Integrated Syllabus

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IIT FOUNDATION & OLYMPIAD

EXPLORER

CLASS - IX

BRAIN MAPPING ACADEMY

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PHYSICS

IIT FOUNDATION & OLYMPIAD

EXPLORER

PHYSICS

CLASS - 9

BRAIN MAPPING ACADEMY
Mapping Your Future

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Published by:

Brain Mapping Academy

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Hyderabad–500 036
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ISBN: 978-93-80299-21-1

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Preface

Speed and accuracy play an important role in climbing the competitive ladder. Students have to integrate the habit of being able to calculate and function quickly as well as efficiently in order to excel in the learning culture. They need to think on their feet, understand basic requirements, identify appropriate information sources and use that to their best advantage.

The preparation required for the tough competitive examinations is fundamentally different from that of qualifying ones like the board examinations. A student can emerge successful in a qualifying examination by merely scoring the minimum percentage of marks, whereas in a competitive examination, he has to score high and perform better than the others taking the examination.

This book provides all types of questions that a student would be required to tackle at the foundation level. The questions in the exercises are sequenced as *Basic Practice, Further Practice, Multiple Answer Questions, Paragraph Questions, Numerical Problems, Conceptual Questions and Brain Nurtures.* Simple questions involving a direct application of the concepts are given in *Basic Practice*. More challenging questions on direct application are given in *Further Practice*. Questions involving higher order thinking or an open-ended approach to problems are given in *Brain Nurtures.* These questions encourage students to think analytically , to be creative and to come up with solutions of their own. Constant practice and familiarity with these questions will not only make him/her conceptually sound, but will also give the student the confidence to face any entrance examination with ease.

Valuable suggestions as well as criticism from the teacher and student community are most welcome and will be incorporated in the ensuing edition.

Publisher

CONTENTS

Chapter 5

Turning Forces and Equilibrium

Common Misconception	Fact
1. The centre of gravity of an object is always situated within the object itself.	1. The centre of gravity of some objects lies outside the objects. An L–shaped piece of cardboard and a ring have the centre of gravity outside the body.
2. We cannot balance our body well if we stand on one foot because we are not used to this position.	2. We cannot balance our body well on one foot because we are less stable – the centre of gravity is raised and the base area is reduced.
3. If two equal and opposite forces are exerted on a body then net force and net torque acting on the body are zero.	3. If two equal and opposite forces are exerted on a body then net force can be zero whereas net torque acting on the body is non-zero as the body can be rotated.

SYNOPSIS

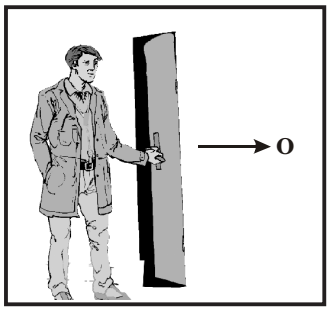
INTRODUCTION

When we pull a door from its outer edge, the door rotates. The whole door is turned or rotated about a fixed axis. So, the force, we apply has a turning effect.

This type of forces which involves turning effect are called turning forces.

MOMENT OF FORCE (TORQUE)

Consider a door fixed at point 'O'



A force 'F' is applied to push the door on application of force, the body rotates or turns about the fixed point (O). This force is unable to displace the body in the direction of force because the body is fixed at point 'O'. Such type of force, is called moment of force or Torque.

Definition

The force that rotates body without displacing it, is called moment of force.

Moment of force is also called Torque which comes from the latin word meaning "To twist". It is denoted by a Greek letter 'τ' (Tau)

Factors affecting the moment of force or turning effect

The turning effect is greater if:

1. the force applied is away from the axis of rotation.
2. the perpendicular distance of the force from the axis of rotation is greater.
3. a greater force would produce a greater turning effect.

Mathematical expression

From above it would be observed that moment of force is directly proportional to the perpendicular distance and applied force.

$\therefore$ moment of force $\propto$ perpendicular distance ---------- (1)

moment of force $\propto$ applied force ---------- (2)

By combining (1) and (2)

τ = K force × perpendicular distance

where 'K' is a constant, with unit value,

Thus,

τ = F × perpendicular distance = F d sin θ

moment of force = Force × perpendicular distance

Mathematical definition of Torque

The moment of a force (or torque) is equal to the product of the magnitude of the force and the perpendicular distance of the line of action of the force, from the axis of rotation.

Units

The SI unit of torque (τ) = Force × perpendicular distance

newton × metre = N–m

Similarly, the CGS unit is dyne–cm

1 N–m = 10^5 dyne × 10^2 cm

1 N–m = 10^7 dyne–cm

The moment of force is a vector quantity.

CLOCK WISE AND ANTICLOCK WISE MOMENT

If the turning effect on body is clockwise, then the moment of force is called the clockwise moment, which is shown below.

Here, the moment is taken as negative.

If the turning effect on body is anticlockwise, then the moment of force is called the anticlockwise moment, which is shown below.

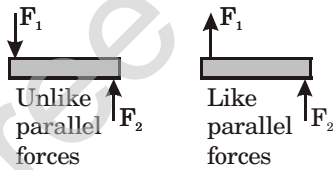
Here, the moment is taken as positive.

Applications of moment of force

1. It is easier to open a door by applying the force at the free end.
2. The hand flour grinder is provided with a handle near its rim.
3. A long spanner is used to loosen a tight nut.

Parallel forces

Forces which are not concurrent and act in opposite direction, and the line of action is not same then such forces are called parallel forces.



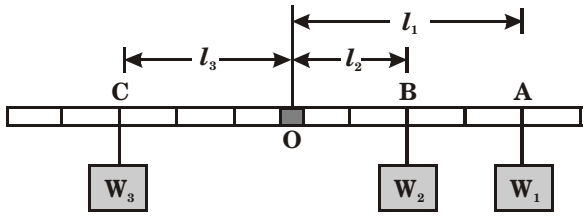
Principle of moment

The principle of moments states that for a body to be in rotational equilibrium, the sum of clockwise torques about any point (which acts as a pivot) must equal to the sum of anti–clockwise torques about that same point.

Sum of clockwise torques = Sum of anti–clockwise torques

Verification of principle of moments

Suspend the metre rule horizontally from its mid–point O, by means of a thread with its other end connected to a fixed support. Now suspend some weights on both sides of the mid–point and adjust their distances in such a way that the scale again becomes horizontal.



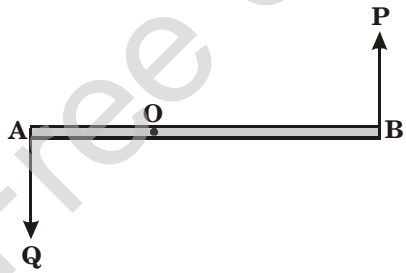
1. Let the weights suspended on the right side of the mid point O be W_1 and W_2 at distance OA = l_1 and OB = l_2 respectively.
2. Let the weight suspended on the left side of the mid point O be W_3 at a distance OC = l_3
3. Total clockwise moment = $W_1 \times l_1 + W_2 \times l_2$
4. Anti–clockwise moment = $W_3 \times l_3$
5. It is found that $W_1 \times l_1 + W_2 \times l_2 = W_3 \times l_3$

Applications of principle of moment

1. To find the mass of an object.
2. To find the mass of metre rule.
3. In simple machines.

COUPLE

Two equal and opposite parallel forces whose lines of action are not the same form a couple.



Arm of couple

Perpendicular distance between two equal and opposite parallel forces is called the arm of couple.

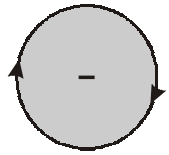
MOMENT OF COUPLE

The product of one of the forces of the couple and arm of the couple is called moment of couple, i.e. Moment of couple = F × d

∴ Moment of couple = Force × Arm of couple

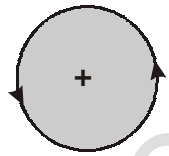
Clockwise and Anticlock wise moment of a couple

If the couple has a tendency to rotate a body in clockwise direction as shown below.



Then its moment is taken as negative.

If the couple has a tendency to rotate a body in anticlockwise direction as shown below.



Then its moment is taken as positive.

Units of moments of couple

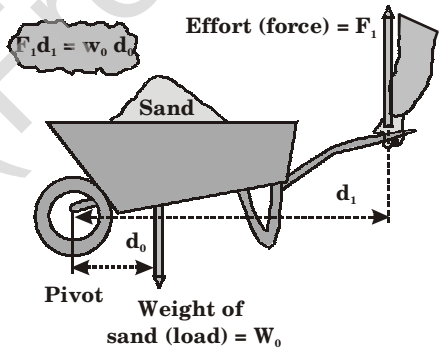
a. In MKS or SI system : newton–metre

b. In CGS system : dyne–cm

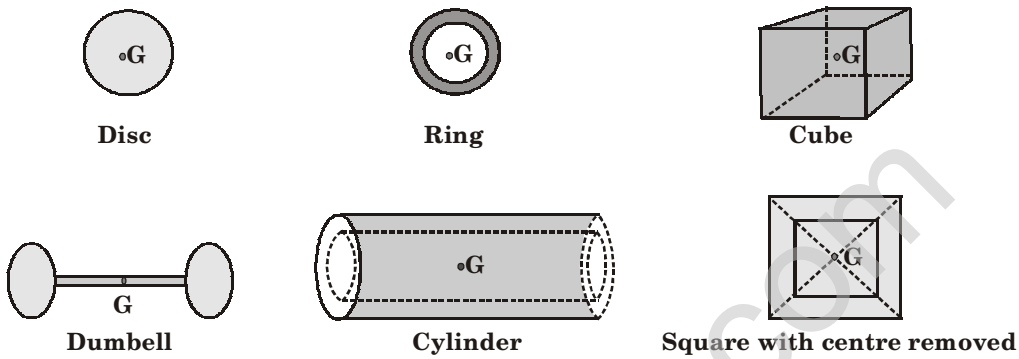
CENTRE OF GRAVITY AND STABILITY

The centre of gravity of an object is defined as the point through which its weight appears to act for any orientation of the object.

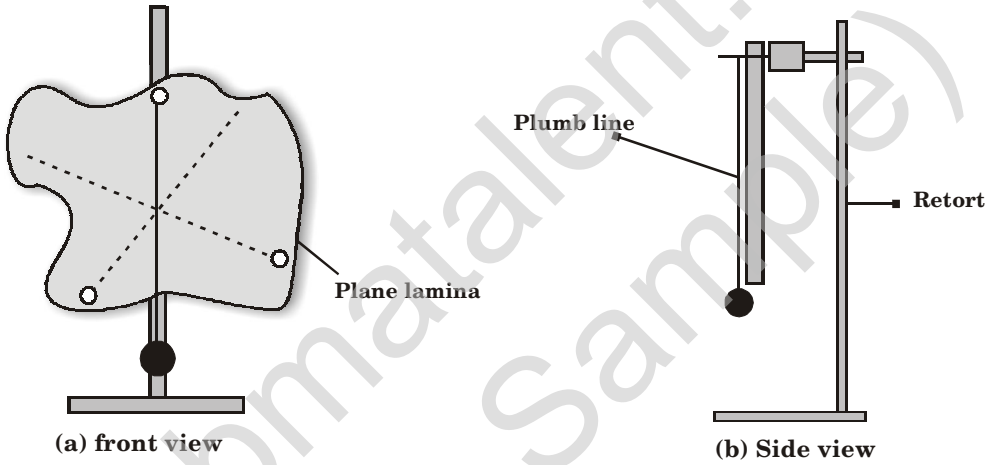
The centre of gravity of an object depends on the distribution of its mass. For certain objects like a ring, the centre of gravity may lie outside the object. Sometimes the term centre of mass is used to denote the word centre of gravity. Both of these will mean the same in a uniform gravitational field.



The centres of gravity of some regular shaped objects



Finding the centre of gravity of an irregular Lamina



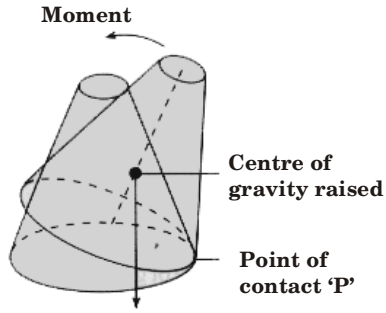
1. Three small holes are made near the edge of the lamina. The holes should be as far apart as possible.
2. The lamina is then suspended freely through one of the holes using a pin and a plumbline is drawn infront of the lamina.
3. The process is repeated with the other holes.
4. The lines of intersection of all the plumblines give the centre of gravity of the lamina.

Stability of an object

Stability refers to the ability of an object to regain its original position after it has been tilted slightly.

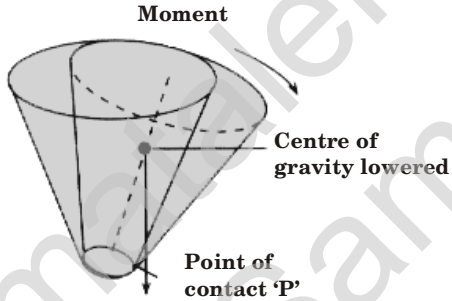
The stability of an object can be better understood by placing a cone shaped object in different positions as shown below and tilting or displacing it slightly.

In figure 1, when the object is tilted slightly, its centre of gravity rises and then falls back again. This is an example of a stable equilibrium. The line of action of weight W of the object lies inside the base area of the object. The applied clockwise moment while tilting the object is counteracted by the anticlockwise moment about the point of contact P of the object with the floor in the tilted position.



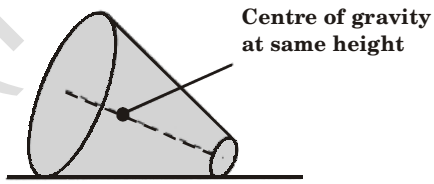
(a) stable equilibrium

In figure 2, the object is placed upside down with the smaller area in contact with the floor. If the object is tilted slightly, it will not return to its original position, but will topple. The centre of gravity falls further. As the line of action of weight W of the object likes outside the base area, the clockwise moment of W about the point of contact P, causes the body to topple. This is an example of an unstable equilibrium.



(b) unstable equilibrium

In figure 3, the object is placed horizontally with its side touching the ground. If the object is rolled or displaced from the original position slightly, it will stay in the new position. The centre of gravity neither rises nor falls but stays at the same level from the ground. The line of action of the reaction R at the point of contact with the ground and the line of action of weight W always coincide. hence, no moment is provided by the weight W about the point of contact to turn the conical object. This is an example of a neutral equilibrium.



(c) unstable equilibrium

The two important factors to increase the stability of an object are:

1. The centre of gravity should be as low as possible.

2. The area of the base should be as wide as possible.

These factors will ensure that the vertical line passing through the centre of gravity of a body will always lie inside the base of the body when it is tilted or inclined.

Examples

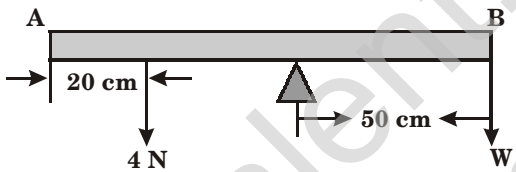
a. Racing cars are designed with low centres of gravity and wide bases.

b. Flower vases, desk lamps, table and pedestal fans, water jugs and various ornamental objects make use of the same principle.

SOLVED EXAMPLES

Example 1:

A uniform metre rule AB is supported at its centre of gravity by a knife–edge. A force of 4 N is applied at a point which is 20 cm from end A of the rule. Calculate the force which must be applied to end B to restore the equilibrium of the rod.



Solution:

Let 'W' be the force applied at end B to restore the equilibrium.

Taking moments about the pivot,

The anticlockwise moment = 4 × 30 (due to 4 N force)

The clockwise moment = W × 50

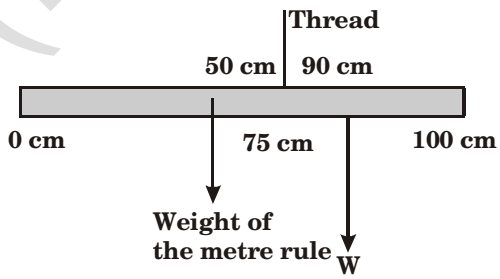
Equating the clockwise and anticlockwise moments

W × 50 = 4 × 30

$$W = \frac{4 \times 30}{50} = 2.4 \text{ N}$$

Example 2:

A uniform metre rule which has a mass of 75 g is suspended by a thread at the 75 cm mark and is balanced by a mass of weight W hanging from the 90 cm mark. Calculate the value of W.



Solution:

Since the metre rule is uniform, its centre of mass will be at the middle is 50 cm mark.

Mass of the rule = 75 g = 0.075 kg

Force due to this mass = 0.075 × 10 = 0.75 N, (g = 10 N kg^{-1})

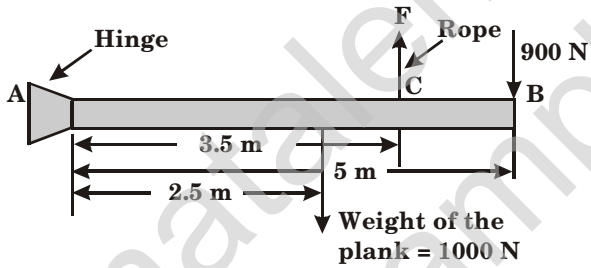
The clockwise moment due to 0.75 N force about the point of the suspension = the anticlockwise moment of W around the same point.

$\therefore$ 0.75 × (75 – 50) = W × (90 – 75)

$$\therefore W = \frac{0.75 \times 25}{15} = 1.25 \text{ N}$$

Example 3:

A uniform wooden plank AB of 5 m length is hinged at the end A and is supported by a vertical rope at C, which is 3.5 m away from the hinge. The wooden plank has a mass of 100 kg. A painter of weight 900 N stands at the end of the plank at B. Calculate the force F on the rope.



Solution:

The total clockwise moment about the hinge = 1000 × 2.5 + 900 × 5

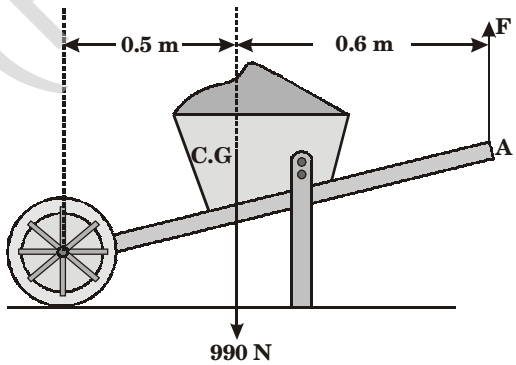
The total anticlockwise moment about the hinge = F × 3.5

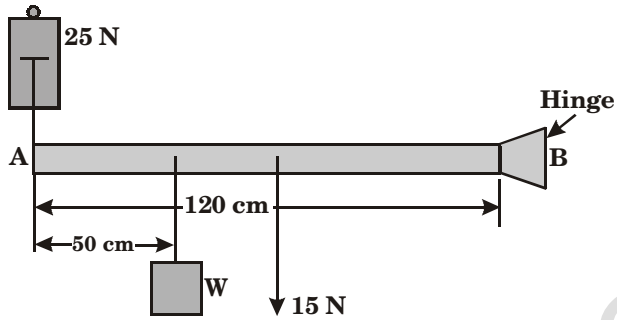
Equating the moments F × 3.5 = 1000 × 2.5 + 900 × 5 = 7000

$$\therefore F = \frac{7000}{3.5} = 2000 \text{ N}$$

Example 4:

A wheelbarrow carrying a load of 990 N is as shown in the figure below. What is the minimum force F required to lift up the end A of the wheelbarrow?





Solution:

The total anticlockwise moment (about the hinge) = 15 × 60 + W × (120 – 50)

The total clockwise moment = 25 × 120

Equating the moments = 15 × 60 + W × 70 = 25 × 120

∴ 70 W = 3000 – 900 = 2100

$$W = \frac{2100}{70} = 30 \text{ N}$$

The mass of object = $\frac{30}{10}$ = 3 kg (g = 10 N kg^{-1})

Example 7:

A man holds a pole of 6.0 ft. horizontally with both hands, one hand at the end, and the other hand at 1.0 ft. from the same end. He just caught a 3 *lb* fish. The pole weighs 2.0 *l*b and its weight can be considered to be concentrated 2.0 ft. from the end near the man's hand. What is the force exerted by each hand?

Solution:

Man uses equal forces by his two hands on the pole. To find the forces used by the man, we have to find clock wise moment and anticlock wise moment.

Clock wise moment produced by two hands about, the balancing point

= F × 2 + F × 1 = 3F × ft .....(1)

Anti clock wise moment produced by the fish of 3 *l*b weight about Balanced point

= 3 × 4 ft = 12 *lb* × ft .....(2)

In the balancing condition, eq. (1) is equal to eq. (2),

3 F × ft = 12 *l*b × ft ⇒ 3F = 12 *l*b

$$F = \frac{12\ lb}{3} = 4lb$$

CONCEPT MAP

TURNING FORCES AND EQUILIBRIUM

Applications: 1. Opening of a door.
2. See-saw
3. A spanner.

Factors affecting:
1. The magnitude of the force perpendicular distance of the line action of the force.
2. The magnitude of the force perpendicular distance of the line action of the force.

Moment of Force Torque): The force that rotates body without displacing it.
τ = F × perpendicular distance
Units : SI: N-m
CGS: dyne-cm

Principles of Moments: If the algebraic sum of moments of all the forces acting on the body is zero, the body is in rotational equilibrium.

RIGID BODY

Force on Rigid bodies

A body, which does not get deformed under the action of a force.

A Force 'F' acts on it at point called point of action of force.

An imaginary line passing through the point of action of force, in the direction of force is called line of action of force.

Couple is a set of two equal, parallel and opposite forces.
Since, the forces are opposite and equal in magnitude, the net resultant force is zero. Therefore, it can produce no motion in body, along straight line direction

Moment of Couple: The moment of a couple is equal to the product of either forces and the perpendicular distance, between the line of action of both forces.

Summative Exercise

SECTION – A

BASIC PRACTICE

FILL IN THE BLANKS

1. _____ is the tendency of a force to rotate an object about an axis.
2. SI unit of moment of couple is _____.
3. The resultant of two like parallel forces 12 N and 7 N is _____ N.
4. The point through which the total weight appears to act for any orientation of the object is _____.
5. The centre of gravity of a regular shaped objects is at their _____.
6. Ratio of SI unit of torque to its CGS unit is _____.
7. The coordinates of edges of a square are O(0, 0), A(0, 4), B(4, 4), C(4, 0) respectively, the centre of gravity of square is at coordinates _____.
8. CG of a triangular lamina is at its _____.
9. Two rigid objects A, B of same dimensions are applied with forces in the ratio 4 : 9 respectively. If the perpendicular distance of the force from the axis of rotation of two objects is same then turning force is greater in _____.
10. In a stable equilibrium, the line of action of weight of the object less _____ the base area of the object.

TRUE OR FALSE

11. The centre of gravity depends on the acceleration due to gravity at the given place.
12. The increase in base area leads to decrease in stability of an object.
13. The spanner with a longer handle can tighten nuts and bolts with less effort.
14. At rotational equilibrium, sum of clockwise moments equals to sum of anti–clockwise moments.
15. A couple produces motion in a straight line.
16. Self balancing toys have curved and heavy base area.
17. A cone resting on its side is an example for neutral equilibrium.
18. The position of centre of gravity of the pot before filling it with water will be at its base.
19. A couple can never be replaced by a single force.
20. To produce pure rotation moment of force need to be applied.

MATCH THE FOLLOWING

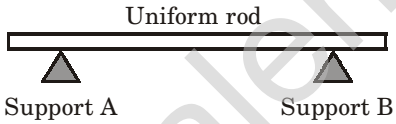
21.

Column A	Column B
A. Torque	p. Wide base area
B. Couple	q. Opening a door
C. CG of circle	r. Opening a tap
D. CG of triangle	s. Intersection of medians
E. Stability	t. Intersection of diameters

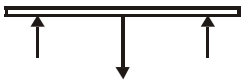
FURTHER PRACTICE

MULTIPLE CHOICE QUESTIONS

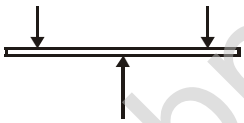
1. A uniform heavy rod is resting on support A and support B as shown.

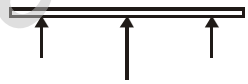


Which of the following shows the correct forces acting on the rod?

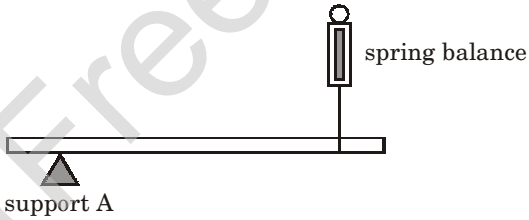
(A) 

(B) 

(C) 

(D) 

2. A uniform heavy rod is being kept in equilibrium by support A and a spring balance as shown.



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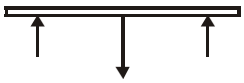
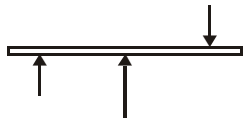
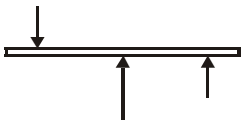
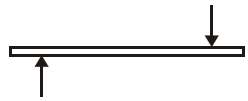
(A) 

(B) 

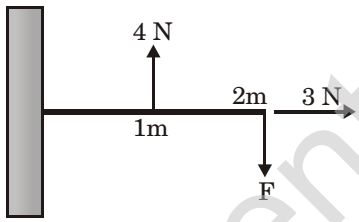
(C) 

(D) 

12. A 1 m long uniform beam of 2 kg mass is being lifted vertically up by a force F at the 100 cm mark. What is the minimum force to do so?

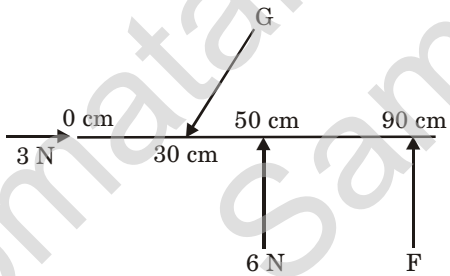
(A) 1 N (B) 2 N (C) 10 N (D) 20 N

13. A uniform beam of 2 m is being fixed to a wall and loaded by the forces shown below. Given that the beam is at equilibrium, calculate force F.



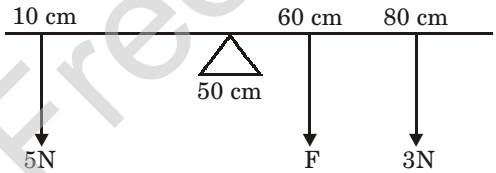
(A) 2 N (B) 4 N (C) 7 N (D) 8 N

14. A 1 m long uniform beam is being balanced as shown below. Calculate force G.



(A) 3.0 N (B) 4.5 N (C) 5.0 N (D) 6.0 N

15. A 1 m long uniform beam is being balanced as shown. Calculate the force F.



(A) 2 N (B) 3 N (C) 7 N (D) 11 N

MULTIPLE ANSWER QUESTIONS

1. Which of the following sports uses the turning effect of forces?

(A) Cycling (B) Swimming (C) Badminton (D) Hockey

2. Which of the following playground equipment make use of the turning effect of forces?

(A) See-saw (B) Slide (C) Swing (D) Toy horse

3. Which of the following objects is/are in equilibrium?

(A) A sleeping cat (B) A flask resting on a table

(C) A rocking see-saw (D) Winding a clock

4. In the following identify the applications of torque:

(A) opening the lid of cool drink bottle. (B) opening the lid of a tin.

(C) opening the door. (D) opening the screw cap of a bottle.

5. Which of the following is/are the properties of moment of a couple?

(A) It tends to produce pure rotation.

(B) It is different about any point in the plane of lines of action of the forces.

(C) It can be replaced by any other couple of the same moment.

(D) The resultant of set of two or more couples is equal to the sum of the moments of the individual couples.

ASSERTION AND REASON TYPE QUESTIONS

The questions given below consists of an Assertion and a Reason. Use the following key to choose the appropriate answer.

(A) If both assertion and reason are CORRECT and reason is the CORRECT explanation of the assertion.

(B) If both assertion and reason are CORRECT, but reason is NOT THE CORRECT explanation of the assertion.

(C) If assertion is CORRECT, but reason is INCORRECT.

(D) If assertion is INCORRECT, but reason is CORRECT.

(E) If both assertion and reason are INCORRECT.

1. **Assertion:** The centre of mass of a body may lie where there is no mass.

   Reason: Centre of mass of a body is a point, where the whole mass of the body is supposed to be concentrated.

2. **Assertion:** The position of centre of mass of a body does not depend upon shape and size of the body.

   Reason: Centre of mass of a body lies always at the centre of the body.

3. **Assertion:** It is harder to open and shut the door if we apply force near the hinge.

   Reason: Torque is maximum at hinge of the door.

4. **Assertion:** A sphere cannot roll on a smooth inclined surface.

   Reason: For a smooth inclined surface force of friction is equal to zero.

5. **Assertion:** To unscrew a rusted nut, we need a wrench with longer arm.

   Reason: Wrench with longer arm reduces the torque of the arm.

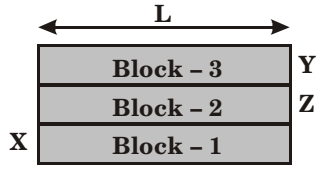
6. **Assertion:** The centre of mass of uniform triangular lamina is centroid.

   Reason: Centroid is centre of symmetry of mass of the triangular lamina.

PARAGRAPH QUESTIONS

Passage - I

I. Three identical blocks of length L are stacked together as shown. The blocks 2 and 3 are slided towards the right.



(i) Find the maximum horizontal distance between side X of block one and side Y of block three before any of the block topples?

(A) 1.5 L (B) 1.75 L (C) 2.25 L (D) 1.25 L

(ii) Find the maximum horizontal distance between side X of block one and side Z of block two before any of the block topples?

(A) 1.4 L (B) 1.75 L (C) 1.25 L (D) 2.3 L

SECTION – B

NUMERICAL PROBLEMS

1. A force of 8 dyne with moment arm 125 cm long, rotates a body in clockwise direction. Find its torque.

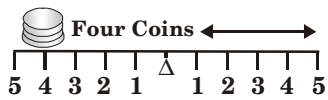
2. A force of 1875 dyne acts on a rigid body, such that perpendicular distance between fulcrum and point of application of force is 20 cm. Calculate moment of force.

3. Calculate the force that produces a moment of force of 2100 dyne-cm, when the perpendicular distance between point of application of force and turning point is 60 cm.

4. The moment of force of 8 N about a point P is 4 N m. Calculate the distance of point of application of the force from the point P.

5. A uniform rule is pivoted at its mid point. A weight of 50 gf is suspended at one end of it. Where should a weight of 100 gf be suspended, to keep the rule horizontal?

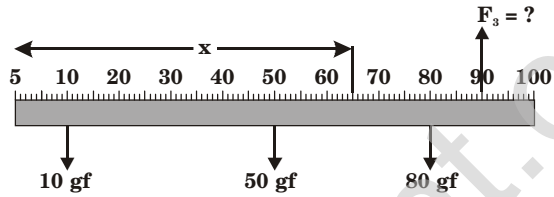
6. The diagram below shows a lever of uniform mass, supported at the middle point. Four coins of equal masses are placed at mark 4 on the left hand side. Where should be the 5 coins of same mass, as that of previous coins should be located?



7. Calculate the force required to lift a load of 60 N, placed at a distance of 3 m, from the fulcrum. The effort force is applied at a distance of 6 cm from the fulcrum.

8. Where should be the uniform rod of length 10 m and weight 100 N is balanced with a weight of 100 N at extreme point?

9. A uniform metre scale has two weights of 10 gf and 8 gf suspended at the 10 cm and 80 cm marks respectively. If the metre scale itself weights 50 gf, find where must the weight be, so that the metre scale stays balanced?



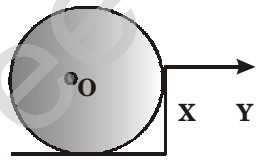
10. A force of 1600 dyne acts on a rigid body, such that the perpendicular distance between force and turning point is 40 cm. Calculate the moment of force.

11. A force of 525 N, produces a moment of force of 420 N-m. Calculate the shortest distance between the point of application of force and the turning point.

12. Two persons A and B carry a load of 1000 kg by hanging it on a pole, supported on their shoulders. If *A* can exert a force 4 times as much as B and the pole is 2.5 m long, where should the load be suspended?

CONCEPTUAL QUESTIONS

1. The diagram below shows a heavy roller with its axle at O, which is to be pulled on a pavement XY, by applying a minimum possible force. Draw the diagram, showing the direction in which the force should be applied.



2. The iron door of a building is x m broad. It can be opened by applying a F_1 N force at the middle of the door. Calculate the least force which can open the door. Where should this force be applied?

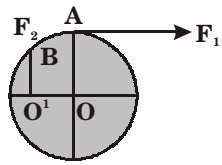
3. Which produces a greater moment, a force of 10 N with a lever arm of 3 m or a force of 8 N with a lever arm of 4 m?

4. A mechanic can open a nut by applying F N force, while using a lever handle of h cm length. What should be the length of the handle required if he wants to open it, by applying a force of only (2F/3) N?

5. The wheel shown in the diagram, has a fixed axle passing through O. The wheel is kept stationary under the action of

(i) A horizontal force F_1 at A and

(ii) A vertical force F_2 at B. Show the direction of F_2 in the diagram. Which is the greater force? Find the ratio between the forces. Given: AO = x cm, BO' = 2x cm and O'O = 3x cm.



6. Suppose the resulting torque on a body is (i) zero (ii) not zero. What is the effect of the acting torques on the body in the two cases?

SECTION – C

PREVIOUS CONTEST QUESTIONS

1. The unit of torque is:

(A) N m^{-1} (B) N m (C) N m^{-2} (D) N m^2

2. If F is force and r is radius, then torque is:

(A) $\vec{r}\times\vec{F}$ (B) $\vec{r}.\vec{F}$ (C) $|r||F|$ (D) r/F

3. A bicycle tyre in motion has:

(A) linear motion only (B) rotatory motion only

(C) linear and rotatory motion (D) vibratory motion only

4. A uniform metre scale balances horizontally on a knife edge placed at 55 cm mark. When a mass of 25 g is supported from one end, then the mass of the scale is:

(A) 200 g (B) 225 g (C) 350 g (D) 275 g

5. The principle involved in the construction of beam balance is:

(A) principle of moments (B) principle of inertia

(C) principle of superposition (D) principle of velocity

6. A couple always tends to produce:

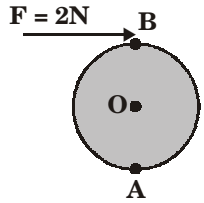
(A) linear motion (B) rotatory motion

(C) both linear and rotatory motion (D) vibratory motion

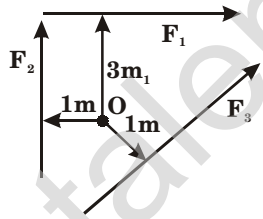
BRAIN NURTURES

1. A wheel of diameter 2 m is shown with axle at 'O'. A force F = 2 N is applied at B in the direction as shown in figure.

   Calculate the moment of force about (i) centre 'O', and (ii) point A.

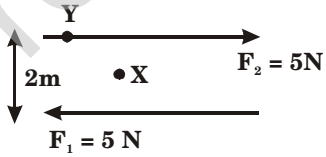


2. F_1 , F_2 and F_3 are three forces as shown. The point O is in the same plane. F_1 = 4 N, F_2 = 4 N and F_3 = 6 N.



   (i) Which force has the least moment about 'O'?
   (ii) Which force has the greatest moment about 'O'?
   (iii) Which force has positive moment?
   (iv) Which force has negative moment?

3. The following diagram shows two parallel, opposite and coplanar forces F_1 and F_2 , each of magnitude 5 N, with their lines of action separated by a distance of 2 m. A point X lies midway between F_1 and F_2, while a point Y lies on F_2. Calculate the total moment of these forces about (i) X, and (ii) Y. State the effect produced by the forces about the point X.

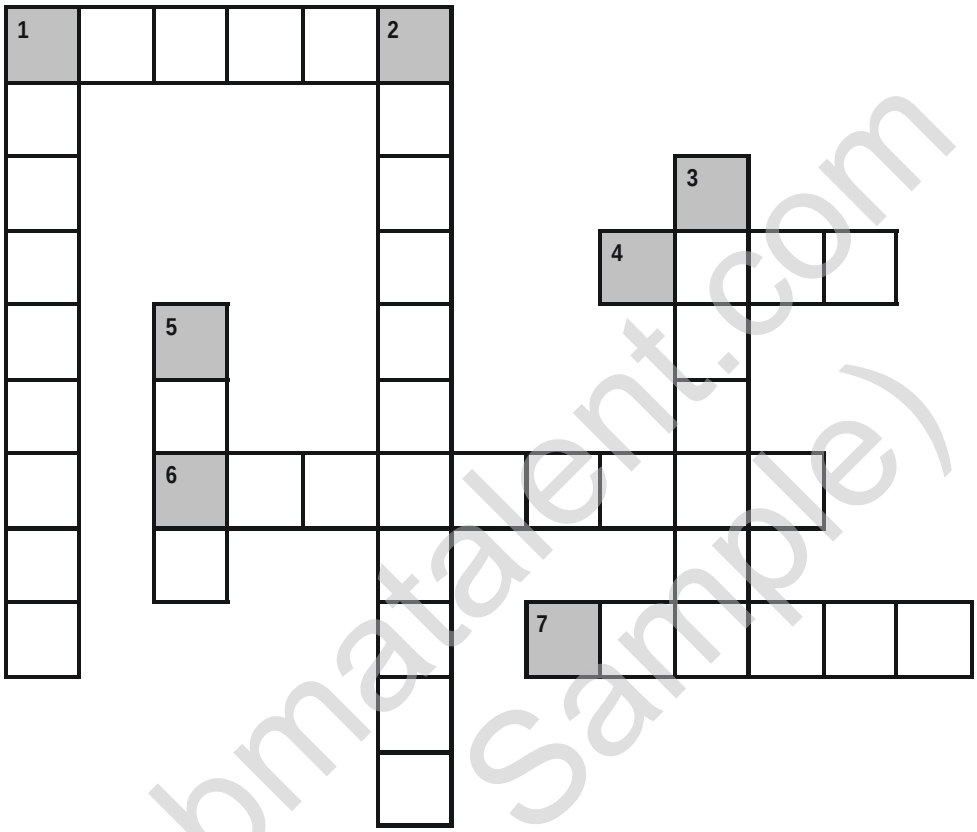


4. A uniform metre scale is balanced at 40 cm mark, when weighs of 25 gf and 10 gf are suspended at 5 cm mark and 75 cm mark respectively. Calculate weight of metre scale.

5. AB is a metre scale, with forces action as shown. Its mass of 100 g. Calculate the algebraic sum of their moments about A.

6. A metre rule is pivoted at its mind point A. 0.6 N weight is suspended from one end. How far from the other end must at 1.00 N weight be suspended for the rule to balance?

CROSSWORD PUZZLE



ACROSS

1 Two equal, parallel, unlike forces whose line of action is not same

4 Racing cars are built with low CG and wide base

6 The ability of an object to regain its original position after it has been disturbed

7 The force that rotates a body without displacing it

DOWN

1 The moment that is taken as negative

2 Sum of clockwise moments is equal to sum of anticlockwise moments when the body is in rotational

3 The turning effect is greater if the perpendicular distance of the force from the axis of rotation is

5 The centre of gravity of an object depends on the distribution of its

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ISBN 978-93-80299-21-1

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