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The "Kirchhoff's Law UPSC Questions" guide is a valuable resource for all aspiring students preparing for the UPSC exam. It focuses on providing a wide range of practice questions to help students gauge their understanding of the exam topics. These questions cover the entire syllabus, ensuring comprehensive preparation. The guide includes previous years' question papers for students to familiarize themselves with the exam's format and difficulty level. Additionally, it offers subject-specific question banks, allowing students to focus on weak areas and improve their performance. Students of UPSC can study Kirchhoff's Law alongwith tests & analysis from the EduRev app, which will help them while preparing for their exam. Apart from the Kirchhoff's Law, students can also utilize the EduRev App for other study materials such as previous year question papers, syllabus, important questions, etc. The EduRev App will make your learning easier as you can access it from anywhere you want. The content of Kirchhoff's Law is prepared as per the latest UPSC syllabus. Do we know how can we find the value of electric current, voltage, and resistance by using ohm's law? Ohm's Law gives you a direct method to find these values. If you know the formula V = IR, then you can easily find your desired value. We can apply ohm's law in any circuit but it works well for simple circuits. As the circuit starts being complex then using ohm's Law becomes time-wasting and confusing because it follows long procedures and working rules. So it is not a good idea to apply ohm's law in complex circuits to find the value of electric current and voltages. So for the complex circuits, in 1845 two different rules or you can say laws were discovered by the German physicist Gustav Kirchhoff. These rules are called Kirchhoff's rules or simply Kirchhoff's laws. German physicist Gustav Robert Kirchhoff Kirchhoff gives two equalities that deal with the electric current and potential difference (commonly known as voltage) in the lumped element model of electrical circuits. The laws which were given by Kirchhoff are based on the conservation of electric charges and conservation of energy. How it is based on these conservations? we will see below. His laws are the generalization of the work of Georg Ohm and preceded the work of James Clark Maxwell. After introducing these two equalities the viewing angle of electrical engineering has been changed completely. It helps engineers to study complex circuits more precisely, accurately, and deeply. These two laws are widely used in electrical engineering and became the basis of network analysis. So in this article, we are going to discuss Kirchhoff's laws in detail. So stay tuned with us till the end. Let's start… Before going further let's discuss some frequent terms which will be used in the explanation of Kirchhoff's law. CIRCUIT – It is a closed conducting path through which electric current flows. PATH – A single line of connecting components and sources. See figure below: A-B-D-A and A-B-C-D-A are different paths in the circuit. NODE – It is the junction where two or more circuit elements are joined together. In other words, it is the point from which two or more branches emerge. It is denoted by dots. It is similar to a railways junction. Denoting nodes in the circuit, source: allaboutelectronics.org As you can see in the figure, the red dots denote the nodes in the circuit. Here A, B, C, and D are different nodes. BRANCH – It is single or groups of components such as resistors or sources that are joined between two nodes. Recall, parallel combination of resistors, in which two or more resistors are joined between two nodes. thus, it forms three branches. LOOP – A loop is a simple closed path in a circuit in which no circuit element or node is encountered more than once. A closed path is said to be a loop when you travel through this path then you will see every component only once. Circuit showing loop, source: allaboutelectronics.org In this figure, you will see there are three different loops. The first loop is A-B-D-A (loop 1), the second loop is B-C-D-B (loop 2), and the third loop are A-B-C-D-A (loop 3). MESH – A mesh is a closed path in the circuit, in which it does not contain any other close path inside it. See figure above – the loop A-B-D-A and B-C-D-B, it doesn't contain any other loop inside them so it is a mesh. But the loop A-B-C-D-A contains loop-1 and loop-2, so it is not a mesh. Entering current is equal to leaving current, source: electrical academia Kirchhoff's current law (KCL) is also called Kirchhoff's first rule or Kirchhoff's junction rule or nodal rule or Kirchhoff's point rule. This is a very important law that is based on the conservation of electric charges. [latexpage] STATEMENT – for any node or junction in electrical circuit, the sum of the current that are entering into the node or junction is equal to the sum of the current which are leaving that node.$$\displaystyle{\sum I_{\text{entering}}=\sum I_{\text{leaving}}}$$ In other words we can say algebraic sum of all the currents meeting at the node is zero. Mathematically, it is given as- $${\displaystyle \sum _{k=1}^{n}{I}_{k}=0}$$ where n is the total number of branches with currents flowing towards or away from the node. Keep in mind that direction is very important in Kirchhoff's laws, if the current is entering the node then it is taken as (+) or positive current but if is leaving or going away from the node then it is taken as (-) or negative current. See figure above – in the above figure current I_1 and I_2 are entering into the node so it will be taken as positive current. But I_3 and I_4 are leaving the node so it will be taken as negative current. We know that the algebraic sum of all the currents meeting at the node is zero, then- $${I_1+I_2-I_3-I_4=0}$$ We know that rate of flow of electric charges gives electric current. We also know that electric charges can't be created nor destroyed. It is a conserved quantity like momentum and mass. Let's considered the charge at any instant of time t, if I current is entered into the junction or node then the total charges entered into the node is It. Let's assume that when this current I is about to leave the junction, it is further divided into three different branches, having current in each branch is I_1, I_2 and I_3. So the amount of electric charges in each branch is given as I_1t, I_2t, and I_3t. So according to the conservation of electric charges, the sum of all the charges before entering is equal to the sum of all the charges after leaving, so mathematically – $$It=I_1t+I_2t+I_3t$$ Canceling t from both sides we get: $$I=I_1+I_2+I_3$$ So this result gives Kirchhoff's current law. Thus, from this, we can say Kirchhoff's current law is the outcome of the conservation of electric charges in any circuit. Written By Saurav_C Last Modified 22-06-2023 Kirchhoff's Laws help in the construction of complicated circuits containing numerous electrical components seen in everyday life. It also helps in the analysis of any electrical circuits, for example, how much current flows in different areas of an electrical circuit? What was the magnitude of the voltage loss in different regions of the network? What is the current direction in each circuit branch? In this article, we will look at Kirchhoff's current and voltage laws and how they are used in electrical appliances to calculate the current flowing and voltage drop in various areas of complicated circuits. Read further to find more. Kirchhoff's Law: Gustav Robert Kirchhoff was a German physicist born in Russia. His work involved researching electrical conduction. In \(1845,\) he formulated two laws known as Kirchhoff's Voltage Law (KVL) and Kirchhoff's Current Law (KCL). They combined known as Kirchhoff's Circuit law. These laws are used for the analysis of circuits. They help in calculating the flow of current in different streams through the network. Kirchhoff's \({{\bf{1}}^{{\bf{st}}}}\) law:- It is also known as Kirchhoff's Current Law (KCL), and it states that the "total current or charge entering a junction or node is exactly equal to the total current or charge leaving the node, as no charge is lost at the node". In other words, the algebraic sum of all the currents entering and leaving a node must be equal to zero. Note:- Kirchhoff's current law supports the law of conservation of charge. So we can say that Nord or junction is a point in a circuit that does not act as a source or sink of charge(s). So, \(\sum\limits_{k = 1}^n {{I_k}} = 0\) Where \(n\) is the total number of all the branches at with currents flowing towards or away from the node. i.e \({I_{{\rm{(exiting) }}}} + {I_{{\rm{(entering) }}}} = 0……..\left(1 \right)\) Let us understand this with an example. Focus on node \(A\) from a resistor network. Four branches are connected to this node. There are two incoming currents named \({i_1}\) and \({i_2}\) and two outgoing currents named \({i_3}\) and \({i_4}.\) Now, according to Kirchhoff's current law, the sum of total incoming and outgoing currents at node \(A\) will be equal to zero. Now, consider the two currents entering the node, \({i_{1,}}\) and \({i_{2,}}\) with a positive value, and the two currents leaving the node, \({i_3}\) and \({i_4}\) are negative in value. So, we can also rewrite the equation \((1)\) as: \({i_1} + {i_2} – {i_3} – {i_4} = 0……\left(2 \right)\) 2. Kirchhoff's \({{\bf{2}}^{{\bf{nd}}}}\) Law:- It is also known as Kirchhoff's Voltage Law (KVL), and it states that the"voltage drop around a loop equals to the algebraic sum of the voltage drop across every electrical component connected in the same loop for any closed network and also equals to zero". Note:- Kirchhoff's Voltage Law is based on the law of conservation of energy, because the net change in the energy of a charge, after the charge completes a closed path must be zero. Let's take an example to understand Kirchhoff's Voltage Law. Consider a part of a resistor network with an internal closed loop, as shown in the figure below. We want to write the voltage drops in the closed-loop. According to Kirchhoff's voltage law, the sum of all the voltage drops across the components connected in the loop \(ABCDA\) is equal to zero. So we can write:-   \(\sum\limits_{k = 1}^n {{V_k}} = 0\) Here, \(n\) is the total number of electrical components in the loop. i.e \({V_{AB}} + {V_{BC}} + {V_{CD}} + {V_{DA}} = 0\) When applying KCL, we have to consider the currents leaving a junction to be negative and the currents entering the junction to be taken as positive in sign. Also, during the application of KVL, we maintain the same anti-clockwise or clockwise direction from the point we started in the loop and account for all voltage drops as negative and rises as positive. This leads us to the starting point where the final sum of all the voltage drop is zero. Sign conventions: An increase of potential difference or \({\rm{EMF}}\) from lower to higher is always considered positive in a loop. A decrease of potential difference or \({\rm{EMF}}\) from higher to lower is always considered negative in a loop.The voltage drop across the resistor is taken as negative if the direction of the looping is the same as the direction of the current flowing through the circuit. To determine the values of current flowing and voltage drop in the different parts of the complex circuit.It helps in knowing the direction of current in different loops of the circuits.Kirchhoff's Laws are useful in understanding the transfer of energy through an electric circuit. The major drawback of Kirchhoff's law is that it assumes there is no fluctuating Magnetic field across the area of the loop which can cause a change in magnetic flux and generation of \({\rm{EMF}}\) in the circuit. This may cause an error in the calculation of high-frequency \({\rm{AC}}\) circuits.Kirchhoff also neglected the effect of the electric field produced due to other parts of the circuit.\({\rm{KCL}}\) is applicable on the assumption that current flows only in conductors and wires. While in High-Frequency circuits where parasitic capacitance can no longer be ignored. In such cases, current may startcan flowing in an open circuit because in these cases, conductors or wires are acting as transmission lines. Q.1. From the given circuit in the below image, find the value of \(I\)? Ans: Apply Kirchhoff's first law to the point \(P\) in the given circuit.Let consider the sign convention as the arrows pointing towards \(P\) is positive and away from \(P\) are negative.Therefore, we have:\(0.2\,{\rm{A}} – 0.4\,{\rm{A}} + 0.6\,{\rm{A}} – 0.5\,{\rm{A}} + 0.7\,{\rm{A}} – I = 0\)\(\Rightarrow 1.5\,{\rm{A}} – 0.9\,{\rm{A}} – I = 0\)\(\Rightarrow 0.6\,{\rm{A}} – I = 0\)\(\Rightarrow I = 0.6\,\rm{A}\) Q.2. Use Kirchhoff's rules to find the value of unknown resistance \(R\) in the below circuit, such that there is no current flowing through \(4\) ohms \(\left(\Omega \right)\) resistance. Also, find the potential difference between points \(A\) and \(D.\) Ans: Since it is given in the question that there is no current flowing through the \(4\,\Omega \) resistor, so all the current flowing along \(FE\) will go along \(ED\) (By Kirchhoff's first law).Then, the current distribution is shown in the below circuit Now, Applying Kirchhoff's second law in mesh \(AFEBA,\)We have:- \(– 1 \times I – 1 \times I – 4 \times 0 – 6 + 9 = 0\)\(\Rightarrow \,\,\, – 2I + 3 = 0\)\(\Rightarrow \,\,\,\,I = \frac{3}{2}\,\rm{A}\,\,\,\,\,\,\,\,\,\,\,\,…..\left({\rm{1}} \right)\)Again, Applying Kirchhoff's \({{\rm{2}}^{{\rm{nd}}}}\) law in mesh \(AFDCA,\)We have: \(– 1 \times I – 1 \times I – I \times R – 3 + 9 = 0\)\(\Rightarrow \,\,\, – 2I – IR + 6 = 0\)\(\Rightarrow 2I + IR = 6……..\left(2 \right)\)From equations \(\left(1 \right)\) and \(\left(2 \right),\) we get\(\Rightarrow \left({2 \times \frac{3}{2}} \right) + \frac{3}{2}R = 6\)\(\Rightarrow R = 2\,\Omega \)Again, for potential differences across \(A\) and \(D\) along with AFD,We have:- \({V_A} – \frac{3}{2} \times 1 – \frac{3}{2} \times 1 = {V_D}\)\(\Rightarrow {V_A} – {V_D} = 3\,\rm{V}\) Kirchhoff's circuit laws are important to circuit analysis. We have the essential instrument to begin studying circuits with the use of these principles and the equations for individual components (resistor, capacitor, and inductor). Gustav Kirchhoff provided a better understanding to solve simple as well as complex circuits and networks.The first law of Kirchhoff states that the total current that enters a node or junction is equal to the total current or charge leaving the node. It is based on Conservation of Charge. This is also called the junction rule. i.e \(\sum\limits_{k = 1}^n {{I_k}} = 0\) 3. The second law of Kirchhoff states that the sum of voltage drops across each electrical component connected in the loop will be equal to zero. It is based on the law of Conservation of Energy. This is also called the loop rule.   i.e \(\sum\limits_{k = 1}^n {{V_k}} = 0\) 4. Kirchhoff's law is not suitable for high-frequency \({\rm{AC}}\) circuits. Q.1. What is the Junction and loop Rule?Ans: The junction rule is also known as Kirchhoff's Current Law KCL and it states that at any junction the sum of the entering currents is equal to the sum of the leaving currents.Kirchhoff's Loop Rule also known as Kirchhoff's Voltage Law KVL and it states that the sum of the voltage differences around the loop must be equal to zero. Q.2. What is Node Voltage?Ans: When we use the term node voltage, we are referring to the potential difference between two nodes of a circuit. We select one of the nodes in the given circuit as a reference node. All the voltages of other nodes are measured concerning this one reference node. Q.3. What is the importance of Kirchhoff's law in daily life?Ans: Kirchhoff's laws can be used to determine the values of unknown values like current, voltage in the circuit. These laws can be applied in any circuit (with some limitations), and useful to find the unknown values in complex circuits and networks. It helps in knowing the energy transfer in different parts of the circuit. Q.4. Does Kirchhoff's law fail at high frequency?Ans: Yes, Kirchhoff's laws fail at high frequency, because both the law \({{\rm{KCL}}}\) and \({{\rm{KVL}}}\) are not suitable for \({{\rm{AC}}}\) circuits of high frequencies. At higher frequencies, the interference of induced emf due to varying magnetic fields becomes significant. We hope this detailed article on Kirchhoff's Laws helps you in your preparation. If you get stuck do let us know in the comments section below and we will get back to you at the earliest. Kirchhoff's Laws act as the best tool for circuit analysis techniques. Georg Ohm's work (Ohm's law) formed the foundation to create Kirchhoff's Current Law (KCL) and Kirchhoff's Voltage Law (KVL) by Gustav Robert Kirchhoff in 1845. The objective of this post is to give a better understanding of Kirchhoff's Laws of Current and Voltage, its applications, advantages and limitation. Kirchhoff's Laws The laws of Kirchhoff are the two equations that address conservation of energy and charge with reference to electrical circuits. They are very important in the analysis of closed and complex electrical circuits such as bridge or T networks in which calculating voltages or currents circulating within the circuit becomes difficult using Ohm's law alone. Fig. 1 – Introduction to Kirchhoff's First and Second Laws Kirchhoff's Laws of Current and Voltage Kirchhoff's Laws of Current and Voltage may be divided in two separate laws, i.e.: Kirchhoff's Current Law (KCL) or First Law Kirchhoff's Voltage Law (KVL) or Second Law Kirchhoff's Current Law (KCL) or First Law: The first law of Kirchhoff's laws is Kirchhoff's Current Law. It states that "The total current or charge entering a junction or node is exactly equal to the current leaving the node, as no charge is lost within the node". It can also be stated as the sum of currents in a network of conductors meeting at a node is equal to zero. Fig. 2 – Visual Representation of Kirchhoff's Current Law From the above figure,we can infer that the sum of the currents entering and leaving a node is equal to Zero (0). The current flowing towards the junction is considered positive and the current flowing away from the node or junction is considered negative. In other words, KCL can be defined as the algebraic sum of all the currents entering and leaving a node must be equal to zero, i.e. Iin + Iout = 0. Kirchhoff's Voltage Law (KVL) or Second Law: The second law of Kirchhoff's laws is Kirchhoff's Voltage Law. It states that in any closed loop network, the sum of the emf values in any closed loop is equal to the sum of the potential drops in that loop. Fig. 3 – Visual Representation of Kirchhoff's Voltage Law In another words, it can also be said as "The total voltage around the loop is equal to the sum of all the voltage drops within the same loop", which is equal to zero. Applications of Kirchhoff's Laws The applications include: They can be used to analyze any electrical circuit. Computation of current and voltage of complex circuits. Advantages of Kirchhoff's Laws The advantages are: Calculation of unknown currents and voltages is easy. Simplification and analysis of complex closed loop circuits becomes manageable. Limitations of Kirchhoff's Laws The limitation of Kirchhoff's both laws is that it works under the assumption that there is no fluctuating magnetic field in the closed loop. Electric fields and emf could be induced which causes the Kirchhoff's loop rule to break in presence of a variable magnetic field. Also Read:Series Circuit – Working Principle, Characteristics, Applications, AdvantageWhat is Parallel Circuit – How to Make, Characteristics, ApplicationsVoltmeter – Working Principle, Voltage Sensitivity, Types and Applications Written By Saurav_C Last Modified 22-06-2023 Kirchhoff's Laws help in the construction of complicated circuits containing numerous electrical components seen in everyday life. It also helps in the analysis of any electrical circuits, for example, how much current flows in different areas of an electrical circuit? What was the magnitude of the voltage loss in different regions of the network? What is the current direction in each circuit branch? In this article, we will look at Kirchhoff's current and voltage laws and how they are used in electrical appliances to calculate the current flowing and voltage drop in various areas of complicated circuits. Read further to find more. Kirchhoff's Law: Gustav Robert Kirchhoff was a German physicist born in Russia. 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Kirchhoff's \({{\bf{2}}^{{\bf{nd}}}}\) Law:- It is also known as Kirchhoff's Voltage Law (KVL), and it states that the"voltage drop around a loop equals to the algebraic sum of the voltage drop across every electrical component connected in the same loop for any closed network and also equals to zero". Note:- Kirchhoff's Voltage Law is based on the law of conservation of energy, because the net change in the energy of a charge, after the charge completes a closed path must be zero. Let's take an example to understand Kirchhoff's Voltage Law. Consider a part of a resistor network with an internal closed loop, as shown in the figure below. We want to write the voltage drops in the closed-loop. According to Kirchhoff's voltage law, the sum of all the voltage drops across the components connected in the loop \(ABCDA\) is equal to zero. 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It helps in knowing the energy transfer in different parts of the circuit. Q.4. Does Kirchhoff's law fail at high frequency?Ans: Yes, Kirchhoff's laws fail at high frequency, because both the law \({{\rm{KCL}}}\) and \({{\rm{KVL}}}\) are not suitable for \({{\rm{AC}}}\) circuits of high frequencies. At higher frequencies, the interference of induced emf due to varying magnetic fields becomes significant. We hope this detailed article on Kirchhoff's Laws helps you in your preparation. If you get stuck do let us know in the comments section below and we will get back to you at the earliest. Written By Saurav_C Last Modified 22-06-2023 Kirchhoff's Laws help in the construction of complicated circuits containing numerous electrical components seen in everyday life. It also helps in the analysis of any electrical circuits, for example, how much current flows in different areas of an electrical circuit? What was the magnitude of the voltage loss in different regions of the network? What is the current direction in each circuit branch? In this article, we will look at Kirchhoff's current and voltage laws and how they are used in electrical appliances to calculate the current flowing and voltage drop in various areas of complicated circuits. Read further to find more. Kirchhoff's Law: Gustav Robert Kirchhoff was a German physicist born in Russia. His work involved researching electrical conduction. In \(1845,\) he formulated two laws known as Kirchhoff's Voltage Law (KVL) and Kirchhoff's Current Law (KCL). They combined known as Kirchhoff's Circuit law. These laws are used for the analysis of circuits. They help in calculating the flow of current in different streams through the network. Kirchhoff's \({{\bf{1}}^{{\bf{st}}}}\) law:- It is also known as Kirchhoff's Current Law (KCL), and it states that the "total current or charge entering a junction or node is exactly equal to the total current or charge leaving the node, as no charge is lost at the node". In other words, the algebraic sum of all the currents entering and leaving a node must be equal to zero. Note:- Kirchhoff's current law supports the law of conservation of charge. So we can say that Nord or junction is a point in a circuit that does not act as a source or sink of charge(s). So, \(\sum\limits_{k = 1}^n {{I_k}} = 0\) Where \(n\) is the total number of all the branches at with currents flowing towards or away from the node. i.e \({I_{{\rm{(exiting) }}}} + {I_{{\rm{(entering) }}}} = 0……..\left(1 \right)\) Let us understand this with an example. Focus on node \(A\) from a resistor network. Four branches are connected to this node. There are two incoming currents named \({i_1}\) and \({i_2}\) and two outgoing currents named \({i_3}\) and \({i_4}.\) Now, according to Kirchhoff's current law, the sum of total incoming and outgoing currents at node \(A\) will be equal to zero. Now, consider the two currents entering the node, \({i_{1,}}\) and \({i_{2,}}\) with a positive value, and the two currents leaving the node, \({i_3}\) and \({i_4}\) are negative in value. So, we can also rewrite the equation \((1)\) as: \({i_1} + {i_2} – {i_3} – {i_4} = 0……\left(2 \right)\) 2. Kirchhoff's \({{\bf{2}}^{{\bf{nd}}}}\) Law:- It is also known as Kirchhoff's Voltage Law (KVL), and it states that the"voltage drop around a loop equals to the algebraic sum of the voltage drop across every electrical component connected in the same loop for any closed network and also equals to zero". Note:- Kirchhoff's Voltage Law is based on the law of conservation of energy, because the net change in the energy of a charge, after the charge completes a closed path must be zero. Let's take an example to understand Kirchhoff's Voltage Law. Consider a part of a resistor network with an internal closed loop, as shown in the figure below. We want to write the voltage drops in the closed-loop. According to Kirchhoff's voltage law, the sum of all the voltage drops across the components connected in the loop \(ABCDA\) is equal to zero. So we can write:-   \(\sum\limits_{k = 1}^n {{V_k}} = 0\) Here, \(n\) is the total number of electrical components in the loop. i.e \({V_{AB}} + {V_{BC}} + {V_{CD}} + {V_{DA}} = 0\) When applying KCL, we have to consider the currents leaving a junction to be negative and the currents entering the junction to be taken as positive in sign. Also, during the application of KVL, we maintain the same anti-clockwise or clockwise direction from the point we started in the loop and account for all voltage drops as negative and rises as positive. This leads us to the starting point where the final sum of all the voltage drop is zero. Sign conventions: An increase of potential difference or \({\rm{EMF}}\) from lower to higher is always considered positive in a loop. A decrease of potential difference or \({\rm{EMF}}\) from higher to lower is always considered negative in a loop.The voltage drop across the resistor is taken as negative if the direction of the looping is the same as the direction of the current flowing through the circuit. To determine the values of current flowing and voltage drop in the different parts of the complex circuit.It helps in knowing the direction of current in different loops of the circuits.Kirchhoff's Laws are useful in understanding the transfer of energy through an electric circuit. The major drawback of Kirchhoff's law is that it assumes there is no fluctuating Magnetic field across the area of the loop which can cause a change in magnetic flux and generation of \({\rm{EMF}}\) in the circuit. This may cause an error in the calculation of high-frequency \({\rm{AC}}\) circuits.Kirchhoff also neglected the effect of the electric field produced due to other parts of the circuit.\({\rm{KCL}}\) is applicable on the assumption that current flows only in conductors and wires. While in High-Frequency circuits where parasitic capacitance can no longer be ignored. In such cases, current may startcan flowing in an open circuit because in these cases, conductors or wires are acting as transmission lines. Q.1. From the given circuit in the below image, find the value of \(I\)? Ans: Apply Kirchhoff's first law to the point \(P\) in the given circuit.Let consider the sign convention as the arrows pointing towards \(P\) is positive and away from \(P\) are negative.Therefore, we have:\(0.2\,{\rm{A}} – 0.4\,{\rm{A}} + 0.6\,{\rm{A}} – 0.5\,{\rm{A}} + 0.7\,{\rm{A}} – I = 0\)\(\Rightarrow 1.5\,{\rm{A}} – 0.9\,{\rm{A}} – I = 0\)\(\Rightarrow 0.6\,{\rm{A}} – I = 0\)\(\Rightarrow I = 0.6\,\rm{A}\) Q.2. Use Kirchhoff's rules to find the value of unknown resistance \(R\) in the below circuit, such that there is no current flowing through \(4\) ohms \(\left(\Omega \right)\) resistance. Also, find the potential difference between points \(A\) and \(D.\) Ans: Since it is given in the question that there is no current flowing through the \(4\,\Omega \) resistor, so all the current flowing along \(FE\) will go along \(ED\) (By Kirchhoff's first law).Then, the current distribution is shown in the below circuit Now, Applying Kirchhoff's second law in mesh \(AFEBA,\)We have:- \(– 1 \times I – 1 \times I – 4 \times 0 – 6 + 9 = 0\)\(\Rightarrow \,\,\, – 2I + 3 = 0\)\(\Rightarrow \,\,\,\,I = \frac{3}{2}\,\rm{A}\,\,\,\,\,\,\,\,\,\,\,\,…..\left({\rm{1}} \right)\)Again, Applying Kirchhoff's \({{\rm{2}}^{{\rm{nd}}}}\) law in mesh \(AFDCA,\)We have: \(– 1 \times I – 1 \times I – I \times R – 3 + 9 = 0\)\(\Rightarrow \,\,\, – 2I – IR + 6 = 0\)\(\Rightarrow 2I + IR = 6……..\left(2 \right)\)From equations \(\left(1 \right)\) and \(\left(2 \right),\) we get\(\Rightarrow \left({2 \times \frac{3}{2}} \right) + \frac{3}{2}R = 6\)\(\Rightarrow R = 2\,\Omega \)Again, for potential differences across \(A\) and \(D\) along with AFD,We have:- \({V_A} – \frac{3}{2} \times 1 – \frac{3}{2} \times 1 = {V_D}\)\(\Rightarrow {V_A} – {V_D} = 3\,\rm{V}\) Kirchhoff's circuit laws are important to circuit analysis. We have the essential instrument to begin studying circuits with the use of these principles and the equations for individual components (resistor, capacitor, and inductor). Gustav Kirchhoff provided a better understanding to solve simple as well as complex circuits and networks.The first law of Kirchhoff states that the total current that enters a node or junction is equal to the total current or charge leaving the node. It is based on Conservation of Charge. This is also called the junction rule. i.e \(\sum\limits_{k = 1}^n {{I_k}} = 0\) 3. The second law of Kirchhoff states that the sum of voltage drops across each electrical component connected in the loop will be equal to zero. It is based on the law of Conservation of Energy. This is also called the loop rule.   i.e \(\sum\limits_{k = 1}^n {{V_k}} = 0\) 4. Kirchhoff's law is not suitable for high-frequency \({\rm{AC}}\) circuits. Q.1. What is the Junction and loop Rule?Ans: The junction rule is also known as Kirchhoff's Current Law KCL and it states that at any junction the sum of the entering currents is equal to the sum of the leaving currents.Kirchhoff's Loop Rule also known as Kirchhoff's Voltage Law KVL and it states that the sum of the voltage differences around the loop must be equal to zero. Q.2. What is Node Voltage?Ans: When we use the term node voltage, we are referring to the potential difference between two nodes of a circuit. We select one of the nodes in the given circuit as a reference node. All the voltages of other nodes are measured concerning this one reference node. Q.3. What is the importance of Kirchhoff's law in daily life?Ans: Kirchhoff's laws can be used to determine the values of unknown values like current, voltage in the circuit. These laws can be applied in any circuit (with some limitations), and useful to find the unknown values in complex circuits and networks. It helps in knowing the energy transfer in different parts of the circuit. Q.4. Does Kirchhoff's law fail at high frequency?Ans: Yes, Kirchhoff's laws fail at high frequency, because both the law \({{\rm{KCL}}}\) and \({{\rm{KVL}}}\) are not suitable for \({{\rm{AC}}}\) circuits of high frequencies. At higher frequencies, the interference of induced emf due to varying magnetic fields becomes significant. We hope this detailed article on Kirchhoff's Laws helps you in your preparation. If you get stuck do let us know in the comments section below and we will get back to you at the earliest. While working engineers were designing hardware for production, a large controversy erupted regarding the validity of Kirchhoff's law. The controversy sprang up when Mehdi Sadadhgar posted this YouTube video challenging former MIT professor Walter Lewin:Sadadhgar is not a crank—he has over 2.5 million subscribers for his electrical engineering videos. The video he posted has 650,000 views. He has a Master's in electrical engineering and observes, "My mom thinks I am mostly OK." In the video Sadadhgar politely and respectfully observes that Lewin teaches in an online course that "Kirchhoff's voltage law, or KVL, doesn't hold true in some cases…" Sadadhgar suggests that Lewin may have a problem with the probing of the circuit.Walter Lewin's "Paradox"Lewin is a physicist, and maintains that it is Faraday's law, not Kirchhoff's, that always holds true. Sadadhgar cites four of Lewin's videos. The first, "8.02x- Lect 16 - Electromagnetic Induction, Faraday's Law, Lenz Law, SUPER DEMO," has 1.2 million views and gives an overview of Faraday's observations on induction between a solenoid and a loop of wire enclosing the solenoid:It's based on a 2002 paper Lewin wrote. To Lewin's credit, he does a physical demonstration of a solenoid inducing a current in a loop of wire.The video that likely incited Sadadhgar's disagreement has the combative title "Kirchhoff's Loop Rule Is For The Birds":Lewin states he will be teaching "…something so non-intuitive that almost all college physics books have it wrong."Lewin starts the lecture with a simple circuit diagram with two resistors in a loop with a nearby solenoid (Fig. 1). Most electrical engineers will realize that either energizing or turning off the solenoid will induce a current in the loop, with the commensurate voltages being created across the resistors. Lewin goes on to show two voltmeters on each side of his two-resistor circuit (Fig. 2). He does the math to show the voltmeters will read differently, despite being hooked to the same two points.1. Walter Lewin sets up his "paradox" with two resistors in a loop that has a nearby solenoid. The circles with dots in the center are looking down on the arrowheads representing the magnetic field coming out of the blackboard. (Courtesy of YouTube)2. Lewin goes on to show two voltmeters attached to the loop, and fills the blackboard with math that shows the voltmeters will read differently due to path dependency. (Courtesy of YouTube)In Lewin's video, he refers to one of his earlier lectures where he hooks two oscilloscopes in place of the voltmeters (see "SUPER DEMO" video above). Sure enough, despite being connected across the same circuit nodes, the oscilloscopes produce different readings (Fig. 3). Lewin credits Faraday, but most engineers would recognize there's a clear probing problem, since the probe wires also form loops that have voltages induced by the changing magnetic field of the nearby solenoid.3. Lewin then connects two oscilloscopes in place of the voltmeters and applies a step function to the solenoid. The 'scopes read differently, in agreement with Lewin's math. (Courtesy of YouTube)A Lesson in Good ProbingThe probing issue was clearly demonstrated in a video by Cyriel Mabilde of Ghent University in Belgium. He posted a video, "Walter Lewin: electromagnetic induction=not for the birds (lecture 16)" that has some truly great experimental results:Mabilde notes how Lewin says the EMF (electromotive force) must be in the resistors, since as long as the voltmeter or oscilloscope in on the same side, moving the probe points closer or further from either resistor yields the same value. Mabilde then notes Lewin's contradictory observation that the EMF must exist in every part of the wires. He admits Lewin's demonstration was "against all intuition." He then states, "I will try to dispel the doubts, not by proclaiming a new theory, but by repeating the experiment in a clearer way."Mabilde then builds a precise solenoid and fashions a two-resistor circuit with copper foil instead of a wire (Fig. 4). He uses a near-field probe to map the magnetic field surrounding the solenoid when he excites it with an ac current. He fashions a loop to demonstrate the zero-flux plane (Fig. 5). He then uses a probe tip with a brush to connect at any point in the copper foil that connects the two resistors. Mabilde then clearly shows the scope result depends on which side of the circuit that you hang the probe wires. He notes, "The measurement error in the wiring as the same order of magnitude as the value we want to measure."4. Cyriel Mabilde built a setup to demonstrate the probing issues in Lewin's setup. He made the single loop with two resistors using copper foil, so he can probe anywhere along the "wire." (Courtesy of YouTube)5. Cyriel Mabilde improves Lewin's demo by exciting the solenoid with ac current instead of a momentary pulse. He shows how a coil of wire in the mid-plane of the solenoid is in a zero-flux environment. (Courtesy of YouTube)Next, Mabilde goes on to use a 5-turn loop in the circuit with the two resistors, to show how the measurement error is proportionally smaller. He then builds an internal loop with the probe wires leaving in the zero-flux plane (Fig. 6). He demonstrates you can measure the EMF in the loop wires if you make sure the probe wires are not adding or subtracting to the measurement. Mabilde concludes, "…the single loop is a very special transformer: if you want to investigate it, be careful to avoid extra unwanted measurements. We know that Kirchhoff is right in this case…. Invoking the theory of path dependency in not the right answer for explaining these simple measurements."6. Mabilde then makes a two-resistor loop that fits inside the solenoid, so he can get the probe wires routed out along the zero-flux plane. Afterward, he shows that EMF exists along the wires, in accordance with a paper by Princeton's Kirk McDonald. (Courtesy of YouTube)Conflict SellsIt's interesting to note that both Sadadhgar and Lewin have millions of views, while Mabilde has 4,360. His video shows the majesty of the scientific method and the precision and diligence needed to set up good experiments. People must find that boring. This explains why Clint Eastwood insists on conflict in his movie scripts. If you watch just one video in this whole article, make it Mabilde's.Mabilde based his video on a paper written by Kirk T. McDonald of Princeton University (Fig. 7). Titled "Lewin's Circuit Paradox," McDonald notes, "Kirchhoff never applied his laws to time-dependent circuits, such as in Lewin's example." So, what we have is a classic case of "it's all in the definitions." If you define Kirchhoff's law as what Gustav Kirchhoff stated in 1845, well, Lewin is right, the law doesn't hold for Lewin's circuit example. Yet electrical engineers think of Kirchhoff's law as the refined principle that incorporated time-dependent circuits and energy addition. McDonald explains how Kirchhoff's law was improved by Heaviside, Helmholtz, Thomson, and Maxwell himself.7. Professor Kirk McDonald of Princeton University at the Temple of Heracles. (Courtesy of Kirk McDonald)Kirchhoff and SpiceI wonder how Bob Pease would have reacted to this brouhaha. We know he hated Spice, and said "Spice lies!" Spice uses matrix math to solve Kirchhoff's equations, so if Kirchhoff is wrong, then so is Spice. Most electrical engineers would look at Lewin's circuit and see that he has a model problem. His circuit shows simple wires connecting the two resistors when, in reality, they are the secondary coil of a transformer. If you change the circuit to show the coils, Kirchhoff's law works once again. You can similarly account for thermal losses or energy gains, you just have to model it in the schematic.Things get murkier with transmission lines, but Spice can solve for that, too, within limits. At RF frequencies, the potential in a wire changes along its length. Also, every component in your circuit is radiating and receiving energy from the other components and the outside world. That's when Kirchhoff and Spice no longer apply.The joust between Sadadhgar and Lewin got quite heated. Lewin did two follow-on videos. One is titled "ha ha ha 5 + 3 - 8 = 0," where he restates his contention that Kirchoff does not always work:He responds to his critics by claiming they are using circular reasoning, as in the arithmetic in the title. In his next video, "Believing and Science are Very Different," he addresses what he feels are criticisms to his argument. Lewin comes across as dismissive, haughty, and arrogant in these videos, which does not help his case:Then Lewin directly addressed Sadadhgar's video with "To Agree or Not to Agree that is Not the Question," and "To Agree or Not to Agree with the Master that is Not what Matters":Lewin's ApologyAt the end of the video, Lewin ridicules Sadadhgar, without naming him, for Sadadhgar's contention that Lewin has a probing problem. Big mistake. Three days later, Lewin posted the video "My Sincere Apologies::He once again invokes Romer's paper, still maintains that he is right, and says that a "modern" interpretation of Kirchhoff's law that deals with non-conservative external fields is "a joke." Lewin says "If I was too blunt and not very tactful, I sincerely apologize. Yes, I really mean that." He then encourages Sadadhgar to keep "entertaining his followers."I am sure this apology came about because of the thousands of Sadadhgar viewers who bombarded Lewin with hostile and often profane comments. Thirteen days later, Sadadhgar ended the confrontation with his video, "Kirchhoff's Voltage Law versus Faraday's Law: the Conclusion":Sadadhgar posts a paper by John W. Belcher, an MIT physics professor (Fig. 8). The paper gives a very rigorous examination of why the two oscilloscopes in Lewin's demonstration gave different readings when attached to the same points in the circuit. To me, it sure seems like the "probing error" that Lewin ridiculed Sadadhgar for suggesting. The video description also cited a lecture by physicist Richard Feynman about Kirchhoff's law. I see this as the "modern" interpretation of Kirchhoff's law that Lewin ridiculed.8. MIT professor John W. Belcher wrote a paper specifically addressing the Lewin "paradox," and the observations of Mehdi Sadadhgar, known as ElectroBoom on YouTube, in his popular EE videos. (Courtesy of MIT)The Sociology of Technical PeopleI find this entire argument more a lesson in sociology than physics. Where Lewin comes across as haughty and self-absorbed, Sadadhgar is engaging and clowns around, purposely shocking himself and creating explosions. It does not help Lewin's case that he was stripped of his emeritus professorship by MIT after they discovered he was sexually harassing female students in his online course. I link to it in case you think it was a silly thoughtless comment or suggestive glance. No, it was some really despicable behavior. This should have no effect on our judgment of the science, but as they say on Perry Mason, "It goes to the witness's character, your Honor."From the comments in the videos, you can see lines drawn between physicists, who tend to support Lewin, and engineers, who take the side of Sadadhgar. Like it or not, we are tribal animals. Now, the Wikipedia entry on KVL notes its limitations. It states, "KCL [Kirchhoff's current law] and KVL both depend on the lumped element model being applicable to the circuit in question. When the model is not applicable, the laws do not apply. KCL and KVL result from the assumptions of the lumped element model." So, you can see Lewin's point. If the wires connecting the two resistors are modeled as superconducting nodes like he states, and you ignore that they are part of a single-turn transformer, yeah, Kirchhoff does not work.Sadadhgar is certainly right that two points in the circuit can't be at different potentials just because the voltmeter is on different sides of the circuit. It is a probing problem. The thing that Lewin ignores is that voltmeters do not measure EMF at the probe tips. They measure the voltage created across their source impedance caused by a current flowing in the probe wires. We have all seen cell phones and air-conditioning units cause errors in our 'scope probes. I would like to observe Lewin's circuit in an electron microscope where you can observe the wire potentials directly, without probes, using voltage contrast microscopy:So, the stubbornness and arguments are because everyone has a slightly different idea of what Kirchhoff's law really is. Many of us would model in the solenoid's effect with a transformer element in the circuit. That would give the right result, but it's not quite the letter of Kirchhoff's law.Commenter RedTriangle53 noted, "If you propose that Kirchhoff's law holds under a varying magnetic field you're basically disagreeing with one of Maxwell's equations (Faraday's law). Under a varying magnetic field, the E-field has curl and so is no longer conservative, and the core assumption of Kirchhoff's law stops being valid (that all closed path integrals over E are zero). I'm amazed at how many self-proclaimed PhDs in electrical engineering in the comment section are confused about this. Could be due to a difference in how physicists are taught electromagnetism vs. electrical engineers. Maybe if you separate the E-field into a conservative part and a non-conservative part and only allow the conservative part to have "voltage", maybe it makes sense, but this seems incredibly contrived to me. It would be interesting to hear if electrical engineers learn things differently, and in that case how."Thing is, we all use Spice, especially LTSpice, to solve power-supply circuits with varying magnetic fields. All of us accept Faraday's Law. Another commenter, woowooNeedsFaith, states, "Modern 'modified KVL' is Faraday's law in disguise. If you have seen Lewin's videos you should have heard it in one form or another… Start with this [see the "ha ha ha 5 + 3 - 8 = 0 video above]. Then here are the derivations in the wrong way [top video] and the right way [bottom video]:So, I do see the physicists' point. Just like Spice runs out of steam in an RF circuit, KVL might not be the right tool to solve a problem with those non-conservative fields that get people so worked up. The thing is, engineers are not concerned with purity or fidelity to laws. We are trying to get working hardware out the door. If we can "fool" Kirchhoff's law to get the job done, we are not cheating—we are getting the problem solved with arithmetic instead of calculus. Laplace transforms do the same thing, and let's all be thankful for that. Kirchhoff's laws are a set of laws that quantify how current flows through a circuit and how voltage varies around a loop in a circuit. They are used to govern the conservation of charge and energy in standard electrical circuits. Two significant circuital laws are applied in every simple and complex electrical circuit in physics. These laws were postulated in 1845 by German physicist Gustav Kirchhoff. The proof of Kirchhoff's law can be obtained by using Maxwell's equations. Current is defined as the rate of change of charge passing through a conducting wire. Kirchhoff's current law states that the "total current entering a junction or node is exactly equal to the current leaving the node." In other words, the algebraic sum of all the currents entering the node must be equal to the algebraic sum of all the currents leaving a node. This law is commonly known as the conservation of charge. The formula is given by Σ Iin = Σ Iout Electric potential represents the concentration of energy in a circuit. The potential quickly spreads to a uniform value throughout an uninterrupted section of the electrical circuit. The difference in electric potential is called the voltage. Kirchhoff's voltage law states that "in any closed-loop network, the sum of voltage drops around the loop is equal to zero." This law is known as the conservation of energy. The formula is given by Σ Vtotal = 0 The term node in an electrical circuit generally refers to a connection or junction of two or more current-carrying paths. Also, for current to flow either in or out of a node, a closed-circuit path must exist. Kirchhoff's Law KCLKVLStates that the sum of all the currents entering a particular node is equal to the sum of all currents leaving the nodeStates that the sum of all the voltages around a closed path (loop) is zeroNodal analysis is preferred to obtain node potentials as the currents entering/leaving the node can be expressed in terms of node potentialLoop analysis is preferred to obtain loop currents as loop potential differences can be expressed in terms of loop currents A circuit diagram consists of a source of current and voltage along with resistances and impedances, which can be in series, or parallel, or combination of the two. The polarity of the source is indicated by positive and negative signs, which automatically applies to the resistances. Resistances are said to be in series when they are connected in a single path. The current from a source flows through all the resistances in a closed loop. Resistances are said to be in parallel when the path branches and each branch consists of one resistance. The current from the source splits into different paths. The equation for replacing resistances in parallel is a bit more complicated. The sign convention for applying signs to the voltage polarities in KVL equations is as follows. When traversing the loop, if the positive terminal of a voltage difference is encountered before the negative terminal, the voltage difference will be interpreted as positive. If the negative terminal is encountered first, the voltage difference will be interpreted as negative. Kirchhoff's Law Circuit Diagram Kirchhoff's laws are applicable to analyze any circuit regardless of the composition and structure of it. Some of its applications include To find the unknown resistances, impedances, voltages, and currents (direction as well as value).In a branched circuit, currents passing each branch are determined by applying KCL at every junction and KVL in every loop.In a looped circuit, the current passing each independent loop is determined by applying KVL for each loop and calculating the currents in any resistance of the circuit. Kirchhoff's laws are limited in their applicability. They are valid for all cases in which total electric charge is constant in the region into consideration. Essentially, this is always true, so long as the law is applied for a specific point. Over a region, however, charge density may not be constant. Because the charge is conserved, the only way this is possible is if there is a flow of charge across the boundary of the region. This flow would result in current, thus violating Kirchhoff's laws. Another limitation is that it works under the assumption that there is no fluctuating magnetic field in the closed-loop. Electric fields and emf could be induced, which causes Kirchhoff's laws to break in the presence of a variable magnetic field. Article was last reviewed on Friday, February 3, 2023