scoresvideosPhysical quantity of circuits related to magnetic flux, voltage and currentFlux linkageCommon symbols , {\displaystyle \Psi ,\lambda } SIunitweber (Wb)Other unitsmaxwellIn SIbase unitskgm2s2A1DimensionM L2 T2 I1In electrical engineering, the term flux linkage is used to define the interaction of a multi-turn inductor with the magnetic flux as described by the Faraday's law of induction.[clarification needed] Since the contributions of all turns in the coil add up, in the over-simplified situation of the same flux {\displaystyle \Phi } passing through all the turns, the flux linkage (also known as flux linked) is = n {\displaystyle \Psi =n\Phi } , where n {\displaystyle n} is the number of turns.[1] The physical limitations of the coil and the configuration of the magnetic field cause some flux to leak between the turns of the coil, forming the leakage flux[2] and reducing the linkage. The flux linkage is measured in webers (Wb), like the flux itself.In a typical application, the term "flux linkage" is used when the flux is created by the electric current flowing through the coil itself. Per Hopkinson's law, = n M M F R {\displaystyle \Psi =n{\frac {MMF}{R}}} , where MMF is the magnetomotive force and R is the total reluctance of the coil. Since M M F = n I {\displaystyle {MMF}=nI} , where I is the current, the equation can be rewritten as = L I {\displaystyle \Psi =LI} , where L = n 2 R {\displaystyle L={\frac {n^{2}}{R}}} is called the inductance.[2] Since the electrical reactance of an inductor X = L = 2 f L {\displaystyle X=\omega L=2\pi fL} , where f is the AC frequency, X = I {\displaystyle X=\omega {\frac {\Psi }{I}}} .This section includes a list of references, related reading, or external links, but its sources remain unclear because it lacks inline citations. Please help improve this section by introducing more precise citations. (January 2021) (Learn how and when to remove this message)In circuit theory, flux linkage is a property of a two-terminal element. It is an extension rather than an equivalent of magnetic flux and is defined as a time integral[citation needed] = E d t , {\displaystyle \Psi =\int {\mathcal {E}}\,dt,} where E {\displaystyle {\mathcal {E}}} is the voltage across the device, or the potential difference between the two terminals. This definition can also be written in differential form as a rate E = d d t . {\displaystyle {\mathcal {E}}={\frac {d\Psi }{dt}}.} The magnitude of the electromotive force (EMF) generated in a conductor forming a closed loop is proportional to the rate of change of the total magnetic flux passing through the loop (Faraday's law of induction). Thus, for a typical inductance (a coil of conducting wire), the flux linkage is equivalent to magnetic flux, which is the total magnetic field passing through the surface (i.e., normal to that surface) formed by a closed conducting loop coil and is determined by the number of turns in the coil and the magnetic field, i.e., = S B d S , {\displaystyle \Psi =\int \limits _{S}{\vec {B}}\cdot d{\vec {S}},} where B {\displaystyle {\vec {B}}} is the magnetic flux density, or magnetic flux per unit area at a given point in space.The simplest example of such a system is a single circular coil of conductive wire immersed in a magnetic field, in which case the flux linkage is simply the flux passing through the loop.The flux {\displaystyle \Phi } through the surface delimited by a coil turn exists independently of the presence of the coil. Furthermore, in a thought experiment with a coil of N {\displaystyle N} turns, where each turn forms a loop with exactly the same boundary, each turn will "link" the "same" (identically, not merely the same quantity) flux {\displaystyle \Phi } , all for a total flux linkage of = N {\displaystyle \Psi =N\Phi } . The distinction relies heavily on intuition, and the term "flux linkage" is used mainly in engineering disciplines. Theoretically, the case of a multi-turn induction coil is explained and treated perfectly rigorously with Riemann surfaces: what is called "flux linkage" in engineering is simply the flux passing through the Riemann surface bounded by the coil's turns, hence no particularly useful distinction between flux and "linkage".Due to the equivalence of flux linkage and total magnetic flux in the case of inductance, it is popularly accepted that the flux linkage is simply an alternative term for total flux, used for convenience in engineering applications. Nevertheless, this is not true, especially for the case of memristor, which is also referred to as the fourth fundamental circuit element. For a memristor, the electric field in the element is not as negligible as for the case of inductance, so the flux linkage is no longer equivalent to magnetic flux. In addition, for a memristor, the energy related to the flux linkage is dissipated in the form of Joule heating, instead of being stored in magnetic field, as done in the case of an inductance.[citation needed]^ Bhatnagar 1997, p.301.^ a b Veltman, Pulle & de Doncker 2016, p.19.L. O. Chua, "Memristor The Missing Circuit Element", IEEE Trans. Circuit Theory, vol. CT_18, no. 5, pp.507519, 1971.Bhatnagar, V.P. (1997). A Complete Course in ISC Physics. Pitambar Publishing. ISBN978-81-209-0202-2. Retrieved 2023-07-03.Veltman, A.; Pulle, D.W.J.; de Doncker, R.W. (2016). Fundamentals of Electrical Drives. Power Systems. Springer International Publishing. ISBN978-3-319-29409-4. Retrieved 2023-07-03.Retrieved from " Magnetic flux density, which measures the strength of a magnetic field B, or B-field, in teslas (T). diagram of a magnetic field indicates the density of magnetic flux by showing the number of flux lines per square metre (Figure 1).Figure 1 Magnetic flux line passing through a surface areaMagnetic flux is defined as magnetic flux density B (in teslas, T) multiplied by the area of the surface, A (in m), where the area A is perpendicular to the lines of flux (Figure 1).Written as an equation, this becomes[math] \text{Flux} = B A [/math]Magnetic flux is measured in webers (Wb), where 1 Wb equals 1 T m.When an area is not perpendicular to the lines of magnetic flux, as shown in Figure 1, the flux through the area A is now the component.[math] \Phi = B A \cos \theta [/math]Magnetic flux has several applications in physics and engineering, including:Electromagnetic induction: A changing magnetic flux can induce an electromotive force (EMF) in a conductor.Magnetic circuits: Magnetic flux is used to analyze and design magnetic circuits, such as those found in motors, generators, and transformers.Particle physics: Magnetic flux is used to study the properties of subatomic particles, such as their magnetic moments. Magnetic flux linkage is defined as , where is the number of flux lines that pass through, or link, with each of the turns of a coil of N turns.Since[math] \text{flux} \, \Phi = BA [/math]for a single loop of wire, then the flux linkage is[math] N = BAN [/math]if the coil of wire has N turns that are perpendicular to the lines of flux.Flux linkage is measured in weber-turns.Flux linkage depends on several factors, as shown in Figure 2: Figure 2 Flux lines(a) the flux density(b) the orientation of the coil and flux lines(c) the coils cross-sectional area(d) the number of turns on the coil.Flux linkage is important because an e.m.f. is induced in a coil, in which the flux linkage changes. You will learn more about this in the next section.Figure 1 (c) shows a coil being turned in a magnetic field. As the coil turns in the magnetic field, the area of the coil perpendicular to the field is given by , and the magnetic flux linkage is given as[math] N \Phi = BAN cos \theta [/math]where N is the number of turns on the coil, o is the magnetic flux (in Wb), B is the magnetic flux density (in T), A is the cross-sectional area of the coil (in m) and is the angle between the axis of the coil and the flux lines.Figure 3 shows a coil of wire formed as a 60 triangle with sides of length 30 cm. The coil has 50 turns. Calculate the magnetic flux linkage with the coil when it is placed with the axis at 40 to a vertical in a uniform horizontal flux of 0.02 T.Figure 3Given data:Magnetic field = B = 0.02TNumber of turns = N = 50Find data:Find the area of coil =?Magnetic flux linkage = N=?Formula:[math] \text{Area of coil} = \frac{1}{2} * \text{base} * \text{height} \\ N \Phi = B A \cos \theta [/math]Solution:Area of coil is[math] \text{Area of coil} = \frac{1}{2} * \text{base} * \text{height} \\ \text{Area of coil} = \frac{1}{2} \cdot 0.30\,\text{m} \cdot 0.30\,\text{m} \cdot \sin 60^\circ \\ \text{Area of coil} = 0.039\,\text{m}^2 [/math]Magnetic flux linkage is[math]N \Phi = B A N \cos \theta \\ N \Phi = (0.02)(0.039)(50) \cos 40^\circ \\ N \Phi = 0.03 \, \text{Wb} [/math] Our lives would be completely different without Michael Faradays discovery of electromagnetic induction in 1831 using insulated coils of wire and changing magnetic fields.(1)Figure 4 using a moving magnet to induce an e.m.f.Electromagnetic induction using a coil of wire connected to a microammeter, as shown in Figure 4.The microammeter flicks one way when a bar magnet is moved into the coil, and the other way when the magnet is pulled out. It is zero when the magnet is stationary inside the coil.An e.m.f. is induced if there is relative movement between the coil and a magnetic field (either the magnet or the coil moves) or the magnetic flux linkage changes (for example, the strength of an electromagnet changes).(2)Figure 8.10 shows electromagnetic induction caused by a length of wire moving between two magnets.Figure 5 Moving a wire into a magnetic field induces an e.m.f.The wire is connected to the microammeter, which flicks one way when the wire moves down, and flicks in the opposite direction when the wire moves up.An e.m.f. is induced in the wire because an electric charge moving perpendicular to a magnetic field experiences a force.Using Flemings left-hand rule, you can see that electrons in a wire move towards one end of the wire when the wire moves perpendicular to the magnetic field.This leaves one end of the wire negatively charged overall and the other end positively charged, creating a potential difference across the wire.A current can flow if the wire is part of a complete circuit for example, when the wire is connected to a microammeter. Faradays Law of Induction is a fundamental principle in electromagnetism, describing the relationship between a changing magnetic flux and the electromotive force (EMF) it produces. It states:The electromotive force (EMF) induced in a closed loop is proportional to the rate of change of the magnetic flux through the loop.Figure 6 Flux linkage in the coil increases as the coil moves closer to the magnet.[math] \varepsilon = \frac{\Delta (N \Phi)}{\Delta t} [/math]Where (N) is the change in flux linkage and t is the time over which that change takes place. Since a coil of wire has a fixed number of turns, this becomes[math] \varepsilon = N \frac{\Delta \Phi}{\Delta t} [/math]Some earlier observations: Relative movement between a magnet and a coil changes the flux linkage in the coil (Figure 6). This generates an e.m.f. Rotating a coil in the plane perpendicular to the field changes the cross- sectional area through which the flux passes. This changes the flux linkage, and generates an e.m.f. Increasing the relative motion, or the speed at which the coil rotates, increases the rate of change of the flux linkage, which increases the induced e.m.f. If there is no relative movement or rotation, the flux linkage does not change, so no e.m.f. is generated.Lenzs Law is a fundamental principle in electromagnetism that describes the direction of the induced current in a conductor when the magnetic flux through the conductor changes. The law states:The induced current flows in a direction such that the magnetic field it produces opposes the change in magnetic flux that induced the current.In other words, Lenzs Law indicates that the induced current will always try to maintain the original magnetic flux by generating a magnetic field that: Opposes an increasing magnetic flux (flux is increasing current flows to decrease flux) Supports a decreasing magnetic flux (flux is decreasing current flows to increase flux)Lenzs Law is often remembered using the following mnemonic:Backward current opposes the change, forward current supports the changeFigure 7 shows the south pole of a magnet moving into a coil. This induces an e.m.f.Figure 7 A magnet being pushed into, or pulled out of, a coil of wire. Lenzs law determines the direction of the induces e.m.fWhen there is a complete circuit, a current-flows and the coil behaves as an electromagnet, with its south pole facing the magnets south pole, repelling the magnet.Pulling the magnet out of the coil induces an e.m.f. such that the same end of the coil becomes a north pole, which attracts the magnet.We can combine Lenzs law with Faradays law and write[math] \varepsilon = \frac{\Delta (N \Phi)}{\Delta t}[/math]where (N) is the change in flux linkage and t is the time over which that change takes place. Since a coil of wire has a fixed number of turns, this becomes[math] \varepsilon = N\frac{\Delta \Phi}{\Delta t}[/math]Lenzs law is the result of conservation of energy.When the south pole of a magnet is pushed into the coil, a current is induced in the wire, which becomes an electromagnet.If the south pole of the electromagnet laces the moving magnet, the poles repel and work must be done to keep pushing the magnet into the coil of wire.If you try this with a very strong magnet in a large coil, you may feel the force you are working against. An induced e.m.f. can be caused by a conductor moving in a magnetic field.For example, a straight wire may be dropped through a uniform magnetic field, or a plane may fly at a constant height and speed in the Earths magnetic field.A credit card includes information stored on a magnetic strip.The credit card reader has a small coil in it, and when the credit card is swiped through the reader, an e.m.f. is induced in the coil.It is important to swipe the card quickly enough so that the induced e.m.f. is large enough to be interpreted.When a conductor moves at a velocity v perpendicular to the flux lines, Faradays law applies and an e.m.f. is generated.For a conductor of length, (l) travelling in a flux density B, the area swept out per second is length* velocity. The induced e.m.f. equals the rate of change of flux linkage, so[math] \varepsilon = B \frac{dA}{dt} [/math]Because the area swept out per second is , this becomes[math] \varepsilon = Blv [/math]Where B is the magnetic flux density (in T), l is the length of the conductor (in m) and v is the velocity of the conductor perpendicular to the field (in ms). When a coil rotates in a magnetic field (figure 8), an a.c. voltage is induced in the coil.Figure 8 Remember to specify the axis of rotation for a coil in a magnetic field, which is shown here as the black dot.To calculate the value of the induces e.m.f. at time (t) , the following equation for a plane coil in a uniform magnetic field so long as the axis of rotation is at right angle to the field:[math] \varepsilon = BAN\omega \sin \omega t [/math]Where is the induced e.m.f. (in V), B is the magnetic flux density (in T), A is the cross-sectional are a of the coil (in m2), N is the number of turns on the coil, is the angular speed of the rotating coil (which can also be expressed as = 2f, where f is the frequency of rotation current) and t is the time (in s).Since the maximum value of sint is 1, the maximum induced e.m.f. is[math] \varepsilon_{\text{max}} = BAN\omega [/math]Figure 9 shows how the magnetic flux linkage and the induced e.m.f. are linked:Figure 9At A, N is a maximum, gradient [math] \frac{d(N\Phi)}{dt}[/math] is 0, = 0.At B, N is 0, gradient [math] \frac{d(N\Phi)}{dt}[/math] is maximum and negative, so is a maximum positive.At C, N is a minimum, gradient [math] \frac{d(N\Phi)}{dt}[/math]is 0, so = 0.At D, N is 0, gradient [math] \frac{d(N\Phi)}{dt}[/math] is a maximum and positive, so is a maximum negative. The inductance of a circuit is defined as the flux linkage per unit current. Therefore, in order to find the inductance of a circuit, the determination of flux linkage is of primary importance. We shall discuss two important cases of flux linkages. 1.Flux linkage due to a Single Current Carrying Conductor:Consider a long straight cylindrical conductor of radirus r metres and carrying a current I amperes (r.m.s.) as shown in Fig. 9.4 (i). This current will set up magnetic field. The magnetic lines of force will exist inside the conductor as well as outside the conductor. Both these fluxes will contribute to the inductance of the conductor.Flux linkages due to internal flux: Refer to Fig. 9.4 (ii) where the X-section of the conductor is shown magnified for clarity. The magnetic field intensity at a point x metres from the centre is given by;Assuming a uniform current density,If (= 0r)is the permeability of the conductor, then flux density at the considered point is given by; Now, flux d through a cylindrical shell of radial thickness dx and axial length 1 m is given by;This flux links with currentTherefore, flux linkages per metre length of theTotal flux linkages from centre upto the conductor surface isFlux linkages due to external flux: Now let us calculate the flux linkages of conductor due to external flux. The external flux extends from the surface of the conductor to infinity. Referring to Fig. 9.5, the field intensity at a distance x metres (from centre) outside the conductor is given by ;Now, flux d though a cylindrical shell of thickness dx and axial length 1 metre isThe flux d links all the current in the conductor once and only once.Total flux linkages of the conductor from surface to infinity,Overall flux linkages,2.Flux linkage in Parallel Current Carrying Conductors:We shall now determinethe flux linkages in a group of parallel current carrying conductors. Fig. 9.6 shows, the conductors A,B,C etc. carrying currents IA,IB,ICetc. Let us consider the flux linkages With one conductor, say conductor A. There will be fluxlinkages with conductor A due to its own current as discussed previously. Also there Will beflux linkages with this conductor due to the mutual inductance effects of IB,IC,IDetc. We shall now determine the total flux linkages with conductor A.Flux linkages with conductor A due to its own currentFlux linkages with conductor A due to current IBFlux linkages with conductor A due to current ICTotal flux linkages with conductor ASimilarly, flux linkage with other conductors can be determined. The above relation provides the basis for evaluating inductance of any circuit. Share copy and redistribute the material in any medium or format for any purpose, even commercially. Adapt remix, transform, and build upon the material for any purpose, even commercially. The licensor cannot revoke these freedoms as long as you follow the license terms. Attribution You must give appropriate credit , provide a link to the license, and indicate if changes were made . You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use. 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Physical quantity of circuits related to magnetic flux, voltage and currentFlux linkageCommon symbols , {\displaystyle \Psi ,\lambda } SIunitweber (Wb)Other unitsmaxwellIn SIbase unitskgm2s2A1DimensionM L2 T2 I1In electrical engineering, the term flux linkage is used to define the interaction of a multi-turn inductor with the magnetic flux as described by the Faraday's law of induction.[clarification needed] Since the contributions of all turns in the coil add up, in the over-simplified situation of the same flux {\displaystyle \Phi } passing through all the turns, the flux linkage (also known as flux linked) is = n {\displaystyle \Psi =n\Phi } , where n {\displaystyle n} is the number of turns.[1] The physical limitations of the coil and the configuration of the magnetic field cause some flux to leak between the turns of the coil, forming the leakage flux[2] and reducing the linkage. The flux linkage is measured in webers (Wb), like the flux itself.In a typical application, the term "flux linkage" is used when the flux is created by the electric current flowing through the coil itself. Per Hopkinson's law, = n M M F R {\displaystyle \Psi =n{\frac {MMF}{R}}} , where MMF is the magnetomotive force and R is the total reluctance of the coil. Since M M F = n I {\displaystyle {MMF}=nI} , where I is the current, the equation can be rewritten as = L I {\displaystyle \Psi =LI} , where L = n 2 R {\displaystyle L={\frac {n^{2}}{R}}} is called the inductance.[2] Since the electrical reactance of an inductor X = L = 2 f L {\displaystyle X=\omega L=2\pi fL} , where f is the AC frequency, X = I {\displaystyle X=\omega {\frac {\Psi }{I}}} .This section includes a list of references, related reading, or external links, but its sources remain unclear because it lacks inline citations. Please help improve this section by introducing more precise citations. (January 2021) (Learn how and when to remove this message)In circuit theory, flux linkage is a property of a two-terminal element. It is an extension rather than an equivalent of magnetic flux and is defined as a time integral[citation needed] = E d t , {\displaystyle \Psi =\int {\mathcal {E}}\,dt,} where E {\displaystyle {\mathcal {E}}} is the voltage across the device, or the potential difference between the two terminals. This definition can also be written in differential form as a rate E = d d t . {\displaystyle {\mathcal {E}}={\frac {d\Psi }{dt}}.} The magnitude of the electromotive force (EMF) generated in a conductor forming a closed loop is proportional to the rate of change of the total magnetic flux passing through the loop (Faraday's law of induction). Thus, for a typical inductance (a coil of conducting wire), the flux linkage is equivalent to magnetic flux, which is the total magnetic field passing through the surface (i.e., normal to that surface) formed by a closed conducting loop coil and is determined by the number of turns in the coil and the magnetic field, i.e., = S B d S , {\displaystyle \Psi =\int \limits _{S}{\vec {B}}\cdot d{\vec {S}},} where B {\displaystyle {\vec {B}}} is the magnetic flux density, or magnetic flux per unit area at a given point in space.The simplest example of such a system is a single circular coil of conductive wire immersed in a magnetic field, in which case the flux linkage is simply the flux passing through the loop.The flux {\displaystyle \Phi } through the surface delimited by a coil turn exists independently of the presence of the coil. Furthermore, in a thought experiment with a coil of N {\displaystyle N} turns, where each turn forms a loop with exactly the same boundary, each turn will "link" the "same" (identically, not merely the same quantity) flux {\displaystyle \Phi } , all for a total flux linkage of = N {\displaystyle \Psi =N\Phi } . The distinction relies heavily on intuition, and the term "flux linkage" is used mainly in engineering disciplines. Theoretically, the case of a multi-turn induction coil is explained and treated perfectly rigorously with Riemann surfaces: what is called "flux linkage" in engineering is simply the flux passing through the Riemann surface bounded by the coil's turns, hence no particularly useful distinction between flux and "linkage".Due to the equivalence of flux linkage and total magnetic flux in the case of inductance, it is popularly accepted that the flux linkage is simply an alternative term for total flux, used for convenience in engineering applications. Nevertheless, this is not true, especially for the case of memristor, which is also referred to as the fourth fundamental circuit element. For a memristor, the electric field in the element is not as negligible as for the case of inductance, so the flux linkage is no longer equivalent to magnetic flux. In addition, for a memristor, the energy related to the flux linkage is dissipated in the form of Joule heating, instead of being stored in magnetic field, as done in the case of an inductance.[citation needed]^ Bhatnagar 1997, p.301.^ a b Veltman, Pulle & de Doncker 2016, p.19.L. O. Chua, "Memristor The Missing Circuit Element", IEEE Trans. Circuit Theory, vol. CT_18, no. 5, pp.507519, 1971.Bhatnagar, V.P. (1997). A Complete Course in ISC Physics. Pitambar Publishing. ISBN978-81-209-0202-2. Retrieved 2023-07-03.Veltman, A.; Pulle, D.W.J.; de Doncker, R.W. (2016). Fundamentals of Electrical Drives. Power Systems. Springer International Publishing. ISBN978-3-319-29409-4. Retrieved 2023-07-03.Retrieved from " and flux linkage are two related concepts in the field of electromagnetism. Flux refers to the amount of magnetic field passing through a given surface area. It is a scalar quantity and is measured in Weber (Wb). On the other hand, flux linkage is a measure of the total magnetic field passing through a closed loop or coil. It is a vector quantity and is measured in Weber-turns (Wb-turns). Flux linkage takes into account the number of turns in a coil, whereas flux does not. In simple terms, flux is the magnetic field passing through a surface, while flux linkage is the magnetic field passing through a coil. Flux and flux linkage are two fundamental concepts in the field of electromagnetism. They both play crucial roles in understanding the behavior of magnetic fields and their interactions with electric currents. While they are related, they have distinct attributes that set them apart. In this article, we will explore the characteristics of flux and flux linkage, highlighting their similarities and differences.FluxFlux, denoted by the symbol , represents the total magnetic field passing through a given surface. It is a scalar quantity that measures the strength of the magnetic field lines penetrating a surface area. Flux is directly proportional to the number of magnetic field lines passing through a surface and is dependent on the strength of the magnetic field and the area of the surface.One of the key attributes of flux is that it is a measure of the magnetic field passing through a surface, regardless of the orientation of the surface. This means that the flux remains the same even if the surface is tilted or rotated, as long as the same number of magnetic field lines pass through it.Flux can be positive or negative, depending on the orientation of the surface with respect to the magnetic field. If the surface is perpendicular to the magnetic field lines, the flux is positive. Conversely, if the surface is parallel or anti-parallel to the magnetic field lines, the flux is negative.Mathematically, flux is defined as the dot product of the magnetic field vector B and the surface area vector A. It can be expressed as = B A, where B is the magnetic field vector and A is the surface area vector.Flux has various applications in different fields, such as electrical engineering, physics, and even biology. It is used to calculate the induced electromotive force (EMF) in Faraday's law of electromagnetic induction, and it is crucial in understanding the behavior of magnetic fields in transformers, motors, and generators.Flux LinkageFlux linkage, denoted by the symbol , is a measure of the total magnetic flux passing through a closed loop or a coil. It is a product of the number of turns in the coil and the flux passing through each turn. Flux linkage is a crucial concept in understanding the behavior of inductors and transformers.One of the key attributes of flux linkage is that it is a measure of the total magnetic flux passing through a closed loop or a coil, taking into account the number of turns. This means that the flux linkage is directly proportional to the number of turns in the coil and the flux passing through each turn.Flux linkage can be positive or negative, depending on the direction of the magnetic field and the orientation of the coil. If the magnetic field and the coil are aligned in the same direction, the flux linkage is positive. Conversely, if the magnetic field and the coil are aligned in opposite directions, the flux linkage is negative.Mathematically, flux linkage is defined as the product of the number of turns in the coil N and the flux passing through each turn. It can be expressed as = N, where N is the number of turns and is the flux passing through each turn.Flux linkage is widely used in the analysis and design of inductors, transformers, and other electromagnetic devices. It helps in calculating the induced voltage and current in inductors, as well as understanding the behavior of magnetic fields in transformers.ComparisonWhile flux and flux linkage are related concepts, they have distinct attributes that differentiate them. Let's compare some of their key characteristics:1. NatureFlux is a scalar quantity that measures the strength of the magnetic field lines passing through a surface. It is independent of the number of turns in a coil. On the other hand, flux linkage is a measure of the total magnetic flux passing through a closed loop or a coil, taking into account the number of turns. It is a vector quantity that depends on both the magnetic field and the number of turns.2. CalculationFlux is calculated by taking the dot product of the magnetic field vector and the surface area vector. It can be expressed as = B A, where B is the magnetic field vector and A is the surface area vector. On the other hand, flux linkage is calculated by multiplying the number of turns in the coil by the flux passing through each turn. It can be expressed as = N, where N is the number of turns and is the flux passing through each turn.3. OrientationFlux is independent of the orientation of the surface through which the magnetic field lines pass. It remains the same even if the surface is tilted or rotated, as long as the same number of magnetic field lines pass through it. Conversely, flux linkage depends on the orientation of the coil with respect to the magnetic field. It changes if the coil is rotated or its orientation is altered.4. SignFlux can be positive or negative, depending on the orientation of the surface with respect to the magnetic field. If the surface is perpendicular to the magnetic field lines, the flux is positive. Conversely, if the surface is parallel or anti-parallel to the magnetic field lines, the flux is negative. On the other hand, flux linkage can also be positive or negative, depending on the direction of the magnetic field and the orientation of the coil. If the magnetic field and the coil are aligned in the same direction, the flux linkage is positive. Conversely, if the magnetic field and the coil are aligned in opposite directions, the flux linkage is negative.5. ApplicationsFlux has various applications in different fields, such as electrical engineering, physics, and biology. It is used to calculate the induced electromotive force (EMF) in Faraday's law of electromagnetic induction and is crucial in understanding the behavior of magnetic fields in transformers, motors, and generators. On the other hand, flux linkage is widely used in the analysis and design of inductors, transformers, and other electromagnetic devices. It helps in calculating the induced voltage and current in inductors, as well as understanding the behavior of magnetic fields in transformers.ConclusionFlux and flux linkage are fundamental concepts in electromagnetism that play crucial roles in understanding the behavior of magnetic fields and their interactions with electric currents. While they are related, they have distinct attributes that set them apart. Flux measures the strength of the magnetic field passing through a surface, while flux linkage measures the total magnetic flux passing through a closed loop or a coil, taking into account the number of turns. Understanding the similarities and differences between flux and flux linkage is essential for comprehending the behavior of magnetic fields in various applications, from transformers and motors to electromagnetic induction. Comparisons may contain inaccurate information about people, places, or facts. Please report any issues.A LevelPhysicsAQA7.5.4Three terms that are closely related but different are magnetic flux, magnetic flux density and magnetic flux linkage.Magnetic flux is a measure of the number of field lines passing through a region of space.Magnetic flux density is a measure of the number of field lines passing through a region of space per unit cross-sectional area.Magnetic flux linkage is the product of the magnetic flux and the number of turns on a coil through which the field passes.The two loops in the diagram have the same flux but different flux densities since area Y is larger than area X.The two loops in the diagram have the same flux density but different flux since area Y is larger than area X.Jump to other topicsUnlimited access to 10,000+ open-ended exam questionsMini-mock exams based on your study historyUnlock 800+ premium courses & e-booksGet started with Seneca PremiumMoving Charges in a Magnetic FieldElectromagnetic InductionPage 2A LevelPhysicsAQA7.5.5A current-carrying wire in a magnetic field may experience a force. In reverse, a potential difference (and hence a current) may be induced in a conductor that experiences a change in magnetic flux.In this demonstration, the magnet falling through the tube takes considerably longer to fall than it would if it were just falling through the air.The copper tube is not magnetic, but it is a conductor experiencing a change in magnetic flux.A current is induced in the tube (in a circle around the magnet), which in turn causes a magnetic field to act so as to slow the magnet down.As the wire cuts through the magnetic field lines, a p.d. and hence a current is induced in the complete circuit. This is registered as a small flicker on the ammeter.The two main laws about electromagnetic induction are from Faraday and Lenz.When the magnetic flux linkage in a circuit changes, an electromotive force (emf) is induced in the circuit.The emf is proportional to the rate of change of the flux linkage. The equation for calculating the emf is:emf = (number of coils x change in flux linkage) change in time emf=Ntemf=-N\frac{{\Delta\phi}}{{\Delta}t}emf=NtThe negative sign at the start of Faraday's law is because of Lenz's law.Lenz's law is that the induced electromotive force will induce a current and a magnetic field which will oppose the change in flux.Jump to other topicsUnlimited access to 10,000+ open-ended exam questionsMini-mock exams based on your study historyUnlock 800+ premium courses & e-booksGet started with Seneca PremiumMagnetic Flux & Flux LinkageElectromagnetic Induction 2 In electrical engineering the term flux linkage is used to define the interaction of a multi-turn inductor with the magnetic flux as described by the Faraday's law of induction. Since the contributions of all turns in the coil add up, in the over-simplified situation of the same flux passing through all the turns, the flux linkage (also known as flux linked) is , where is the number of turns. The physical limitations of the coil and the configuration of the magnetic field make some flux to leak between the turns of the coil, forming the leakage flux and reducing the linkage. The flux linkage is measured in webers (Wb), like the flux itself.Relation to inductance and reactance In a typical application the term "flux linkage" is used when the flux is created by the electric current flowing through the coil itself. Per Hopkinson's law, } , where is the magnetomotive force and is the total reluctance of the coil. Since , where is the current, the equation can be rewritten as , where } is called the inductance. Since the electrical reactance of an inductor , where is the AC frequency, .In circuit theory In circuit theory, flux linkage is a property of a two-terminal element. It is an extension rather than an equivalent of magnetic flux and is defined as a time integral where is the voltage across the device, or the potential difference between the two terminals. This definition can also be written in differential form as a rate Faraday showed that the magnitude of the electromotive force (EMF) generated in a conductor forming a closed loop is proportional to the rate of change of the total magnetic flux passing through the loop (Faraday's law of induction). Thus, for a typical inductance (a coil of conducting wire), the flux linkage is equivalent to magnetic flux, which is the total magnetic field passing through the surface (i.e., normal to that surface) formed by a closed conducting loop coil and is determined by the number of turns in the coil and the magnetic field, i.e., =\int\limitsS\vec{B} d\vec{S}, where is the magnetic flux density, or magnetic flux per unit area at a given point in space.The simplest example of such a system is a single circular coil of conductive wire immersed in a magnetic field, in which case the flux linkage is simply the flux passing through the loop. The flux through the surface delimited by a coil turn exists independently of the presence of the coil. Furthermore, in a thought experiment with a coil of turns, where each turn forms a loop with exactly the same boundary, each turn will "link" the "same" (identically, not merely the same quantity) flux , all for a total flux linkage of . The distinction relies heavily on intuition, and the term "flux linkage" is used mainly in engineering disciplines. Theoretically, the case of a multi-turn induction coil is explained and treated perfectly rigorously with Riemann surfaces: what is called "flux linkage" in engineering is simply the flux passing through the Riemann surface bounded by the coil's turns, hence no particularly useful distinction between flux and "linkage".Due to the equivalence of flux linkage and total magnetic flux in the case of inductance, it is popularly accepted that the flux linkage is simply an alternative term for total flux, used for convenience in engineering applications. Nevertheless, this is not true, especially for the case of memristor, which is also referred to as the fourth fundamental circuit element. For a memristor, the electric field in the element is not as negligible as for the case of inductance, so the flux linkage is no longer equivalent to magnetic flux. In addition, for a memristor, the energy related to the flux linkage is dissipated in the form of Joule heating, instead of being stored in magnetic field, as done in the case of an inductance. Sources Understanding Magnetic Flux (= BA)Analysing Flux Linkage (N)Rotating Rectangular Coil in a Magnetic FieldPractical Investigation: Search Coil and OscilloscopeApplications and ExamplesChallenges in Understanding and SolutionsMagnetic flux, denoted by (Phi), quantifies the magnetic field, considering its strength and the area it encompasses. The equation = BA succinctly represents this, where:B is the magnetic flux density, measured in teslas (T).A is the area through which the magnetic field lines pass, measured in square meters (m).Detailed Insights into Magnetic FluxMagnetic flux is a scalar quantity, meaning it has magnitude but no direction.The value of magnetic flux depends on the angle between the magnetic field and the area considered. The maximum flux occurs when the field is perpendicular to the area.Magnetic flux lines, though imaginary, are a useful concept to visualize the field. The denser these lines, the stronger the magnetic field.Flux linkage expands upon the concept of magnetic flux. It is the product of the number of turns (N) in a coil and the magnetic flux () through one turn of the coil. This concept is critical in electromagnetic induction.In-depth Exploration of Flux LinkageFormula: Flux linkage = N, with N representing the coil's turns.Flux linkage is integral in the process of inducing electromotive force (EMF) in a coil, a principle underpinning many electrical devices and applications.Rotating Rectangular Coil in a Magnetic FieldInvestigating a rotating rectangular coil in a magnetic field provides a practical and visual way to comprehend magnetic flux and flux linkage.Principles and DynamicsAs the coil rotates within a magnetic field, the angle between the magnetic field lines and the coil's area vector varies.This variation in angle alters the magnetic flux through the coil, illustrating how flux is dependent on orientation and position relative to the magnetic field.Key ObservationsWhen the coil's plane is perpendicular to the magnetic field, the flux through the coil is at its maximum.Conversely, when the coil's plane is parallel to the magnetic field, the flux is minimal or zero.Practical Investigation: Search Coil and OscilloscopeA practical experiment using a search coil and an oscilloscope provides a hands-on approach to studying how changing angles impact magnetic flux linkage.Experimental Procedure1. Setup: Connect the search coil to the oscilloscope.2. Method: Rotate the coil within a uniform magnetic field at different angles.3. Observations: Record the oscilloscope's readings, which reflect changes in the flux linkage through the coil.Educational ValueThis experiment visually demonstrates the dynamic relationship between the coil's orientation and magnetic flux linkage.The oscilloscope serves as a real-time visual tool, making the abstract concept of flux linkage more tangible and understandable.Applications and ExamplesMagnetic flux and flux linkage are not just theoretical constructs but have practical applications in various fields:Electric Generators: These devices convert mechanical energy to electrical energy using the principle of electromagnetic induction. A rotating coil in a magnetic field experiences a change in flux linkage, inducing an EMF.Inductive Sensors: These are used in various fields to detect the position or motion of objects. They operate on the principle of changes in magnetic flux linkage caused by the movement of an object within a magnetic field.Challenges in Understanding and SolutionsGrasping Abstract ConceptsUtilizing visual aids, such as diagrams and animations, can significantly aid in understanding these abstract concepts.Practical experiments, like the rotating coil and oscilloscope setup, provide a hands-on experience, reinforcing theoretical knowledge.Real-world ApplicationsRelating the theoretical aspects to real-world devices and scenarios helps in solidifying the understanding of these concepts.Discussing applications like electric generators or inductive sensors provides context and showcases the relevance of these principles in everyday technology.In conclusion, the study of magnetic flux and flux linkage is a blend of theoretical knowledge and practical application. Understanding these concepts is crucial for students, as they form the basis for many phenomena and technologies in the field of physics. Through experiments like the investigation of a rotating coil in a magnetic field and the use of oscilloscopes, students can gain a comprehensive understanding and appreciation of these fundamental principles in electromagnetism.AQA A-Level PhysicsPhysics Practice QuestionsNeed help from an expert?The worlds top online tutoring provider trusted by students, parents, and schools globally.Please fill out the form and we'll find a tutor for you.Consider carefully the value of , it is the angle between the field lines and the line normal (perpendicular) to the plane of the area the field lines are passing through. If it helps, drawing the normal on the area provided will help visualise the correct angle.Just like for magnetic flux, the flux linkage through a coil may not be entirely perpendicular.The magnetic flux linkage through a rectangular coil increases as the angle between the field lines and the normal decreasesIn this case, you can just substitute the equation forB into the equation for N, such that the flux linkage is calculated by:As before, you should remember that since cos (0) = 1, the flux linkage is a maximum when the angleis zero. This means the flux and coil face are perpendicular (i.e. the normal line to the coil face and the flux lines are parallel).Page 2A beta particle is incident at 70 to a magnetic field of flux density 0.5 mT, travelling at a speed of 1.5 106 m s1.Calculate:a) The magnitude of the magnetic force on the beta particleb) The magnitude of the maximum possible force on a beta particle in this magnetic field, travelling with the same speedAnswer:Part (a)Step 1: Write out the known quantitiesMagnetic flux densityB = 0.5 mT = 0.5 103 TSpeedv = 1.5 106 m s1Angle between the flux and the velocity = 70Step 2: Substitute quantities into the equation for magnetic force on a charged particleA beta particle is an electronTherefore, the magnitude of electron charge Q = 1.6 1019 CSubstituting values gives:F=BQvsin F = (0.5 103) (1.6 1019) (1.5 106) sin (70)F = 1.1 1016 NPart (b)Step 1: Write out the known quantitiesMagnetic flux densityB = 0.5 mT = 0.5 103 TSpeedv = 1.5 106 m s1Step 2: Determine the angle to the flux linesAngle between the flux and the velocity = 90 if the magnetic force is a maximumStep 3: Substitute quantities into the equation for magnetic force on a charged particleThe magnitude of electron charge Q = 1.6 1019 CSubstituting values gives:F=BQvsin =BQvwhen sin 90 = 1F = (0.5 103) (1.6 1019) (1.5 106)F = 1.2 1016 NPage 3A current flows perpendicularly to a uniform magnetic field as shown in the diagram below.As a result, the conductor carrying the current experiences a magnetic force,F.Determine the direction of the current flowing in the conductor.Answer:Step 1: Apply the instructions for Fleming's Left Hand RuleUsing Flemings Left Hand Rule for the quantities given:First finger is the magnetic field, B = into the page (or screen!)Thumb is the direction of the magnetic force F= vertically downwardsStep 2: Determine the direction of the conventional currentThe first finger should be pointing into the page (or screen!) along the direction of the fieldRotating the entire hand allows the thumb to point downwards, along the direction of forceThe second finger should be pointing towards the left of the page (or screen!)Page 4Electromagnetic induction is a phenomenon which occurs when an e.m.f is induced when a conductor moves through a magnetic fieldIf there is a change in magnetic flux or magnetic flux linkage NMechanical work (from moving the conductor in the field) is transformed into electrical energyTherefore, if attached to a complete circuit, a current will be induced in the conductorThis is known as electromagnetic induction and is defined as:The process in which an e.m.f is induced in a closed circuit due to changes in magnetic flux (linkage)This can occur either when:A conductor cuts through a magnetic fieldThe magnetic flux (linkage) through a coil changes, e.g. becomes more or less dense, or changes directionElectromagnetic induction is used in:Electrical generators which convert mechanical energy to electrical energyTransformers which are used in electrical power transmissionThis phenomenon can easily be demonstrated with a magnet and a coil, or a wire and two magnetsWhen a coil is connected to a sensitive voltmeter, a bar magnet can be moved in and out of the coil to induce an e.m.f in the coilA bar magnet is moved through a coil connected to a voltmeter to induce an e.m.fThe observations are:When the bar magnet is not moving, the voltmeter shows a zero readingWhen the bar magnet is held still inside, or outside, the coil, the rate of change of flux is zero, so, there is no e.m.f inducedWhen the bar magnet begins to move inside the coil, there is a reading on the voltmeterAs the bar magnet moves, its magnetic field lines cut through the coil, generating a change in magnetic flux()This induces an e.m.f within the coil, shown momentarily by the reading on the voltmeterWhen the bar magnet is taken back out of the coil, an e.m.f is induced in the opposite directionAs the magnet changes direction, the direction of the current changesThe voltmeter will momentarily show a reading with the opposite signIncreasing the speed of the magnet induces an e.m.f with a higher magnitudeAs the speed of the magnet increases, the rate of change of flux increasesThe direction of the electric current, and e.m.f, induced in the conductor is such that it opposes the change that produces itAn e.m.f is induced only when the bar magnet is moving through the coilFactors that will increase the induced e.m.f are:Moving the magnet faster through the coilAdding more turns to the coilIncreasing the strength of the bar magnetRotating CoilsWhen a coil rotates in a uniform magnetic field, the magnetic flux through the coil will vary as it rotatesTherefore, since the flux linkage through the coil also varies, this will induce an e.m.f that also variesThe maximum e.m.f is when the coil cuts through the most field linesThe varying e.m.f induced is called an alternating voltageEven though the flux linkage through the coil is maximum when = 0, the change in flux linkage is minimal as the coil rotates, so the induced e.m.f is a minimum. The opposite is true when = 90Increasing the coil's frequency of rotation increases:The frequency of the alternating voltageThe amplitude of the alternating voltageDid this page help you?

Flux linkage vs flux. What is flux linkage in physics. What is magnetic flux linkage measured in. Difference between flux and flux linkage. What is flux linkage. Unit of flux linkage.