Inductance

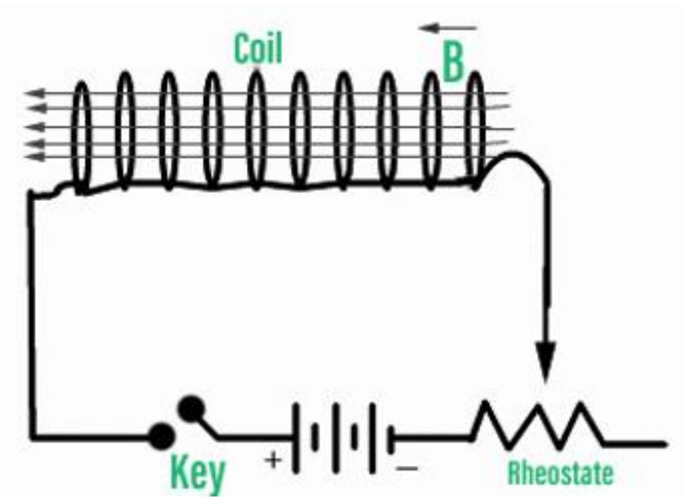
Electromagnetic induction, often known as induction, is a process in which a conductor is placed in a certain position and the magnetic field varies or remains stationary as the conductor moves. A voltage or EMF (Electromotive Force) is created across the electrical conductor as a result of this.
Michael Faraday discovered this electromagnetic induction rule. He built up a leading wire similar to the diagram below, which he linked to a device that measured the voltage across the circuit. The voltage in the circuit is measured when a bar magnet passes through the device. The significance of this is that it is a method of creating electrical energy in a circuit by employing magnetic fields rather than batteries. The principle of electromagnetic induction is used by equipment such as generators, transformers, and motors.

Inductor and Inductance

A resistor is an electrical component that opposes and regulates the flow of electricity. Resistance is the ability of a conductor to resist current flow. While a capacitor is a device that briefly stores charge and energy, capacitance refers to a capacitor's ability to store energy.

An **inductor** is nothing more than a coil. To make a coil, a conducting wire is tightly coiled. It will produce its constant magnetic field when a direct current is supplied through it. Instead, if we use an alternating current or a continually changing source, the current flowing through the coil will change. It will induce its emf in the opposite direction to the supply due to shifting magnetic flux. This is referred to as inductance. So, inductance refers to a conductor's ability to resist changing current, but an inductor is an electrical device that does so.

Self-Inductance



The battery will produce a constant current in the coil if the rheostat resistance is kept constant. A continuous magnetic field will be induced inside the coil due to the constant current provided to it.

As the resistance of the rheostat is changed, the current flowing through the coil will also change. Since the current is changing, they will be a changing magnetic flux inside the coil. Due to the effect of changing magnetic flux, an emf will be induced inside this coil, trying to oppose the magnetic flux. Hence, due to the induced emf, the direction of current induced will be opposite to that of current supplied.

The current flowing in the coil determines the flux induced in the coil:

$$\phi \propto I$$

As a result, the flux-to-current ratio must be constant, as this will define the coil's capacity to create magnetic flux in relation to the current provided. Self-inductance is the name for this constant (L).

$$L=\phi/I$$

An inductor is the result of this process. If there are N turns on the coil, then

$$L=N\phi/I$$

$$N\phi=LI$$

Differentiating this equation in terms of time on both sides

$$d/dt\ (N\phi)=d/dt\ (LI)$$
$$N\ d\phi/dt=L\ dI/dt$$

But, according to Faraday's law of EMI, emf induced in a coil is,

$$\varepsilon=-N\ d\phi/dt$$

The negative sign indicates that the induced emf is in the opposite direction of the present rate of change.

$$\varepsilon=-L\ dI/dt$$
$$L=-\varepsilon\ /dI/dt$$

As a result, self-inductance may alternatively be defined as the emf induced per unit rate of current change within the coil minus the emf induced per unit rate of current change.

The SI unit of inductance is: **Wb/A=Vs/A=Henry (H)**

Magnetic Energy Stored in an Inductor

An inductor stores energy in the form of a magnetic field because it may induce its emf. Let us calculate the magnetic energy stored in an inductor using the following equation:

The rate of work done for a current I in the circuit may be represented as:

$$dW/dt=\varepsilon\ I$$

Substituting the following equation for the coil's induced emf:

$$dW/dt=-L\ dI/dt\ I$$
$$dW=-LI\ dI$$

Integrating both sides of this equation:

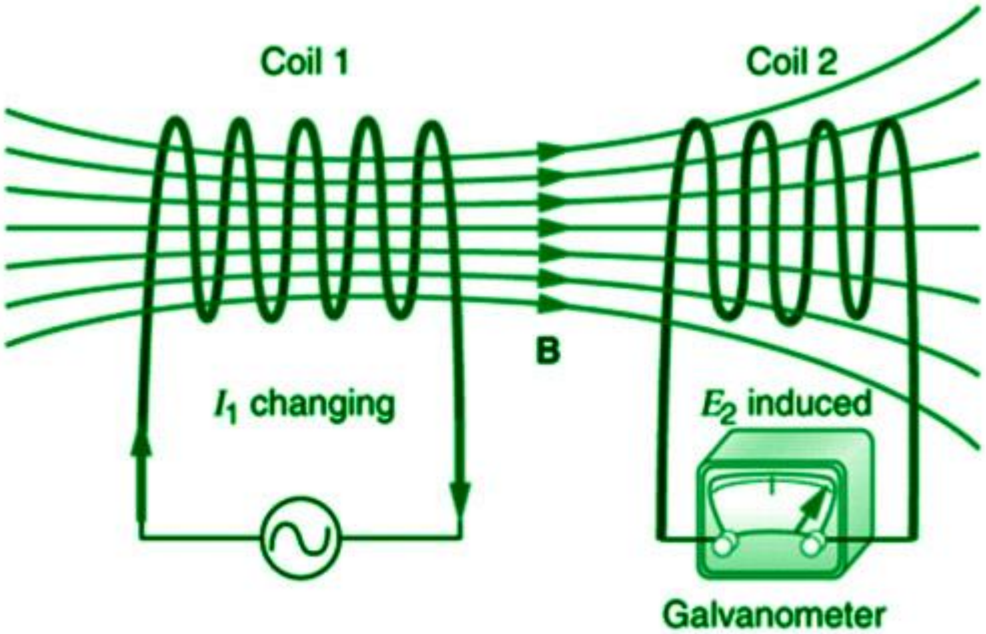
$$\int dW=\int -LI\ dI$$
$$W=-1/2\ LI^2$$

Work done is the inverse of energy stored. So, if the inductor's initial magnetic energy is zero, the energy stored in the inductor is:

$$U = 1/2\ LI^2$$

Mutual Inductance

Self-inductance is similar to mutual inductance. Instead, it consists of only two coils. One of them is given current, while the other is given emf.



Coil-1 is linked to a supply and a rheostat in the diagram, whereas coil-2 is connected to a galvanometer. Coil-1 will begin to flow with a fluctuating current. It will be induced with a shifting magnetic flux as a result of this. Because the coils are so near together, the changing magnetic flux will be connected to the other. Because the magnetic flux through coil-2 is constantly changing with respect to time, an emf opposing this magnetic flux will be induced in coil-2, causing a current to flow in the opposite direction of the provided current. As a consequence, we may claim that the current delivered in coil-1 causes the flux via coil-2.

$$\phi_2 \propto I_1$$

As a result, the flux through coil-2 and the current delivered in coil-1 will have a constant ratio. Mutual inductance in coil-2 owing to coil-1 is the name for this constant.

$$M_{21}=\phi_2 / I_1$$

We may define mutual inductance between two coils as the ratio of flux associated with one coil per unit current delivered in the other coil using the following equation.

$$\phi_2=M_{21}\ I_1$$

Taking the preceding equation and differentiating it with regard to time

$$d/dt(\phi_2)=d/dt(M_{21}\ I_1)$$

Using Faraday's law of EMI

$$\varepsilon_2=-M_{21}\ dI_1/dt$$
$$M_{21}=-\varepsilon_2/dI_1/dt$$

As a result, mutual inductance may alternatively be defined as the emf induced per unit rate of change in current in the inducing coil minus the emf induced per unit rate of change in current in the inducing coil.

Linear Momentum and Angular Momentum

Momentum is a property of moving objects that have mass. Often, we talk about two types of momenta: linear and angular. The **main difference** between linear momentum and angular momentum is that **linear momentum is a property of an object which is in motion with respect to a reference point** (i.e. any object changing its position with respect to the reference point) **while angular momentum is a property of objects which are not only changing their position but also the direction of their position with respect to a reference point** (i.e. they are not moving in a straight line).

What is Linear Momentum

Linear momentum of an object is the product of the object's mass and velocity. Linear momentum is a **vector quantity**, and the direction of momentum is taken to be the direction of the object's velocity. If the mass of the object is m and the velocity of the object is $\vec{v}$, then the linear momentum $\vec{p}$ is given by:

$$\vec{p} = m\vec{v}$$

Linear momentum is a conserved quantity: the total linear momentum of particles in a system is conserved if no external forces act on the system. If there is a resultant external force on the system, then the momentum changes, so that the rate of change of momentum is equal to the resultant external force:

$$\sum \vec{F} = \frac{\mathrm{d}\vec{p}}{\mathrm{d}t}$$

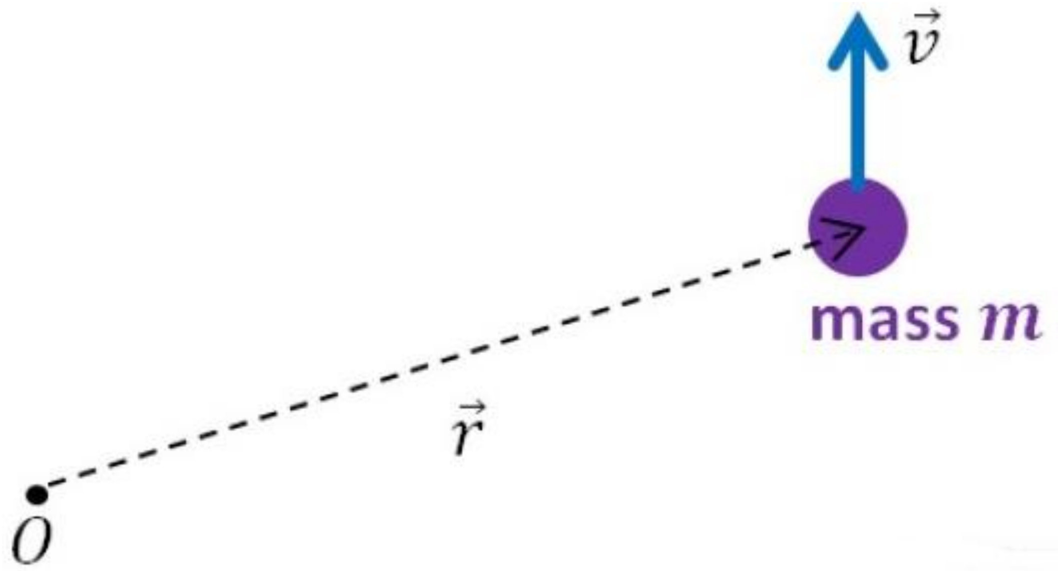
The SI **units for measuring linear momentum** is kg m s^{-1}.

What is Angular Momentum

For an object with mass m moving at a velocity $\vec{v}$, the angular momentum $\vec{L}$ with respect to a reference point is defined using the cross product as:

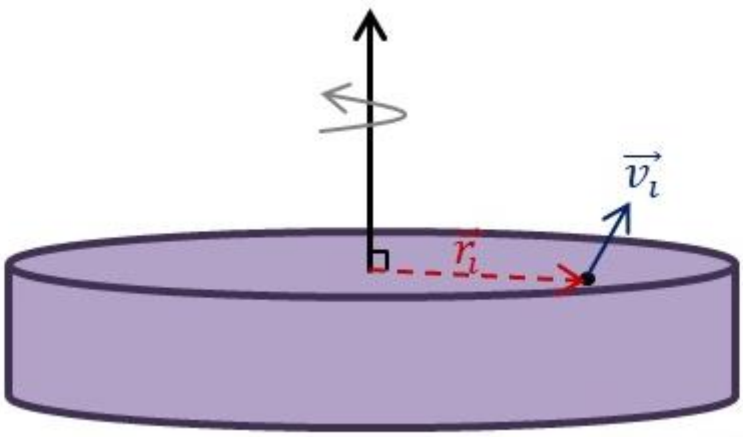
$$\vec{L} = \vec{r} \times m\vec{v} = \vec{r} \times \vec{p}$$

where $\vec{r}$ is the position vector of the object that describes the object's position with respect to the reference point. The units for measuring angular momentum is kg m^2 s^{-1}. Since angular momentum is defined in terms of a cross product, the direction of the angular momentum vector is taken to be in a direction perpendicular to both the particle's position vector $\vec{r}$ and its velocity vector $\vec{v}$.



Using the definition above, we can come up with an expression for calculating angular velocity of a rigid body which is rotating about an axis that is at right angles to the plane in which the particles are rotating. The rigid body is made of many particles, and the sum of angular momenta of all the particles gives the total angular momentum of the rigid body. Then, in terms of the masses and velocities of individual particles, we can write the total angular momentum as:

$$L = \sum_i r_i m_i v_i$$



Note that since the axis of rotation is perpendicular to the plane in which the particles are rotating, the cross product boils down to a simple multiplication. We can write the linear velocity v of the particles in terms of their angular velocities (ω):

$$L = \sum_i {r_i}^2 m_i \omega_i$$

Since the object is rigid, all particles rotate in unison. This means that the angular velocity for all particles is common. Then,

$$L = \sum_i \left({r_i}^2 m_i\right) \omega$$

The quantity $L = \sum_i \left(r_i{}^2 m_i\right)$ is the object's $,I$. Then, we can write the angular momentum in the object as:

$$L = I\omega$$

Like linear momentum, angular momentum is also a conserved quantity. The angular momentum of a system of particles is conserved if no external torques act on the system. If there is a resultant external torque, the angular momentum changes so that the resultant torque is equal to the rate of change of angular momentum of the object:

$$\sum \vec{\tau} = \frac{\mathrm{d}\vec{L}}{\mathrm{d}t}$$

Difference Between Linear Momentum and Angular Momentum

Type of Motion

Linear momentum is a property of objects which are changing their position with respect to a reference point.
Angular momentum is a property of objects which are changing the angle of their position vector with respect to a reference point.

Conservation

Linear momentum of a system of particles is conserved so long as there is no resultant force on the system.
Angular momentum of a system of particles is conserved so long as there is no resultant torque on the system.

Rate of Change

The rate of change of **linear momentum** of a system of particles is equal to the resultant force acting on the system.
The rate of change of **angular momentum** of a system of particles is equal to the resultant torque acting on the system.

SI Units

Linear Momentum is measured in units of kg m^2 s^{-1}.
Angular momentum is measured in units of kg m^2 s^{-1}.