PHYSICS SS 2
1ST TERM NOTE 2024/2025 SESSION

SCALAR AND VECTOR QUANTITIES

*Concept of scalars as physical quantities with magnitude and no direction; Mass, distance, speed and time as examples of scalars.
*Concept of vectors as physical quantities with both magnitude and direction. Weight, displacement, velocity, and acceleration as examples of vectors.
*Vector representation
*Resolution of vectors
*Resultant and equilibrant of forces. Obtain the resultant of two velocities analytically and graphically
*Parallelogram of forces. Triangle of forces should be treated experimentally.
*Resultant velocity using vector representation; Obtain the resultant of two velocities analytically and graphically
Concept of direction as a way of locating a point (bearing) Use of compass and a protractor.

EQUILIBRIUM OF FORCES

*Concept of equilibrium of forces
*Condition of equilibrium

i. parallel coplanar forces
ii. non- parallel coplanar forces

*Stability of a body
*Moment of force
*Principle of moments,
*couple and its applications
*Moment of Torque; Simple treatment of a couple, e.g. turning of water tap, corkscrew, etc.
*Centre of gravity and; Treatment should include stable, unstable and neutral equilibria

NEWTON'S LAWS MOTION

*First Law: Inertia of rest and inertia of motion; Distinction between inertial mass and weight
*Second Law: Force, acceleration, momentum and impulse; Use of timing devices e.g. ticker-timer to determine the acceleration of a falling body and the relationship when the accelerating force is constant.
*Third Law: Action and reaction; Applications: recoil of a gun, jet and rocket propulsions.
*Linear momentum and its conservation. Collision of elastic bodies in a straight line

PROJECTILE AND FALLING BODIES

*Concept of projectiles as an object thrown/released into space (falling bodies)
* Projection at an angle from a height
*Applications of projectiles in warfare, sports etc.
*Simple problems involving range, maximum height and time of flight may be set.

SIMPLE HARMONIC MOTION

*Illustration, explanation and definition of simple harmonic motion (S.H.M.); Use of a loaded test-tube oscillating vertically in a liquid, simple pendulum, spiral spring and bifilar suspension to demonstrate simple harmonic motion.
*Definition of Speed and acceleration of S.H.M; Relate linear and angular speeds, linear and angular accelerations.

*Definitions of Period, frequency and amplitude of a body executing S.H.M; Experimental determination of ‘g’ with the simple pendulum and helical spring. The theory of the principles should be treated but derivation of the formula for ‘g’ is not required.
*Energy of S.H.M.
*Forced vibration and resonance; Simple problems may be set on simple harmonic motion. Mathematical proof of simple harmonic motion in respect of spiral spring, billiard suspension and loaded test-tube is not required.

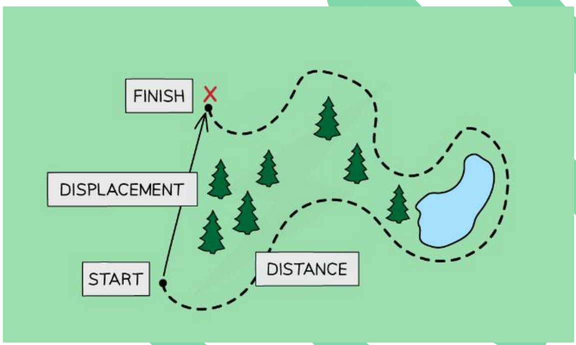
MACHINES

*Types of machines: Levers, pulleys, inclined plane, wedge, screw, wheel and axle, gears: *The force ratio (F.R.), mechanical advantage (M.A.), velocity ratio (V.R.) and efficiency of each machine.
*Identification of simple machines that make up a given complicated machine e.g. bicycle.
*Effects of friction on machines, Reduction of friction in machines.
*Simple calculations

1. SCALARS & VECTORS

What are Scalar & Vector Quantities?

- A **scalar** is a **quantity** which **only** has a magnitude (size)
- A **vector** is a quantity which has **both** a magnitude and a direction
- For example, if a person goes on a hike in the woods to a location which is a couple of miles from their starting point
    - As the crow flies, their **displacement** will only be a few miles but the **distance** they walked will be much longer



Displacement is a vector while distance is a scalar quantity

- **Distance** is a scalar quantity because it describes how an object has travelled overall, but not the direction it has travelled in
- **Displacement** is a vector quantity because it describes how far an object is from where it started and in what direction
- There are a number of common scalar and vector quantities

Scalars and Vectors Table

SCALARS	VECTORS
DISTANCE	DISPLACEMENT
SPEED	VELOCITY
MASS	ACCELERATION
TIME	FORCE
ENERGY	MOMENTUM
VOLUME	
DENSITY	
PRESSURE	
ELECTRIC CHARGE	
TEMPERATURE	

Combining Vectors

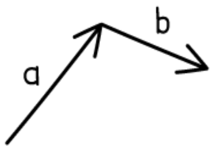
- **Vectors** are represented by an arrow
  - The arrowhead indicates the **direction** of the vector
  - The length of the arrow represents the **magnitude**
- Vectors can be combined by **adding** or **subtracting** them from each other
- There are two methods that can be used to combine vectors: the **triangle method** and the **parallelogram method**
- To combine vectors using the triangle method:
  - **Step 1:** link the vectors head-to-tail
  - **Step 2:** the resultant vector is formed by connecting the tail of the first vector to the head of the second vector
- To combine vectors using the parallelogram method:
  - **Step 1:** link the vectors tail-to-tail
  - **Step 2:** complete the resulting parallelogram
  - **Step 3:** the resultant vector is the diagonal of the parallelogram
- When two or more vectors are added together (or one is subtracted from the other), a single vector is formed and is known as the **resultant** vector

Vector Addition

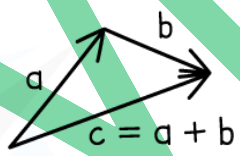
Draw the vector c = a + b

TRIANGLE METHOD

STEP 1: LINK THE VECTORS HEAD–TO–TAIL

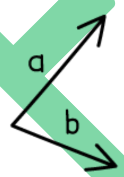


STEP 2: FORM THE RESULTANT VECTOR FROM LINKING THE TAIL OF a TO THE HEAD OF b

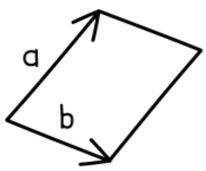


PARALLELOGRAM METHOD

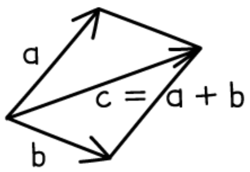
STEP 1: LINK THE VECTORS TAIL–TO–TAIL

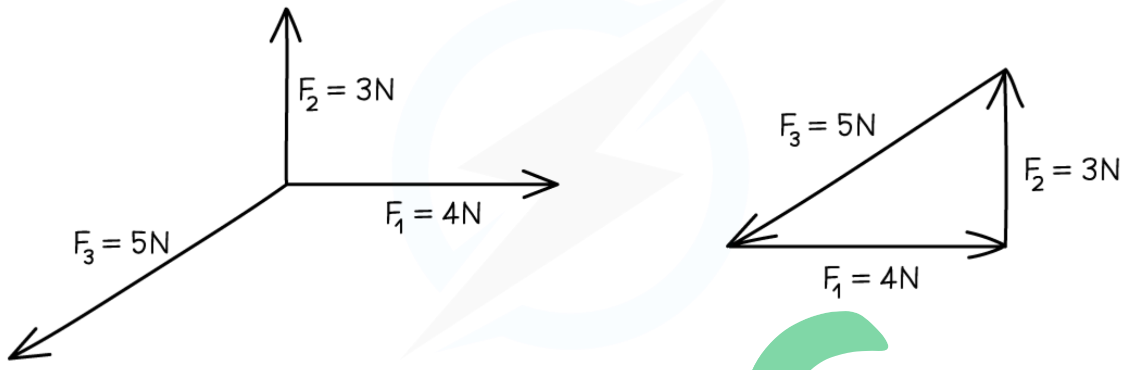


STEP 2: COMPLETE THE RESULTING PARALLELOGRAM



STEP 3: THE RESULTANT VECTOR IS THE DIAGONAL OF THE PARALLELOGRAM

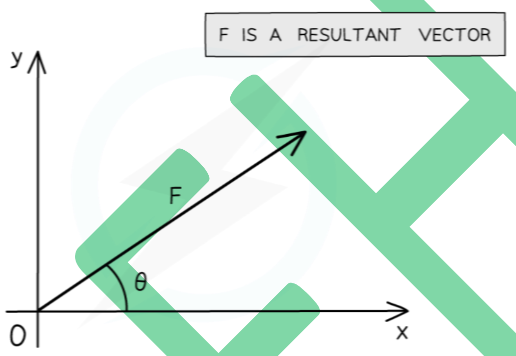




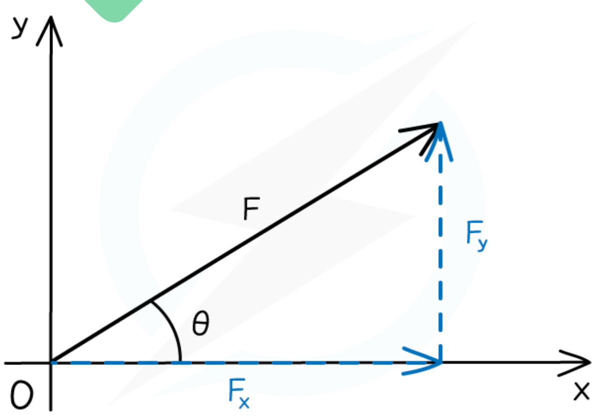
If three forces acting on an object are in equilibrium; they form a closed triangle

Resolving Vectors

- Two vectors can be represented by a single **resultant vector** that has the same effect
- A single resultant vector can be resolved and represented by **two** vectors, which in combination have the same effect as the original one
- When a single resultant vector is broken down into its **parts**, those **parts** are called components
- For example, a force vector of magnitude F and an angle of θ to the horizontal is shown below



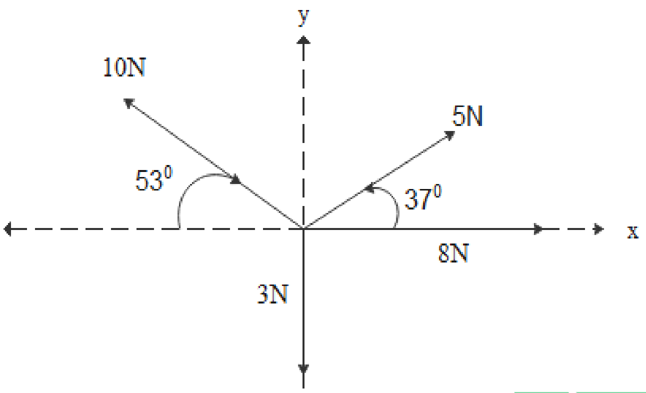
- It is possible to **resolve** this vector into its **horizontal** and **vertical** components using trigonometry



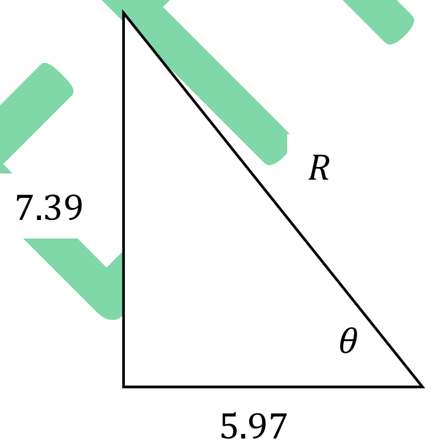
- For the **horizontal component**, $F_x = F\cos\theta$
- For the **vertical component**, $F_y = F\sin\theta$

More than 2 vectors can also be reolved and their resultant gotten as shown below:

Find the resultant of the following forces



$x - componenet$	$y - componenet$
$+5cos37 = +3.99$	$+5sin37 = +2.40$
$-10cos53 = -6.02$	$+10sin53 = +7.99$
$3cos90 = 0.00$	$-3sin90 = -3.00$
$+8cos0 = +8.00$	$8sin0 = 0.00$
5.97	7.39



Using Pythagoras theorem

$R^2 = 7.39^2 + 5.97^2$

$R = 9.5N$

$tan\theta = \frac{y}{x}$

$$tan\theta = \frac{7,39}{5.97}$$

$$\theta = 51.1°$$

2. EQUILIBRIUM

Equilibrium:
A body is said to be in equilibrium if it does not experience a change in its rest or uniform motion, even under the influence of external forces.
Types of equilibrium:

1. **Stable equilibrium**
2. **Unstable equilibrium**
3. **Neutral equilibrium**

Stable equilibrium:

1. A body is said to be in stable equilibrium if it regains its original position on the removal of the external force after being slightly disturbed by it.
2. A body is said to be in stable equilibrium, if the line joining the centre of gravity and the centre of earth must fall within the base of the body, after being lightly disturbed by it.

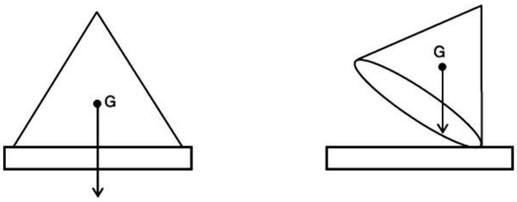
Example:

1. A cone resting on its base.

2. A book lying on a flat surface.

Diagram:

Diagram:



Stable equilibrium of a cone

From the figure, it is clear that the line joining the centre of gravity and the centre of earth falls within the base of the body, even after being lightly disturbed by it. So the cone is in stable equilibrium.

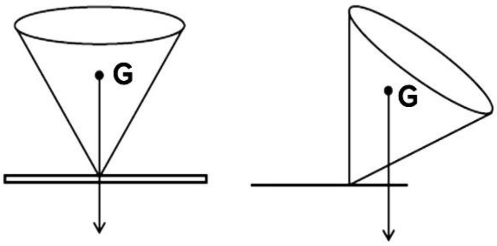
Unstable equilibrium:

1. A body is said to be in unstable equilibrium if it does not regains its original position after being slightly disturbed by an external force.
2. Here the line joining the centre of gravity and the centre of earth falls outside its base, after being lightly disturbed by an external force.

Example:

1. A cone resting on its apex.
2. A bottle standing on the edge of its mouth.

Diagram:



Unstable equilibrium of a resting on its apex

Here the base of the body is small and the top portion is heavier as it raises the height of the centre of gravity from its base.

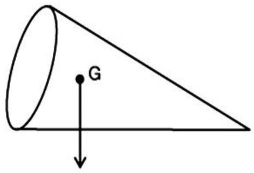
Neutral equilibrium:

A body is said to be in neutral equilibrium when it moves to a new place on the application of an external force and on the removal of the external force the body may or may not come back to its original place, but the height of its centre of gravity from a reference surface remains the same.

Example:

1. A rolling ball.
2. A cone resting on its side.

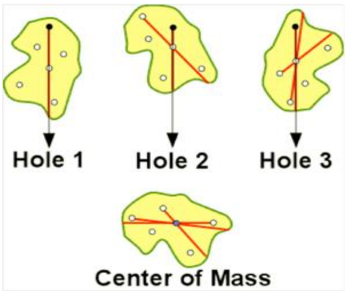
Diagram:



1. In neutral equilibrium the line joining the centre of gravity and the centre of earth falls within the base of the body on the application of an external force.
2. The height of its centre of gravity does not change even after the application of an external force.

Centre of gravity

Centre of gravity is the point through which the resultant weight of a body passes. For uniform bodies, the centre of gravity is usually at the centre of the body. For non-uniform bodies, it can be determined by using a plumb line. To do this, hang the body on a peg through the desired hole. Hang a plumb bob in front. Mark plumb line with marker. Repeat with other holes. Where the lines cross is the centre of gravity (as shown below).



How centre of gravity affects the stability of a body

A body with a low centre of gravity usually is more stable than a body with a higher centre of gravity.

Moment of a force

The moment of a force about a point can be defined as the product of the force and the perpendicular distance from the line of action of the force to that point.

Conditions for equilibrium under the action of non-parallel coplanar forces

1. The vector sum of all the forces acting on the body must be zero i.e the sum of forces in a particular direction is equal to the sum of forces in the opposite direction.

2. The algebraic sum of clockwise moments about a point must be equal to the algebraic sum of anticlockwise moments about the same point. This is referred to as the principle of moments.

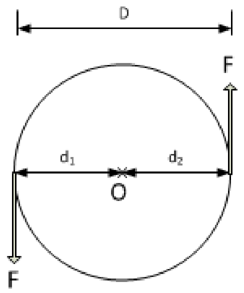
Conditions for equilibrium under action of three non-parallel forces

1. The forces must lie in a plane.
2. Their lines of action must intersect at a common point.

3. The vector representing the three forces can be arranged to form a closed triangle with sides respectively parallel to their directions and proportional in length to the magnitude of the force.

Couples

A couple is a pair of equal parallel forces that are opposite in direction not acting along the same point.



The moment of a couple is simply the product of one of its forces and the perpendicular distance between the forces.

3. NEWTON'S LAWS OF MOTION AND LINEAR MOMENTUM

Isaac Newton proposed three laws of motion which are as follows:

Law 1

A body will remain in its state of rest or uniform motion until an external force acts on it.

Law 2

The time rate of change of momentum is directly proportional the applied force.

Mathematically,

$$F \propto \frac{m(v-u)}{t}$$

$$F = \frac{km(v-u)}{t} = ma$$

$$Ft = km(v-u)$$

So, from the equation above, we can see that impulse is directly proportional to the change in momentum.

Law 3

For every action, there is an equal and opposite reaction.

Applications of Newton's third law of motion

1. Jet and rocket propulsion.
2. Recoil of a gun.
3. A man walking on the ground.
4. Automatic water sprinkler system.

Law of Conservation of linear momentum

In a closed or isolated system, the total momentum before collision is equal to the total momentum after collision.

Types of collisions

We have two types of collisions which are:

i. Elastic collision
ii. Inelastic collision

For elastic collision,

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

For inelastic collision,

$$m_1u_1 + m_2u_2 = v(m_1 + m_2)$$

4. PROJECTILES

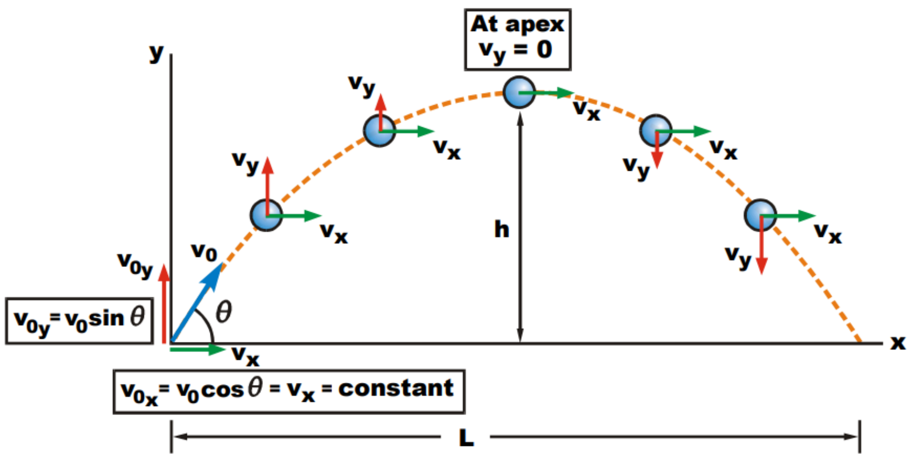
What is a projectile?

A projectile is any object that once projected or dropped continues in motion by its own inertia and is influenced only by the downward force of gravity.

Examples of projectiles in sports include: a thrown basketball, a thrown javelin, a thrown shotput etc.

Examples of projectiles in warfare include: a launched missile, a shot arrow, a shot bullet etc.

The path through which a projectile follows is called a trajectory.



Take note that for a projectile motion, the horizontal component of the velocity remains constant throughout the journey while the vertical component of the velocity changes due to acceleration due to gravity.

Important terms in projectiles

1. Time of flight (T): this is the time taken for the projectile to return back to the same horizontal level from which it was launched.
   Mathematically, time of flight is given as:
   $T = \frac{2Usin\theta}{g}$

2. Maximum height (H): this is the maximum vertical distance as measure from the horizontal plane of projection.
   Mathematically, the maximum height is given as:
   $H = \frac{U^2sin^2\theta}{2g}$

3. Range (R): this is the horizontal distance from the point of projection of the projectile to the point where the projectile hits the projection plane again.
   Mathematically, the range is given as:
   $$R = \frac{U^2sin2\theta}{g}$$

   To obtain maximum range, the angle of projection needs to be $45°$; so maximum range is given as:

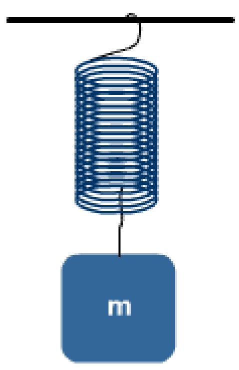
   $$R_{max} = \frac{U^2}{g}$$

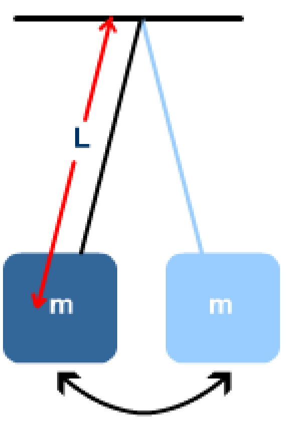
5. SIMPLE HARMONIC MOTION

A body is undergoing SHM when the acceleration on the body is proportional to its displacement, but acts in the opposite direction.

Acceleration is proportional to displacement
$a\,\alpha - s$

There are two common examples of simple harmonic motion, a loaded spring and a simple pendulum.





$$T = 2\pi\sqrt{\frac{m}{k}}$$

$$T = 2\pi\sqrt{\frac{L}{g}}$$

Where $m = mass$, $l = length\ of\ pendulum$, $g = acceleration\ due\ to\ gravity$ and $k = spring\ constant/stiffness$

Condition for SHM

In order for an object to display simple harmonic motion, the resultant force acting on the object must be directly proportional to its displacement from its equilibrium point, and must act towards the equilibrium point - it must act in the opposite direction to the displacement. In equation form, this is:

$$\boldsymbol{F} = -k\boldsymbol{x}$$

In the above equation, $\boldsymbol{F}$ is the resultant force, $\boldsymbol{x}$ is the displacement from equilibrium, and k, is some constant of proportionality that depends on the physical system. By dimensional analysis we can see that k, must have SI units of kgs^{-2}, or Nm^{-1}.

An object undergoing simple harmonic motion oscillates sinusoidally. This motion may be described by the following equation:

$$x = x_0 \cos(\omega t + \phi)$$

Where x_0 and ϕ are constants, and ω is the angular frequency of the oscillations.

Simple Harmonic Motion Formulas

1. General Equation of SHM

Displacement x =A sin (ωt + Φ)

Here (ωt + Φ) is the phase of the motion, and Φ is the initial phase of the motion

2. Angular Frequency (ω)

ω = 2π/T = 2πf

T is the time period

f is the frequency

3. Frequency (f):

Number of oscillations completed in the unit time interval

f = 1/T = ω/2π

4. Time Period (T)

T = 2π/ω

5. Hooke's law

Force (F) = -kx (for small extension x)

k is the spring constant

6. Acceleration

a = $-\omega^2 x = -\omega^2 A \sin(\omega t + \Phi)$

7. Velocity

v = $A\cos(\omega t + \Phi) = \pm\omega\sqrt{A^2 - x^2}$

8. Potential Energy

U = $\frac{1}{2} kx^2$ (as a function of x)

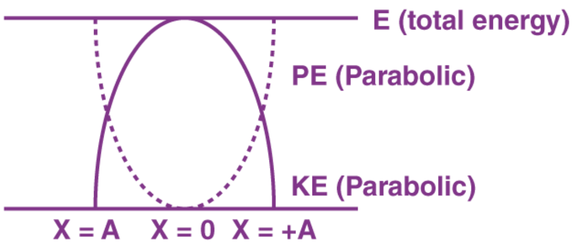
9. Kinetic Energy

K = $\frac{1}{2} m\omega^2(A^2 - x^2)$

K = $\frac{1}{2} k(A^2 - x^2)$

10. Total Energy

E = U+K



E= $\frac{1}{2} m\omega^2 A^2$

6. MACHINES

What is a machine?

A machine is an object or mechanical device that receives an input amount of work and transfers the energy to an output amount of work. For an ideal machine, the input work and output work are always the same. The seven common simple machines are the lever, wheel and axle, pulley, inclined plane, wedge, gears and screw.

Mechanical advantage

Mechanical advantage (force ratio) is the ratio of load to effort.

Mathematically, it is given by:

$$MA = \frac{load}{effort}$$

Velocity ratio

Velocity ratio is a ratio of the distance moved by effort to the distance moved by load.

Mathematically, it is given by:

$$VR = \frac{distance\ moved\ by\ effort}{distance\ moved\ by\ load}$$

Efficiency of a machine

The efficiency of a machine is given by:

$$\in= \frac{MA}{VR} \times 100\%$$

Types of machines

1. Pulleys: A pulley is a simple machine that consists of a wheel with a groove in its rim that holds a rope or cable. It is used to lift or move heavy objects by applying force to the rope, which then pulls the object up or down. Pulleys can be either fixed or movable and can change the direction of the applied force.
   The mechanical advantage of a simple pulley is usually gotten from the number of pulleys.

2. Levers: A lever is a simple machine consisting of a rigid bar that pivots on a fulcrum. It is used to lift or move heavy objects by applying force to one end of the lever, which then rotates around the fulcrum and applies force to the other end. Levers can be used to increase force or distance, and they are commonly found in many tools and machines.
   Levers are generally grouped into three classes namely: first class, second class and third class levers based on the arrangements of the fulcrum, effort and load.

3. Inclined plane: An inclined plane is a simple machine consisting of a flat surface that is tilted at an angle. It is used to lift or move heavy objects by reducing the amount of force needed to lift them vertically. Instead, the object is slid up or down the inclined plane, which requires less force than lifting it straight up. Inclined planes are commonly found in ramps and staircases.
   The velocity ratio of an inclined plane is given as:
   $VR = \frac{1}{sin\theta}$

4. Screw: A screw is a simple machine consisting of an inclined plane wrapped around a cylinder or cone. It is used to lift or move objects by rotating the screw, which then moves the object up or down the thread. Screws can be used to increase force or distance, and they are commonly found in many tools and machines.
   The velocity ratio of a screw is given as:
   $VR = \frac{2\pi r}{p}$, where $p = pitch$ and $r = radius\ or\ length\ of\ tommy\ bar$

5. Wedge: A wedge is a simple machine consisting of a triangular-shaped object with a pointed end. It is used to split, lift or move objects by applying force to the wide end of the wedge, which then drives the pointed end into the object. Wedges can be used to increase force or distance, and they are commonly found in tools like axes, chisels, and knives.
   The velocity ratio of a wedge is given by:
   $VR = \frac{slant\ height}{thickness}$

6. Gears: Gears are simple machines consisting of toothed wheels that mesh with each other. They are used to transmit power and motion between shafts or axes, and can change the speed, direction, and torque of a machine. Gears are commonly found in many machines like bicycles, cars, and clocks.
   The velocity ratio of gears is given by:
   $VR = \frac{number\ of\ teeth\ on\ driven\ gear}{number\ of\ teeth\ on\ driving\ gear}$

7. Wheel and axle: A wheel and axle is a simple machine that consists of a circular wheel attached to a central axle. The wheel and axle work together to transfer force and motion from one place to another. The wheel rotates around the axle, which remains stationary, and this movement is

used to create mechanical advantage, making it easier to move heavy objects or accomplish other tasks. Examples of wheel and axle in everyday life include car wheels, bicycle wheels, and the spindles used in sewing machines. This simple machine has been used by humans for thousands of years, and it remains an important part of many technologies and industries today. The velocity ratio of a wheel and axle is given by:

$VR = \frac{R}{r}$, where $R = radius\ of\ wheel,\ r = radius\ of\ axle$