Force: This is a vector quantity associated with the pull or push of an object, when in contact with another object.

External Forces are forces acting along the surface boundary of the rigid body, which could be on contact (eg pressure on wall, pull etc), or Non contacting forces such as magnetic, gravitational, electrical etc.

Internal Forces are forces acting within the body, which usually is due to the action of the external forces on the body, or effect of environmental conditions.

Single force system: This is just a single force acting on one body
Several/Multiple force system:
Normal force: This is a force perpendicular to a surface.
Shearing/parallel force: Shear force is a force that acts parallel to the cross-section of a material and tends to cause deformation or failure by sliding one part of the material relative to another

Incline force: An inclined force could be defined as a force that acts at an angle to the horizontal.

Coplanar forces: This refers to a system of forces in which the lines of action of all the forces lie within the same plane.

Collinear forces: Collinear forces are forces that have a common line of action i.e. the line of actionn of forces lie along the same line.

Concurrent forces: These are forces that intersect at a common point.

Non-concurrent forces

MOMENT: Moment is a parameter, which involve the product of distance and a physical quantity (e.g. force), measured with respect to an origin. It describes, how the physical quantity is located or arranged with respect to a reference axis. Example includes, moment of Force, Mass (or Inertia).
Moment of a force $M = Fd\sin\theta$ or $M = Fd$

Rigid bodies: These are solid objects that can be subjected to force application, with little or no significant deformation and changes to its geometrical configuration. It can also be said as a solid body in which deformation is zero or negligibleA rigid body is usually considered as a continuous distribution of mass. The distance between any two given points on a rigid body remains constant in time regardless of external forces exerted on it.

Couple: This is a pair of equal parallel forces acting in opposite direction.

PROPERTIES OF COUPLE

1. Forces are equal: $F_1 = F_2 = F$
2. The resultant forcce is zero $\sum F = 0$
3. Distance between the forces is equal (d)
4. Moment is the product of one of the forces and their distance apart

MOMENT OF A COUPLE

The momenet of a couple is the turning effect of the couple. The moment is also called torque

$M = F_1 d = F_2 d = Fd$

RESULTANT FORCE: A single force that can be used to replace a system of forces.

EQUIVALENT FORCE SYSTEMS: Two systems are said to be equivalent if they havethe same resultant force and resultant moment.

SYSTEM OF CONCURRENT FORCES: In a system of concurrent forces, the forces of that system act at a certain point on the body and [usually the body is in equilibrium]

SYSTEM OF NON-CONCURRENT FORCES: In a system of non-concurrent forces, the forces do not act at a point. Their resultant must be 0 and they usually create a moment (a turning effect).

TYPES OF SUPPORT AND REACTIONS

To ensure, the static equilibrium condition, supports are required to provide the necessary reactive forces that will ensure the rest position of no motion. There are three common type of supports, and are classified by the available reactive forces at the support to prevent motion of the rigid body.

ROLLER SUPPORT: The reaction force is a single linear force perpendicular to the surface. It cannot prevent translation movement in the horizontal or lateral direction, and rotational movement, but can only prevent vertical translations, and capable of resisting normal displacement.
Roller support reactions: Vertical reaction R_y

PINNED/HINGE SUPPORT; the support can exerts force acting in perpendicular directions (ie, horizontal and vertical), which prevents translation movement or relative displacement at member ends, but it cannot prevent rotational movement. It is an improved support to the roller support because of the available 2 reactive forces.
Reactions for hinge support: R_x and R_y

FIXED SUPPORT; It can provides both force and moment resistance, and exerts forces acting in any direction that prevents translational movements in the horizontal and vertical direction, as well as the rotational movement of the member. It is a rigid

type of support, that holds the member firmly than the roller or hinge support, because of the increase resistance action.
Reactions for a fixed support are: R_x, R_y and M

STATICALLY DETERMINATE BEAMS

The distance between two supports is known as the beam span, while a beam with a fixed support is called cantilever beam, since it posses only one rigid support.
Statically determinate beams are beams whose reactions and internatinal forces and/or moments can be calculated using the 3 equilibrium equations.

$$\sum F_y = 0$$

$$\sum F_x = 0$$

$$\sum M = 0$$

Statically Indeterminate Structures are structures in which the reaction forces and the internal forces CAN NOT be calculated by the 3 Equilibrium equations. When trying to solve the 3 Equilibrium equations for an indeterminate structure, you will experience that you have 4 or more Unknowns when we only have three equations ofor the solution.

FORCES ACTING ON BEAMS

Forces acting on beams are classified as follows,

External forces – comprise the static equilibrium action of the applied force and the reactive forces.

Applied Forces – the forces applied or expected on the structure for design purpose

Reactive Forces – the support reactions

Internal Forces - the forces acting within the beam, as a result of the static equilibrium condition. The internal forces are established through the path of the force line-of-action within

the member. The internal force must be lower than the internal resistive force (or energy) of the member (ie, beam) for adequate and safe force transmission unto the supports.

The internal forces in Beams, are **Shear forces**, **bending Moments** and **Axial forces**, which occur due to the resistance of beam-component to applied loading.

TYPES OF LOADS

1. Point load: A load that acts on a single point of a structure.
2. Distributed load: A load that acts on a continuous area of a structure. Distributed load is further divided into two types.
- Uniformly Distributed load (UDL): A uniformly distributed load (UDL) is a load that is evenly distributed over a given area or length
- Uniformly Varying load (Non-uniformly distributed load).

Generally, for distributed loads, the total force is the area of the shape and the poin of action is the centroid of the shape.

3. Coupled load: A load that consists of two equal and opposite forces acting on a structure.
4. Dead load: A load that consists of the self-weight of the structure and its permanent components.
5. Live load: A load that consists of moving or variable loads like people, furniture, temporary stores, etc.
6. Wind load: A load that acts horizontally on the surfaces of the walls, roofs, and pitched roofs of the structure.
7. Snow load: A load that acts on the roofs of the structure due to the accumulation of snow.
8. Earthquake load: A load that acts on the structure due to the ground motion caused by an earthquake.
9. Other load: A load that includes any other force or weight acting on the structure, such as impact load, thermal load, settlement load, etc.

Equivalent Load for Distributed Loading systems

An equivalent load is the resultant load of the distributed load, acting at the centroid of the load distribution. Hence it is a concentrated load equal in magnitude to the distributed load and acting at the centroid.

Equivalent load magnitude = $\int f(x)\delta x$ = area under the integral curve, defined by the limits of the distributed load.

Thus for uniformly distributed load, $E = w x$,
where w is the intensity and w is the width of the udl. (ie area of a rectangle), and the centroid is that of rectangle.

Also for triangular loading $E = ½kx$ = area of triangle, and positioned at the centroid of triangle.

A force is anything that causes motion and is defined by its line of action

For equilibrium,

$\sum F_x = 0$

$\sum F_y = 0$

$\sum M = 0$

$M = Fd\sin\theta$

Moment of a force can be defined as the product of the force and the perpendicular distance

After getting the reactions, move on to showing the shear force diagram.It usually starts at zero and ends at zero to show that it is in equilibrium

QUESTIONS TO SOLVE FOR CEG

1a. List three force system and state their characteristics with an example.

1b. State Hooke’s Law and Principle of Superposition. Write the equations governing them

1c. Explain the material behaviour under load and indicate all important points

d. Discuss, the relationship between ultimate load, factor of safety and safe load

Solution:

1a
i. Concurrent Force System:

Characteristics:
- All forces in a concurrent force system have their lines of action intersecting at a single point.
- The resultant force of a concurrent system can be determined by finding the vector sum of all individual forces.

Example:

Consider the forces acting on a pin-jointed structure (like a truss). The forces at each joint intersect at a common point, making it a concurrent force system.

ii. Non-Concurrent Force System:

Characteristics:
In a non-concurrent force system, the lines of action of forces do not intersect at a single point.
Additional considerations such as moments and couples are needed to determine the overall effect on the object.

Example:
Forces acting on a beam or a truss structure form a non-concurrent force system.

iii. Coplanar Force System:
Characteristics:

a. Coplanar force systems consist of forces lying in the same plane.
b. These forces can be either concurrent or non-concurrent.

Example:
Forces acting along a straight rod or a cable subjected to tension or compression form a coplanar force system.