Distance, Displacement, Speed, Velocity

28th Oct

A scalar quantity has a magnitude (size) only.

e.g. mass, temperature, speed, distance, energy

A vector quantity has both a magnitude and a direction.

e.g. displacement, velocity, acceleration, momentum, force

Directions may given with arrows, descriptions, compass directions, bearings (an angle measured clockwise from North)

The DISTANCE an object travels is far it covers, regardless of direction.

The DISPLACEMENT of a travelling object tells us how far it travelled in a specific direction from its starting point.

The SPEED of an object tells us the distance travelled in a certain time.

$$\text{average speed} = \frac{\text{total distance travelled}}{\text{time taken}}$$

The VELOCITY of an object tells us the speed in a certain direction.

Velocity can change when an object speeds up, slows down or changes direction.

We can be asked to perform calculations with estimated values such as:

Walking ~ 1.5 m/s
Running ~ 3 m/s
Cycling ~ 6 m/s
Car ~ 20 m/s
Aeroplane ~ 150 m/s
Sound (in air) ~ 330 m/s
Light (in vacuum/air) ~ 300,000,000 m/s

Acceleration

27th Nov

Acceleration is the RATE of CHANGE OF VELOCITY.

$$\text{acceleration} = \frac{\text{change in velocity}}{\text{time}}$$

in m/s^2

in m/s

in s

$$a = \frac{\Delta v}{t}$$

$$\Delta v = v - u$$

change in velocity = final velocity - initial velocity

$$(\text{final velocity})^2 - (\text{initial velocity})^2 = 2 \times \text{acceleration} \times \text{displacement}$$

$$v^2 - u^2 = 2as$$

Note: 'at rest', 'stationary', 'comes to a stop' all imply that either v or u are 0 m/s.

Objects in free fall (falling with no air resistance/drag) accelerate at $9.8\ m/s^2$.

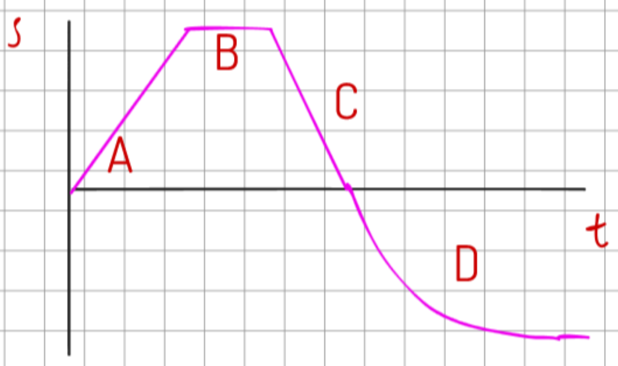
Graphs of motion

2nd Dec

These graphs always have time on the x-axis and then either distance/displacement or speed/velocity on the y-axis.

The GRADIENT of a displacement-time graph gives us the VELOCITY.

A positive gradient/displacement means motion in one direction, and negative indicates the reverse direction.



A: moving forward with constant velocity

B: stationary

C: moving backwards with a constant velocity, greater than that during A.

D: moving backwards, to behind the start point, with a decreasing velocity.

The GRADIENT of a velocity-time graph gives us the ACCELERATION.

Negative values for velocity show movement in the opposite direction than the positive values.

A positive acceleration means acceleration in the same direction as the positive velocity.

A negative acceleration means acceleration in the opposite direction to the one we have deemed to be positive i.e. if we defined forwards to be positive then a negative acceleration or velocity implies a backwards direction.

Newton's Laws of Motion

5th Dec

First Law: an object will remain in its current state of motion unless acted on by an external RESULTANT force

This means that if an object is speeding up, slowing down, or changing direction there MUST be a resultant force acting on it.

Second Law: the acceleration of an object is DIRECTLY PROPORTIONAL to the RESULTANT FORCE, in the same direction as the resultant force, and it is INVERSELY PROPORTIONAL to the MASS of the object.

$$\underbrace{a \propto F \qquad a \propto \frac{1}{m}}$$

$$a \propto \frac{F}{m} \quad \text{so} \quad a = \frac{kF}{m}$$

Resultant force = mass x acceleration

$$F = ma$$

in newtons, N

in kilograms, kg

in metres per square second, m/s^2

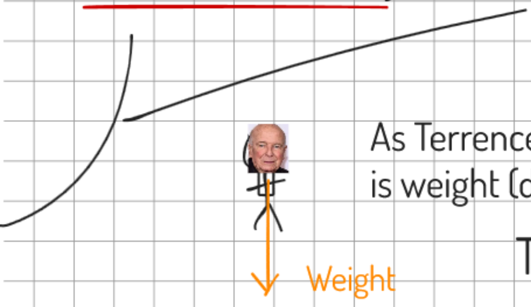
The INERTIA of an object describes a resistance to a change in its motion. Moving objects have inertia, so require a resultant force to change their motion.

The inertial mass of an object is the mass found when relating a resultant force to the acceleration produced:

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

Terminal Velocity

9th Dec



As Terrence steps out of the plane (willingly), the only force acting on him vertically is weight (due to gravity)

This means that: Resultant force = weight

A large resultant force downwards means a large acceleration downwards.

A few seconds later...

Terrence has some velocity downwards. Drag increases with velocity.

Resultant force = Weight - drag

According to N2L as his resultant force decreases, so does his acceleration.

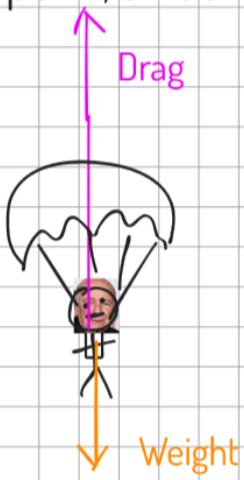
Eventually...

Eventually the drag force reaches the same magnitude as the weight.

Resultant force = 0

Hence Terrence stops accelerating, and drag stops increasing. Terrence has reached TERMINAL VELOCITY.

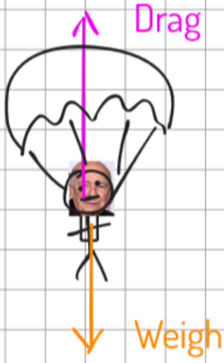
Past this point, all being well, the parachute is opened.



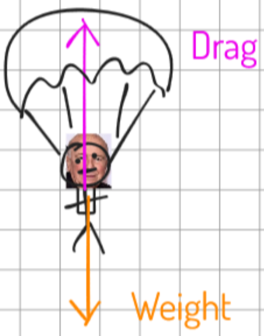
Increased surface area due to parachute increases drag.

Resultant force upwards.

Terrence slows down.



As velocity decreases so does drag.

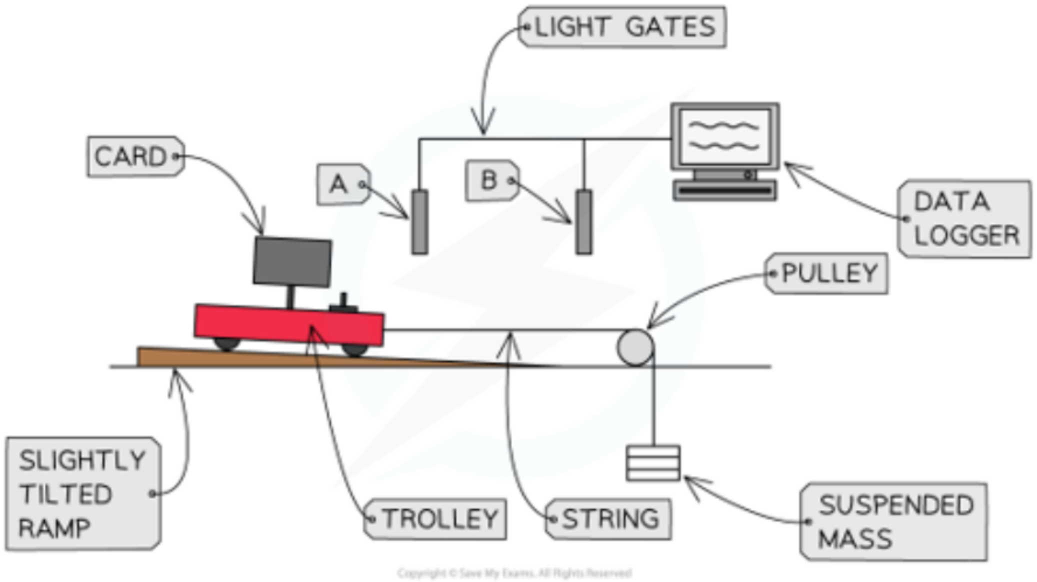


Eventually drag = weight, so Terrence reaches a new, lower, terminal velocity.

Investigating Newton's Second Law (GCSE Required Practical 7)

9th Dec

Labelled Diagram



How to change and measure variables

- We exert a force on the trolley using masses on a hanger. We measure this force with a NEWTONMETER. We change the force by changing the mass on the hanger.
- We tilt the ramp to compensate for FRICTION. If the ramp is tilted so that the trolley just rolls on its own at a constant velocity we can then assume that the weight of the suspended masses is equal to the RESULTANT FORCE on the trolley.
- We use an ELECTRONIC BALANCE to measure the MASS (of trolley and suspended masses).
- We tell the datalogger the length of the card. It measures how long the card takes to pass through the light gate. It uses these two measurements to calculate velocity.
- We can do this twice, and measure the time between the two speeds. Using $a = \frac{v-u}{t}$ the datalogger calculates acceleration.

Method 1: How does changing the resultant force affect acceleration?

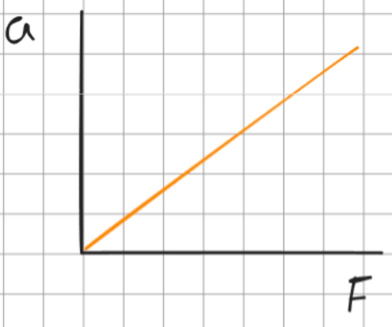
Independent variable: Resultant force

Dependent variable: Acceleration

Control variable: Mass

Notes To keep the total mass constant we must transfer masses from the hanger to the trolley. This means we are changing the resultant force that accelerates the system, whilst also not changing the total mass.

Force [N]	initial velocity [m/s]	final velocity [m/s]	time [s]	acceleration [m/s^2]
0.75	0.75	1.24	0.589	0.832
0.60	0.66	1.07	0.451	0.909
0.50	0.61	0.94	0.744	0.444
0.40	0.47	0.89	0.857	0.490
0.30	0.34	0.75	0.903	0.454
0.20	0.23	0.39	1.443	0.111



The ACCELERATION is DIRECTLY PROPORTIONAL to the RESULTANT FORCE.

So halving the resultant force halves the acceleration (when mass is constant).

Method 2: How does changing the mass affect acceleration?

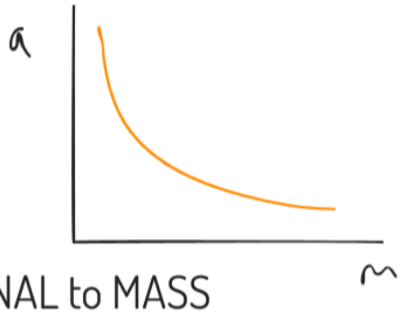
Independent variable: Mass

added masses to trolley

Dependent variable: Acceleration

Control variable: Resultant Force

same mass on hanger



Notes Acceleration is INVERSELY PROPORTIONAL to MASS (for the same resultant force).

Mass [kg]	initial velocity [m/s]	final velocity [m/s]	time [s]	acceleration [m/s^2]
1.06	0.70	1.12	0.429	0.979
1.16	0.54	0.96	0.523	0.803
1.26	0.65	0.99	0.472	0.699
1.36	0.55	0.89	0.541	0.628
1.46	0.51	0.84	0.578	0.571

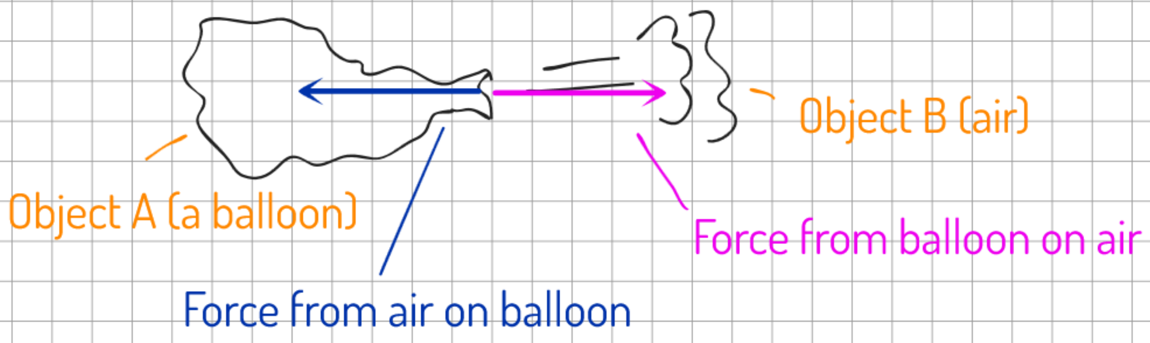
Newton's 3rd Law

16th Dec

Consider two objects interacting and call them Object A and Object B.

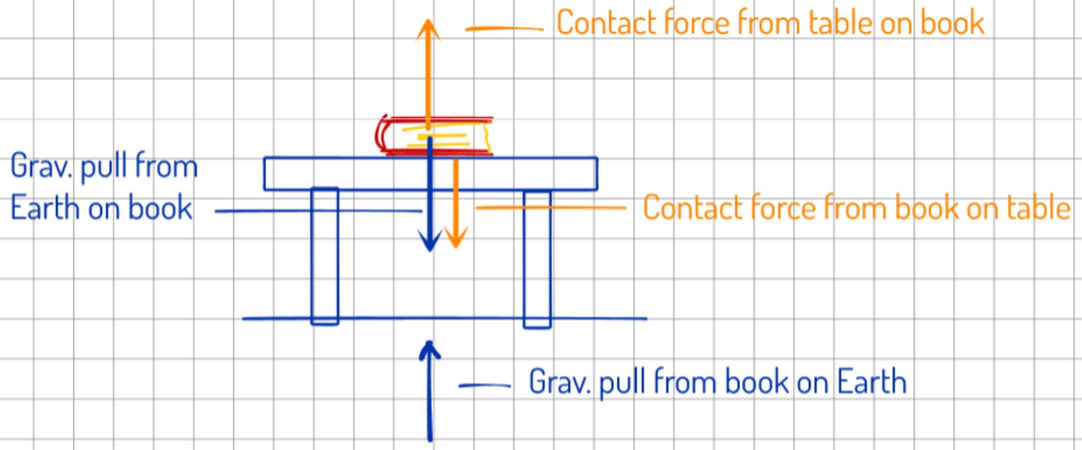
N3L tells us that;

If Object A exerts a force on Object B, then Object B will exert a force of equal magnitude (but in the opposite direction) on Object A.

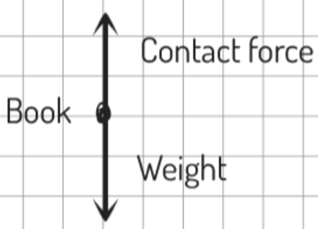


Note: This pair of forces are often called an 'action-reaction pair'. The forces in such a pair must always be the SAME TYPE i.e. both contact forces, both friction forces or gravitational forces.

Example: Book on table



To see the effect of these forces we must look at one object at a time.



We can then use N1L and N2L to describe any effect.

Here, there is no resultant force so no acceleration.

Stopping Distances

13th Jan

The STOPPING DISTANCE of a vehicle is the distance travelled in the time between seeing a hazard, pressing the brakes and coming to a stop.

Stopping Distance = Thinking Distance + Braking Distance

Thinking distance: the distance travelled during reaction time

$$s = vt$$

thinking distance

reaction time

Braking distance: the distance travelled in the time between pressing the brakes and stopping

Work done (by the brakes) = Kinetic energy (of vehicle)

$$Fs = \frac{1}{2}mv^2$$

braking force

braking distance

mass of vehicle

speed before braking

Braking distance = $\frac{mv^2}{2F}$

Anything which impacts a driver's reaction time will directly impact their thinking distance. Anything that impacts friction will directly affect braking distance.

The speed of travel affects both thinking and braking distance. A greater mass would mean more kinetic energy at the same speed so the brakes must do more work to stop the vehicle.

		Thinking	Braking
1	tiredness	✓	
2	use of drugs or medicine	✓	
3	alcohol	✓	
4	mass of car		✓
5	speed of car	✓	✓
6	faulty brakes		✓
7	use of mobile phone	✓	
8	weather		✓
9	tyre wear		✓
10	colour of car		

We can measure the reaction time of a person using computer software, or experimentally with the 'ruler drop' test.

This involves a metre ruler being held level with the top of a persons open hand. The ruler is then dropped and caught. The distance the ruler fell is noted.

The drop should be repeated and a mean taken, once anomalous values have been removed.

Example mean drop distance = 0.208 m

Use: $v^2 - u^2 = 2as$ to find how fast the ruler was travelling when caught.

Where u = 0 m/s, a = 9.8 m/s^2 and s = 0.208 m.

$$v = \sqrt{2as}$$
$$= \sqrt{2 \times 9.8 \times 0.208}$$
$$= 2.02 \text{ m/s}$$

We can then use $a = \frac{v-u}{t}$ to find t, the reaction time.

$$t = \frac{2.02 - 0}{9.8}$$
$$= 0.206 \text{ s}.$$

Stopping Distance and Speed

16th Jan

When speed increases so does thinking distance and braking distance.

If your speed were to double:

Thinking distance DOUBLES, as s = vt and reaction time is constant.

Braking distance increases by a FACTOR OF 4. This is because the KINETIC ENERGY increases by a factor of 4 (as speed is squared in its equation). Therefore the WORK DONE by the brakes increases by a factor of 4. We know that W = Fs. We assume F is constant.

Momentum

20th Jan

The momentum of an object is a measure of how difficult it would be to stop an object and is defined as:

momentum = mass x velocity

$$p = mv$$

in metres per second m/s

in kilogram, kg

in kilogram metres per second, kg m/s

In any event (such as a collision, or explosion) the TOTAL MOMENTUM is always CONSERVED. This means the total momentum of all objects in the system is the same before and after the event (in an isolated system).

Note: an isolated system is one with no external forces acting

Consider the following:

In this scenario the person on the left is running, and the tiny child on the right is standing still (and terrified).

The total momentum in this system is all in the person running. This momentum acts to the right.

Momentum in any collision is CONSERVED. The (incredibly tiny and slightly frail) child has GAINED momentum. This means that the running person must LOSE momentum.

As we know, p = mv, so the running persons velocity must decrease after the collision.

Momentum is a VECTOR quantity. This means it has MAGNITUDE as well as direction.

One way to deal with this in momentum calculations is to define one direct as POSITIVE (usually to the right) and other as NEGATIVE (usually to left).

Changes in Momentum

22nd Jan

When a person is a car accident where the car comes to a sudden stop, both the person and the car experience a resultant force.
The magnitude of this resultant force is determined by the mass of the object and their acceleration.

A large acceleration means a large resultant force and more risk to the occupants of a vehicle.

Safety features such as: airbags, seatbelts, crash mats, cycle helmets all INCREASE THE TIME over which an objects momentum changes during a collision.

This REDUCES the ACCELERATION, and REDUCES the RESULTANT FORCE experience. This reduces the risk of harm.

From N2L: $F = ma$ $a = \frac{\Delta v}{t}$

$$F = \frac{m\Delta v}{t}$$

Resultant force = $\frac{\text{change in momentum}}{\text{time}}$

Note that $\Delta v = v - u$ as in the equation for acceleration above