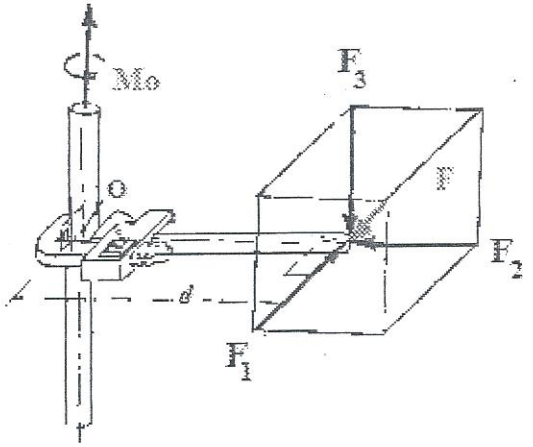
Mechanics 4

Coplanar Force Systems

A force can provide the effect of turning as axis if it does not act parallel to the axis or have a line of action which passes through the axis. For example, consider force **F** in figure, which acts on the handle of the wrench and is located a distance *d* form the vertical axis of the pipe. If the resolved into three perpendicular components, it is seen that only $\mathbf{F}_1$ tends to rotate the wrench and pipe about the axis. Obviously, $\mathbf{F}_2$ intersects the axis and $\mathbf{F}_3$ is parallel to it. This rotational effect of $\mathbf{F}_1$ is called the *moment of a force* or simply the *moment* $\mathbf{M}_O$.



In the more general case, the force **F** and point O lie in a shaded plane as shown in the figure. The moment $\mathbf{M}_O$ about a point O, or about an axis passing through O and perpendicular to the plane, is a vector quantity since it has a specified magnitude and direction and adds according to the parallelogram law.

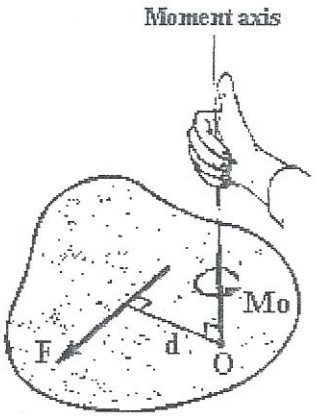
Magnitude. The magnitude of $\mathbf{M}_O$ is

$$M_O = F\,d$$

where *d* is referred to as the *moment arm* or perpendicular distance from the axis at point O to the line of action of the force. Units of moment magnitude consist of force dimes distance, e.g., N . m or lb . ft.

Direction. The direction of $\mathbf{M}_O$ will be specified by suing the "right-hand rule." The fingers of the right hand are curled such that they follow the sense of rotation as caused by the force acting about the axis; thumb then points in the direction of the moment vector along the moment

axis, which is perpendicular to the shaded plane containing **F** and *d*. By the definition, the moment $\mathbf{M}_O$ can be considered as a ***sliding vector*** and acts at any point along the moment axis.

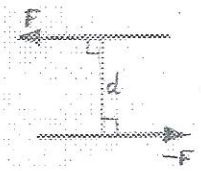


Principle of Moments.

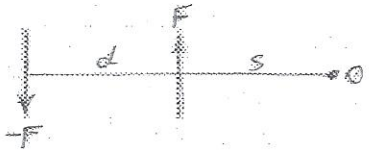
"The moment of a force about a point is equal to the sum of the moments of the force's components about the point".

Moment of a Couple- Scalar Formulation

A couple is defined as two parallel forces that have the same magnitude, opposite direction, and are separated by a perpendicular distance *d*. Since the resultant force of the two forces composing the couple is zero, the only effect of a couple is to produce a rotation or tendency of rotation in a specified direction.



The moment produced by a couple, called a *couple moment*, is equivalent to sum of the moments of both couple forces, computed about any arbitrary point. For example, consider the couple moment in the figure.



If the moments of the two forces are computed about point O, then assuming positive moments are directed out of the page, i.e., counterclockwise by the right-hand rule, we have

$$+M_C = -F s + F (d + s)$$

$$= F d$$

This result indicates that the couple moment is a ***free vector*** since $\mathbf{M}_C$ depends only on the distance between the forces and not on the location s of the point O. Consequently, a couple is unlike the moment of a force, which required a definite point (or axis) about which it is computed.

Magnitude

The moment o a couple $\mathbf{M}_C$ is defined as having a magnitude of

$$M_C = F d$$

where F is the magnitude of one of the forces and d is the perpendicular distance or moment arm between the forces.

Direction

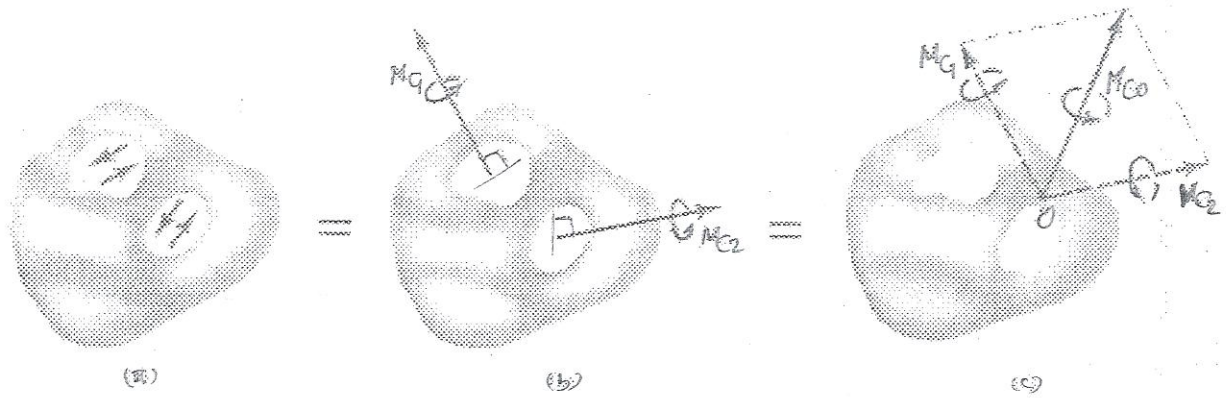
The direction of the couple moment is determined by the right-hand rule. In all cases, $\mathbf{M}_C$ acts perpendicular to the plane containing the two forces.

Equivalent Couple

Two couples are said to be equivalent if they produce the same moment. Since the moment produced by a couple is always perpendicular to the plane containing the couple forces, it is therefore necessary that the forces of equal couples lie either in the same plane or in planes that are parallel to one another.

Resultant couple

Since couple moments are free vectors, they may be applied at any point P on a body and added vectorially.

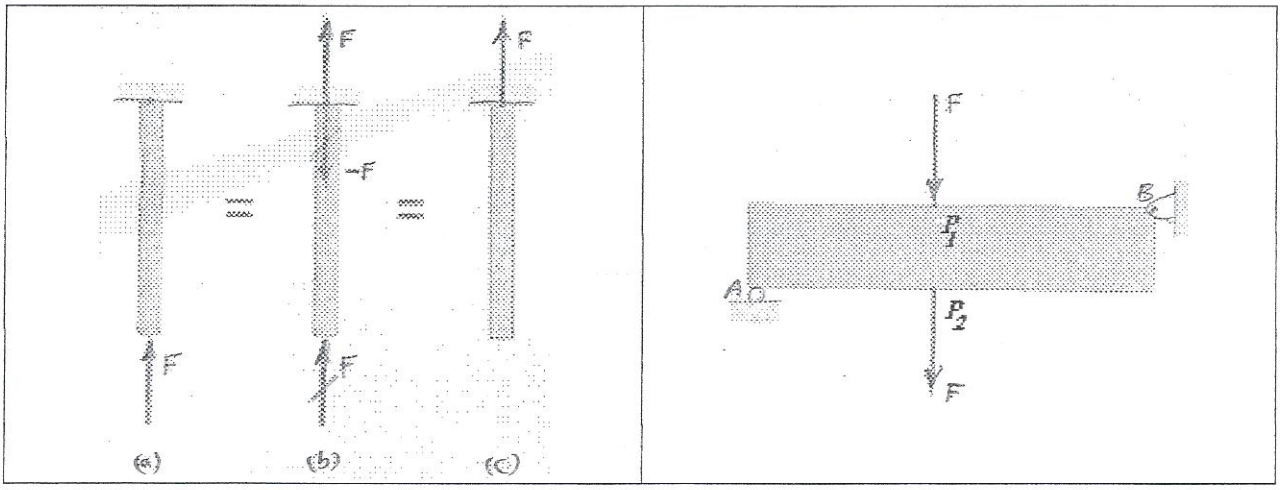


The Principle of Transmissibility

The principle of transmissibility is an important concept often used in mechanics for studying the action of a force on a rigid body.

The external effects on a rigid body remain unchanged when a force, acting in a given point on the body, is applied to another point lying on the line of action of the force.

In another word, the force can be considered as a ***sliding vector.***



Resolution of a Force into a Force and a Couple

Many problems in statics deal with a rigid body subjected to a system of forces. In order to understand fully what external effects these forces have on the body, it is best to reduce the system to simplest resultant possible.

The foregoing concept regarding the movement of a force to any point on a body may be summarized by the following two statements:

1- If force is to be moved t a point *O* located on its line of action, by principle of transmissibility, simply move the force to the point.

2- If the force is to be moved to a point *O* that is not located on its line of action, an equivalent system is maintained when the force is moved to point *O* and a couple moment is placed on the body. The magnitude and direction of the couple moment are determined by the finding the moment of the force about point *O*.