SCIENCE DEPARTMENT

Year 8

Physics Friend

Further Forces

This booklet contains information to support your work in science lessons. You **must** bring it with you to all science lessons on the Further Forces topic. Replacement booklets must be paid for at a cost of £1.

Teacher : Tell me what force, velocity and acceleration are examples of

Me:

Name:

Form:

Science Teacher:

CONTENT

Key Words

speed, velocity, acceleration, constant, thrust, friction, streamlining, air resistance, drag, terminal velocity, distance-time graph, stopping distance, pressure, fluid, centre of mass

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Speed, Velocity and Acceleration

How fast something is moving is called its speed. It measures how far it travels in a certain period of time. There are three commonly used units for speed.

Often, when we are travelling by car, the most convenient unit is miles per hour (mph). The national speed limit on A roads in the UK is 60mph. This means that you could travel 60 miles in one hour. In towns the speed limit is 30mph. This is clearly half as fast and so you could only travel 30 miles in an hour.

The second unit is the commonly used unit in Europe and is called kilometres per hour (kph). 100kph is the same speed as 60mph.

The standard unit of speed used in physics is metres per second (m/s). Notice in the symbol for the unit the '*per*' part is represented by a back slash (/).

Calculating Speed

To calculate the speed of an object we use the formula,

$$speed = \frac{dist}{time}$$

In fact, in most cases we are calculating the **average** speed of an object over its journey, as the object may not travel at the same speed all the time. In the case of a car, it may stop at traffic lights and junctions. For a runner they take time at the start of the race to speed up.

Example 1

A cyclist travels 957m in 87 seconds. How fast were they travelling?

Firstly write down what you know:

Distance = 957m
Time = 87 s

Speed = distance/time

Speed = 957/87

Speed = 11 m/s

Example 2

A car travels 30 000m in $\frac{3}{4}$ of an hour. What is the speed?

Firstly, we need to decide what unit we are going to use. We could use m/s or kph.

In m/s	**In kph**
Distance = 30 000m	Distance = 30 Km
Time = 45*60 = 2700s	Time = 0.75 hours
Speed = distance/time	Speed = distance/time
Speed = 30 000/2700	Speed = 30/0.75
Speed = 11m/s	Speed = 40kph

These are both the same speed, just in different units

Using the Equation

Sometimes we may need to use the equation to work out the distance travelled, or the time taken, rather than speed. In this case, we need to rearrange the equation for either distance or time.

Distance = speed x time

Time = distance/speed

Velocity

Speed is an example of what is known as a <u>scalar</u> quantity. It has only a size (or magnitude). When we express speed, we need to use only a number and an appropriate unit (e.g. m/s). Other examples of scalars include mass, temperature and energy.

Some quantities have a <u>direction</u> as well as a magnitude. These are known as <u>vector</u> quantities.

An example of a vector quantity that we met in year 7 is force. Another example is <u>velocity</u>, which is defined as <u>speed in a given direction</u>.

When we specify the velocity of an object we need to give three things: a number, a unit and a direction.

The direction might, for example, be upwards, north, or left to right. Sometimes in physics we use positive numbers to represent velocity in one direction and negative numbers to represent velocity in the other direction.

Acceleration

An object is accelerating whenever its velocity is changing. This means it can be speeding up, slowing down or changing direction.

We define the acceleration of an object as the change in its velocity per unit time.

This can be calculated using the equation:

acceleration = (change in velocity) / time

or

$a = \Delta v / t$ (where Δv or delta v means *change in velocity*)

or

$a = (v - u) / t$

(Here, v means the 'final' velocity, i.e. the velocity that the object finished up with; u means 'initial' velocity, i.e. the velocity that it started with)

The unit of acceleration is metres per second squared (m/s^2).

How to set out a calculation in physics.

1. Write down the information that you know.
2. Convert quantities into standard units.
3. Write down the equation that you are going to use
4. Substitute numbers into the equation (ensuring they are in the correct units)
5. Rearrange the equation if necessary
6. Work out the answer using your calculator
7. Round the answer to a suitable number of significant figures
8. Make sure you include an appropriate unit in your answer

Questions:

1. What is the standard unit of speed in physics?

2. What is the equation used to calculate speed?

3. What is the difference between speed and velocity?

4. Is velocity a scalar or a vector quantity?

5. What happens to an object's velocity if it changes direction but keeps moving at the same speed?

6. What is meant by acceleration?

7. In what three ways can an object accelerate?

8. What is the equation for calculating acceleration?

9. What is the unit of acceleration?

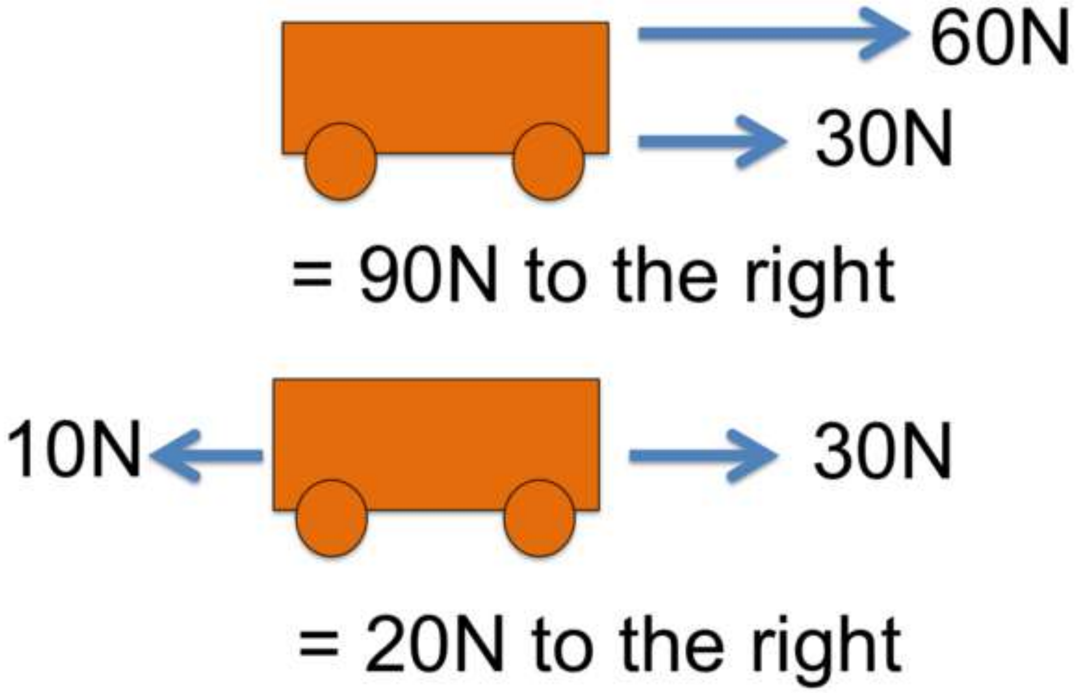
10. A runner completes a 200 metre race in 25 seconds. What is their average speed?

11. A cyclist is travelling at 6 m/s. How far will they travel in 15 seconds?

12. A car travels 100 km in 2 hours. What is its speed in m/s? (Hint: 1 km = 1000 m, 1 hour = 3600 s)

Newton's 1st Law of Motion

The resultant force on an object is a single force which could be used to replace all of the forces acting on the object and which would have the same effect. In other words, it is the overall force acting on the object. To work it out, we need to take into account all of the forces acting and their directions.



In order for an object to change its velocity it must have a resultant force acting upon it. So whenever you see an object changing velocity, either slowing down, speeding up or changing direction, there must be a resultant force on the object.

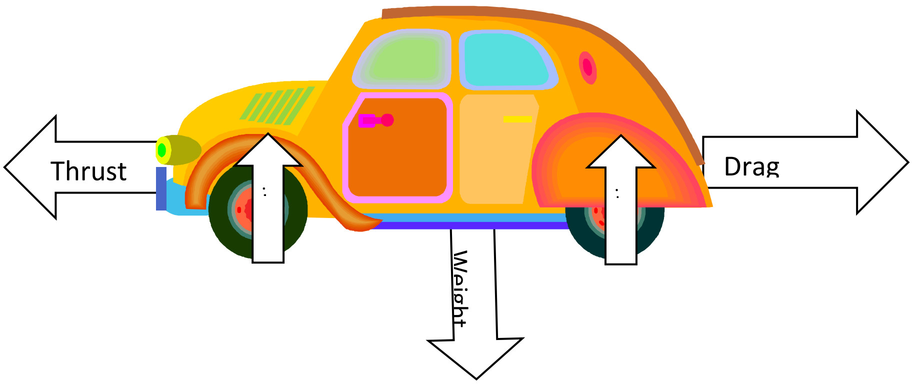
Newton's 1st Law is written as:

An object will remain stationary or travelling at constant velocity unless acting on by a resultant force.

In other words, if the forces on an object are balanced (no resultant force), it keeps doing whatever it is already doing – its velocity remains constant. If the forces are unbalanced (so there is a resultant force), the object's velocity changes – it accelerates I the direction of the resultant force.

If you set an object going off in space, even if there is no thrust on it, because there is no drag either, there is no resultant force and so the object will continue at a constant speed. We see something like this on an ice rink where the drag is very low. If you push off from the side, you keep going. Sports such as curling use this effect.

So let's draw the forces on a car which is travelling at **constant velocity**.



The car is moving at constant velocity. This means that it is not accelerating and so the thrust force must be equal to the drag so that the resultant force on the car is zero.

However, if the thrust became bigger, then there would be a resultant force forward and so the car would get faster. If the drag force becomes greater because the driver puts the brakes on, then the car would slow down.

Questions:

1. What is the resultant force acting on an object?

2. What do we call the forces on an object when the resultant force is zero?

3. What do we call the forces on an object when the resultant force is not zero?

4. What happens to an object if the forces on it are balanced?

5. State Newton's 1st Law of Motion.

6. What happens to an object when there is a non-zero resultant force acting on it?

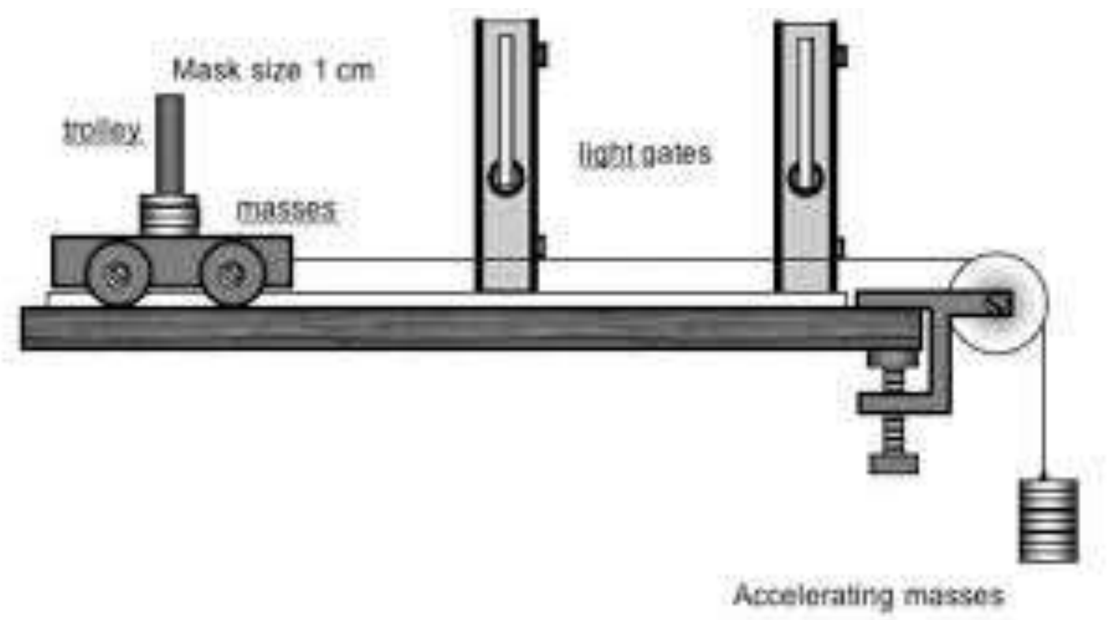
7. Why does a sliding book on a table eventually slow down and stop?

8. What would happen to a moving object in space if no forces were acting on it?

Force and Acceleration

As well as the **size of the resultant force** acting on an object, the other factor that affects how quickly it will accelerate is its **mass**.

We can do an experiment to see the effect of resultant force and mass on the acceleration of an object using the equipment below.



The masses on the end of the string apply a force to the trolley, causing it to accelerate. The light gates measure the velocity of the trolley as it passes through them. If we also record the time taken for the trolley to pass between the light gates, then we have measurements of initial velocity (u), final velocity (v) and time (t). We can therefore find acceleration using the equation:

$$a = (v - u) / t$$

In the first part of the experiment, we change the resultant force by changing the amount of masses hanging on the end of the string. To keep the total mass of the system constant, every time we remove a mass from the end of the string we must place it on top of the trolley.

In the second part of the experiment, we keep the resultant force constant and we change the mass of the trolley by adding masses to it.

We can then plot two graphs, one of acceleration (on the y-axis) against resultant force (on the x-axis) and the other of acceleration (on the y-axis) against mass (on the x-axis). This allows us to see clearly the relationships between the different variables.

Questions:

1. What are the two factors that affect how quickly an object accelerates?

2. What piece of equipment can be used to measure the initial and final velocities of a moving trolley in an experiment?

3. In an experiment investigating the effect of force on acceleration, why do we transfer masses from the hanger to the trolley after each run?

4. What would you expect the graph of acceleration against resultant force look like if mass is kept constant?

5. When plotting a graph of acceleration against mass, what would you expect to happen to the acceleration as the mass increases (if resultant force is constant)?

6. Write the equation that links force, mass and acceleration.

Newton’s 2nd Law of Motion

The acceleration of an object is directly proportional to the resultant force exerted on it, but is inversely proportional to its mass.

What this means is that if you double the force then you double the acceleration, if the mass is the same. However, if you double the mass then you halve the acceleration for the same force.

1. What happens to the acceleration of an object if the resultant force on it is increased while its mass stays the same?

2. What happens to the acceleration of an object if its mass is increased while the resultant force stays the same?

3. State Newton’s 2nd Law of Motion.

4. If the resultant force on an object doubles, what happens to its acceleration (if mass stays the same)?

5. If the mass of an object doubles, what happens to its acceleration (if the resultant force stays the same)?

6. What is the equation that links resultant force, mass and acceleration?

7. What are the units used in this equation for force, mass and acceleration?

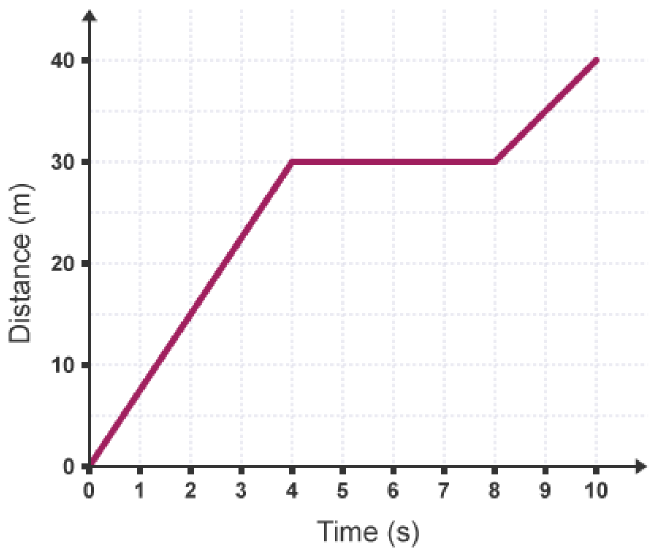
Distance-Time Graphs and Stopping Distances

One way of illustrating a journey is to plot a **distance–time graph**. This shows how far from the starting place the object was at various times.

The **gradient** of a distance-time graph gives us the **speed** that the object is travelling at.

If the gradient is zero, i.e. the graph is a **horizontal line**, it means that the object's speed is zero, i.e. it is **not moving**.

An example of a distance-time graph is shown below:



In the first 4s of the journey, the object travelled a distance of 30m. Its speed was therefore:

speed = distance / time

= 30m / 4s

= 7.5 m/s

The object then stayed stationary for the next 4s, so the graph is a horizontal line.

In the final part of the journey, the object travelled 10m in 2s, so its speed was:

Speed = 10m / 2s

= 5 m/s

Stopping Distances

Now let us think about vehicles slowing down and stopping in an emergency. If a driver sees an obstruction or hazard in the road ahead, he cannot stop his vehicle at once; it takes time, and during that time the vehicle is still travelling.

The distance that the vehicle travels between the driver deciding to stop and the vehicle actually stopping is called the **stopping distance**.

There are two parts to stopping distance:

1. The driver realises he must stop, but it takes time, his **reaction time**, before he can put the brakes on. During his reaction time the car travels a distance that we call the **thinking distance**.

2. Once he hits the brakes, the brakes exert a frictional force on the wheels, but do not stop the wheels turning immediately. The vehicle slows down, but travels a distance that we call the **braking distance** before it stops.

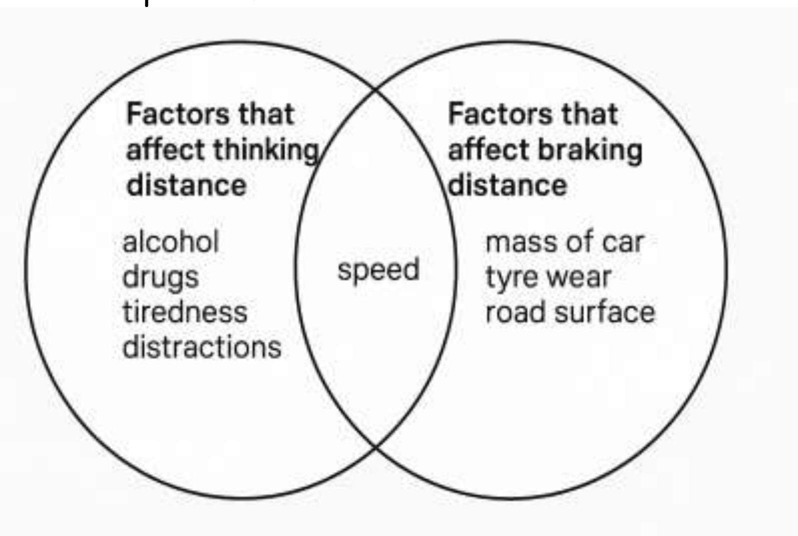
The total stopping distance is therefore given by:

Stopping distance = Thinking Distance + Braking Distance.

Reaction time, and, therefore, **thinking distance** will be longer if the driver is tired or under the influence of alcohol or drugs. The thinking distance will also be longer if he is *travelling faster*. (Higher speed means that he will cover a greater distance during reaction time.)

The **braking distance** will be longer if the brakes or the tyres are worn, the road surface is wet or icy, the car is heavier and if the car's *speed is higher*.

Can you see why we have speed limits on our roads?



Questions:

1. What does the gradient (steepness) of a distance-time graph show?

2. What does a horizontal line on a distance-time graph represent?

3. How can you find the speed of an object during part of a journey from a distance-time graph?

4. What is the thinking distance?

5. What is the braking distance?

6. What is the total stopping distance?

7. Give two factors that affect thinking distance.

8. Give two factors that affect braking distance.

9. Which factor affects both thinking distance and braking distance?

Air Resistance and Streamlining.

When an object moves through the air, it experiences a force in the opposite direction to its motion. This is called **air resistance** or drag.

This forces is caused by the object colliding with of air molecules, which are too small to see. Each one of these tiny molecules that the object hits exerts a tiny force on it. When all of these are added up it becomes a big force.

Air resistance will **always try to oppose the motion** of the object. This means that it will tend to slow the object down.

The faster an object moves through the air, the more air molecules it collides with and the harder it hits them. Therefore, the **faster an object moves, the greater the air resistance**.

So let's go back to the example of the car when we were looking at resultant force.

If you increase the thrust so it is greater than the air resistance, then the car will speed up. But this will increase the drag until it is the same as the thrust again at which point the car will continue to go at its new speed without accelerating.

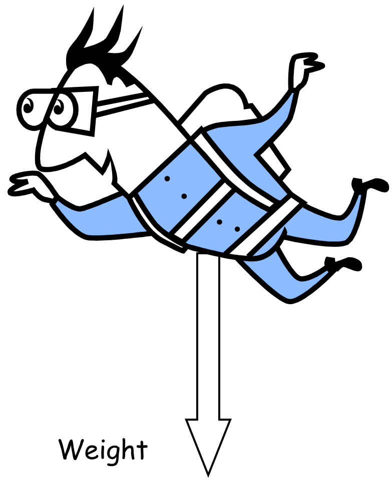
This will put a limit on the top speed of the car. It will only be able to go at top speed when the thrust is maximum against the drag. To go faster the car would have to have a more powerful engine or reduce the drag.

Modern cars are designed to have a shape which reduces air resistance or drag. This is called **streamlining**. You see it all over the place, not just on cars, but also high speed trains, racing cars, cycle helmets and planes.

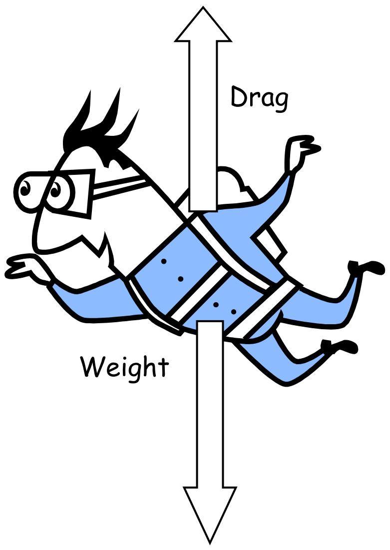
Of course, the same effect is felt in water. Here again, streamlining is used. Think about the shape of fish and sharks etc. Also boats are designed to be streamlined in the water.

Falling and Terminal Velocity

An object falling through a fluid (a liquid or gas, such as air) is subject to forces. Imagine a parachutist jumping out of a plane.



When the parachutist has just jumped from the plane, he is not yet moving there is no drag, but only his weight. Hence he has a resultant force (*downwards!!*) and so he starts to accelerate downwards.



As he gets faster the drag force starts to increase. This then reduces the resultant force and his rate of acceleration gets less.

Eventually, the drag increases so much that it becomes equal to his weight. At this point, the resultant force on the parachutist is zero, so he falls at a **constant velocity**.

This constant velocity is called **terminal velocity**.

Questions:

1. What causes resistive forces such as air resistance and water resistance?

2. In which direction do resistive forces act?

3. What happens to the size of resistive forces as the speed of an object increases?

4. What is streamlining and why is it useful?

5. What is terminal velocity?

6. When a parachutist first jumps out of a plane, what is the only force acting on them?

7. Why does the parachutist stop accelerating and reach terminal velocity?

8. What happens when a parachutist opens their parachute?

Pressure

When we exert a force on an object, the effect that the force has depends on how concentrated or spread out the force is. If it is concentrated on a small area, it is likely to have a bigger effect than if it is spread out over a larger area. We can represent this by calculating the pressure exerted by the force.

$$\text{pressure} = \text{force} \div \text{area}$$

The units of pressure depend on which units we have used to measure force and area. The standard unit of pressure in physics is newtons per square metre (N/m^2), which is also known as pascals (Pa).

You will also see pressure measured sometimes in newtons per square centimetre (N/cm^2).

Questions:

1. What is the equation used to calculate pressure?

2. What are the standard units for pressure in physics?

3. Why does standing on a sharp object like a drawing pin produce a high pressure?

4. Why do snowshoes reduce the pressure you exert on snow?

5. In a practical measuring pressure on sand, what variables must be kept the same each time to keep the test fair?

6. A force of 20 N is applied to an area of 4 m^2. What is the pressure?

7. A pressure of 200 Pa is exerted on an area of 0.5 m^2. What is the force?

8. A force of 50 N produces a pressure of 10 Pa. What is the area over which the force is applied?

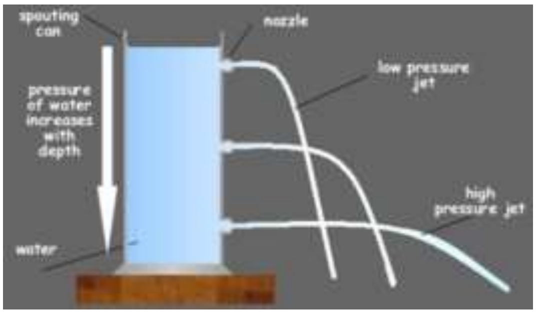
Pressure in Fluids

Fluids (that means liquids and gases) exert a pressure on objects which are immersed in them and also on the walls of their container. This is because the particles inside the fluid move around colliding with the object or the walls and applying a force.

The air exerts a pressure (at sea level) of around 100,000 Pa. That's equivalent to the weight of a 10 tonne truck pressing onto an area of 1 m^2. You can see just how big a pressure this is by removing the air from the inside of a can or bottle using a vacuum pump. The can/bottle will implode as the outside air pressure pushes it inwards, with nothing to balance it.

In a fluid, the pressure gets greater the deeper you go. This explains why deep sea divers need to wear rigid suits to protect them from the water pressure. It also explains why the pressure is low outside an aeroplane flying through the sky, as the pressure in the atmosphere gets lower the higher up you are.

The way that pressure increases with depth in a fluid can be seen in the experiment shown in the diagram below. The water is pushed out of the lower holes with more force due to the higher pressure deeper in the can.



Hydraulics.

A hydraulic system can be used to transmit a force from one place to another, and also to multiply the size of the force. An input force is applied to a piston at one end of the system. This exerts a pressure on the liquid in the system, which is transmitted through the liquid and produces an output force on the piston at the other end. A liquid is used because liquids, unlike gases, cannot be compressed.

1. Why does a fluid exert a pressure on objects inside it?

2. What happens to the pressure in a fluid as you go deeper?

3. Why don't we notice the very large air pressure around us at sea level?

4. What happens to air pressure as you go higher up a mountain?

5. What happens to pressure as you dive deeper underwater?

6. Why can gases be compressed but liquids and solids cannot?

7. In a hydraulic system, why does a smaller input piston make it easier to push?

8. What is the trade-off when using a hydraulic system to multiply force?

Moments

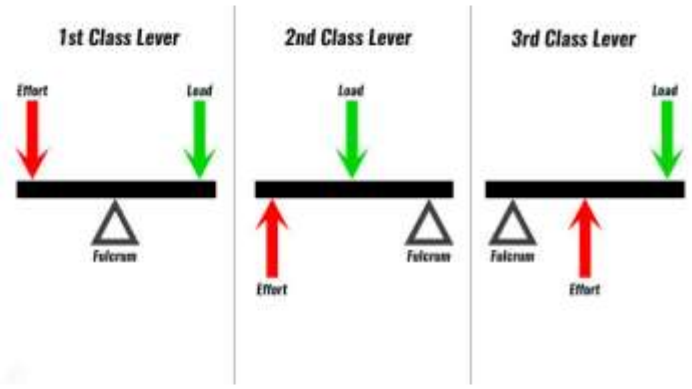
The moment of a force is the turning effect that it exerts about a particular point. It can be calculated using the equation:

Moment = Force x Perpendicular distance from the force to the point

The unit of moment is newton metres (N m) or newton centimetres (N cm) depending on the unit used to measure the distance.

Levers are simple machines which use the idea of moments. All levers consist of three things: the effort (input force), a pivot/fulcrum (turning point) and the load (output force). There are three classes of lever, which is defined by which of the three things is in the middle.

The skeletons of humans (and other animals) contain levers, where the joint acts as the pivot and muscles provide the effort force.



The **Principle of Moments** states that:

For an object to be in rotational equilibrium (i.e. balanced), the sum of the clockwise moments about any point must be equal to the sum of the anticlockwise moments about the same point.

In other words, it is possible to balance a see-saw with a heavy object on one side and a lighter object on the other provided the lighter object is placed further from the pivot.

Questions:

1. What are the three parts that every lever has?

2. How are the three classes of lever defined?

3. What is the turning effect of a force called?

4. What is the equation used to calculate a moment?

5. What is the unit of a moment?

6. What is the Principle of Moments?

7. If an elephant weighing 40,000 N is sitting 0.5 m from a pivot, what moment does it produce?

8. If a person weighing 600 N is sitting on the other side of a seesaw, how far from the pivot would they need to be to balance the elephant in question 7?

Centre of Mass

The centre of mass of an object is the point where all of the mass of the object may be treated as if it is concentrated. It is also the point through which we can treat the object's weight as acting.

For regular objects, the centre of mass lies on the lines of symmetry that pass through the object. Some objects, such as a donut or boomerang, can have a centre of mass that lies outside the object itself.

An object is stable if its centre of mass lies above its base, whereas it will topple over if the centre of mass goes outside of being above the base. To make an object more stable, we can lower its centre of mass, or make its base wider.

Questions:

1. What is meant by the centre of mass of an object?
2. Where does the weight of an object act through?
3. What simple method can be used to find the centre of mass of an irregularly shaped object?
4. What is meant by the line of action of a force?
5. When is an object stable and unlikely to topple over?
6. When will an object topple over?
7. Give two ways to make an object more stable.
8. Why do high jumpers use the Fosbury Flop technique?

Revision Questions

1. **What is the correct unit for measuring speed in physics?**
   A) N
   B) m/s^2
   C) m/s
   D) Pa

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2. **Which of the following is a vector quantity?**
   A) Distance
   B) Mass
   C) Temperature
   D) Velocity

3. **If a resultant force acts on an object, what will happen to the object?**
   A) Stay at rest
   B) Move at constant speed
   C) Accelerate in the direction of the force
   D) Disappear

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4. **Which formula correctly links force, mass and acceleration?**
   A) F = m ÷ a
   B) F = m × a
   C) F = a ÷ m
   D) F = a × a

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5. **What does the gradient of a distance-time graph show?**
   A) Acceleration
   B) Velocity
   C) Speed
   D) Force

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6. **Which factor affects both the thinking distance and the braking distance of a car?**
   A) Speed of the vehicle
   B) Road surface
   C) Reaction time
   D) Brake condition

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7. **What is terminal velocity?**
   A) The highest possible speed of a vehicle
   B) The constant speed when resistive force balances weight
   C) The point an object changes direction
   D) The pressure at sea level

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8. **Pressure is calculated using which formula?**
   A) Pressure = Force × Area
   B) Pressure = Mass × Area
   C) Pressure = Area ÷ Force
   D) Pressure = Force ÷ Area

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9. **What is the Principle of Moments?**
   A) The heaviest object always turns a lever
   B) Clockwise moments equal anticlockwise moments for balance
   C) The largest force wins
   D) Force is directly proportional to time

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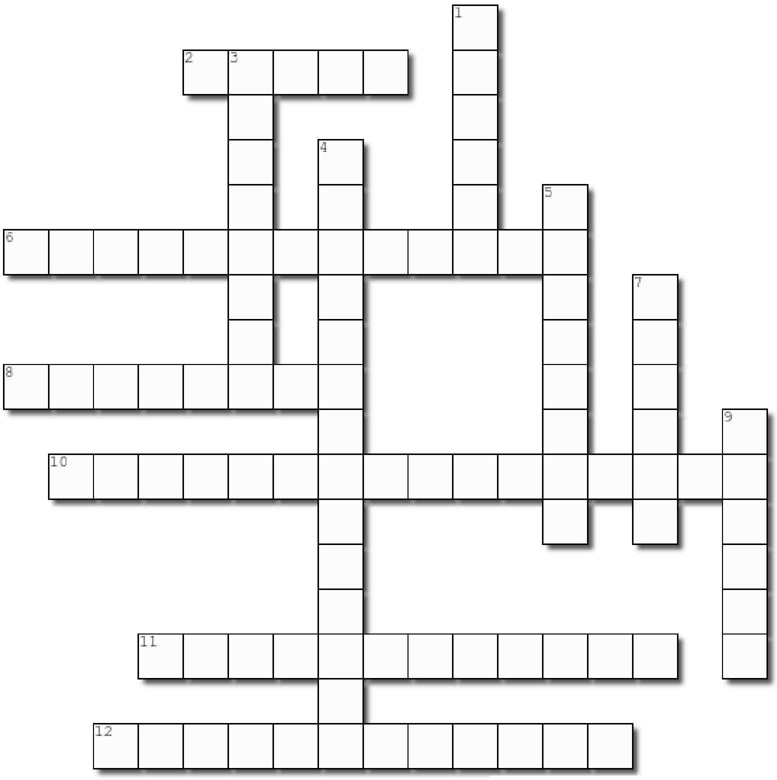
10. **How can you increase the stability of an object?**
   A) Move its centre of mass higher
   B) Narrow its base
   C) Lower its centre of mass and widen its base
   D) Increase the force acting on it

Name:____________________

Complete the crossword puzzle below



Across

2. This is equal to distance divided by time
6. A force that acts in the opposite direction to an object's motion as it moves through air
8. On a distance-time graph, this gives the object's speed
10. This is equal to thinking distance plus braking distance
11. The point where an object's mass may be treated as being concentrated
12. This can mean speeding up, slowing down, or changing direction

Down

1. The standard unit for force
3. This is equal to force divided by area
4. The overall force acting on an object
5. Speed in a given direction
7. The turning effect of a force
9. A quantity that has both a magnitude and a direction