TIMES AND EQUIVALENT SYSTEMS III

2.5 moment of a force with respect to a shaft and a couple time:
In mechanics, a couple is a system of forces with a resultant (a.k.a. net or sum) moment but no resultant force. A better term is force couple or pure moment. Its effect is to create rotation without translation, or more generally without any acceleration of the centre of mass. In rigid body mechanics, force couples are free vectors, meaning their effects on a body are independent of the point of application.

The resultant moment of a couple is called a torque. This is not to be confused with the term torque as it is used in physics, where it is merely a synonym of moment. Instead, torque is a special case of moment. Torque has special properties that moment does not have, in particular the property of being independent of reference point.

Simple couple

Definition- A couple is a pair of forces, equal in magnitude, oppositely directed, and displaced by perpendicular distance or moment.

The simplest kind of couple consists of two equal and opposite forces whose lines of action do not coincide. This is called a "simple couple". The forces have a turning effect or moment called a torque about an axis which is normal (perpendicular) to the plane of the forces. The SI unit for the torque of the couple is newton metre.

If the two forces are **F** and **−F**, then the magnitude of the torque is given by the following formula:

$$\tau = Fd$$

where

τ is the torque
F is the magnitude of one of the forces
d is the perpendicular distance between the forces, sometimes called the *arm* of the couple

The magnitude of the torque is always equal to $F\,d$, with the direction of the torque given by the unit vector $\hat{e}$, which is perpendicular to the plane containing the two forces. When **d** is taken as a vector between the points of action of the forces, then the couple is the cross product of **d** and **F**. I.e.,

$$\tau = \mathbf{d} \times \mathbf{F}.$$

Independence of reference point

The moment of a force is only defined with respect to a certain point *P* (it is said to be the "moment about *P*"), and in general when *P* is changed, the moment changes. However, the moment (torque) of a *couple* is *independent* of the reference point *P*: Any point will give the same moment. In other words, a torque vector, unlike any other moment vector, is a "free vector". (This fact is called *Varignon's Second Moment Theorem*.)

Forces and couples

A force F applied to a rigid body at a distance d from the center of mass has the same effect as the same force applied directly to the center of mass and a couple Cℓ = Fd. The couple produces an angular acceleration of the rigid body at right angles to the plane of the couple. The force at the center of mass accelerates the body in the direction of the force without change in orientation. The general theorems are:

A single force acting at any point O′ of a rigid body can be replaced by an equal and parallel force F acting at any given point O and a couple with forces parallel to F whose moment is M = Fd, d being the separation of O and O′. Conversely, a couple and a force in the plane of the couple can be replaced by a single force, appropriately located.

Any couple can be replaced by another in the same plane of the same direction and moment, having any desired force or any desired arm.

Couples are very important in mechanical engineering and the physical sciences. A few examples are:

- The forces exerted by one's hand on a screw-driver
- The forces exerted by the tip of a screw-driver on the head of a screw
- Drag forces acting on a spinning propeller
- Forces on an electric dipole in a uniform electric field.
- The reaction control system on a spacecraft.

In a liquid crystal it is the rotation of an optic axis called the director that produces the functionality of these compounds. As Jerald Ericksen explained

At first glance, it may seem that it is optics or electronics which is involved, rather than mechanics. Actually, the changes in optical behavior, etc. are associated with changes in orientation. In turn, these are produced by couples. Very roughly, it is similar to bending a wire, by applying couples.

2.6 equivalent systems of forces and equivalent systems of vectors:

In general it is not feasible to consider bodies as point objects while considering the effect of forces. For tackling practical problems we need to take the dimension of bodies into account.

A body which doesn't deform by the application of force is termed as rigid bodies. Actual structures and machines, however, are never absolutely rigid and deform under the loads to which they are subjected

In the following unit we will be dealing with principle of transmissibility of forces , moment of a force about a point ,moment of a force about an axis ,moment of a couple ,addition of couple moments , resolution of a force into a force couple system ,resolution of a system of force into a force couple system , resolution of a system of forces into wrench .

Principle of transmissibility, sliding vectors

Let's assume that a force F acts at on the rigid body. Let's say that the force F' has the same magnitude and direction and acts along the same line of action as that of F .Principle of transmissibility states that without altering the equations of equilibrium or motion and provided the above conditions are satisfied , the force F can be equivalently replaced by force F'. Therefore the force acting on the rigid body can be termed as a sliding vector, which is allowed to slide along its line of action.

Effect of a force not only depends on its magnitude and direction, but also depends on its point of application. Force is responsible for translational as well as rotational motion of a object.

Within vectors there are couple systems: A couple system consist of two parallel forces equal in magnitude but opposite in direction. The above diagram shows the exact situation. Since the algebraic sum of force vectors is zero, the force will produce no translational effect on the body. But the body will tend to rotate in effect of the two forces. The derived result for moment due to couple turns out to be: $MO = r \times F$ Where F is the force vector and r is the vector joining points of application of two forces. We also get, $|MO|=|F||r| \sin \alpha = |F|d$, where α is the angle between the two vectors , where 'd' is the perpendicular distance between two parallel force vectors(as shown in figure above). Points to note:

Since the results turns out to be independent of origin the same result would have been obtained if the origin was shifted. Therefore couple moment is a free vector which can be applied at any point. Rotation is anti-clockwise if moment vector points outward to the plane of forces and vice versa.

Since couple moments are vector quantities, it is derivable that individual couple moments acting upon a rigid body can be added up vectorialy.
Two sets of couples producing same couple moment in the same direction are said to be equivalent couples. Couple moments are represented as vectors pointing outwards or inwards as the case maybe

In the systems sciences the term system equivalence is the notion that a parameter or component of a system behaves in a similar way as a parameter or component of a different system. Similarity means that mathematically the parameters/components will be indistinguishable from each other. Equivalence can be very useful in understanding how complex systems work.

Overview
Examples of equivalent systems are first- and second-order (in the independent variable) translational, electrical, torsional, fluidic, and caloric systems.

Equivalent systems are mostly used to change large and expensive mechanical, thermal, and fluid systems into a simple, cheaper electrical system. Then the electrical system can be analyzed to validate that the system dynamics will work as designed. This is a preliminary inexpensive way for engineers to test that their complex system performs the way they are expecting.

This testing is necessary when designing new complex systems that have many components. Businesses do not want to spend millions of dollars on a system that does not perform the way that they were expecting. Using the equivalent system technique, engineers can verify and prove to the business that the system will work. This lowers the risk factor that the business is taking on the project.

Discussion

The system equivalence method may be used to describe systems of two types: "vibrational" systems (which are thus described - approximately - by harmonic oscillation) and "translational" systems (which deal with "flows"). These are not mutually exclusive; a system may have features of both. Similarities also exist; the two systems can often be analysed by the methods of Euler, Lagrange and Hamilton, so that in both cases the energy is quadratic in the relevant degree(s) of freedom, provided they are linear.

Vibrational systems are often described by some sort of wave (partial differential) equation, or oscillator (ordinary differential) equation. Furthermore, these sorts of systems follow the capacitor or spring analogy, in the sense that the dominant degree of freedom in the energy is the generalized position. In more physical language, these systems are predominantly characterised by their potential energy. This often works for solids, or (linearized) undulatory systems near equilibrium.

On the other hand, flow systems may be easier described by the hydraulic analogy or the diffusion equation. For example, Ohm's law was said to be inspired by Fourier's law (as well as the work of C.-L. Navier). Other laws include Fick's laws of diffusion and generalized transport problems. The most important idea is the flux, or rate of transfer of some important physical quantity considered (like electric or magnetic fluxes). In these sorts of systems, the energy is dominated by the derivative of the generalized position (generalized velocity). In physics parlance, these systems tend to be kinetic energy-dominated. Field theories, in particular electromagnetism, draw heavily from the hydraulic analogy.