3. TYPES of FORCES

Forces can be of various types depending on how they arise.

Gravity - the force acting on a body because of its being attracted to the centre of the earth.
It is proportional to its mass, and is considered to act through a body's centre of mass (or centre of gravity).

F = mg where **m** is in kg
g is the gravitational constant (9.81 m/s^2)
F is in Newtons

Pull forces - these act 'away' from their point of application. Note that rope, chains, strings or any flexible cable can <u>only</u> apply a pull force. They cause <u>tension</u> in the cable.

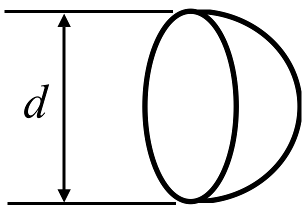
Push forces - these act 'towards' their point of application. Members that apply a push force are often called <u>struts</u>.
Push forces cause <u>compression</u> in the strut. Struts are usually 'solid' and resist bending (as opposed to being flexible like a cable). Note that struts can also apply a pull force, in which case they are often called <u>ties</u>.

Forces owing to pressure - a fluid at a pressure acting on a surface exerts a total force on the surface.

F = pressure x area where **pressure** is in N/m^2
area is in m^2

If the surface is curved the 'projected' area is used.

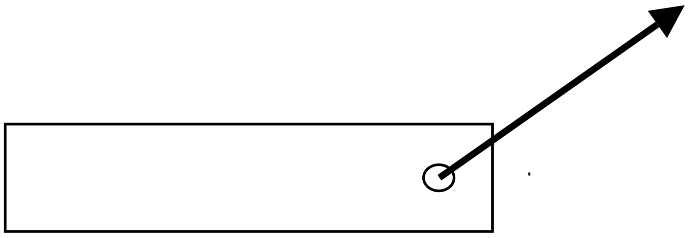
$$\text{Force on the curved surface} = p \times \frac{\pi}{4} d^2$$



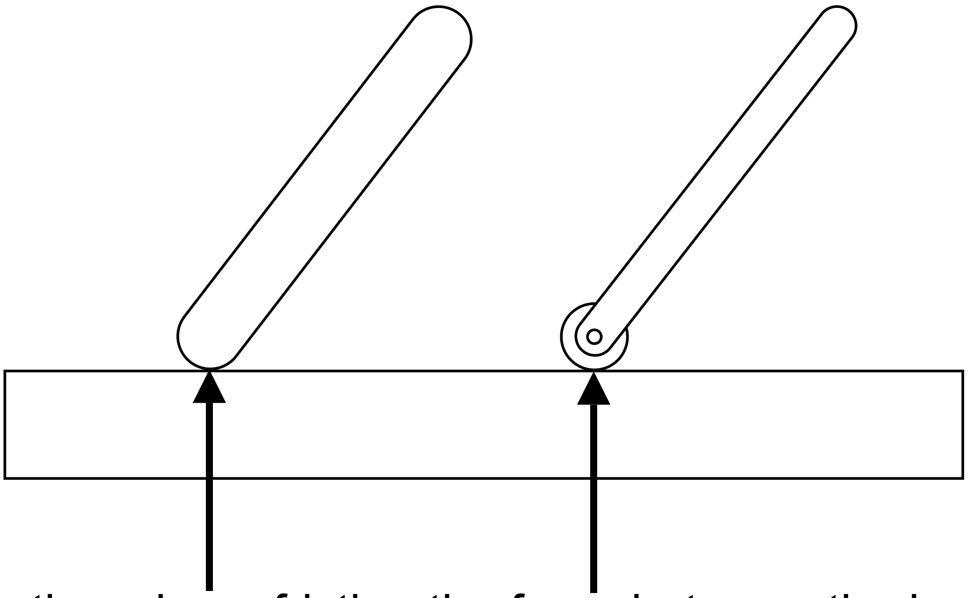
TYPES OF CONTACT BETWEEN BODIES and the FORCES which arise because of them.

In general, wherever and whenever two or more elements (or bodies) interact (or touch) each other, each will exert a force on the other.
The nature of the force depends on the nature of the interaction.

We have, for example, already noted that a flexible cable can ONLY exert a tension force in the direction of the cable itself.

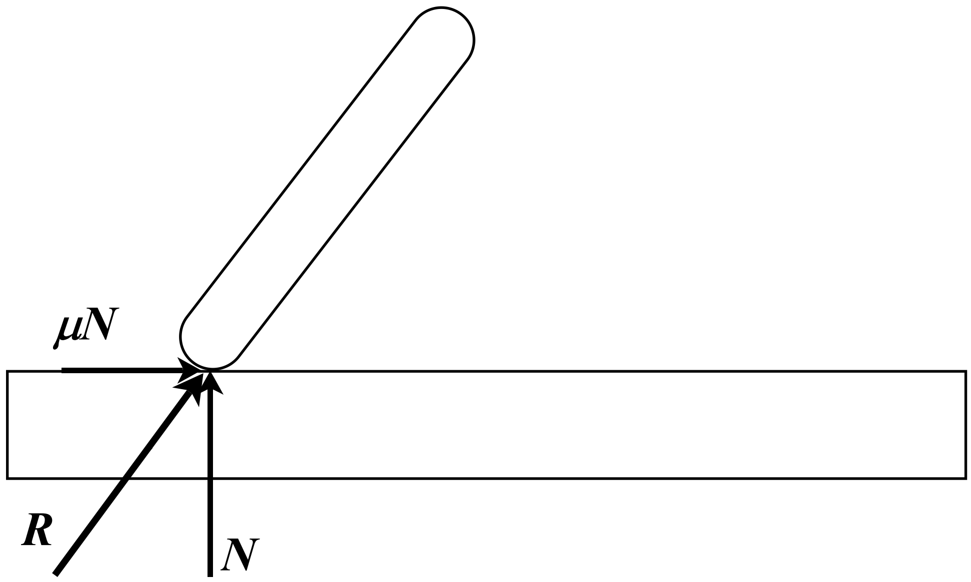


If there is no friction between two bodies the interaction between them is described as <u>smooth.</u> In practice this is never true, but where friction is very low such as between two polished and lubricated surfaces, or where there is rolling contact, it is very close to true.



Because there is no friction the force between the bodies can ONLY be at right angles (or normal) to the interface at which they touch. Note that there is an equal and opposite force applying to the rectangular block.

If there <u>is</u> friction between two bodies the interaction between them is described as <u>rough.</u>

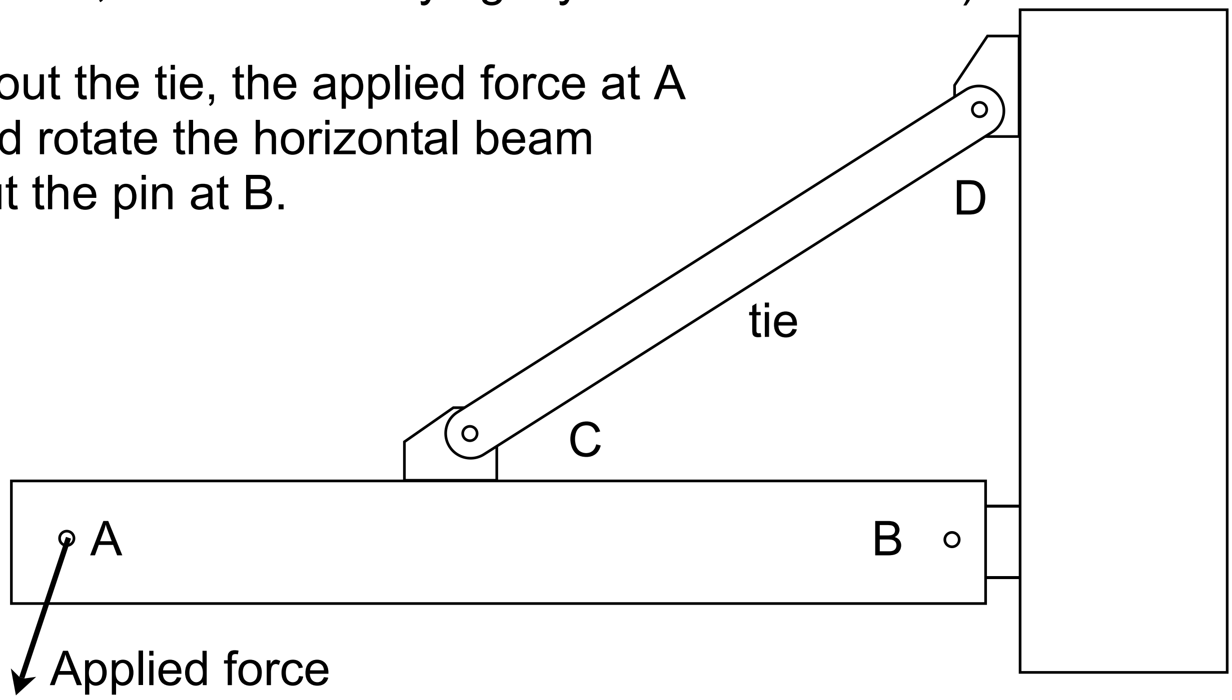


Because there is friction the resultant force **R** between the bodies will be at an angle to the interface.

Pin joints

If an interaction is <u>pin jointed</u>, there is no friction at the pin. This means that the pin can only transmit a force and has no ability to resist rotation.
(The pin could resist rotation if it became 'seized' because of corrosion, or if it was very tightly bolted or welded.)

Without the tie, the applied force at A would rotate the horizontal beam about the pin at B.

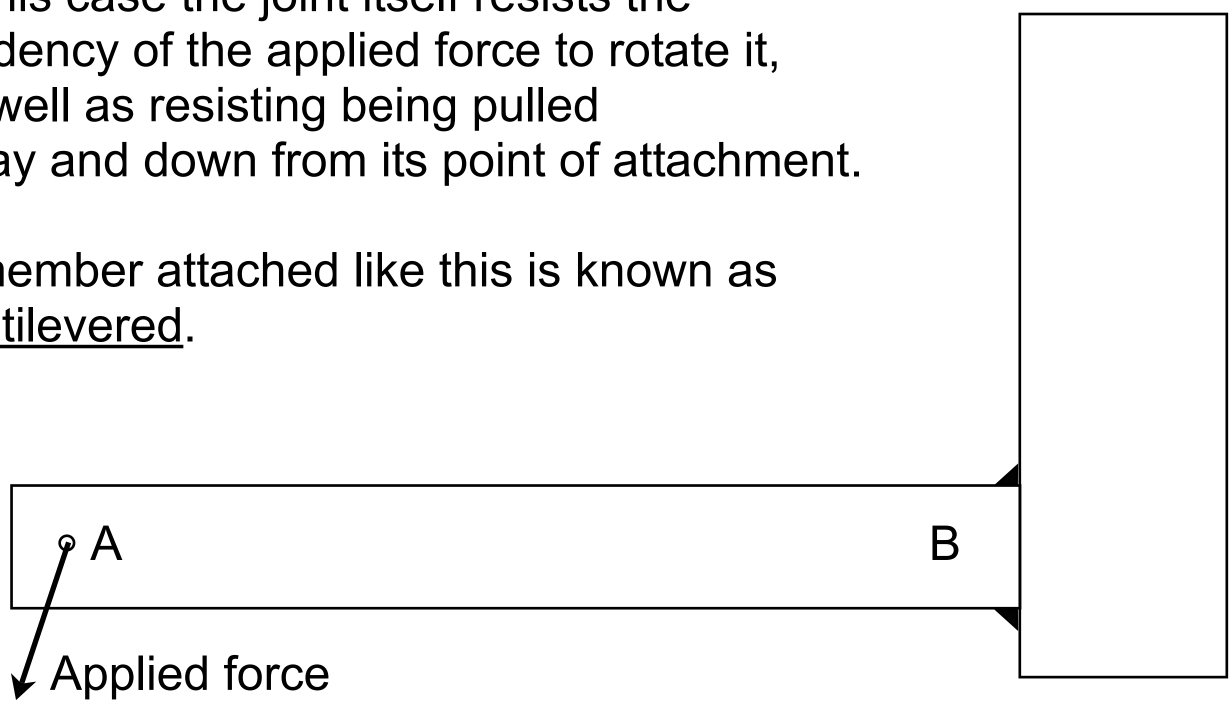


Rigid Joints

If an interaction is described as rigid, (or solid) it can resist rotation as well as transmitting forces. Such a joint or interaction may also be described as 'built in' or 'encastré' (embedded).

In this case the joint itself resists the tendency of the applied force to rotate it, as well as resisting being pulled away and down from its point of attachment.

A member attached like this is known as cantilevered.



Bodies or Components in Equilibrium

If an object, or a component which is part of a structure or mechanism, is acted on by a number of different forces but is not accelerating in either a translational or rotational sense, then it is described as being in equilibrium under the action of forces.

Most of the objects around us (including ourselves) are in equilibrium. The force of gravity pulls us 'down', the reaction of the floor or chair or the ground pushes us 'up'.
We are not accelerating either upwards or downward so we are in equilibrium under the action of these two forces.
i.e. their net effect is zero.

This principle can applied to all bodies in equilibrium under the action of forces.

If a body is not accelerating translationally* and if it is not accelerating rotationally†, then:

The vector sum of the forces acting on the body must sum to zero, and the vector sum of the moments of the forces about any point must also sum to zero.

* it may be moving in a straight line with constant velocity.
† it may be rotating with a constant rotational speed.

Mathematically this is written:

$$\sum \vec{F} = 0 \quad \text{and} \quad \sum \vec{\mathrm{M}} = 0$$

It follows that if we know some of the forces acting on a body and we also know that it is in equilibrium, we can use this principle to find the forces we don't know.

If we split each force into its vertical and horizontal components we can also write this as:

$$\sum F_x = 0 \quad \text{and} \quad \sum F_y = 0 \quad \text{and} \quad \sum \vec{\mathrm{M}} = 0$$

We can take moments about any point we like, but in practice if we choose this point sensibly it can help us use the principle more easily.

FREE BODY DIAGRAMS (FBD's)

In order to apply the principle of equilibrium to an object or component or body, we need to be able to identify all of the forces (& torques if there are any) acting on it.

We normally do this by separating (or freeing) the body from its context, and then drawing on it all of the forces (& torques) that we know are acting on it. This is known as a free body diagram.

This is an important skill and will take practice.

We tend to think of objects or bodies as being held in place by their being attached to, or resting on, other objects or bodies. In actual fact they are held in place by the forces which these bodies apply to them. Even if they are continuous bodies (or welded together), each part applies forces and/or moments to the adjacent parts and we can separate them as such.

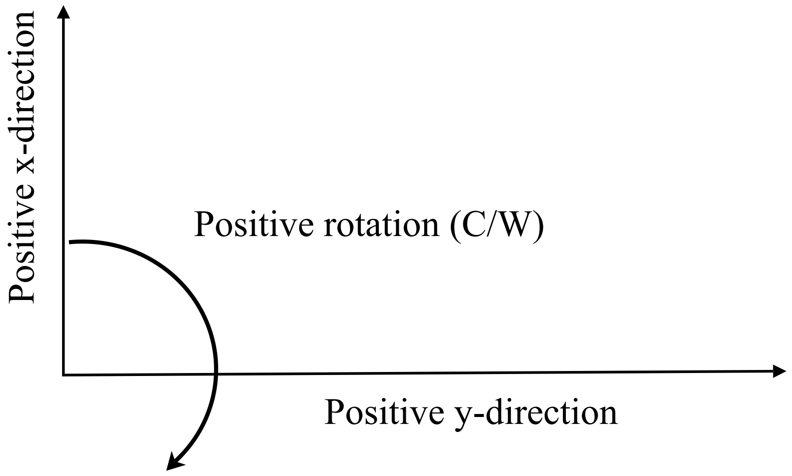
In general, a force and/or a moment will be present at every point where two (or more) bodies interact or join.

Examples of free body diagrams (FBD's) follow:

Procedure for solving equilibrium problems

1. Identify the body or object or component which is in equilibrium.

2. Designate a sign convention defining which directions and rotations are positive and negative.



3. Draw the FBD showing **ALL** the forces and moments.
[Some forces will be known in both magnitude and direction, some in direction only, for others neither may be known. Draw them all in.]

4. Apply the conditions of equilibrium in order to find the unknown forces and moments.

Hint: Problems can often be readily solved by initially applying the condition $\Sigma \mathbf{M}=\mathbf{0}$.
If the point about which moments are taken is chosen to be on the line of action of a first unknown force, then it may leave only a second unknown force which can be found using $\Sigma \mathbf{M}=\mathbf{0}$.
The first unknown force can then be found by applying the condition $\Sigma \mathbf{F}=\mathbf{0}$.

Note:
1. If there are only two forces acting on a body in equilibrium, they must be equal and opposite.
2. If there are only three forces acting on a body in equilibrium, their lines of action must all go through a common point.
If they didn't then there would be a net moment on the body and hence it would not be in equilibrium.