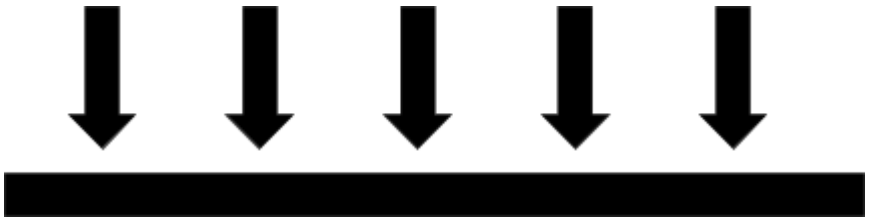
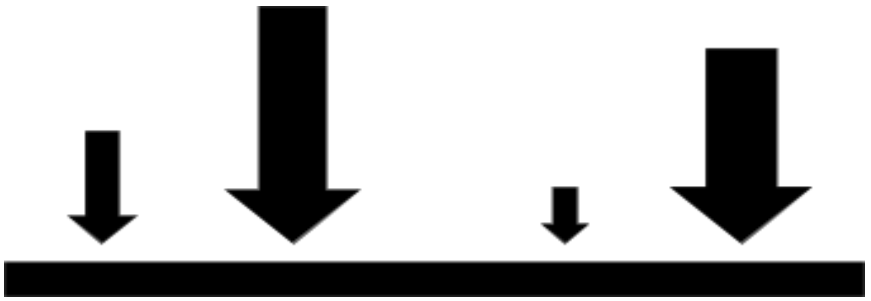
Forces, Strengths and Properties of Materials:

- Forces on Structures:
    - Static Forces
        - Force that doesn't move e.g. a person standing on a trampoline
    - Dynamic Forces
        - Force where something moving hits the structure e.g. a person jumping on a trampoline
- Loads on Structures:
    - Even Loads
        - When the load is evenly spread along the length of the structure

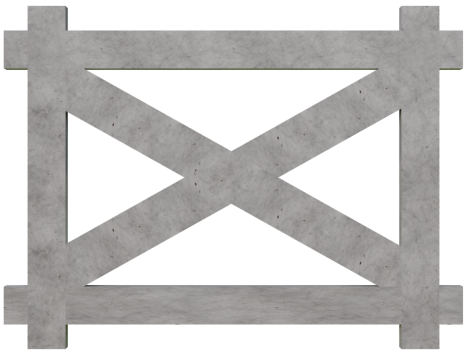


    - Uneven Loads
        - When the load isn't evenly spread along the length of the structure
        - Can be caused by adding multiple separate weights

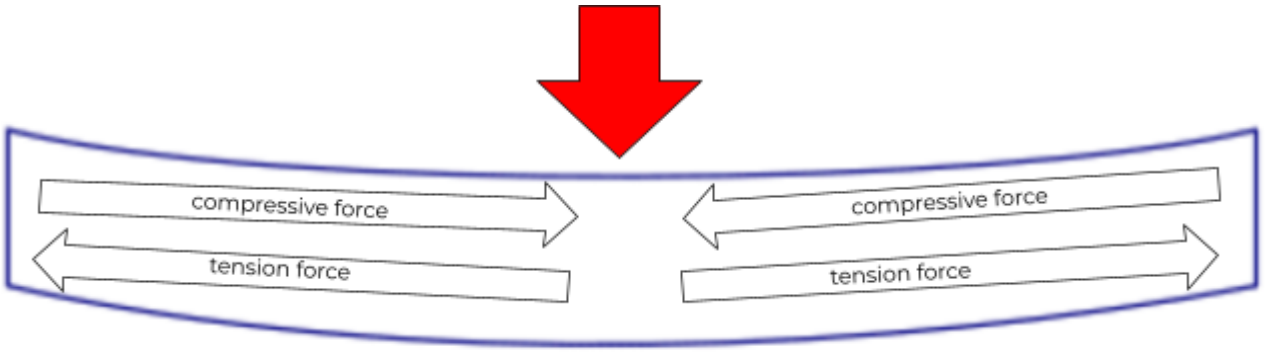


- Different Types of Forces:
    - There are 4 main types of force:
        - Tensile/tension force
            - Pulling force
            - E.g. pulling on a rope/stretching an elastic band

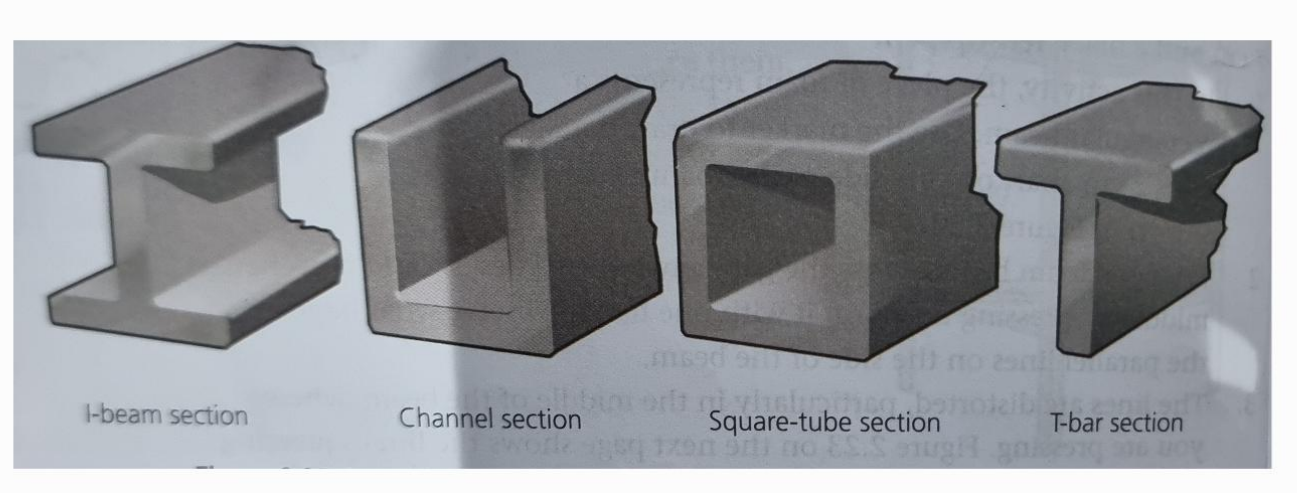
        - Compressive/compression force
            - Pushing/pressing force (tends to squash the structure)
            - E.g. the weight of a building pressing down on a pillar
        - Torsion force
            - Twisting force
            - E.g. twisting the lid off a jar
        - Shear force
            - Cutting force (acts parallel to the structures surface)
            - E.g. cutting paper with scissors
- Internal Cross-bracing:
    - Used to prevent torsion forces from damaging structures



    - An example of cross-bracing is given above
- Bending of Beams:
    - When a load is placed on a beam, it bends, creating a concave shape
    - The top of the beam receives compressive force while the bottom of the beam receives tension force
        - The compressive force is directed inward to the centre of the beam
        - The tension force is directed outward to the edges of the beam

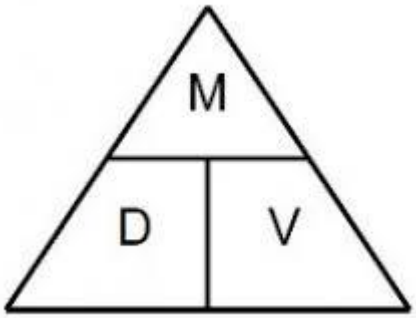


- How to make metal beams resistant to bending:
  - The shape of the beam, known as the cross section, affects its resistance to bending.
  - The most common cross section is the I-beam, shaped like the letter I
  - Here are the 4 most common designs:



- Properties of Materials:
  - Mass
    - The measure of the amount of matter in an object
    - E.g. a kilogram of feathers has the same mass as a kilogram of lead
  - Density
    - The measure of how concentrated the mass is in an object
    - Measured by finding the mass of a cubic metre of the material
      - We can use the formula Density = mass/volume (mass divided by volume) or D = m/v
    - E.g. the kilogram of lead will take up a lot less space than the kilogram of feathers as it has a much higher density
      - Lead has a density of around 11340kg/m^3 while feathers have a density of around 2-3kg/m^3
    - Low-density materials are often used in manufacturing for various reasons

        - Density affects durability, speed and longevity of the material
        - In cars, lightweight (low-density) wheels are used for quick acceleration, often made from magnesium due to its low density.
    - The formula pyramid for density is:



- Hardness
    - The measure of a material's resistance to damage, such as holes, dents, scratches, and wear caused by friction
    - Tested using a Brinell hardness tester, where a hard spherical indenter is pressed into the material. The material is given a number score (the higher the number the harder it is)
        - Diamond is very hard with a score of 7000, however lead is very soft with a score of 5
- Stiffness/flexibility
    - The measure of a material’s ability to bend without breaking
        - An example of a flexible material is rubber
    - Stiff materials are also called brittle materials
        - The material is resistant to bending from regular forces, but it will break under extremely strong forces
        - An example of a brittle materials is concrete
- Corrosion
    - Corrosion refers to the deterioration of metals, commonly known as rust

- Metals often corrode/rust over time, the most common of which being iron
- Factors that affect corrosion of iron:
    - Water
        - Accelerates the corrosion process
    - Moisture
        - Necessary for corrosion to take place
    - Acid
        - Greatly accelerates the corrosion process
    - Salt
        - Greatly accelerates the corrosion process
- Prevention of Rust/Corrosion:
    - Paint
        - Some high-quality paints can prevent rust from reaching the metal beneath
    - Galvanisation
        - Coating a metal with a layer of zinc as a protective barrier.
        - Corrosion is significantly prevented by galvanisation
    - Non-iron Metals
        - Using metals such as brass and stainless steel prevents corrosion
    - Electroplating
        - Coating a metal object with a thin layer of another metal using electrical current

Pneumatics and Hydraulics:

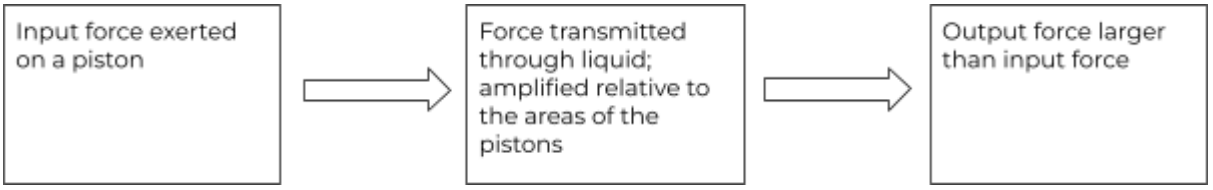
- NB: Any fractions in this chapter will be represented as x/y, where x is the numerator and y is the denominator (e.g. 3/4 is three quarters)
- Difference between pneumatic and hydraulic systems:

Pneumatic Systems	**Hydraulic Systems**
Force transmitted through a gas	Force transmitted through a liquid
Force exerted on one piston, transmitted through gas to push out another piston	Force exerted on one piston, transmitted through the liquid to push out the other piston
Force compresses gas before transmission for increased efficiency	Immediate transmission of force due to the inability of liquids to be compressed
Direction of force can be changed using bent tubes filled with compressed gas	Direction of force can be changed using bent tubes or pipes filled with liquid, without affecting output force

- Pascal's Principle:
  - Pascal's principle states that pressure exerted on one part of a system with an enclosed space is transferred equally and immediately to all parts of the system without any loss of intensity
- Pressure Formula:
  - $P = \frac{f}{a}$
    - P is pressure
    - F is force
    - A is area
  - Pascal's Principle states that $P_1 = P_2$
    - P_1 is the pressure of the input piston
    - P_2 is the pressure of the output piston
  - $F_1 / A_1 = F_2 / A_2$
    - F_1 is the force exerted on the input piston
    - A_1 is the area of the input piston
    - F_2 is the force exerted by the output piston

        - A_2 is the area of the output piston

    - The output force (F_2) is equal to:
        - $A_2 / A_1 \times F_1$
    - Hydraulic systems can be represented by a systems diagram, for example:



- Mechanical Advantage (MA)
    - Mechanical Advantage refers to the difference in force between the input and output in a system
    - Characteristics/principles of mechanical advantage:
        - Longer levers or stronger forces increase the output force
        - Having a smaller input surface area and a larger output surface area amplifies the force or pressure
        - Force is evenly distributed across the system
        - Input force is multiplied to generate a greater output force
    - There are 2 formulas you can choose from to find out the MA of a system:
        - MA = load (output force) / effort (input force)
        - MA = area of output piston / area of input piston
    - If the mechanical advantage of a system is 6 for example, the output force will be 6 times greater than the input force
        - E.g. if the input force is 8N (newtons), the output force will be 8x6, which is 48N.
    - If the output force is larger than the input force, the distance moved by the output piston will be less than the distance moved by the input piston
        - If the mechanical advantage is 4, the output piston will move 4x less distance than the input distance (e.g. input distance = 20cm; output distance 5cm)

    - If the area of the output > the area of the input:
        - Output force is larger
        - Output distance covered is smaller
        - Force is multiplied
    - If the area of the output < the area of the input:
        - Output force is smaller
        - Output distance covered is larger
        - Force is divided
    - Remember that $F_1D_1 = F_2D_2$
        - F is the force applied
        - D is the distance covered by the pistons
- Hydraulic Jack:
    - Hydraulic system which uses a valve and a reservoir
    - Used to lift a car by being pumped by the jack handle
        - When the jack handle is moved, the input piston pumps oil from the reservoir into the main cylinder through a one-way valve
        - Each pump of the handle raises the car a short distance, as only a small amount of oil is pumped
        - This design allows the person pumping to exert a small force while lifting the heavy load of the car
    - When the vehicle is lowered, the valve is opened, allowing the weight of the vehicle to push the oil back into the reservoir.
- Controlling Hydraulic Systems:
    - In hydraulic systems, controlling or preventing the load from falling back after lifting is important.
    - Holding the input piston still can be used to stop the output piston and prevent the load from falling, but it is not very efficient.
    - Using a valve is a more efficient way to stop the force in a hydraulic system and prevent the load from falling back.
        - A valve allows better control over the hydraulic system and enables lifting a load higher by using multiple pumps
        - Valves control the force in a hydraulic system by stopping and starting the flow of liquid.

            - Its design also prevents the liquid (in this case oil) from flowing back through the valve
    - Safety valves are sometimes found in hydraulic systems
        - They release the liquid if the pressure gets too high to prevent the pipes/cylinder from bursting
- Using reservoirs to move a piston further:
    - When there is a need to lift a load higher than what a single piston can allow, a reservoir is used to store the oil, which can be released when required
- Advanced Hydraulic Systems:
    - Hydraulic jacks and hydraulic brakes require humans to exert the force, but electric pumps are often used for hydraulic systems too
        - Various vehicles and equipment such as rubbish trucks, aeroplanes, cranes, etc., utilise these pumps.
        - Many industries, including mining, construction, and manufacturing, employ electric pumps for hydraulic systems.
        - Hydraulic systems are utilised for lifting, pushing, pulling, pressing, and other applications
- Advantages and Disadvantages of Hydraulics:
    - Advantages:
        - Can generate output force in hard-to-reach areas due to the flexibility of the pipes to take any shape, fit into small spaces, and go around corners
        - Small forces can be multiplied many times
        - Can control linear motion precisely
            - Distance moved by the output piston can be controlled
    - Disadvantages:
        - Extremely expensive
        - Require strong, heavy components
        - Can be dangerous (high pressure in systems)