Newton's 2nd Law

IB PHYSICS | FORCES

What is Momentum?

An object's tendency to continue moving

$$\text{Momentum} = m \times v$$

Newton's Second Law

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.

$$F_{net} = \frac{mv - mu}{t} = m\left(\frac{v - u}{t}\right) = ma$$

$$v = u + at$$

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

$$F_{net} = ma$$

Newton's Second Law

Force = mass × acceleration

Symbols

$$F = m \times a$$

Units

Newton → $N = kg \times m\ s^{-2}$

2nd Law | Try This… | #1

Your shiny new motorcycle has an engine capable of 2450 N of force. If it has a max acceleration of 15 m s^{-2}, what is its mass in kilograms?

$$F = 2450 \text{ N}$$

$$a = 15 \text{ m s}^{-2}$$

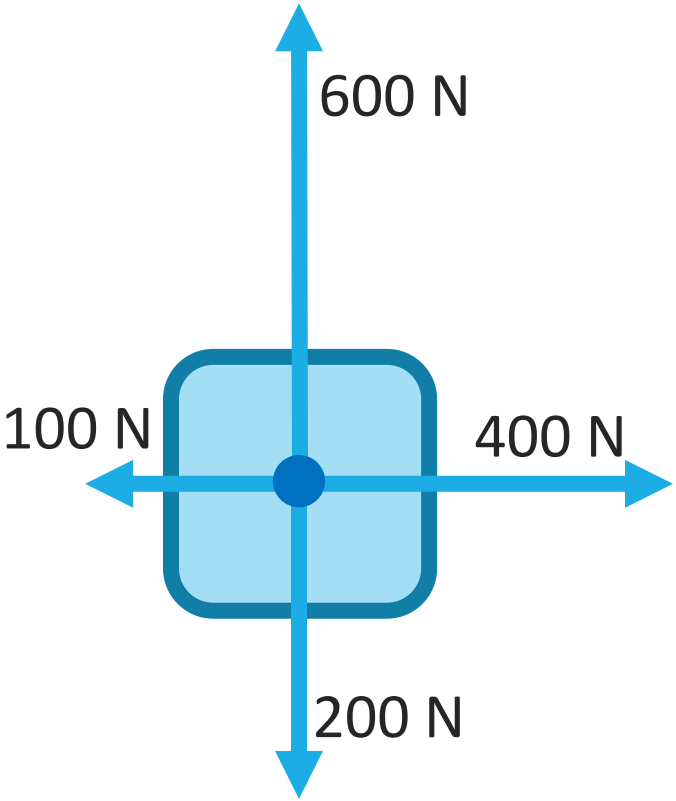
$$F = ma$$

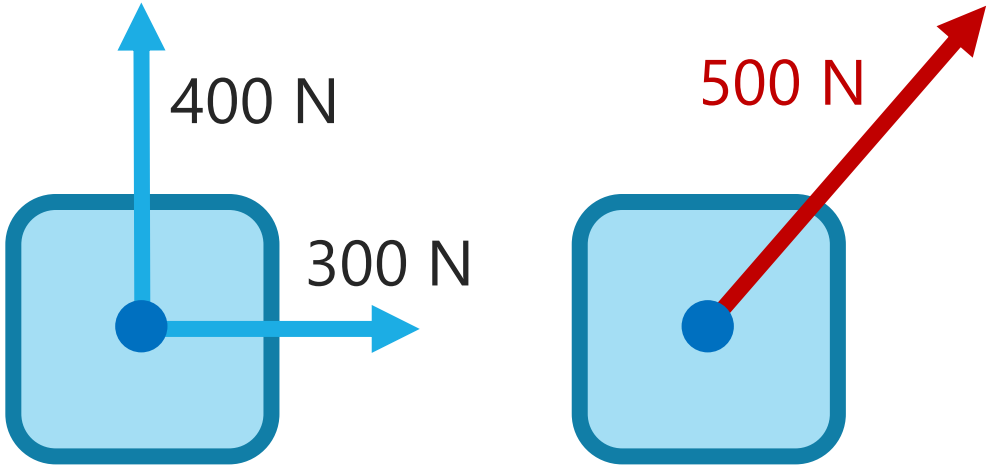
$$m = \frac{F}{a} = \frac{2450}{15}$$

$$m = 163 \text{ kg}$$

2nd Law | Try This… | #2

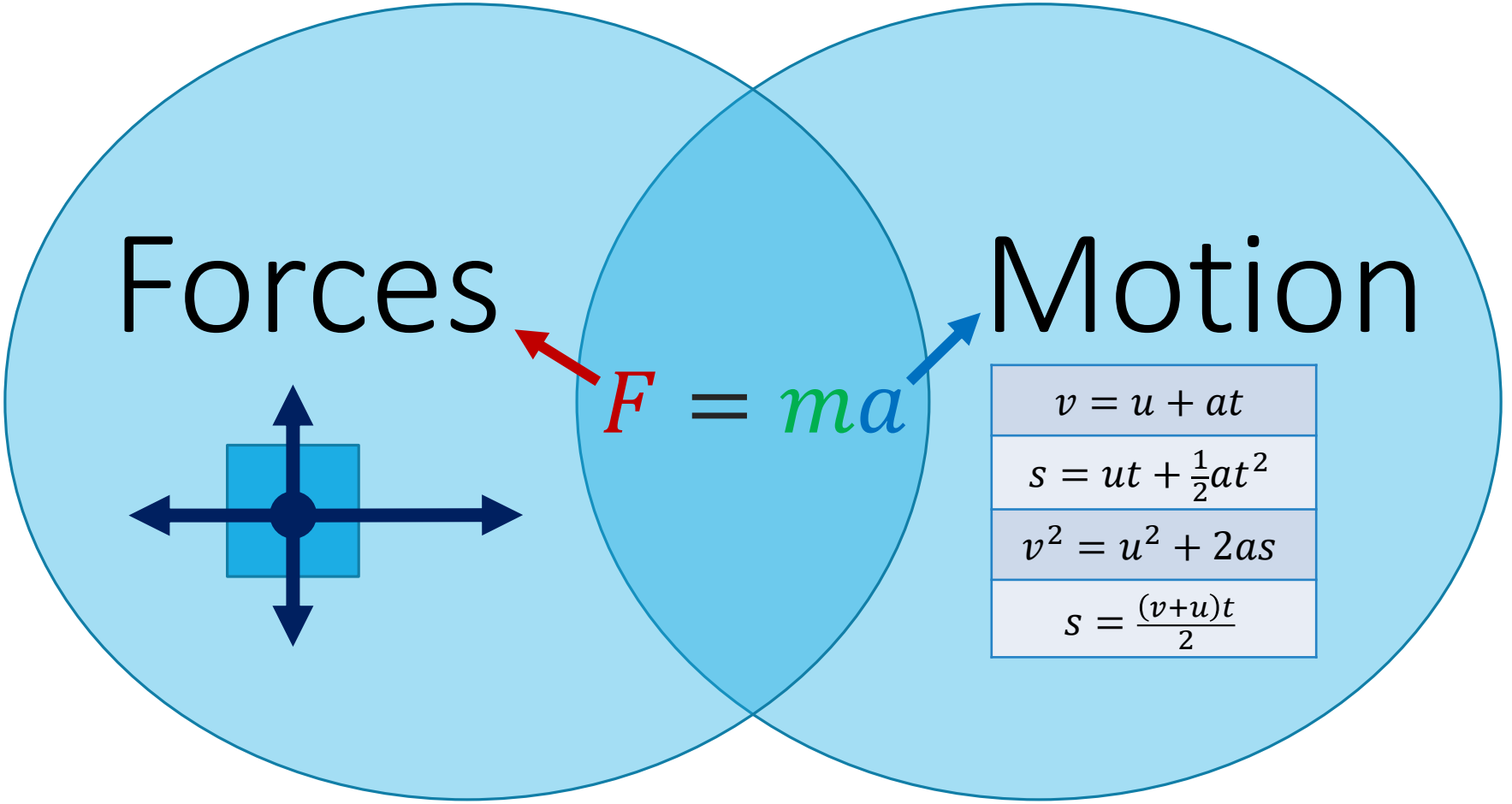
How fast is this 100 kg block accelerating?





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

2nd Law is the Bridge



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

2nd Law | Try This… | #3

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

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

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

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

$$F = ma$$

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

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

2nd Law | Try This… | #4

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 force of friction?

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

$$v = u + at$$

$$0 = 12 + a(3)$$

$$a = -4 \text{ m } s^{-2}$$

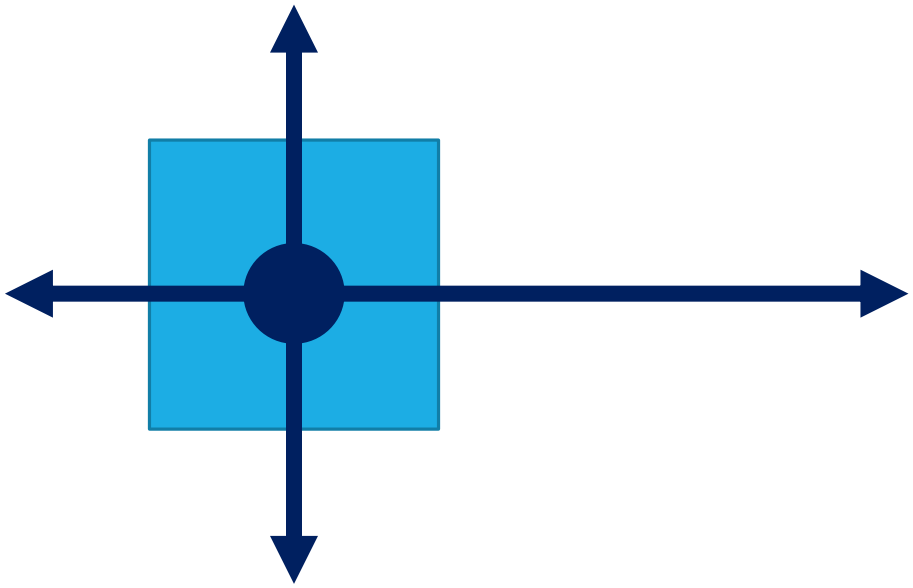
$$F = ma$$

$$F = (0.2)(-4)$$

$$F = -0.8 \text{ N}$$

Net Force → Acceleration

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



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

Equilibrium → Acceleration = 0

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

This can mean two different things:

- Not Moving
- Constant Velocity

Lesson Takeaways

- ❑ I can describe Newton's second law in terms of momentum
- ❑ I can calculate force given mass and acceleration and calculate acceleration given force and mass
- ❑ I can combine Newton's second law with the kinematic equations to solve force/motion problems
- ❑ I can explain the connection between constant velocity and balanced forces