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1. If R1 = 2 Ω, R2 = 4 Ω, R3 = 6 Ω, determine the electric current flows in the circuit below.Known :Resistor 1 (R1) = 2 Ω Resistor 2 (R2) = 4 ΩResistor 3 (R3) = 6 ΩSource of emf 1 (E1) = 9 VSource of emf 2 (E2) = 3 VWanted: Electric current (I)Solution :This question relates to Kirchhoff's law. How to solve this problem:First, choose the direction of the current. You can decide the opposite current or direction in the clockwise direction.Second, when the current through the resistor (R) there is a potential decrease so that V = IR signed negative. Third, if the current moves from low to high voltage (- to +) then the source of emf (E) signed positive because of the charging of energy at the emf source. If the current moves from high to low voltage (+ to -) then the source of emf (E) signed negative because of the emptying of energy at the emf source.In this solution, the direction of the current is the same as the direction of clockwise rotation.– I R1 + E1 – I R2 – I R3 – E2 = 0– 2 I + 9 – 4 I – 6 I – 3 = 0– 12 I + 6 = 0– 12 I = – 6I = -6 / -12I = 0.5The electric current flows in the circuit are 0.5 A. The electric current signed positive means that the direction of the electric current is the same as the direction of clockwise rotation. If the electric current is negative, then the electric current is opposite the clockwise direction.See also Kinetic theory of gases - problems and solutions2. Determine the electric current that flows in the circuit as shown in the figure below.Solution :In this solution, the direction of the current is the same as the direction of clockwise rotation.-20 – 5I -5I – 12 – 10I = 0-32 – 20I = 0-32 = 20II = -32 / 20I = -1.6 ABecause the electric current is negative, the direction of the electric current is actually opposite to the clockwise direction.

The direction of electric current is not the same as estimation.3. Determine the electric current that flows in the circuit as shown in the figure below.Solution :In this solution, the direction of current is the same as the direction of clockwise rotation.– I – 6I + 12 – 2I + 12 = 0-9I + 24 = 0-9I = -24I = 24 / 9I = 8 / 3 A4. An electric circuit consists of four resistors, R1 = 12 Ohm, R2 = 12 Ohm, R3 = 3 Ohm and R4 = 6 Ohm, are connected with source of emf E1 = 6 Volt, E2 = 12 Volt. Determine the electric current flows in the circuit as shown in figure below.Known :Resistor 1 (R1) = 12 ΩResistor 2 (R2) = 12 ΩResistor 3 (R3) = 3 ΩResistor 4 (R4) = 6 ΩSource of emf 1 (E1) = 6 VoltSource of emf 2 (E2) = 12 VoltWanted : The electric current flows in the circuit (I)Solution :Resistor 1 (R1) and resistor 2 (R2) are connected in parallel. The equivalent resistor :1/R12 = 1/R1 + 1/R2 = 1/12 + 1/12 = 2/12R12 = 12/2 = 6 ΩIn this solution, the direction of current is the same as the direction of clockwise rotation.– I R12 – E1 – I R3 – I R4 + E2 = 0– 6 I – 6 – 3I – 6I + 12 = 0– 6I – 3I – 6I = 6 -12– 15I = – 6I = -6/-15I = 2/5 A5. Determine the electric current that flows in circuit as shown in figure below.Known :Resistor 1 (R1) = 10 ΩResistor 2 (R2) = 6 ΩResistor 3 (R3) = 5 ΩResistor 4 (R4) = 20 ΩSource of emf 1 (E1) = 8 VoltSource of emf 2 (E2) = 12 VoltWanted : The electric current that flows in circuitSolution :Resistor 3 (R3) and resistor 4 (R4) are connected in parallel. The equivalent resistor :See also Springs in series and parallel – problems and solutions1/R34 = 1/R3 + 1/R4 = 1/5 + 1/20 = 4/20 + 1/20 = 5/20R34 = 20/5 = 4 ΩIn this solution, the direction of current is the same as the direction of clockwise rotation.– I R1 – I R2 – E1 – I R34 + E2 = 0– 10I – 6I – 8 – 4I + 12 = 0– 10I – 6I – 4I = 8 – 12– 20I = – 4I = -4/-20I = 1/5 AI = 0.2 A6. Determine the electric current that flows in circuit as shown in figure below.Known :Resistor 1 (R1) = 1 ΩResistor 2 (R2) = 6 ΩResistor 3 (R3) = 6 ΩResistor 4 (R4) = 4 ΩSource of emf 1 (E1) = 12 VoltSource of emf 2 (E2) = 6 VoltWanted : The electric current that flows in circuitSolution :Resistor 1 (R1) and resistor 2 (R2) are connected in parallel.

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By the end of this section, you will be able to: Analyze a complex circuit using Kirchhoff's rules, using the conventions for determining the correct signs of various terms. Many complex circuits, such as the one in Figure 21.21, cannot be analyzed with the series-parallel techniques developed in Resistors in Series and Parallel and Electromotive Force: Terminal Voltage. There are, however, two circuit analysis rules that can be used to analyze any circuit, simple or complex. These rules are special cases of the laws of conservation of charge and conservation of energy.

The rules are known as Kirchhoff's rules, after their inventor Gustav Kirchhoff (1824–1887). Figure 21.21 This circuit cannot be reduced to a combination of series and parallel connections. Kirchhoff's rules, special applications of the laws of conservation of charge and energy, can be used to analyze it. (Note: The script E in the figure represents electromotive force, emf.) Kirchhoff's first rule—the junction rule. The sum of all currents entering a junction must equal the sum of all currents leaving the junction.

Kirchhoff's second rule—the loop rule. The algebraic sum of changes in potential around any closed circuit path (loop) must be zero. Explanations of the two rules will now be given, followed by problem-solving hints for applying Kirchhoff's rules, and a worked example that uses them. Kirchhoff's first rule (the junction rule) is an application of the conservation of charge to a junction; it is illustrated in Figure 21.22. Current is the flow of charge, and charge is conserved; thus, whatever charge flows into the junction must flow out.

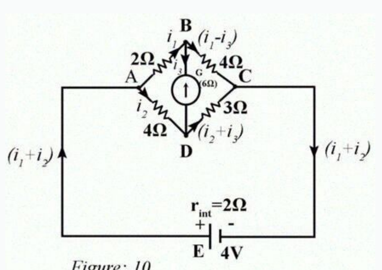

Figure: 10

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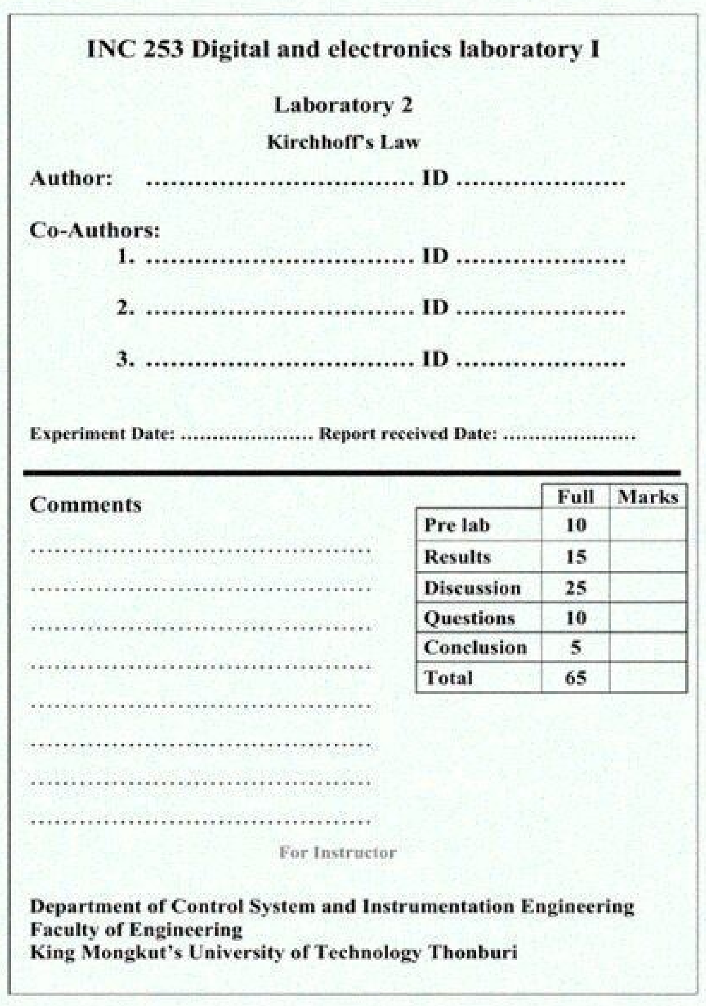

INC 253 Digital and electronics laboratory I

Laboratory 2

Kirchhoff's Law

Author: .... **ID** ....

Co-Authors:

1. .... **ID** ....
2. .... **ID** ....
3. .... **ID** ....

Experiment Date: .... **Report received Date:** ....

Comments

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	Full	Marks
Pre lab	10	
Results	15	
Discussion	25	
Questions	10	
Conclusion	5	
Total	65	

For Instructor

Department of Control System and Instrumentation Engineering
Faculty of Engineering
King Mongkut's University of Technology Thonburi

How to solve this problem:First, choose the direction of the current. You can decide the opposite current or direction in the clockwise direction.Second, when the current through the resistor (R) there is a potential decrease so that V = IR signed negative. Third, if the current moves from low to high voltage (- to +) then the source of emf (E) signed positive because of the charging of energy at the emf source. If the current moves from high to low voltage (+ to -) then the source of emf (E) signed negative because of the emptying of energy at the emf source.In this solution, the direction of the current is the same as the direction of clockwise rotation.– I R1 + E1 – I R2 – I R3 – E2 = 0– 2 I + 9 – 4 I – 6 I – 3 = 0– 12 I + 6 = 0– 12 I = – 6I = -6 / -12I = 0.5The electric current flows in the circuit are 0.5 A. The electric current signed positive means that the direction of the electric current is the same as the direction of clockwise rotation. If the electric current is negative, then the electric current is opposite the clockwise direction.See also Kinetic theory of gases - problems and solutions2. Determine the electric current that flows in the circuit as shown in the figure below.Solution :In this solution, the direction of the current is the same as the direction of clockwise rotation.-20 – 5I -5I – 12 – 10I = 0-32 – 20I = 0-32 = 20II = -32 / 20I = -1.6 ABecause the electric current is negative, the direction of the electric current is actually opposite to the clockwise direction. The direction of electric current is not the same as estimation.3. Determine the electric current that flows in the circuit as shown in the figure below.Solution :In this solution, the direction of current is the same as the direction of clockwise rotation.– I – 6I + 12 – 2I + 12 = 0-9I + 24 = 0-9I = -24I = 24 / 9I = 8 / 3 A4. An electric circuit consists of four resistors, R1 = 12 Ohm, R2 = 12 Ohm, R3 = 3 Ohm and R4 = 6 Ohm, are connected with source of emf E1 = 6 Volt, E2 = 12 Volt. Determine the electric current flows in the circuit as shown in figure below.Known :Resistor 1 (R1) = 12 ΩResistor 2 (R2) = 12 ΩResistor 3 (R3) = 3 ΩResistor 4 (R4) = 6 ΩSource of emf 1 (E1) = 6 VoltSource of emf 2 (E2) = 12 VoltWanted : The electric current flows in the circuit (I)Solution :Resistor 1 (R1) and resistor 2 (R2) are connected in parallel. The equivalent resistor :1/R12 = 1/R1 + 1/R2 = 1/12 + 1/12 = 2/12R12 = 12/2 = 6 ΩIn this solution, the direction of current is the same as the direction of clockwise rotation.– I R12 – E1 – I R3 – I R4 + E2 = 0– 6 I – 6 – 3I – 6I + 12 = 0– 6I – 3I – 6I = 6 -12– 15I = – 6I = -6/-15I = 2/5 A5. Determine the electric current that flows in circuit as shown in figure below.Known :Resistor 1 (R1) = 10 ΩResistor 2 (R2) = 6 ΩResistor 3 (R3) = 5 ΩResistor 4 (R4) = 20 ΩSource of emf 1 (E1) = 8 VoltSource of emf 2 (E2) = 12 VoltWanted : The electric current that flows in circuitSolution :Resistor 3 (R3) and resistor 4 (R4) are connected in parallel. The equivalent resistor :See also Springs in series and parallel – problems and solutions1/R34 = 1/R3 + 1/R4 = 1/5 + 1/20 = 4/20 + 1/20 = 5/20R34 = 20/5 = 4 ΩIn this solution, the direction of current is the same as the direction of clockwise rotation.– I R1 – I R2 – E1 – I R34 + E2 = 0– 10I – 6I – 8 – 4I + 12 = 0– 10I – 6I – 4I = 8 – 12– 20I = – 4I = -4/-20I = 1/5 AI = 0.2 A6.

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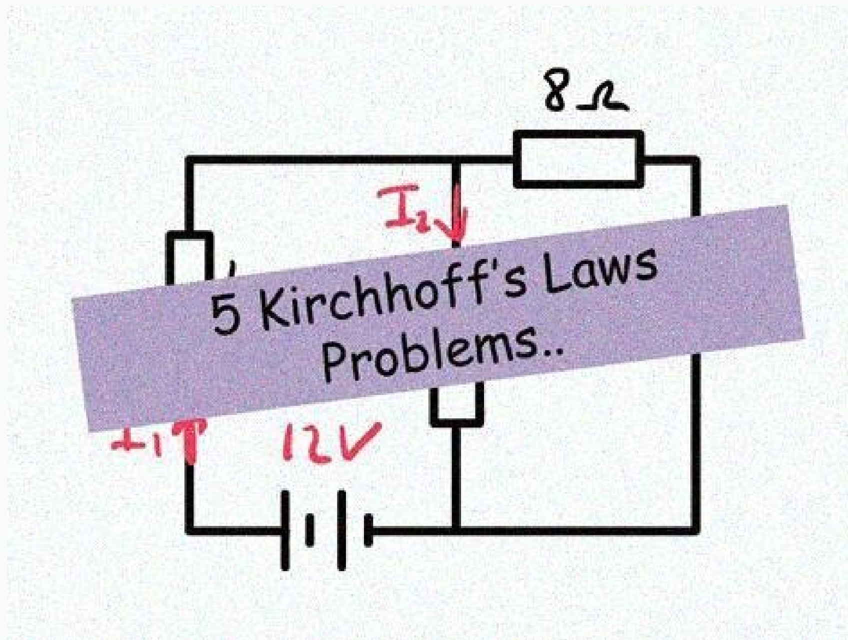

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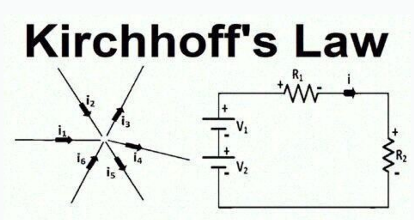
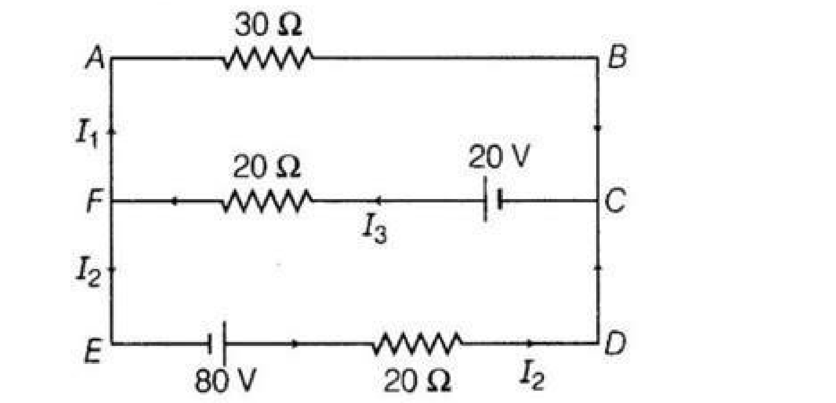
Many complex circuits, such as the one in Figure 21.21, cannot be analyzed with the series-parallel techniques developed in Resistors in Series and Parallel and Electromotive Force: Terminal Voltage. There are, however, two circuit analysis rules that can be used to analyze any circuit, simple or complex. These rules are special cases of the laws of conservation of charge and conservation of energy. The rules are known as Kirchhoff’s rules, after their inventor Gustav Kirchhoff (1824–1887). Figure 21.21 This circuit cannot be reduced to a combination of series and parallel connections. Kirchhoff’s rules, special applications of the laws of conservation of charge and energy, can be used to analyze it. (Note: The script E in the figure represents electromotive force, emf.) Kirchhoff’s first rule—the junction rule. The sum of all currents entering a junction must equal the sum of all currents leaving the junction. Kirchhoff’s second rule—the loop rule. The algebraic sum of changes in potential around any closed circuit path (loop) must be zero. Explanations of the two rules will now be given, followed by problem-solving hints for applying Kirchhoff’s rules, and a worked example that uses them. Kirchhoff’s first rule (the junction rule) is an application of the conservation of charge to a junction; it is illustrated in Figure 21.22. Current is the flow of charge, and charge is conserved; thus, whatever charge flows into the junction must flow out. Kirchhoff’s first rule requires that I1=I2+I3I1=I2+I3 (see figure). Equations like this can and will be used to analyze circuits and to solve circuit problems. Kirchhoff’s rules for circuit analysis are applications of conservation laws to circuits. The first rule is the application of conservation of charge, while the second rule is the application of conservation of energy. Conservation laws, even used in a specific application, such as circuit analysis, are so basic as to form the foundation of that application. Figure 21.22 The junction rule. The diagram shows an example of Kirchhoff’s first rule where the sum of the currents into a junction equals the sum of the currents out of a junction. In this case, the current going into the junction splits and comes out as two currents, so that I1=I2+I3I1=I2+I3. Here I1I1 must be 11 A, since I2I2 is 7 A and I3I3 is 4 A. Kirchhoff’s second rule (the loop rule) is an application of conservation of energy. The loop rule is stated in terms of potential, VV, rather than potential energy, but the two are related since PEelec=qVPEelec=qV. Recall that emf is the potential difference of a source when no current is flowing. In a closed loop, whatever energy is supplied by emf must be transferred into other forms by devices in the loop, since there are no other ways in which energy can be transferred into or out of the circuit. Figure 21.23 illustrates the changes in potential in a simple series circuit loop.Kirchhoff’s second rule requires emf−Ir−IR1−IR2=0emf−Ir−IR1−IR2=0. Rearranged, this is emf=Ir+IR1+IR2emf=Ir+IR1+IR2, which means the emf equals the sum of the IRIR (voltage) drops in the loop. Figure 21.23 The loop rule. An example of Kirchhoff’s second rule where the sum of the changes in potential around a closed loop must be zero. (a) In this standard schematic of a simple series circuit, the emf supplies 18 V, which is reduced to zero by the resistances, with 1 V across the internal resistance, and 12 V and 5 V across the two load resistances, for a total of 18 V. (b) This perspective view represents the potential as something like a roller coaster, where charge is raised in potential by the emf and lowered by the resistances. (Note that the script E stands for emf.) By applying Kirchhoff’s rules, we generate equations that allow us to find the unknowns in circuits. The unknowns may be currents, emfs, or resistances. Each time a rule is applied, an equation is produced.

If there are as many independent equations as unknowns, then the problem can be solved. There are two decisions you must make when applying Kirchhoff’s rules. These decisions determine the signs of various quantities in the equations you obtain from applying the rules. When applying Kirchhoff’s first rule, the junction rule, you must label the current in each branch and decide in what direction it is going. For example, in Figure 21.21, Figure 21.22, and Figure 21.23, currents are labeled I1I1, I2I2, I3I3, and II, and arrows indicate their directions. There is no risk here, for if you choose the wrong direction, the current will be of the correct magnitude but negative. When applying Kirchhoff’s second rule, the loop rule, you must identify a closed loop and decide in which direction to go around it, clockwise or counterclockwise. For example, in Figure 21.23 the loop was traversed in the same direction as the current (clockwise). Again, there is no risk; going around the circuit in the opposite direction reverses the sign of every term in the equation, which is like multiplying both sides of the equation by –1.–1. Figure 21.24 and the following points will help you get the plus or minus signs right when applying the loop rule. Note that the resistors and emfs are traversed by going from a to b. In many circuits, it will be necessary to construct more than one loop. In traversing each loop, one needs to be consistent for the sign of the change in potential. (See Example 21.5.) Figure 21.24 Each of these resistors and voltage sources is traversed from a to b. The potential changes are shown beneath each element and are explained in the text. (Note that the script E stands for emf.) When a resistor is traversed in the same direction as the current, the change in potential is −IR−IR. (See Figure 21.24.) When a resistor is traversed in the direction opposite to the current, the change in potential is +IR+IR. (See Figure 21.24.) When an emf is traversed from –– to + (the same direction it moves positive charge), the change in potential is +emf. (See Figure 21.24.) When an emf is traversed from + to –– (opposite to the direction it moves positive charge), the change in potential is − − emf. (See Figure 21.24.) Find the currents flowing in the circuit in Figure 21.25. Figure 21.25 This circuit is similar to that in Figure 21.21, but the resistances and emfs are specified. (Each emf is denoted by script E.) The currents in each branch are labeled and assumed to move in the directions shown. This example uses Kirchhoff’s rules to find the currents. Strategy This circuit is sufficiently complex that the currents cannot be found using Ohm’s law and the series-parallel techniques—it is necessary to use Kirchhoff’s rules. Currents have been labeled I1I1, I2I2, and I3I3 in the figure and assumptions have been made about their directions. Locations on the diagram have been labeled with letters a through h. In the solution we will apply the junction and loop rules, seeking three independent equations to allow us to solve for the three unknown currents.Solution We begin by applying Kirchhoff’s first or junction rule at point a. This gives since I1I1 flows into the junction, while I2I2 and I3I3 flow out. Applying the junction rule at e produces exactly the same equation, so that no new information is obtained. This is a single equation with three unknowns—three independent equations are needed, and so the loop rule must be applied. Now we consider the loop abcdea. Going from a to b, we traverse R2R2 in the same (assumed) direction of the current I2I2, and so the change in potential is −I2R2−I2R2. Then going from b to c, we go from –– to +, so that the change in potential is +emf1+emf1. Traversing the internal resistance r1r1 from c to d gives −I2r1−I2r1. Completing the loop by going from d to a again traverses a resistor in the same direction as its current, giving a change in potential of −I1R1−I1R1.The loop rule states that the changes in potential sum to zero. Thus, −I2R2+emf1−I2r1−I1R1=−I2(R2+r1)+emf1−I1R1=0.−I2R2+emf1−I2r1−I1R1=−I2(R2+r1)+emf1−I1R1=0. Substituting values from the circuit diagram for the resistances and emf, and canceling the ampere unit gives−3I2+18−6I1=0.−3I2+18−6I1=0. Now applying the loop rule to aefgha (we could have chosen abcdefgha as well) similarly gives +I1R1+I3R3+I3r2−emf2= +I1R1+I3R3+r2−emf2=0.+I1R1+I3R3+I3r2−emf2= +I1R1+I3R3+r2−emf2=0. Note that the signs are reversed compared with the other loop, because elements are traversed in the opposite direction. With values entered, this becomes +6I1+2I3−45=0.+6I1+2I3−45=0.



1. If R1 = 2 Ω, R2 = 4 Ω, R3 = 6 Ω, determine the electric current flows in the circuit below.Known :Resistor 1 (R1) = 2 Ω Resistor 2 (R2) = 4 ΩResistor 3 (R3) = 6 ΩSource of emf 1 (E1) = 9 VSource of emf 2 (E2) = 3 VWanted: Electric current (I)Solution :This question relates to Kirchhoff’s law. How to solve this problem:First, choose the direction of the current. You can decide the opposite current or direction in the clockwise direction.Second, when the current through the resistor (R) there is a potential decrease so that V = IR signed negative. Third, if the current moves from low to high voltage (- to +) then the source of emf (E) signed positive because of the charging of energy at the emf source. If the current moves from high to low voltage (+ to -) then the source of emf (E) signed negative because of the emptying of energy at the emf source.In this solution, the direction of the current is the same as the direction of clockwise rotation.– I R1 + E1 – I R2 – I R3 – E2 = 0– 2 I + 9 – 4 I – 6 I – 3 = 0– 12 I + 6 = 0– 12 I = – 6I = -6 / -12I = 0.5The electric current flows in the circuit are 0.5 A. The electric current signed positive means that the direction of the electric current is the same as the direction of clockwise rotation. If the electric current is negative, then the electric current is opposite the clockwise direction.See also Kinetic theory of gases - problems and solutions2. Determine the electric current that flows in the circuit as shown in the figure below.Solution :In this solution, the direction of the current is the same as the direction of clockwise rotation.-20 – 5I -5I – 12 – 10I = 0-32 – 20I = 0-32 = 20II = -32 / 20I = -1.6 ABecause the electric current is negative, the direction of the electric current is actually opposite to the clockwise direction. The direction of electric current is not the same as estimation.3. Determine the electric current that flows in the circuit as shown in the figure below.Solution :In this solution, the direction of current is the same as the direction of clockwise rotation.– I – 6I + 12 – 2I + 12 = 0-9I + 24 = 0-9I = -24I = 24 / 9I = 8 / 3 A4. An electric circuit consists of four resistors, R1 = 12 Ohm, R2 = 12 Ohm, R3 = 3 Ohm and R4 = 6 Ohm, are connected with source of emf E1 = 6 Volt, E2 = 12 Volt. Determine the electric current flows in the circuit as shown in figure below.Known :Resistor 1 (R1) = 12 ΩResistor 2 (R2) = 12 ΩResistor 3 (R3) = 3 ΩResistor 4 (R4) = 6 ΩSource of emf 1 (E1) = 6 VoltSource of emf 2 (E2) = 12 VoltWanted : The electric current flows in the circuit (I)Solution :Resistor 1 (R1) and resistor 2 (R2) are connected in parallel. The equivalent resistor :1/R12 = 1/R1 + 1/R2 = 1/12 + 1/12 = 2/12R12 = 12/2 = 6 ΩIn this solution, the direction of current is the same as the direction of clockwise rotation.– I R12 – E1 – I R3 – I R4 + E2 = 0– 6 I – 6 – 3I – 6I + 12 = 0– 6I – 3I – 6I = 6 -12– 15I = – 6I = -6/-15I = 2/5 A5. Determine the electric current that flows in circuit as shown in figure below.Known :Resistor 1 (R1) = 10 ΩResistor 2 (R2) = 6 ΩResistor 3 (R3) = 5 ΩResistor 4 (R4) = 20 ΩSource of emf 1 (E1) = 8 VoltSource of emf 2 (E2) = 12 VoltWanted : The electric current that flows in circuitSolution :Resistor 3 (R3) and resistor 4 (R4) are connected in parallel. The equivalent resistor :See also Springs in series and parallel – problems and solutions1/R34 = 1/R3 + 1/R4 = 1/5 + 1/20 = 4/20 + 1/20 = 5/20R34 = 20/5 = 4 ΩIn this solution, the direction of current is the same as the direction of clockwise rotation.– I R1 – I R2 – E1 – I R34 + E2 = 0– 10I – 6I – 8 – 4I + 12 = 0– 10I – 6I – 4I = 8 – 12– 20I = – 4I = -4/-20I = 1/5 AI = 0.2 A6. Determine the electric current that flows in circuit as shown in figure below.Known :Resistor 1 (R1) = 1 ΩResistor 2 (R2) = 6 ΩResistor 3 (R3) = 6 ΩResistor 4 (R4) = 4 ΩSource of emf 1 (E1) = 12 VoltSource of emf 2 (E2) = 6 VoltWanted : The electric current that flows in circuitSolution :Resistor 1 (R1) and resistor 2 (R2) are connected in parallel.

According to the question,



Applying Kirchhoff's junction rule at F node

$$I_3 = I_1 + I_2 \qquad \ldots\text{(i)}$$

Applying Kirchhoff's second rule in loop $ABCF$,

$$-30I_1 + 20 - 20I_3 = 0$$

$$3I_1 + 2I_3 = 2 \qquad \ldots\text{(ii)}$$

In loop $ABDE$, **(1)**

$$-30I_1 + 20I_2 - 80 = 0$$

$$-3I_1 + 2I_2 = 8 \qquad \ldots\text{(iii)}$$

Problems related to kirchhoff's law. Class 12 kirchhoff law problems and solutions pdf.

1. If R1 = 2 Ω, R2 = 4 Ω, R3 = 6 Ω, determine the electric current flows in the circuit below.Known :Resistor 1 (R1) = 2 Ω Resistor 2 (R2) = 4 ΩResistor 3 (R3) = 6 ΩSource of emf 1 (E1) = 9 VSource of emf 2 (E2) = 3 VWanted: Electric current (I)Solution :This question relates to Kirchhoff's law. How to solve this problem:First, choose the direction of the current.

You can decide the opposite current or direction in the clockwise direction.Second, when the current through the resistor (R) there is a potential decrease so that V = IR signed negative. Third, if the current moves from low to high voltage (- to +) then the source of emf (E) signed positive because of the charging of energy at the emf source. If the current moves from high to low voltage (+ to -) then the source of emf (E) signed negative because of the emptying of energy at the emf source.In this solution, the direction of the current is the same as the direction of clockwise rotation.– I R1 + E1 – I R2 – I R3 – E2 = 0– 2 I + 9 – 4 I – 6 I – 3 = 0– 12 I + 6 = 0– 12 I = – 6I = -6 / -12I = 0.5The electric current flows in the circuit are 0.5 A. The electric current signed positive means that the direction of the electric current is the same as the direction of clockwise rotation. If the electric current is negative, then the electric current is opposite the clockwise direction.See also Kinetic theory of gases - problems and solutions2. Determine the electric current that flows in the circuit as shown in the figure below.Solution :In this solution, the direction of the current is the same as the direction of clockwise rotation.-20 – 5I -5I – 12 – 10I = 0-32 – 20I = 0-32 = 20II = -32 / 20I = -1.6 ABecause the electric current is negative, the direction of the electric current is actually opposite to the clockwise direction. The direction of electric current is not the same as estimation.3. Determine the electric current that flows in the circuit as shown in the figure below.Solution :In this solution, the direction of current is the same as the direction of clockwise rotation.– I – 6I + 12 – 2I + 12 = 0-9I + 24 = 0-9I = -24I = 24 / 9I = 8 / 3 A4. 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Determine the electric current that flows in circuit as shown in figure below.Known :Resistor 1 (R1) = 10 ΩResistor 2 (R2) = 6 ΩResistor 3 (R3) = 5 ΩResistor 4 (R4) = 20 ΩSource of emf 1 (E1) = 8 VoltSource of emf 2 (E2) = 12 VoltWanted : The electric current that flows in circuitSolution :Resistor 3 (R3) and resistor 4 (R4) are connected in parallel. The equivalent resistor :See also Springs in series and parallel – problems and solutions1/R34 = 1/R3 + 1/R4 = 1/5 + 1/20 = 4/20 + 1/20 = 5/20R34 = 20/5 = 4 ΩIn this solution, the direction of current is the same as the direction of clockwise rotation.– I R1 – I R2 – E1 – I R34 + E2 = 0– 10I – 6I – 8 – 4I + 12 = 0– 10I – 6I – 4I = 8 – 12– 20I = – 4I = -4/-20I = 1/5 AI = 0.2 A6. Determine the electric current that flows in circuit as shown in figure below.Known :Resistor 1 (R1) = 1 ΩResistor 2 (R2) = 6 ΩResistor 3 (R3) = 6 ΩResistor 4 (R4) = 4 ΩSource of emf 1 (E1) = 12 VoltSource of emf 2 (E2) = 6 VoltWanted : The electric current that flows in circuitSolution :Resistor 1 (R1) and resistor 2 (R2) are connected in parallel. The equivalent resistor :1/R12 = 1/R1 + 1/R2 = 1/1 + 1/6 = 6/6 + 1/6 = 7/6R12 = 6/7 ΩThe direction of current is the same as the direction of clockwise rotation.E1 – I R12 – E2 – I R4 – I R3 = 012 – (6/7)I – 6 – 4I – 6I = 012 – 6 – (6/7)I – 4I – 6I = 06 – (6/7)I – 10I = 06 = (6/7)I + 10I6 = (6/7)I + (70/7)I6 = (76/7)I(6)(7) = 76I42 = 76II = 42/76I = 0.5 A By the end of this section, you will be able to: Analyze a complex circuit using Kirchhoff's rules, using the conventions for determining the correct signs of various terms. Many complex circuits, such as the one in Figure 21.21, cannot be analyzed with the series-parallel techniques developed in Resistors in Series and Parallel and Electromotive Force: Terminal Voltage. There are, however, two circuit analysis rules that can be used to analyze any circuit, simple or complex. These rules are special cases of the laws of conservation of charge and conservation of energy. The rules are known as Kirchhoff's rules, after their inventor Gustav Kirchhoff (1824–1887). Figure 21.21 This circuit cannot be reduced to a combination of series and parallel connections. Kirchhoff's rules, special applications of the laws of conservation of charge and energy, can be used to analyze it. (Note: The script E in the figure represents electromotive force, emf.) Kirchhoff's first rule—the junction rule. The sum of all currents entering a junction must equal the sum of all currents leaving the junction.

Kirchhoff's second rule—the loop rule. The algebraic sum of changes in potential around any closed circuit path (loop) must be zero. Explanations of the two rules will now be given, followed by problem-solving hints for applying Kirchhoff's rules, and a worked example that uses them.

Kirchhoff's first rule (the junction rule) is an application of the conservation of charge to a junction; it is illustrated in Figure 21.22. Current is the flow of charge, and charge is conserved; thus, whatever charge flows into the junction must flow out. Kirchhoff's first rule requires that I1=I2+I3I1=I2+I3 (see figure). Equations like this can and will be used to analyze circuits and to solve circuit problems.

Kirchhoff's rules for circuit analysis are applications of conservation laws to circuits.

The first rule is the application of conservation of charge, while the second rule is the application of conservation of energy. Conservation laws, even used in a specific application, such as circuit analysis, are so basic as to form the foundation of that application. Figure 21.22 The junction rule. The diagram shows an example of Kirchhoff's first rule where the sum of the currents into a junction equals the sum of the currents out of a junction. In this case, the current going into the junction splits and comes out as two currents, so that I1=I2+I3I1=I2+I3. Here I1I1 must be 11 A, since I2I2 is 7 A and I3I3 is 4 A. Kirchhoff's second rule (the loop rule) is an application of conservation of energy. The loop rule is stated in terms of potential, VV, rather than potential energy, but the two are related since PEelec=qVPEelec=qV. Recall that emf is the potential difference of a source when no current is flowing. In a closed loop, whatever energy is supplied by emf must be transferred into other forms by devices in the loop, since there are no other ways in which energy can be transferred into or out of the circuit. Figure 21.23 illustrates the changes in potential in a simple series circuit loop.Kirchhoff's second rule requires emf−Ir−IR1−IR2=0emf−Ir−IR1−IR2=0. Rearranged, this is emf=Ir+IR1+IR2emf=Ir+IR1+IR2, which means the emf equals the sum of the IRIR (voltage) drops in the loop. Figure 21.23 The loop rule. An example of Kirchhoff's second rule where the sum of the changes in potential around a closed loop must be zero. (a) In this standard schematic of a simple series circuit, the emf supplies 18 V, which is reduced to zero by the resistances, with 1 V across the internal resistance, and 12 V and 5 V across the two load resistances, for a total of 18 V. (b) This perspective view represents the potential as something like a roller coaster, where charge is raised in potential by the emf and lowered by the resistances. (Note that the script E stands for emf.) By applying Kirchhoff's rules, we generate equations that allow us to find the unknowns in circuits. The unknowns may be currents, emfs, or resistances. Each time a rule is applied, an equation is produced. If there are as many independent equations as unknowns, then the problem can be solved. There are two decisions you must make when applying Kirchhoff's rules. These decisions determine the signs of various quantities in the equations you obtain from applying the rules. When applying Kirchhoff's first rule, the junction rule, you must label the current in each branch and decide in what direction it is going. For example, in Figure 21.21, Figure 21.22, and Figure 21.23, currents are labeled I1I1, I2I2, I3I3, and II, and arrows indicate their directions. There is no risk here, for if you choose the wrong direction, the current will be of the correct magnitude but negative.

When applying Kirchhoff's second rule, the loop rule, you must identify a closed loop and decide in which direction to go around it, clockwise or counterclockwise. For example, in Figure 21.23 the loop was traversed in the same direction as the current (clockwise). Again, there is no risk; going around the circuit in the opposite direction reverses the sign of every term in the equation, which is like multiplying both sides of the equation by –1.–1. Figure 21.24 and the following points will help you get the plus or minus signs right when applying the loop rule. Note that the resistors and emfs are traversed by going from a to b. In many circuits, it will be necessary to construct more than one loop. In traversing each loop, one needs to be consistent for the sign of the change in potential. (See Example 21.5.) Figure 21.24 Each of these resistors and voltage sources is traversed from a to b. The potential changes are shown beneath each element and are explained in the text. (Note that the script E stands for emf.) When a resistor is traversed in the same direction as the current, the change in potential is −IR−IR. (See Figure 21.24.) When a resistor is traversed in the direction opposite to the current, the change in potential is +IR+IR. (See Figure 21.24.) When an emf is traversed from –– to + (the same direction it moves positive charge), the change in potential is +emf. (See Figure 21.24.) When an emf is traversed from + to –– (opposite to the direction it moves positive charge), the change in potential is − − emf. (See Figure 21.24.) Find the currents flowing in the circuit in Figure 21.25. Figure 21.25 This circuit is similar to that in Figure 21.21, but the resistances and emfs are specified. (Each emf is denoted by script E.) The currents in each branch are labeled and assumed to move in the directions shown. This example uses Kirchhoff's rules to find the currents. Strategy This circuit is sufficiently complex that the currents cannot be found using Ohm's law and the series-parallel techniques—it is necessary to use Kirchhoff's rules. Currents have been labeled I1I1, I2I2, and I3I3 in the figure and assumptions have been made about their directions. Locations on the diagram have been labeled with letters a through h. In the solution we will apply the junction and loop rules, seeking three independent equations to allow us to solve for the three unknown currents.Solution We begin by applying Kirchhoff's first or junction rule at point a. This gives since I1I1 flows into the junction, while I2I2 and I3I3 flow out. Applying the junction rule at e produces exactly the same equation, so that no new information is obtained. This is a single equation with three unknowns—three independent equations are needed, and so the loop rule must be applied.

Now we consider the loop abcdea.

Going from a to b, we traverse R2R2 in the same (assumed) direction of the current I2I2, and so the change in potential is −I2R2−I2R2. Then going from b to c, we go from –– to +, so that the change in potential is +emf1+emf1. Traversing the internal resistance r1r1 from c to d gives −I2r1−I2r1. Completing the loop by going from d to a again traverses a resistor in the same direction as its current, giving a change in potential of −I1R1−I1R1.The loop rule states that the changes in potential sum to zero. Thus, −I2R2+emf1−I2r1−I1R1=−I2(R2+r1)+emf1−I1R1=0.−I2R2+emf1−I2r1−I1R1=−I2(R2+r1)+emf1−I1R1=0. Substituting values from the circuit diagram for the resistances and emf, and canceling the ampere unit gives−3I2+18−6I1=0.−3I2+18−6I1=0. Now applying the loop rule to aefgha (we could have chosen abcdefgha as well) similarly gives +I1R1+I3R3+I3r2−emf2= +I1R1+I3R3+r2−emf2=0.+I1R1+I3R3+I3r2−emf2= +I1R1+I3R3+r2−emf2=0. Note that the signs are reversed compared with the other loop, because elements are traversed in the opposite direction. With values entered, this becomes +6I1+2I3−45=0.+6I1+2I3−45=0. These three equations are sufficient to solve for the three unknown currents. First, solve the second equation for I2I2: Now solve the third equation for I3I3: I3=22.5−3I1.I3=22.5−3I1. Substituting these two new equations into the first one allows us to find a value for I1I1: I1=I2+I3=(6−2I1)+(22.5− 3I1)=28.5− 5I1.I1=I2+I3=(6−2I1)+(22.5− 3I1)=28.5− 5I1. Combining terms gives 6I1=28.5, and6I1=28.5, and I1=4.75 A.I1=4.75 A. Substituting this value for I1I1 back into the fourth equation gives I 2 = 6 − 2I 1 = 6 − 9.50 I 2 = 6 − 2I 1 = 6 − 9.50 I2=−3.50 A.I2=−3.50 A. The minus sign means I2I2 flows in the direction opposite to that assumed in Figure 21.25. Finally, substituting the value for I1I1 into the fifth equation gives I 3 = 22.5 − 3I 1 = 22.5 − 14 . 25 I 3 = 22.5 − 3I 1 = 22.5 − 14 . 25 I3=8.25 A.I3=8.25 A. Discussion Just as a check, we note that indeed I1=I2+I3I1=I2+I3.

The results could also have been checked by entering all of the values into the equation for the abcdefgha loop. Make certain there is a clear circuit diagram on which you can label all known and unknown resistances, emfs, and currents. If a current is unknown, you must assign it a direction. This is necessary for determining the signs of potential changes. If you assign the direction incorrectly, the current will be found to have a negative value—no harm done. Apply the junction rule to any junction in the circuit. Each time the junction rule is applied, you should get an equation with a current that does not appear in a previous application—if not, then the equation is redundant. Apply the loop rule to as many loops as needed to solve for the unknowns in the problem. (There must be as many independent equations as unknowns.) To apply the loop rule, you must choose a direction to go around the loop. Then carefully and consistently determine the signs of the potential changes for each element using the four bulleted points discussed above in conjunction with Figure 21.24. Solve the simultaneous equations for the unknowns. This may involve many algebraic steps, requiring careful checking and rechecking. Check to see whether the answers are reasonable and consistent.

The numbers should be of the correct order of magnitude, neither exceedingly large nor vanishingly small.

The signs should be reasonable—for example, no resistance should be negative. Check to see that the values obtained satisfy the various equations obtained from applying the rules. The currents should satisfy the junction rule, for example. The material in this section is correct in theory. We should be able to verify it by making measurements of current and voltage. In fact, some of the devices used to make such measurements are straightforward applications of the principles covered so far and are explored in the next modules. As we shall see, a very basic, even profound, fact results—making a measurement alters the quantity being measured. Can Kirchhoff's rules be applied to simple series and parallel circuits or are they restricted for use in more complicated circuits that are not combinations of series and parallel? Kirchhoff's rules can be applied to any circuit since they are applications to circuits of two conservation laws. Conservation laws are the most broadly applicable principles in physics. It is usually mathematically simpler to use the rules for series and parallel in simpler circuits so we emphasize Kirchhoff's rules for use in more complicated situations. But the rules for series and parallel can be derived from Kirchhoff's rules. Moreover, Kirchhoff's rules can be expanded to devices other than resistors and emfs, such as capacitors, and are one of the basic analysis devices in circuit analysis. naval-personnel.pdfA fairly complicated three-wire circuit is shown below. The source voltage is 120 V between the center (neutral) and the outside (hot) wires. Load currents on the upper half of the circuit are given as 10 A, 4 A, and 8 A for the load resistors j, k, and l, respectively. Load currents on the lower half of the circuit are given as 6 A and 12 A for the load resistors m and n, respectively. The resistances of the connecting wires a, b, c, d, e, f, g, h, and i are also given. Determine... the current through each of the connecting wires (a, b, c, d, e, f, g, h, i) with the direction (left, right); the voltage drop across each load element (j, k, l, m, n); and the resistance of each load element (j, k, l, m, n). A three-wire circuit I (A) V (V) R (Ω) a 22 4.4 0.2 b 12 2.4 0.2 c 08 1.6 0.2 d 04 0.8 0.2 e 06 0.6 0.1 f 00 0.0 0.1 g 04 0.8 0.2 h 18 5.4 0.3 i 12 3.6 0.3 j 10 114.8 11.48 k 04 113.0 28.25 l 08 112.2 14.03 m 06 114.8 19.13 n 12 110.4 09.20 Given the circuit below with 3 A of current running through the 4 Ω resistor as indicated in the diagram to the right. Determine... the current through each of the other resistors the voltage of the battery on the left the power delivered to the circuit by the battery on the right Let's identify the currents through the resistors by the value of the resistor (I1, I2, I3, I4) and the currents through the batteries by the side of the circuit on which they lay (IL, IR). Start with the 2 Ω resistor. Apply the loop rule to the circuit on the lower right. 20 V = I2(2 Ω) + (3 A)(4 Ω) I2 = 4 A Proceed to the 3 Ω resistor.

Apply the junction rule to the junction in the center of the circuit. I2 = I3 + I4 4 A = I3 + 3 A I3 = 1 A The current through the 1 Ω resistor most certainly runs from right to left. If we apply the loop rule to the top circuit, we'll have to run against that current. This changes what is normally considered a potential drop into a potential increase. (Kind of like skiing up a mountain instead of down.) I1(1 Ω) = (4 A)(2 Ω) + (1 A)(3 Ω) I1 = 11 A Apply the loop rule to the outer circuit to get the voltage of the battery on the left (continuing with the assumption that the current is running counterclockwise).

We find ourselves running through the left battery backwards. This changes what is normally considered a potential increase into a potential decrease.

(Kind of like using the ski lift to travel down a mountain instead of up.) 20 V = (11 A)(1 Ω) + VL VL = 9 V Let's verify this result by repeating the procedure for the bottom circuit. 20 V = (4 A)(2 Ω) + (1 A)(3 Ω) + VL VL = 9 V Good, we got the same answer using two different approaches. We must be doing the right thing. The power delivered to the circuit by the battery on the right is the product of its voltage times the current it drives around the circuit. We already have the voltage (it's given in the problem) all that remains is to determine the current. Apply the junction rule to the junction on the left... IL = I1 + I3 IL = 11 A + 1 A IL = 12 A and again to the junction at the bottom... IR = IL + I4 IR = 12 A + 3 A IR = 15 A to find the power of the battery on the right... P = VI P = (20 V)(15 A) P = 300 W Determine the current through each resistor in the circuit shown below.

Let's number the currents from left to right: I1, I2, and I3, respectively. Assume that the current will flow clockwise in the left circuit and counterclockwise in the right circuit; that is, that I1 and I3 are running up the page and that I2 is running down the page. Apply Kirchhoff's rules and see what happens. I2 = I1 + I3 [1] top junction 12 V = (4 Ω)I2 + (3 Ω)I1 [2] left circuit 5 V = (4 Ω)I2 + (2 Ω)I3 [3] right circuit Solve using the methods of linear algebra. (We'll omit the units for clarity.) combine [1] & [2] +4(00 = I1 − I2 + I3) +1(12 = 3I1 + 4I2) 12 = 7I1 + 4I3 [4] combine [1] & [3] +4(00 = I1 − I2 + I3) +1(05 = 2I3 + 4I2) 5 = 4I1 + 6I3 [5] combine [4] & [5] +3(12 = 7I1 + 4I3) −2(05 = 4I1 + 6I3) 26 = 13I1 [6] Continue until each current has been found. The negative value of I3 means that current is running down the page, not up as we assumed. This shows the self-correcting nature of Kirchhoff's rules. Write something completely different.