SRIMAAN

TNPSC CTSE

Combined Technical Services Examination (Non-Interview Posts)

MECHANICAL / MANUFACTURING / PRODUCTION ENGINEERING

UNIT-1- MECHANICS, KINETICS AND DYNAMICS

TNPSC-CTSE STUDY MATERIALS

TNPSC - CTSE

Combined Technical Services Examination (Non-Interview Posts)

MECHANICAL / MANUFACTURING / PRODUCTION ENGINEERING

UNIT I: MECHANICS, KINETICS AND DYNAMICS

Statics of Particles, Equilibrium of Rigid bodies, Mechanism of Deformable Bodies, Properties of Surfaces and Solids, Centroid, Centre of Gravity, Dynamics of Particles, Elements of Rigid Body Dynamics, Basics of Mechanisms, Kinematics of mechanisms, gyroscope, Gears and Gear Trains, Fly Wheels and Governors, Balancing of Rotating and Reciprocating Masses, Friction in Machine Elements, Force Analysis, Balancing, Single Degree Free Vibration, Forced Vibration, mechanisms for Vibration Control, Effect of Damping, Vibration Isolation, Resonance, Critical Speed of Shaft.

FREE BODY DIAGRAM

Free body diagram is a diagram which shows all the forces acting at a rigid body involving

1) self weight, 2) Normal reactions, 3) frictional force, 4) Applied force, 5) External moment applied.

In a rigid body mechanics, the concept of free body diagram is very useful to solve the problems.

Free body diagram for rigid bodies:

In order to draw the FBD for each member of a rigid body follow the instructions below:

- Isolate the object from its surroundings,
- Draw the outline of the object; consider all dimensions and angles,
- Include all forces and couple moments that the surroundings exert on the body. Forces include *loadings*, *support reactions* and *weights*.
- Known forces and moments should be labeled with their proper *magnitudes* and *directions*.
- Magnitudes and direction angles of unknown forces and moments should be represented with *letters*.

FBD is a sketch of the outlined shape of the body, which represents it being isolated from its surroundings.

- It is necessary to show all the forces and couple moments that the surroundings exert on the body so that these effects can be accounted for when equations of equilibrium are applied.
- Free Body Diagram As a general rule, if a support prevents translation of a body in a given direction, then a force is developed on the body in the opposite direction. Similarly, if rotation is prevented, a couple moment is exerted on the body.
- The problem becomes much simple if each body is considered in isolation i.e, separate from the surrounding body or bodies. Such a body which has been so separated or isolated from the surrounding bodies is called as Free Body.

- The sketch showing all the forces and moments acting on the body is called as the free body diagram.

It is a diagram of the body in which the bodies under consideration are freed from all contact surfaces and all the forces acting on it are clearly indicated.

Procedure for Drawing a FBD:

1.Draw outlined shape - Isolate rigid body from its surroundings

2.Show all the forces - Show all the external forces and couple moments. These typically include

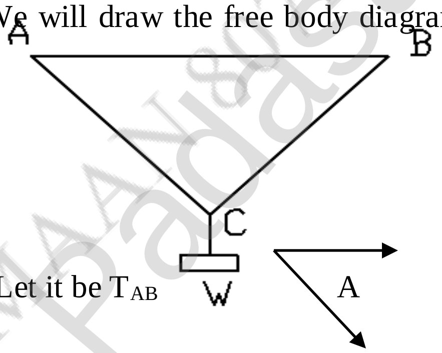
- ❖ Applied Loads
- ❖ Support reactions
- ❖ The weight of the body

3.Identify each force

- ❖ Known forces should be labeled with proper magnitude and direction
- ❖ Letters are used to represent magnitude and directions of unknown forces.

Examples

Consider the diagram shown in fig. We will draw the free body diagram at A, B and C and for the whole structure



The forces acting on A are

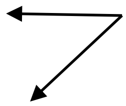
- Tension on string AB, Let it be T_{AB}

A T_{AB}

- Tension on string BC, Let it be T_{AC}

T_{AC}

Free body Diagram at B



The forces acting on B are

- Tension on string BA, Let it be T_{BA}
- Tension on string BC, Let it be T_{BC}

T_{BA} B

TBC

Free body Diagram at C

The forces acting on C are

T_{CA} T_{CB}

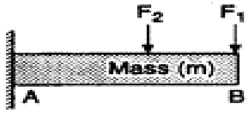
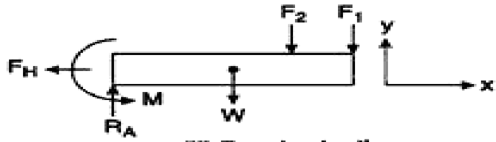
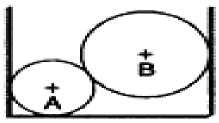
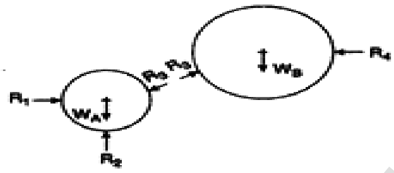
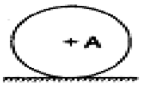
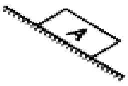
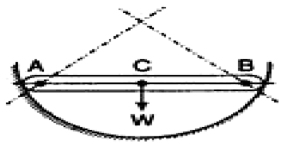
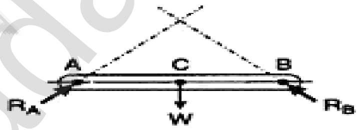
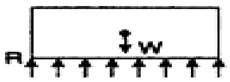
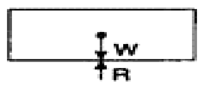
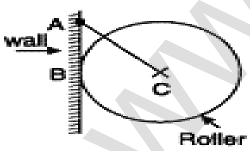
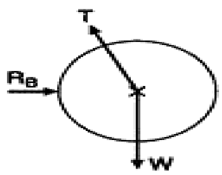
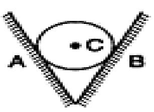
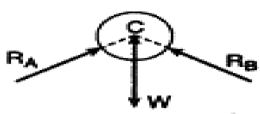
- Tension on string CA, Let it be T_{CA}
- Tension on string BC, Let it be T_{BA}

C

Weight at C, Let it be W_c

W_C

EXAMPLES

Problem	Free Body Diagram
 a(i) Cantilever beam	 a(ii) Free body diagram
 b(i) Two spheres in equilibrium	 b(ii) Free body diagram
 (c) Ball resting on a surface	 c (ii) Free body diagram
 d(i) Frictionless surface	 d(ii) Free body diagram
 e(i) A bar placed in a hemispherical cup	 e(ii) Free body diagram
 f(i) Block on surface	 f(ii) Free body diagram  f(iii) Free body diagram
 g(i) Hanging roller	 g(ii) Free body diagram
 h(i) Sphere in groove	 h(ii) Free body diagram

Worked out examples

An electric light fixture weighting 15 N hangs from a point C, by two strings AC and BC. The string AC is inclined at 60° to the horizontal and BC at 45° to the horizontal as shown in Figure. Using Lami's theorem, or otherwise, determine the forces in the strings AC and BC.

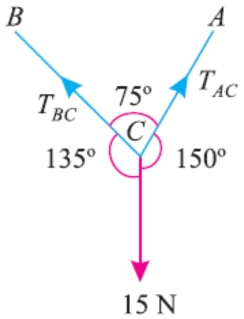
Given:

Weight at C = 15 N

Let TAC = Force in the string AC, and

TBC = Force in the string BC.

The system of forces is shown in Figure.



From the geometry of the figure, we find that angle between TAC and 15 N is 150° and angle between TBC and 15 N is 135°.

$$\therefore \quad \angle ACB = 180° - (45° + 60°) = 75°$$

Applying Lami's equation at C,

$$\frac{15}{\sin 75°} = \frac{T_{AC}}{\sin 135°} = \frac{T_{BC}}{\sin 150°}$$

or
$$\frac{15}{\sin 75°} = \frac{T_{AC}}{\sin 45°} = \frac{T_{BC}}{\sin 30°}$$

$$\therefore \quad T_{AC} = \frac{15 \sin 45°}{\sin 75°} = \frac{15 \times 0.707}{0.9659} = 10.98\,\text{N}$$

and
$$T_{BC} = \frac{15 \sin 30°}{\sin 75°} = \frac{15 \times 0.5}{0.9659} = 7.76\,\text{N}$$

Worked out examples

A smooth circular cylinder of radius 1.5 meter is lying in a triangular groove, one side of which makes 15° angle and the other 40° angle with the horizontal. Find the reactions at the surfaces of contact, if there is no friction and the cylinder weights 100 N.

Solution

Given: Weight of cylinder = 100 N

Let R_A = Reaction at A, and

R_B = Reaction at B.

The smooth cylinder lying in the groove is shown in Fig. (*a*). In order to keep the system in equilibrium, three forces *i.e.* R_A, R_B and weight of cylinder (100 N) must pass through the centre of the cylinder. Moreover, as there is no *friction, the reactions R_A and R_B must be normal to the surfaces as shown in Fig. The system of forces is shown in Fig.

Applying Lami's equation, at O,

$$\frac{R_A}{\sin (180° - 40°)} = \frac{R_B}{\sin (180° - 15°)} = \frac{100}{\sin (15° + 40°)}$$

or
$$\frac{R_A}{\sin 40°} = \frac{R_B}{\sin 15°} = \frac{100}{\sin 55°}$$

$$\therefore \quad R_A = \frac{100 \times \sin 40°}{\sin 55°} = \frac{100 \times 0.6428}{0.8192} = 78.5\,\text{N} \qquad \textbf{Ans.}$$

and
$$R_B = \frac{100 \times \sin 15°}{\sin 55°} = \frac{100 \times 0.2588}{0.8192} = 31.6\,\text{N} \qquad \textbf{Ans.}$$

Worked out examples

A string ABCD, attached to fixed points A and D has two equal weights of 1000 N attached to it at B and C. The weights rest with the portions AB and CD inclined at angles as shown in Figure. Find the tensions in the portions AB, BC and CD of the string, if the inclination of the portion BC with the vertical is 120°.

Solution

Given:

Load at *B* = Load at *C* = 1000 N

For the sake of convenience, let us split up the string *ABCD* into two parts. The system of forces at joints *B* and is shown in Figure (*a*) and (*b*).

Let T_{AB} = Tension in the portion *AB* of the string,

T_{BC} = Tension in the portion *BC* of the string, and

T_{CD} = Tension in the portion *CD* of the string.

Applying Lami's equation at joint *B*,

$$\frac{T_{AB}}{\sin 60^\circ} = \frac{T_{BC}}{\sin 150^\circ} = \frac{1000}{\sin 150^\circ}$$

$$\frac{T_{AB}}{\sin 60^\circ} = \frac{T_{BC}}{\sin 30^\circ} = \frac{1000}{\sin 30^\circ} \quad \ldots[\because \sin(180^\circ - \theta) = \sin\theta]$$

$$\therefore \quad T_{AB} = \frac{1000 \sin 60^\circ}{\sin 30^\circ} = \frac{1000 \times 0.866}{0.5} = 1732\text{ N} \quad \textbf{Ans.}$$

$$T_{BC} = \frac{1000 \sin 30^\circ}{\sin 30^\circ} = 1000\text{ N} \quad \textbf{Ans.}$$

Again applying Lami's equation at joint *C*,

$$\frac{T_{BC}}{\sin 120^\circ} = \frac{T_{CD}}{\sin 120^\circ} = \frac{1000}{\sin 120^\circ}$$

$$\therefore \quad T_{CD} = \frac{1000 \sin 120^\circ}{\sin 120^\circ} = 1000\text{ N} \quad \textbf{Ans.}$$

Worked out examples

Two cylinders P and Q rest in a channel as shown in Figure. The cylinder P has diameter of 100 mm and weighs 200 N, whereas the cylinder Q has diameter of 180 mm and weighs 500 N. If the bottom width of the box is 180 mm, with one side vertical and the other inclined at 60°, determine the reactions at all the four points of contact.

Solution

Given:

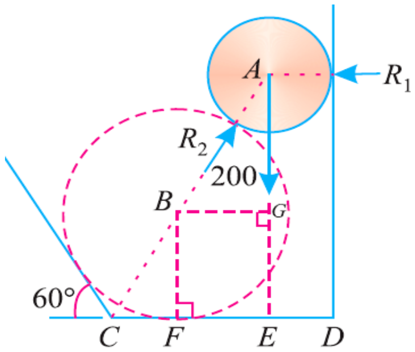
Diameter of cylinder P = 100 mm

Weight of cylinder P = 200 N

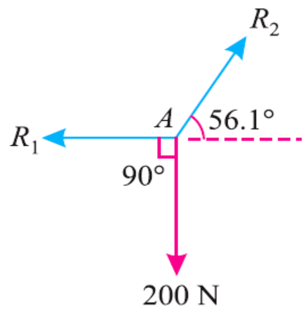
Diameter of cylinder Q = 180 mm

Weight of cylinder Q = 500 N and

Width of channel = 180 mm.



(a) Free body diagram



(b) Force diagram

First of all, consider the equilibrium of the cylinder P. It is in equilibrium under the action of the following three forces which must pass through A i.e., the centre of the cylinder

1. Weight of the cylinder (200 N) acting downwards.
2. Reaction (R_1) of the cylinder P at the vertical side.
3. Reaction (R_2) of the cylinder P at the point of contact with the cylinder Q.

From the geometry of the figure, we find that

$$ED = \text{Radius of cylinder } P = \frac{100}{2} = 50 \text{ mm}$$

Similarly $$BF = \text{Radius of cylinder } Q = \frac{180}{2} = 90 \text{ mm}$$

and $$\angle BCF = 60^\circ$$

$$\therefore \quad CF = BF \cot 60^\circ = 90 \times 0.577 = 52 \text{ mm}$$

$$\therefore \quad FE = BG = 180 - (52 + 50) = 78 \text{ mm}$$

and $$AB = 50 + 90 = 140 \text{ mm}$$

$$\therefore \quad \cos \angle ABG = \frac{BG}{AB} = \frac{78}{140} = 0.5571$$

or $$\angle ABG = 56.1^\circ$$

Applying Lami's equation at A,

$$\frac{R_1}{\sin (90^\circ + 56.1^\circ)} = \frac{R_2}{\sin 90^\circ} = \frac{200}{\sin (180^\circ - 56.1^\circ)}$$

$$\frac{R_1}{\cos 56.1^\circ} = \frac{R_2}{1} = \frac{200}{\sin 56.1^\circ} \qquad R_1 = \frac{200 \cos 56.1^\circ}{\sin 56.1^\circ} = \frac{200 \times 0.5571}{0.830} = 134.2 \text{ N} \quad \textbf{Ans.}$$

$$R_2 = \frac{200}{\sin 56.1^\circ} = \frac{200}{0.8300} = 240.8 \text{ N} \quad \textbf{Ans.}$$

1. Weight of the cylinder Q (500 N) acting downwards.
2. Reaction R_2 equal to 240.8 N of the cylinder P on cylinder Q.
3. Reaction R_3 of the cylinder Q on the inclined surface.
4. Reaction R_4 of the cylinder Q on the base of the channel.

A little consideration will show that the weight of the cylinder Q is acting downwards and the reaction R_4 is acting upwards. Moreover, their lines of action also coincide with each other. ∴ Net downward force = (R_4 – 500) N

Applying Lami's equation at B,

$$\frac{R_3}{\sin(90° + 56.1°)} = \frac{240.8}{\sin 60°} = \frac{R_4 - 500}{\sin(180° + 30° - 56.1°)}$$

$$\frac{R_3}{\cos 56.1°} = \frac{240.8}{\sin 60°} = \frac{R_4 - 500}{\sin 26.1°}$$

$$\therefore \quad R_3 = \frac{240.8 \times \cos 56.1°}{\sin 60°} = \frac{240.8 \times 0.5577}{0.866} = 155 \text{ N} \quad \textbf{Ans.}$$

$$R_4 - 500 = \frac{240.8 \times \sin 26.1°}{\sin 60°} = \frac{240.8 \times 399}{0.866} = 122.3 \text{ N}$$

$$\therefore \quad R_4 = 122.3 + 500 = 622.3 \text{ N} \quad \textbf{Ans.}$$

TYPES OF SUPPORTS AND THEIR REACTIONS

In architectural structures, supports refer to the part of the structure which may help other parts to resist loads.

- ❖ Roller Supports
- ❖ Hinged Supports
- ❖ Fixed Supports

Roller Supports:

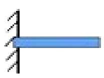
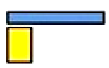
- ➢Roller supports are free to rotate and translate along the surface upon which the roller rests. The surface can be horizontal, vertical, or sloped at any angle.
- ➢The resulting reaction force is always a single force that is perpendicular to, and away from, the surface.
- ➢ Roller supports are commonly located at one end of long bridges.
- ➢This allows the bridge structure to expand and contract with temperature changes.
- ➢The expansion forces could fracture the supports at the banks if the bridge structure was "locked" in place.
- ➢Roller supports can also take the form of rubber bearings, rockers, or a set of _
- ➢A roller support cannot provide resistance to lateral forces. Imagine a structure on roller skates.
- ➢ It would remain in place as long as the structure must only support itself and perhaps a perfectly vertical load
- ➢ As soon as a lateral load of any kind pushes on the structure it will roll away in response to the force.
- ➢ The lateral load could be a shove, a gust of wind or an earthquake.
- ➢ Since most structures are subjected to lateral loads it follows that a building must have other types of support in addition to roller supports.

Hinged Supports:

- A hinged support can resist both vertical and horizontal forces but not a moment.
- They will allow the structural member to rotate, but not to translate in any direction.
- Many connections are assumed to be pinned connections even though they might resist a small amount of moment in reality.
- It is also true that a pinned connection could allow rotation in only one direction; providing resistance to rotation in any other direction.
- It is also used in doors to produce only rotation in a door.
- Hinge support reduces sensitivity to earthquake.

Fixed Support:

- Fixed support can resist vertical and horizontal forces as well as moment since they restrain both rotation and translation.
- They are also known as rigid support. For the stability of a structure there should be one fixed support.
- All three equations of equilibrium can be satisfied.
- A flagpole set into a concrete base is a good example of this kind of support. The representation of fixed supports always includes two forces (horizontal and vertical) and a moment.

S.no	Types of Support	Representation by	Reaction Force	Resisting Load
1.	**Roller Support**		Vertical	Vertical loads
2.	**Pinned Support**		Horizontal and vertical	Vertical and horizontal loads
3.	**Fixed Support**		Horizontal, vertical and moments	All types of loads Horizontal, vertical and Moments
4.	**Simple Support**		Vertical	Vertical loads

Supports and its respective reactions

TYPES OF LOADING

Though there are many types of loading, yet the following are important from the subject point of view:

- Concentrated or point load,
- Uniformly distributed load,
- Uniformly varying load.

CONCENTRATED OR POINT LOAD

A load, acting at a point on a beam is known as a concentrated or a point load

UNIFORMLY VARYING LOAD

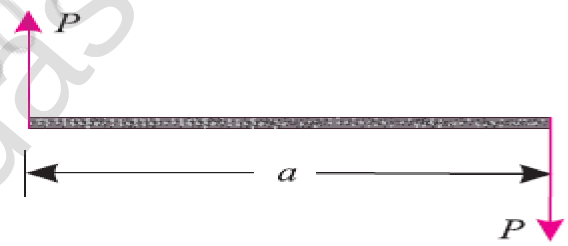
- A load, which is spread over a beam, in such a manner that its extent varies uniformly on each unit length (say from w_1 *per unit length at one support to* w_2 *per unit length at the other support) is* known as *uniformly varying load as shown in Figure.*
- Sometimes, the load varies from zero at one support to w at the other. Such a load is also called triangular load.

MOMENTS AND COUPLES

A pair of two equal and unlike parallel forces (*i.e*. forces equal in magnitude, with lines of action parallel to each other and acting in opposite directions) is known as a couple. As a matter of fact, a couple is unable to produce any translatory motion (*i.e*., motion in a straight line). But it produces a motion of rotation in the body, on which it acts. The simplest example of a couple is the forces applied to the key of a lock, while locking or unlocking it.

Arm of a couple

The perpendicular distance (a), between the lines of action of the two equal and opposite parallel forces, is known as arm of the couple as shown in Figure.



MOMENT OF A COUPLE

The moment of a couple is the product of the force (*i.e*., one of the forces of the two equal and opposite parallel forces) and the arm of the couple.

Mathematically:

Moment of a couple = *P* × *a*

Classification of Couples

The couples may be, broadly, classified into the following two categories, depending upon their direction, in which the couple tends to rotate the body, on which it acts:

1) Clockwise couple, and
2) Anticlockwise couple

A couple, whose tendency is to rotate the body, on which it acts, in a clockwise direction, is known as a **clockwise couple** as shown in Figure (a). Such a couple is also called positive couple.

A couple, whose tendency is to rotate the body, on which it acts, in an anticlockwise direction, is known as an **anticlockwise couple** as shown in Figure (b). Such a couple is also called a negative couple.

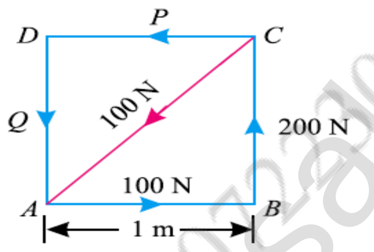
Characteristics of a couple

A couple (whether clockwise or anticlockwise) has the following characteristics:

- The algebraic sum of the forces, constituting the couple, is zero.
- The algebraic sum of the moments of the forces, constituting the couple, about any point is the same, and equal to the moment of the couple itself.
- A couple cannot be balanced by a single force. But it can be balanced only by a couple of opposite sense.
- Any no. of coplanar couples can be reduced to a single couple, whose magnitude will be equal to the algebraic sum of the moments of all the couples.

Worked out example

A square ABCD has forces acting along its sides as shown in Figure. Find the values of P and Q, if the system reduces to a couple. Also find magnitude of the couple, if the side of the square is 1 m.



Solution:

Values of P and Q

We know that if the system reduces to a couple, the resultant force in horizontal and vertical directions must be zero. Resolving the forces horizontally,

$100 - 100 \cos 45° - P = 0$

$\therefore P = 100 - 100 \cos 45°$ N $= 100 - (100 \times 0.707) =$ **29.3 N**

Now resolving the forces vertically,

$200 - 100 \sin 45° - Q = 0$

$\therefore Q = 200 - (100 \times 0.707) =$ **129.3 N**

Magnitude of the couple

We know that moment of the couple is equal to the algebraic sum of the moments about any point.

Therefore moment of the couple (taking moments about *A*)

$= (-200 \times 1) + (-P \times 1) = -200 - (29.3 \times 1)$ N.m $=$ **– 229.3 N.m**

Since the value of moment is negative, therefore the couple is anticlockwise.

VARIGNON's THEOREM

Moment of a force about any point is equal to the sum of the moments of the components of that force about the same point. To prove this theorem, consider the force **R** acting in the plane of the body. The forces **P** and **Q** represent any two nonrectangular components of **R.** The moment of **R** about point O is $\mathbf{M_0} = \mathbf{r} \times \mathbf{R}$

Because **R** = **P**+**Q**, we may write

r × **R** = **r** × (**P**+**Q**)

Using the distributive law for cross products, we have $\mathbf{M_0} = \mathbf{r} \times \mathbf{R} = \mathbf{r} \times \mathbf{P} + \mathbf{r} \times \mathbf{Q}$

This says that the moment of R about O equals the sum of the moments about O of its components P and Q.

This proves the theorem. Varignon's theorem need not be restricted to the case of two components, but it applies equally well to three or more where we take the clockwise moment sense to be positive.

Theorem of Varignon's

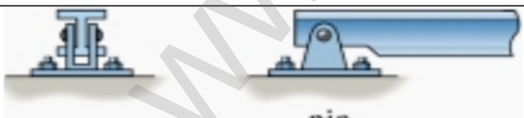
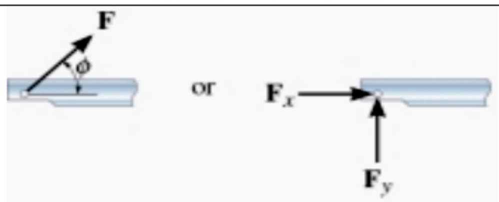
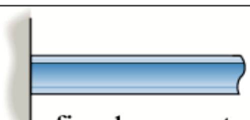
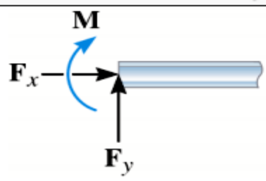
The moment of the resultant of two concurrent forces with respect to a centre in their plane is equal to the algebraic sum of the moments of the components with respect to some centre.

Introduction

In our day-to-day work, we see that whenever we apply a force on a body, it exerts a reaction, *e.g.*, when a ceiling fan is hung from a girder, it is subjected to the following two forces:

1. Weight of the fan, acting downwards, and
2. Reaction on the girder, acting upwards.

A little consideration will show, that as the fan is in equilibrium therefore, the above two forces must be equal and opposite. Similarly, if we consider the equilibrium of a girder supported on the walls, we see that the total weight of the fan and girder is acting through the supports of the girder on the walls. It is thus obvious, that walls must exert equal and upward reactions at the supports to maintain the equilibrium. The upward reactions, offered by the walls, are known as support reactions. As a matter of fact, the support reaction depends upon the type of loading and the support.

Constraints	Type and direction of forces produced
 The connection point on the bar can not move downward.	
 The joint can not move in vertical and horizontal directions.	
 The support prevents translation in vertical and horizontal directions and also rotation, Hence a couple moment is developed on the body in that direction as well.	

Supports and Reactions

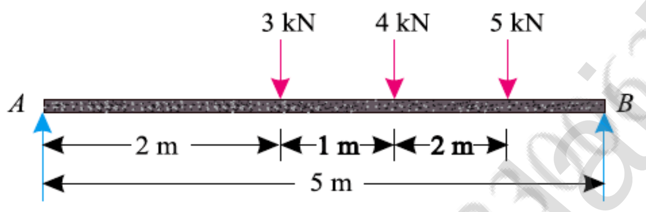
TYPES OF END SUPPORTS OF BEAMS

Though there are many types of supports, for beams and frames, yet the following three types of supports are important from the subject point of view:

1. Simply supported beams,
2. Roller supported beams, and
3. Hinged beams

Worked out examples

A simply supported beam AB of span 5 m is loaded as shown in Figure. Find the reactions at A and B.



Solution:

Given: Span (l) = 5 m

Let R_A = Reaction at A, and

R_B = Reaction at B.

The example may be solved either analytically or graphically. But we shall solve analytically only. We know that anticlockwise moment due to R_B about A

$= R_B \times l = R_B \times 5$

$= 5\ R_B$ kN-m ...(i)

And sum of the clockwise moments about A, $= (3 \times 2) + (4 \times 3) + (5 \times 4)$

$= 38$ kN-m ...(ii)

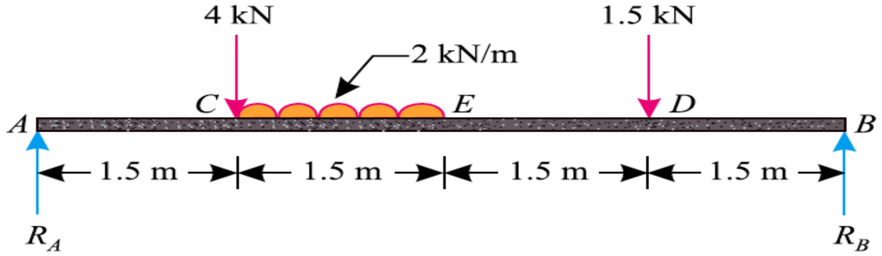
Now equating anticlockwise and clockwise moments given in (i) and (ii), $5\ R_B = 38$

$$R_B = \frac{38}{5} = 7.6 \text{ kN}$$

$$R_A = (3 + 4 + 5) - 7.6 = 4.4 \text{ kN}$$

Worked out examples

A simply supported beam, AB of span 6 m is loaded as shown in Figure. Determine the reactions RA and RB of the beam



Solution:

Given:

Span (l) = 6m

Let R_A = Reaction at A, and

R_B = Reaction at B.

The example may be solved either analytically or graphically. But we shall solve it analytically only.

We know that anticlockwise moment due to the reaction R_B about A.

$= R_B \times l = R_B \times 6 = 6\ R_B$ KN.m ...(i) And sum of the clockwise moments about A

$= (4 \times 1.5) + (2 \times 1.5)\ 2.25 + (1.5 \times 4.5) = 19.5$ KN.m ...(ii)

Equating anticlockwise and clockwise moments given in (i) and (ii),

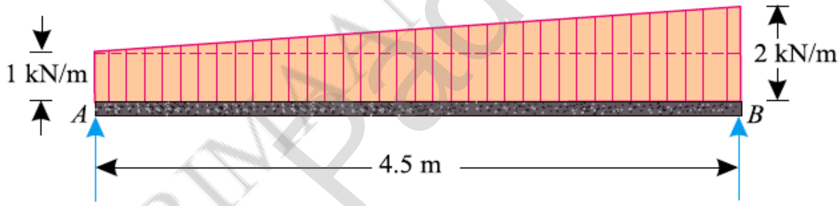
$6\ R_B = 19.5\ R_B = 19.5 / 6$ **R_B = 3.25 KN**

And $R_A = 4 + (2 \times 1.5) + 1.5 - 3.25$

R_A = 5.25 KN

Worked out examples

A simply supported beam AB of span 4.5 m is loaded as shown in Figure. Find the support reactions at A and B.



Solution:

Given: Span (l) = 4.5 m

Let R_A = Reaction at A, and

R_B = Reaction at B.

We know that anticlockwise moment due to R_B about A

$= R_B \times l = R_B \times 4.5 = 4.5\ R_B$ kN-m ...(i)

And sum of clockwise moments due to uniformly varying load about A

$= (1 \times 4.5 \times 2.25) + (2.25 \times 3)$

$= 16.875$ kN-m ...(ii)

Now equating anticlockwise and clockwise moments given in (i) and (ii),

$$4.5\ R_B = 16.875$$

$$R_B = \frac{16.875}{4.5} = 3.75 \text{ kN}$$

$$R_A = [1 \times 4.5] + \left[4.5 \times \frac{0+1}{2}\right] - 3.75 = 3.0 \text{ kN}$$

Equivalent Force Couple System

Every set of forces and moments has an **equivalent force couple system**. This is a single force and pure moment (couple) acting at a single point that is **statically equivalent** to the original set of forces and moments.

Any set of forces on a body can be replaced by a single force and a single couple acting that is statically equivalent to the original set of forces and moments. This set of an equivalent force and a couple is known as the equivalent force couple system.

To find the equivalent force couple system, you simply need to follow the steps below.

1. First, choose a point to take the equivalent force couple system about. Any point will work, but the point you choose will affect the final values you find for the equivalent force couple system. Traditionally this point will either be the center of mass of the body or some connection point for the body.
2. Next resolve all the forces not acting though that point to a force and a couple acting at the point you chose.
3. To find the "force" part of the equivalent force couple system add together all the force vectors. This will give you the magnitude and the direction of the force in the equivalent force couple system.
4. To find the "couple" part of the equivalent force couple system, add together any moment vectors (this could be moments originally acting on the body or moments from the resolution of the forces into forces and couples). This will give you the magnitude and direction of the pure moment (couple) in the equivalent force couple system.

Properties of Surfaces and Solids

INTRODUCTION

An important part of the job of a skilled construction tradesperson involves making measurements based on instructions such as blueprints and then building based on those measurements. Before you begin construction, one of the challenges may be to take those measurements and to make calculations such as perimeter, area and volume. For example, to make a window frame, a glazier must calculate the perimeter around the glass in order to know how much trim will be needed. A reinforcing rod worker would need to calculate the total area of concrete coverage in order to determine the number of reinforcing rods to use.

This skill sheet reviews the steps in finding the perimeter, area and volume of simple two and three dimensional geometric figures, including:

1. Two dimensional figures
2. Finding the perimeter

3. Finding the area
4. Three dimensional figures
5. Finding the surface area
6. Finding the volume

TWO DIMENSIONAL GEOMETRIC FIGURES

A simple, closed, two dimensional (flat) figures with three or more straight sides is called a polygon. Triangles, squares, rectangles, and parallelograms (figures with 2 pair of opposite sides parallel) are all examples of polygons. A circle is also a flat, closed figure but it is a curve, consisting of points that are all the same distance from the centre.

Different ways.

a. Whenever we use measurements to make calculations with geometric figures, all measurements must be in the same linear units.
b. The units might be meters or centimeters, but they can't be a mix of meters and centimeters.

FINDING THE PERIMETER

The **perimeter** (P) of any polygon is the distance around its boundary. Perimeter is found by adding together the lengths of the sides.

Perimeter of a Rectangle

A **rectangle** is a polygon with four 90° (right angles) and with each pair of parallel sides the same length (see Figure 1).This means that we can find the perimeter of a rectangle by adding the lengths of the two long side to the lengths of the two shorter side.

The perimeter of a rectangle equals twice the length (l) added to twice the width (w). The formula is written in two forms:

$P = 2l + 2w$ or $P = 2(l + w)$

where

P is the perimeter, l is the length and w is the width of the rectangle.

Note: When finding perimeter, all units must be the same. If the length is measured in feet and the width in yards, one unit must be changed to that of the other.

Example: Find the perimeter of a house that is 30 m long and 16 m wide.

$P = 2l + 2w$

$= 2(30\text{ m}) + 2(16\text{ m})$

$= 60\text{ m} + 32\text{ m} = 92\text{ m}$

The perimeter is 92 m.

Example: Find the amount of fencing required to close in a space that is 400 yd wide and 1500 ft long.

Known:

l = 1500 ft

w = 400 yd = 1200 ft   400 yd x3 = 1200 ft

Find perimeter (P)

P = 2(l + w)

=2 (1500 ft + 1200 ft)

=2(2700 ft)

=5400 ft

The space will require 5400 ft of fencing.

Perimeter of a Square

A square is a rectangle with all four sides the same length.

To find the perimeter of a square, multiply the length by 4.

Perimeter of a square = 4l

Example: How much baseboard trim is required for a bedroom that is 12 ft square? (If a room is 12 ft square, it measures 12 ft by 12 ft.)

P = 4l

=4(12)

=48 ft

48 ft of trim is required.

Often a space is more complicated than a simple square.

Example: If the bedroom has two door openings, each measuring 36 in. and a closet with two sides measuring 32 in. and a back length of 44 in, how much trim will be required now?

Solution

A diagram can help you with these calculations. When you have to find the perimeter or area and a diagram is not shown, it is helpful to draw one. First convert the 36 in door openings to feet.

36 in 12 = 3 ft

32 in + 32 in + 44 in = 108 in   Add the widths of the closet 108 in ÷ 12 = 9 ft convert the inches to feet

= 48 ft - 2(3 ft) + 9 ft

= 48 ft - 6 ft + 9 ft

= 51 ft

51 ft of trim is needed.

To find the perimeter of an irregular shape, you basically add all the lengths together. Just make sure all the measurements are in the same units.

Finding the Length of an Unknown Side When the Perimeter Is Known

If you know the perimeter of a rectangle and the length of one side, you can find the other side.

1. Manipulate (or rearrange) the variables in the formula for perimeter so the letter for length or width is by itself on the left side.
2. Solve to find the unknown side.

Note: whatever you do to one side of the formula, you need to do to the numbers and letters on the other side.

Example: The perimeter of a window is 144 inches. The height of the window is 42 inches. What is the width?

P = 2l + 2 w

144 = 2(42) + 2w

144 = 84 + 2w

84 + 2w = 144 Reverse the equation.

84 + 2w

2w = 60

w = 30 Write in the units, inches.

The width is 30 inches.

FINDING THE AREA

The **area** of a polygon is the measure of the surface inside the boundary. The units of area are squared units.

Area of a Rectangle

The area of a rectangle is the amount of surface enclosed within its boundaries of **length** and width**.**

Example: The area of a room is the amount of floor space it has.

Area is calculated by multiplying the length of the rectangle times its width.

The formula for area is:

A = lw

Note: When finding the area of a rectangle, the units used to measure the length and the width must be the same. If the length is in meters, the width must also be in meters. If the units are different, one must be converted to the other before you can multiply.

Example: Find the area of a rectangle that is 52 cm long and 44 cm wide. (The units are the same so we don't have to convert.)

Example: Find the area of a space with length 5 m and width 142 cm. We must convert one of the units so both are the same.

Known: l = 5 m w = 142 cm w = 1.42 m

A = lw = 5 m x 1.42 m **A= 7.1 m^2**

Example: Find the floor space of a box that measures 60 inches long by 40 inch wide by 20 inches high. (The information on height is not needed to answer this question.) Known: l = 40 in w = 20 in

Find: A

Use A= lw

A = lw

=60 x 40

=2400 sq in

Example: In order to calculate the quantity of terrazzo tile for a family room you need to calculate the area of the floor. If the family room measures 5 m by 3.5 m, what is the floor space to be covered?

Known: l = 5m
W = 3.5 m Find: A
A = lw

=5 x 3.5

=17.5 m^2

The floor space to be covered is 17.5 m^2

Area of a Square :

The four sides of a square are all the same length. To find the area of a square, square the length. (To square a number, multiply it by itself. Three squared is 3 x 3 = 9.)

Example: Find the area of a square with sides 15 ft long.

Known: l = 15 ft w = 15 ft

Find A :A = lw or l^2 A = 15 ft x 15 ft

A = 225 sq ft

Area of a Parallelogram

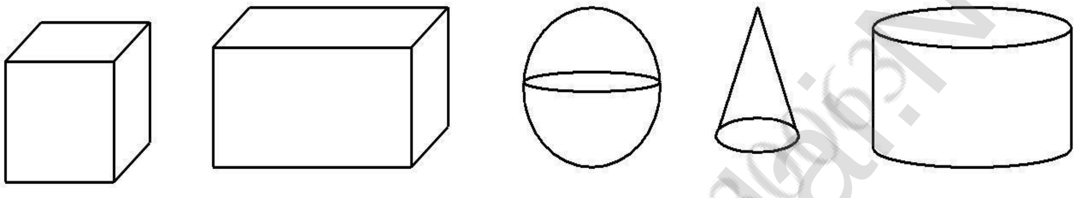
The area of a parallelogram is equal to the altitude or height times the base. The formula is:

A = ab or bh

Example: Find the area of a parallelogram with a height of 12 cm and a base of 15 cm.

THREE DIMENSIONAL FIGURES

A closed, solid geometric figure has three dimensions. It has length, width and height or depth. Some solid figures are the cube, the rectangular solid, the cylinder, the cone and the sphere.



Solid Geometric Figures

SURFACE AREA OF THREE DIMENSIONAL FIGURES

The surface area of a three dimensional figure is the combined areas of all the outside surfaces or faces of the figure. When finding the surface area, all measurements must be in the same linear units. The answer will be in square units.

Finding the surface area of a rectangular solid

To find the total area of the outside surface of a rectangular solid, we have to find the areas of each face of the figure.

1. First find the area of the front surface by multiplying the length times the height.
   - The back surface is the same area, so multiply that answer by 2.
2. Next find the area of one side by multiplying the width times the height.
   - Since the opposite side is the same, multiply the answer by 2.
3. Now find the base by multiplying the length times the width.
   - The top is the same as the base, so multiply that answer by 2 also.

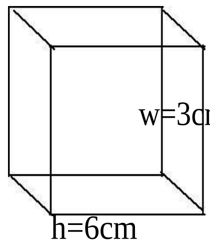
The formula is:

A = 2lh + 2wh + 2lw

or A = 2(lh + wh + lw) or A = 2(lh + wh + lw)

Example: Find the total area of the outside surface of a rectangular solid 5 cm long, 3 cm wide and 6 cm high.

Draw and label the solid



Known:

l = 5 cm

w = 3 cm

h = 6 cm

Find:

Outside surface area of the solid A = 2(lh + wh + lw)

A= 2 (lh + wh + lw)

=2(5cm x 6cm + 3cm x 6cm + 5cm x 3cm)

=2(30 cm^2 + 18 cm^2 + 15 cm^2)

=2(63 cm^2)

=126 cm^2

<u>Finding the surface area of a cube</u>

A cube is made of six identical squares. Each edge is the same length, each side has the same area.

To find the area of a cube:

1. Find the area of one side (l^2) and multiply it by 6. The formula is:

A = 6 (l^2)

Example: Find the total surface area of a cube whose edges measure 10 in.

Known:

Edges of cube = 10 in

Find: A = 6(l)

Surface area of cube

A = 6 (l^2)

= 6(10^2)

= 6(100)

= 600 sq in.

<u>Finding the surface area of a cylinder</u> The surface area of a cylinder consists of the outside curved surface, which is actually a rectangle if it is straightened, and the circular areas at the top and bottom.

To find the surface area of a cylinder:

1. Find the area of each of the top and bottom circles.
2. Find the area of the rectangular side:
3. Add the areas together.

1. **To find the area of the top and bottom:** Use the formula $A = \pi r^2$. A cylinder has two circles (the top and the bottom), so we need to find the two areas, $2\pi r^2$.

Note: $\pi = 3.14$

2. **To find the area of the side of the cylinder (a rectangle):** Multiply the length times the width.

TO BE CONTINUED……

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