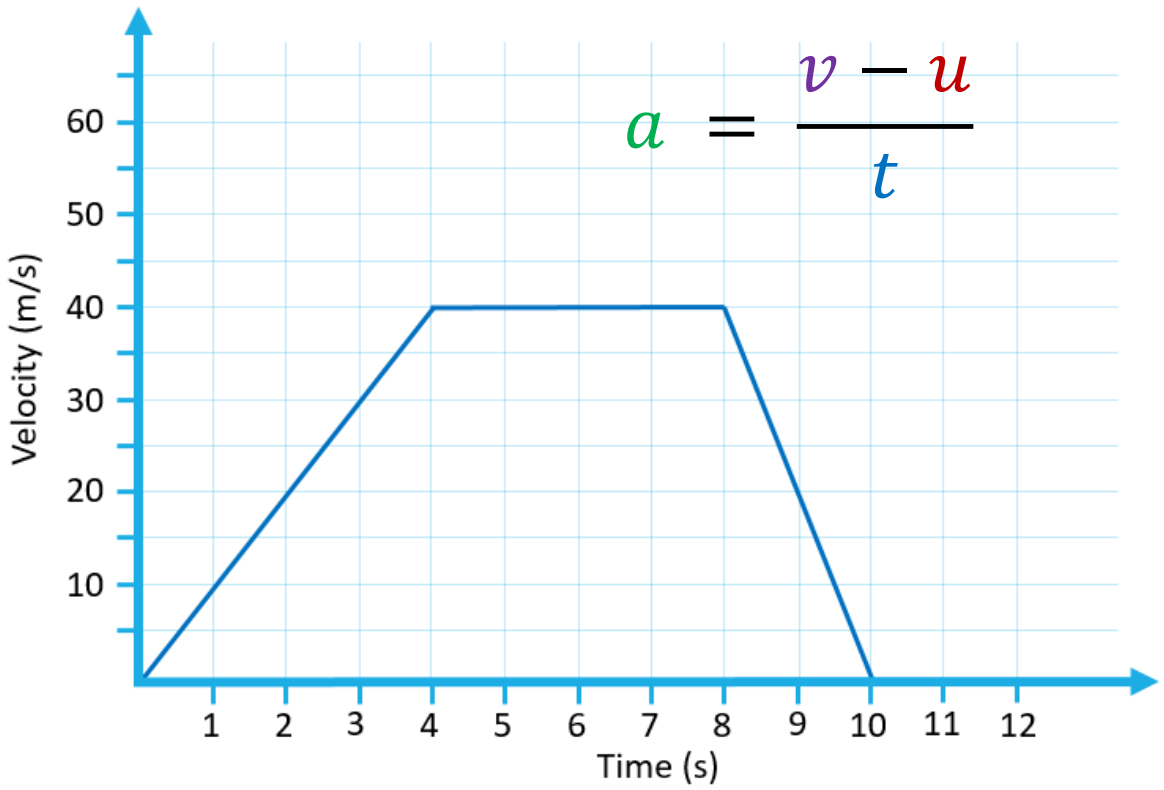


m/s/s

m/s^2

m s^{-2}

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

A.1

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

*Tip: You can get a negative value!

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

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

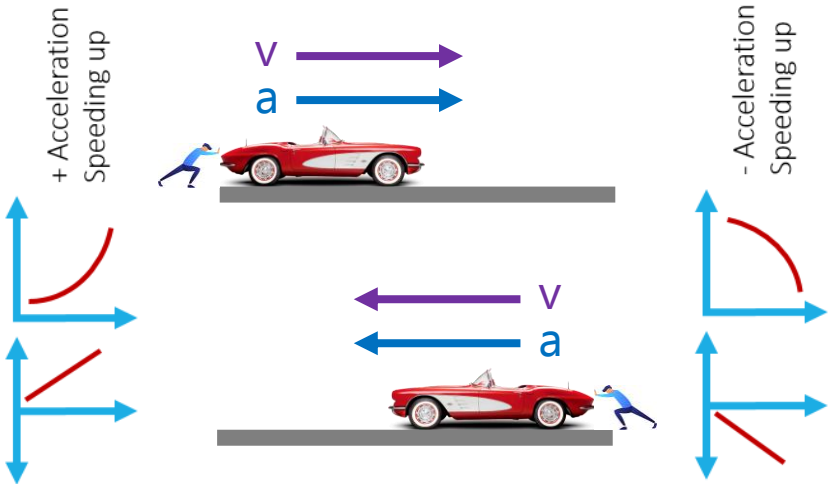
$$\boldsymbol{a = -1.5\ ms^{-2}}$$

Acceleration | Slowing or Speeding?

A.2

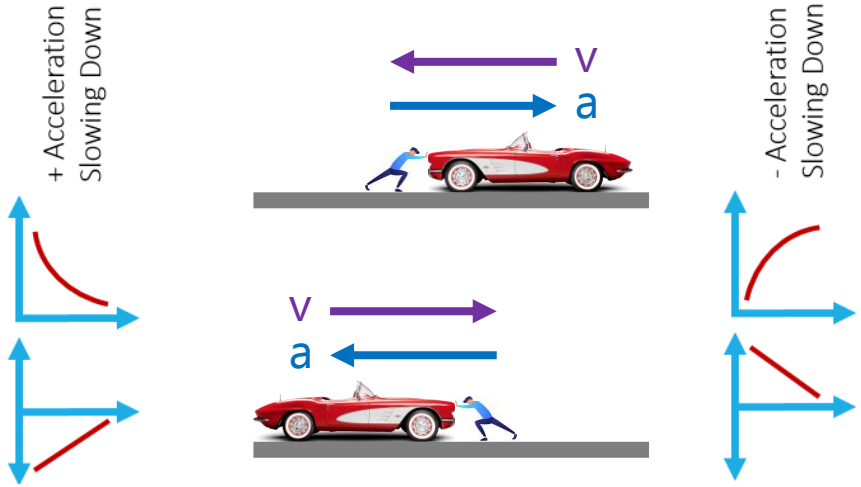
When the acceleration is in the **same** direction as the velocity the object is speeding up

Net force with motion



When the acceleration is in the **opposite** direction as the velocity the object is slowing down

Net force opposing motion

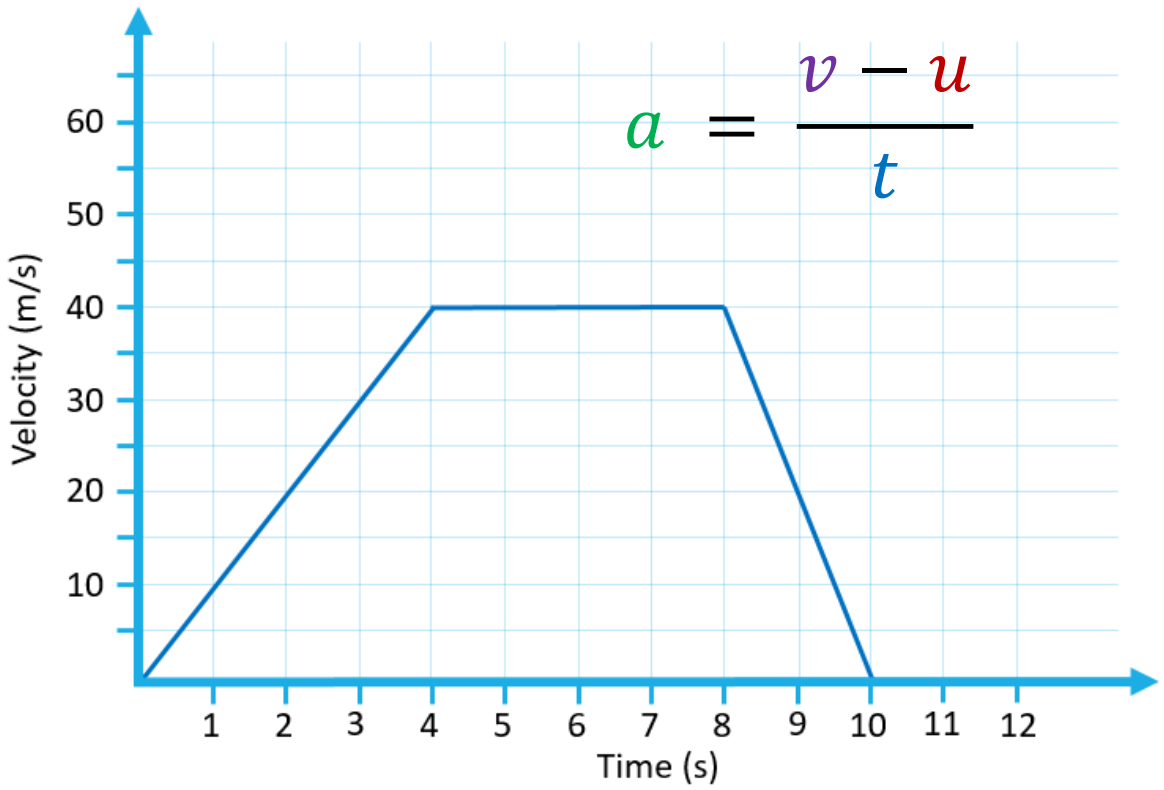


IB Physics Data Booklet

A.2

A.2 Forces and momentum	
	$F_f \leq \mu_s F_N$
	$F_f = \mu_d F_N$
	$F_H = -kx$
	$F_d = 6\pi\eta rv$
	$F_b = \rho Vg$
	$F_g = mg$
	$p = mv$
	$J = F\Delta t$
	$F = ma = \frac{\Delta p}{\Delta t}$
	$a = \frac{v^2}{r} = \omega^2 r = \frac{4\pi^2 r}{T^2}$
	$v = \frac{2\pi r}{T} = \omega r$

Think about this unit...



m/s/s

m/s^2

$m\ s^{-2}$

Equilibrium → Acceleration = 0

A.2

If the net force is 0 N, then the object is not accelerating.

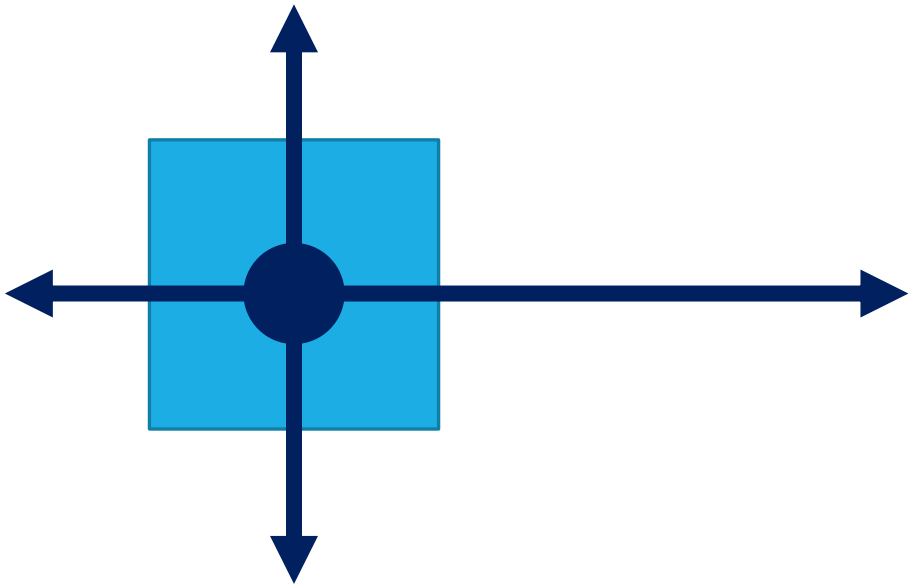
This can mean two different things:

- Not Moving
- Constant Velocity

Net Force → Acceleration

A.2

Any time there is a net force that is not zero, there will be acceleration in that direction

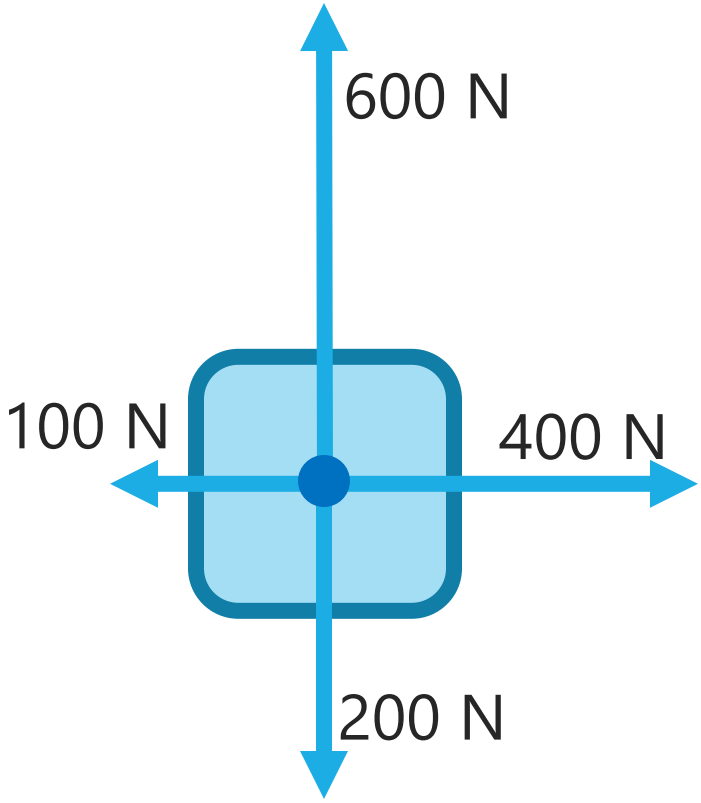


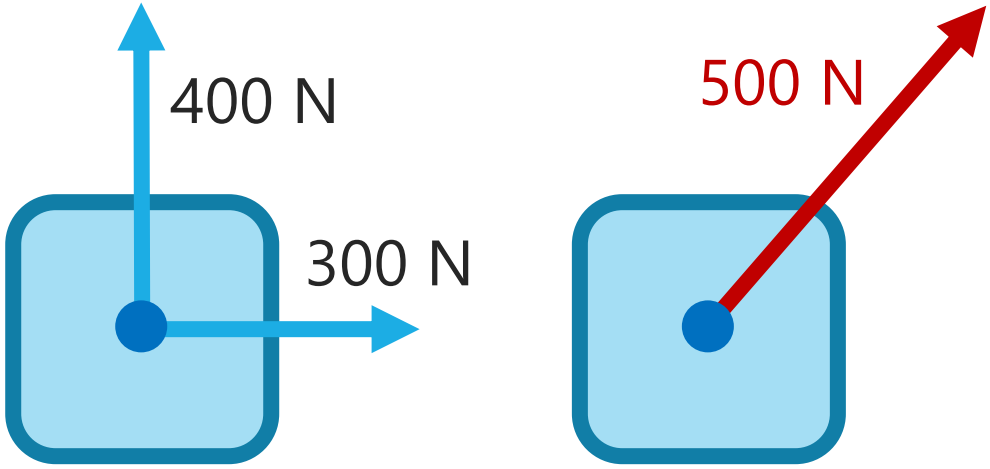
$$a = \frac{F}{m}$$

2nd Law | Try This... | #1

A.2

How fast is this 100 kg block accelerating?



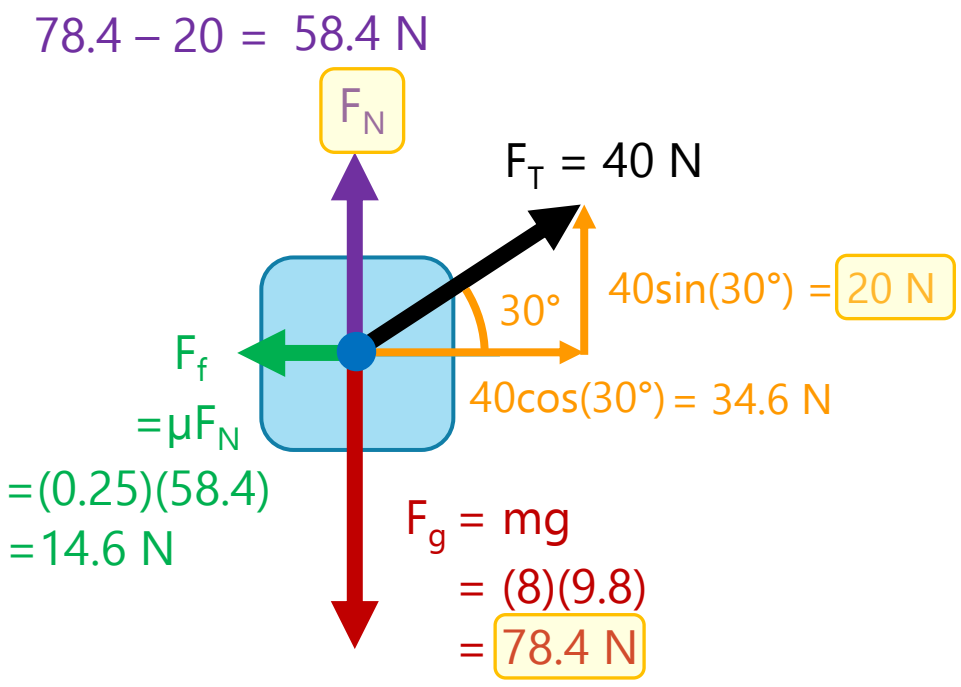


$$a = \frac{F}{m} = \frac{500\ \text{N}}{100\ \text{kg}} = \mathbf{5\ m\ s^{-2}}$$

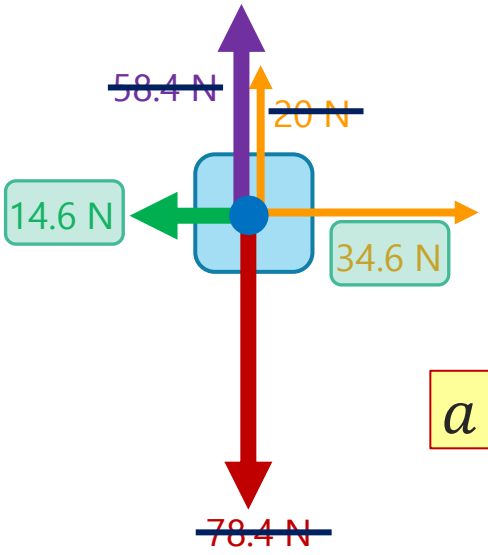
2nd Law | Try This... | #2

A.2

What is the net force for an 8 kg object being pulled with a force of 40 N at an angle of 30° to a surface with a $\mu_d = 0.25$? What is the acceleration of this block?



$$F = ma \rightarrow a = \frac{F}{m}$$



$$a = \frac{20\ \text{N}}{8\ \text{kg}}$$

$$a = 2.5\ m/s^2$$

Motion Variables

A.1

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.

The Kinematic Equations

A.1

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

Physics Data Booklet

A.1

A.1 Kinematics	$s = \frac{u+v}{2}t$ $v = u + at$ $s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$

Try This | 1

A.1

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

$s = \frac{u+v}{2}t$	s	u	v		t
$v = u + at$		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	?
u	0 m s^{-1}
v	30 m s^{-1}
a	------
t	5 s

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

Try This | 2

A.1

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?

$s =$

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

$s = 540$ m

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

Try This | 3

A.1

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?

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

$s =$

$u =$

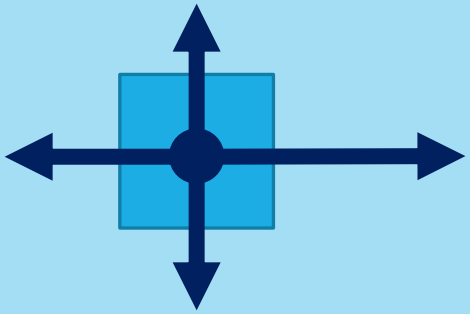
s	9 m
u	?
v	0 m s^{-1}
a	-----
t	3 s

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

A.2

2nd Law is the Bridge

Forces



$F = ma$

Motion

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

Try This | 4

A.2

A race car has a mass of 710 kg. It starts from rest and travels 40 meters in 3.0 seconds. That car is uniformly accelerated during the entire time. What net force is applied to it?

s	40 m
u	0 m s^{-1}
v	---
a	?
t	3 s

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

$$40 = \frac{1}{2}(a)(3)^2$$

$$a = 8.89 \text{ m } s^{-2}$$

$$F = ma$$

$$F = (710)(8.89)$$

$$F = 6311 \text{ N}$$

Try This | 5

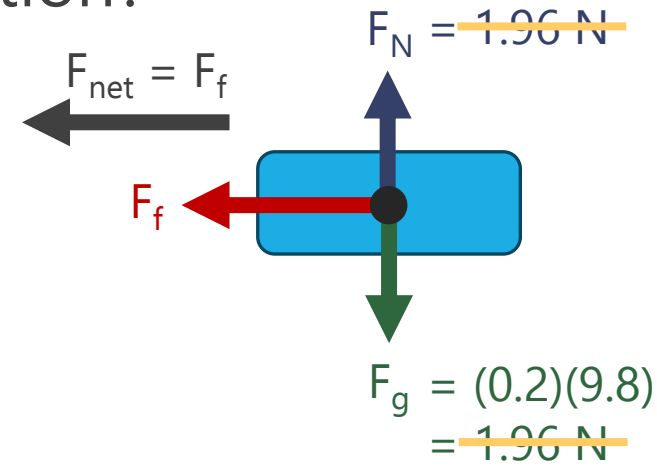
A.2

You slide a 0.20 kg hockey puck on the ice at a velocity of 12 m s^{-1}. After 3 seconds, the force of friction causes it to stop. What is the coefficient of friction?

s	---
u	12 m s^{-1}
v	0 m s^{-1}
a	?
t	3 s

$$v = u + at$$
$$0 = 12 + a(3)$$
$$\boxed{a = -4 \text{ m } s^{-2}}$$

$$F = ma$$
$$F = (0.2)(-4)$$
$$\boxed{F = -0.8 \text{ N}}$$



$F_f = \mu F_N$

$0.8 = \mu(1.96)$

$\mu = 0.408$

Lesson Takeaways

A.2

- ❑ I can identify the 5 primary variables of motion
- ❑ I can describe Newton's second law in terms of momentum
- ❑ I can explain the connection between constant velocity and balanced forces
- ❑ I can use the kinematic equations to solve for an unknown variable with constant acceleration
- ❑ I can combine Newton's second law with the kinematic equations to solve force/motion problems