an introduction to

STRUCTURAL ENGINEERING

PUPIL NAME ______________________ CLASS ______________________

INTRODUCTION

Humans have come a long way since we were hunter-gatherers, 12,000 years ago, wandering the land looking for food and water in small tribes.

For a start, we don't have quite so many blisters on our feet from all the walking. But perhaps more importantly we have created buildings that make our lives safer, easier and more enjoyable.

It is thanks to designers and engineers that we have been able to tame our hostile planet. We have learnt how to create structures that don't fall down on us (important!), and protect us from the weather.

We have made all sorts of buildings using lots of different materials and in this unit, we learn about the engineering science of structures...

LEARNING OBJECTIVES

In this unit we cover a lot of engineering science principles and knowledge. Specifically you will learn about the following topics.

- ☐ Different structural engineering professions.
- ☐ Structures by other species.
- ☐ Structures made by humans.
- ☐ Why we build bridges.
- ☐ Different types of bridge.
- ☐ Understanding force and mass.
- ☐ Different types of beams.
- ☐ Different types of force.
- ☐ Difference between compression and tension.
- ☐ Framing structures.
- ☐ Balanced forces.
- ☐ Calculating moments round a fulcrum.

ASSESSMENT

You will be assessed in a number of ways. Your teacher will discuss the assessment with you.

Specifically, you will be graded on the following:

- ☐ Your answers in this booklet.
- ☐ Your submissions to projects in this booklet.
- ☐ Worksheets accompanying this booklet.
- ☐ Topic exam.
- ☐ Design of your own small bridge truss.
- ☐ Manufacture of your own small bridge truss.

TASK 1

"*Gobekli Tepe*" is considered one of the oldest human structures ever found.
Research *Gobekli Tepe* and record (i) It's age (ii) location (iii) material (iv) size and (v) function.

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____[5 MARKS]

TEACHER MARKED ☐

WHO ARE STRUCTURAL ENGINEERS?

There are many people involved in the designing and building of structures. All of them are considered engineers and each one is incredibly important to the process.

Each career option has a different route into the world of work. Working in structural (or civil) engineering can be an exciting and well paying career option.

Some jobs require you to have a degree from a university. Other routes can be achieved by studying at college or completing an apprenticeship.

Whichever path or career you choose, getting the best qualifications you can at school is the best spring-board to success later in life.

TASK 2

Research one of the career options above, either online or by interviewing a person you know. **Create** an A4 poster explaining the career, the average salary, and the qualifications required.

TASK 3

There are different levels of qualification offered at school, college and university. **Describe** the qualifications and levels offered in your school's Design & Technology department.

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STRUCTURES IN NATURE

Humans are not the only animal that likes to build structures. In fact, other species have been constructing homes for millions of years.

Other animals have had their construction ambitions limited by their lack of industrial tools and advanced materials, but this does not mean that there is nothing to learn from our cousins in the animal kingdom.

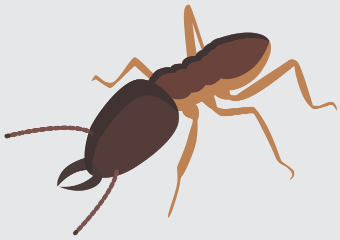
Designers and engineers have started to look at how different animals construct their habitats and learn their techniques.

Human construction has a largely negative environmental impact, whilst other animals create suitable structures that cause little or no damage. What could our structures look like in the future if we learn from different animals?

BIRDS

Blackbirds are good :)

OTTERS



TERMITES

Bees or ants will also do!

TASK 4

Three families of animal are shown above. Select one of these species to research.
Create an A4 poster explaining how your chosen animal makes a habitat.

FORMS OF STRUCTURE

There are different 'forms' of structure. These can be broken down into '*mass*', '*frame*' and '*shell*'.

MASS

Mass structures are ones that work simply because they are heavy. Bricks or stones cemented together hold the structure up.

FRAME

A **frame** structure is one with a 'skeleton' structure that takes the bulk of the weight.

SHELL

Shell structures work where the 'skin' of the building holds things together - usually sheet metal.

TASK 5

Spiders are another animal that creates structures - webs, spun from fibres from its' own body.
Research the material from spiders and how this compares with steel.

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____ [2 MARKS]

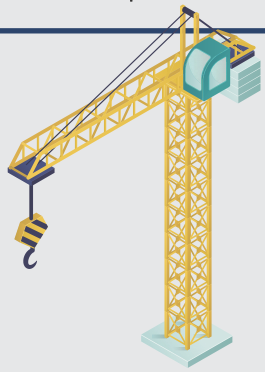
STRUCTURES BY PEOPLE

Okay, humans are pretty awesome at building structures. After 12,000 years designers and engineers have become quite good at the process.

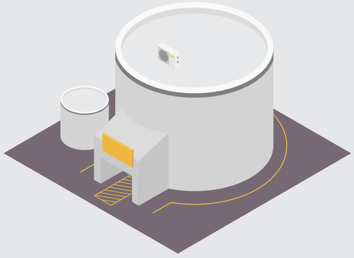
Different things have influenced building design. Access to different materials, construction techniques, requirements of people and function of buildings. (We didn't need to build factories or 100,000 seat sport stadiums 12,000 years ago…)

Human buildings can be divided into 'mass', 'frame' and 'shell' structures.

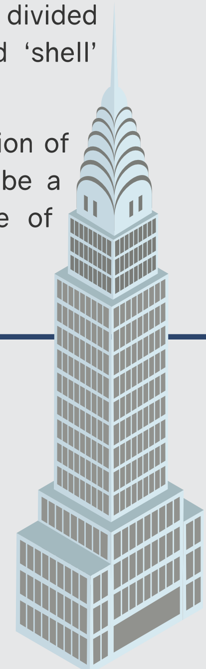
The materials and function of the building can often be a useful hint to the type of structure it is.



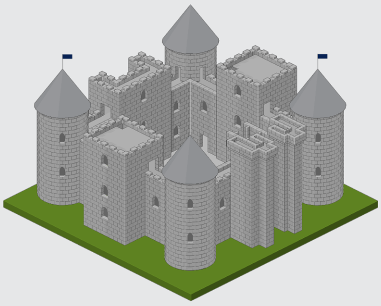
CRANE



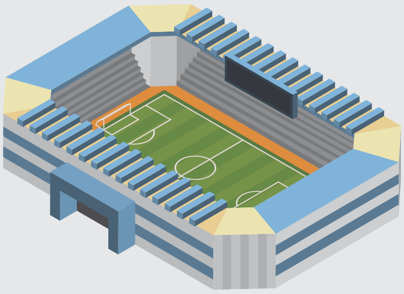
STORAGE SILO



SKY SCRAPER



MEDIEVAL CASTLE



SPORTS STADIUM

MODERN HOUSE

TASK 6

Six humans structures are shown above.
State whether these are 'mass', 'frame' or 'shell' structures. You many need to do research.

TASK 7

Humans have made large and small structures for different purposes.
Research the largest ever human structure, what it is made from and what form of structure it is.

[3 MARKS]

BRIDGES

Bridges are one of the most impressive and important structures that humans construct. The very first bridges were likely just trees that had fallen across rivers. The oldest arch bridge still in use today is the '*Arkadiko*' bridge in Greece, built over 3,300 years ago.

Bridges have an impact on the '*environment*' and the '*economy*' of an area.

The *environment* concerns anything to do with nature. This includes wildlife, plant-life, fish, and pollution. This includes impacts on human health.

The *economy* concerns human finances and trade. This includes people travelling for jobs, selling or buying goods and tourism. The time it takes humans to do different things is also an economic issue.

ENVIRONMENTAL AND ECONOMIC IMPACT

Designers and engineers must consider the environment and economic impact of the structures they design. This can be one of the most difficult aspects of designing and constructing new things.

TASK 8

A scene with a wide river is shown below. Some people are wanting to build a bridge to cross it. **Describe** the different things that must be considered. You may label the scene below.

TASK 9

The environment - and in particular the weather - can cause issues with bridges. **Describe** why weather conditions can impact the design and placement of bridges.

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____[2 MARKS]

TEACHER MARKED ☐

TYPES OF BRIDGE

There are many different types of bridges that designers and engineers can construct.

When choosing what type of bridge to construct there are several things to consider.

Span: the distance the bridge must cross.

Cost: how much money you have to construct the bridge.

Volume of traffic: how many people, trains or motors vehicles must cross. Usually calculated as traffic-per-minute.

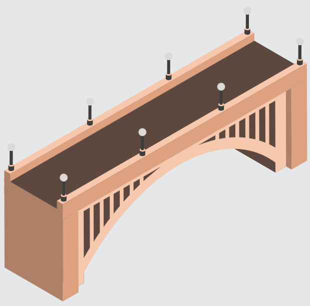
Weight of traffic: The weight of objects crossing

Environment/weather: What local weather is like.

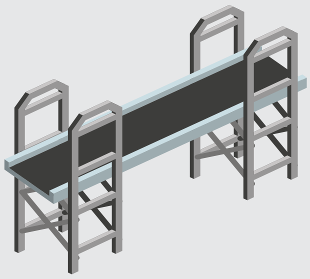
Lifespan: How long will the bridge last before you need to replace it.

SUSPENSION

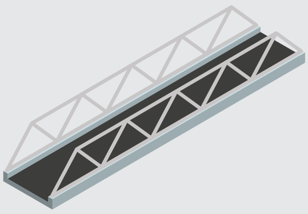
CABLE-STAYED



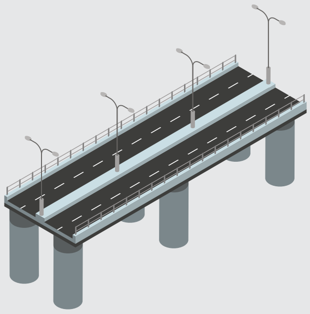
ARCH



CANTILEVER



TRUSS



BEAM

TASK 10

Select one of the six bridges shown above and research a real-life example.
Create an A4 poster about your chosen bridge, including details about it's construction

TASK 11

There are bridges all over the world.
State (i) oldest bridge in Scotland (ii) longest bridge in the world (iii) shortest international bridge.

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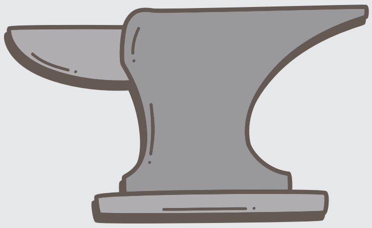
____[3 MARKS]

UNDERSTANDING FORCE & MASS

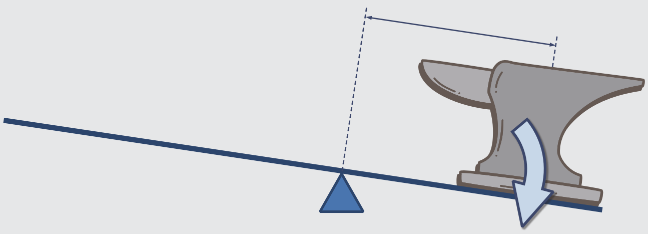
Force and mass are everyday words but often used incorrectly. Designers and engineers must understand both these terms and how they apply to designing and constructing structures.



MASS

Mass is the amount of matter in an object and is expressed in kilograms. Don't confuse this with weight - you'll learn why in the future.

Two objects that are the same size and shape but have a different mass will fall to the ground with the same acceleration because of gravity.



FORCE

Force is a physical influence, which when applied to an object causes it to accelerate in the direction from which it was applied.

Force is measured in **Newtons**, with the unit '**N**'.

There are different types of force that you will learn about later.

When designing a structure, engineers must know about the mass of the objects that will be held up and the mass of their structure. This is called the '*strength-to-weight ratio*'.

Engineers will try to make their structure as light as possible (it is usually less expensive to construct), whilst being able to hold as much mass as possible.

TASK 12

Skyscrapers are common in cities today thanks to the properties of steel.
Describe the first building to ever use a steel frame, including location and when constructed.

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____[2 MARKS]

TASK 13

Different structures use different materials.
Explain why aeroplanes use aluminium rather than steel for their frame.

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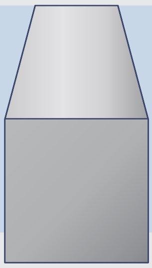
BEAMS & SECTIONS

Metal is commonly used in many structures, particularly bridges and large framed buildings like sports-stadiums, skyscrapers, hospitals and schools.

A length of metal is called a 'beam'. The shape of the beam when you cut-through it is called the 'section'. Beams are named by the shape of the section.

TASK 14

Nine different shaped beams are shown below.
State the name of the section shown below. You can find out more at DesignClass.co.uk



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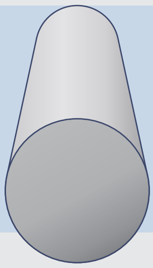

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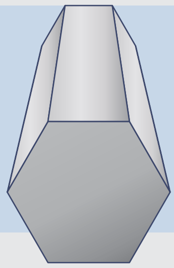

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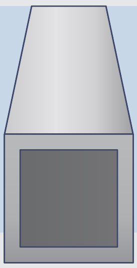

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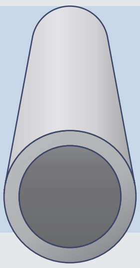

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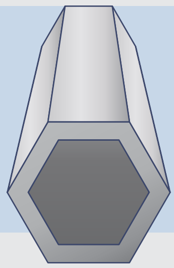

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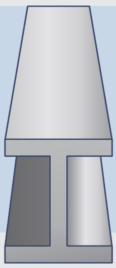

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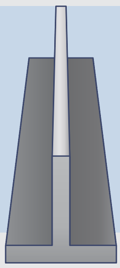

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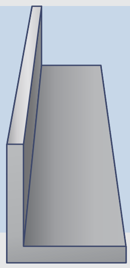

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TASK 15

Metal is an excellent material for construction, however it is affected by temperature.
Explain why temperature is an issue when building structures made from metal.

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____[2 MARKS]

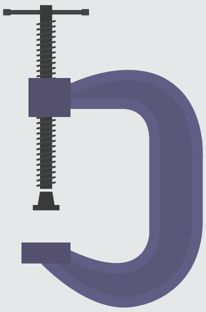
TYPES OF FORCES

A '*force*' can be described as either a *pull* or a *push* upon an object.

If the object being pushed or pulled does not have another force working in the opposite direction, it will begin to move and accelerate. Acceleration is not good for buildings, as generally, buildings are not meant to move. If the whole structure is moving it usually it means it is falling down(!)

Understanding forces is important for designers and engineers. There are many different types of force, describing how an object is being pushed or pulled (or both, at the same time!)

Here we consider different types of force.



STATIC

A *static force*, as the name suggests, is one that is constant and **doesn't** change in **value** or **direction**.

Friction is also an example of a static force. If you try to push a heavy box along the floor, you need to apply enough force to overcome the friction and begin moving.

DYNAMIC

A *dynamic force* is one that **can** change in **value** or **direction**.

Dynamic forces can be tricky to calculate and can be difficult for designers and engineers to solve as it relies on predicting where forces may come from and how large they may be.

You don't need to worry about these right now.

TORSIONAL

A *torsional force* - often called '***torque***' - is one that is twisting along a centre axis.

If you have ever used a screwdriver you will know that you need to apply a force in a circle to drive a screw in or out of a hole.

Calculating torsional forces is important when designing an engine or structures with moving parts.

SHEARING

A shearing force is one where an object is being pushed from one direction on one side, then slightly further along its length it is being pushed from the other side. Scissors are a good example. One blade pushed from one side, and another blade from the other side. The two blades are slightly apart.

TASK 16

The mass of an object is measured in Kilograms (Kg). The force of an object in Newtons (N)
Research how many Kilograms equals one Newton. (To one decimal place).

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____[1 MARKS]

TEACHER MARKED ☐

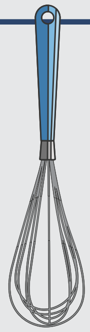
TYPES OF FORCES

Designers and engineers involved in creating structures look at the world in terms of forces.

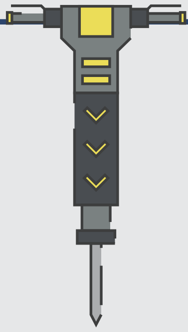
Forces can be either intentional, accidental or caused by the environment and engineers try to anticipate them in the products and structures they make.

Questions engineers ask themselves include;

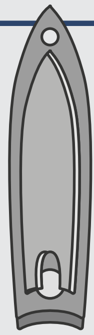
- *What forces are working on a structure, object or person?*
- *Are these forces intentional?*
- *Are these forces useful or harmful?*
- *What type of forces are being applied?*



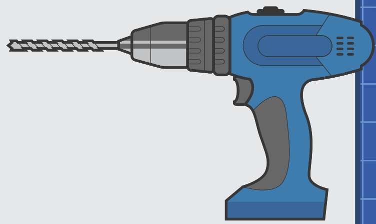
WHISK



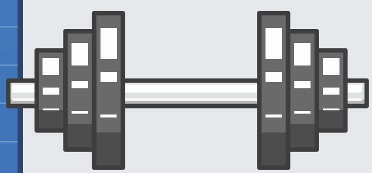
JACKHAMMER



NAIL CLIPPERS

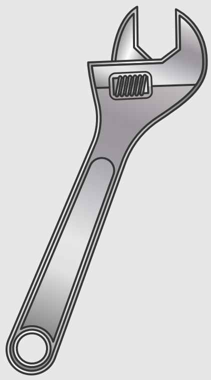


DRILL

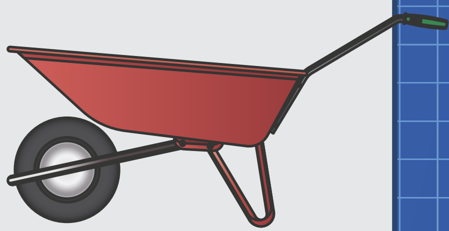


DUMBBELL

AXE



SPANNER



WHEEL BARROW

TASK 17

Eight tools are shown above.
State the type of force they exert when being used normally.

TASK 18

The weather can cause forces to impact structures.
Describe a weather scenario that could impact the design of a bridge in terms of forces.

[2 MARKS]

COMPRESSION AND TENSION

Tension and compression are two ways which a force can impact a material and understanding tension and compression is essential when designing and making frame structures.

A **tension** force is one that pulls materials apart.

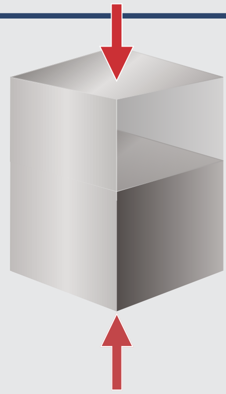
A **compression** force is one that squeezes material together.

Certain materials can be incredibly strong with tension forces, but weak with compression forces. For instance, a weight can be hung (tension) from dry spaghetti, but will easily snapped if compressed.

Other materials are excellent with compression, but cannot take any tension. Concrete is a good example of this.

TENSION

The force that tries to make a material longer is called tension.



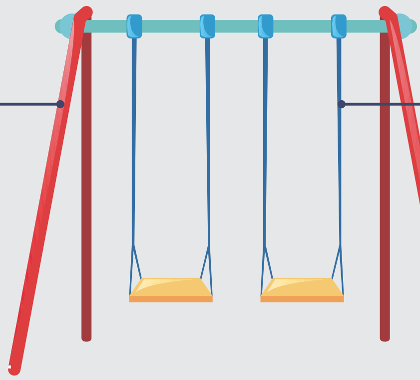
COMPRESSION

The force that tries to shorten (or squeeze) a material is called compression.

TASK 19

State whether each component highlighted below is in tension or compression when a child is on the swing.

LEG COMPONENT



CHAIN COMPONENT

TASK 20

Most products will experience compression or tension forces at some point during their use. **Describe** two products in your house and if they experience either comprssion or tensile forces.

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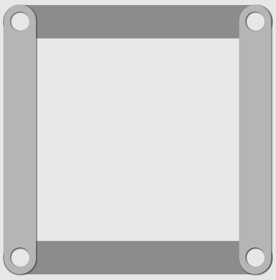
____ [2 MARKS]

FRAMES

Frames are one of the most common ways of constructing structures. Frames can be an excellent way of 'distributing' forces round a structure whilst also being very light themselves. Frames also have the advantage of being quite simple to calculate how forces will be distributed and you will learn about this later in Engineering Science.

Frames involve joining lengths of material together. There are different ways of joining materials and this can impact how strong a frame is. Whilst learning the basics of frames we don't consider how the frame is joined - it can get quite complex when you are learning the basics.

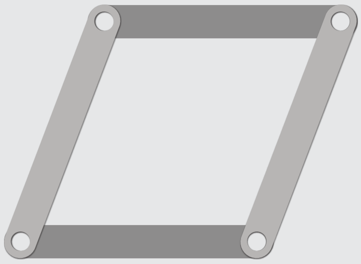
Here we consider some basics of constructing frames.



SIMPLE FRAME

A framed structure is one that is made by a skeleton that is able to stand by itself as a rigid structure without depending on floors or walls to resist deforming.

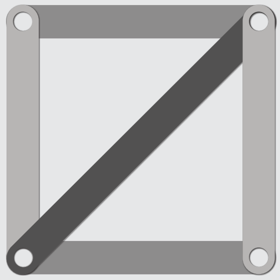
Materials such as wood and steel which are strong in both tension and compression, make the best members for framing. Frames are clad to make walls and floors, but the frame is doing the 'work'.



RACKING

Racking is the term used to describe a frame that deforms in shape. This usually occurs when an unwanted force is applied to a frame and the force cannot be shared through the structure properly.

A simple example would be a square frame where a force is applied to only one corner. This is likely to cause the frame to move and deform.



CROSS-BRACING

A simple method to eliminate racking would be to 'stiffen' the structure by adding '*cross-bracing*'.

Cross-bracing involves joining one corner to another, effectively creating smaller triangular frames.

Triangular frames are excellent as they will not rack or fail unless an individual beam bends or snaps.

TASK 21

Structural frames are commonly made from metal.
Create an A4 poster showing three ways that can be used to join metal beams to create frames.

TASK 22

The 'Forth Rail Bridge', joining Fife to Queensferry is a famous cantilever bridge.
Research the history of the Forth Rail Bridge, what it is made from and how it was made.

[4 MARKS]

TEACHER MARKED

UNDERSTANDING MOMENTS

A *moment* is the turning effect of a force.

Moments act about a point in a clockwise or anticlockwise direction.

The point chosen could be any point on the object, but the pivot - also known as the **fulcrum** - is usually chosen.

If an object is balanced, the total clockwise moment about a pivot is equal to the total anticlockwise moment about that pivot.

Turning forces are found in many everyday situations and are essential for machines to function. Moments are also calculated when constructing structures.

CALCULATING MOMENTS

You will only be expected to work out balanced forces. The size of a 'moment' can be calculated using the equation:

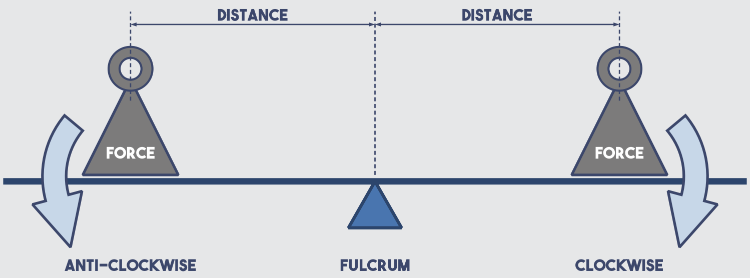
moment of a **force** = **force** × **distance**

This is when:

moment (M) is measured in newton-metres (Nm)

force (F) is measured in newtons (N)

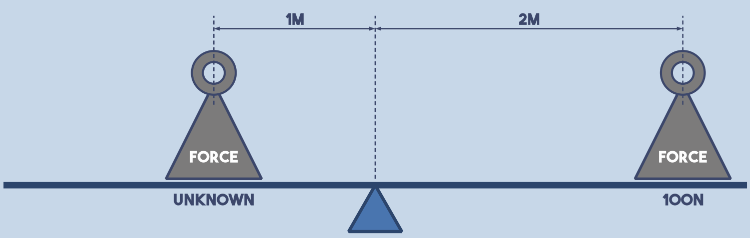
distance (d) is measured in metres (m)



Sum of the **forces** × **distance** acting **clockwise** = **Sum** of the **forces** × **distance** acting **anti-clockwise**

$$F \times d_{cw} = F \times d_{acw}$$

WORKED EXAMPLE



A balanced system is shown above.

The forces acting clockwise = 100N × 2m

The forces acting anti-clockwise = unknown N × 1m

How can we work out the unknown force?

$F \times d_{cw} = F \times d_{acw}$

100N × 2m = unknown N × 1m

200Nm = unknown N × 1m

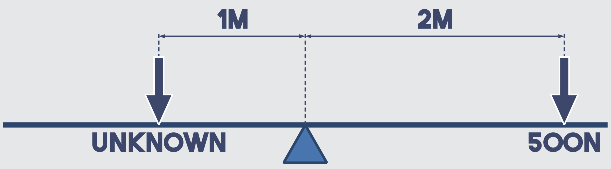
$\frac{\text{200Nm}}{1} = \frac{\text{unknown N} \times \text{1m}}{1}$

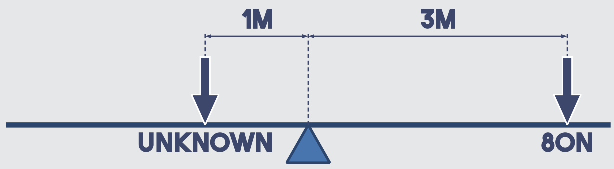
200N = unknown

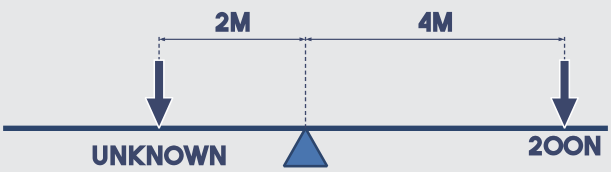
So the unknown force is 200N for the system to be balanced.

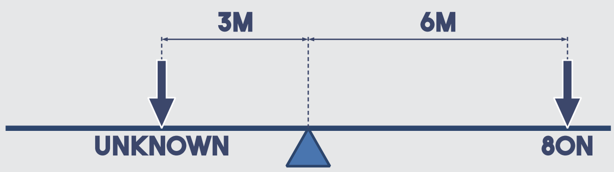
CALCULATING MOMENTS

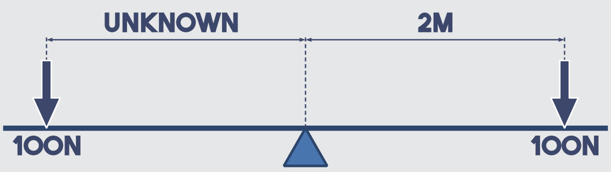
Complete the following moments calculations. Remember, you can get help and tutorials at DesignClass.co.uk.

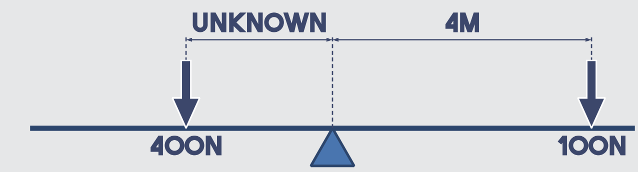


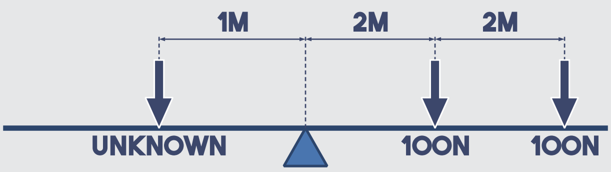


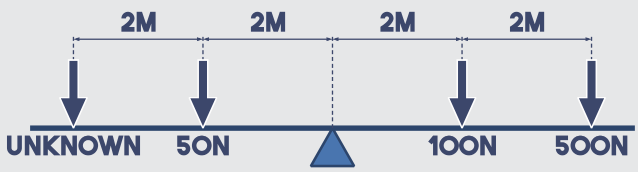


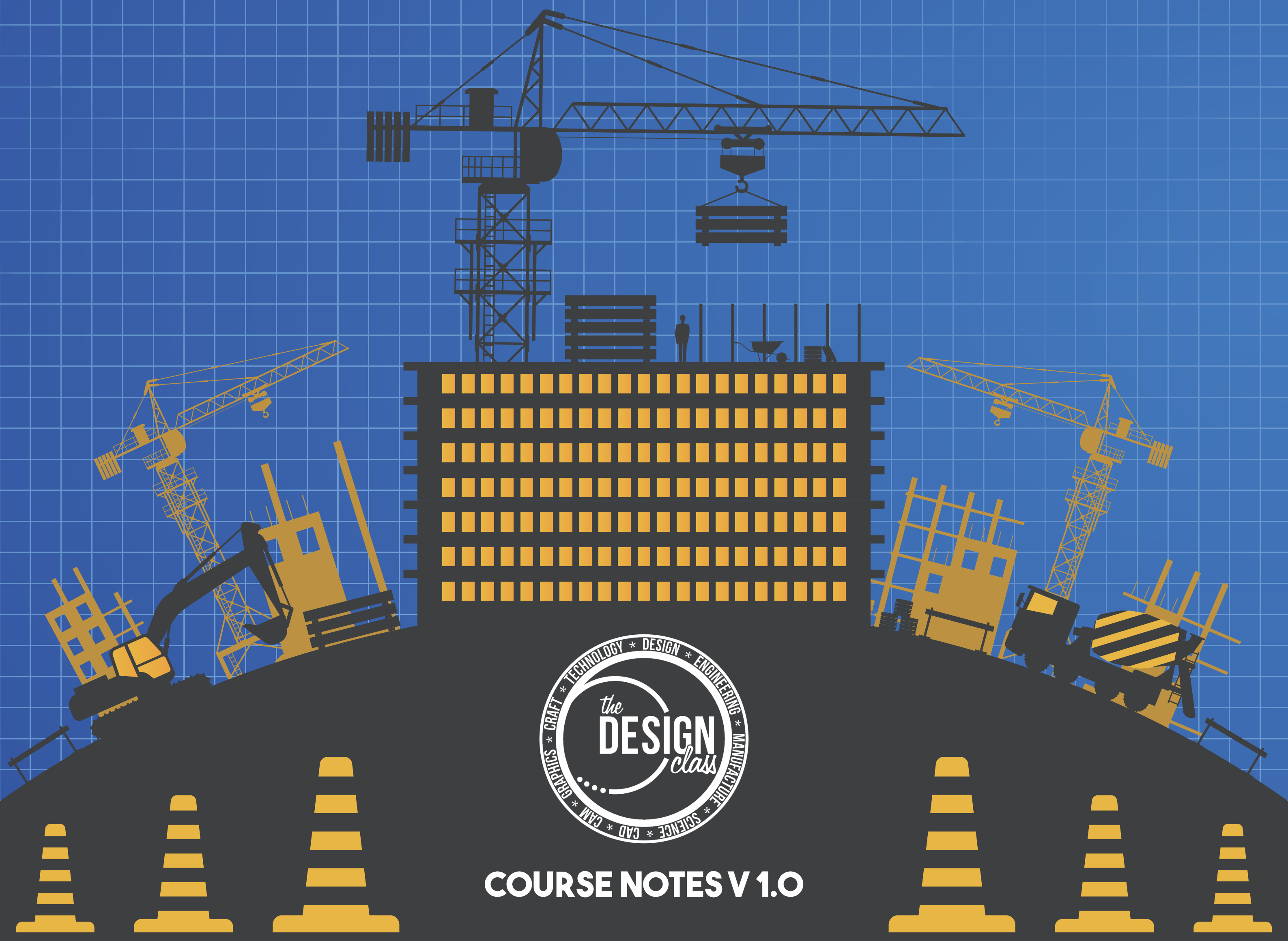








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