Scalar and Vectors

Scalars only have **size**, **Vectors** have **size and direction**.

- Scalars - mass, temp., time, length, speed, energy.
- Vectors - displacement, force, velocity, acceleration, momentum.

You can **add vectors** using **pythagoras** (a2 + b2 = c2) and **trigonometry** (SOHCAHTOA). You can also use pythagoras and trigonometry for adding **resultant forces or velocities**.

When adding vectors make sure they are **tip to tail**, and if the vectors aren't at right angles you should do a scale drawing.

Equations of Motion

Uniform acceleration is **constant** acceleration. Acceleration could mean a **change in speed** or **direction** of both.

The four **equations of motion** -

- **V = u + at**

V is final velocity, u is initial velocity, a is acceleration, t is time

- **s = ut + 1/2 at^2**

s is displacement

- **v^2 = u^2 +2as**
- **s = (u+v)/2 x t**

Newton's Laws of Motion

Newton's 1st Law - The velocity of an object will not **change** unless a **resultant force acts on it**. Eg. Apple on a table wont go anywhere because the forces on it are balanced.

Reaction (R) = weight (kg)

Newton's 2nd Law - **Acceleration** is **proportional** to the **force.**

resultant force (N) = mass (kg) x acceleration (ms-2) [F = m x a]

Remember - Resultant force is the vector sum of all the forces. The **acceleration** is **independant** of the mass.

All objects fall at **the same rate** (if you ignore air resistance).

Newton's 3rd Law - Each force has an **equal, opposite reaction force**. Eg. If an object A exerts a force on object B, then object B exerts an equal but opposite force on object A. The forces are always the same type but the forces are not both applied to the same object.

Weight, Mass and the Centre of Gravity

W = mg

Weight = mass x gravity

Mass is **scalar** and force (weight) is a **vector**.

Density is mass per unit volume. Density **doesnt** vary with size or shape. Is it calculated by **p = m/v**

Density = mass/ volume (density is measured in **gcm-3** or **kgm-3**)

Centre of gravity - assume all the mass is in one place. An object will be nice and stable if it has a low centre of gravity and a **wide base area.**

Forces

Free body force diagrams show all the **forces** on a **single body**. If a body is in **equilibrium** the forces acting on it will be **balanced**. Some of the forces to look out for - **mg (weight), drag, push, friction, resistance (to earth)**.

Force calculations - **Resolving a force**. Resolving a force means **spliting it into components - vertical and horizontal**. Replace the Force (F) with vertical force (Fv) and horizontal force (Fh) and this is resolving the Force (F). You use **trigonometry** to find **Fv** and **Fh**.

Fh = F cos (the angle)

Fv = F sin (the angle)

Use **vector addition** to get the **resultant force**. First add the vectors together and use **pythagoras** to get the length, then divide your A and B from pythagoras section, take that answer and put it to**tan-1**. You now have the angle, most answers go along the lines of **Force 999N at an angle 99 degrees from north**.

Work

Work is done whenever **energy is transferred**.

Work (J) = Force (N) x Distance (m) [W=Fs]

Work is the energy thats been **changed** from **one form to another** - not always the total energy. The equation **assumes** that the direction of force is the same as the direction of movement.

Definition of a Joule - **one joule** is the **work done** when a force of **1 newton** moves an object through a distance of **1 metre**.

The direction of force isnt always in the same direction as the movement. If not you use **horizontal and vertical components**.

W = Fs cos (the angle)

Power

Power equals **work done per second.**

Power (W) = Work Done (J) / Time (s) [P=Wt]

The **watt** is defined as a **rate of energy** transfer equal to **1 joule per second**.

Power (W) = Force (N) x Velocity (ms-1) [P=Fv]

This equation can be helpful when you are given **speed** in a question.Sometimes in a power question the **force** and the **motion** are in **different directions**, like with work, we then use **horizontal and vertical components**.

P = Fv cos (the angle)

Mechanics in the Real World

Many **factors** affect how **quickly a car stops**.

Thinking distance + Braking distance = stopping distance

Thinking distance = Speed x Reaction time

Car **safety features** are usually designed to **slow you down** more gradually and increase the **collision time**, some are designed to **reduce the force** on you. Example features - **Seatbelts, airbags, crumple zones (at the front and back of the car) and safety cages (around the car to prevent crushing).**

Forces act on **sports people**. People who bungee and rock climb have forces acting on them all the time, these can be shown using **free body diagrams** (see forces). **Gravity** is the **only** force acting on **projectiles**.

Conservation of Energy

Principle of Conservation of Energy - Energy cannot be **created or destroyed**. Energy can be **transferred** from one form to another but the **total amount** of energy in a closed system will **not change**.

Ek = 1/2 mv2 - **Kinetic Energy**

(m = mass, v = velocity)

Eg = mgh - **Gravitational Potential Energy**

(m = mass, g = gravity, h = height)

E = 1/2 Ke2 - **Elastic Potential**

(e = extension, K= stiffness)

Hookes Law

Hookes law states that **extension** is **proportional to force.**

F = Ke (K = stiffness constant, e = extension)

Hookes law can apply to **springs**. The **extension** or **compression** of a spring is proportional to the force applied. **Tensile** - stretch spring, **Compressive** - squash spring.

Hookes law stops working when the **load** is great enough. On a graph, if there is a **straight line relationship** between load and extension then **Hookes law is obeyed.**

When the graph starts to **curve**, this is where point E, the **Elastic limit** is. Increase the load past the elastic limit and the material will be **permanently stretched.**

A stretch can be **plastic** or **elastic** -

- **Elastic** - Material returns to its **original shape** when the forces are removed. For a metal, elastic deformation happens as long as Hookes law is obeyed.
- **Plastic** - Material is **permanently stretched**. A metal stretched past its elastic limit shows plastic deformation.

Young Modulus

The **Young Modulus** is **stress/strain**. Below the limit of proportionality for a material, stress divided by strain is a **constant**, the constant is called the **Young Modulus (E)**. It is used by **engineers** to make sure materials can withstand forces.

E = stress/strain = F/A / e/l

To find the Young Modulus you need a **very long wire**. Use a rule, marker and a pulley with some weights. The **longer and thinner** the wire, the more it extends for the same force. Take the correct measurements down and you can find the Young Modulus.

Use a **stress-strain graph** to find **E**.

Gradient = stress / strain = E (Young Modulus)

The **area under** a stress-strain graph gives the **stored energy**. When **Hookes law** is obeyed the stress-strain graph will have a **straight line** so you can calculate the **energy per unit volume** -

energy = 1/2 x strain x stress

Stress and Strain

A **stress** causes a **strain**.

Stress = F/A (F = force, A = cross-sectional area)

Strain = e / l (e = extension, l = original length)

A material subjected to a pair of **opposite forms** might **deform**. A **stress** big enough to **break** the material is called the **breaking stress**. The **maximum stress** the material can withstand is called the **ulitimate tensile stress**. On a graph the **breaking stress (B)** would be the end of the line and the **ultimate tensiles stress (UTS)** would be just before it around where the curve goes slightly down.

Elastic strain energy is the **energy stored** in a stretched material. Elastic strain energy is given by the **area under a stress-strain graph**.

You can calculate the **energy stored** in a stretched wire provided it obeys **Hookes law**.

E = 1/2 Ke2

Behaviour of solids

- **Brittle** - materials **break suddenly** without plastically deforming. Eg. chocolate bar, ceramics
- **Ductile** - materials can be **drawn into wires without losing their strength**. Eg. copper for wires.
- **Malleable** - materials **change shape** but may **lose their strength**. Eg. Gold, gold rings can be changed shape very easily but a gold bar wouldnt.
- **Hard** - materials are **very resistant to cutting, indentation and abrasions**. Eg. cutting tool like a chisel, diamond.
- **Stiff** - materials have a high **resistance to bending and stretching**. **Stiffness is measured by the Young Modulus - the higher the value, the stiffer the material**. Eg. Helmets.
- **Tough** - materials are really **difficult to break**. **Really tough materials can absorb a lot of energy so are very difficult to break**. Eg. Polymers.

Stress-strain graphs for **ductile** materials **curve**. A straight line shows it obeys **Hookes law**, the **limit of proportionality (P)** is the point where the graph starts to curve, the **elastic limit (E)** is where the material wouldnt return to its original length and the **yield point (Y)** is where the material starts to stretch without any extra load.

Velocity - Time Graphs

The **gradient** of a **Velocity-Time graph** gives you the **acceleration**. The **distance travelled = area under the graph**. Non uniform acceleration (not constant, changing) is a curve on a Velocity-Time graph.

Displacement - Time Graphs

Acceleration means a **curved Displacement-Time Graph**. Different acceleration have different gradients, **bigger** accelerations have **steeper** gradients. **Decreasing** acceleration has the curve going the other way. The **gradient** of a Displacement-Time graph gives you the **velocity** and its the same with **curved lines**, you just have to draw a **tangent**.

velocity = change in displacement / time taken

Streamlines and Flow

Streamlines are **stable** flowlines. A flowline is the **path** that a particular **fluid** element takes.

Streamlines are **parallel** in **laminar flow**, this usually occurs when a fluid is flowing **slowly**.

Flowlines are **unstable** in **turbulent flow**, this usually occurs when a fluid is flowing **quickly**. In turbulent flow, the fluid often moves around in **miniature whirlpools** - called **eddy currents**.

Both types of flow are used in **manufacturing**. Laminar flow, smooth flow is used in **pipes**. Turbulent flow, mixed flow is used in **mixing chemicals**.

Viscous drag is the **force of friction** produced by a flowing fluid. Friction **opposes motion**, so the force acts to **slow the flow**. The size of the force depends on the **viscosity** of the fluid - the higher the viscosity, the larger the force. **Viscous drag** is much larger when the flow is **turbulent**.

Viscosity

Rate of flow depends on **viscosity**. The **higher the viscosity** of a fluid, the **slower its rate** of flow. **Viscosity** depends on **temperature**. The viscosity of most fluids decreasess as the temperature increases, fluids generally **flow faster** it they're **hotter**.

Rate of flow = Volume moved / time taken

Viscous drag acts on objects **moving through fluids**. You can calculate the force due to viscous drag on a sperical object moving through a fluid using **stokes law** -

F = 6 (pi) n r v

(n = viscosity (Nsm-2), r = radius (m), v = velocity (ms-1)

(pi) is the mathematical symbol and is equal to 3.14159.

Fluids exert **upthrust** on **immersed objects**.

Upthrust = weight of fluid displaced.