4 Turning Effects of Forces

Section A Multiple Choice Questions (M.C.Qs)

Tick mark (✓) the correct answer:

01. *A pair of unlike parallel forces having different lines of force produce_____.*
(a) equilibrium (b) torque (c) a couple (d) unstable equilibrium

02. *Head to tail rule can be used to add_____ forces.*
(a) two (b) three (c) five (d) any number of

03. *A force of 15 N makes an angle of 60° with horizontal. Its vertical component will be:*
(a) 15N (b) 10N (c) 13N (d) 7N

04. *A body is in equilibrium when it has:*
(a) uniform speed (b) uniform acceleration
(c) both a and b (d) zero acceleration

05. *A body is in stable equilibrium after slight tilt if its center of gravity:*
(a) remains above the point of contact (b) remains on one side of point of contact
(c) passes over the point of contact (d) is at lowest position

06. *A body is in unstable equilibrium after slight tilt if its center of gravity:*
(a) remains on one side of the point of contact (b) remains above the point of contact
(c) passes over the point of contact (d) is positioned at its bottom

07. *A body is in neutral equilibrium when its center of gravity:*
(a) is at the lowest position (b) remains at same height
(c) is at highest position (d) is at its base

08. *Bunsen burner is made stable by:*
(a) increasing its length (b) increasing its mass
(c) decreasing its base area (d) increasing its base area

09. *A right rope walker carries a long pole to:*
(a) increase his weight (b) raise his centre of gravity
(c) lower his centre of gravity (d) keep his centre of gravity in fixed position

10. *Stability of a racing car is increased by:*
(a) increasing its height (b) raising its centre of gravity
(c) decreasing its width (d) lowering its centre of gravity

11. *The forces that act along opposite directions are called:*
(a) parallel forces (b) like parallel forces
(c) unlike parallel forces (d) None of these

12. *Force has:*
(a) only magnitude (b) only direction
(c) both magnitude & direction (d) None of these

13. *Graphical method is used for addition of:*
(a) one–dimensional vector quantities (b) two–dimensional vector quantities
(c) three–dimensional vector quantities (d) All of these

14. *sin θ = :*
(a) $\frac{\text{base}}{\text{hypotenuse}}$ (b) $\frac{\text{perpendicular}}{\text{hypotenuse}}$ (c) $\frac{\text{base}}{\text{perpendicular}}$ (d) $\frac{\text{perpendicular}}{\text{base}}$

15. $\frac{\text{perpendicular}}{\text{base}}$ = :
(a) sin θ (b) cos θ (c) tan θ (d) cosec θ

16. *The turning effect of force is called:*
(a) moment of force (b) torque (c) Both 'a' & 'b' (d) None of these

17. *Torque depends upon:*
(a) the magnitude of the velocity and fulcrum (b) the mass & fulcrum
(c) the direction of the force & fulcrum (d) the magnitude of the force & fulcrum

18. *Moment of force about a point is equal to:*
(a) $\tau = d \times F$ (b) $\tau = F \times d$ (c) $\tau = d \cdot F$ (d) $\tau = F \cdot d$

19. *SI unit of the torque or moment of force is:*
(a) Newton (b) Newton per second (c) Newton–second (d) Newton-metre

20. *The Center of gravity of uniform square or a rectangular sheet is the:*
(a) point of intersection of its diagonals (b) the mid–point on its axis
(c) the point of intersection of its medians (d) its center

21. *The Center of gravity of a uniform triangular sheet is:*
(a) point of intersection of its diagonals (b) the mid–point on its axis
(c) the point of intersection of its medians (d) its center

22. *They form a couple.*
(a) two unlike parallel forces of the same magnitude acting along the same line
(b) two unlike parallel forces of the same magnitude not acting along the same line
(c) two like parallel forces of the same magnitude acting along the same line
(d) two like parallel forces of the same magnitude not acting along the same line

23. *To form a couple, two forces must be:*
(a) equal in magnitude (b) parallel, but opposite in direction
(c) separated by a distance (d) All of these

24. *A wall hanging, buildings, bridges or any object lying in rest on the ground are some examples of:*
(a) dynamic equilibrium (b) static equilibrium
(c) inertia (d) acceleration due to gravity

25. *A body must satisfy _____ conditions to be in equilibrium.*
(a) two (b) three (c) four (d) five

26. *According to the first condition for equilibrium:*
(a) sum of the all forces acting on a body must be constant
(b) sum of the all forces acting on a body must be equal to zero
(c) sum of all torques acting on a body is constant
(d) sum of all torques acting on a body is zero

27. *The following expression represents:*
(a) Newton's first law of motion (b) Newton's second law of motion
(c) the first condition of equilibrium (d) the second condition of equilibrium

28. *A paratrooper moving down with terminal velocity satisfies:*
(a) law of gravitation (b) Newton's second law of motion
(c) the first condition of equilibrium (d) the second condition of equilibrium

29. *According to the second condition for equilibrium:*
(a) sum of the all forces acting on a body must be constant
(b) sum of the all forces acting on a body must be equal to zero
(c) sum of all torques acting on a body is constant
(d) sum of all torques acting on a body is zero

30. *States of equilibrium are:*
(a) two (b) three (c) four (d) five

31. *When a body is slightly displaced and then released it returns to its previous position then the equilibrium will be:*
(a) stable equilibrium (b) unstable equilibrium
(c) neutral equilibrium (d) None of these

32. *If a body is slightly titled and does not return back to its previous position, the body is said to be in:*
(a) stable equilibrium (b) unstable equilibrium
(c) neutral equilibrium (d) None of these

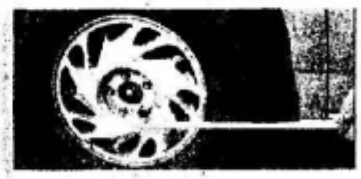
Answers

1.	(c)	2.	(d)	3.	(c)	4.	(d)	5.	(a)	6.	(b)	7.	(b)
8.	(d)	9.	(c)	10.	(d)	11.	(c)	12.	(c)	13.	(a)	14.	(b)
15.	(c)	16.	(c)	17.	(d)	18.	(b)	19.	(d)	20.	(a)	21.	(c)
22.	(b)	23.	(d)	24.	(b)	25.	(a)	26.	(b)	27.	(c)	28.	(c)
29.	(d)	30.	(b)	31.	(a)	32.	(b)						

Section B & C Short & Detailed Answer Questions

Introduction

Have you ever seen a driver changing wheel? Why does he use a long spanner? Sometimes he adds a piece of pipe to the spanner to increase the length as shown in the figure.



Have you visited a circus where you might have seen a man walking on a tight rope carrying a long beam? How that beam helps him to keep balance while walking on the tight rope. After learning this unit, you will be able to answer these questions and some other similar question.

Q.1 *Define force.*

Ans: ***Force:*** Force is a push or pull which moves the objects. It can stop the objects. It also gives shape to the objects. It is a vector quantity. Therefore, it has a specific direction. It is measured in Newton (N).

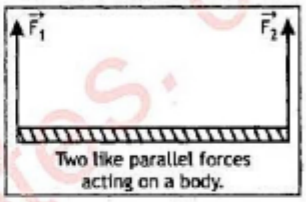
Q.2 *Define Parallel forces.*

Ans: The parallel forces can be define as, "when a number of forces act on a body and if their directions are parallel they are called parallel forces.

Q.3 What is meant by like and unlike forces?

Ans: ***Like Parallel Forces:*** The forces that act along the same direction are called like parallel forces.
Like parallel forces can add up to a single resultant force, therefore, can be replaced by a single force. If many people pushing a car to move it, all of these forces are called like parallel forces because these are acting along same line.

Examples: "Consider two like parallel forces $\vec{F}_1$ and $\vec{F}_2$ acting on a body at "A" and "B". Suppose $\vec{R}$ is the resultant force of $\vec{F}_1$ and $\vec{F}_2$, then "$\vec{R} = \vec{F}_1 + \vec{F}_2$



Two like parallel forces acting on a body.

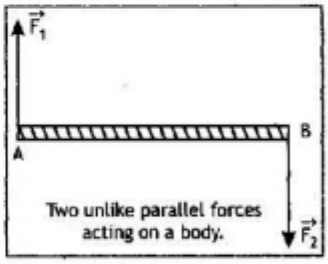
Unlike Parallel Forces: The forces that act long opposite directions are called unlike parallel forces.

Examples: For example, a ceiling fan suspended in a hook, through supporting rod. The forces acting on it are:

(i) weight of the fan acting vertically downwards, and
(ii) tension in the supporting rod pulling it vertically upwards.

These two forces are also parallel but opposite to each other and acting along the same line. Thus, these forces are called unlike parallel forces. These forces also add up to a single resultant force. But, when a pair of unlike forces do not act along the some line as shown in the given figure, can be responsible for rotation of objects. Such unlike parallel forces cannot be replaced by a single resultant force and form a couple. A couple can only by balanced by an equal and opposite forces directed at the two different ends of the rod.

Examples: "Consider two unlike parallel forces $\vec{F}_1$ and $\vec{F}_2$ acting on a body at point "A" and "B". Suppose $\vec{R}$ is the resultant force of $\vec{F}_1$ and $\vec{F}_2$. Here $\vec{F}_1$ is greater than $\vec{F}_2$.
$\vec{R} = \vec{F}_1 - \vec{F}_2$



Two unlike parallel forces acting on a body.

Q.4 How can a force be represented?

Ans: ***Representation of a Force:*** Force is a vector quantity. It has both magnitude (size) and direction. In diagrams, it is represented by a line segment with an arrow-head at one end to show its direction of action. Length of line segment gives the magnitude of the force act on an object.

Q.5 Define resultant of forces.

Ans: ***Resultant Force:*** We need to add the forces acting on a body to get a single resultant force. Single force that has the same effect as the combined effect of the forces to be added is called resultant force.

Q.6 Describe the methods of addition of forces.

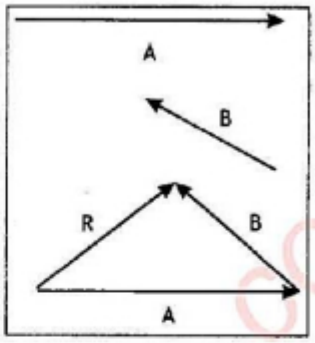
Ans: ***Addition of Forces:*** Ordinary arithmetic rules cannot be used to add the forces. Two different methods are used for the addition of forces (i.e., in general addition of vectors):

(i) Graphical Method (ii) Analytical Method

Q.7 Describe the graphical method of addition of forces.
OR Which rule is used to find the resultant of more than two forces?

Ans: ***Graphical Method:*** This method is used for addition of one–dimensional vector quantities. In this method head to tail rule of vector addition is used for the addition of forces.

Head to Tail Rule: The given figure shows head to tail rule of vector addition.



Step 1: Choose a suitable scale.

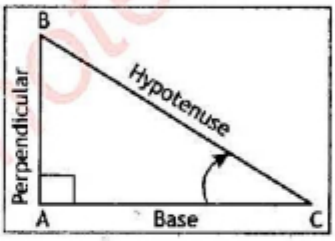
Step 2: Draw all the force vectors according to scale, vectors A and B in this case.

Step 3: Now take any vector as first vector and draw next vector in such a way that it tail coincides with head of the previous. If number of vectors is more than two then continue to process till last vector is reached.

Step 4: Use a straight line with arrow pointed towards last vector to join the tail of first vector with the head of last vector. This is the resultant vector.

Q.8 *Define trigonometric ratios.*

Ans: ***Trigonometric Ratios:*** The ratio between any two sides of a right–angled triangle is given specific name and the ratio of any two sides of a right-angled triangle is called trigonometric ratio.



There are six ratios in total, out of which three are main ratios and other three are their reciprocals. Three main ratios mostly used in physics are sine, cosine and tangent. Consider a right angled triangle ΔACB having angle θ at C.

$$\sin\theta = \frac{Perpendicular}{Hypotenous} = \frac{AB}{BC}$$

$$\cos\theta = \frac{Base}{Hypotenous} = \frac{AC}{BC}$$

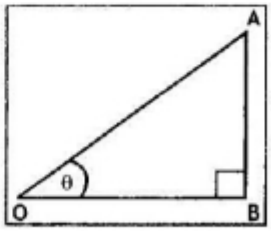
$$\tan\theta = \frac{Perpendicular}{Base} = \frac{AB}{AC}$$

Ratio θ	0°	30°	45°	60°	90°
Sin θ	0	0.5	0.7070	0.8660	1
Cos θ	1	0.8660	0.7070	0.5	0
Tan θ	0	0.577	1	1.732	∞

Q.9 *What is meant by resolution of forces? By using trigonometric ratios find its horizontal and vertical components.*

Ans: ***Resolution of Forces:*** A force (vector) may be split into components usually perpendicular to each other; the components are called perpendicular components and the process is known as resolution of vectors.

In other words, the process of splitting of a vector into mutually perpendicular components is called resolution of vectors.



The given figure shows a force F represented by a line segment OA which makes an angle with x axis. Draw a perpendicular AB on x–axis from A. The components OB = F_x and BA = F_y are perpendicular to each other. They are called perpendicular components of OA = F. Therefore,

$$F = F_x + F_y$$

The trigonometric ratio can be used to find the magnitudes F_x and F_y. In right–angled triangle ΔOBA,

$$\frac{F_x}{F} = \frac{OB}{OA} = \cos\theta$$

$$F_x = F\cos\theta \quad \text{----------(1)}$$

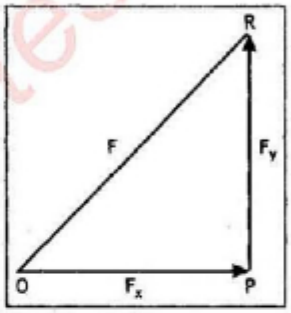
Also, $$\frac{F_y}{F} = \frac{BA}{OA} = \sin\theta$$

$$F_y = F\sin\theta \quad \text{----------(2)}$$

Equations (1) and (2) give the perpendicular components respectively.

Q.10 *How can we determine force from its perpendicular components? How the direction of a vector is obtained from its components?*

Ans: ***Determination of Force from its Perpendicular Components:*** This is opposite to the process of resolution. If the perpendicular components of a force are known then the process of determining the force itself from the perpendicular components is called composition.



Suppose F_x and F_y are the perpendicular components of the force F and are represented by line segments OP and PR with arrow head respectively as shown in the given figure.

Applying the head to tail rule: $OR = OP + PR$

Here OR represents the force F whose x and y-components are F_x and F_y respectively.

Thus, $F = F_x + F_y$

In order to find the magnitude of F apply Pythagorean Theorem to right angled triangle OPR, i.e.

$$(OR)^2 = (OP)^2 + (PR)^2 \quad \text{or} \quad F^2 = F_x^2 + F_y^2$$

Therefore, $$F = \sqrt{F_x^2 + F_y^2}$$

The direction of F with x-axis is given by:

$$\tan\theta = \frac{PR}{OP} = \frac{F_y}{F_x}$$

$$\theta = \tan^{-1}\frac{F_y}{F_x}$$

Q.11 *Define torque or moment. Write down its formula and units. List the factors on which moment of force depends.*

Ans: ***Torque OR Moment of Force:*** The turning effect of force is called moment of force or Torque.

Formula: Moment of force about a point = Force × Perpendicular distance from point

$$\vec{\tau} = \vec{F} \times \vec{d}$$

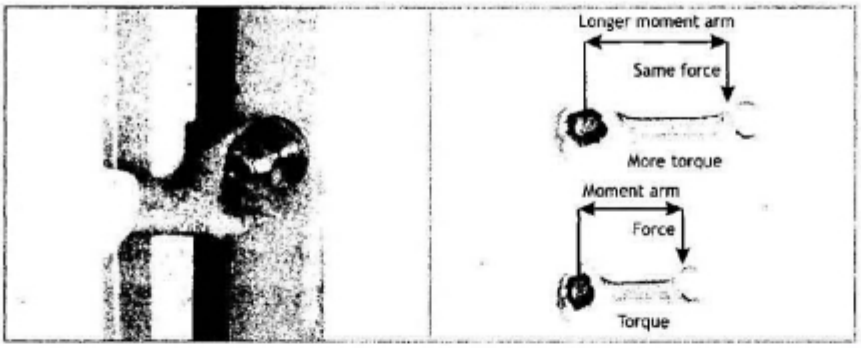
Units: SI unit of the torque or moment of force is newton-meter (Nm).

Moments are described as clockwise or anticlockwise.

Weblinks

Web links for moment of force.

- http://www.saburchill.com/physics/chapters/0018.html
- http://www.walter.fendt.de/ph11e/lever.html
- http://www.lovephysics.com/tur



A door handle is fixed at the outer edge of the door so that it opens easily. A larger force would be required if the handle were fixed near the inner edge close to the hinge.

Similarly, it is easier to tighten or loosen a nut with a long spanner as compared to a short one.

Q.12 *List the factors on which moment of force depends.*

Ans: It depends upon:

(i) the magnitude of force.

(ii) The perpendicular distance of the point of application of force from the pivot or fulcrum.

Q.13 *What is the principle of the moment?*

Ans: ***Principle of Moment:*** According to the principle of moments:
The sum of the clockwise moments about a point is equal to the sum of the anticlockwise moments about that point.

Q.14 *How is the see–saw balanced?*

Ans: Two children playing on the see–saw. Fatima is sitting on the right side and Faheem on the left side of the pivot. When the clockwise turning effect of Fatima is equal to the anticlockwise turning effect of Faheem, then see-saw balances. In this case, they cannot swing.
When the sum of all the clockwise moments on a body is balanced by the sum of all the anticlockwise moments, this is known as the principle of moments.

Q.15 *Give three examples in which the principle of the moment is observed.*

Ans: Moments are everywhere. If we try to undo a bolt with our fingers is almost impossible, but if we add a spanner and suddenly it becomes very easy to turn. This is because we are increasing the distance between the force and the pivot and therefore we are increasing the turning moment.
The same principle applies when using a screwdriver to pry open a can of syrup or paint, or closing the handles of a pair of scissors to slice through a sheet of card or a piece of string. The further away we apply the force from the pivot, the easier the task will become.
Moments don't have to be on opposite sides of the pivot, either. A heavy load in a wheelbarrow is close to the wheel, while the handles are further away. This means that we need less force to lift the contents.
Some of the everyday examples where moments or the turning effect is observed are opening and closing doors and windows, nutcracker etc. Further, some examples of moments involve the application of lever, such as seesaw.

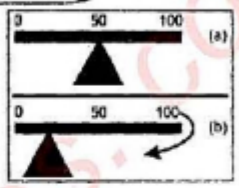
Q.16 ***Define centre of mass or centre of gravity.***

Ans: ***Center of Mass OR Center of Gravity:*** A body behaves as if its whole mass is concentrated at one point, called its centre of mass or centre of gravity, even though earth attracts every part of it.

Q.17 ***Where does the position of the center of gravity of a uniform rod lie?***

Ans: The centre of mass of a uniform meter rod is at its centre and when supported at that point, it can be balanced as shown in figure (a).

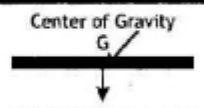
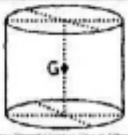
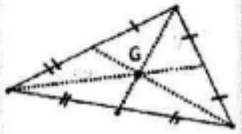
If it is supported at any other point it topples because the moment of its weight W about the point of support is not zero as shown in figure (b).



Q.18 ***Write down the position of center of gravity of the following object:***

(a) a uniform rod
(b) a uniform square or rectangle sheet
(c) a solid or hollow sphere
(d) a uniform circular ring
(e) a uniform circular disc
(f) a uniform solid or hollow cylinder
(g) a uniform triangular sheet

Ans: The centre of gravity of regular–shaped uniform objects is their geometrical centre.

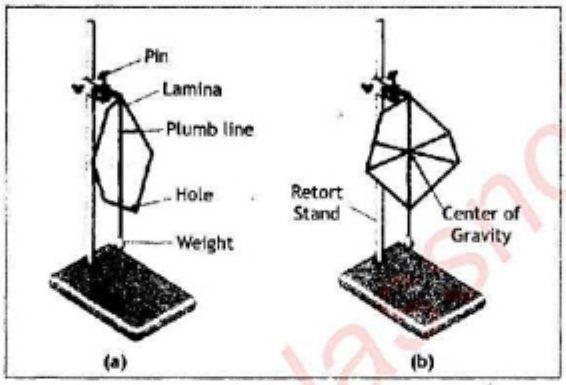
S.No.	Name of the object	Position of the center of gravity	
(a)	A uniform rod	The center of gravity of the uniform rod is its mid–point.	
(b)	a uniform square or rectangle sheet	The centre of gravity of a uniform square or a rectangular sheet is the point of intersection of its diagonals.	
(c)	a solid or hollow sphere	The center of gravity of a solid or hollow sphere is the center of the sphere.	
(d)	a uniform circular ring	The center of gravity of a uniform circular ring is the center of the ring.	
(e)	a uniform circular disc	The center of gravity of a uniform circular disc is its center.	
(f)	a uniform solid or hollow cylinder	The center of gravity of a uniform solid or hollow cylinder is the mid–point on its axis.	
(g)	a uniform triangular sheet	The center of gravity of a uniform triangular sheet is the point of intersection of its medians.	

PHYSICS NOTES FOR CLASS 9TH (FOR SINDH)

Q.19 *How can you find the centre of gravity of an irregular shaped thin lamina or metal sheet or card sheet?*

Ans: ***Center of Gravity of Irregular Shaped Thin Lamina***

Step 1: Make three small holes near the edges of the lamina farther apart from each other.
Step 2: Suspend the lamina freely from one whole on retort stand through a pin as shown in figure (a).
Step 3: Hang a plumb line or weight from the pin in front of the lamina as shown in figure (b).
Step 4: When the plumb line is steady, trace the line on the lamina.
Step 5: Repeat steps 2 to 4 for the second and third holes. The point of intersection of three lines is the position of the center of gravity.



Q.20 *What is a couple? Calculate the moment of the couple.*

Ans: ***Couple:*** Two unlike parallel forces of the same magnitude but not acting along with the same line form a couple.

Examples:

(i) When a boy riding the bicycle pushes the pedals, he exerts forces that produce a torque. This torque turns the toothed wheel making the rear wheel rotate. These forces act in opposite directions and form a couple.

(ii) Another example is the forces required to turn the steering wheel of a car. The two equal and opposite forces balance, so the wheel will not move up, down or sideways. However, the wheel is not in equilibrium. The pair forces will cause it to rotate. A pair of forces like that is called a couple. A couple has a turning effect but does not cause an object to accelerate.

The Moment or Torque of the Couple: The turning effect or moment of a couple is known as its torque. We can calculate the torque of the couple in the above figure by adding the moments of each force about the center O of the wheel:

$$\text{Torque of couple} = (F \times OP) + (F \times OQ)$$
$$= F \times (OP + OQ)$$
$$= F \times d$$

Torque of couple = one of the force x perpendicular distance between the forces

Q.21 *Write three necessary conditions for two forces to form a couple.*

Ans: To form a couple, two forces must be:

(i) equal in magnitude (ii) parallel, but opposite in direction
(iii) separated by a distance

Q.22 Define equilibrium. What are the kinds of equilibrium?

Ans: ***Equilibrium:*** When a body does not possess any acceleration, neither linear nor angular then it is said to be in equilibrium. For example, a book lying on a table at rest, a paratrooper moving downwards with terminal velocity, a chair lift hanging on supporting ropes.

Kinds of Equilibrium: There are two kinds of equilibrium:

(i) Static Equilibrium (ii) Dynamic Equilibrium

Q.23 Define static and dynamic equilibrium.

Ans: ***Static Equilibrium:*** A body at rest is said to be in static equilibrium.

Examples: A wall hanging, buildings, bridges or any object lying in rest on the ground are some examples of static equilibrium.

Dynamic Equilibrium: A moving object that does not possess any acceleration neither linear nor angular is said to be in dynamic equilibrium.

Examples: Uniform downward motion of stoolball through viscous liquid and jumping of the paratrooper from the Helicopter are examples of dynamic equilibrium.

Q.24 Write down conditions of equilibrium.

Ans: ***Conditions for Equilibrium:*** A body must satisfy certain conditions to be in equilibrium. There are two conditions for equilibrium.

First Condition for Equilibrium: According to this condition for equilibrium sum of all forces acting on a body must be equal to zero. Suppose n number of force, F_1, F_2, F_3,....., F_n are acting on a body then according to the first condition of equilibrium.

$$F_1 + F_2 + F_3 + \ldots\ldots\ldots + F_n = 0 \quad \text{or} \quad \Sigma F = 0$$

The symbol Σ (a Greek letter Sigma) is used for summation. The above equation is known as first condition for equilibrium.

In terms of x and y components of the forces acting on the body, the first condition for the equilibrium can be expressed as:

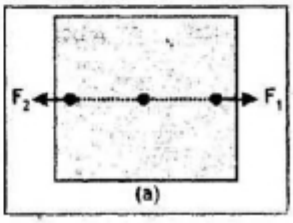
$$F_{1x} + F_{2x} + F_{3x} + \ldots\ldots\ldots + F_{nx} = 0 \text{ and}$$
$$F_{1y} + F_{2y} + F_{3y} + \ldots\ldots\ldots + F_{ny} = 0 \text{ or}$$
$$\Sigma F_x = 0 \quad \text{and} \quad \Sigma F_y = 0$$

Examples: A basket of apples resting on the table or a clock hanging on the wall are at rest and hence satisfy the first condition for equilibrium. A paratrooper moving down with terminal velocity also satisfies the first condition for equilibrium.

Weblinks

The teacher may encourage learners to visit the condition of equilibrium on the internet at
- http://www.ul.ie/-gaughrn/Gildea/page4.html

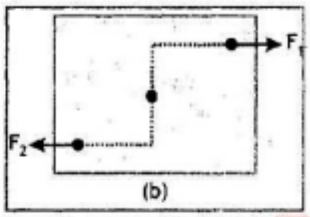
Second Condition for Equilibrium: The first condition for the equilibrium does not confirm that a body is in equilibrium because a body may have angular acceleration even though the first condition is satisfied. For example, consider two forces F_1 and F_2 are acting on a body as shown in figure (a). The two forces are equal and opposite to each other. The line of action of the two forces is the same, thus resultant will be zero. The first condition for equilibrium is satisfied; hence we may think that the body is in equilibrium. However, if we change the position of the forces as shown in figure b, now the body is not in equilibrium even though the first condition for equilibrium is still satisfied. This shows that there



must be an additional condition for equilibrium to be satisfied for a body to be in equilibrium. This is called the second condition for equilibrium.

The Sum of all clockwise and anticlockwise torques acting on a body is zero. Mathematically,

$$\tau = 0$$



Q.25 *Write down the three states of equilibrium. Give examples of each.*
OR *List three states of equilibrium.*

Ans: ***States of Equilibrium:*** There are three states of equilibrium:

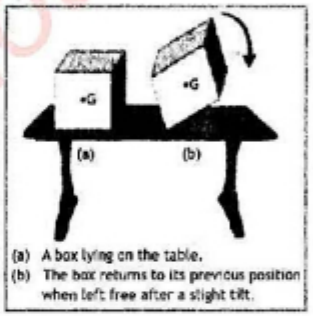
(i) Stable equilibrium (ii) Unstable equilibrium, and (iii) Neutral equilibrium

A body may be in one of the above states of equilibrium.

(i) Stable Equilibrium: A body is in stable equilibrium if when slightly displaced and then released it returns to its previous position.

A body is in stable equilibrium when:

- its centre of gravity is at the lowest position.
- it is tilted its centre of gravity rises
- it returns to a stable state by lowering its centre of gravity



(a) A box lying on the table.
(b) The box returns to its previous position when left free after a slight tilt.

A body remains in a stable state of equilibrium as long as its centre of gravity acts through the base of the body.

Example: Suppose a box is lying on the table. It is in equilibrium. Tilt the box slightly about its one edge as shown in the figure. On releasing it returns to its original position. This state of the body is known as stable equilibrium.

(ii) Unstable Equilibrium: A body is said to be in unstable equilibrium when slightly titled does not return to its previous position.

A body is in unstable equilibrium when:

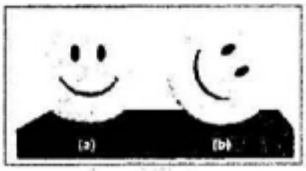
- its centre of gravity is at its highest position
- when it is tilted its centre of gravity is lowered
- its previous position cannot be restored by raising its centre of gravity

Example: We take a paper cone and try to keep it in a vertical position on its vertex as shown in the figure. It topples down on releasing. This state of the body is known as unstable equilibrium.

(iii) Neutral Equilibrium: A body is said to be in neutral equilibrium when displaced from the previous position remains in equilibrium in a new position.

A body is said to be in neutral equilibrium when:

- its centre of gravity always remains above the point of contact.
- when it is displaced from its previous position its centre of gravity remains at the same height.
- all the new states in which the body is moved are stable.



Example: Let us consider a ball placed on a horizontal surface as shown in figure (a). It is in equilibrium. When it is displaced from its previous position it remains in its new position still in equilibrium as shown in figure (b). This is called neutral equilibrium.

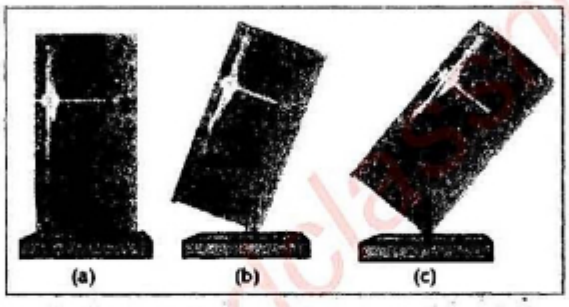
Q.26 Describe stability.

Ans: ***Stability:*** In most situations, we are interested in maintaining stable equilibrium, or balance, for example, the design of structure racing cars and in working with the human body.

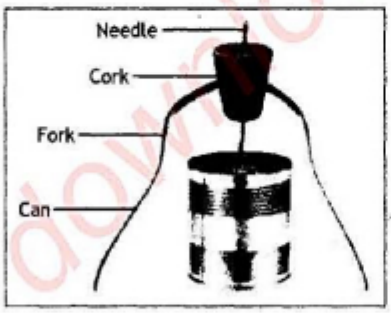
We consider a refrigerator if it is tilted slightly (Fig b) it will return to its original position due to torque on it. But if it is tilted more (Fig. c), it will fall down. The critical point is reached when the centre of gravity shifts from one side of the pivot point to the other. When the centre of gravity is on the one side of the pivot point, the torque pulls the refrigerator back onto its original base of support (Fig. b). If the refrigerator is tilted further, the centre of gravity crosses onto the other side of the pivot point and the torque causes the refrigerator to topple (Fig. c).

More Information:

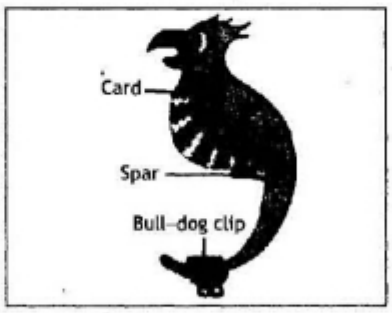
A man walking on a tight rope carries a long beam that helps him to maintain balance by lowering his Center of mass.



In general, a body whose centre of gravity is above its base of support will be stable if a vertical line projected downward from the centre of gravity falls within the base of support.



A sewing needle fixed in a cork. The forks are hanged on the cor to balance it on the tip of the needle. The forks lower the center of mass of the system. If it is disturbed, it will return to its original position.



A perched parrot is made heavy at the tail which lowers its centre of gravity. It can keep itself upright when titled. In general, the larger the base and lower the centre of gravity, the more stable the body will be.

Differences

01. ***Differentiate like and unlike forces using examples.***

Ans: ***Distinguish Between Like and Unlike Forces***

	Like Forces	Unlike Forces
1.	Forces that are parallel and acting in the same direction are called like parallel forces.	Forces that are parallel and acting in opposite directions are called unlike parallel forces.
2.	Like parallel forces can add up to a single resultant force, therefore, can be replaced by a single force. If there are two like forces F_1 and F_2, then the resultant force $R = F_1 + F_2$.	If there are two unlike forces F_1 and F_2, then the resultant force $R = -F_1 + F_2$ where the negative force is the force acting in the downward direction.
3.	**Example:** If many people pushing a car to move it, all of these forces are called like parallel forces because these are acting along the same line.	**Example:** a ceiling fan suspended in a hook, through a supporting rod. The forces acting on it are (i) the weight of the fan acting vertically downwards and (ii) tension in the supporting rod pulling it vertically upwards. These two forces are also parallel but opposite to each other and acting along the same line. Thus, these forces are called unlike parallel forces.

Scientific Reasons

01. ***Why a body in unstable equilibrium does not return to its original position when given a small tilt?***

Ans: The centre of gravity of the body is at its highest position in a state of unstable equilibrium. As the body topples over about its base (tip), its centre of gravity moves towards its lower position and does not return to its previous position.

02. ***Why racing cars are made heavy at the bottom?***

Ans: The sports or racing cars are made heavy at the bottom which lowers the centre of mass and hence increases the stability.

03. ***Why the base area of the Bunsen burner is made large?***

Ans: They are made to have a broad and heavy base to make them more stable. This is to reduce the chances of the burner accidentally tipping over. Knocking over a lit Bunsen burner could have very bad results.

PHYSICS NOTES FOR CLASS 9TH (FOR SINDH)

Section D — Numerical

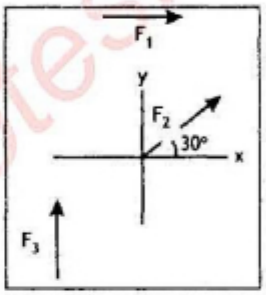
Worked Examples of the Textbook

01. ***Find the resultant of three forces 15N along the x–axis, 10N making an angle of 30° with x axis and 10N along the y–axis.***

Solution:

Step 1: Write the known quantities and choose a suitable scale.

Here, F_1 = 15N along x–axis
F_2 = 10N 30° with x-axis
F_3 = 10N along y–axis
Scale: 2 N = 1 cm

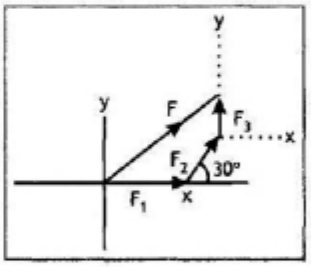


Step 2: Draw the representative vectors for the forces F_1, F_2, F_3 according to the scale in the given directions as shown in the given figure.

Step 3: Take F_1 as the first vector and draw F_2 and F_3 in such a way that the tail of the next vector coincides with the head of the previous vector as shown in the figure given below.

Step 4: Join the tail of the F_1 with the head F_3 with a straight–line F with an arrow pointing towards F_3.

Step 5: Measure the length of F with a ruler and multiply it with $2Ncm^{-1}$ that is the magnitude of the resultant. Measure the angle with the protector that F makes with F_1. This gives the direction of the resultant force.



02. ***A man is pushing a wheelbarrow on a horizontal ground with a force of 300N making an angle of 60° with the ground (the given figure). Find the horizontal and vertical components of the force.***

Solution:

Step 1: Write the known quantities and point out quantities to be found.

F = 300 N $\quad \theta = 60°$
F_x = ? $\quad F_y$ = ?

Step 2: Write the formula and rearrange if necessary.

$F_x = F\cos\theta$
$F_y = F\sin\theta$

Step 3: Put the value in formula and calculate:

F_x = 300N × cos 60° = 300N × 0.5 = 150 N
F_y = 300N × sin 60° = 300N × 0.866 = 259.8 N

Therefore, horizontal and vertical components of pushing force are 150N and 259.8N respectively.

03. ***A car driver tightens the nut of a wheel using a 20cm long spanner by exerting a force of 300N. Find the torque.***

Solution:

Step 1: Write the known quantities and point out the quantity to be found.

F = 300 N $\quad L$ = 20 cm = 0.20 m $\quad \tau$ = ?

Step 2: Write the formula and rearrange if necessary.

$$\tau = F \times L$$

Step 3: Put the value in the formula and calculate.

$$\tau = 300N \times 0.20m = 60\ Nm$$

Thus, the torque of 60Nm is used to tighten the nut.

04. ***Consider a meter rod supported at mid-point O as shown in the figure. The block of 20N is suspended at point A 30cm from O. Find the weight of the block that balances it at point B, 20cm from O.***

Solution:

Step 1: Write known quantities and point out unknown quantities.

$W_1 = 20\ N$

Moment of arm of W_1 = OA = 30 cm = 0.30 m

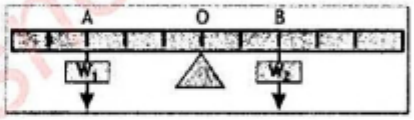
Moment of arm of W_2 = OB = 20 cm = 0.20 m

Step 2: Write a formula and rearrange if necessary.

Clockwise moments = Anticlockwise moment

$W_1 \times AO = W_2 \times OB$

$$W_2 = \frac{W_1 \times OA}{OB}$$



Step 3: Put the value and calculate.

$$W_1 = \frac{20\ N \times 0.3\ m}{0.20\ m} = 30\ N$$

Thus, the weight of the block suspended at point B is 30N.

05. ***A uniform rod of length 2.0m is placed on a wedge at 0.5m from its one end. A force of 150N is applied at one of its ends near the wedge to keep it horizontal. Find the weight of the rod and the reaction of the wedge.***

Solution:

Step 1: Write the known quantities and point out unknown:

$F = 150\ N$ $\quad OA = 0.5\ m$

$AG = BG = 1.0\ m$

$OG = AG - AO = 1.0\ m - 0.5\ m = 0.5\ m$

$W = ?$ $\quad R = ?$

Step 2: Write formula and substitute values:

For W applying the second condition of equilibrium, taking torques about O.

$\Sigma\tau = 0$

$F \times AO + R \times 0 + W \times OG = 0$

$150 \times 0.5 - W \times 0.5 = 0$ or

$W \times 0.5 = 150 \times 0.5$

$$W = \frac{150 \times 0.5}{0.5} = 150\ N$$

For R applying first condition of equilibrium:

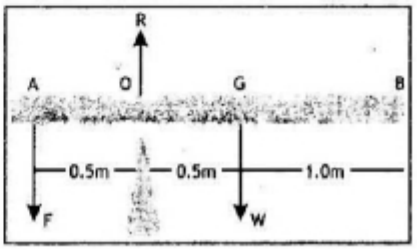
$\Sigma F_y = 0$

$R - F - W = 0$

$R - 150 - 150 = 0$ or

$R = 300\ N$

Therefore, the weight of the rod is 150N and the reaction of the wedge is 300N.



PHYSICS NOTES FOR CLASS 9TH (FOR SINDH)

Solved Numerical

01. *A pair of like parallel forces 15N each are acting on a body. Find their resultant.*

Solution: *Data:* $F_1 = 15$ N $F_2 = 15$ N $F = ?$

Equation: $F = F_1 + F_2$

Calculation: $F = 15 + 15 = \boxed{30\text{ N}}$ Ans.

02. *Two unlike parallel forces 10N each acting along the same line. Find their resultant.*

Solution: *Data:* $F_1 = 10$ N $F_2 = -10$ N $F = ?$

Equation: $F = F_1 - F_2$

Calculation: $F = 10 - 10 = \boxed{0\text{ N}}$ Ans.

03. *Three forces 12N along the x–axis, 8N making an angle of 45° with x–axis and 8N along the y–axis.*

(i) Find their resultant *(ii) Find the direction of resultant*

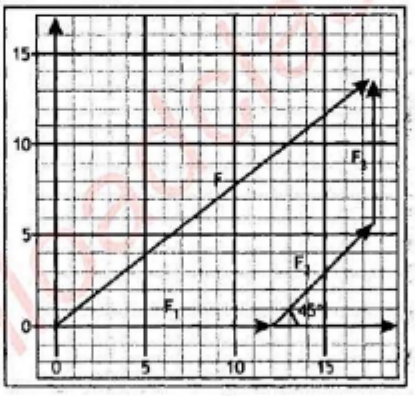
Solution: *Data:* $F_1 = 12$ N along x–axis

$F_2 = 8$ N making an angle of 45° with x–axis

$F_3 = 8$ N along y–axis

Scale: 1 N = 1 square (You can also take 2 N = 1 cm)

Graphical Representation:



(i) Measuring the length of F with a ruler, it is found that 22.322 N.

(ii) Measuring the angle with the protector that F makes with F1, it is found that 37.72°.

04. *A gardener is driving a lawnmower with a force of 80N that makes an angle of 40° with the ground*

(i) Find its horizontal component *(ii) Find the vertical component*

Solution: *Data:* Force = F = 80 N Angle = θ = 40°

Horizontal component = F_x = ? Vertical component = F_y = ?

Equation: $F_x = F\cos\theta$ and $F_y = F\sin\theta$

Calculation: $F_x = (80)\cos 40°$ and $F_y = (80)\sin 40°$

$= (80)(0.766)$ and $= (80)(0.642)$

$= 61.28$ N and $= 51.36$ N

Therefore, horizontal and vertical components of the force are 61.28 N and 51.36 N respectively.

05. *Horizontal and vertical components of a force are 4N and 3N respectively. Find*

(i) resultant force *(ii) direction of resultant*

Solution: *Data:* Horizontal component = $F_x = 4$ N

Vertical component = $F_y = 3$ N

(i) Resultant Force = F = ?

Equation: $F = \sqrt{F_x^2 + F_y^2}$

Calculation: $F = \sqrt{(4)^2 + (3)^2} = \sqrt{16 + 9} = \sqrt{25} = 5N$

Therefore, the resultant force is 5N. Ans.

(ii) Direction of resultant force = θ = ?

Equation: $\theta = \tan^{-1} \frac{F_y}{F_x}$

Calculation: $\theta = \tan^{-1} \frac{3}{4} = \tan^{-1} (0.75) = 36.87°$

Therefore, the direction of the resultant force is 36.87°. Ans.

06. ***A spanner of 0.3m length can produce a torque of 300Nm.***

(i) determine the force applied to it.

(ii) What should be the length of the spanner if torque is to be increased to 500Nm with the same applied force?

Solution:

(i) *Data:* Length of the spanner = L = 0.3 m Torque = τ = 300 Nm

Applied force = F = ?

Equation: $\tau = F \times L$

Calculation: $300 = F \times (0.3)$

$$F = \frac{300}{0.3} = 1000\ N$$

Therefore, the applied force on the spanner is 1000 N. Ans.

(ii) *Data:* Applied force = F = 1000 N Torque = τ = 500 Nm

Length of the spanner = L = ?

Equation: $\tau = F \times L$

Calculation: $500 = (1000) \times L$

$$L = \frac{500}{1000} = 0.5\ m$$

Therefore, the length of the spanner will be 0.5 m. Ans.

07. ***A uniform meter rule is supported at its centre is balanced by two forces 12N and 20N***

(i) if 20N force is placed at a distance of 3m from pivot find the position of 12N force on the other side of the pivot

(ii) if the 20N force is moved to 4cm from pivot then find the force to replace the 12N force.

Solution:

(i) *Data:* 1st Force = F_1 = 20 N 2nd Force = F_2 = 12 N

Moment arm of F_1 = d_1 = 3 m Moment arm of F_2 = d_2 = ?

Working Formula: Clockwise moments = Anticlockwise moments

$F_1 \times d_1 = F_2 \times d_2$

Calculation: $20 \times 3 = 12 \times d_2$

$60 = 12 d_2$

$$d_2 = \frac{60}{12} = 5\ m$$

Therefore, the moment arm of F_2 is 5 m on the other side of pivot. Ans.

(ii) *Data:* 1st Force = F_1 = 20 N 2nd Force = F_2 = ?

Moment arm of F_1 = d_1 = 4 m Moment arm of F_2 = d_2 = 5 m

Working Formula: Clockwise moments = Anticlockwise moments

$F_1 \times d_1 = F_2 \times d_2$

Calculation: $20 \times 4 = F_2 \times 5$

$$80 = 5F_2$$

$$F_2 = \frac{80}{5} = 16\ N$$

if the 20N force is moved to 4cm from pivot then the 12N force would be replaced by 16N force.

(08.) ***(a) A mechanic uses a double arm spanner to turn a nut. He applies a force of 15N at each end of the spanner and produces a torque of 60Nm. What is the length of the moment arm of the couple?***

(b) If he wants to produce a torque of 80Nm with the same spanner then how much force he should apply?

Solution:(a) *Data:* Applied force = F = 15 N Torque produced = τ = 60 Nm
length of the moment arm of the couple = d = ?

Working Formula: $\tau = F \times d$

Calculation: $60 = 15 \times d$

$$d = \frac{60}{15} = 4\ m$$

Therefore, the length of the moment arm of the couple is 4 m. Ans.

(b) *Data:* Applied force = F = ? Torque produced = τ = 80 Nm
length of the moment arm of the couple = d = 4 m

Working Formula: $\tau = F \times d$

Calculation: $80 = F \times 4$

$$F = \frac{80}{4} = 20\ N$$

If he wants to produce a torque of 80Nm with the same spanner, he should apply 20N force. Ans.

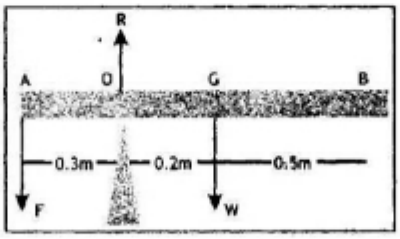
(09.) ***A uniform meter rule is balanced at the 30cm mark when a load of 0.80N is hung at the zero mark.***

(i) At what point on the rule is the center of gravity of the rule?

(ii) Calculate the weight of the rule.

Solution:

(i) *Data:* Load = F = 0.80 N Moment arm of F = OA = 30 cm = 0.3 m
Length of the rule = L = 1 m



Calculation: Center of gravity of the uniform meter rod = $\frac{AB}{2} = \frac{1}{2} = 0.5\ m$

Therefore, the center of gravity lies at 0.5 m or 50 cm. Ans.

(ii) *Data:* Load = F = 0.80 N Moment arm of F = OA = 30 cm = 0.3 m
Weight of the rule = W = ?
Moment arm of W = OG = 20 cm = 0.2 m

Working Formula: $\Sigma\tau = 0$

Calculation: $F \times AO + R \times 0 - W \times OG = 0$

$0.8 \times 0.3 + 0 - W \times 0.20 = 0$

$0.24 - W \times 0.20 = 0$

$W \times 0.20 = 0.24$

$$W = \frac{0.24}{0.20} = 1.2\ N$$

Therefore, the weight of the rod is 1.2 N. Ans.

10. ***What will be moment of force when 500N force is applied on a 40cm long spanner to tighten a nut?***

Solution: *Data:* $F = 500\ N$ $L = 40\ cm = 0.40\ m$ $\tau = ?$

Formula: $\tau = F \times L$

Calculation: $\tau = (500)(0.40) = \boxed{200\ Nm}$ Ans.

11. ***If two forces 5N each from a couple and the moment arm is 0.5m. Then what will be the torque of the couple?***

Solution: *Data:* $F = 5\ N$ $d = 0.5\ m$ $\tau = ?$

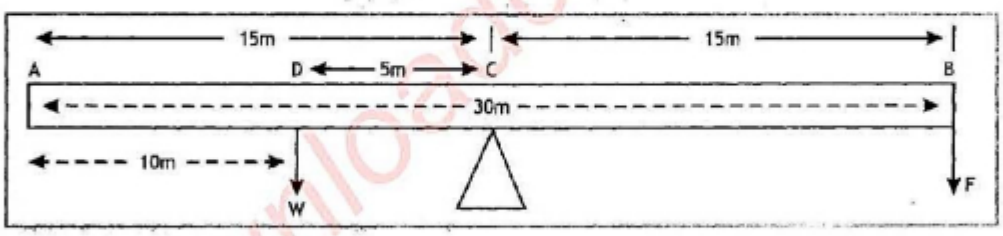
Formula: $\tau = F \times d$

Calculation: $\tau = (5)(0.5) = \boxed{2.5\ Nm}$ Ans.

12. ***A telephone pole of mass 300kg is 30m long. Its center of gravity is 10m from the thick end. What force must be applied at the thin end to maintain the pole in horizontal position when it is supported at its mid point?***

Solution: *Data:* Mass of the pole = 300 kg
Length of the pole = 30m
Center of gravity = 10m

Required Data: Force = F = ?
Weight of the pole = ?



Formula: $W = mg$

$W = 300 \times 9.8$

$W = 2940N$

Forces acting on the pole are shown in the figure where W represents the weight of the pole and F represents the force applied to the thin end to maintain the pole in a horizontal position when it is supported at its mid point.

$\therefore$ From figure we have,

AB = 30m, AC = 15m, BC = 15m, DC = 5m

Now

According to 2nd condition of equilibrium about C, we have

$$\Sigma\tau = 0$$
$$W \times DC - F \times BC = 0$$
$$2940 \times 5 - F \times 15 = 0$$
$$14700 - 15F = 0$$
$$15F = 14700$$
$$F = \frac{14700}{15}$$
$$\boxed{F = 980N}$$ Ans.

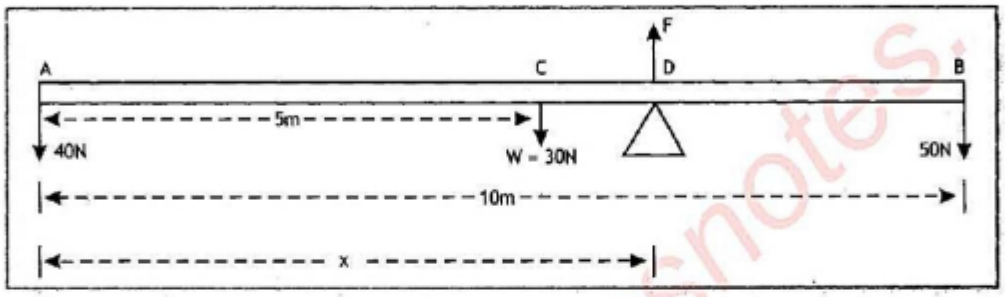
PHYSICS NOTES FOR CLASS 9TH (FOR SINDH)

13. ***A uniform rod 10 meters long and weighing 30N is supported in a horizontal position on a fulcrum with weight of 40N and 50N suspended from its ends as shown in the figure. Find the position of the fulcrum.***

Solution: *Data:*

The length of rod = AB = 10m
The weight of point C = W_c = 30N
The weight of point A = W_A = 40N
The weight of point B = W_B = 50N
The length of rod between A and C = 5m

Required Data: Position of fulcrum = x = ?



Formula:

The weight of the uniform rod acts at "C". Let D be the fulcrum and F be the upward force at the fulcrum. Suppose x is the position of the fulcrum with respect to A. the rod is in equilibrium. Now by applying 1st condition of equilibrium.

$$\Sigma F_x = 0$$
$$\Sigma F_y = 0$$
$$F - 40 - 30 - 50 = 0$$
$$F - 120\ N = 0$$
$$F = 120N$$

According to 2nd condition of Equilibrium.

$$\Sigma \tau = 0$$
$$F \times AD - W \times AC - 50 \times AB = 0$$
$$120 \times x - 30 \times 5 - 50 \times 10 = 0$$
$$120x - 650 = 0$$
$$120x = 650$$
$$x = \frac{650}{120}$$
$$x = 5.41m \quad \textbf{Ans.}$$

14. ***A force of 25N acts on a baby. If moment arm is 2m, find the value of torque.***

Solution: *Data:*

Force = F = 25N
Moment arm = d = 2m

Required Data: Torque = τ = ?

Formula:

$$\tau = F \times d$$
$$\tau = 25 \times 2$$
$$\tau = \boxed{50Nm} \quad \text{Ans.}$$

15. ***A force is applied perpendicularly on a door 4 meters wide which requires a torque of 120 Nm to open it. What will be the minimum force required?***

Solution: *Data:*

Moment arm = d = 4m

Torque = τ = 120Nm

Required Data: Force = F = ?

Formula: $\tau = F \times d$

$$F = \frac{\tau}{d}$$

$$F = \frac{120}{40}$$

$F = \boxed{30N}$ Ans.

(16.) ***What is the moment of the couple of 10N acting at the extremities of a rod 5m long as shown in figure. How can this couple be balanced?***

Solution: *Data:* Force = F = 10N

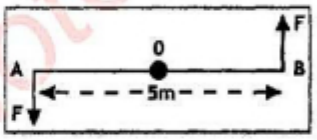
Couple arm = d = 5m

Required Data: Moment of couple or torque = τ = ?

Formula: $\tau = F \times d$

$\tau = 10 \times 5$

$\tau = \boxed{50Nm}$ Ans.



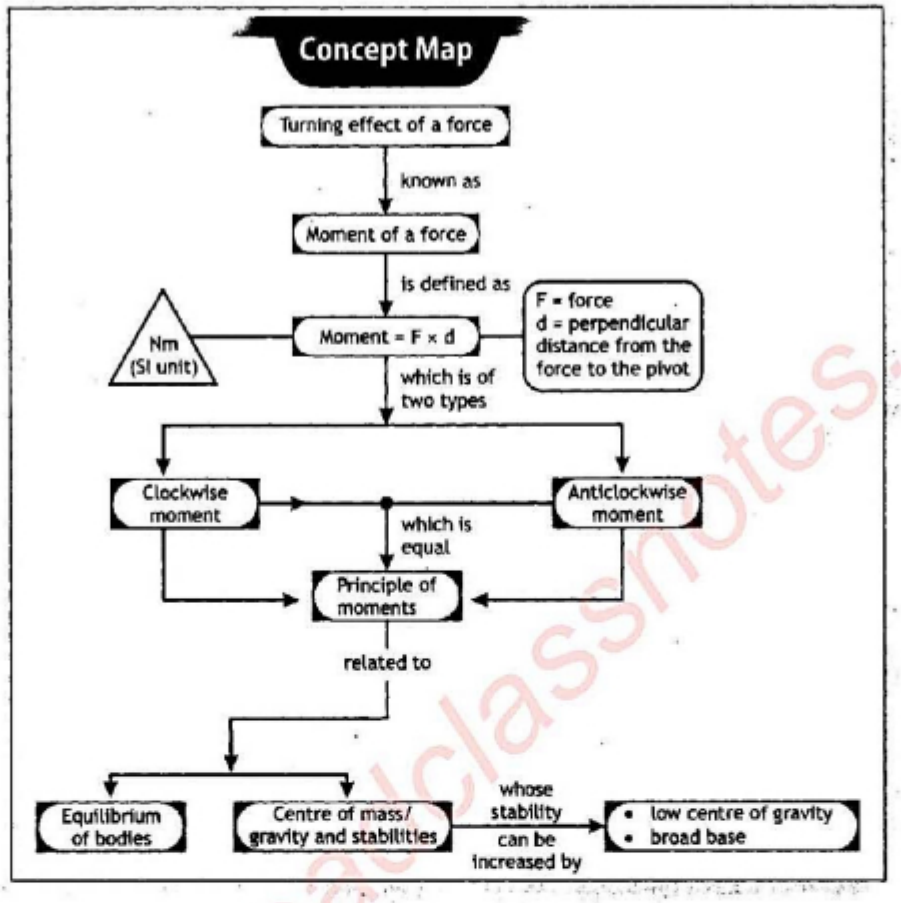
Summary

- Lines of action of parallel forces are parallel to each other.
- Parallel forces with the same direction are called like parallel forces.
- Parallel forces with opposite directions are called unlike parallel forces.
- The sum of the two or more forces is called the resultant of forces.
- The graphical method for the addition of forces is called the head-to-tail rule.
- Splitting a force into two perpendicular components is called the resolution of force. The components are

  $F_x = F\cos\theta$, $F_y = F\sin\theta$
- Perpendicular components can be used to determine a force as

  $F = \sqrt{F_x^2 + F_y^2}$, $\theta = \tan^{-1}\frac{F_y}{F_x}$
- The turning effect of force is called 'moment of force or torque'.
- The product of the force and the moment arm of the force is equal to the torque.
- The principle of moment states that a body is in equilibrium if the sum of the clockwise moments acting on a body is equal to the sum of the anticlockwise moments acting on the body.
- The center of mass or center of gravity is a point where the whole weight of the body acts vertically downward.
- Two equal and opposite forces acting along different lines of action form a couple.
- The first condition for equilibrium is satisfied if the net force acting on a body is zero.
- The second condition for equilibrium is satisfied if the sum of clockwise torques acting on a body is equal to the sum of the anticlockwise torques.
- A body is said to be in stable equilibrium if it returns to its previous position after a slight tilt.
- A body is said to be in unstable equilibrium if it does not return to its previous position on releasing after a slight tilt.
- A body is to be in neutral equilibrium if it does not return to its previous position but remains in equilibrium at a new position after disturbance.

PHYSICS NOTES FOR CLASS 9TH (FOR SINDH)



End of Unit Questions Solution

SECTION – A: MULTIPLE CHOICE QUESTIONS

Tick Mark (✓) the correct answer:

See "Multiple Choice Questions (M.C.Qs)" – (1) to (10)

SECTION – B: STRUCTURED QUESTIONS

Force on bodies

01. ***(a)*** ***Define like and unlike forces.***

(b) ***A pair of like parallel forces 15N each are acting on a body. Find their resultant.***

(c) ***Two unlike parallel forces 10N each acting along the same line. Find their resultant.***

Ans: **(a)** See 'Short & Detailed Answer Questions' – Q.3

(b) See 'Solved Numericals' – Q.1 **(c)** See 'Solved Numericals' – Q.2

Addition on forces

02. ***(a)*** ***Describe the head-to-tail rule of the vector addition of forces.***

(b) ***Three forces 12N along the x-axis, 8N making an angle of 45° with x-axis and 8N along the y-axis.***

(i) ***Find their resultant*** ***(ii)*** ***Find the direction of resultant***

Ans: **(a)** See 'Short & Detailed Answer Questions' – Q.7

(b) See 'Solved Numericals' – Q.3

PHYSICS NOTES FOR CLASS 9TH (FOR SINDH)

Resolution of forces

03. (a) *How a force can be resolved into its perpendicular components?*
(b) *A gardener is driving a lawnmower with a force of 80N that makes an angle of 40° with the ground*
(i) *Find its horizontal component* (ii) *Find the vertical component*

Ans: (a) See 'Short & Detailed Answer Questions' – Q.9
(b) See 'Solved Numerical' – Q.4

04. (a) *How can you determine a force from its rectangular components?*
(b) *Horizontal and vertical components of a force are 4N and 3N respectively. Find*
(i) *resultant force* (ii) *direction of resultant*

Ans: (a) See 'Short & Detailed Answer Questions' – Q.10
(b) See 'Solved Numerical' – Q.5

Moment of forces

05. (a) *What do you mean by a moment of fore?*
(b) *A spanner of 0.3m length can produce a torque of 300Nm.*
(i) *determine the force applied to it.*
(ii) *What should be the length of the spanner if torque is to be increased to 500Nm with the same applied force?*

Ans: (a) See 'Short & Detailed Answer Questions' – Q.11
(b) See 'Solved Numerical' – Q.6

Principle of forces

06. (a) *State the principle of the moment.*
(b) *A uniform meter rule is supported at its centre is balanced by two forces 12N and 20N*
(i) *if 20N force is placed at a distance of 3m from pivot find the position of 12N force on the other side of the pivot*
(ii) *if the 20N force is moved to 4cm from pivot then find the force to replace the 12N force.*

Ans: (a) See 'Short & Detailed Answer Questions' – Q.13
(b) See 'Solved Numerical' – Q.7

Center of mass

07. (a) *Define the center of mass or center of gravity.*
(b) *How will you determine the centre of mass or centre of gravity?*

Ans: (a) See 'Short & Detailed Answer Questions' – Q.16
(b) See 'Short & Detailed Answer Questions' – Q.19

Couple

08. (a) *Define couple as a pair of forces tending to produce torque.*
(b) *A mechanic uses a double arm spanner to turn a nut. He applies a force of 15N at each end of the spanner and produces a torque of 60Nm. What is the length of the moment arm of the couple?*
(c) *If he wants to produce a torque of 80Nm with the same spanner then how much force he should apply?*

Ans: (a) See 'Short & Detailed Answer Questions' – Q.20
(b) See 'Solved Numerical' – Q.8 (a)
(c) See 'Solved Numerical' – Q.8 (b)

Equilibrium

09. (a) *State two conditions necessary for an object to be in equilibrium.*
(b) *A uniform meter rule is balanced at the 30cm mark when a load of 0.80N is hung at the zero mark.*
(i) *At what point on the rule is the center of gravity of the rule?*
(ii) *Calculate the weight of the rule.*

Ans: (a) See 'Short & Detailed Answer Questions' – Q.24
(b) See 'Solved Numerical' – Q.9