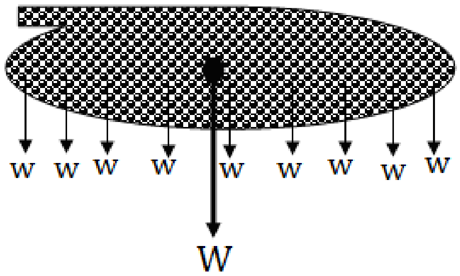
TOPIC: MECHANICS AND PROPERTIES OF MATTER
General Objective: The Learner should be to use the knowledge of turning effect of a force to explain stability of stationary objects, and relate machines to the concept of energy.

SUB-TOPIC: CENTRE OF GRAVITY, TURNING EFFECT OF FORCES (MOMENTS).

SPECIFIC OBJECTIVES
The learner should be able to;
- Define centre of gravity.
- Describe an experiment to locate the centre of gravity of a uniform lamina.
- Practically, determine the weight of a beam using the principles of moments.
- Explain types of equilibria.
- Define moments of force.
- State the principle of moments.
- Solve numerical problems using the principle of moments.
- Describes practical applications of the principle of moments.
- Define a couple and torque.
- Describe effect of couple and give examples.

Centre of gravity of a body
Everybody may be regarded as being made up of a very large number of very tiny and equal particles (according to Dalton Atomic theory). Each of these particles is pulled towards the centre of the earth as shown in figure below.



Thus, the earth's pull on the body consists of very large number of equal parallel forces. The resultant of the forces is equal to the total force of gravity on the body and it acts through a point **G** called the centre of gravity.

Definition: The centre of gravity of a body is defined as the point of application of the resultant force on a body due to the earth's attraction on it.

Resultant force is a single force which has the same effect as two or more forces acting on a body.

Methods to locate the Centre of gravity of a body
The method chosen to determine the centre of gravity of a body depends on the following factors:
(i) The nature and
(ii) The shape of the body.

The shape may either be regular or irregular.

(a) A regular body
The centre of gravity of a regular body is found by using:
(i) Balancing and
(ii) Intersection of diagonal method.

(i) **Balancing method**

The centre of gravity of a long uniform object such as a metre rule may be determined by balancing method.

In this method, the metre rule may be balanced on a knife edge or hang from a loop of thread and then adjusted until it balances horizontally.

The point at the knife edge is the centre of gravity.

Note:

- A uniform metre rule or a uniform body is one in which the particles are uniformly distributed.
- The centre of gravity of a **uniform body** is always at its **centre/middle point.**

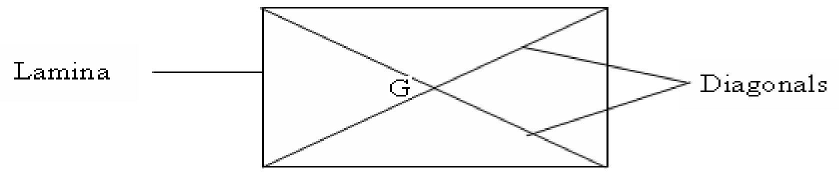
(ii) **Intersection of diagonals method**

This method applies mostly to two dimensional figures e.g a rectangular lamina or cardboard.

An experiment to determine the centre of gravity of a regular lamina

Procedure

Straight lines are drawn along the diagonals of the lamina as shown in the diagram below.



The point of intersection **G** is the centre of gravity.

(b) **Irregular Body**

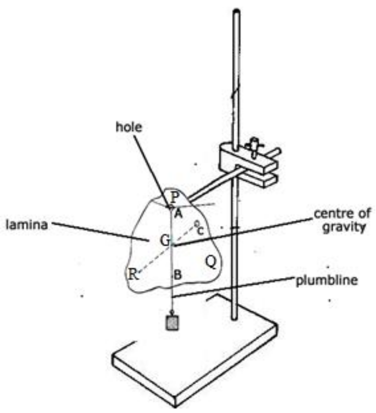
The centre of gravity of irregular body is determined by using plumb line method.

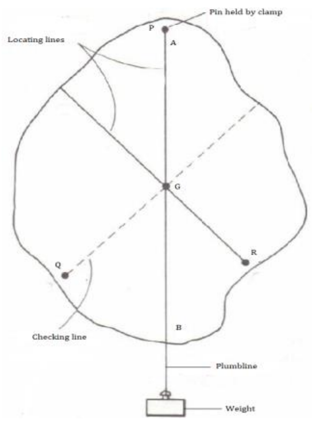
An experiment to determine the centre of gravity of irregular lamina

Apparatus

Retort stand/Clamp, a pin fixed to a rubber bang, plumb, thin string, paper punch machine

Procedure





Three small well-spaced holes P, Q and R are made near the edge of the irregularly shaped laminar.

A drawing pin is clamped using two wooden pieces.

The laminar is suspended on the clamp using the drawing pin through one of the holes, say P. A plumbline (a thin thread with a small weight at one end) is also suspended from the same pin as shown in the diagram (a) above.

When both the plumbline and the laminar have settled, a mark **A** is made at the point where the plumb line crosses the edge. Two points A and B are marked along the plumbline far apart and a line joining them is drawn on the laminar.

The procedure is repeated with the laminar supported from hole **Q** and point G where the two lines intersect is marked.

The accuracy of the method is checked by suspending the laminar at R. The plumbline should pass through G.

The results can be checked by balancing the lamina about G. The lamina should balance horizontally. Point G is the centre of gravity of the irregular lamina.

Note:

(i) In the laboratory, the plumb can be replaced by a pendulum bob.
(ii) The centre of gravity of a body does not always lie within the material, it may also be at a point in space nearby. The best examples are tripod and a laboratory stool.

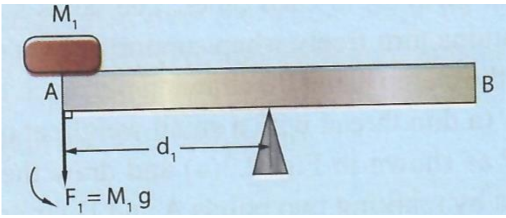
TURNING EFFECT OF FORCE (MOMENT OF A FORCE)

A force has to be applied to a machine for it to do work. It's important to know where the force should be applied for the machine to be more efficient in doing work. In this chapter we are going to study the turning effect of a force.

An experiment to investigate the turning effect of a force.

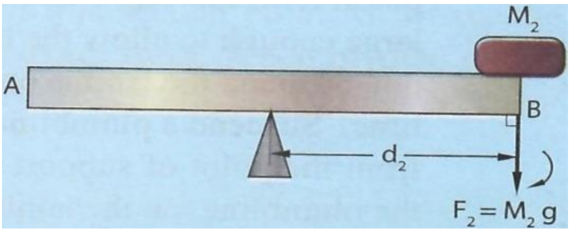
A metre rule is balanced on a knife edge.
A force F_1 is applied at a point A a distance d_1 from the knife edge as shown below.

(a) Anticlockwise turning



The experiment is repeated by applying another force F_1 on the other end B of the metre rule at distance d_1 from the knife edge as shown below.

(a) Clockwise turning



Observation

In both cases, the metre rule turns about the knife edge. In the first case the metre rule turns in the **anticlockwise direction** about the knife edge.
In the other case, the metre rule turns in the **clockwise direction.**

Both F_1 and F_2 produce a **turning effect** on the metre rule **about the knife edge.**
The turning effect of a force about a point is called **moment of a force about that point.**
This moment depends on
(i) **the force** applied and

(ii) its **perpendicular distance** between the **turning point** and the **line of action of the force.**

Definition.
Moment of a force about a point is the product of the force and the perpendicular distance from the point to the line of action of the force.

Moment of a force is either clockwise or anticlockwise about the point.

In diagram (a), the anticlockwise moment about the knife edge is $F_1 \times d_1$
In diagram (b), the clockwise moment is $F_2 \times d_2$

Moment of a force = Force × perpendicular distance
Moment of a force $= F \times d$

The S.I unit of moment
S.I unit of moment = newton metre (Nm)

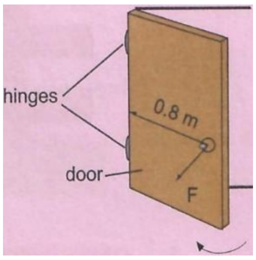
Moment of a force is a vector quantity since it has both magnitude and direction

The turning effects of forces are seen in the following actions (applications of turning effects of forces)

(i) Opening or closing - a door, window, lid of a container e.g. a Jerry can, turning on a tap etc.
(ii) Doing or undoing a nut using a spanner.
(iii) Children playing on a see-saw
(iv) A pair of scissors or garden shears in use.
(v) A beam balance being used to find mass of an object.
(vi) A screwdriver being used to tighten/loosen a screw.
etc.

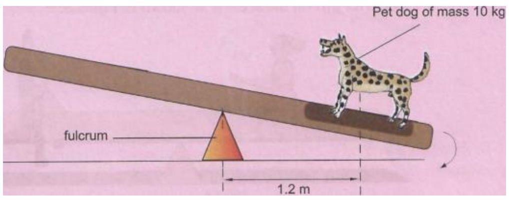
Example

1. A student applies a force of 10N to the handle of a door which is 0.8m from the hinges of the door below.



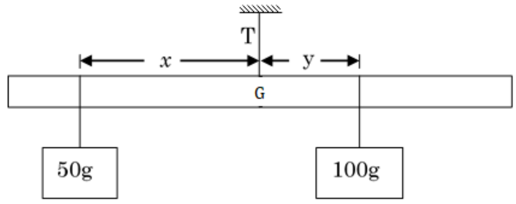
Calculate the moment of a force.

2. Calculate the moment of a force about the fulcrum when a pet dog of mass 10kg is at a distance of 1.2m from the fulcrum of a seesaw shown below.



Sub topical exercise 2.1 page 30-31

PRINCIPLE OF MOMENTS
INVESTIGATION OF THE PRINCIPLE OF MOMENTS.
Experiment 1



By means of thread T, a metre rule is hang so that it balances horizontally with its scale facing upwards. The point G where it balances is noted.

50g mass is hang from the 10cm mark. The distance x, of the 50g mass from T is determined.

A 100g mass is hang on the other side of the metre ruler. The position of the 100g is adjusted until the metre rule balances again horizontally. The distance y of the 100g from the thread is determined.

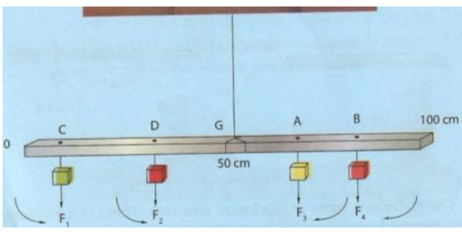
The above procedures are repeated when the 50g mass is hung at 15cm, 20cm, 25cm, and 30cm marks.

The results are filled in a table including values of 50x and 100y as shown below.

Position of 50g mass from zero mark (cm)	x(cm)	y (cm)	50x	100y
10				
15				
20				
25				
30				

Observation
The values in columns 50y and 100x are the same.
Conclusion
The moments are equal in magnitude but opposite in direction.

Experiment 2
INVESTIGATION OF THE PRINCIPLE OF MOMENTS WITH MORE THAN TWO FORCES
The above experiment is repeated using four masses. The masses are moved until the ruler balances horizontally.



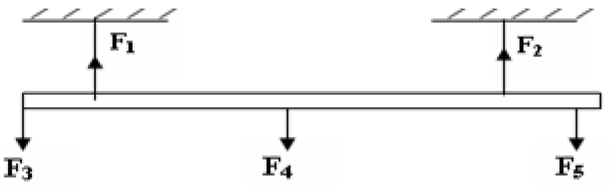
The moments about G are calculated.
The sum of the clockwise moments $= F_3 \times GA + F_4 \times GB$
The sum of the anticlockwise moments $= F_1 \times GC + F_2 \times GD$

Conclusion
The sum of the clockwise moments about a point is equal to the sum of the anticlockwise moments about the same point, when the metre rule is balanced (in equilibrium).

Note:
When a body is balanced under the action of a number of forces, it is said to be in equilibrium.

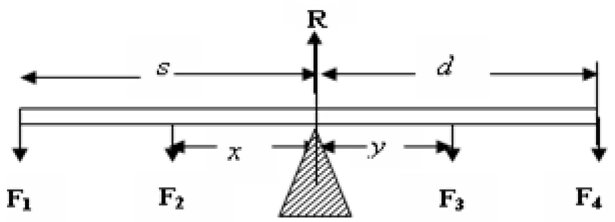
The Principle of Moment states that:
When a body is **in equilibrium** under the action of forces, the **sum of clockwise moments** about any point is equal to the **sum of anti-clockwise moments** about the same point.
Conditions for a body to be in equilibrium
The following are the conditions for a body to be in equilibrium when under the action of a number of parallel forces.
(i) The sum of forces acting in one direction is equal to the sum of forces acting in the opposite direction. i.e. the net resultant force on the body is zero.
(ii) The sum of clockwise moments about any point is equal to the sum of anti-clockwise moments about the same point.

Consider the diagrams below showing a uniform body in equilibrium under the action of parallel forces below for conditions (i) and (ii) above.



In the diagram, three forces (F_3, F_4 and F_5) act one direction and two forces (F_1 and F_2) act in the opposite direction.
Since the body is in equilibrium, then using condition (i) above we have:
Sum of forces in one direction = sum of the forces in the opposite direction

$$(F_1 + F_2) = (F_3 + F_4 + F_5)$$



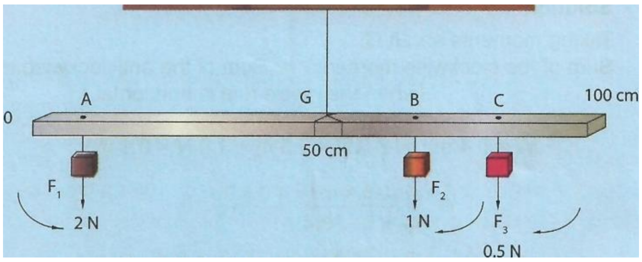
Using condition (ii)
Sum of clockwise moments = Sum of anti-clockwise moments

$$\therefore \quad F_3y + F_4d = F_1s + F_2x$$

And Using condition (i) above we have:

$$R = F_1 + F_2 + F_3 + F_4$$

An experiment to verify the principle of moments.
By means of thread T, a metre rule is hang so that it balances horizontally with its scale facing upwards. The point G where it balances is noted.
Three masses; 200g, 100, and 50g are suspended and their positions A, B and C are adjusted till the system is in equilibrium as shown below.



The distances GA, GB and GC are calculated and the values are entered in a table as shown below.
The experiment is repeated by changing the positions of A or B or C all the three so that the metre rule is balanced horizontally in each case.

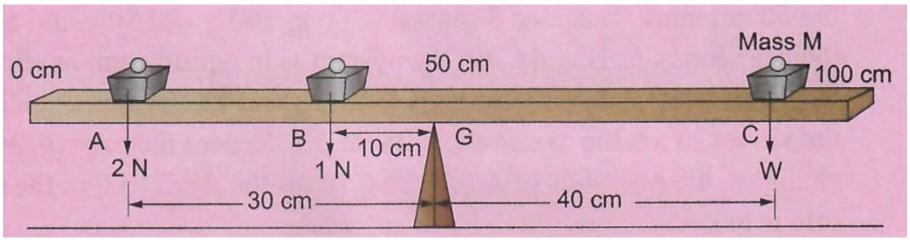
GA(m)	GB(m)	GC(m)	$F_1 \times GA$(Nm)	$(F_2 \times GB + F_3 \times GC)$(Nm)

Conclusion
The last two columns are equal for each set of results providing that the sum of the clockwise moments are equal to the sum of the anticlockwise moments

$$F_1 \times GA + F_3 \times GC = F_1 \times GA$$

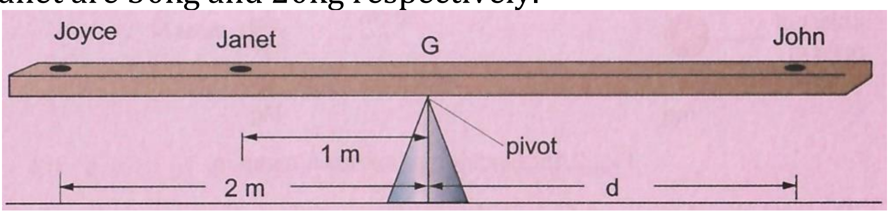
Examples

1. A uniform metre rule is pivoted at its centre G, and three masses are suspended at A, B and C as shown below.



Find the value of the weight W of the mass M placed at C so that the metre rule is balanced horizontally.
Solution
Taking moments about G,
Sum of the clockwise moments = sum of the anticlockwise moments

2. John, Joyce and Janet are seated on a seesaw as shown below. Where should John, whose mass is 60kg, sit so that the seesaw is balanced horizontally if the masses of Joyce and Janet are 50kg and 20kg respectively.

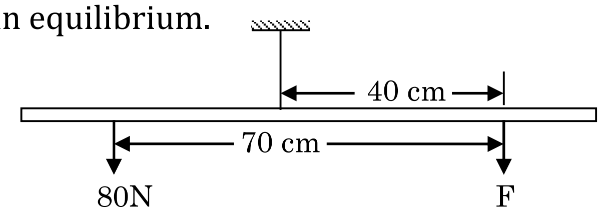


Taking moments about G,

Sum of the clockwise moments = sum of the anticlockwise moments

Example 3

The bar shown below is in equilibrium.



Find the force F.

Solution:

We shall take moments about the point of support. F tends to turn the bar clockwise about the point of support. So it is said to have a clockwise moment about that point. On the other hand, the 80 N force tends to turn the bar anticlockwise about the same point. So it has an anticlockwise moment about the same point.

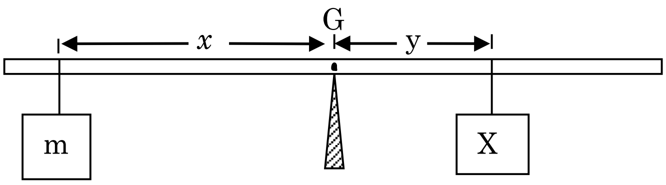
The 80 N force is (70 – 40) cm from the point of support. Thus, applying the principle of moments:

$$F \times 40 = 80 \times 30$$

$$\therefore \quad F = \frac{80 \times 30}{40} = 60\ N$$

AN EXPERIMENT TO DETERMINE THE MASS OR WEIGHT OF AN OBJECT USING A UNIFORM METRE RULE AND A STANDARD MASS OR WEIGHT

Procedure



The metre rule is first placed on a knife edge and the position, G, of the knife edge at which it balances horizontally is noted.

A known mass, m, is hung from, say the 5cm mark.

The object, X, whose mass is required, is hung on the opposite side of the knife edge.

While maintaining the point of support, the position of X is adjusted until equilibrium is restored as shown in the diagram above.

The distances x and y are noted.

Let M be the mass of X.

Applying moments,

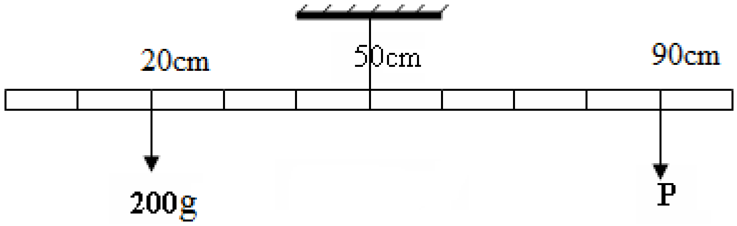
$$yM = xm$$

$$M = \frac{xm}{y}$$

Note: To get the weight once, we use a standard (known) weight directly instead of a Standard (known) mass.

Example

The metre rule below is in equilibrium, calculate the value of P.



Applying the principle of moments

Sum of clockwise moments = Sum of anti-clockwise moments

P x (90 – 50) cm = 200 g x (50 – 20) cm

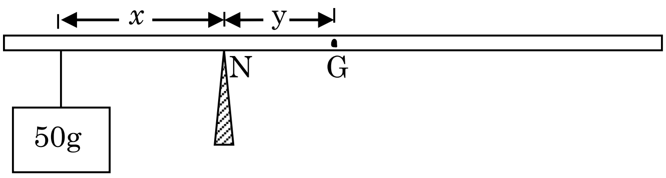
P x 40 cm = 200g x 30 cm

$$\frac{P \text{ x } 40cm}{40cm} = \frac{200g \text{ x } 30cm}{40cm}$$

P = 150 g

NB: To get the weight (W) of the object, we use the formula:
W = mg Where: **g** = gravity and
m = **mass of the object in kg.**

An experiment to determine the mass of a uniform metre rule using a standard (known) mass.



The metre rule is first placed on a knife edge and the position, G, of the knife edge at which it balances horizontally is noted.

A known mass say 50 g, is hung from the 5cm mark and the metre rule is adjusted until equilibrium is restored. The new position, N, of the knife edge is noted.

The distance between the point of support of the 50 g mass and point N is measured and noted as x. Also the distance y is noted.

Let the mass of the metre rule be M,
Applying the principle of moments

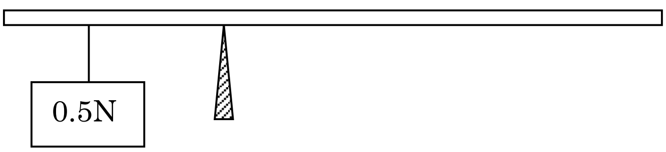
$$yM = 50x$$

$$M = \frac{50x}{y}$$

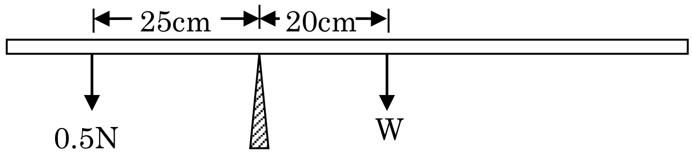
The procedure is repeated using different positions of the hanging mass and the average value of M, obtained.

Example 1

The figure shows a uniform metre rule in horizontal equilibrium supported at the 30cm mark while weight of 0.5N hangs from its 5cm mark. Find the weight of the metre rule.



Solution
The first task is to indicate all the forces acting on the metre rule and the distances at which they act.
Let the weight of the metre rule be W. It acts through the mid-point of the rule



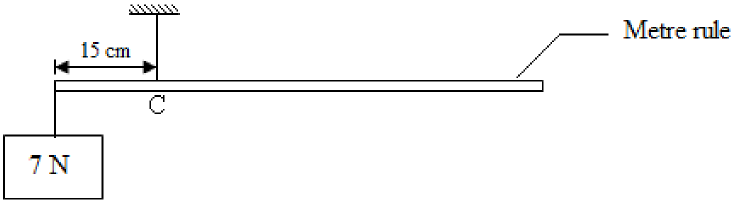
Taking moments about the point of support:

$$W \times 20 = 0.5 \times 25$$

$$\therefore \quad W = \frac{0.5 \times 25}{20} = 0.625\ N$$

Example 2 (UNEB 2013 PAPER TWO NO. 2(f))

A uniform metre is balanced horizontally on a pivot at the 15 cm mark when a load of 7 N is attached at the zero mark as shown in figure below.



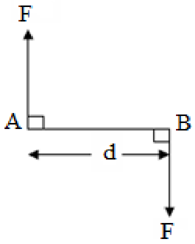
Find the weight of the metre rule (03 marks)

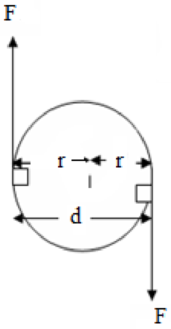
Hint: The first task is to indicate all the forces acting on the metre rule and the distances at which they act.
Let the weight of the metre rule be W. It acts through the mid-point of the rule

Example 3 (UNEB 2008 P1 no. 49)

A Couple (Parallel forces)
A couple refers to two equal and opposite parallel forces acting on a body.
Note:
1. Parallel forces which act in the same direction are called **like parallel forces.**
2. Parallel forces which act in the opposite directions are called **unlike parallel forces**

A couple produces rotation and can only be stopped or balanced by an equal and opposite couple. **or**





The effect of a couple is to rotate the body.

Characteristics of a body under the action of a couple

(i) The resultant force on the body is zero.
(ii) The turning effects of the forces cause a rotational effect.
(iii) The forces act in opposite directions.

Moment of a couple (Torque)

The moment of a couple is the product of one force and the perpendicular distance between the two forces.

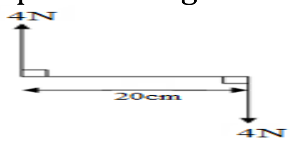
The moment due to the couple in figure above is given by the formula:

Moment of a couple (Torque)

$$= \text{One of the forces x the perpendicular distance between the forces} = F \times d$$

Examples

1. Calculate the moment of the couple in the figure below.

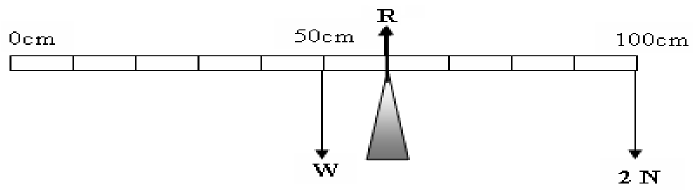


More Worked Examples

Note: When solving problems involving the law of moments, identify the force(s) which tend to cause clockwise moment(s) and anti-clock wise moment(s). So that you substitute them correctly. Experience has shown that many students tend to forget this by putting clockwise moments under anti-clock wise moments and vice versa.

1. A uniform metre rule balances horizontally on a knife edge placed at 60 cm when 2 N weight is suspended at one end.
   (a) With a help of diagram show at which end of the metre rule the 2 N weight must be suspended.
   (b) Calculate:
      (i) the weight,
      (ii) the mass of the metre rule,
      (iii) the reaction, R, at the knife edge. (Take g = 10 ms^{-2})

   Solution: (a)



Since the metre rule is uniform, its weight **W** acts through centre, i.e at 50cm mark, then the 2 N weight must be suspended on the other side of the pivot so as to balance it.

(b) (i) Applying the principle of moments

Clockwise moment = Anti-Clockwise moments

$$2\,N \times (100 - 60)\,cm = W \times (60 - 50)\,cm$$
$$2\,N \times 40\,cm = W \times 10\,cm$$
$$\frac{10W}{10} = \frac{80}{10}$$
$$\boldsymbol{W = 8\,N}$$

(ii)

$$W = 8\,N, g = 10\,ms - 2, m = ?$$
$$Using\ \boldsymbol{W} = \boldsymbol{mg}$$
$$8 = m\,x\,10$$
$$m = \frac{8}{10}$$
$$m = 0.8\,kg$$

(iii) Applying the condition for a body in equilibrium,

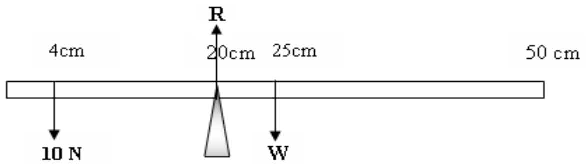
Sum of the forces in one direction = Sum of the forces in the opposite direction

$$R = W + 2\,N$$
$$= 8\,N + 2\,N$$
$$\therefore R = 10\,N$$

2. A uniform half-metre rule is freely pivoted at the 20 cm mark and it balances horizontally when a weight of 10 N is suspended at the 4 cm mark.
   (a) Draw a sketch diagram showing all the forces acting on the metre rule.
   (b) Calculate:
      (i) the weight of the metre rule.
      (ii) the reaction at the knife edge.

Solution

(a) A sketch diagram showing the forces acting on a half-metre rule



(b) (i) Applying the principle of moments

Sum of clockwise moments = Sum of anti-Clockwise moments

$$W \times (25 - 20)cm = 10 \times (20 - 4)\,cm$$
$$W \times 5\,cm = 10 \times 16\,cm$$
$$W = \frac{160}{5}\,N$$

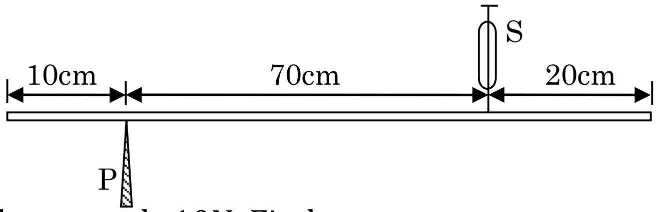
$$\therefore W = 32\,N$$

(ii) Applying

Sum of the forces in one direction = Sum of the forces in the opposite direction

$$R = W + 10\,N$$
$$= 32\,N + 10\,N$$
$$\therefore \boldsymbol{R = 42\,N}$$

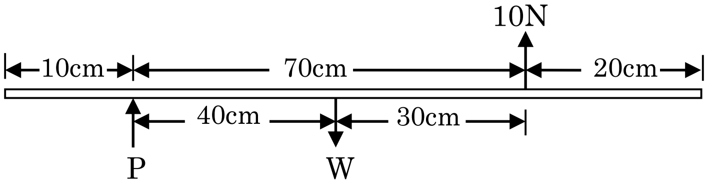
3. The figure shows a uniform horizontal bar supported by a peg P and spring balance S.



The spring balance reads 10N. Find
(i) The weight of the bar
(ii) The reaction of the peg

Solution:

Hint: The first task is to show all the forces acting on the bar remembering that, since the bar is uniform, its weight acts through the mid-point, which is 50 cm from either end.



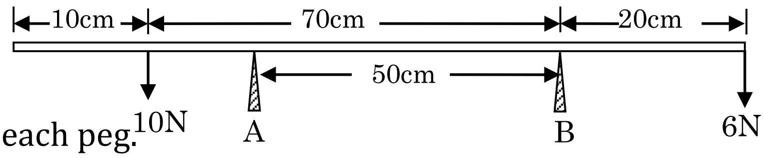
(i) Let W be the weight of the bar and P the reaction of the peg.
Then, taking moments about the peg, we have:
Sum of clockwise moments = Sum of anti-Clockwise moments

$$W \times 40 = 10 \times 70$$
$$\therefore \quad W = \frac{10 \times 70}{40} = 17.5\,N.$$

(ii) Sum of the forces in one direction = Sum of the forces in the opposite direction

$$\therefore P + 10 = W$$
$$\therefore \quad P = W - 10 = 17.5 - 10 = 7.5\,N.$$

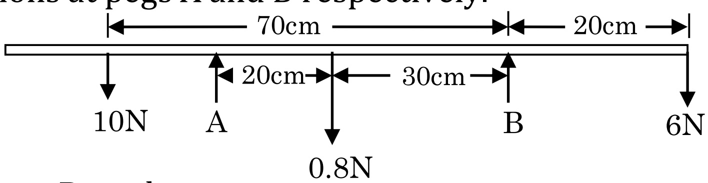
3. The diagram shows a uniform bar of weight 0.8 N resting on pegs A and B.



Find the reaction at each peg.

Solution:

The length of the bar is 10 + 70 + 20 = 100 cm.
Since the bar is uniform, its weight acts through its mid-point. We can therefore redraw the bar to show all the forces acting on it as follows:
Let A and B be the reactions at pegs A and B respectively.



Taking moments about peg B, we have:
Sum of clockwise moments = sum of anticlockwise moments

$$A \times 50 + 6 \times 20 = 10 \times 70 + 0.8 \times 30$$

$$\therefore 50A + 120 = 700 + 24$$

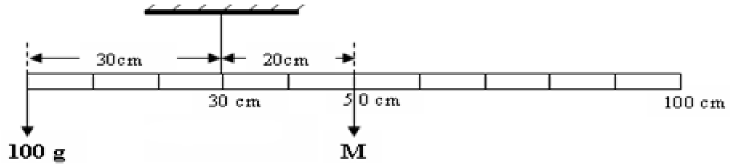
$$\therefore \quad A = \frac{604}{50} = 12.08\,N$$

Now, Sum of the forces in one direction = Sum of the forces in the opposite direction

$$A + B = 10 + 0.8 + 6$$

$$\therefore B = 16.8 - 12.08 = 1.72\,N$$

4. Consider the diagram in figure below



Applying the principle of moments

Sum of clockwise moments = sum of anticlockwise moments

M x (50 – 30) cm = 100 g x (30 – 0) cm

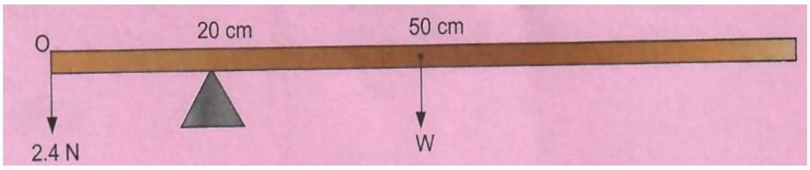
M x 20 cm = 100 g x 30 cm

M = 150 g

5. A uniform metre rule is balanced at the 20cm mark by a mass of 240g placed at one end.
   (a) Draw a diagram to show the state of balance of the metre rule.
   (b) Determine the weight and mass of the metre rule.

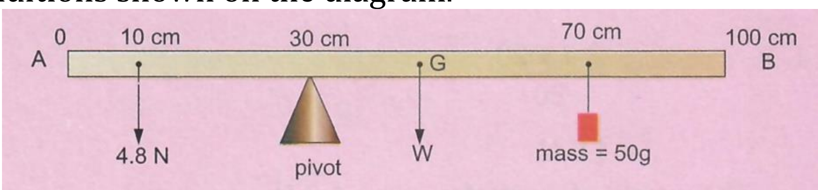
   Solution

   (a)



   (b)

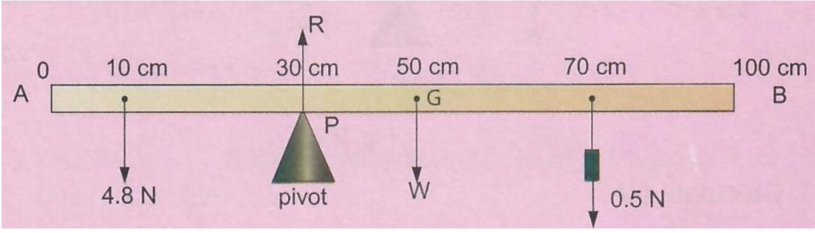
6. The figure below shows a uniform metallic metre rule balanced when pivoted at the 30cm mark under the conditions shown on the diagram.



   (a) Redraw the diagram showing all the forces acting on the metre rule.

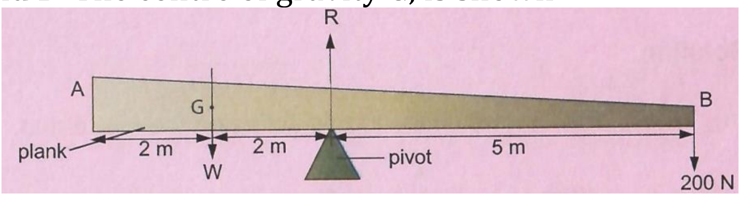
   (b) Calculate the weight W of the metre rule.

(a)



(b)

7. A non-uniform plank AB shown in the figure below is balanced when a force of 200N is applied at the end B. The centre of gravity G, is shown.



Calculate the:

(a) weight

(b) mass of the plank

Resultant Moment

When dealing with problems involving a number of moments acting on a body which is NOT in equilibrium, the following steps are taken:

(i) Draw the sketch diagram indicating all the forces and their respective distances from the pivot (fulcrum).

(ii) Give a **positive sign to anticlockwise moments** and a **negative sign to clockwise moments**.

(iii) Add the moments algebraically. The numerical value of the answer gives the magnitude of the resultant moment and the arithmetic sign of the answer gives the direction of the resultant moment.

Example 1

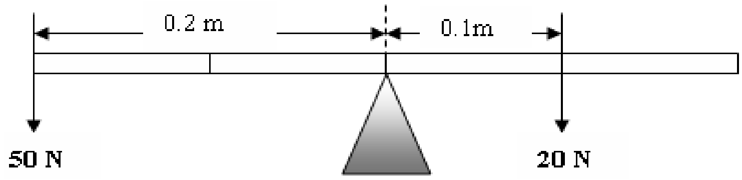
1. Two forces 20 N and 50 N act on a body as shown in figure 6.5. If the 20 N is 0.1 m from the pivot and has clock wise effect while 50 N is 0.2 m from the pivot and has ant clockwise effect.

(a) Sketch the diagram showing all the forces and their respective distances from the pivot.

(b) Calculate the resultant moment on the body.

Solution:

(a)



(b) $Resultant\ moment = -(20 \times 0.1) + +(50 \times 0.2)$

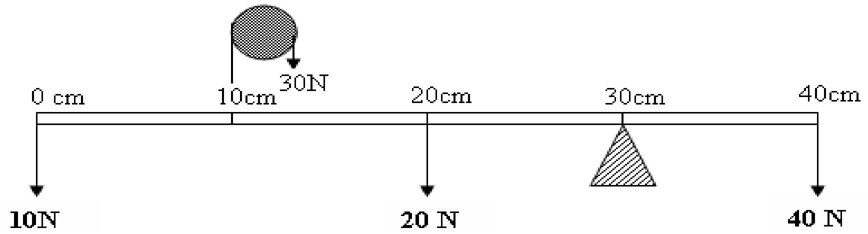
$$= -2.0 + 10$$

$$= +8\ Nm$$

Hence the resultant moment is 5 Nm acting in anti-clockwise direction.

2. Four forces, 10 N, 20 N, 40 N, act downward and 30 N acts upward on a body which is 40 cm long. The 10 N is hung at 0 cm mark, the 30 N acts at 10 cm mark, 20 N acts at 20 cm mark and 40 N acts at 40 cm mark. If the knife edge is placed at 30 cm mark, calculate the resultant moment on the body,

The sketch of the diagram showing the four forces acting on a body.



Calculations

Resultant moment = $+10 \text{ x} \left(\frac{30-0}{100}\right) + 20 \text{ x} \left(\frac{30-20}{100}\right) - 30 \text{ x} \left(\frac{30-10}{100}\right) - 40\text{x} \left(\frac{40-0}{100}\right)$

$$= +10 \text{ x} \frac{30}{100} + 20 \text{ x} \frac{10}{100} - 30 \text{ x} \frac{20}{100} - 40 \text{ x} \frac{10}{100}$$

$$= \frac{300}{100} + \frac{200}{100} + \frac{-600}{100} + \frac{-400}{100}$$

$$= +3 + 2 - 6 - 4$$

$$= +5 - 10$$

= -5 Nm

Hence the resultant moment is 5 Nm acting in a clockwise direction.

Applications of the Principle of Moments

The principle of moment is applied in: the following.

- The determination of Mass or weight of a uniform metre rule.
- The determination of Mass or weight of an object.

Stability and Equilibrium

(a) Stability

Stability as the difficulty in causing a body to fall or topple over.

Or

Stability is the state of rest of the body.

(b) Equilibrium

Equilibrium refers to the state of a body where the net force acting on the body is zero.

Types (states) of Equilibrium

Mechanical equilibrium can be of three kinds:

(i) Stable Equilibrium,

(ii) Unstable Equilibrium and

(iii) Neutral Equilibrium

Stable Equilibrium

Stable equilibrium is a state of a body in which a body returns to its original position after a slight displacement on it.

Characteristics of a body in stable equilibrium

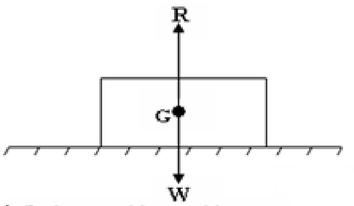
A body in a stable equilibrium is characterized by or is associated with the following:

(i) The centre of gravity of the body is at the lowest position.

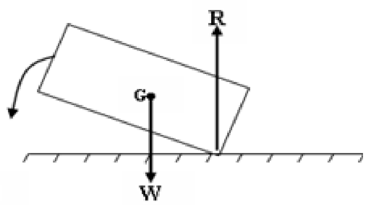
(ii) The base area is large.

Thus on a slight displacement of a body in stable equilibrium, the centre of gravity is raised and the body returns to its original position after the displacement.

Consider a glass block resting on a table as shown in figure below.



(a) Body in stable equilibrium:



(b) Body slightly displaced: The Centre of gravity is at lowest point. centre of gravity rises and the block returns to its original position.

Explanation

The block of glass exerts force, W, (its weight) on the table and the table exerts an upward force called reaction force, R, equal to the weight of the block. Since the weight and the reaction are equal and opposite forces, the resultant force on the block is zero, so the block is stable (i.e. does not move).

When the block is tilted slightly, the two forces act as shown in figure (b). The reaction, R, acts at the point of contact while the weight, W, still acts through G, the centre of gravity, but outside the point of contact. The result is a couple, two equal and opposite parallel forces, which tend to rotate the block in anti-clockwise direction and therefore, the block falls back to its original position.

Unstable Equilibrium

Unstable equilibrium refers to a state of a body in which on a slight displacement it does not return to its original position.

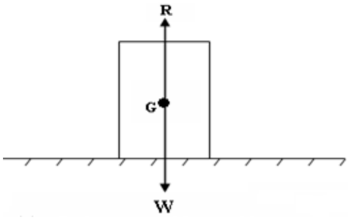
Characteristics of a body in unstable equilibrium

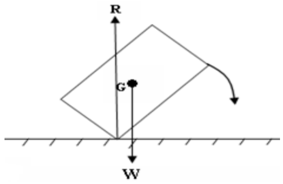
A body in an unstable equilibrium is associated with the following:

(i) The centre of gravity of the body is at the highest position.

(ii) The base area is small.

Thus on a slight displacement of a body in unstable equilibrium, the centre of gravity is lowered and the body does not return to its original position after the displacement; it topples over.





(a) Body in unstable equilibrium:

(b) Body slightly displaced: The Centre of gravity is at highest point.centre of gravity is lowered and the body topples over

Explanation

In figure (a), the block is in an unstable equilibrium. When it is tilted slightly, the two forces act as shown in figure (b). The reaction, R, acts at the point of contact while the weight, W, still acts through G, the centre of gravity, but outside the point of contact. The result is a couple, two equal and opposite parallel forces which tend to rotate the block in clockwise direction and does not return to its original position, hence topples over.

Neutral Equilibrium

This is a state of a body in which on slight displacement its centre of gravity is neither raised nor lowered.

Characteristics of a body in neutral equilibrium

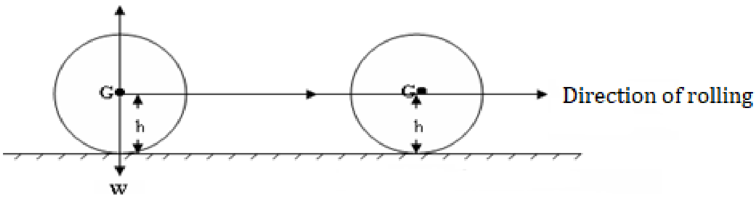
A body in a neutral equilibrium is associated with the following:

(i) The centre of gravity of the body is always at the same height and directly above the point of contact.

(ii) The area in contact is very small.

A slight displacement does not alter the position of the centre of gravity, thus the body is always at rest whichever position it is placed.

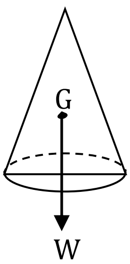
Example of a body in neutral equilibrium is any perfect sphere.



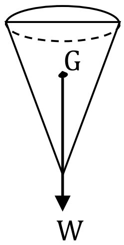
A body in a neutral equilibrium:
G is at a height H, above the ground.

On slight displacement:
The sphere rolls to a new position.
The G is still at the same height, h

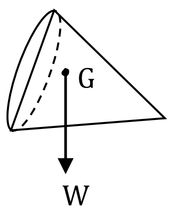
Illustration of states of equilibrium.
A cone



(i) Stable



(ii) Unstable



(iii) Neutral

NB: Using the characteristics of a body in stable equilibrium, a body be designed such that it is in stable equilibrium.

Making a body Stable

In engineering, the stability of a structure is increased by:

(i) Making its base wide and

(ii) Keeping its centre of gravity as low as possible by putting more weight in the lower part than in the upper part.

Notable examples are seen in the following – **applications of stability.**

(i) Racing cars - which have both a low centre of gravity and a wide wheel base.

(ii) Modern Isuzu/Scania coach buses
They have fairly wide wheel base and low centre of gravity which is achieved by packing load in boots.

Note: The old system of loading buses on the racks of buses raises the centre of gravity of the bus thus making it unstable on the road.

(iii) Containers for holding liquids such as conical flasks in the laboratory and cooking vessels in the kitchen have broad vessels to improve their stability.

(iv) A hydrometer is to stay upright in liquid because it is weighted at the centre of its base and therefore its centre of gravity is at the centre.

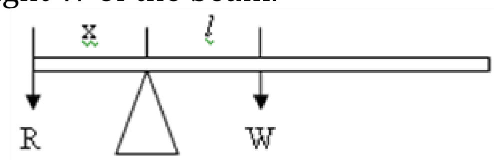
THE END

Attempt all questions in Revision exercise 2 pages 50-56 Longhorn bk2

MORE REVISION QUESTIONS ON MOMENTS UNEB PAST PAPERS.

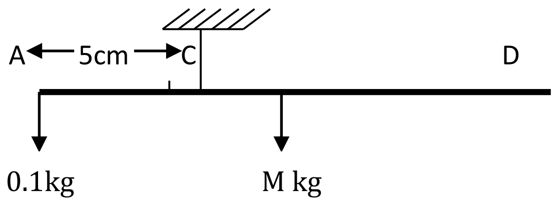
SECTION A

1. Figure below shows a uniform beam in equilibrium when a force R acts on it at one end. Find the weight W of the beam.



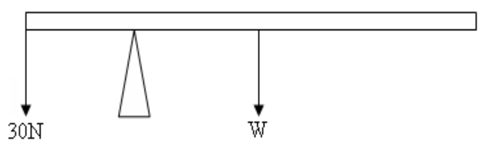
A. $\frac{x}{Rl}$ B. $\frac{Rl}{x}$ C. $\frac{l}{Rx}$ D. $\frac{Rx}{l}$ $\frac{Rx}{l}$

2. The diagram in the figure below shows a uniform half-meter rule suspended at point C. The mass of the rule is



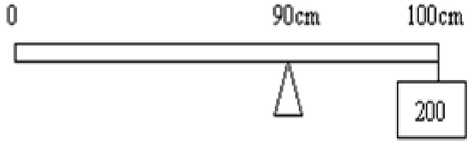
A. 0.020 kg B. 0.025 kg C. 0.100 kg D. 0.125 kg

3. A uniform wooden beam of weight W is pivoted at a distance $\frac{1}{5}$ of its length from the end A and kept in equilibrium by applying a force of 30 N as shown in figure below. The force exerted by the pivot on the beam is



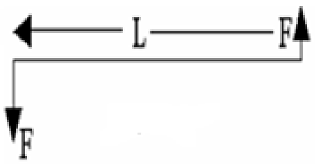
A. 50 B. 40 C. 30 D. 20

4. A uniform rod 100cm long pivoted at the 90 cm mark, balances horizontally when a mass of 200 g is suspended at the 100cm mark as shown in the figure below. The mass of the rod is



A. 40 g B. 50 g C. 400 g D. 800 g

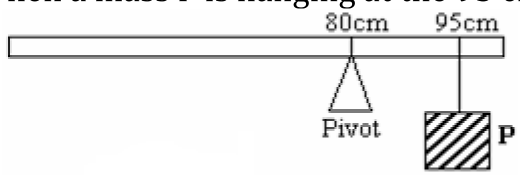
5. Which one of the following statements is true about two equal forces acting on a bar of length l , shown in the figure.



(i) The resultant force on the bar is zero.
(ii) The forces cause a rotational effect.
(iii) The forces act in opposite directions.
(iv) The forces produce different turning effects.

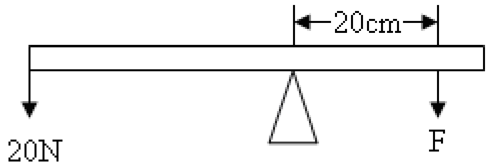
A. (i) only B. (i) and (ii) only C. (i), (ii) and (iii) only D. All

6. The figure below shows a uniform metre rule of mass 0.1kg pivoted at the 80 cm mark. It balances horizontally when a mass P is hanging at the 95 cm mark. Find P.



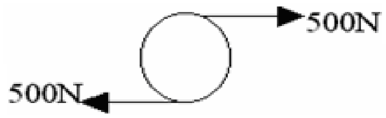
A. 0.08 kg B. 0.2Kg C. 0.4 kg D. 1 kg

7. A uniform metre-rule is pivoted at its centre shown in the figure. If the rule is in equilibrium, find value of F.



A. 4 N B. 33.3 N C. 50 N D. 100 N

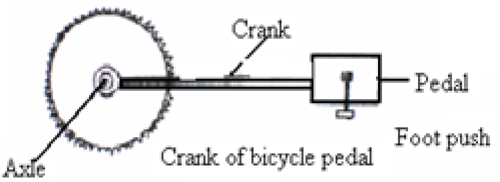
8.



The shaft in an engine is subjected to two parallel but opposite forces of 500N each as shown in the figure. The rotation is best stopped by applying.

A. Two forces of 500 N acting at right angles to each other
B. A single force of 1000 N.
C. Two parallel but opposite forces of 500 N
D. A single force of 250 N.

9. The above figure shows a crank of a bicycle pedal. The force a cyclist exerts on the pedal varies from a minimum to maximum. When does the cyclist exert maximum turning effort?



A. crank makes 90^0 with the foot push B. crank makes 0^0 with the foot push
C. cyclist is climbing a hill D. cyclist is turning a corner

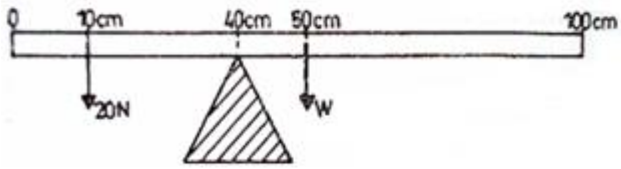
10. Find the weight, w, of a uniform metre rule if a force of 60 N at one end balances it as shown figure.

A. 24 N B. 40 N C. 90 N D. 100 N

SECTIONS B

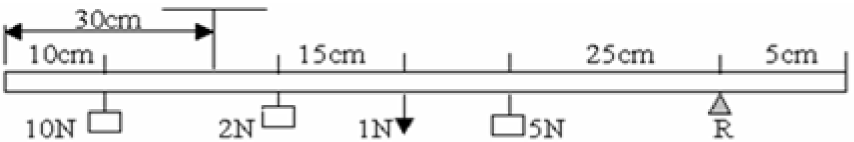
11. (a) (i) Define moment of a force and state its SI unit.
(ii) State the principle of moments.
(iii) State the conditions for a body to be in equilibrium.

(b)



A uniform meter ruler is pivoted at the 40 cm mark as shown in the figure above. The meter ruler is the equilibrium under its weight W and a 20 N force acting at the 10 cm mark. Calculate:
(i) The weight W of the metre rule.
(ii) The reaction at the knife edge.

12. (a) What is meant by centre of gravity?
(b) (i) Describe an experiment to determine the centre of gravity of an irregular lamina.
(ii) Describe how you would measure the mass of a metre rule using a known mass and a knife-edge only.
(c) If the metre is in equilibrium when weights of 10N, 2N and 5N are attached to it as shown in figure below.

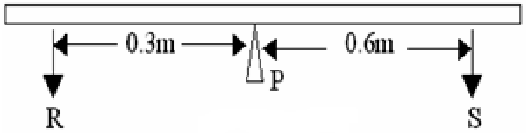


Calculate the:
(i) Tension in the string.
(ii) Normal reaction, R, at the wedge.

14. (a) State
(i) the types of equilibrium.
(ii) the characteristics associated with the types of equilibrium you have stated in 5 (a) above.
(b) (i) Explain giving reasons whether it is advisable to load a bus on the rack.

(ii) Describe how you would design a given structure to have a high stability.

(c) A uniform beam of weight 2.5 N is pivoted at its mid-point P, as shown in figure below.



The beam remains in equilibrium when force R and S act on it. If R is 5N, find the:

(i) Value of S.

(ii) Reaction at the pivot

15. (a) (i) It is easier to open a door by applying a force at the extreme side from the hinge than when the force is applied near the hinge. Explain.

(ii) State three applications of moments.

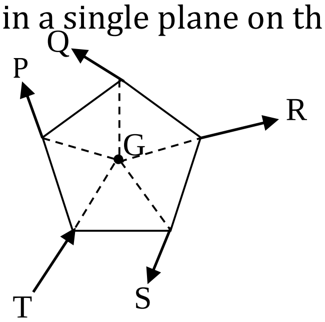
(iii) Describe how you would find the mass of a bar without using a balance if an abject of known mass is available.

(b) (i) What is meant by centre of gravity?

(ii) What are the conditions for equilibrium of a rigid body?

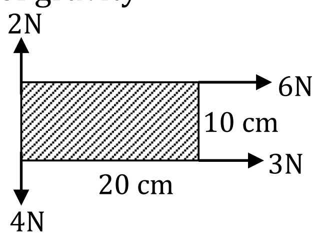
(iii) What is meant by stability of a body?

16. Forces P, Q, R, S and T act in a single plane on the plate shown.



Name which forces have clockwise and which one have anticlockwise moments about. Point

17. For the forces shown below acting on the rectangular uniform plate, find the resultant moment about its centre of gravity.



18. A uniform metre rule AB of weight 2N supports 5N at a point 20cm from end A and 3N at a point 10cm from end B. Find

(i) how far from the mid-point of the rule must a spring balance be fixed for the rule to balance horizontally.

(ii) the reading of the balance

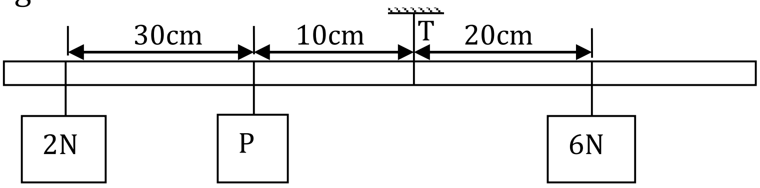
19. Two spring balances P and Q support a uniform metre rule of weight 0.8N at the 10cm mark and 80cm mark respectively. A weight of 0.2N is hung at the 90cm mark.

Find

(a) the readings of the spring balances

(b) where the 0.2N must be shifted to for the balances to read the same.

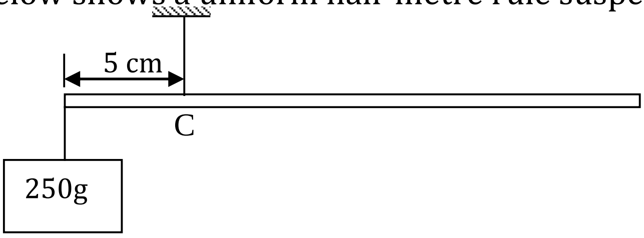
20. A light beam AB is in equilibrium when forces of 2N, P and 6N act on it as shown in the diagram below.



Find the magnitude of P and the tension in the supporting thread T

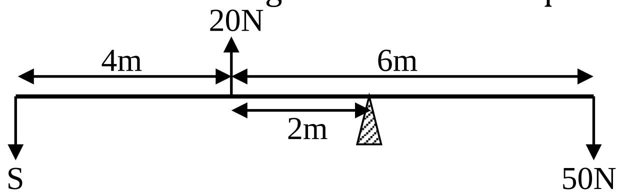
21. A uniform roller of radius 30cm and weight 200N is resting on a horizontal floor and in contact with a 10cm high step. If the step is rough, find the magnitude of a horizontal tangential force, H, that will reduce the reaction at the floor to zero.

22. The diagram below shows a uniform half-metre rule suspended at point C

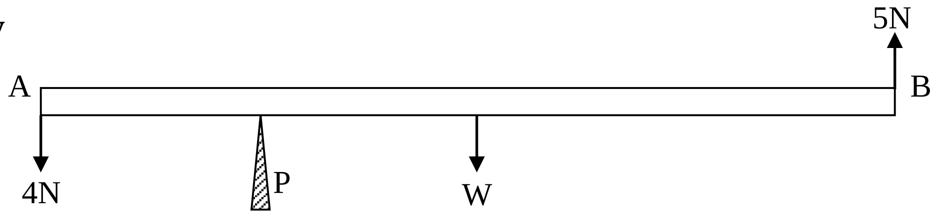


Find the mass of the half-metre rule and the tension in the supporting string

23. If the system shown in the diagram below is in equilibrium, find the value of S.



24. A uniform metal bar of weight W is pivoted at a distance which is $\frac{1}{4}$ of its length from end A and kept in equilibrium by applying forces of 4N and 5N as shown in the diagram below

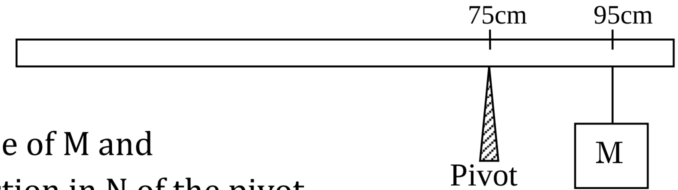


Find

(i) the weight W

(ii) the force exerted by the pivot, P, on the bar.

25. The figure below shows a uniform metre rule of mass 1.2 kg pivoted at the 75-cm mark. It balances horizontally when a mass M is hung at the 95-cm mark.

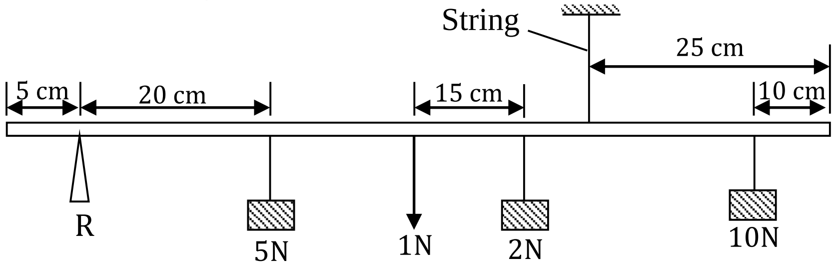


Find:

(i) the value of M and

(ii) the reaction in N of the pivot

26. A uniform metre rule of weight 1N is pivoted on a wedge 5 cm away from one end and suspended by a string 25 cm from the other end.



If the metre rule is in equilibrium when weights of 5N, 2N and 10N are attached to it as shown in the diagram, calculate the tension in the string and the normal reaction, R, at the wedge.

UNEB QUESTIONS ON MOMENTS FROM UCE PHYSICS UNEB (CANTAB) BOOKLET.

2017 P2 no.6, 2016 P1 no.46, 2014 P2 no.1, 2013 P2 no.1, 2012 P1 no.39, 2011 P1 no.14, 2009 P2 no.2, 2008 P1 no.49, 2007 P1 no.17, 2005 P1 no.27, 2002 P1 no.11,42. 2003 P1 no.5, 2004 P1 no.47, 2005 P1 no.27, 2006 P1 no.18,25. 2007 P2 no.5. 2007 P1 no.17. 2000 P1 no.11,19. Section B no.2. 2009 P1 no.5,6.

END.