Forces - B McMULLEN

- The force acting on an object can be a push, pull or twist.
- If a force acts on an object it can change its speed, shape and direction.
- A newton balance is the instrument used to measure force.

* Newton's First law (NI)

An object will remain at rest or move with a constant speed unless acted on by an unbalanced force.

* Newton's Second law (NII)

An object will accelerate or decelerate if an unbalanced force acts on it.

This is shown by the equation.

$$F = ma$$

- F → Unbalanced Force (Newtons) (N)
- m → mass (Kilograms) (kg)
- a → acceleration (metres per second squared) (ms^{-2})

* • Newton's Third Law (NIII)

When one object exerts a force on a secondary object, then the second object simultaneously exerts a force which is equal in magnitude and opposite in direction on the first object.

ie For every action force there is an equal and opposite reaction force.

From NII, an object will accelerate or decelerate if an unbalanced force acts on it.

* CASE 1 - (F kept Constant)

$$F = ma \Rightarrow a = \frac{F}{m} \Rightarrow a = \frac{k}{m}$$

As k is the constant of proportionality, then

$$a \propto \frac{1}{m}$$

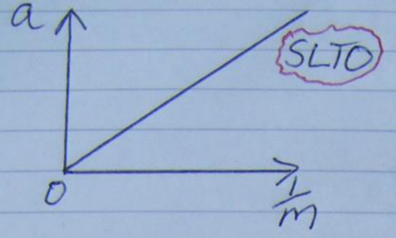
This means that either

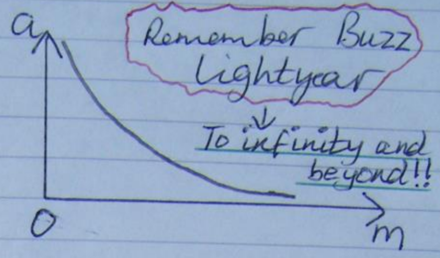
- a is inversely proportional to m

  OR

- a is directly proportional to $\frac{1}{m}$.

Graphically

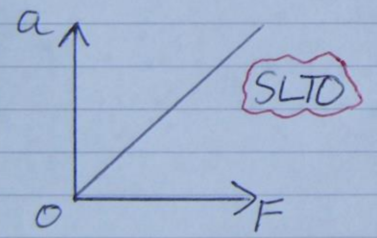




* CASE 2 – (m kept constant)

$F = ma \Rightarrow F = ka \Rightarrow F \propto a$

- Unbalanced force is directly proportional to the acceleration.

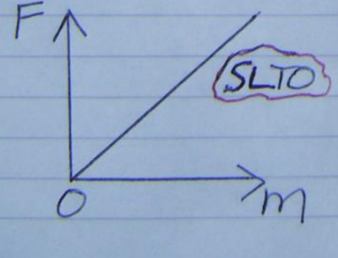


* CASE 3 – (a kept constant)

$F = ma \Rightarrow F = mk \Rightarrow F = km$

$\Rightarrow F \propto m.$

- Unbalanced force is directly proportional to the mass.



Balanced forces

This occurs when the unbalanced force acting on an object = 0.

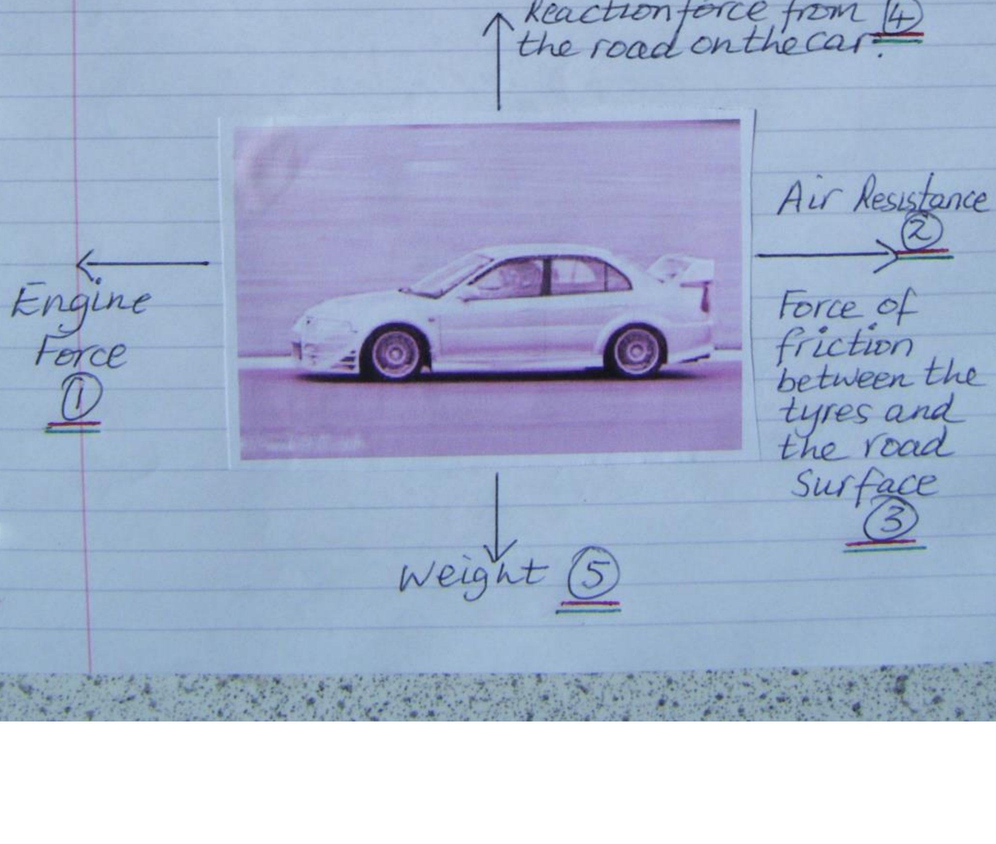
eg 18N → [6Kg] ← 18N $F = 18 - 18 = 0N.$

$\therefore a = 0.$

This means that the forces acting on an object are equal and opposite.

ie Equal in magnitude and opposite in direction.

(A) eg A car moving with a constant speed of 70mph ($112 Kmh^{-1}$).



Vertical forces

↑ Reaction force from the road on the car (4) = ↓ Weight (5)

Horizontal forces

← Engine Force (1) = → Air Resistance (2) + → Force of friction between the tyres and the road surface. (3).

(B) eg Aeroplane flying at a constant speed at a constant altitude.

↑ Lift force from the wings (1)

← Air Resistance Force (4)

→ Engine Force (3).

↓ Weight (2)

Vertical forces

↑ Lift force from the wings ① = ↓ Weight ②

Horizontal forces

Engine force ③ → = Air Resistance ④ ←

In each of these examples with the car and the aeroplane, both the horizontal and vertical forces are balanced. These two sets of forces are equal in magnitude and opposite in direction.

Ex 1

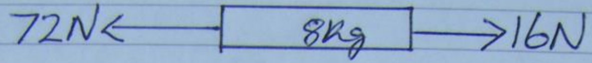
[4.5 Kg] ⟶ 18N

Q Calculate the acceleration of the block.

A $a = \frac{F}{m}$ from $F = ma$

$\Rightarrow a = \frac{18}{4.5} = 4\,ms^{-2}$ to the right

Ex2

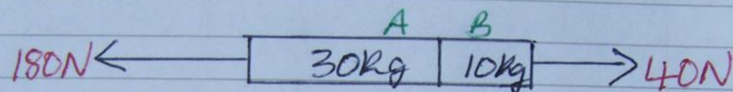


Q Calculate the acceleration of the 8kg block.

A From $F = ma \Rightarrow a = \frac{F}{m} = \frac{72-16}{8} = \frac{56}{8}$

$\Rightarrow a = 7ms^{-2}$ to the left

Ex3



Blocks **A** and **B** are joined together.

Q Calculate or find:

a) The acceleration of blocks A and B.

b) i) The unbalanced force on block A.

ii) The unbalanced force on block B.

A a) From $F = ma \Rightarrow a = \frac{F}{m} = \frac{180-40}{30+10} = \frac{140}{40}$

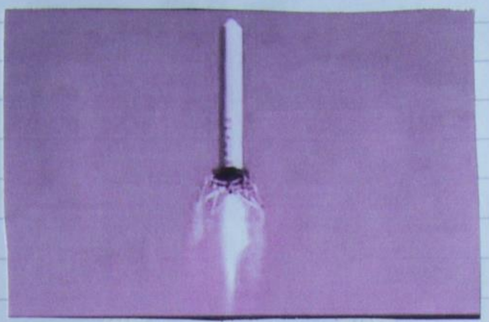
$\Rightarrow a = 3{\cdot}5ms^{-2}$ to the left.

b) i) $F_A = m_A a = 30 \times 3{\cdot}5 = 105N$ to the left

ii) $F_B = m_B a = 10 \times 3{\cdot}5 = 35N$ to the left

Ex4

↑ Upthrust force



mass of rocket = 25,000kg

Upthrust on the rocket = 300,000N

↓ Drag Force (Assume this is zero in this question)

↓ Weight

Q a) Label the forces acting on the rocket at take-off.

b) Calculate or find:

I) Unbalanced force acting on the rocket at take-off

II) Initial acceleration of the rocket at take-off.

c) How will the acceleration of the rocket vary during its flight within the Earth's atmosphere?

4. a) Forces labelled on the diagram.

b) i) F = Upthrust ↑ − Weight ↓
force

$W = mg = 25{,}000 \times 9.8 = \underline{245{,}000\,N}$ ↓

$F = 300{,}000 - 245{,}000\,N = \underline{55{,}000\,N}$

ii) $F = ma$

$\Rightarrow a = \frac{F}{m} = \frac{55{,}000}{25{,}000} = \underline{2.2\,ms^{-2}}$ ↑

c) The acceleration will increase during the flight.

- The mass will continually decrease due to the fuel being burned off.

  $a \propto \frac{1}{m}$, as the mass decreases the acceleration increases.

- The unbalanced force F will increase as the weight of the rocket decreases.

  F = Upthrust − Weight

  ↑ = ⟷ − ↓

Lifts

Lifts can either ascend ↑, descend ↓ or be stationary.

The two forces that will be examined at every stage are:

- Reaction force ↑ (OR Tension in the cable)
- Weight ↓

The combination of these two forces will determine the magnitude and direction of the unbalanced force, at each stage of the journey.

Ex5

A 55kg person visits a relative who lives on the 15^{th} floor of a block of flats.
They enter a lift on the ground floor and then accelerate upwards at $1{\cdot}2\,ms^{-2}$ until they reach a constant speed. The lift then decelerates at $0{\cdot}8\,ms^{-2}$ until it comes to rest on the 15^{th} floor.

Q/ Calculate the reaction force of the floor on the 55kg at each of the 5 stages of the journey as shown below:

a) Stationary at the ground floor

b) Accelerating upwards at $1.2ms^{-2}$.

c) Moving with a constant speed

d) Decelerating upwards at $0.8ms^{-2}$.

e) Stationary at the 15th floor.

A a) $\uparrow R$ and $\downarrow W$ } $F=0$

$W = mg = 55 \times 9.8 = 539N$

$\therefore \uparrow R = W\downarrow = 539N\uparrow$

b) $\uparrow R$ and $\downarrow W$ } $F\uparrow$

$R\uparrow > W\downarrow$

$F = ma$

$F = 55 \times 1.2 = 66N$

$\therefore \uparrow R = W + F = 539 + 66 = 605N\uparrow$

c) $\uparrow R$ and $\downarrow W$ } $F = 0$.

$\therefore \uparrow R = W\downarrow = 539N$

d) ↑R and ↓W

↑R < W↓

∴ ↑R = W − F = 539 − 44

⇒ ↑R = **495N**

{ F↓

F = ma

F = 55×0.8

F = 44N ↓

e) ↑R and ↓W

↑R = W↓ = **539N**

{ F = 0.

- Variation of the readings at the 5 stages for Reaction Force:

①	②	③	④	⑤
539N →	605N →	539N →	495N →	539N
⟷	↑	⟷	↓	⟷

- If a Lift is accelerating upwards, then the unbalanced force acts upwards.

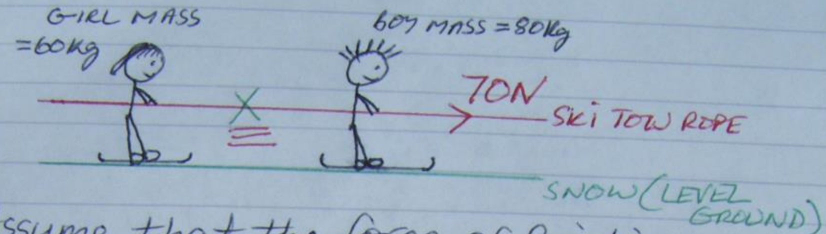
  ∴ Reaction Force > Weight

- If a Lift is decelerating upwards, then the unbalanced force acts downwards

  ∴ Reaction Force < Weight

Ex6

Tension in a ski tow rope.



* Assume that the force of friction between the skis and the snow is negligible *

Q Calculate or find:

a) Acceleration of the two skiers if the tow rope pulls them with a force of 70N.

b) How does the motion of the two skiers vary after the tow rope snaps at point X.

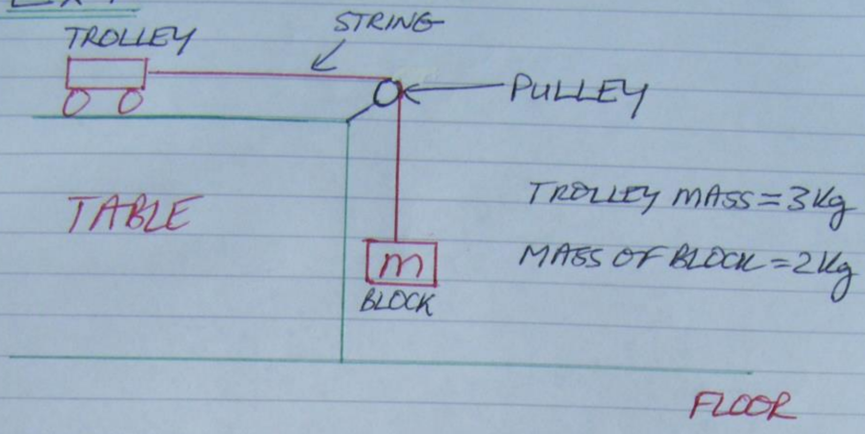
A a) $F = ma \Rightarrow a = \frac{F}{m} = \frac{70}{80+60} = \frac{70}{140}$

$\therefore a = 0{\cdot}5\,ms^{-2}$ to the right (M + D's)

b) • The boys acceleration will increase as he has the 70N pulling force from the tow rope to himself now.

• The girl will continue at the same speed at the point when the rope snapped.

Ex 7



Q When the block is released, calculate or find:

a) Acceleration of the trolley

b) The tension in the string.

A a) $W = mg = 2 \times 9.8 = \underline{19.6N}$

The unbalanced force on the trolley is the weight of the mass.

$$a = \frac{F}{m} = \frac{W}{m} = \frac{19.6}{3+2} = \frac{19.6}{5} = \underline{3.92ms^{-2}}$$

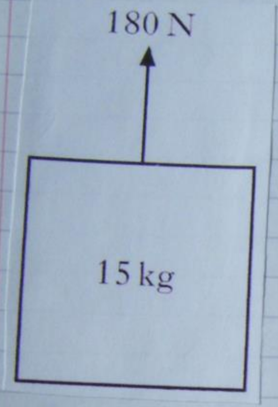
b) $T = ma$ (T is the tension in the string.)

$$T = ma = 3 \times 3.92 = \underline{11.8N}$$

The mass in this calculation is 3kg, which means that the tension is due to pulling the 3kg trolley.

Ex8

Q A force of 180N is applied vertically upwards to a box of mass 15Kg



Calculate the acceleration of the box

A $W = mg = 15 \times 9.8 = \underline{147N}$

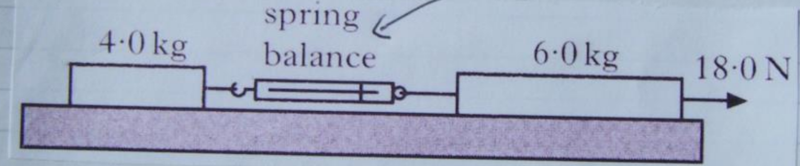
$$a = \frac{F}{m} = \frac{180 - 147}{15} = \frac{33}{15}$$

$$\Rightarrow \underline{a = 2.2\,ms^{-2}} \uparrow$$

Ex9

negligible mass

Q



Calculate the reading on the spring balance if the blocks are placed on a frictionless surface.

A
- mass of entire system $= 6 + 4 = 10Kg$
- acceleration of entire system

$$a = \frac{F}{m} = \frac{18.0}{10} = \underline{1.8\,ms^{-2}}$$

- Reading on spring balance, $F = ma = 4.0 \times 1.8 = \underline{7.2N}$

  ↑ mass being pulled!!