

NATURAL SCIENCE SOLUTION

Accelerating Academic Skills



SUMMARY NOTES (EDEXCEL AS PHYSICS UNIT-1)

Topics:

1. **Vector and Scalar**
2. **Motion of a particle (Kinematics)**
3. **Material**
4. **Fluid**

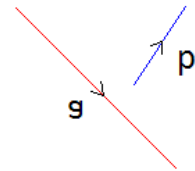
“Knowing the path is good but not enough, walking the path with determination leads to destiny”

Vectors and Scalars

Vector:

A vector is a physical quantity that has both magnitude (size) and direction.

Examples of Vectors: Displacement, velocity, force, acceleration and momentum.



Scalar:

A scalar is a physical quantity that has magnitude only (it doesn't act in a certain direction).

Examples of Scalars: Distance, speed, energy, power, pressure, temperature and mass.

Vectors addition/resultant vector:

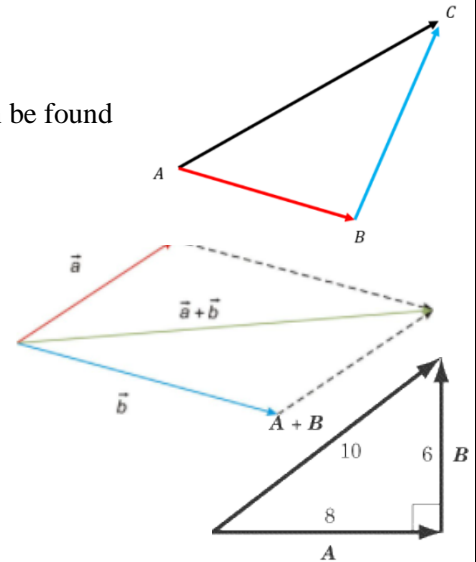
1. Vectors are added by joining **head to tail** rule and the **resultant** can be found by using **scaled diagram** or **sin and cosine** rule.

Vector \vec{AC} is the resultant vector of \vec{AB} and \vec{BC} vectors.

2. If two vectors are given the resultant can also be found by **joining the tails of the given vectors** and **completing the parallelogram**.

Vector $\vec{a} + \vec{b}$ is the resultant vector of \vec{a} and \vec{b} .

3. If two vectors are **perpendicular** the resultant is found by using **Pythagoras theorem**.



Sine and Cosine Rules:

The sine rule;

$$\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$$

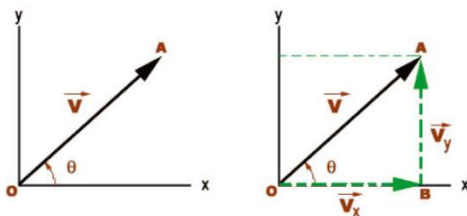
The Cosine rule;

$$\begin{aligned} a^2 &= b^2 + c^2 - 2bc \cos A \\ b^2 &= a^2 + c^2 - 2ac \cos B \\ c^2 &= a^2 + b^2 - 2ab \cos C \end{aligned}$$

The sine and the cosine rules can be used to find the resultant vector \vec{AC}

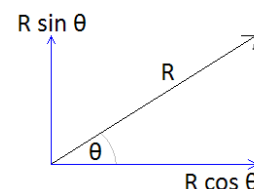
Resolving Vectors:

A vector can be broken down or *resolved* into its vertical and horizontal components.



$$V_x = V \cos \theta$$

$$V_y = V \sin \theta$$



The two components can also be drawn with the tail of the given vector (**$R \sin \theta$ and $R \cos \theta$**).

Use of sin and cosine depends on the angle given in the diagram.

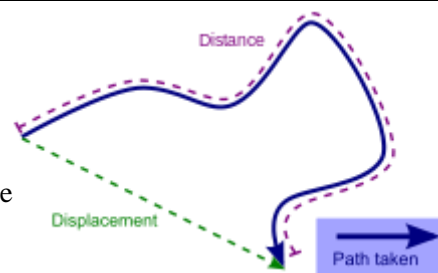
Motion of particle

Distance:

Distance is a scalar quantity. It is a measure of the total length you have moved.

Displacement:

Displacement is a vector quantity. It is a measure of how far you are from the starting position. (See the figure above)



(Distance and Displacement are measured in metres, m)

Speed:

Speed is a measure of how the distance changes with time. Speed is a scalar quantity.

$$\text{speed} = \frac{\text{Distance}}{\text{Time}} \quad v = \frac{s}{t}, \text{ Where } s \text{ is the distance.}$$

Velocity:

Velocity is measure of how the displacement changes with time. Velocity is a vector quantity.

$$\text{Velocity} = \frac{\text{Displacement}}{\text{Time}} \quad v = \frac{s}{t}, \text{ Where } s \text{ is the displacement.}$$

(Speed and Velocity are measured in metres per second, m/s or more appropriately ms⁻¹)

Acceleration:

Acceleration is the rate at which the velocity changes. Since velocity is a vector quantity, so is acceleration.

$$a = \frac{(v-u)}{t} \quad \text{OR} \quad a = \frac{\Delta v}{\Delta t}$$

- a positive acceleration means an increase in the velocity/speeding up
- a negative acceleration means a decrease in the velocity/slowng down

(Acceleration is measured in metres per second squared, m/s² or more appropriately ms⁻²)

Uniform Acceleration:

In this situation the acceleration is constant – the velocity changes by the same amount each unit of time. For example: If acceleration is 3ms⁻², this means the velocity increases by 3ms⁻¹ every second.

Time (s)	0	1	2	3	4	5
Velocity (ms ⁻¹)	0	3	6	9	12	15
Acceleration (ms ⁻²)		3	3	3	3	3

Non-Uniform Acceleration:

In this situation the acceleration is changing – the velocity changes by a different amount each unit of time.

Time (s)	0	1	2	3	4	5
Velocity (ms ⁻¹)	0	2	6	10	18	28
Acceleration (ms ⁻²)		2	4	6	8	10

Graphs and calculation:

There are two types of calculations we do in A level. Finding the gradient of the graph and the area under the given graph. Both the gradient and the area represent some quantities. For example.

1. Gradient of distance-time/ displacement-time graph is speed/velocity.
2. Gradient of velocity-time graph is acceleration.
3. Area under speed-time/velocity time graph is distance/displacement.

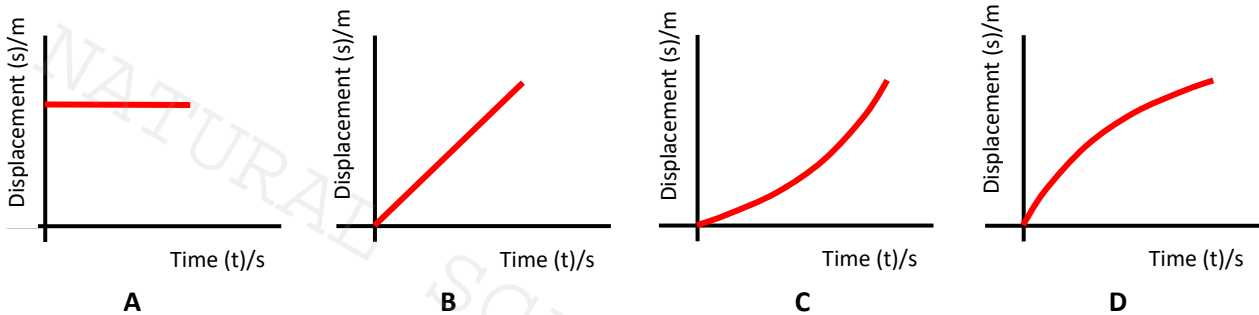
Displacement-Time Graphs/Distance-Time Graph:

Graph A: Horizontal line (zero gradient) the object is rest/stationary.

Graph B: Straight line with positive gradient, the object is moving at constant speed/uniform motion.

Graph C: A curve with increasing gradient, the object is accelerating/speeding up.

Graph D: A curve with decreasing gradient, the object is decelerating/slowing down.



Remember: **Gradient** of distance-time/ displacement-time graph is **speed/velocity**.

Velocity-Time Graphs/Speed-Time Graph:

Graph A: Horizontal line above the time axis (zero gradient) the object is moving at constant speed/uniform motion.

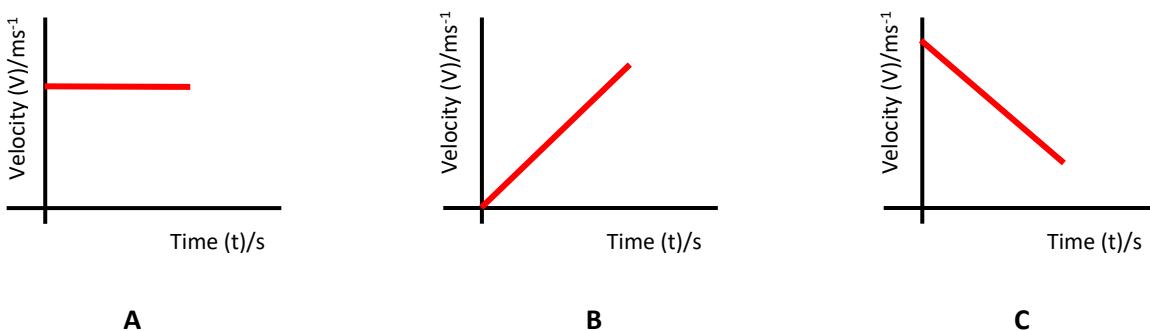
Graph B: Straight line above the time axis with positive gradient, the object is accelerating/speeding up (**the speed is increasing at constant rate/uniformly accelerated motion**).

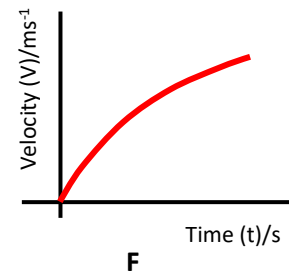
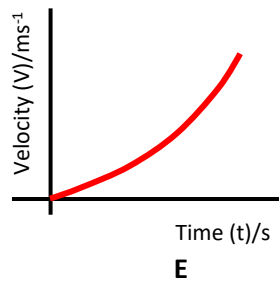
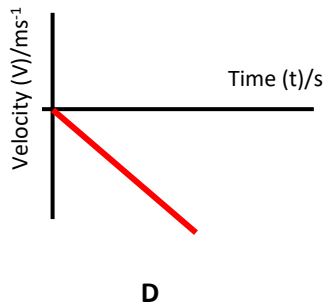
Graph C: Straight line above the time axis with negative gradient, the object is decelerating/slowing down (**the speed is decreasing at constant rate/uniformly decelerated motion**).

Graph D: Straight line below the time axis with negative gradient, the object is accelerating/speeding up but in opposite direction. (**the speed is increasing at constant rate/uniformly accelerated motion in opposite direction**).

Graph E: A curve with increasing gradient, speed/velocity is increasing with **increasing rate (increasing acceleration)**.

Graph F: A curve with decreasing gradient, speed/velocity is increasing with **decreasing rate (decreasing acceleration)**.





Remember: *Gradient* of speed-time/velocity-time graph is **acceleration**.
Area under speed-time/velocity-time graph is **distance/displacement**.

Equations of Motion (SUVAT):

Defining Symbols:

The variables associated with uniform accelerated motion.

Displacement	= s	m
Initial Velocity	= u	m/s (ms ⁻¹)
Final Velocity	= v	m/s (ms ⁻¹)
Acceleration	= a	m/s ² (ms ⁻²)
Time	= t	s

First Equation: $v = u + at$

Second Equation: $s = \frac{1}{2}(u + v)t$

Third Equation: $v^2 = u^2 + 2as$

Fourth Equation: $s = \frac{1}{2}(u + v)t$

Note: If you use any of the equation to solve a given problem, you assume that *the motion is with UNIFORM ACCELERATION. (Assumption)*

Free Fall Motion:

Acceleration Due To Gravity/Gravitational field strength:

Ignoring air resistance, because of the force of gravity (**weight of the object**), a falling object accelerates towards the Earth.

The size of this acceleration **does not depend on mass**, so a **feather and a bowling ball accelerate at the same rate**. On the Moon they hit the ground at the same time, on Earth the resistance of the air slows the feather more than the bowling ball.

Near the surface of the Earth the gravitational field strength is $g = 9.81 \text{ Nkg}^{-1}$. This is also the acceleration a free-falling object would have on Earth. In the equations of motion, $a = g = 9.81 \text{ ms}^{-2}$.

Mass is a property that tells us how much matter it is made of. **(Mass is measured in kilograms, kg).**

Weight is a force caused by gravity acting on a mass: **weight = mass x gravitational field strength**

$$w = mg$$

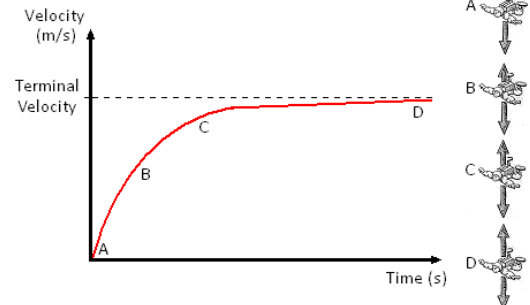
Weight is measured in Newtons, N (the SI Unit)

Note: acceleration due to gravity always acts downward. *Its graph is at -9.81ms^{-2}*

Terminal Velocity:

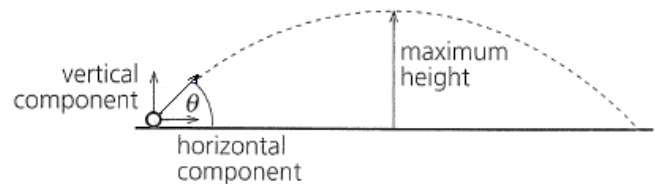
If an object starts to fall from some height, it will accelerate towards the ground because of its weight (due to the Earth's gravity). Its velocity will increase as it falls. After a while the drag force (air resistance) starts acting on the object.

The drag force increases with the speed. Eventually the air resistance will balance the weight of the object. This means there will be no overall/net force which means there will be no acceleration. The object stops accelerating and has reached its terminal velocity.



Projectiles:

If an object is kicked or thrown making some angle with the horizontal, **or** thrown horizontally from some height. The object follows a parabolic path like that shown to the right.



The initial velocity of u , can be resolved into its horizontal and vertical components. The horizontal component is $u_h = u \cos \theta$ and the vertical component is $u_v = u \sin \theta$. The projectile questions can be solved using the equations of motion (SUVAT) we already know.

Note:

To solve horizontal motion, we use only one equation. i.e. $S = ut$, where u is the horizontal component.

To solve vertical motion, we use SUVAT equations, where u is the vertical component.

Time, Range, and height of a Projectiles:

If launch and land positions of a projectile are at the same level, the height, time, and the range can directly be found as follows;

Formula for time to reach maximum height:
$$t = \frac{u \sin \theta}{g}$$

Formula for Range:
$$R = \frac{u^2 \sin 2\theta}{g}$$

Formula for maximum height
$$h = \frac{u^2 \sin^2 \theta}{2g}$$

Newton's 1st Law:

An object will remain at rest, or continue to move with uniform velocity in straight line, unless it is acted upon by an external force or resultant/net/unbalanced force.

Newton's 2nd Law:

If there is a resultant/net/unbalanced force, there has to be some acceleration in the same direction as that of the resultant/net/unbalanced force. The acceleration is proportional to the net force and inversely proportional to the mass of the object.

$$F = ma$$

Newton's 2nd Law in terms of momentum:

The rate of change of an object's linear momentum is directly proportional to the resultant external force. The change in the momentum takes place in the direction of the force.

Newton's 3rd Law:

When body A exerts a force on body B, body B exerts an equal but opposite force on body A.

Newton's 3rd Law pair of forces:

Two forces are called Newton's 3rd law pair of forces if;

1. The forces have same magnitude.
2. They are of same type forces.
3. The forces act in opposite direction.
4. The forces act on different objects.

The first two points are similarities and the rest two are differences between the Newton's 3rd law pair of forces.

Momentum

Momentum:

The momentum of an object is given by the equation: *momentum = mass x velocity* OR $p = mv$
 Since it depends on the velocity and not speed, momentum is a vector quantity.

If we assign the right direction to be positive, the particle moving right would have a positive momentum. So, an object moving left will have negative velocity so it would have negative momentum.

Momentum is measured in kilogram metres per second, kg m/s or kg m s⁻¹.

Ns is also another unit of the momentums

Momentum and force:

The rate of change of momentum is force.
$$F = \frac{mv - mu}{t}$$

Gradient of momentum-time graph gives force:

If a constant force acts for time t then Impulse is defined as;

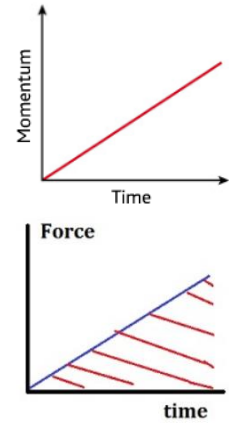
Impulse = Force X time OR $I = Ft$

Change in momentum is also called impulse.

$I = mv - mu$

Impulse is measured Ns.

Area under force-time graph gives Impulse:



Momentum Conservation:

In an isolated system (if no external forces are acting) the linear momentum is conserved.

We can say that: ***the total momentum before = the total momentum before***

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

Explosion:

A particle splits into two or more pieces (fragments).

In A-level we only consider splitting a single particle into two pieces (fragments).

In order to conserve momentum the two pieces always move in opposite direction.

momentum of fragment A = - momentum of fragment B

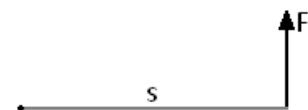
$m_A v_A = - m_B v_B$

Moment

Moments:

The moment of a force is its turning affect about a fixed point (pivot).

The magnitude of the moment is given by:



moment = force x perpendicular distance from force to the pivot

$moment = FS,$

where S is the perpendicular distance from the pivots

***Note: The above formula is used only if the force is perpendicular to the distance.
The SI unit of moment is Nm.***

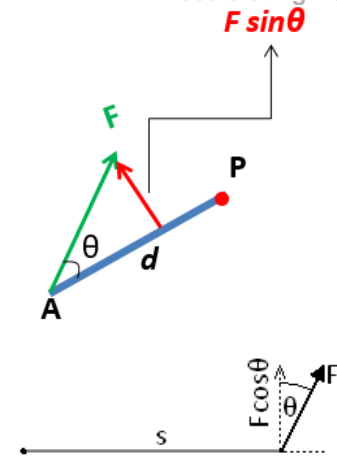
Force at an angle:

If the force acts at some angle then we resolve the force or the distance into its component. As per given figure P is the pivot, the component of the force (red arrow) is $F \sin \theta$. The moment can be found by using;

$$\text{Moment} = F \sin \theta \times d$$

Sometimes we use cos component; (it depends how the angle is given)

$$\text{moment} = F \cos \theta \cdot s$$



Couples and moment due to couple:

A couple is a pair of equal forces acting in opposite directions.

If a couple acts on an object it rotates in about its centre. The moment of a couple is also called torque.

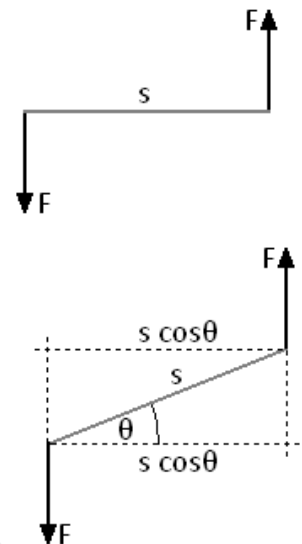
The torque is calculated as: **torque = force x perpendicular distance between forces.**

$$\text{torque} = Fs$$

In the diagram to the right we need to calculate the perpendicular distance, $s \cos \theta$.

So in this case: $\text{torque} = Fs \cos \theta$

Torque is also measured in Newton metres, Nm



Centre of Gravity:

The centre of gravity of an object is the point where all the weight of the object appears to act.

We can represent the weight of an object as a downward arrow acting from the centre of mass or gravity. This can also be called the line of action of the weight.

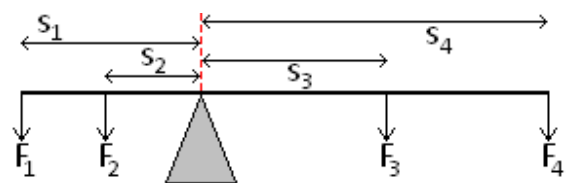
Balancing: Sum of clockwise moments = sum of anticlockwise moments

If the seesaw to the left is balanced then the clockwise moments must be equal to the anticlockwise moments.

$$F_3 s_3 + F_4 s_4 = F_1 s_1 + F_2 s_2$$

Stability:

The stability of an object can be increased by lowering the centre of mass and by widening the base. An object will topple over if the line of action of the weight falls outside of the base.



Work, Power, and Energy

Work Done:

In Physics work is done when a force moves through a displacement/distance.

$$\text{Work Done} = \text{Force} \times \text{Distance moved in the direction of the force} \quad W = Fs$$

The above formula is used only if constant force acts in the same direction as that of the displacement/distance.

If there is some angle θ between the 'line of action' of the force' and the displacement.

Remember, to calculate the work done we must find the component of the force in the direction of distance. which is $F\cos\theta$. Now the work can be calculated as follows,

$$\boxed{\text{Work Done} = Fs \cos \theta}$$

Work Done is measured in joules, J (The work done is transferred as energy

Power:

The rate of energy transfer or work done per unit time is called power.

Power is a measure of how quickly something can transfer energy. Power is linked to energy by the equation:

$$\boxed{\text{Power} = \frac{\text{Energy Transferred}}{\text{time taken}}} \quad \boxed{P = \frac{\Delta E}{\Delta t}}$$

But Work Done = Energy Transferred.

$$\text{Power} = \frac{\text{Work Done}}{\text{time taken}} \quad P = \frac{\Delta W}{\Delta t}$$

Power can also be found in terms of force and instantaneous velocity.

$$P = Fv$$

Power is measured in Watts (W).

Energy:

We already know that energy appears in a number of different forms and may be transformed from one form to another. But what is energy? **Energy is the ability to do work.**

We can say that the work done is equal to the energy transferred

$$\text{Work done} = \text{energy transferred} \quad W = E$$

All types of energies are measured in joule (J).

Energy Transformation/Law of conservation of energy:

Energy cannot be created or destroyed, it only transforms from one type/form to another.

Eg. a speaker transforms electrical energy to sound energy with the energy itself is being transferred to the surroundings.

Kinetic Energy:

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

Energy due to motion of an object.

If work is done on an object due to which object starts moving then, the work has transformed into kinetic energy.

Work done = gained in kinetic energy

If a moving object comes to rest due to some opposing force, the force has done some work to stop the object...

lose in kinetic energy = work done against resistive force

Potential Energy:

Energy due to Position of an object against some force.
There are different types of potential energies...

1. Gravitational Potential Energy:
2. Elastic Potential Energy: (We'll discuss in strength of material topic/unit-1)
3. Electric Potential Energy: (We'll discuss in electricity topic/unit-2)

I.e. if an object moves against some force an energy is stored in the object this stored energy is called potential energy.

Gravitational Potential Energy:

Energy due to Position of an object in a gravitational field. In case of the Earth, **the energy stored in an object due to some height.**

$$\Delta E_p = mg\Delta h$$

Work Done against....

In many situations gravitational potential energy is converted into kinetic energy, or vice versa. Some everyday examples of this are:

Swings and pendulums:

If we pull a pendulum back we give it GPE, when it is released it falls, losing its GPE but speeding up and gaining KE. When it passes the lowest point of the swing it begins to rise (gaining GPE) and slow down (losing KE).

Bouncing or throwing a ball:

Holding a ball in the air gives it GPE, when we release this it transforms this into KE. As it rises it loses KE and gains GPE.

Slides and ramps:

A ball at the top of a slide will have GPE. When it reaches the bottom of the slide it has lost all its GPE, but gained KE.

In each of these cases it appears as though we have lost energy.

1. The pendulum doesn't swing back to its original height.
2. The ball never bounces to the height it was released from.

This is because work is being done against resistive forces Such as air drag or drag in case of pendulum and bouncing ball and friction during motion on a ramp (inclined plane).

Efficiency: (it gives idea how useful some system or machine is.)

Ratio between **output energy** to the **input energy**.

$$\text{Efficiency (E)} = \frac{\text{Input energy}}{\text{output energy}}$$

Or

Ratio between **output power** to the **input power**.

$$\text{Efficiency (E)} = \frac{\text{Input power}}{\text{output power}}$$

Efficiency has no units, it is a ratio of two similar quantities.

Material

Hooke's Law:

"Within the limit of proportionality, the elastic restoring force is directly proportional to the extension of the spring"

We can write this in equation form:

$$F \propto \Delta x \quad \text{or} \quad F = k\Delta x$$

Here k is the constant that shows us how much extension in length we would get for a given force. It is called spring constant or stiffness.

rearrange Hooke's Law we get: $k = \frac{F}{\Delta x}$

The SI unit of K is Nm^{-1}

The Stiffness:

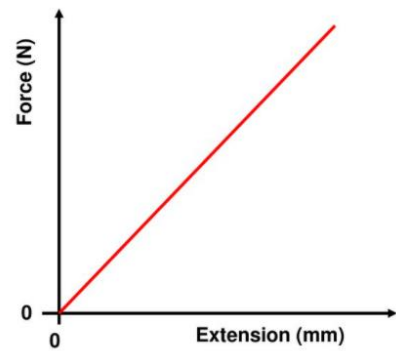
The spring constant gives us an idea of force needed to extend/compress a spring. **This is also known as the stiffness of the material.**

From the linear section of the force extension graph, the gradient gives the stiffness or spring constant.

$$\text{Gradient} = \text{stiffness}; \quad k = \text{gradient}$$

If extension against force graph is given then;

$$k = 1/\text{gradient}$$



Springs in Series and parallel:

If two springs are connect in series the net stiffness is also decreased. I.e. the combination is easy to stretch.

The net stiffness is given by;

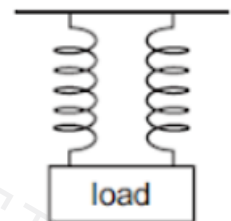
$$\frac{1}{k_T} = \frac{1}{k_A} + \frac{1}{k_B}, \text{ if the springs are the same i.e. } k_A = k_B;$$

$$k_T = \frac{k}{2}$$

If two springs are connect in Parallel the net stiffness is increased. I.e. the combination is difficult to stretch.

$$k_T = k_A + k_B \text{ if the springs are the same i.e. } k_A = k_B;$$

$$\text{So, } k_T = 2k$$



Energy Stored/Elastic Strain Energy:

When a material is deformed within the limit (stretched /compressed spring/stretched wire etc.), energy is stored within the material.

The energy stored in a deformed material is equal to the work done on it.

$$E = \frac{1}{2} F \Delta x \quad E = \frac{1}{2} k \Delta x^2$$

Tensile Stress (σ):

Tensile stress is defined as the force applied per unit cross-sectional area (which is the same as pressure).

This is represented by the equations:

$$\text{stress} = \frac{F}{A} \quad \sigma = \frac{F}{A}$$

The SI unit of the stress is $\text{Nm}^{-2} = \text{Pa}$ (pascal)

Tensile Strain, (ϵ):

Tensile strain is measure of change in length per unit length.

This is represented by the equations:

$$\text{strain} = \frac{\Delta l}{l} \quad \epsilon = \frac{\Delta l}{l}$$

Strain has no units, it is a ratio of two lengths

Stress and strain:

A tensile stress will cause a tensile strain. Or *Stress causes Strain.*

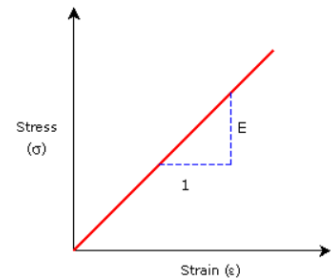
“Within the limit of proportionality, the stress is directly proportional to the strain”

The stress-strain graph is a straight line passing through origin.

The gradient of stress-strain graph is a constant called Young's modulus.

$$Y = \frac{\sigma}{\epsilon} \quad Y = \frac{Fl}{A\Delta l}$$

The SI unit of the Young's modulus is $\text{Nm}^{-2} = \text{Pa}$ (pascal)



Energy density/(Toughness):

Amount of energy stored per unit volume is called energy density. Also known as Toughness.

It is given by the equation: $E = \frac{1}{2} \text{stress} \times \text{strain}$

$$E = \frac{1}{2} \frac{F}{A} \frac{\Delta l}{l}$$

The area under a stress-strain graph gives us the energy density or energy per unit volume.

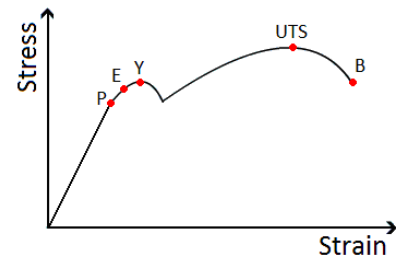
Elasticity: Property of regaining original shape after removal of deforming force. A material can be described as elastic if it returns to its original length when the stress is removed. They obey Hooke's Law as extension is proportional to the force applied.

Limit of Proportionality: Up to this point the material obeys Hooke's Law; extension is proportional to the force applied. The point P is the limit of proportionality.

Elastic Limit: The elastic limit is the final point where the material will return to its original length if we remove the stress which is causing the extension (take the masses off). There is no change to the shape or size of the material.

We say that the material acts plastically beyond its elastic limit.
The point E is the elastic limit.

Yield Point: Beyond the elastic limit a point is reached where small increases in stress cause a massive increase in extension (strain). The material will not return to its original length and behaves like a plastic.
The point Y is the yield point.



Plasticity: Materials extend in length when a stress is applied to them (masses hung from them). A material can be described as plastic if it does not return to its original length when the stress is removed. There is a permanent change to its shape.

Breaking Stress – Ultimate Tensile Strength, (UTS): This is the maximum amount of stress that can be applied to the material without making it break. It is sometimes referred to as the strength of the material. It determines the strength of a material. (Look UTS in the graph above)

Breaking Point, (B): This is (surprisingly?) the point where the material breaks.

Stiffness: If different materials were made into wires of equal dimensions, the stiffer materials bend the least. **Stiff materials have low flexibility**

Ductility: Material that can undergo a large plastic deformation under **tensile force**. It can pull and drawn into wire without breaking. They have high energy density (toughness). Such as Copper, Aluminium etc.

Malleable: Material that can undergo a large plastic deformation under compressive force. It can hammered into thin sheet without breaking. They have high energy density (toughness). Such as Gold, Copper, Aluminium etc.

Brittle: Materials that are very stiff and undergo little or no plastic deformation before fracture (snapping). Such as Glass, pottery and chocolate are examples of brittle materials.

Hard: Material that are difficult to indent or scratch.. Such as Copper, Aluminium etc.

Fluid

Density, ρ : Density gives idea about an object that how heavy an object is?

Density is the **mass per unit volume of a material**, it is given by the equation:

$$\rho = \frac{m}{V}$$

Density is measured in kilograms per metre cubed, kg/m^3 or kg m^{-3}

Upthrust, U:

The upward force exerted on an object immersed in a fluid, equal to the weight of the fluid displaced; denoted by, U

$$U = \text{weight of displaced fluid} \qquad U = \rho \times v \times g$$

Where, ρ is the density of the fluid, v is the volume of the object, and g is the gravitational field strength.

Laminar Flow:

Smooth fluid flow in which layers have a **constant velocity**. In general, laminar flow occurs at lower speed. The lines of laminar fluid flow are called **streamlines**.

Turbulent Flow:

Irregular, chaotic fluid flow in which **eddies** form. The fluid **velocity is not constant** over time.

Viscosity:

A measure of resistance of a fluid flow. Viscosity is due to frictional forces b/w the molecules of the fluid.

Viscosity has a direct effect on the rate of flow of the fluid. **In general viscosity decreases with the increase of temperature.**

Viscous Drag:

The friction force acting to oppose motion through fluid. **The viscous drag increases with speed through the fluid.**

If an object **falls** through a fluid/liquid, **upthrust and drag act upward**. When the weight exactly balance the sum of the upthrust and the drag (**$W = U + D$**). The velocity of the falling object remains constant. This velocity is called **terminal velocity**.

If an object **rises** upward through a fluid/liquid, **upthrust acts upward drag acts downward**. When the upthrust exactly balance the sum of weight and the drag (**$U = W + D$**). The velocity of the rising object remains constant. This velocity is called **terminal velocity**.

Stokes' Law: The drag force acting on a small sphere moving slowly in fluid is given by;

$$F = 6\pi\eta rv$$

Where, η = Coefficient of viscosity, r = radius of the sphere, v = velocity of the sphere

The drag force is proportional the radius and velocity of the sphere.

ALL THE BEST