

**Class: 9th**

**Subject: Physics**

**Chapter 4: Turning Effects Of Force**

**A Exercise MCQs**

(i) A particle is simultaneously acted upon by two forces of 4 N and 3 N. The net force on the particle is:

- (a) 1 N
- (b) Between 1 N and 7 N
- (c) 5 N
- (d) 7 N

(ii) A force  $F$  is making an angle of  $60^\circ$  with the x-axis. Its y-component is equal to:

- (a)  $F$
- (b)  $F \times \sin 60^\circ$
- (c)  $F \times \cos 60^\circ$



(d)  $F \times \tan 60^\circ$

**(iii) Moment of force is called:**

(a) Moment arm

(b) Couple arm

(c) Couple

(d) Torque

**(iv) A body will be completely in equilibrium when:**

(a)  $\Sigma F = 0$  and  $\Sigma \tau = 0$

(b)  $\Sigma F = 0$  and  $\Sigma \tau \neq 0$

(c)  $\Sigma F \neq 0$  and  $\Sigma \tau = 0$

(d)  $\Sigma F \neq 0$  and  $\Sigma \tau \neq 0$

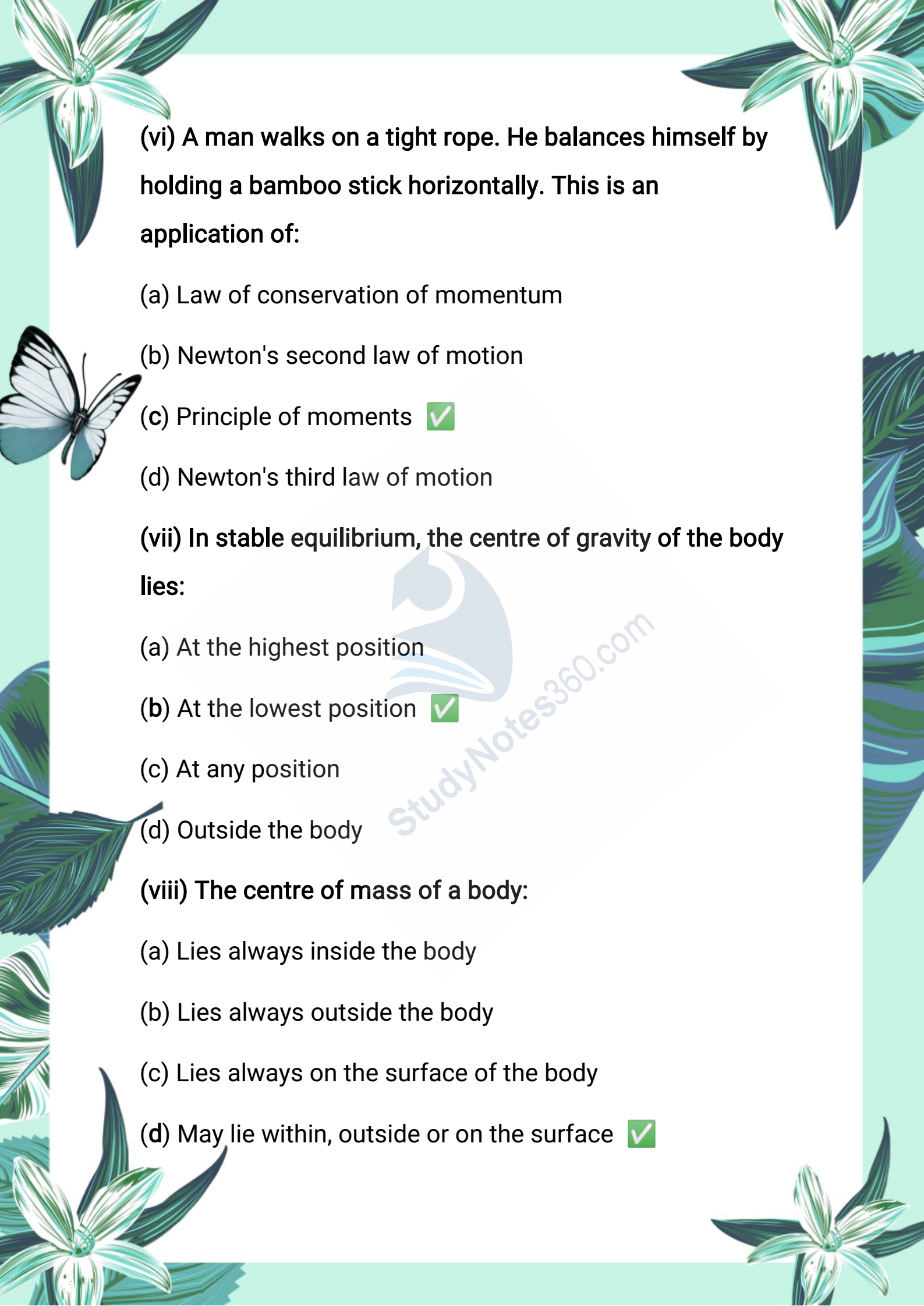
**(v) A shopkeeper sells his articles by a balance having unequal arms of the pans. If he puts the weights in the pan having shorter arm, then the customer:**

(a) Loses

(b) Gains

(c) Neither gains nor loses

(d) Not certain



**(vi) A man walks on a tight rope. He balances himself by holding a bamboo stick horizontally. This is an application of:**

- (a) Law of conservation of momentum
- (b) Newton's second law of motion
- (c) Principle of moments
- (d) Newton's third law of motion

**(vii) In stable equilibrium, the centre of gravity of the body lies:**

- (a) At the highest position
- (b) At the lowest position
- (c) At any position
- (d) Outside the body

**(viii) The centre of mass of a body:**

- (a) Lies always inside the body
- (b) Lies always outside the body
- (c) Lies always on the surface of the body
- (d) May lie within, outside or on the surface

(ix) A cylinder resting on its circular base is in:

- (a) Stable equilibrium
- (b) Unstable equilibrium
- (c) Neutral equilibrium
- (d) None of these

(x) Centripetal force is given by:

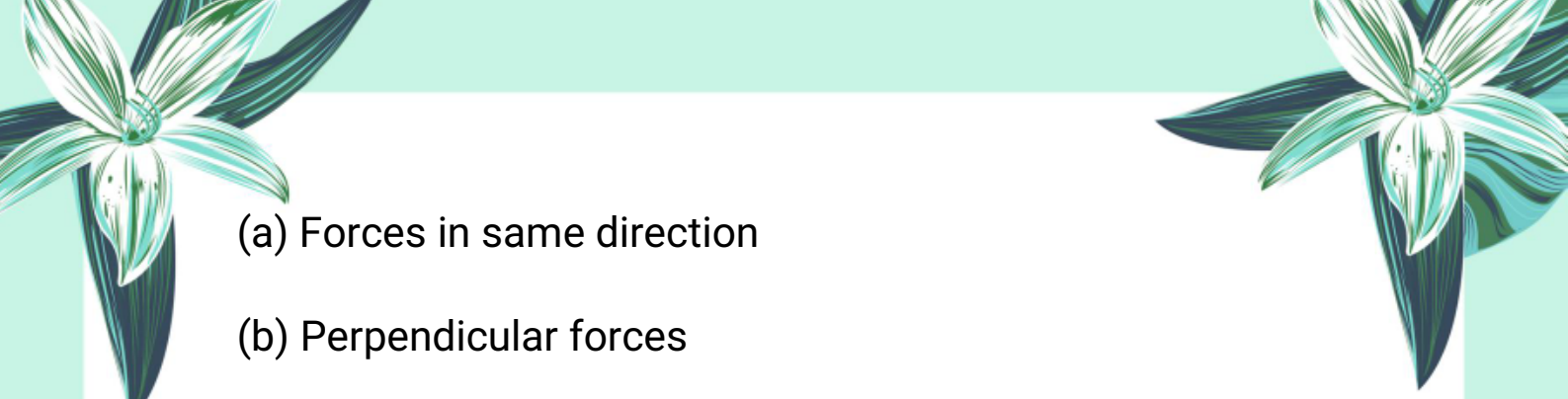
- (a)  $rF$
- (b)  $rF\cos\theta$
- (c)  $mv^2/r$
- (d)  $mv/t^2$

### Important MCQs :

1. What are like parallel forces?

- (a) Forces in opposite directions
- (b) Forces of unequal magnitudes
- (c) Forces acting along same line
- (d) Forces in same direction

2. What are unlike parallel forces?

- 
- (a) Forces in same direction
  - (b) Perpendicular forces
  - (c) Opposite direction forces
  - (d) Rotational forces



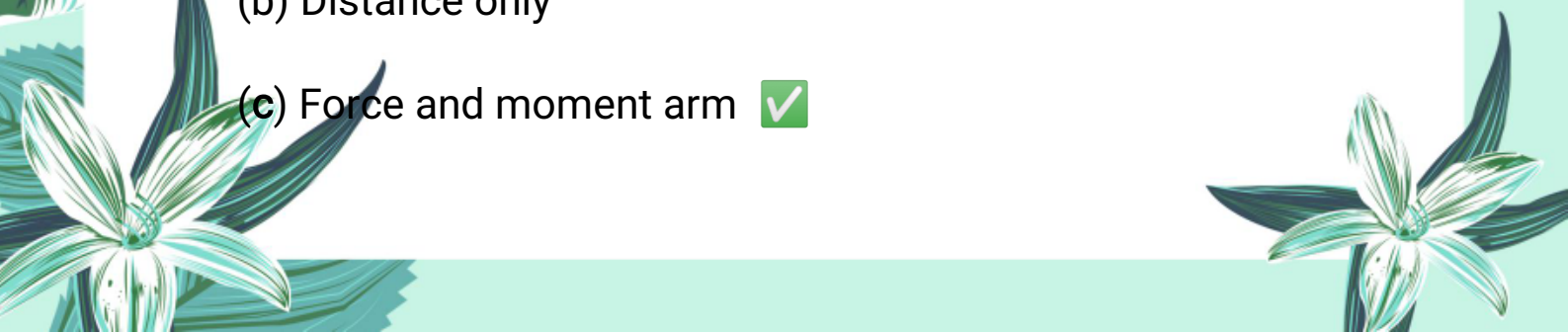
**3. Which rule is used to add force vectors?**

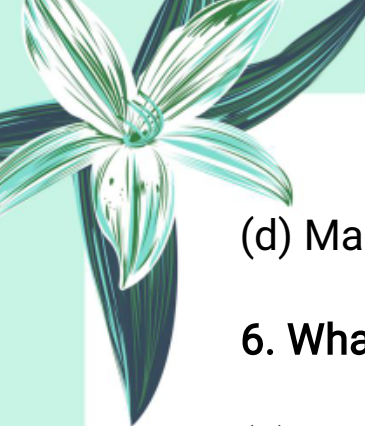
- (a) Tail-to-tail rule
- (b) Triangle rule
- (c) Head-to-tail rule
- (d) Parallelogram rule

**4. What is the unit of torque in SI system?**

- (a) Joule
- (b) Newton
- (c) Newton-metre
- (d) Kilogram

**5. Turning effect of force depends on:**

- (a) Only force
  - (b) Distance only
  - (c) Force and moment arm
- 



(d) Mass of object

**6. What is moment arm?**

(a) Line of action of force

(b) Axis of rotation

(c) Perpendicular distance from axis to line of action

(d) The direction of force

**7. When the force passes through axis of rotation, torque is:**

(a) Maximum

(b) Infinite

(c) Zero

(d) Negative

**8. What is the direction of positive torque?**

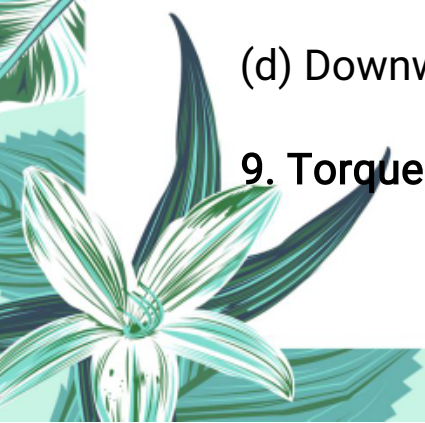
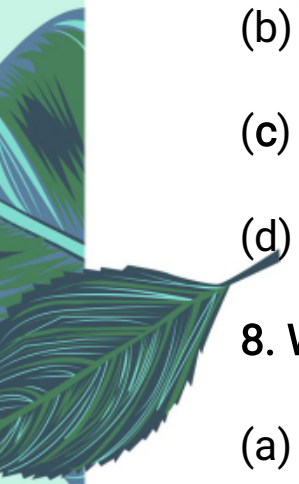
(a) Clockwise

(b) Horizontal

(c) Anticlockwise

(d) Downward

**9. Torque is negative when rotation is:**






(a) Anticlockwise

(b) Clockwise

(c) Leftward

(d) Forward

10. Formula for torque is:



(a)  $\tau = m \times a$

(b)  $\tau = F \times l$

(c)  $\tau = F / l$

(d)  $\tau = l / F$

11. What is the line along which a force acts called?

(a) Moment arm

(b) Line of action

(c) Axis

(d) Lever arm

12. What is a rigid body?

(a) A body which can stretch

(b) Body that changes shape under force

(c) Body with constant distance between points





(d) Liquid surface

**13. What is a couple?**

(a) A pair of unequal forces

(b) A pair of perpendicular forces



(c) Two equal and opposite parallel forces

(d) Rotational friction

**14. Which of the following is an example of a couple?**

(a) Pulling a rope

(b) Lifting a box

(c) Turning a tap

(d) Walking on road

**15. A door opens easily when force is applied at:**

(a) Near the hinge

(b) At the top

(c) Closer to the axis

(d) Handle (far from hinge)

**16. What is resolution of a vector?**

(a) Adding two vectors



(b) Dividing a vector into components ✓

(c) Rotating a vector

(d) Balancing forces

**17. Perpendicular components of a vector are usually taken along:**

(a) Diagonals

(b) Random directions

(c) X and Y axes ✓

(d) Z and W axes

**18. The x-component of a force  $F$  at angle  $\theta$  is:**

(a)  $F \sin \theta$

(b)  $F \cos \theta$  ✓

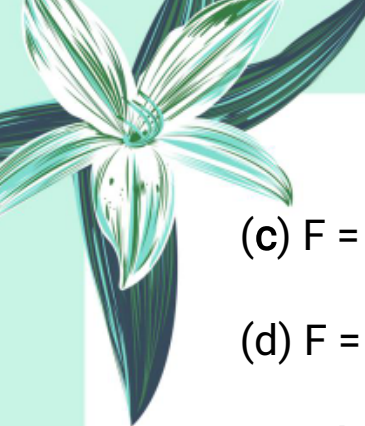
(c)  $F \tan \theta$

(d)  $F / \cos \theta$

**19. The formula to find magnitude of a vector from its components is:**

(a)  $F = F_x + F_y$

(b)  $F = F_x - F_y$




(c)  $F = \sqrt{F_x^2 + F_y^2}$  ✓

(d)  $F = F_x \times F_y$

20. The direction of a vector is found using the formula:

(a)  $\sin \theta = F_x / F_y$



(b)  $\theta = \tan^{-1}(F_y / F_x)$  ✓

(c)  $\theta = F_x / F_y$

(d)  $\theta = \cos^{-1}(F_y / F_x)$

21. What is the principle of moments?

(a) Torque = Force  $\times$  Velocity

(b) Total moments are always zero

(c) Sum of clockwise moments = sum of anticlockwise moments ✓

(d) Torque causes motion

22. A couple is formed by:

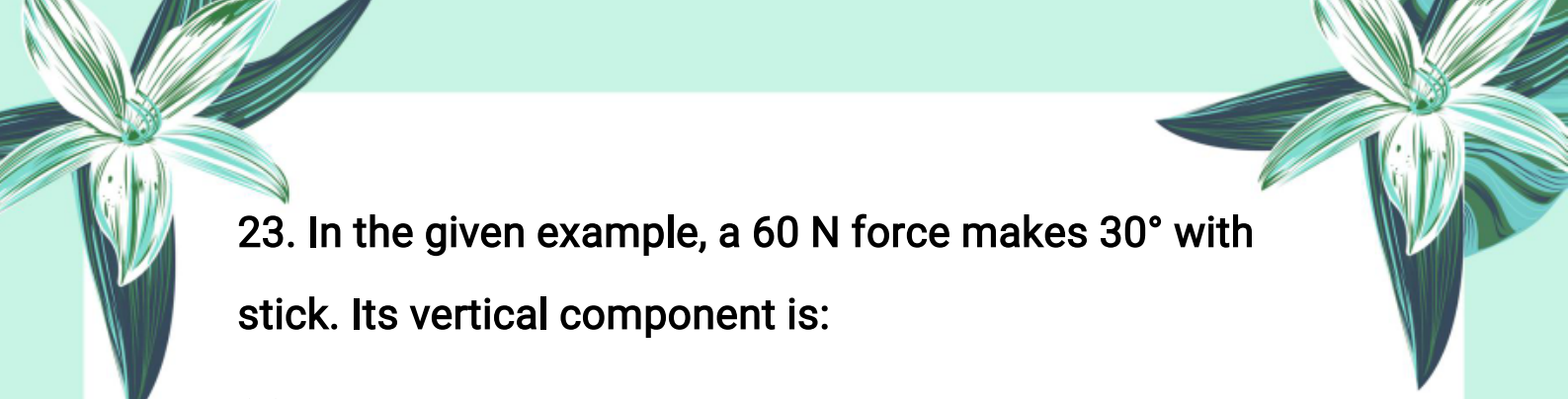
(a) Two equal and opposite forces along same line

(b) Two perpendicular forces

(c) Two equal and opposite parallel forces ✓

(d) Two random forces





23. In the given example, a 60 N force makes  $30^\circ$  with stick. Its vertical component is:

(a)  $60 \times \cos 30^\circ$

(b)  $60 \times \sin 30^\circ$

(c)  $60 / \tan 30^\circ$

(d)  $60 \times \tan 30^\circ$



24. Which component of a force produces torque?

(a) Component passing through axis

(b) Component perpendicular to axis

(c) Both components

(d) None of these

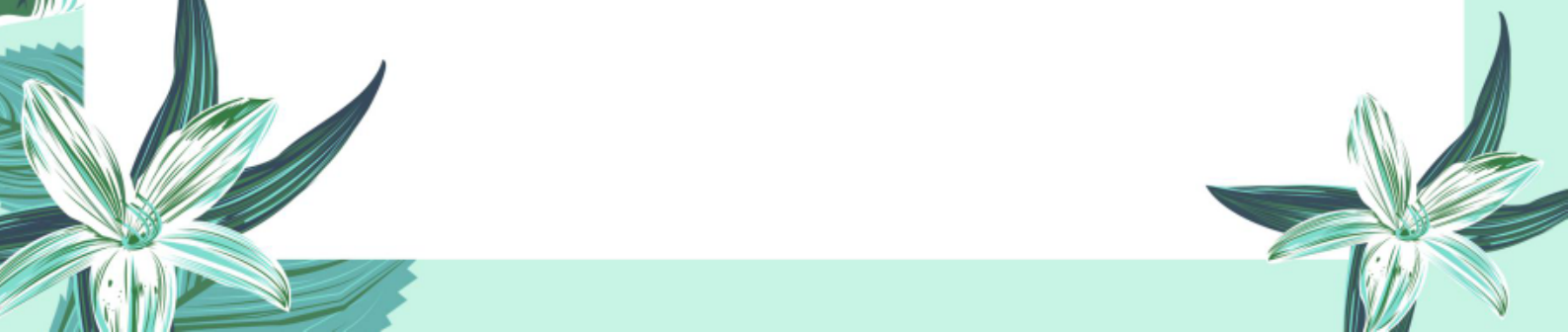
25. Where is the centre of gravity of a regular sphere located?

(a) At its surface

(b) At its top

(c) At its geometrical centre


(d) Outside the body





26. For an irregular shaped lamina, the centre of gravity can be found by:

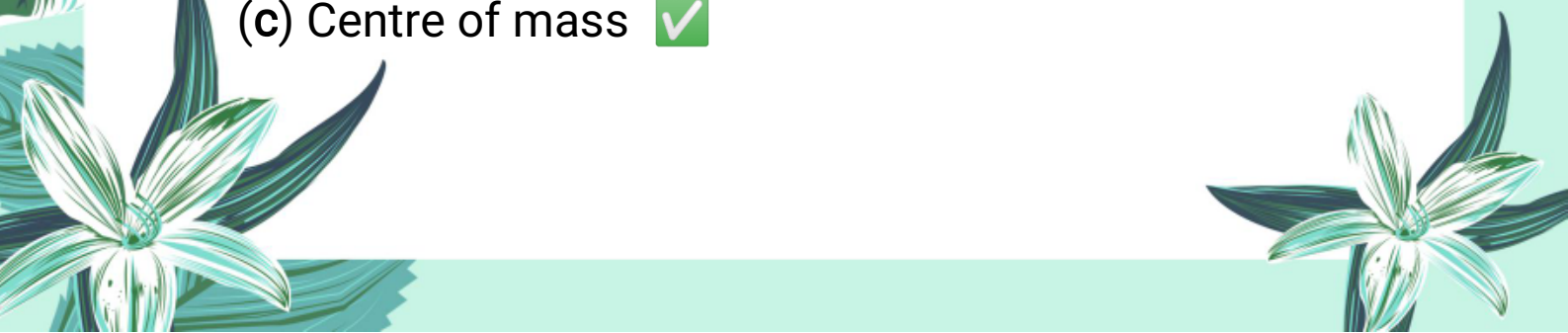
- (a) Measuring thickness
- (b) Balancing on finger
- (c) Suspending through different points
- (d) Heating the object

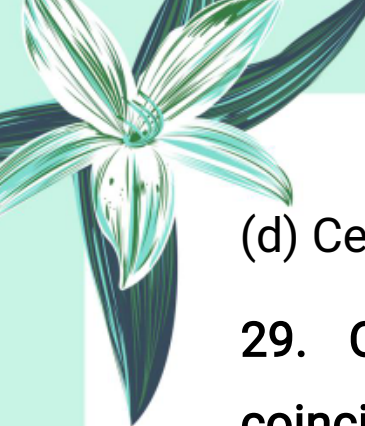


27. The centre of gravity of a lamina lies at the point:

- (a) With minimum mass
- (b) Where two vertical lines from suspension points cross
- (c) Where area is maximum
- (d) At the edge of lamina

28. The point where whole mass of a body is assumed to be concentrated is called:

- (a) Axis of rotation
  - (b) Mass centre
  - (c) Centre of mass
- 



(d) Centre of shape

**29. On Earth's surface, the centre of mass coincides with:**

(a) Axis of rotation

(b) Magnetic field

(c) Centre of pressure

(d) Centre of gravity

**30. A body is in equilibrium when:**

(a) It rotates in circle

(b) Its acceleration is zero

(c) Its speed is increasing

(d) It changes direction

**31. A book lying on a table is in:**

(a) Dynamic equilibrium

(b) Static equilibrium

(c) Rolling motion

(d) Unstable condition



The page features decorative illustrations of white flowers with green leaves in the corners and a butterfly on the left side. A faint watermark of a bird and the text 'StudyNotes360.com' is visible in the background.

**32. A paratrooper descending with uniform velocity is an example of:**

- (a) Free fall
- (b) Static equilibrium
- (c) Dynamic equilibrium
- (d) Translational motion

**33. First condition of equilibrium is:**

- (a) Net torque is zero
- (b)  $\Sigma F = 0$
- (c) Net acceleration is high
- (d) Object is rotating


**34. Second condition of equilibrium is fulfilled when:**

- (a) Body falls freely
- (b)  $\Sigma \tau = 0$
- (c) Centre of gravity shifts
- (d) Object changes direction



**35. When two equal forces act along different lines of action, they form:**



- (a) Resultant force
- (b) Balanced forces
- (c) Couple
- (d) Static motion



**36. Which condition must be satisfied for a body to be in equilibrium?**

- (a)  $\Sigma F = 0$
- (b)  $\Sigma \tau = 0$
- (c) Both (a) and (b)
- (d) None of these


**37. In stable equilibrium, the centre of gravity:**

- (a) Rises and remains above the base
  - (b) Falls below the base
  - (c) Moves outside the base
  - (d) Remains at the same height
- 
- 



**38. What happens in unstable equilibrium if a body is slightly tilted?**

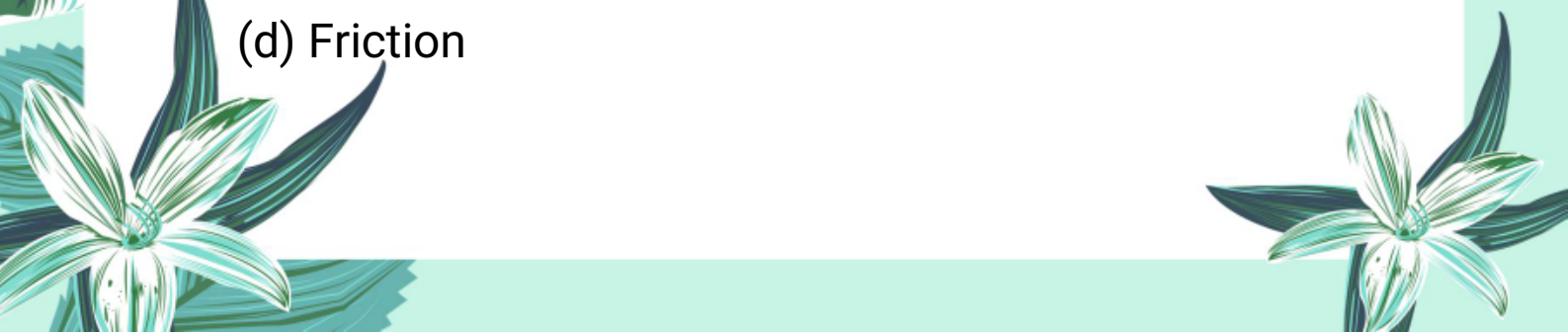
- (a) It returns to its original position
- (b) It remains at rest
- (c) It falls further away
- (d) It rotates back slowly



**39. A ball rolling on a horizontal surface is an example of:**

- (a) Stable equilibrium
- (b) Unstable equilibrium
- (c) Neutral equilibrium
- (d) Rotational motion


**40. Which force causes a cone in stable equilibrium to return to its original position?**

- (a) Parallel force
  - (b) Centripetal force
  - (c) Torque
  - (d) Friction
- 



**41. To improve stability of a body, one should:**

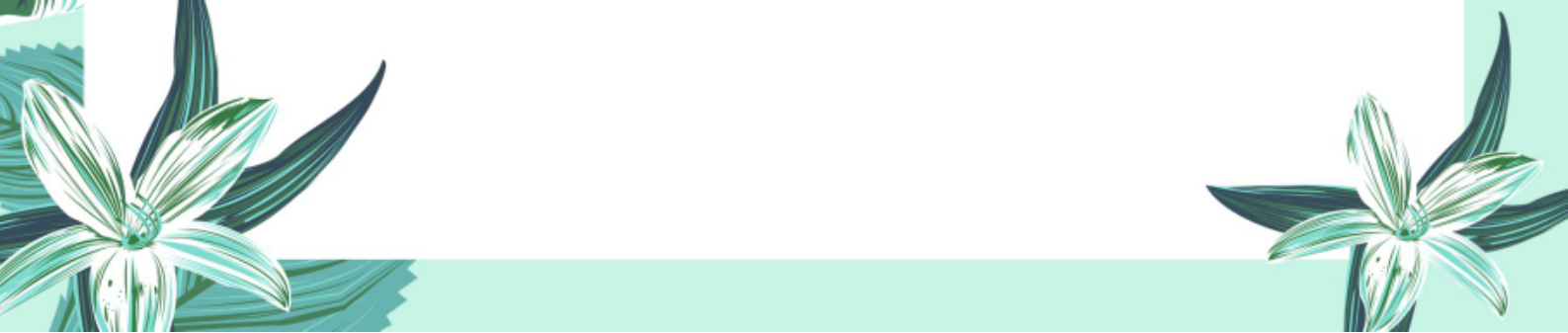
- (a) Raise its centre of gravity
- (b) Widen its base
- (c) Both (a) and (b)
- (d) Lower centre of gravity and widen base



**42. In neutral equilibrium, what happens to the centre of gravity when body is disturbed?**

- (a) It is lowered
- (b) It is raised
- (c) It remains unchanged
- (d) It disappears


**43. What is the main reason a double-decker bus may topple easily when loaded on top?**

- (a) Narrow wheels
  - (b) High centre of gravity
  - (c) High speed
  - (d) Less weight
- 



44. Which one of the following does NOT affect equilibrium directly?


- (a) Torque
- (b) Base width
- (c) Colour of the object
- (d) Centre of gravity



45. What does a diagram showing only the forces acting on the object help with?

- (a) Calculating speed
- (b) Applying conditions of equilibrium
- (c) Measuring temperature
- (d) Finding mass

46. What plays the same role in rotational motion as force does in translational motion?

- (a) Angular momentum
  - (b) Moment of inertia
  - (c) Torque
  - (d) Angular velocity
- 



47. In circular motion, the direction of velocity at any point is:

- (a) Towards the centre of circle
- (b) Along the radius
- (c) Tangent to the circle
- (d) Perpendicular to the radius

48. What is the formula for centripetal force acting on a body of mass  $m$ , moving with speed  $v$ , in a circle of radius  $r$ ?

- (a)  $F = m \times r^2$
- (b)  $F = m \times v$
- (c)  $F = m \times v^2 / r$
- (d)  $F = v^2 / m \times r$

49. Which of the following provides the centripetal force to a satellite orbiting the Earth?

- (a) Air resistance
- (b) Earth's gravity
- (c) Centrifugal force



(d) Satellite's engine

50. In a washing machine dryer, water escapes through the holes because:

(a) Water is heavier than clothes

(b) No centripetal force acts on water

(c) Clothes repel water

(d) Water is pulled by gravity



## B Exercise Short Questions

4.1. Define like and unlike parallel forces.

- **Like parallel forces** are those forces that act in the same direction and are parallel to each other.
- **Unlike parallel forces** are those that are parallel but act in opposite directions.

4.2. What are rectangular components of a vector and their values?

When a vector is resolved into two mutually



perpendicular components, they are called rectangular components.

If a vector  $F$  makes angle  $\theta$  with  $x$ -axis, then:

- Horizontal component =  $F_x = F \cos\theta$
- Vertical component =  $F_y = F \sin\theta$

#### 4.3. What is the line of action of a force?

The line of action of a force is an imaginary line along which the force acts. The turning effect of the force depends on the perpendicular distance from this line to the point of rotation.

#### 4.4. Define moment of a force. Prove that $\tau = rF\sin\theta$ .

Moment of force (torque) is the turning effect of a force about a point or axis.

$$\tau = r \times F = rF \sin\theta$$

Where:

$\tau$  = torque

$r$  = position vector from axis to point of force

$F$  = force

$\theta$  = angle between  $r$  and  $F$

**Proof:**

Torque is the product of force and perpendicular distance from the pivot.

$$r_{\perp} = r \sin\theta$$

$$\text{So, } \tau = F \times r_{\perp} = F \times r \sin\theta$$

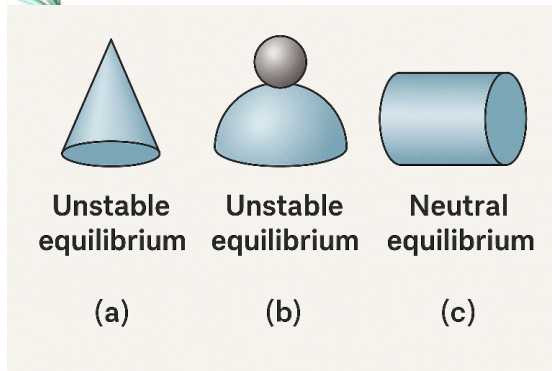
**4.5. With the help of a diagram, show that the resultant force is zero but the resultant torque is not zero.**



Resultant force = 0,  
Resultant torque  $\neq 0$

When two equal and opposite forces act on a body at different points, they cancel each other out (net force = 0) but produce a couple, causing rotation (net torque  $\neq 0$ ).

**4.6. Identify the state of equilibrium in each case in the figure given below.**



**(a)** Cone standing on its tip  $\Rightarrow$  **Unstable equilibrium**

If slightly disturbed, the cone will topple over because its center of gravity is high and not well-supported.

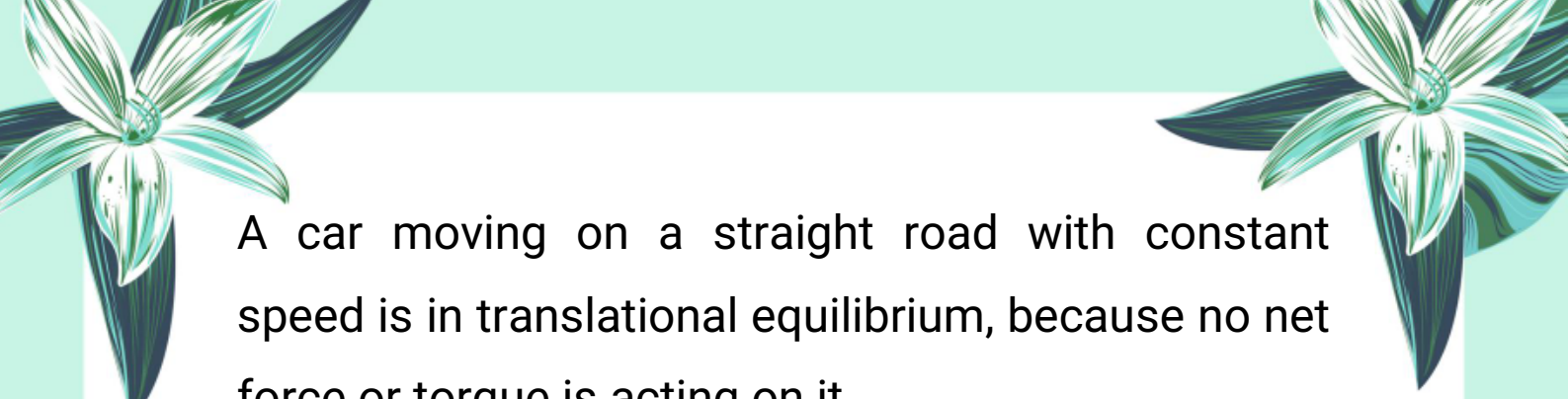
**(b)** Hemisphere with a ball balanced on top  $\Rightarrow$  **Unstable equilibrium**

If slightly disturbed, the ball will roll off since any displacement moves it further away from balance.

**(c)** Cylinder lying on its side  $\Rightarrow$  **Neutral equilibrium**


If slightly disturbed, the cylinder will roll but remain in equilibrium since its center of gravity stays at the same level.

**4.7. Give an example of the body which is moving yet in equilibrium.**



A car moving on a straight road with constant speed is in translational equilibrium, because no net force or torque is acting on it.

**4.8. Define centre of mass and centre of gravity of a body.**

- 
- **Centre of Mass** is the point at which the whole mass of the body appears to be concentrated.
  - **Centre of Gravity** is the point at which the entire weight of the body acts, and about which it balances in all directions.

**4.9. What are two basic principles of stability in physics which are applied in designing balancing toys and racing cars?**

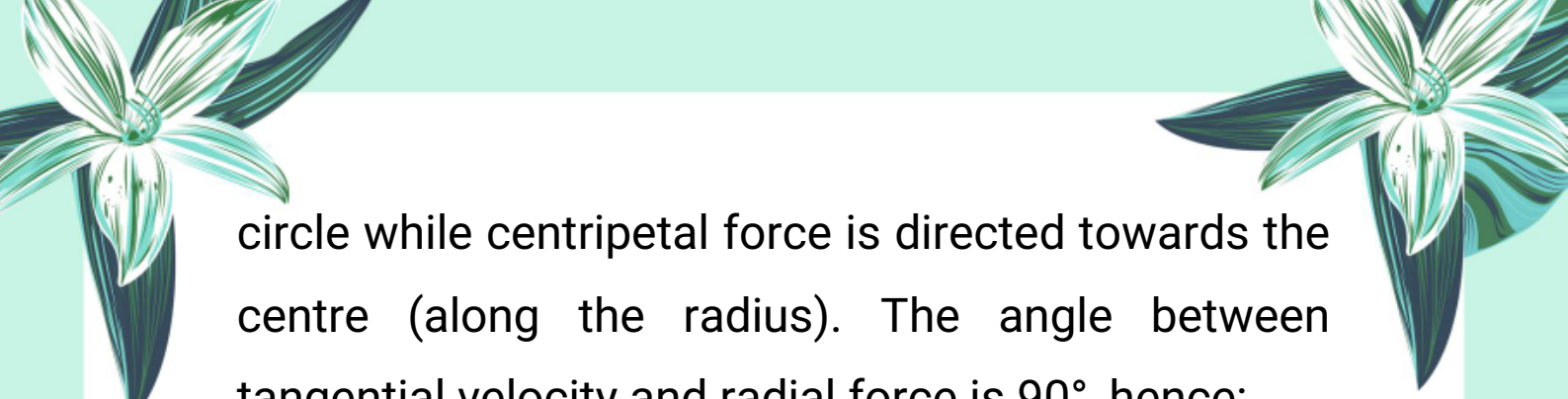
1. The centre of gravity should be low.
2. The base area should be wide.

These ensure that the line of action of weight remains within the base to maintain stability.

**4.10. How can you prove that the centripetal force always acts perpendicular to velocity?**

In circular motion, the velocity is tangent to the





circle while centripetal force is directed towards the centre (along the radius). The angle between tangential velocity and radial force is  $90^\circ$ , hence:

$F \cdot v = Fv \cos 90^\circ = 0$ , showing they are perpendicular.



### Important short questions:

#### 1. What are like parallel forces?

Like parallel forces are those forces which act in the same direction and are parallel to each other.

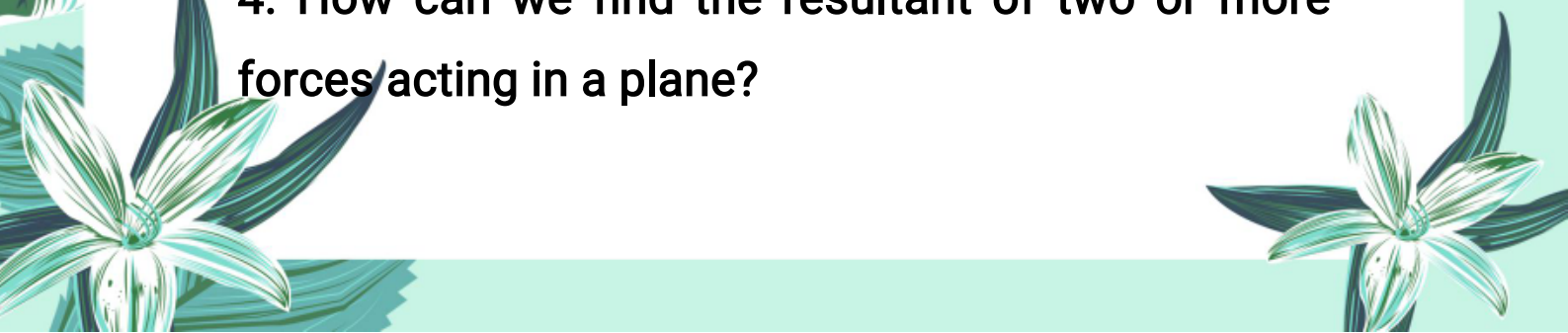
#### 2. What are unlike parallel forces?

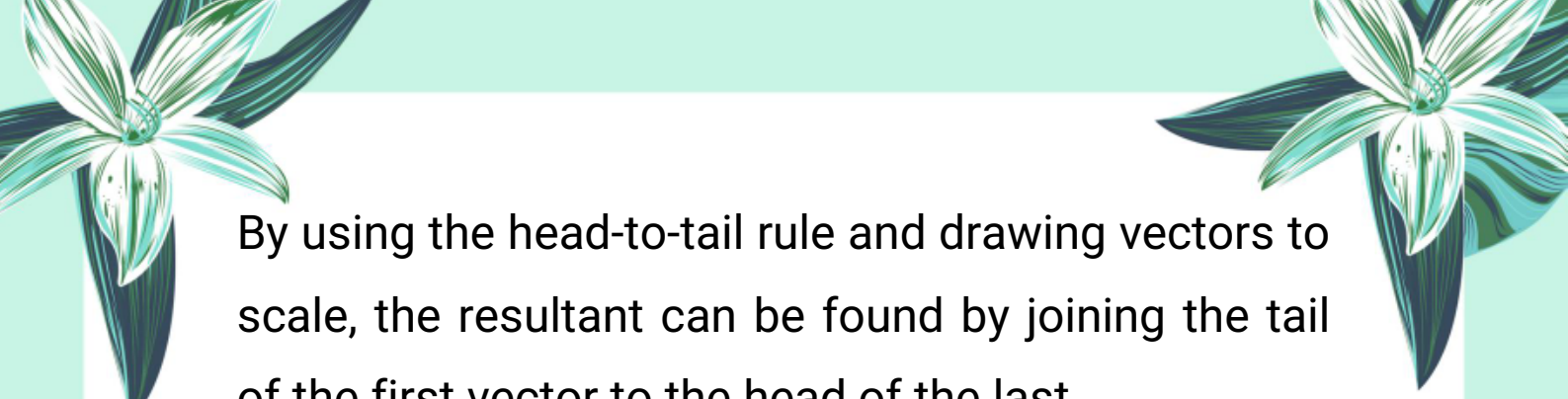
Unlike parallel forces are parallel forces that act in opposite directions.

#### 3. What is meant by head-to-tail rule in vector addition?

It is a method of adding vectors by placing the tail of one vector at the head of the previous vector.

#### 4. How can we find the resultant of two or more forces acting in a plane?





By using the head-to-tail rule and drawing vectors to scale, the resultant can be found by joining the tail of the first vector to the head of the last.

### **5. What is meant by the turning effect of a force?**



It is the tendency of a force to rotate a body about an axis.

### **6. What is a rigid body?**

A rigid body is a body whose shape and size do not change under the effect of force.

### **7. What is axis of rotation?**

It is the straight line about which a body rotates.

### **8. What is meant by the line of action of a force?**

It is the straight line along which the force acts on a body.

### **9. Define moment arm of a force.**

It is the perpendicular distance from the axis of rotation to the line of action of the force.

### **10. What is moment of force or torque?**

It is the product of force and its moment arm:






Torque = Force  $\times$  Moment Arm.

**11. Write the formula for torque when the force is perpendicular to the moment arm.**

$\tau = F \times r$ , where  $\tau$  is torque,  $F$  is force, and  $r$  is moment arm.



**12. In which case is the torque of a force equal to zero?**

When the line of action of the force passes through the axis of rotation.

**13. What is the SI unit of torque?**

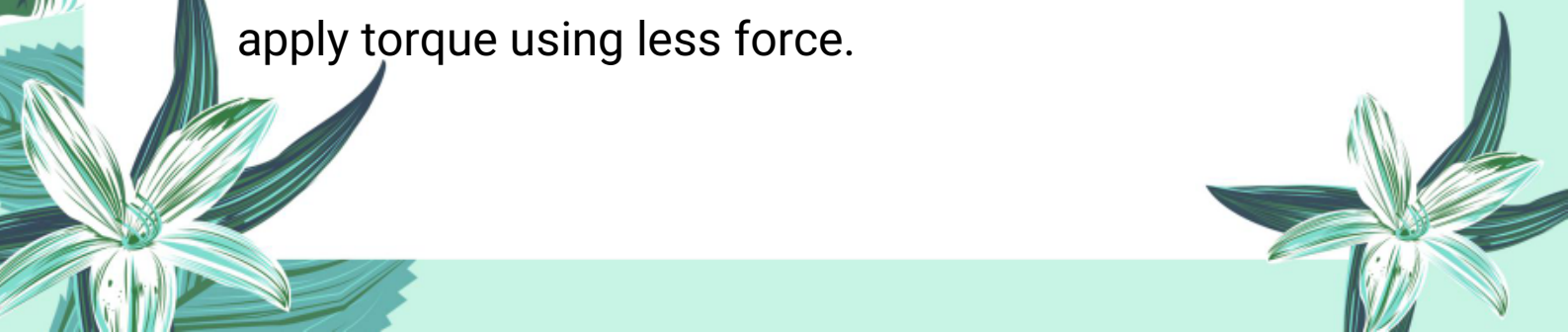
The SI unit of torque is newton metre (N·m).

**14. When is torque taken as positive and when as negative?**

Torque is positive for anticlockwise rotation and negative for clockwise rotation.

**15. Why are door handles placed far from the hinges?**

To increase the moment arm and make it easier to apply torque using less force.





**16. What is meant by the resolution of a vector?**

**Answer:**

The process of dividing a vector into two or more parts (components) is called the resolution of a vector. These parts, when added, give back the original vector.



**17. What are rectangular components of a force?**

**Answer:**

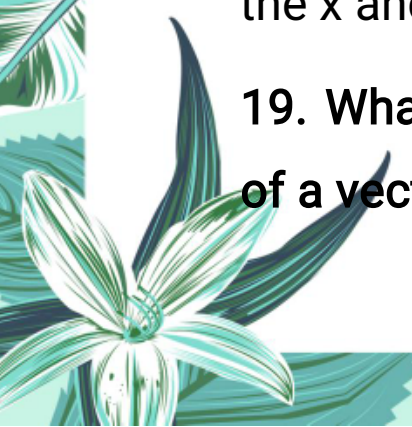
Rectangular components are two perpendicular components (usually along x and y axes) of a force vector. These components are called  $F_x$  (x-component) and  $F_y$  (y-component).

**18. How are the x and y components of a force vector found graphically?**

**Answer:**

The x and y components are found by dropping perpendiculars from the tip of the force vector onto the x and y axes respectively.

**19. What is the physical meaning of a component of a vector?**





**Answer:**

A component of a vector is its effective value in a specific direction, such as along the x-axis or y-axis.

**20. Why are the x and y components called perpendicular components?**



**Answer:**

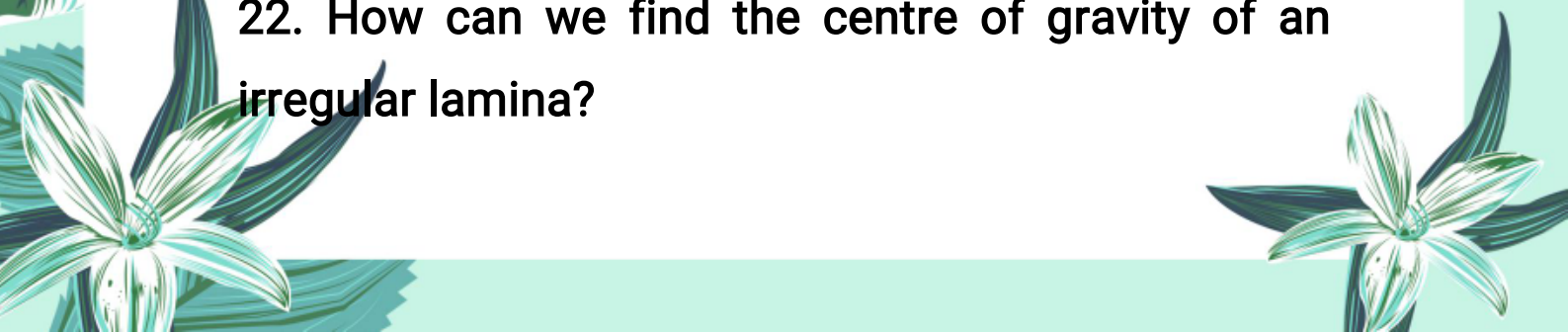
They are called perpendicular components because they act at right angles ( $90^\circ$ ) to each other – one along the x-axis and the other along the y-axis.

**21. Define centre of gravity. How does it affect the balance of a body?**

**Answer:**


- **Centre of gravity** is the point where the entire weight of a body appears to act.
- If a body is **supported** at its **centre of gravity**, it remains **balanced** and does not rotate. Hence, the centre of gravity helps in maintaining the balance of a body.

**22. How can we find the centre of gravity of an irregular lamina?**





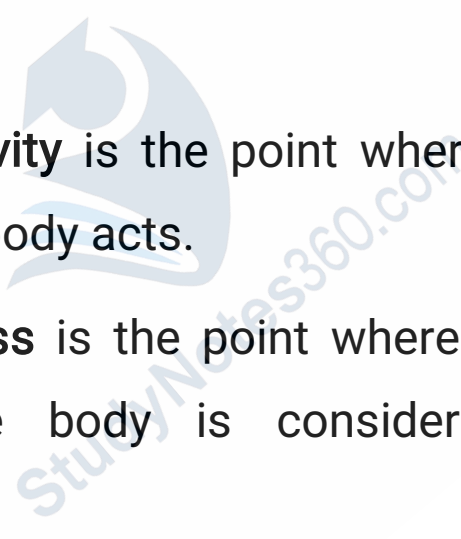
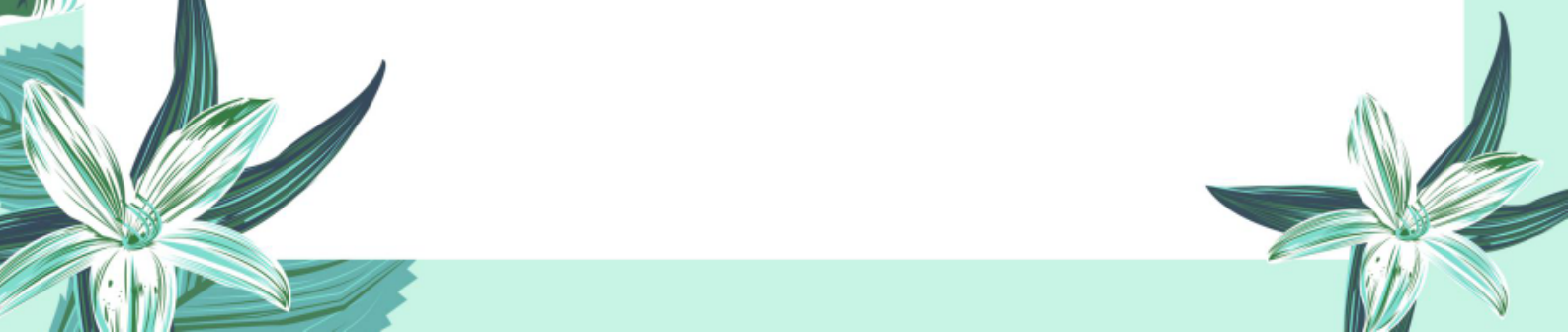
**Answer:**



To find the centre of gravity of an irregular lamina, suspend it freely from two or more different points. Draw vertical lines from the point of suspension using a plumb line. The point where these lines intersect is the centre of gravity.

**23. What is the difference between centre of mass and centre of gravity? Give one example.**

**Answer:**

- 
- **Centre of gravity** is the point where the total weight of the body acts.
  - **Centre of mass** is the point where the whole mass of the body is considered to be concentrated.
  - For small objects on Earth, both points usually coincide.
  - **Example:** In a rotating wrench, its centre of mass follows a straight path even if the wrench rotates.
- 

The page is decorated with various illustrations: a large white flower with green leaves in the top left and bottom left corners; a white butterfly with black markings on its wings on the left side; and a large green leaf on the right side. The background is a light green color.

**24. Why does an object balance at its centre of gravity?**

**Answer:**

An object balances at its centre of gravity because at that point, the total weight is uniformly distributed on all sides. There is no torque acting to rotate the body, so it remains in equilibrium.

**25. What path is followed by the centre of mass of a rotating object in absence of any external force?**

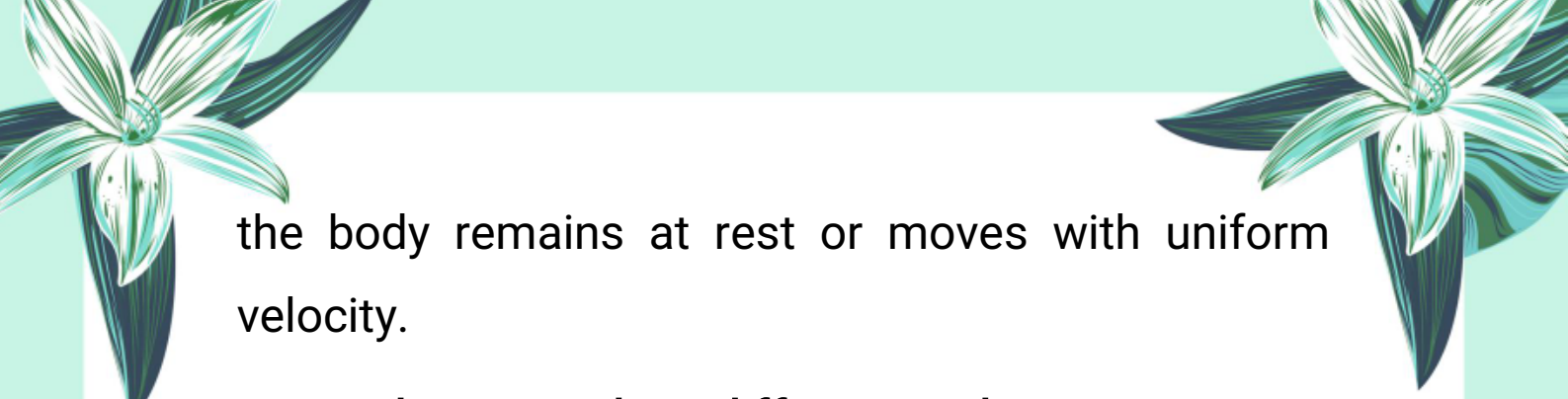
**Answer:**

In the absence of any external force, the centre of mass of a rotating object follows a straight-line path with constant speed, even if the object itself is rotating.

**26. Define equilibrium in terms of forces and acceleration.**

**Answer:**


A body is said to be in equilibrium if the resultant of all the external forces acting on it is zero, which means the body has no acceleration. In other words,



the body remains at rest or moves with uniform velocity.

**27. What is the difference between static equilibrium and dynamic equilibrium?**

**Answer:**

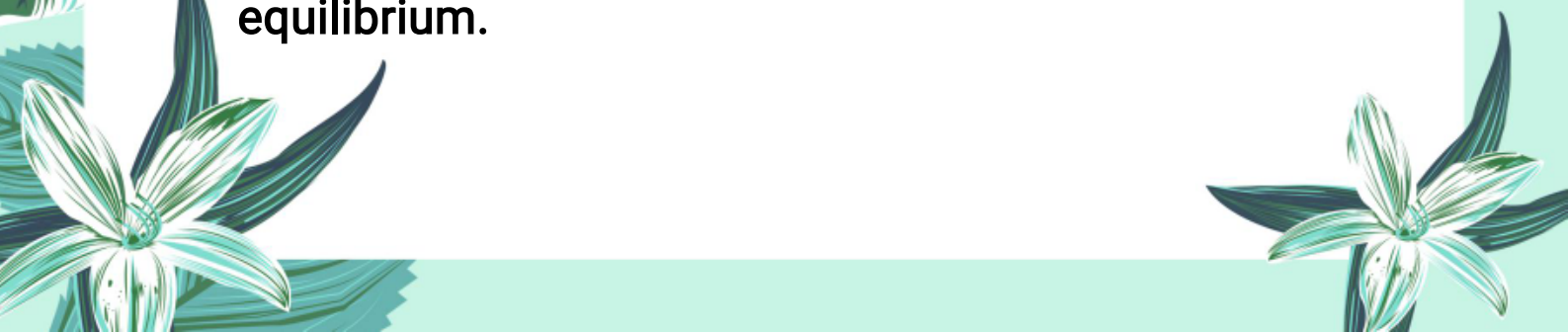
- 
- **Static equilibrium:** When a body is at rest and the forces acting on it balance each other so that it does not move.
  - **Dynamic equilibrium:** When a body is moving with a constant velocity and the forces acting on it balance each other so that it does not accelerate.

**28. Give two examples of objects in static equilibrium.**

**Answer:**

- A book lying on a table.
- An electric bulb hanging from the ceiling.

**29. Explain why a book lying on a table is in static equilibrium.**



The page is decorated with various illustrations: a large white flower with green leaves in the top-left and bottom-left corners, a white butterfly in the middle-left, and a large green leaf in the middle-right. The background is a light green color.

**Answer:**

The book has two forces acting on it: its weight acting downwards and the normal force from the table acting upwards. These two forces are equal in magnitude and opposite in direction, so they cancel each other. Since the net force is zero, the book does not move and is in static equilibrium.

**30. What is the first condition of equilibrium? Write its mathematical form.**

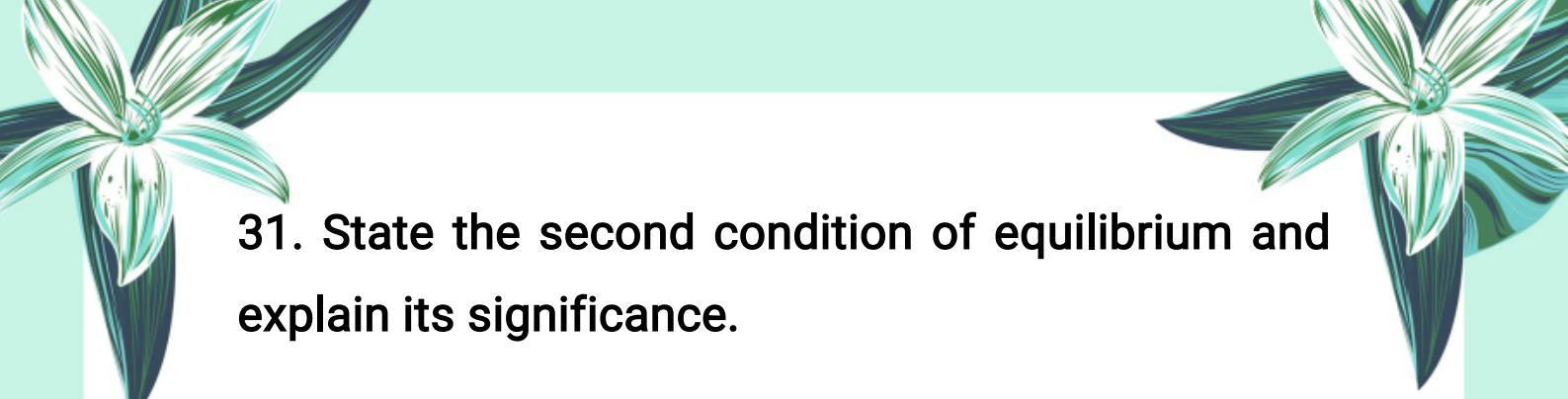
**Answer:**

The first condition of equilibrium states that the vector sum of all external forces acting on a body must be zero for the body to be in translational equilibrium.

**Mathematically,**


$$\sum \mathbf{F} = 0$$

$$\sum F_x = 0 \quad \text{and} \quad \sum F_y = 0$$



**31. State the second condition of equilibrium and explain its significance.**

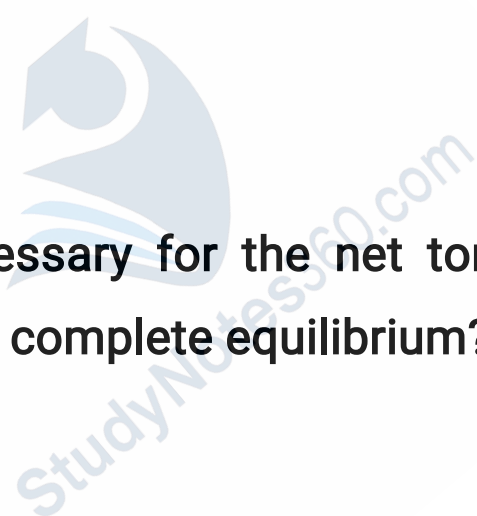
**Answer:**



The second condition of equilibrium requires that the net torque (moment) acting on a body about any point must be zero. This ensures the body does not rotate.


**Mathematically,**

$$\sum \tau = 0$$



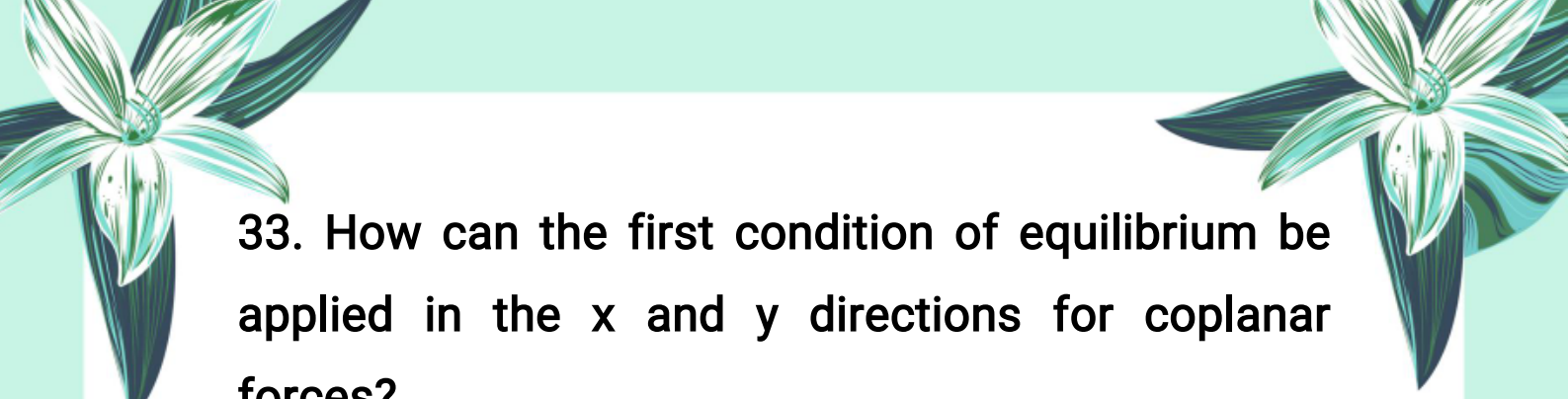
**32. Why is it necessary for the net torque on a body to be zero for complete equilibrium?**

**Answer:**




Even if the net force on a body is zero (first condition), unequal forces acting at different points can create a turning effect (torque) that causes the body to rotate. To prevent this rotation, the sum of all torques must be zero, ensuring the body stays stable and does not rotate.






**33. How can the first condition of equilibrium be applied in the x and y directions for coplanar forces?**

**Answer:**

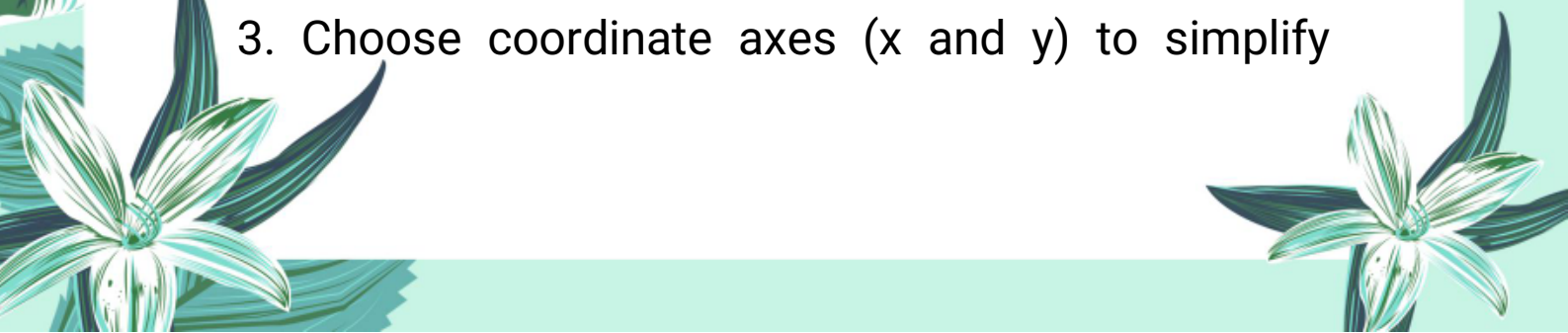


When forces act in a plane, their components along the x-axis and y-axis are considered separately. The sum of all forces along the x-axis must be zero, and the sum of all forces along the y-axis must also be zero. This ensures no net movement in either direction.


$$\sum F_x = 0, \quad \sum F_y = 0$$

**34. What are the steps to solve problems using conditions of equilibrium?**

**Answer:**

1. Select the object(s) to analyze.
  2. Draw a clear diagram showing all forces acting on the object(s).
  3. Choose coordinate axes (x and y) to simplify
- 



force components.

4. Resolve forces into components if needed.

5. Apply the first condition:  $\Sigma F_x = 0$  and  $\Sigma F_y = 0$ .

6. Apply the second condition:  $\Sigma \tau = 0$  (sum of torques).

7. Solve the resulting equations simultaneously to find unknown forces or distances.

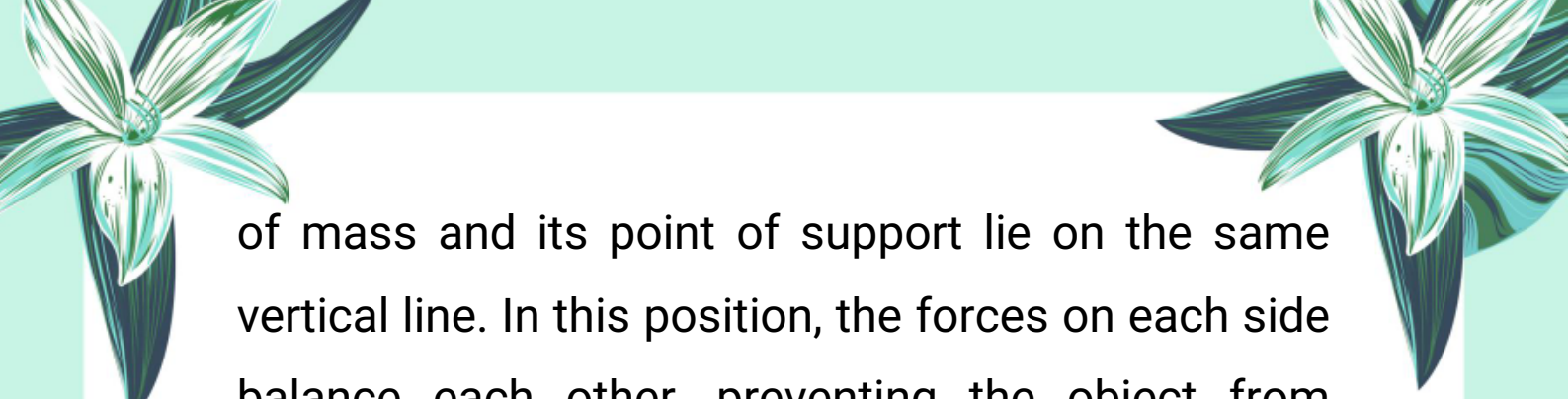
**35. Explain how a paratrooper achieves dynamic equilibrium during descent.**

**Answer:**

After opening the parachute, the downward gravitational force acting on the paratrooper is balanced by the upward air resistance (drag) on the parachute. Since these two forces are equal and opposite, the net force becomes zero. The paratrooper then descends with a constant velocity, meaning there is no acceleration, which is dynamic equilibrium.


**36. What is meant by equilibrium in terms of centre of mass and point of support?**

An object is said to be in equilibrium when its centre



of mass and its point of support lie on the same vertical line. In this position, the forces on each side balance each other, preventing the object from toppling or moving.

**37. Define stable equilibrium with an example.**



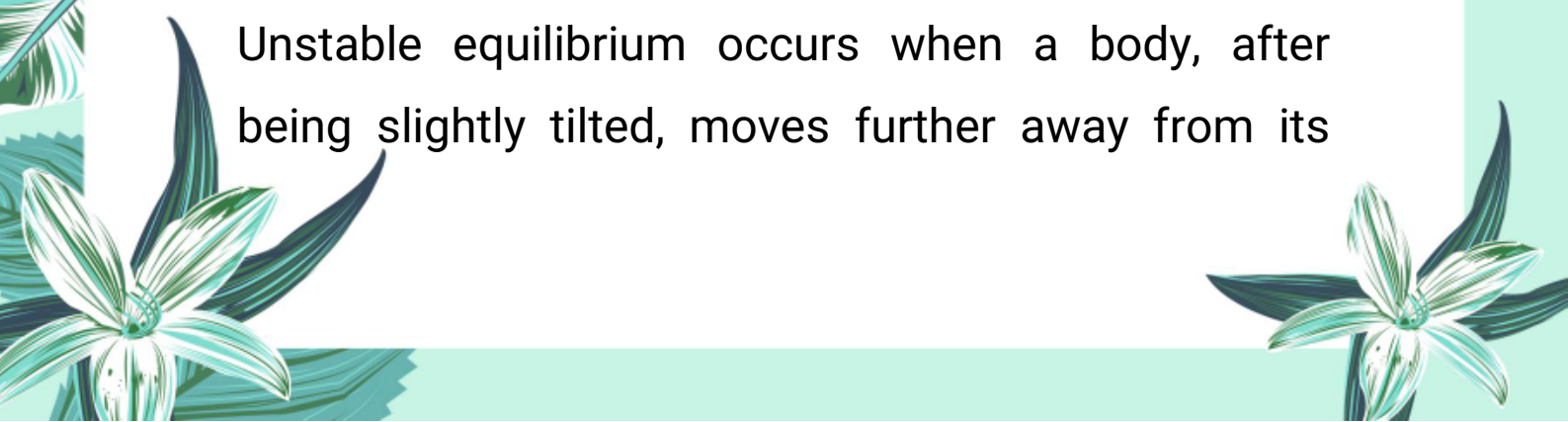
A body is in stable equilibrium if, after being slightly tilted, it returns to its original position. **For example,** a cone resting on its broad base is in stable equilibrium because when tilted slightly, the torques act to bring it back upright.

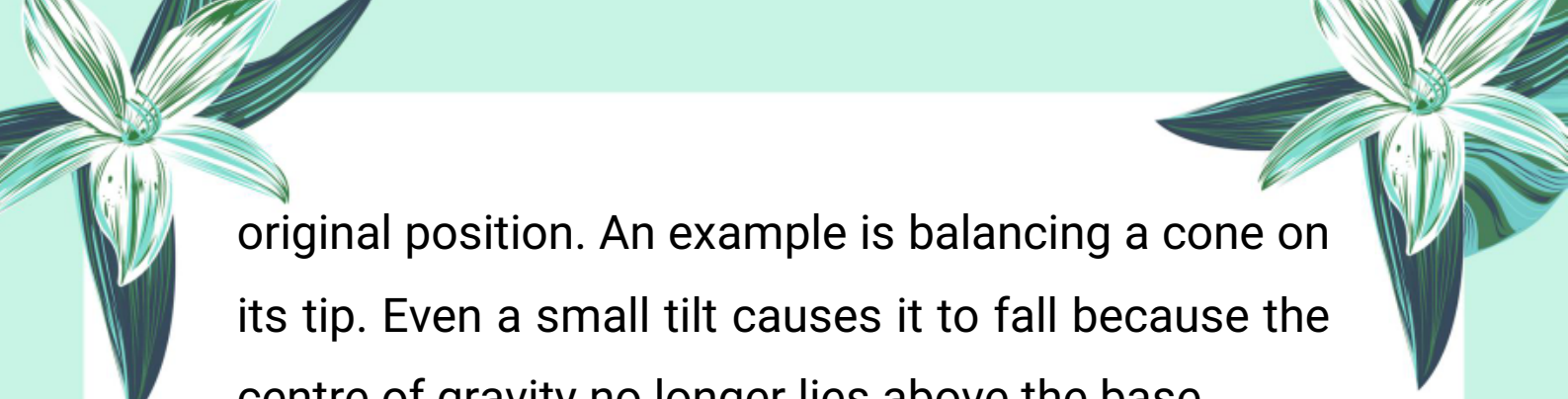
**38. Explain why a cone resting on its base is in stable equilibrium.**

When the cone is slightly tilted, its centre of gravity rises but remains above the base. The weight and normal reaction forces act like unlike parallel forces creating a restoring torque that moves the cone back to its original position, maintaining equilibrium.

**39. What is unstable equilibrium? Give an example.**


Unstable equilibrium occurs when a body, after being slightly tilted, moves further away from its





original position. An example is balancing a cone on its tip. Even a small tilt causes it to fall because the centre of gravity no longer lies above the base.

**40 Describe neutral equilibrium and give two examples.**



In neutral equilibrium, if a body is slightly displaced, it stays in the new position without any tendency to return or move further. The height of the centre of mass remains unchanged. **Examples** include a cylinder resting on a horizontal surface and a ball rolling on a flat surface.

### **Important Long Questions:**

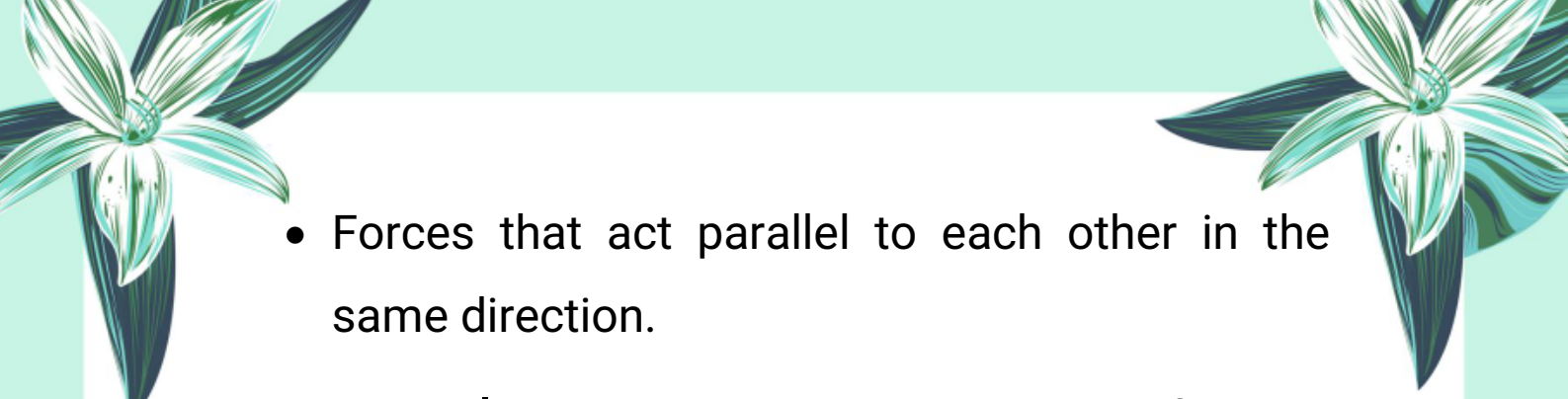
**Q1: Explain the difference between like and unlike parallel forces with examples.**

Include definitions, diagrams, and real-life examples to show how these forces act on a rigid body.

#### **1. Definition**

##### **Like Parallel Forces:**



- 
- Forces that act parallel to each other in the same direction.
  - **Example:** Two people pushing a cart forward together.



### Unlike Parallel Forces:

Forces that act parallel to each other but in opposite directions.

**Example:** Two people pulling a rope from opposite ends.

### 2. Action on a Rigid Body

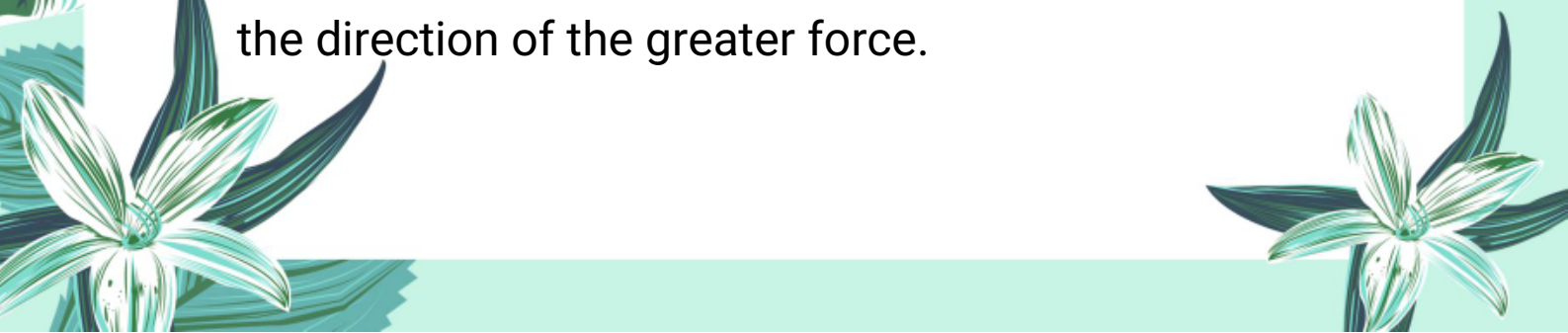
A rigid body is an object that does not deform when forces are applied.

#### Like Parallel Forces:

Add together to produce a larger net force in the same direction.

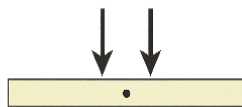
#### Unlike Parallel Forces:

Work against each other. The resultant force is equal to the difference between them and acts in the direction of the greater force.



### Like parallel forces

Parallel forces that act in the same direction



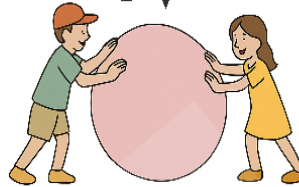
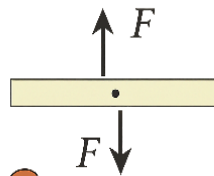
Rigid body



A rigid box

### Unlike parallel forces

Parallel forces that act in opposite directions



A rigid balloon

## 4. Real-life Examples

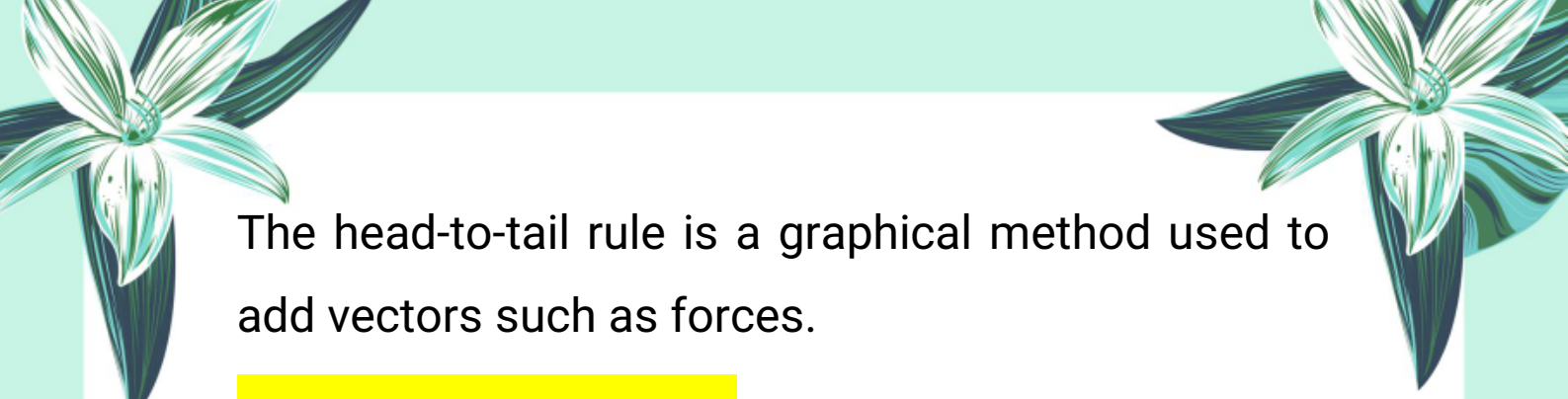
### Type Example

- Like Parallel Forces Two people pushing a car in the same direction
- Unlike Parallel Forces Tug of war – teams pulling rope in opposite directions

**Q2: What is the head-to-tail rule? How can it be used to find the resultant of two or more forces acting in a plane?**


Explain the rule with an example and diagram using three forces acting at different angles.

### 1. Definition of Head-to-Tail Rule



The head-to-tail rule is a graphical method used to add vectors such as forces.

## 2. Steps to Use the Rule

- 
1. Draw the first force vector to scale in the correct direction.
  2. Place the tail of the second vector at the head of the first.
  3. Repeat this process for all vectors.
  4. The resultant vector is drawn from the tail of the first vector to the head of the last vector.

## 3. Example with Three Forces

Given:

$$F_1 = 200 \text{ N at } 30^\circ$$

$$F_2 = 300 \text{ N at } 45^\circ$$

$$F_3 = 250 \text{ N at } 60^\circ$$

Scale: 100 N = 1 cm

Steps:

- Draw  $F_1$  as 2 cm at  $30^\circ$
- 

- Draw  $F_2$  as 3 cm at  $45^\circ$ , starting from  $F_1$ 's head
- Draw  $F_3$  as 2.5 cm at  $60^\circ$ , starting from  $F_2$ 's head
- Draw resultant from tail of  $F_1$  to head of  $F_3$

### Result:

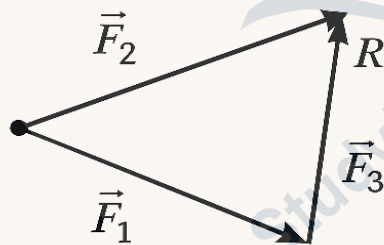
Resultant length = 7.1 cm  $\Rightarrow$  Magnitude = 710 N

Direction =  $43^\circ$  with x-axis

### 4. Diagram

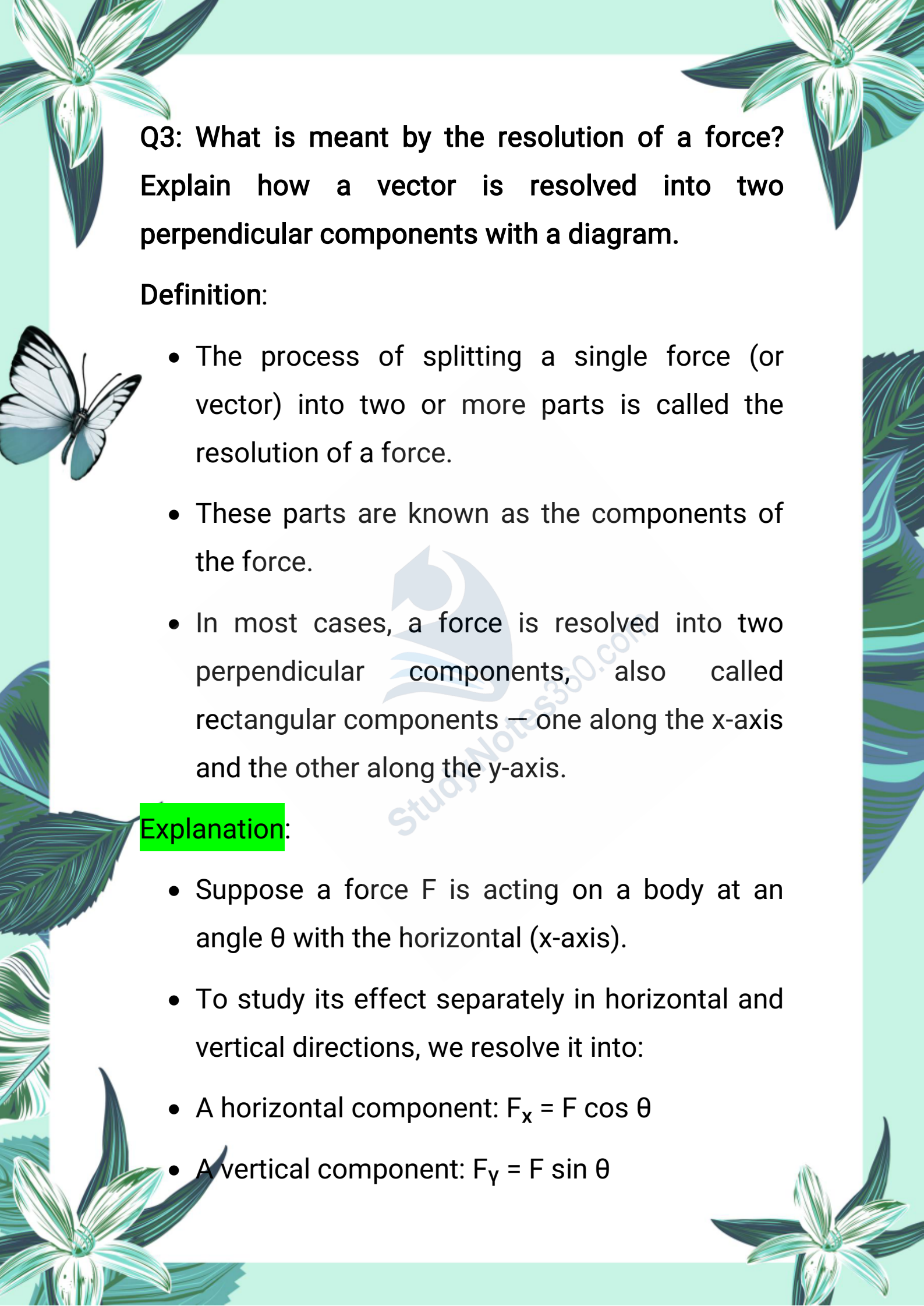
#### Head-to-Tail Rule

The resultant of two or more forces can be found by arranging them head-to-tail.



### 5. Real-life Example

- Aircraft Navigation: Pilot calculates the resultant of wind force and engine thrust.
- Engineering: To find net force acting on a building or beam from different angles.

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**Q3: What is meant by the resolution of a force? Explain how a vector is resolved into two perpendicular components with a diagram.**

**Definition:**

- The process of splitting a single force (or vector) into two or more parts is called the resolution of a force.
- These parts are known as the components of the force.
- In most cases, a force is resolved into two perpendicular components, also called rectangular components — one along the x-axis and the other along the y-axis.

**Explanation:**

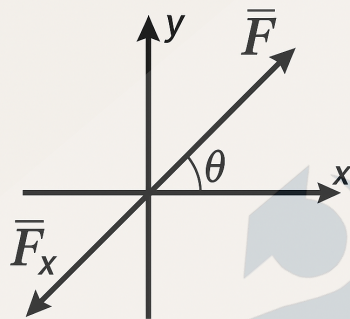
- Suppose a force  $F$  is acting on a body at an angle  $\theta$  with the horizontal (x-axis).
- To study its effect separately in horizontal and vertical directions, we resolve it into:
- A horizontal component:  $F_x = F \cos \theta$
- A vertical component:  $F_y = F \sin \theta$

- These components are perpendicular to each other.

Geometrical Representation (Diagram Description):

### Resolution of a Force

A vector can be resolved into two perpendicular components as shown



- Draw vector  $F$  at an angle  $\theta$  from the x-axis.
- From the tip of vector  $F$ , draw a line vertically downward to x-axis  $\Rightarrow$  This gives the x-component ( $F_x$ ).
- From the same tip, draw a horizontal line to y-axis  $\Rightarrow$  This gives the y-component ( $F_y$ ).
- These lines form a right-angled triangle, with  $F$  as the hypotenuse.


Mathematical Formulas:


$$F_x = F \cos \theta$$

$$F_y = F \sin \theta$$

$$\text{Resultant force: } F = \sqrt{F_x^2 + F_y^2}$$

### Real-Life Example:

- 
- Suppose you push a trolley up a ramp with a force  $F$  at an angle.
  - To understand how much of your force helps the trolley move up the ramp (horizontal) and how much of it acts against gravity (vertical), we resolve the force into two perpendicular components.

**Q4: What is meant by centre of gravity? Explain how to find the centre of gravity of regular and irregular shaped objects.**

### Definition:

The centre of gravity of a body is the point at which the total weight of the body appears to act, regardless of the body's orientation.

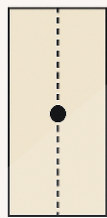
### Centre of Gravity of Regular Objects:



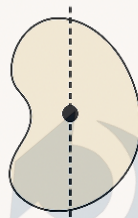
- For objects of regular shape and uniform density (like a square, rectangle, or circle), the centre of gravity lies at their geometrical center.
- **For example**, in a square lamina, it lies at the point where the diagonals intersect.

### Centre of Gravity

The point where the entire weight acts is called the centre of gravity.



Regular object



Irregular object

### Centre of Gravity of Irregular Objects:

For irregular shaped objects like an uneven cardboard piece, the centre of gravity is found using the plumb line method:


1. Suspend the object freely from a point.
2. Hang a plumb line from the same point and mark the vertical line.
3. Repeat this by suspending the object from



another point.

4. The point where the lines intersect is the centre of gravity.

### **Importance:**



If an object is supported at its centre of gravity, it stays in balance without tilting or rotating.



**Q5: What is centre of mass? How does it help in analyzing the motion of a system of particles? Give examples.**

### **Definition:**

The centre of mass of a system is the point where the entire mass of the system can be considered to be concentrated for the purpose of analyzing motion.

### **Application of Newton's Second Law:**

Even if individual parts of a system are moving differently, Newton's second law can be applied to the centre of mass to determine the overall motion of the system.





### Example:

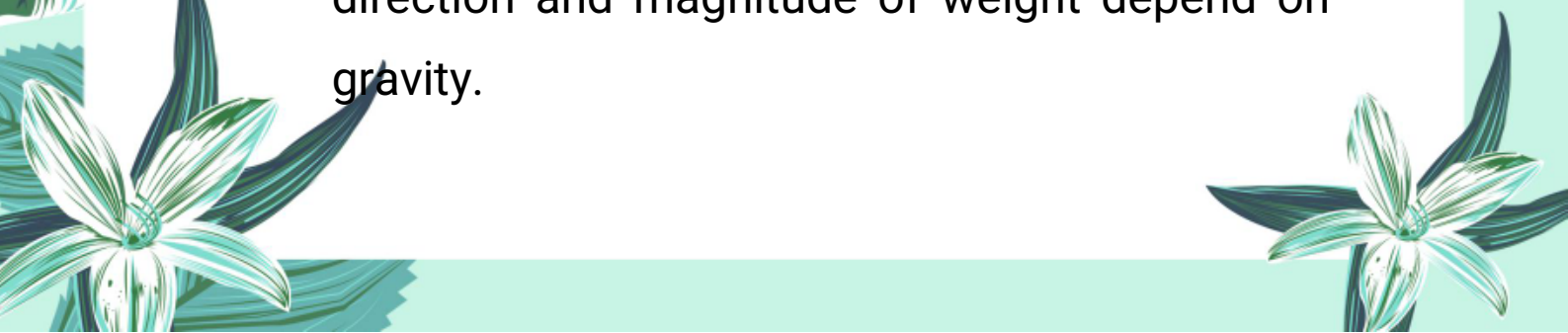
Consider a rotating wrench sliding along a frictionless floor. The wrench rotates, but its centre of mass moves in a straight line at constant speed because there is no net force acting on it.

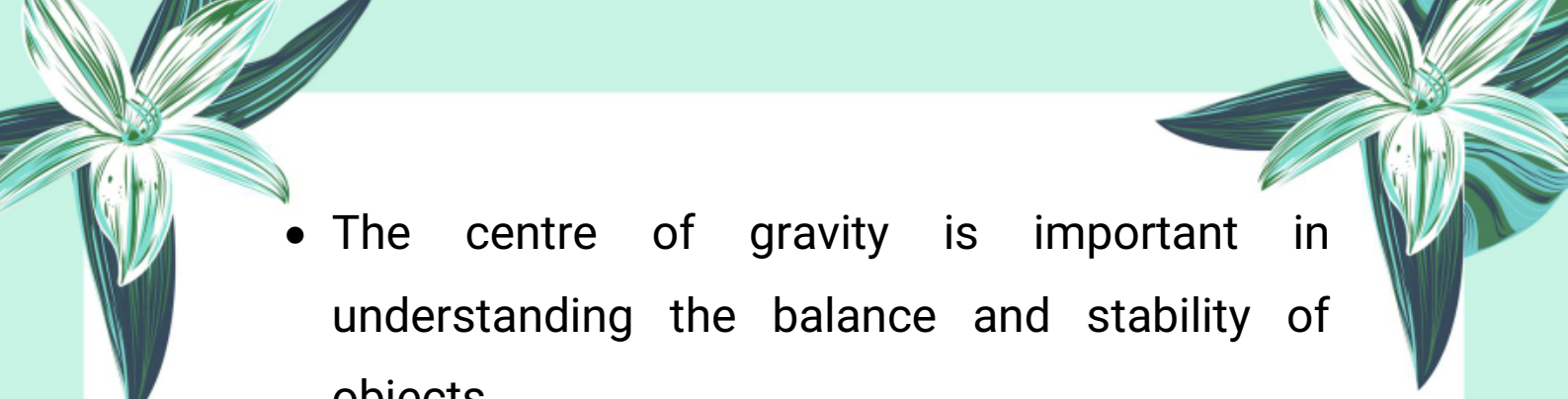


### Other Real-Life Examples:


- A rocket in space moves according to the motion of its centre of mass.
- A walking person's body parts move differently, but the body moves smoothly due to the predictable motion of its centre of mass.
- Differentiate between Centre of Gravity and Centre of Mass with Examples

### Centre of Gravity:

- The centre of gravity is defined as the point in a body or object where the total weight of the body appears to act.
  - It depends on the gravitational field. The direction and magnitude of weight depend on gravity.
- 

- 
- The centre of gravity is important in understanding the balance and stability of objects.

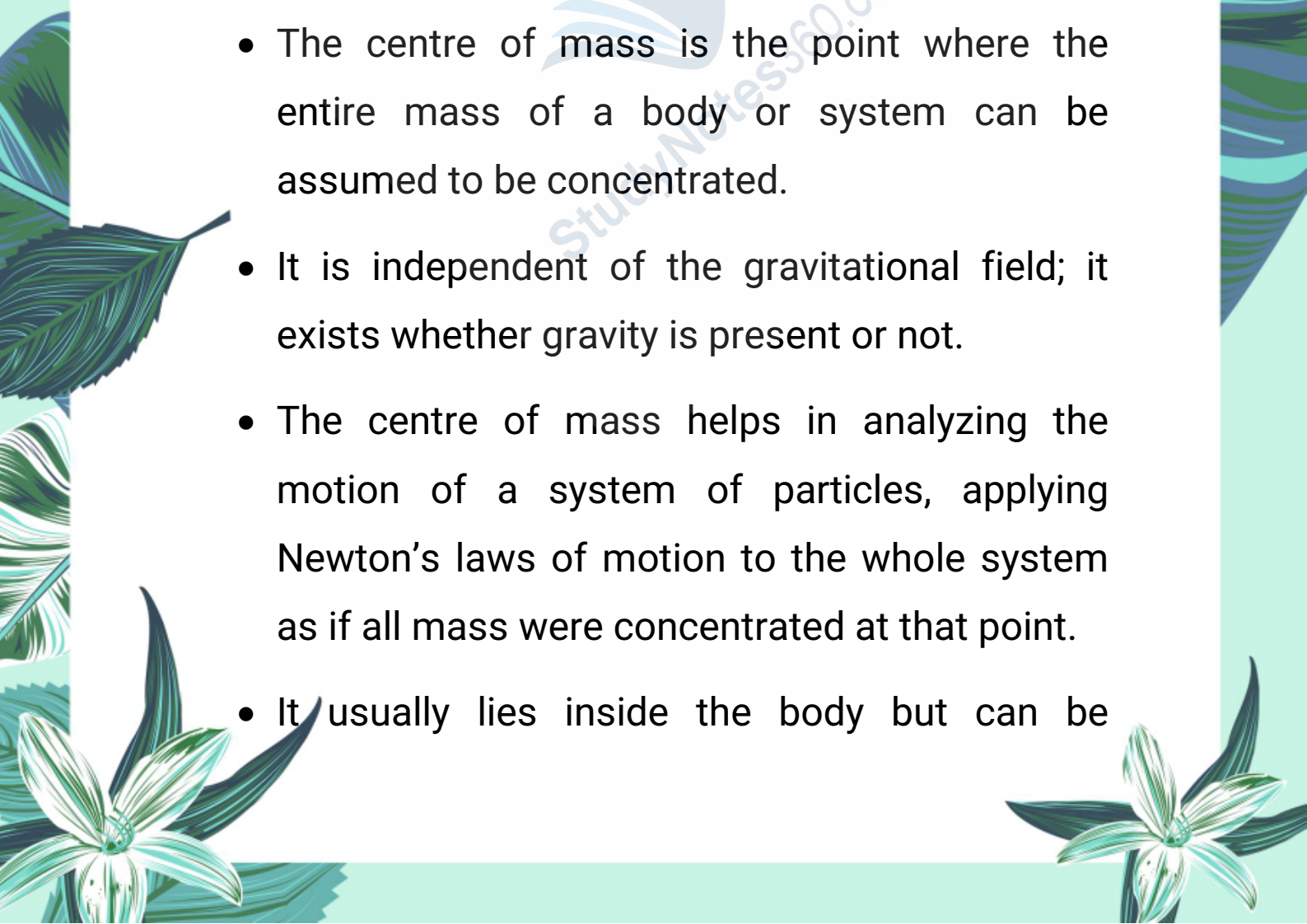
It may lie inside or outside the object depending on the shape and mass distribution.



**For example,** the centre of gravity of a cup lies outside the material.

- It is generally considered when objects are near the Earth or under the influence of gravity.

### Centre of Mass:


- 
- The centre of mass is the point where the entire mass of a body or system can be assumed to be concentrated.
  - It is independent of the gravitational field; it exists whether gravity is present or not.
  - The centre of mass helps in analyzing the motion of a system of particles, applying Newton's laws of motion to the whole system as if all mass were concentrated at that point.
  - It usually lies inside the body but can be



outside in some special cases.

For example, in space, satellites and spacecraft motion is analyzed using their centre of mass.

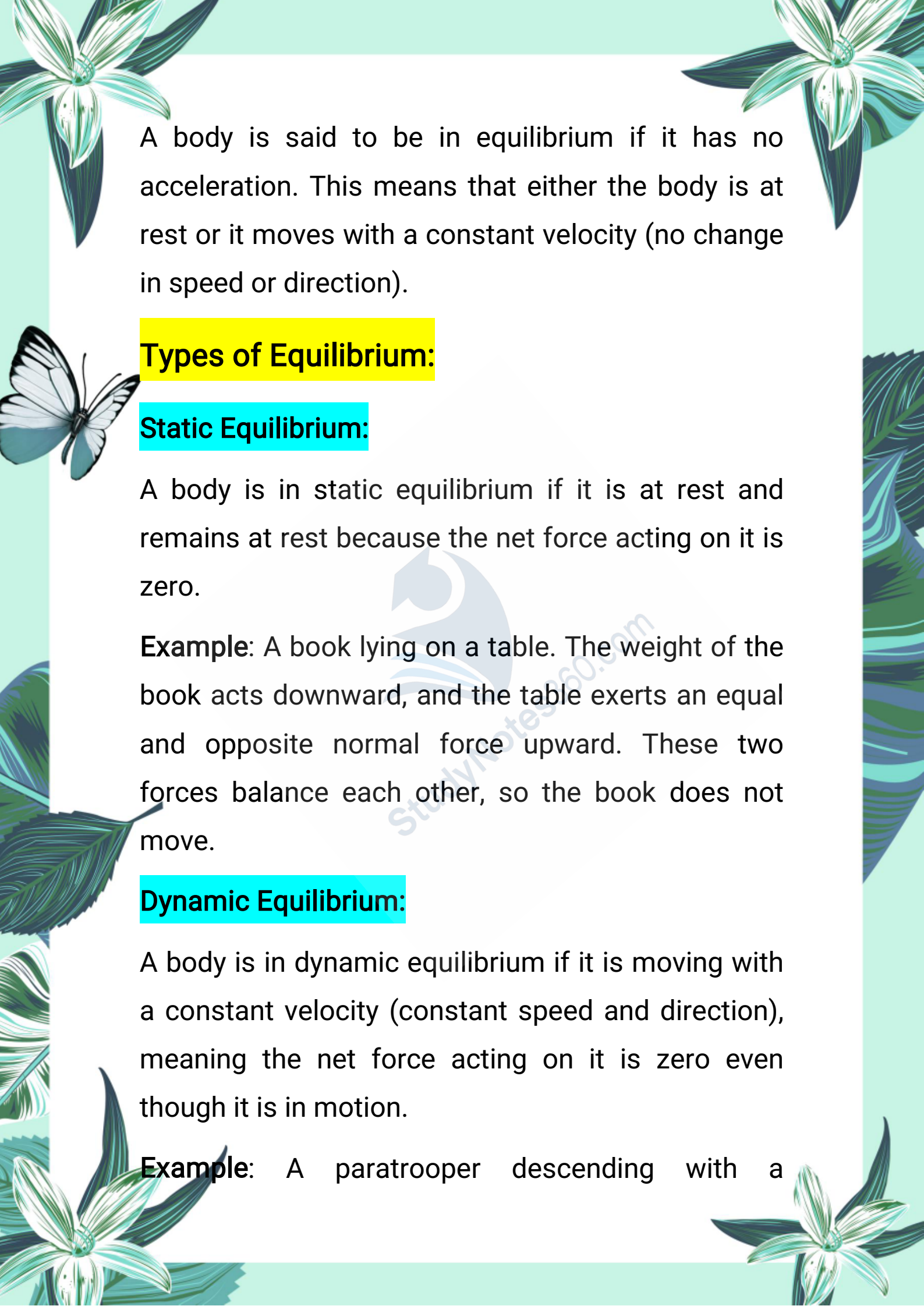
### Examples:

- 
- A solid uniform sphere has its centre of gravity and centre of mass at the geometrical center.
  - A cup has its centre of gravity outside the material, but its centre of mass is at the same point as its mass distribution.
  - A rotating wrench sliding on a frictionless floor moves such that its centre of mass follows a straight path despite rotation.
  - In space, the motion of a rocket is analyzed by tracking its centre of mass because gravitational forces are negligible.

**Q6: Define equilibrium. Differentiate between static equilibrium and dynamic equilibrium with suitable examples.**

**Definition of Equilibrium:**



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A body is said to be in equilibrium if it has no acceleration. This means that either the body is at rest or it moves with a constant velocity (no change in speed or direction).

## Types of Equilibrium:

### Static Equilibrium:

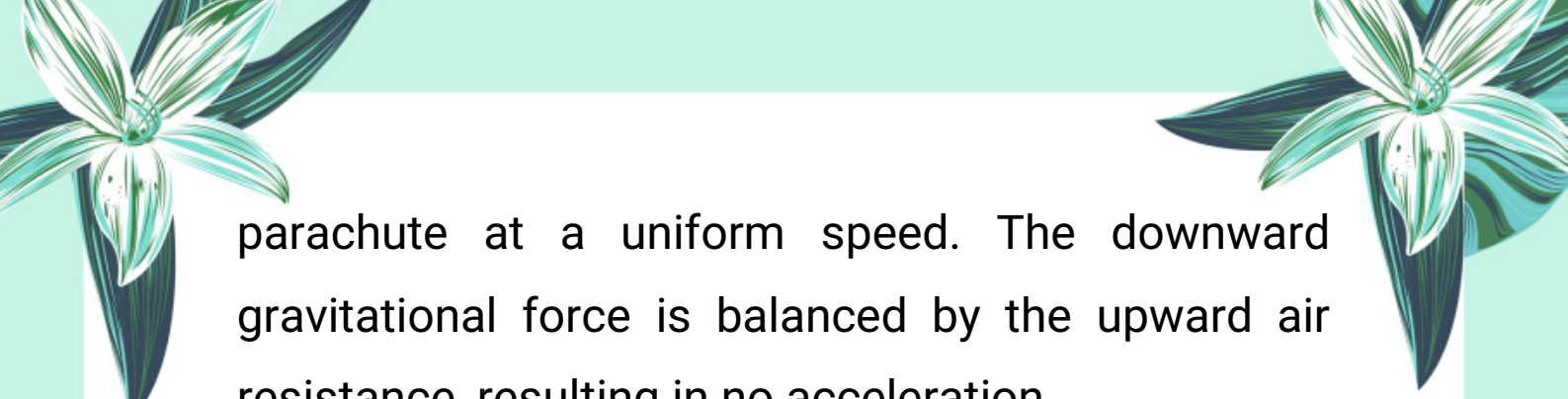
A body is in static equilibrium if it is at rest and remains at rest because the net force acting on it is zero.

**Example:** A book lying on a table. The weight of the book acts downward, and the table exerts an equal and opposite normal force upward. These two forces balance each other, so the book does not move.


### Dynamic Equilibrium:

A body is in dynamic equilibrium if it is moving with a constant velocity (constant speed and direction), meaning the net force acting on it is zero even though it is in motion.

**Example:** A paratrooper descending with a



parachute at a uniform speed. The downward gravitational force is balanced by the upward air resistance, resulting in no acceleration.



**Q7: Explain the first condition of equilibrium. How is it applied to coplanar forces? Give mathematical expressions.**

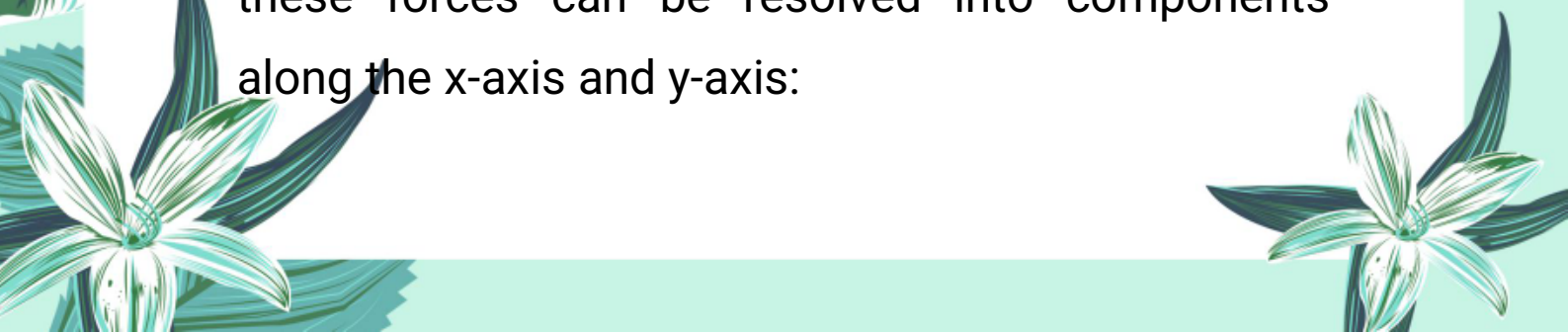
### **First Condition of Equilibrium:**

For a body to be in translational equilibrium, the net external force acting on it must be zero. According to Newton's second law,  $F = ma$ . If acceleration  $a = 0$ , then the net force  $F = 0$ .

**Mathematically:**

$$\sum \mathbf{F} = 0$$

For coplanar forces (forces lying in the same plane), these forces can be resolved into components along the x-axis and y-axis:



- Sum of all forces along x-axis:

$$\sum F_x = 0$$

- Sum of all forces along y-axis:

$$\sum F_y = 0$$

This means the forces balance out both horizontally and vertically to keep the body in equilibrium.

**Q8: What is the second condition of equilibrium?**

**Explain its significance with the help of an example involving forces acting on a rigid body.**

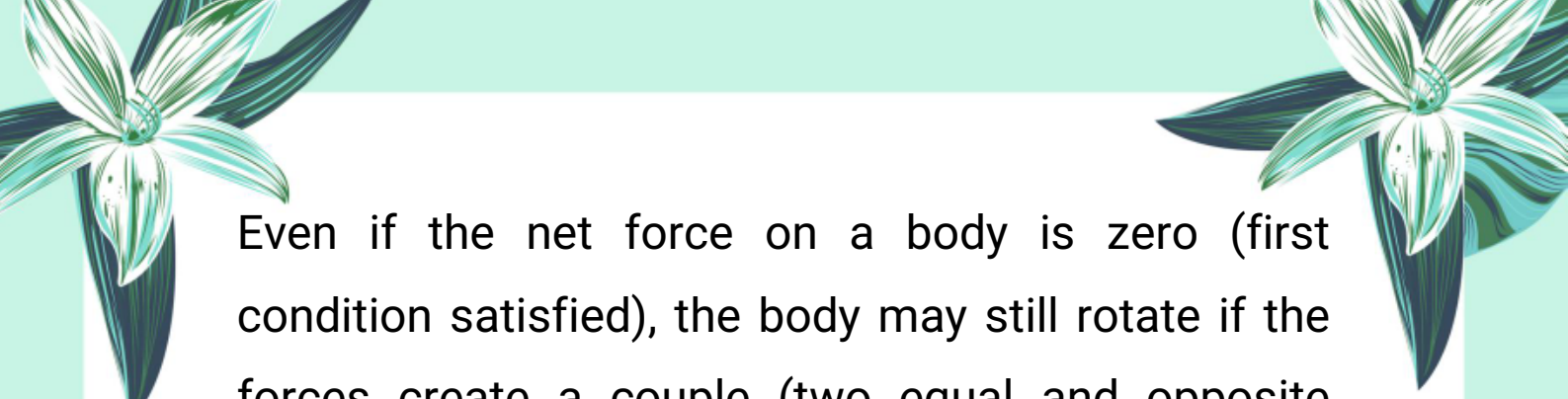
### **Second Condition of Equilibrium:**

The body should not rotate under the action of forces. This means the net torque (moment of force) about any point must be zero.

**Mathematically:**

$$\sum \tau = 0$$

**Significance:**




Even if the net force on a body is zero (first condition satisfied), the body may still rotate if the forces create a couple (two equal and opposite forces whose lines of action do not coincide). To prevent rotation, the total torque must be zero.



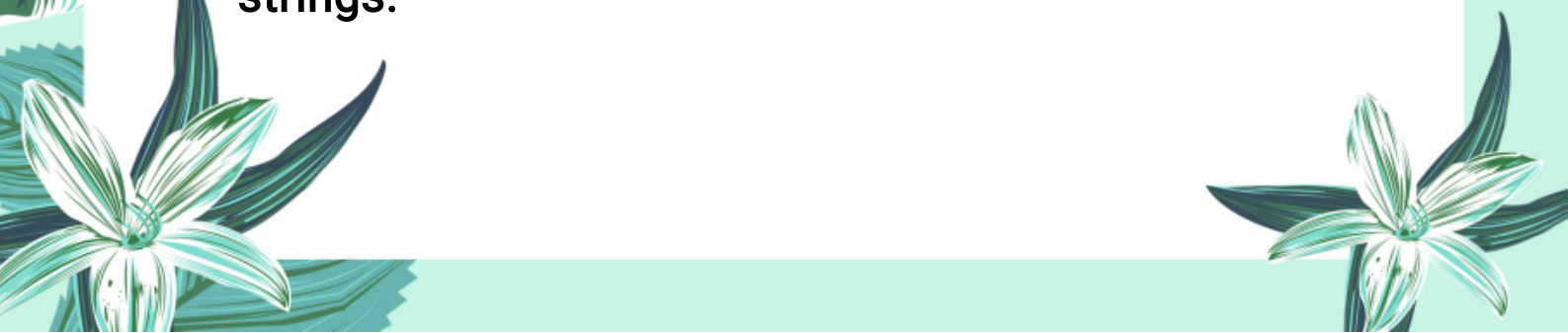
**Example:**

- Consider a rigid beam acted upon by two equal and opposite forces:
- **Case (a):** Both forces act along the same line of action – no rotation, no torque.
- **Case (b):** Forces act along different lines of action – they form a couple, creating torque and causing rotation unless balanced.



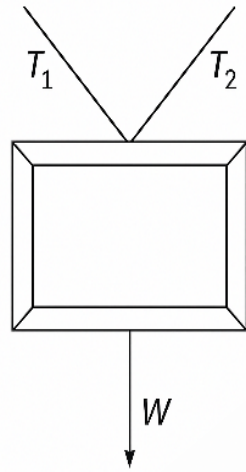
Thus, for complete equilibrium, both conditions must be met.

**Q9:** Describe the steps to solve problems using the conditions of equilibrium. Explain with the help of an example where a picture is suspended by two strings.



## Steps to solve problems using the conditions of equilibrium

Example: A picture is suspended by two strings



1. Draw the free-body diagram
2. Resolve the forces into components
3. Apply the equilibrium conditions  $\Sigma F_x = 0$ ,  $\Sigma F_y = 0$
4. Solve the equations

### Steps to solve equilibrium problems:

1. Select the object(s) to analyze separately.
2. Draw a free body diagram showing all the forces acting on the object(s). Only include external forces acting on the object.
3. Choose coordinate axes ( $x$  and  $y$ ) such that as many forces as possible lie along these axes to simplify calculations.
4. Resolve forces that are not along the axes into rectangular components ( $x$  and  $y$  directions).

5. Apply the first condition of equilibrium:

$$\sum F_x = 0 \quad \text{and} \quad \sum F_y = 0$$

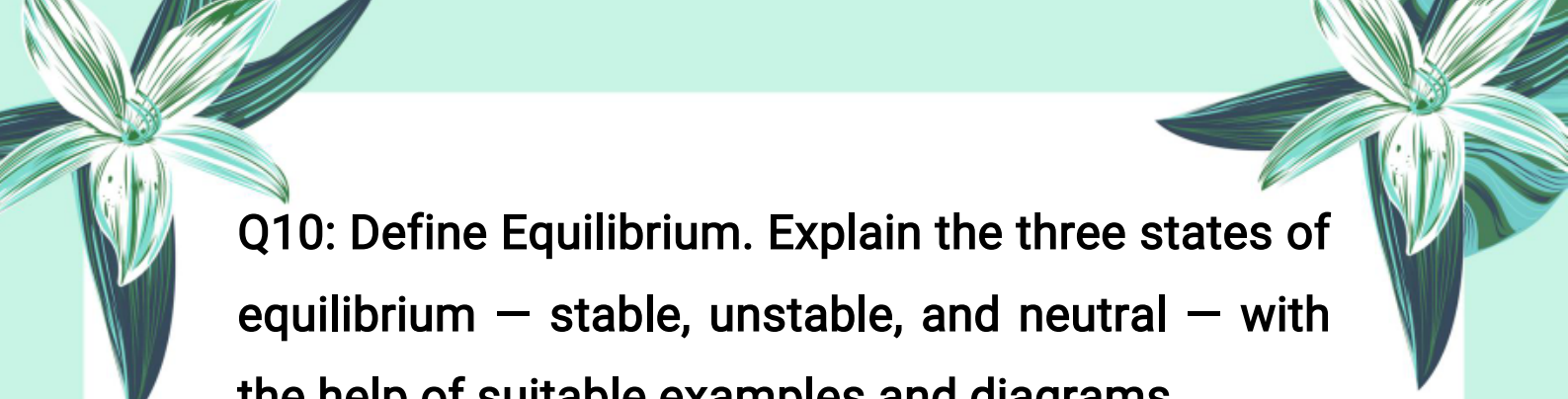
1. Apply the second condition of equilibrium (if rotation possible):

$$\sum \tau = 0$$

1. Solve the resulting equations to find unknown forces or tensions.


**Example: Picture suspended by two string**

- The picture has weight  $W = 5, N$ , acting vertically downward at its center of gravity.
- Two strings support the picture at angles, creating tensions  $T_1$  and  $T_2$ .
- Draw forces:  $W$  downward,  $T_1$  and  $T_2$  along the strings upward.
- Resolve tensions into components.
- Apply  $\sum F_x = 0$  and  $\sum F_y = 0$  to get two equations.
- Solve these equations to find  $T_1$  and  $T_2$ .



**Q10: Define Equilibrium. Explain the three states of equilibrium – stable, unstable, and neutral – with the help of suitable examples and diagrams.**

**Definition of Equilibrium:**

- 
- A body is said to be in equilibrium when it is balanced in such a way that there is no net force or net torque acting on it. This means the body has no acceleration and either remains at rest or continues to move with constant velocity.
  - In other words, the object's centre of mass lies vertically above its point of support, so the forces acting on the body balance each other, preventing any movement or rotation.

**Three States of Equilibrium:**

The equilibrium of a body can be classified into three types based on its behavior when slightly disturbed:

**1. Stable Equilibrium:**

- **Definition:** A body is in stable equilibrium if,
- 

when slightly tilted or displaced, it returns to its original position.

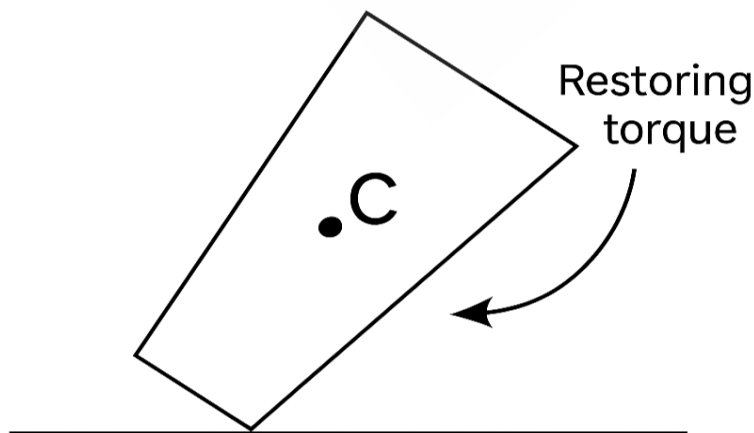
- **Why?** Because the restoring forces or torques act in such a way that they bring the body back to its initial balanced position.
- **Condition:** The centre of mass of the body rises when tilted, creating a torque that pushes it back.

### Example:

- A cone resting on its broad base.
- A book lying flat on a table.

### Diagram Explanation:

When the cone is slightly pushed, the centre of gravity moves slightly but remains above the base. This produces a restoring torque that returns the cone to its original position.



## 2. Unstable Equilibrium:

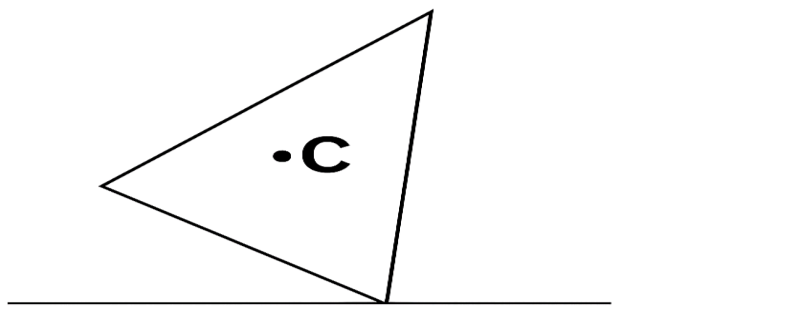
- **Definition:** A body is in unstable equilibrium if, when slightly tilted or displaced, it moves further away from its original position.
- **Why?** Because the restoring forces or torques act in such a way that they increase the displacement.
- **Condition:** The centre of mass lowers when tilted, causing a torque that pushes it further from equilibrium.

### Example:

- A cone balanced on its sharp tip.
- A pencil balanced on its point.

### Diagram Explanation:

When the cone is slightly tilted on its tip, its centre of gravity falls outside the base area, and the body topples over instead of returning to balance.



### 3. Neutral Equilibrium:

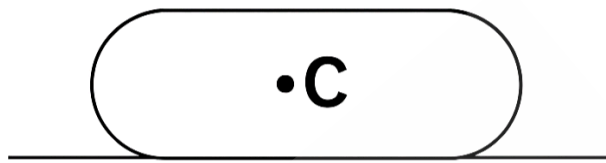
- **Definition:** A body is in neutral equilibrium if, when displaced slightly, it neither returns to its original position nor moves further away, but remains in the new position.
- **Why?** Because the centre of mass stays at the same height, and there are no restoring or overturning torques.
- **Condition:** The potential energy remains constant, and the weight and support force always act along the same vertical line.

#### Example:

- A cylinder rolling on a flat surface.
- A ball resting on a flat horizontal surface.
- A cone resting on its curved surface.

#### Diagram Explanation:

When the cylinder rolls a little, its centre of gravity remains at the same height, so it neither moves back nor falls further, resting in the new position.



### Summary Table:

State of Equilibrium	Behaviour on Displacement	Centre of Mass Movement	Example
Stable	Returns to original pos	Rises	Cone on base, book
Unstable	Move Further Away	Lowers	Cone on tip, pencil
Natural	Stays a new position	Remains same	Cylinder, ball

## C Constructed Response Questions

4.1. A car travels at the same speed around two curves with different radii. For which radius the car experiences more centripetal force? Prove your answer.

Answer:

The formula for centripetal force is:

$$F_c = \frac{mv^2}{r}$$

Where:

- $F_c$  is the centripetal force
- $m$  is the mass of the car
- $v$  is the speed of the car
- $r$  is the radius of the circular path

From the formula, we can see that:


- Centripetal force is inversely proportional to the radius ( $r$ ).
- If speed is constant, a smaller radius will result



in greater centripetal force.

**4.2. A ripe mango does not normally fall from the tree. But when the branch of the tree is shaken, the mango falls down easily. Can you tell the reason?**

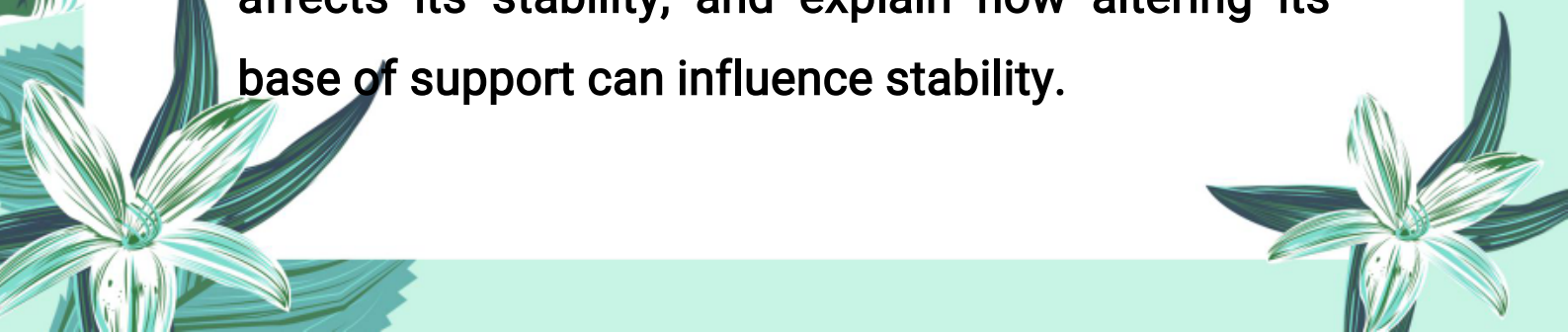
**Answer:**

- 
- The mango remains at rest due to inertia (a tendency to remain in its state of rest).
  - When the branch is shaken suddenly, the branch moves but the mango tries to stay at rest (due to inertia).
  - This relative motion causes the stem to break, and the mango falls.

**Conclusion:**

The mango falls due to inertia of rest when the branch is suddenly moved.

**4.3. Discuss the concepts of stability and centre of gravity in relation to objects toppling over. Provide an example where an object's centre of gravity affects its stability, and explain how altering its base of support can influence stability.**





## Answer:

- Stability of an object depends on the position of its centre of gravity (CG) and the base of support.
- An object topples when its CG falls outside the base of support.



## Example:

- A tall box on a narrow base can easily topple when slightly pushed because:
- Its centre of gravity is high, and
- A small tilt moves the CG outside the base.

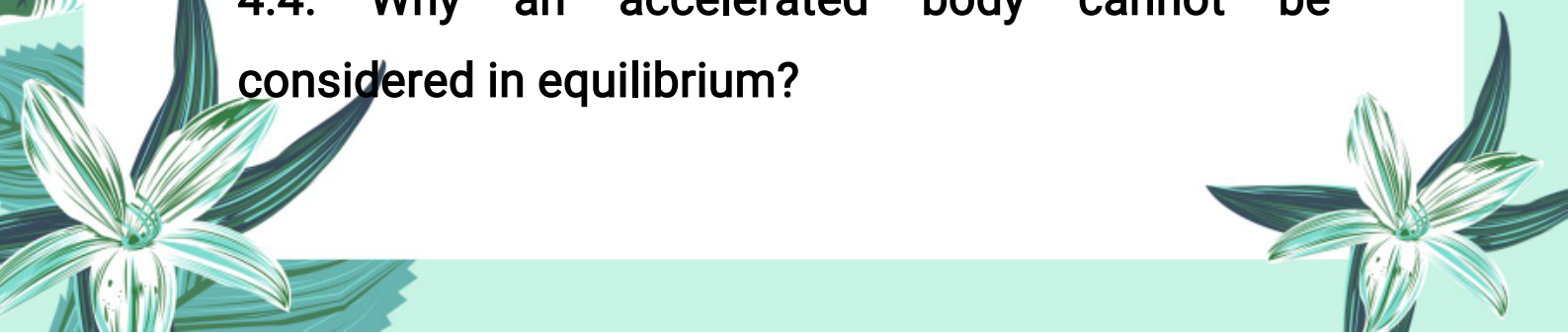
## Improving Stability:

- Lower the centre of gravity.
- Increase the width of the base.

## Conclusion:

Stability increases when the centre of gravity is low and the base is wide.

**4.4. Why an accelerated body cannot be considered in equilibrium?**





**Answer:**

- A body is in **equilibrium** only when the **net force** and **net torque** acting on it are **zero**.
- If a body is **accelerating**, then:

$$F_{\text{net}} = ma \neq 0$$

**Conclusion:**

An accelerated body is not in equilibrium because it experiences a net external force.

**4.5. Two boxes of the same weight but different heights are lying on the floor of a truck. If the truck makes a sudden stop, which box is more likely to tumble over? Why?**

**Answer:**

- Both boxes have the same weight, but the taller box has a higher centre of gravity.
- When the truck stops suddenly, inertia causes the boxes to tip forward.

- The box with the higher centre of gravity will tip more easily, as its line of action moves outside its base more quickly.

### Conclusion:

The taller box is more likely to tumble because of its higher centre of gravity and reduced stability.

## D Comprehensive Questions

4.1. Explain the principle of moments with an example.

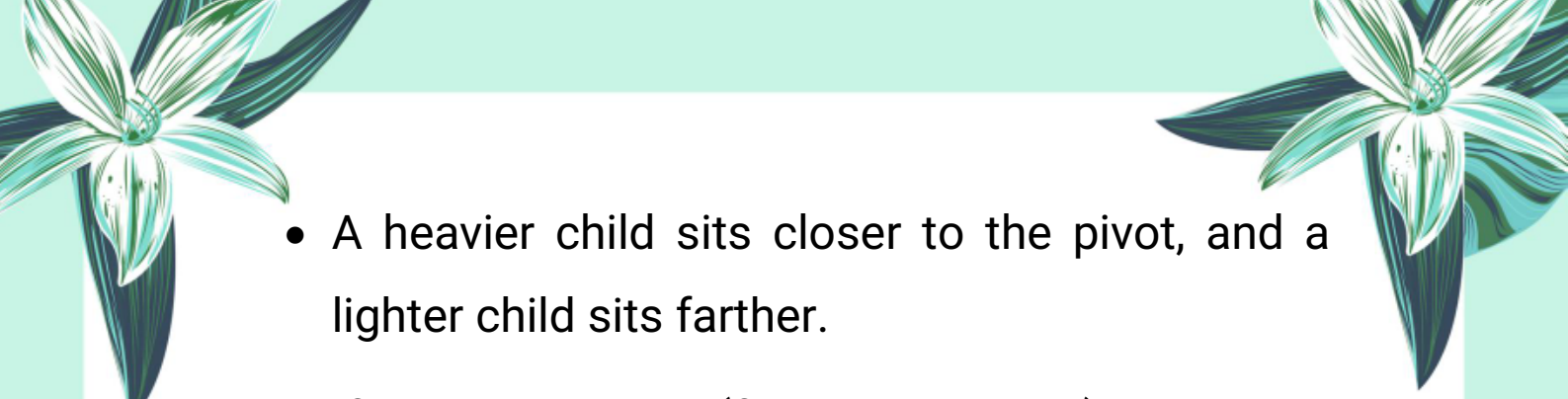
### Answer:


The principle of moments states: For an object to be in rotational equilibrium, the total clockwise moments about a pivot must equal the total anticlockwise moments.

Moment = Force  $\times$  Perpendicular distance from pivot

### Example:

- A seesaw balanced by two children.

- 
- A heavier child sits closer to the pivot, and a lighter child sits farther.
  - If their moments (force  $\times$  distance) are equal, the seesaw remains balanced.



**4.2. Describe how you could determine the centre of gravity of an irregular-shaped lamina experimentally.**

**Answer:**

1. Suspend the lamina (flat shape) from any point using a string.
2. Allow it to hang freely and attach a plumb line from the same point.
3. Draw a straight line along the plumb line on the lamina.
4. Repeat the process from a different suspension point.
5. The point where the two lines intersect is the centre of gravity of the lamina.

**4.3. State and explain two conditions of equilibrium.**



**Answer:**

## 1. First Condition – Translational Equilibrium:

- The sum of all forces in horizontal and vertical directions must be zero.
- $\sum F_x = 0$  and  $\sum F_y = 0$
- This ensures the body doesn't move in a straight line.

## 2. Second Condition – Rotational Equilibrium:

- The sum of all clockwise and anticlockwise moments must be zero.
- $\sum \tau = 0$
- This ensures the body doesn't rotate.

**When both conditions are satisfied, the body is in complete equilibrium.**

**4.4. How can the stability of an object be improved?  
Give a few examples to support your answer.**

**Answer:**

- **Ways to improve stability:**

**1. Lower the centre of gravity – more stable if CG is**



low.

2. **Increase the base area** – wider base gives better support.

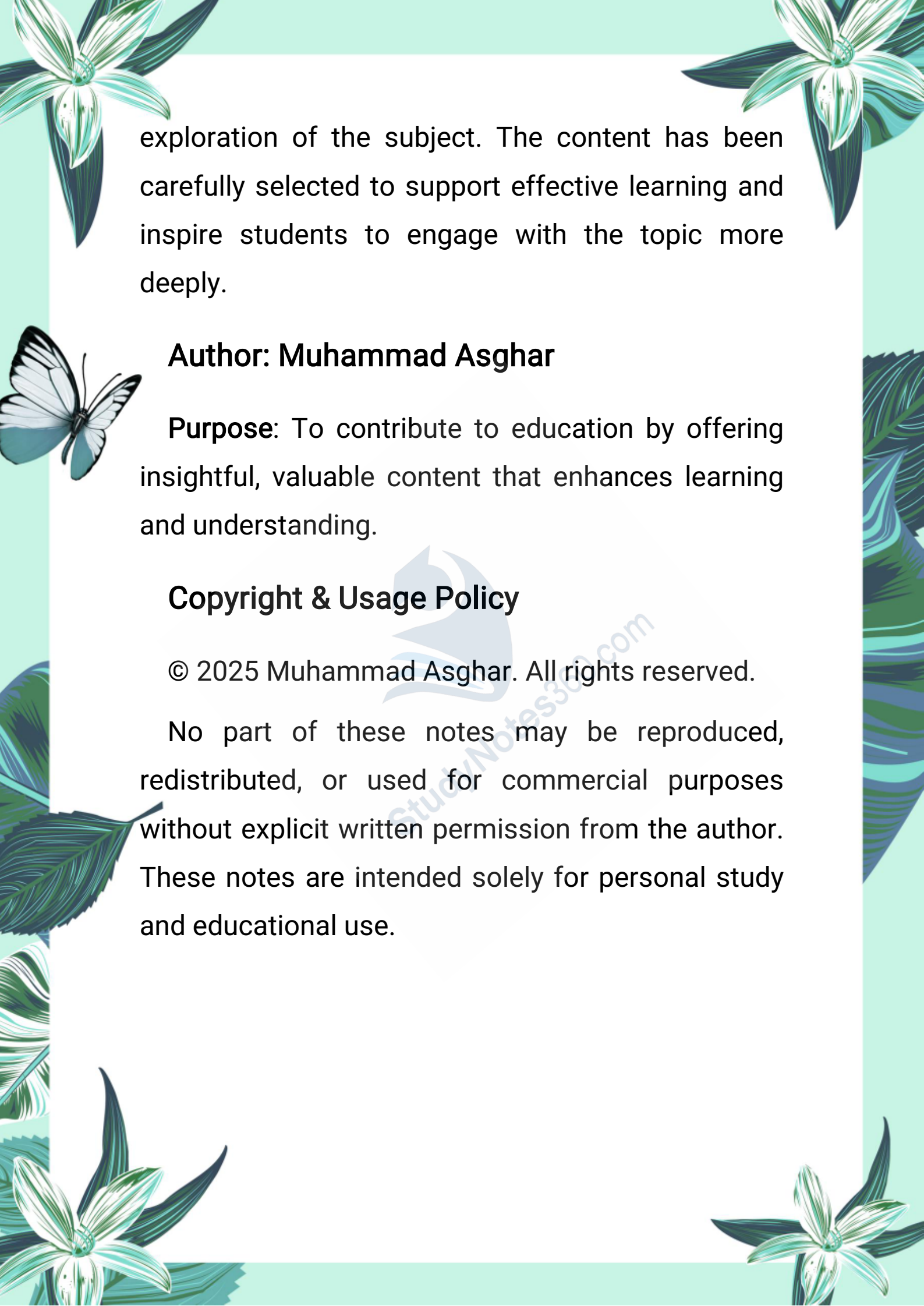
3. **Increase the weight** – heavier objects are harder to topple.

### **Examples:**

- A sports car has a low centre of gravity and wide base, making it more stable.
- A wide-legged chair is more stable than a narrow one.
- A pyramid-shaped tent is more stable than a tall, narrow tent.

### **Note:**

This chapter is designed to provide a solid foundation of knowledge, with the goal of deepening understanding and encouraging further

The page is decorated with various botanical and nature-themed illustrations. In the top corners, there are stylized flowers with long, pointed petals. On the left side, a butterfly with white wings and dark markings is shown in flight. The bottom corners also feature floral designs. The background is a light, solid color, and the text is centered in a clean, black font.

exploration of the subject. The content has been carefully selected to support effective learning and inspire students to engage with the topic more deeply.

**Author: Muhammad Asghar**

**Purpose:** To contribute to education by offering insightful, valuable content that enhances learning and understanding.

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