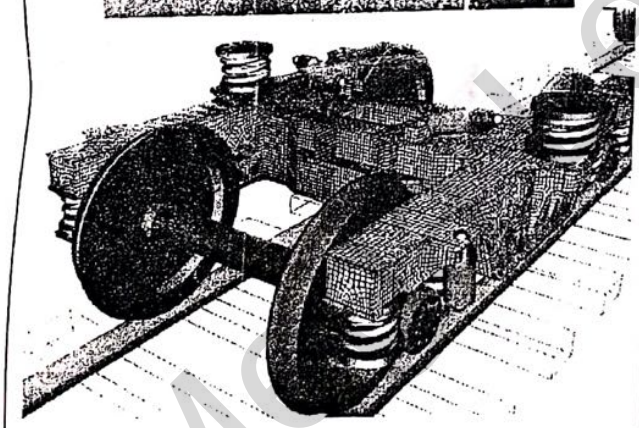
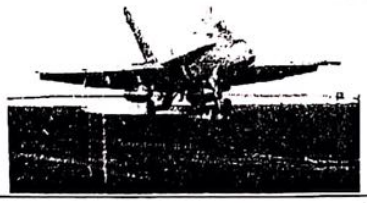
O Level Physics Syllabus Content for CAIE 2019-22 Exams

# CHAPTER 3: DYNAMICS





**Syllabus Content**

3.1 Balanced and unbalanced forces
3.2 Friction
3.3 Circular motion

**Learning outcomes**

**Candidates should be able to:**

**a)** State Newton's third law.

**b)** Describe the effect of balanced and unbalanced forces on a body.

**c)** Describe the ways in which a force may change the motion of a body.

**d)** Recall and use the equation force = mass × acceleration.

**e)** Explain that friction is a force that impedes motion and produces heating.

**f)** discuss the effect of friction on the motion of a vehicle in the context of tyre surface, road conditions

**g)** (Including skidding), braking force, braking distance, thinking distance and stopping distance.

**h)** Describe qualitatively motion in a circular path due to a constant perpendicular force, including



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# DYNAMICS

A Force is that which changes a body's state of rest or of uniform motion in straight line.

A Force denotes a "push" or a "pull".

**A Force causes a body to accelerate.**

When an unbalanced force F acts on a body of mass "m" , it causes the body to accelerate with an acceleration "a". The acceleration produced is directly proportional to the applied force, and inversely proportional too mass of the body.

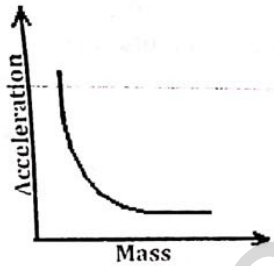
$F \propto a$ and $a \propto \frac{1}{m}$ Or $F = ma$

## NEWTON'S 2nd LAW

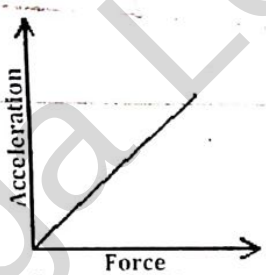
$\vec{F} = m\vec{a}$

Where 'm' is the constant mass of the body

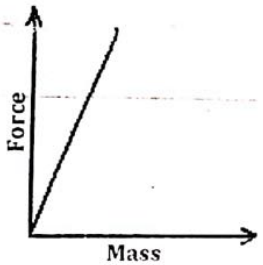
- "a" is directly proportional to the force
- 'a' is inversely proportional to the mass


When Force is Constant




When mass is Constant



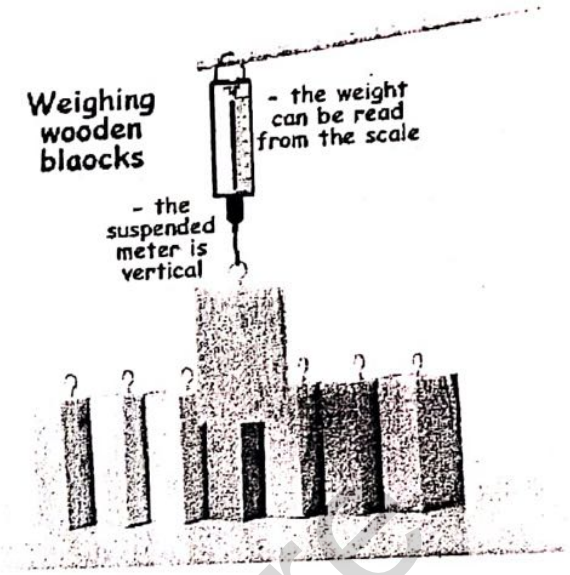

When acceleration is Constant

When the mass is measured in (kg), and the acceleration measured in ($m/s^2$), the force unit is the Newton (N).

**Definition:**

One Newton is the force which gives a mass of one kg acceleration of $1 m/s^2$.

Force is measured in the laboratory by using a spring balance / Newton meter / dynamo meter as shown.




Where m is the constant mass of the body

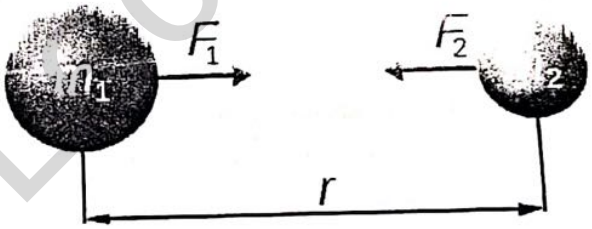
- "a"is directly proportional to the force
- "a' is inversely proportional to the mass

When the mass is measured in (kg), and the acceleration measured in ($m / s^2$), the force unit is the Newton (N).

## Types of Forces

### 1. Gravitational Force:

It is mutually attractive force between any two masses in the universe. Force of gravity increases as the two masses increase, but it decreases as the distance between them increases.




The weight of body is the gravitational force by which pulls the body towards its center.

The weight of a body is a pulling force measured in Newton.

$W = m.g$

M is the mass (in kg) & g is the acceleration due to gravity (in $m/s^2$)

- The acceleration due to gravity "g" is constant for all bodies falling near the earth's surface; its value is about 10 $m/s^2$.
- The force of gravity per kilogram is 10 N /kg which is called the earth gravitational field.

**Variations in "g":**

Although the mass of a body is always constant yet its weight may change due to the variations occurring in the value of "g".

i. The acceleration due to gravity "g" equals 10m $/s^2$ near the surface earth; but at very high altitudes above the earth the value of "g" decrease gradually.

ii. Different planets have different masses; the value of "g" is different at each planet. Because the mass of the moon is smaller than that of earth.

a. g = 1.67 m/s2 on the moon (about 1/6 its value on earth).

b. A 60kg person weighs 600 N on the earth; if the travels to the moon, his weight would be

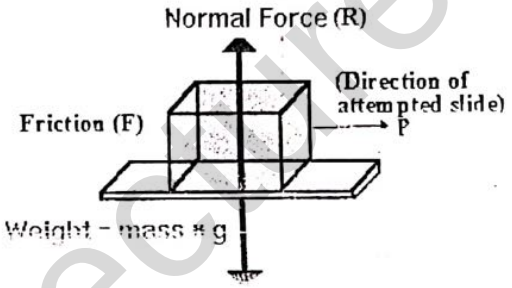
$$W = mg = 60 \times 1.67 = 100N$$

His weight is reduced (due to smaller g) while his mass remains constant

## 2. Force of Friction:

Friction is an "opposing" force; it always acts in a direction opposite to the applied force, or opposite to motion.

a. Friction between two solid surfaces as in the case of pushing a heavy box on the ground. Sometimes the box remains at rest because the opposing force, this is called *"Static friction"*. When the box is moving, the force of friction opposing the motion is called *"Sliding friction"*. The static friction is usually greater than the sliding friction (that is why it is harder to set in motion than to continue its motion).




b. Friction of fluids with bodies moving through them, as in the case of a plane flying through air, or a boat moving through water. The friction depends on the shape of body; and

The force of friction increases by the increase of:

i. The roughness of two surfaces in contact.
ii. The normal force between the two surfaces (due to weight)
iii. It increases considerably by the increase if speed.

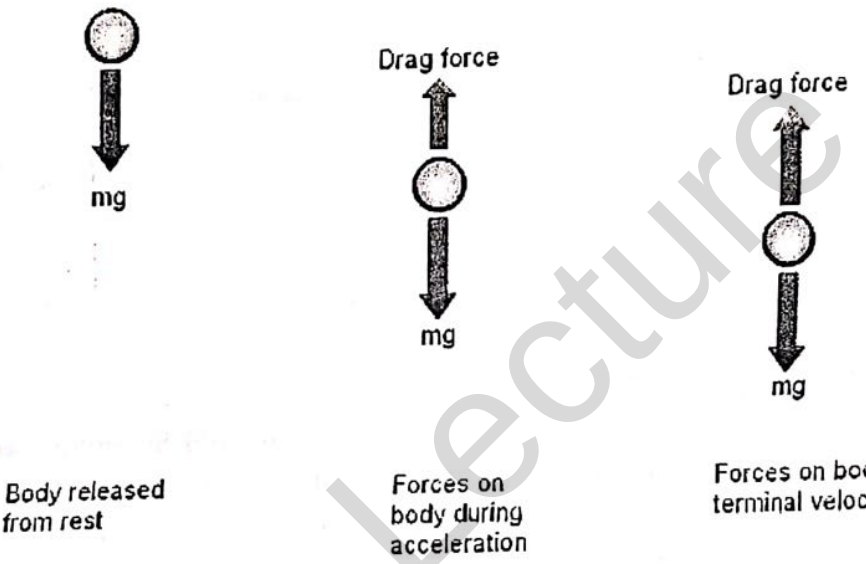
**Advantages** of friction are important in walking, stopped a speedy car, reducing the speed of a parachute, holding nails in wood, etc.

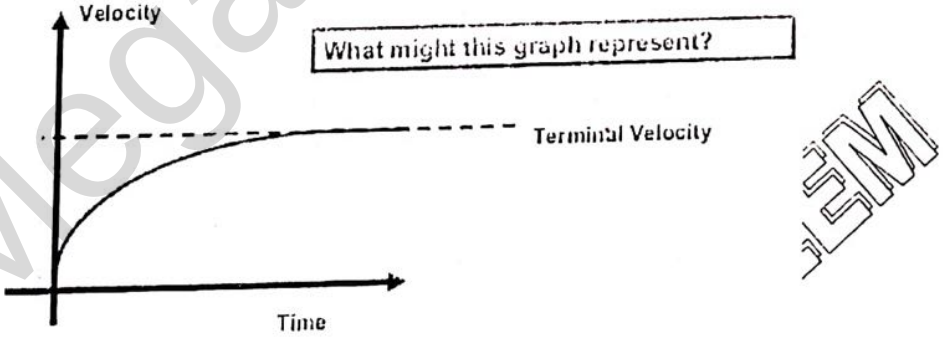
**Disadvantages** of frictional forces are mainly in machines where the kinetic energy is wasted and converted to heat. The friction can be reduced by smoothing the surfaces by using oil and lubricants, or by separating the surface by air cushions, of by using streamlined shapes of cars and planes; also by rolling the bodies instead of sliding them (like ball bearings).

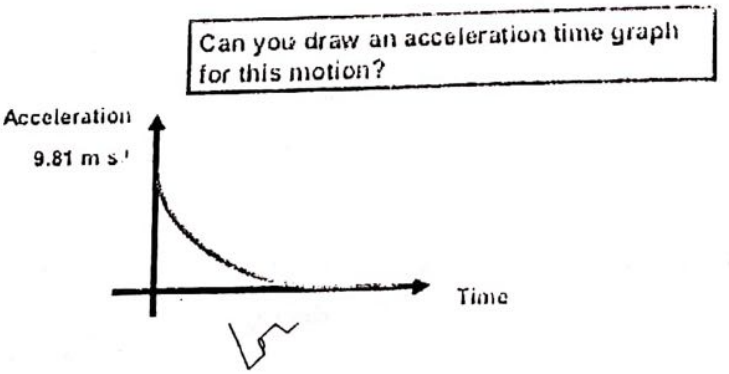
## Air Resistance and Terminal Velocity:

As the velocity of a body moving in a fluid increases, the resistive forces of the fluid opposing the body's motion increase as well.

When a body is failing under the pull of gravity in air, its velocity increases, so the resistive force of air increases, and the resultant force pulling it down decreases which reduces its acceleration until a moment is reached when the pull of earth (the body's weight) equals the upwards resistive force of air. Since the forces are now balances, the body moves with uniform velocity called its terminal velocity.

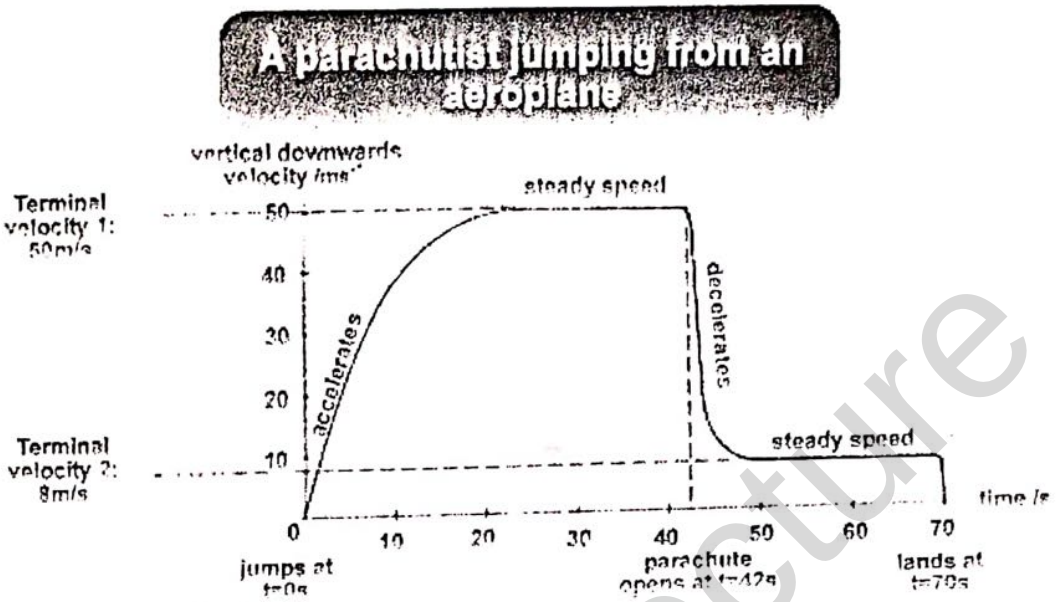


## Motion of a Parachutist

A parachutist jumps from an aircraft. A short time after jumping he pulls the ripcord to open the parachute. The graph below shows how his speed varies from the time the jumps from the plane, until he reaches the ground.



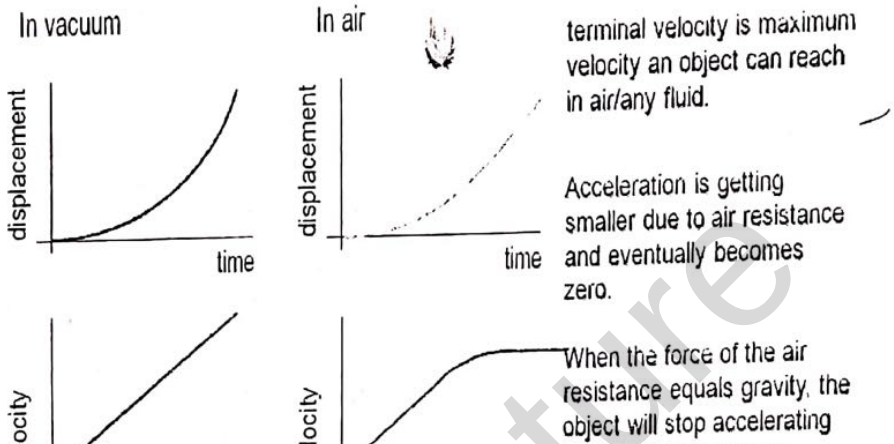

You *should notice the following:*

1. During the period "0s to 20s", the speed is increasing and his body accelerating downwards. This is because his weight is greater than air resistance and there is a resultant downward force.
2. At the time "42s" he opens the parachute.
3. During the period "43s to 45s", the speed is decreasing and the body is deceleration while still moving downwards. This is because the air resistance of the parachute became larger than the weight of his body and the resultant upward force is opposing the downward motion.
4. When the speed decreases the resistive force also decreases until it finally equals the weight at "50s".
5. During the period "50s to 70s" the net force in the body is "zero" and the acceleration is "zero", so the body moves down with constant speed (called the terminal velocity").
6. When his body suddenly hits the ground the speed drops suddenly to zero.

**Free Fall:**

If a body is falling freely without friction, its acceleration is constant and its speed increases uniformly as shown, but the distance moved increases non-uniformly

Comparison of free fall with no air resistance and with air resistance




terminal velocity is maximum velocity an object can reach in air/any fluid.

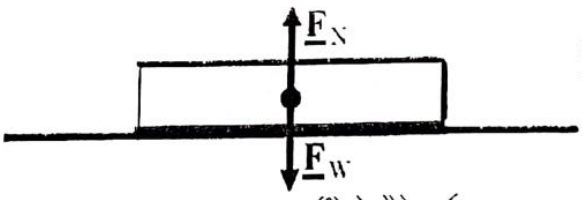
Acceleration is getting smaller due to air resistance and eventually becomes zero.

When the force of the air resistance equals gravity, the object will stop accelerating and maintain the same speed.

It is different for different bodies.

## 3. Reaction Forces

When two bodies are in contact, one body presses by a certain force, and the other pushes back by an equal and opposite force called the reaction. This rule is given by Newton's third law which states that: "To every action there is an equal and opposite reaction". Notice that the action and reaction must act on different bodies.



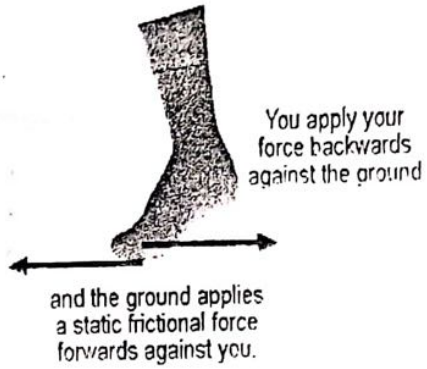

Forces on the book are

i. Force from attraction to earth – weight
ii. Force from table – normal force

These are not an action-reaction pair, even though they are equal and opposite.

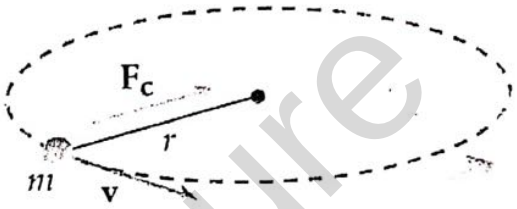
**In the third law:**

1- Force act on two different bodies.
2- They do not cancel each other because they don't act on the same body.
3- Their number must be two only.
4- They are of same type (gravitational, electrical)
5- They are equal, opposite, and act on same line for same time.




## 4. Centripetal Force

A moving body, free from any force, travel in a straight line. The motion in a circle requires a central force directed towards the center of the circular path. It is called the centripetal force.




Gravitational force between the earth and the moon provides the centripetal force required for the circular path on the moon around the earth.

***For uniform circular motion:***

1. Speed is constant.
2. Direction is always changing
3. Velocity is also changing; therefore there are acceleration and force action on the body.

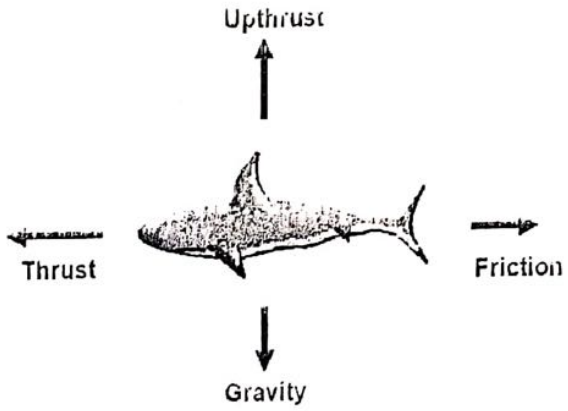
The centripetal force required for circular motion, increase

i. The increase of mass of moving body.
ii. the increase of its velocity, and
iii. The decrease if radius of circular path.

If the centripetal force, provided by the friction of car tires with the road, is small; then one has to reduce the speed of car and to increase the radius of the circular path so that the circular path would be suitable for the small centripetal force given.

## 5. Up thrust

If a body is placed into a liquid (or in a gas) the liquid will push the body towards, this upward force is called the up thrust. This force is proportional.




i. To the volume of the body, and
ii. To the density of the liquid

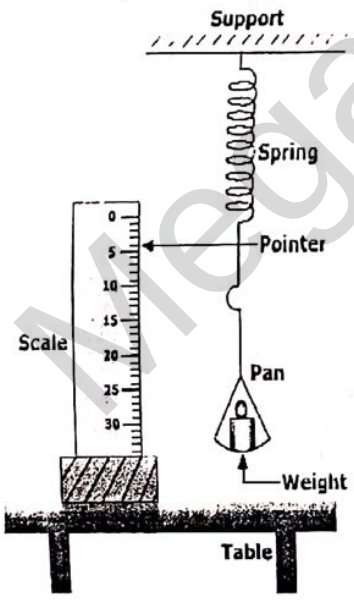
Any object placed in a fluid experiences a downward force due to its weight and an upward force due to fluid's up thrust. The final state of the body depends on which force is greater, thus it may sink or float or may be suspended in filed.

## 6. Elastic Forces:

Elasticity is the ability of a substance to recover its original shape and size after deformation. The extension produced is a spring is the difference between the stretched length and original

**Experiment:**

*Relation between Load and Extension:*




| Mass m / kg | Load L/N | Scale reading / mm | Extension / mm |
|---|---|---|---|
| 0.0 | 0.0 | 9.0 | 0.0 |
| 0.1 | 1.0 | 12.0 | 3.0 |
| 0.2 | 2.0 | 15.0 | 6.0 |
| . | . | . | . |
| . | . | . | . |
| . | . | . | . |

1. In the apparatus shown, take the scale reading when the pas is empty (no load)
2. Add 100g mss (equal 1 N) to the pan and record the new scale reading then record the extension.

3. Repeat step 2 several times to increase the load gradually and record the extension on produced each time.

Precautions:

i. To get accurate readings, fix a pointer at the lower end of the spring.
ii. Repeat taking all the reading again while unloading the spring.

4. Plot the relation between the lad and the extension.

From the graph we notice the following:

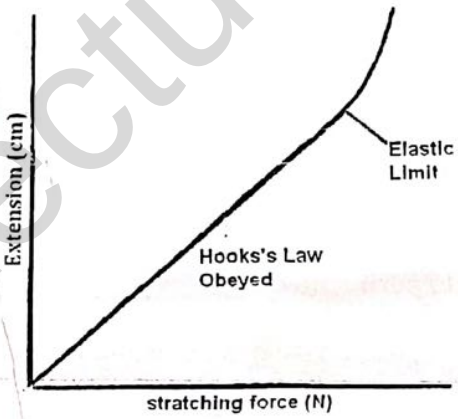
In the elastic region, the graph is straight line, and "the extension is directly proportional to the stretching force. This relation is called:

## Hooke's Law

Extension is directly proportional to applied load within the limit of proportionality.

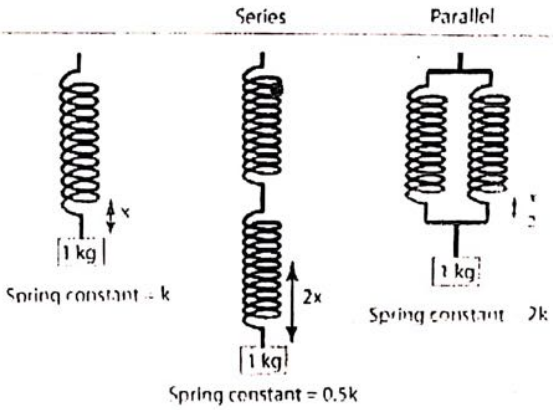
In this region of proportionality, we get that:
Extension = constant x Load

The end of the straight line is called "elastic limit". In the region of the straight line, the spring returns to its original length when the load is removed. Beyond the elastic limit, the relation is not proportional and the body become permanently stretched or deformed.



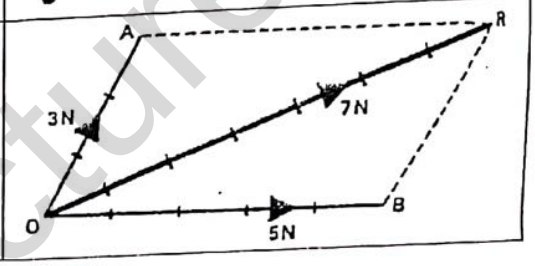

- Two springs connected in series produce twice the extension and two springs connected in parallel produce half the extension.
- A spring with larger cross sectional area produces smaller extension for a particular force.

**Combination of Springs**



## Combining Forces:

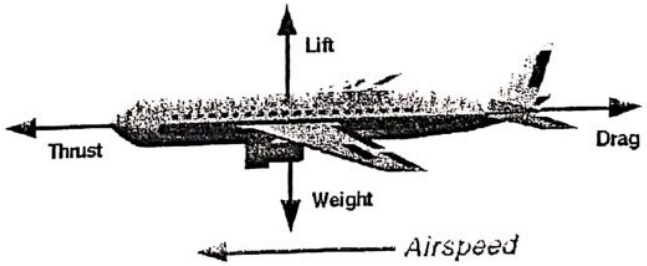
Two or more forces acting at a point can be combined into a single force known as the resultant force.

| | |
|---|---|
| 1. If the vectors are acting in the same direction, the resultant is sum of both, in same direction. This is value is the maximum we can get from these two vectors. | Forces: 2 N, 4 N<br>Resultant force: 6 N |
| 2. If the two vectors are acting in opposite direction. Resultant is the difference and acts in the direction of larger vectors. This value is maximum we can get from these two vectors. | Forces: 2 N, 4 N<br>Resultant force: 2 N |
| 3. Parallel rule for two vectors: Let two vectors be adjacent sides of a parallelogram the resultant, R. Is the diagonal (magnitude &direction?) |  |

**Note:** *If several forces are in equilibrium, the resultant R is zero.*

## Balanced Forces

Balanced Forces means forces in equilibrium. The resultant of all forces is equal to zero.




Lift = Weight
Thrust = Drag

Airplane moves in a straight line at constant airspeed.

They can occur two cases:

1. When body at rest, e.g. a parked car, a box at rest,
   Usually the downward weight balances the upwards reactions.
2. When body is moving with uniform speed in a straight line,
   e.g., a car or plane moving with uniform speed in a straight line.
   Usually the driving force of the engine balances the forces of friction or drag force.

$F = m \times a$, the force equal the mass times the acceleration.

**Inertia**

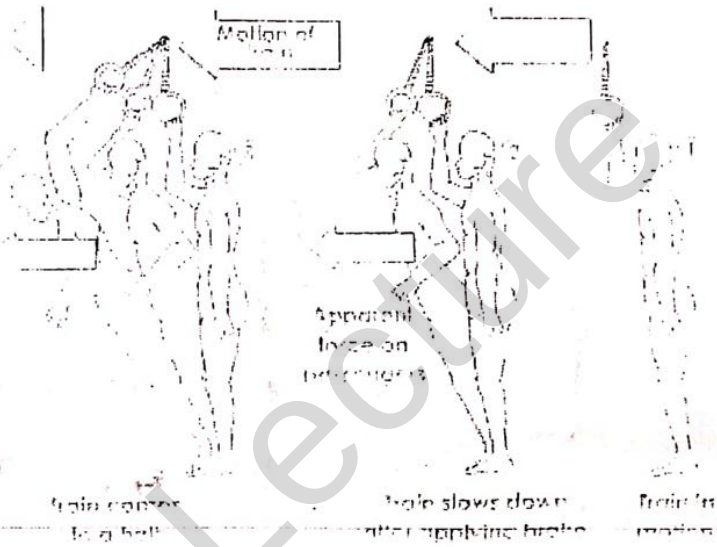
Inertia of a body is its tendency to remain in its state:

i. If it is at rest it tends to continue at rest.
ii. If it is moving at constant velocity it continues to move with the same velocity in a straight line.

Inertia of a body resists the change in its state of rest or uniform motion. Inertia of a body is proportional to the mass of the body.

**Examples:**

1. When a bus start to move suddenly, the feet of a person standing move forward with the bus, But the rest of person's body remain still due to its inertia, thus he falls backwards.
2. For the same reason, your body it's pushed forward when the car comes to a sudden stop.



Due to inertia, the body tends to move in a direction opposite to the direction of the acceleration.