UNIT-1 DC CIRCUITS

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Imagine electricity is like water flowing through a pipe.

DC (Direct Current) is like a water hose where the water always flows in the same direction, from one end to the other.

- The water pressure is constant.
- The water always flows "forward."
- There's a positive (+) side where the water comes from and a negative (-) side where it goes.

Real-Life Examples:

- **Batteries:** Think of the batteries in your TV remote, flashlight, or smartphone. They have a (+) and a (-) end. The electricity flows from the (+) end, through the device, and back to the (-) end.
- **USB Chargers:** The power coming out of your USB charger to charge your phone is DC. The brick plugs into the wall (which is AC—we'll get to that later), and it converts the power to DC for your phone's battery.
- **Cars:** The battery in your car is a DC power source. It powers things like the radio, lights, and starter motor.

Why is DC important?

- **It's great for storing energy.** This is why we use batteries for all our portable electronics.
- **It's essential for electronics.** Most of the tiny components inside your computer, phone, and TV need a steady, one-directional flow of electricity to work correctly.

Memory Tip:

- **D**C stands for **D**irect **C**urrent. Think of a **D**irection, like a one-way street. The electricity only goes one way.

In summary, if you can imagine a battery and the one-way flow of electricity it provides, you understand the core concept of DC!

Imagine an electric circuit is like a **lap track for electricity**.

A circuit is a **complete, closed loop** that allows electricity to flow from a power source, through a device, and back to the power source. If the path is broken anywhere, the electricity can't complete the "lap," and the device won't work.

Key Components of a Simple Circuit

Every basic circuit has three main parts:

- **Power Source:** This is what provides the electricity, like a battery. It's the "starting line" for the electrons.
- **Conductor:** This is the material that the electricity flows through, usually a wire. Think of it as the "race track." The wire must be made of a material that electricity can travel through easily, like copper.
- **Load:** This is the device that uses the electricity to do work, such as a light bulb, a fan, or a speaker. This is the "goal" of the lap—to power something useful.

Real-Life Example: A Flashlight

A simple flashlight is a perfect example of a circuit.

1. **Power Source:** The **batteries** inside the flashlight. They push the electricity.
2. **Conductor:** The **wires and metal strips** that connect everything inside the flashlight.
3. **Load:** The **light bulb**. It uses the electricity to produce light.
4. **The Switch:** This is the on/off button. When you flip the switch "on," you **close the circuit**, creating a complete path for the electricity to flow from the batteries, through the wires, to the bulb, and back to

the batteries. The bulb lights up. When you flip the switch "off," you **open the circuit**, breaking the path. The electricity stops flowing, and the bulb goes out.

Memory Tip: The "CCC" Rule

- **C**omplete: The path must be whole, with no breaks.
- **C**losed: The switch must be "on."
- **C**urrent: When the path is complete and closed, the electricity can flow.

Just remember that for something to work, the electricity needs a clear, uninterrupted path to make a complete "lap." 🏁

The Three Main Circuit Elements: R, L, and C

In a circuit, a component that uses electricity to do something is called a **circuit element.** Think of them as the "players" on your electricity "team." The three most common players are R, L, and C. They are:

- **R** is for **Resistor**.
- **L** is for **Inductor**.

- **C** is for **Capacitor**.

1. Resistor (R)

Imagine electricity flowing through a pipe. A **resistor** is like a **narrow section of that pipe** that makes it harder for the water to flow. It **resists** or opposes the flow of electric current.

- **What it does:** It controls how much current can pass through a part of the circuit. By adding a resistor, you can "throttle" or limit the flow of electricity.
- **Real-life example:** The volume knob on a stereo. When you turn it, you are adjusting a variable resistor. When you increase the resistance, less current reaches the speaker, and the sound gets quieter. When you decrease the resistance, more current flows, and the sound gets louder.

2. Inductor (L)

An **inductor** is basically a **coil of wire**. When electricity flows through it, it creates a magnetic field. This magnetic field can "fight back" against changes in current.

- **What it does:** An inductor opposes any *change* in the current flowing through it. If you try to turn the current on suddenly, the inductor resists that change. If you try to turn it off suddenly, the inductor tries to keep it flowing for a short time. Think of it as an electrical "flywheel" that keeps things stable.

- **Real-life example:** The ignition coil in a car. It's a type of inductor that stores energy in its magnetic field and then releases it as a high-voltage spark to ignite the fuel. Inductors are also used in things like power supplies to filter out noise.
- **Memory Tip: L** is for inductor. Think of an inductor as a **L**azy device—it doesn't like change and prefers to keep the current steady.

3. Capacitor (C)

A **capacitor** is like a **tiny, temporary battery**. It stores electrical energy in an electric field between two metal plates.

- **What it does:** A capacitor stores electrical charge and then releases it quickly. It can be used to smooth out bumpy current, like filling a bucket with water to make sure the flow stays even.
- **Real-life example:** The flash in a camera. The capacitor stores up

energy from the battery slowly and then releases it all at once to power the bright light. Capacitors are also used in the keyboard of a computer; when you press a key, you are changing the capacitance, which the computer detects as a keystroke.

- **Memory Tip: C**apacitor = **C**harge **C**ollector. It **C**ollects and stores electrical charge.

Imagine an electrical circuit is like a water system with pipes and pumps.

Voltage Source 🔋

A **voltage source** is like a **pump** in a water system. Its job is to create **pressure** that pushes the water (the electricity) through the pipes.

- **What it does:** It provides a constant electrical "pressure" to the circuit, regardless of how much electricity is flowing. This pressure is measured in **volts (V)**.
- **Real-life example:** A **battery**. A 9V battery will always try to maintain 9 volts of pressure between its positive and negative terminals. It doesn't matter if you connect a tiny light or a big fan; the battery will still provide that 9-volt pressure.

- **Memory Tip: V**oltage source = a source of electrical **V**olume or pressure. Think of it as the "push."

Current Source ⚡

A **current source** is like a pump that guarantees a **constant flow rate** of water, no matter what pipes or obstructions are in the way.

- **What it does:** It provides a constant, steady flow of electricity (measured in **amps, A**), even if the "pressure" (voltage) has to change to make that happen.
- **Real-life example:** These are less common in everyday devices but are crucial in electronics. For example, a specialized power supply for an LED light might be a current source. An LED needs a very specific amount of current to light up properly without burning out. A current source ensures that a steady flow of electricity reaches the LED, adjusting the voltage as needed.
- **Memory Tip: C**urrent source = a source of **C**onstant flow. Think of it as the "flow rate."

The key difference is what they prioritize: a **voltage source** provides a constant **pressure**, while a **current source** provides a constant **flow**.

Source transformation is a powerful technique used to simplify complex electrical circuits by converting a **voltage source with a series resistor** into an equivalent **current source with a parallel resistor**, and vice versa. It's a fundamental tool in circuit analysis that allows you to rearrange and combine components to make solving a circuit easier.

The Core Idea: Equivalence

The key principle is that these two different circuit arrangements can behave identically to the rest of the circuit. Imagine a "black box" with two wires coming out. Whether you put a voltage source and a resistor in series, or a current source and a resistor in parallel inside that box, the rest of the circuit will "see" the exact same electrical behavior as long as the transformation is done correctly.

This works because both configurations follow the same fundamental law: Ohm's Law.

- **From Voltage Source to Current Source:**
  - You have a voltage source (

    V

) in series with a resistor (

R

).

- The equivalent current source will have a value of

  $I=V/R$

  .

- The resistor

  R

  is then placed in parallel with the new current source.

- **From Current Source to Voltage Source:**
  - You have a current source I

    in parallel with a resistor R

    The equivalent voltage source will have a value of

    $V=I\times R$

- The resistor R

  is then placed in series with the new voltage source.

The resistor's value always stays the same during the transformation.

Real-Life Example and Analogy

While you won't physically "transform" a real battery into a current source, the concept is essential for analyzing how different power sources affect a larger system.

Imagine a water pump and a pipe with a valve.

- **Voltage Source:** A pump that always maintains a certain pressure (voltage), with a small valve (resistor) right at the pump's exit that slightly restricts the flow.
- **Current Source:** A pump that always maintains a certain flow rate (current), with a parallel bypass pipe and a valve (resistor) to divert some of the water.

Both of these systems can be designed to deliver the exact same amount of water and at the same pressure to a house connected to the end of the line. Source transformation is the math that proves this equivalence. It's used by engineers to simplify circuits with multiple sources, making it easier to solve for the current or voltage at a specific point.

Memory Tip

- **V**oltage source **V**oltage **S**eries resistor: **V**ery **S**imple to **S**olve.
- **C**urrent source **C**urrent **P**arallel resistor: **C**ool and **P**ractical.

Just remember that a voltage source and its resistor are always in series, while a current source and its resistor are always in parallel. Use Ohm's Law $V=IR$ to find the value of the new source, and keep the resistor value the same.

The relationship between voltage and current for passive elements (resistors, inductors, and capacitors) explains how each component responds to electricity flowing through it. This relationship is different for each element.

1. Resistor (R)

The relationship for a resistor is the simplest and is described by **Ohm's Law**. The voltage across a resistor is directly proportional to the current flowing through it.

- **Relationship:** $V=I\times R$
  - V is the voltage (the "push").
  - I is the current (the "flow").
  - R is the resistance (the "roadblock").
- **Explanation:** A resistor's job is to resist the flow of current. If you increase the voltage (push harder), more current flows, but the

resistor's resistance stays the same. The voltage and current are always "in phase," meaning they rise and fall at the same time.

- **Real-life example:** The heating element in a toaster. The voltage and current relationship for the resistive wire causes it to get hot. If you increase the voltage, the current increases, and it gets hotter.

2. Inductor (L)

An inductor's relationship is based on the **rate of change** of the current. It creates a magnetic field that resists any *change* in the current.

- **Relationship:** V=LdtdI
  - L is the inductance.
  - dtdI is the rate of change of the current over time.
- **Explanation:** The voltage across an inductor is proportional to how quickly the current is changing. If the current is steady (not changing), the inductor's voltage is zero. When you turn the current on or off, the voltage spikes to oppose that change.
- **Memory Tip:** An inductor **L**oves a **L**azy current. It doesn't like it when the current changes. The voltage "leads" the current by 90 degrees in AC circuits, meaning the voltage peaks before the current does.

- **Real-life example:** An ignition coil in a car. The coil (an inductor) is used to create a huge voltage spike when the current is rapidly turned off, which is what creates the spark for the engine.

3. Capacitor (C)

A capacitor's relationship is the opposite of an inductor's; it's based on the **rate of change** of the voltage. It stores energy in an electric field that resists any *change* in the voltage.

- **Relationship:** I=CdtdV
  - C is the capacitance.
  - dtdV is the rate of change of the voltage over time.
- **Explanation:** The current flowing through a capacitor is proportional to how quickly the voltage is changing. If the voltage is steady (not changing), the capacitor acts like a break in the circuit, and no current flows. When you quickly apply a voltage, a burst of current flows as the capacitor charges.
- **Memory Tip:** A **C**apacitor wants a **C**onstant voltage. It doesn't like it when the voltage changes. The current "leads" the voltage by 90 degrees in AC circuits, meaning the current peaks before the

voltage does.

- **Real-life example:** A camera flash. A capacitor slowly charges from the battery, and when you press the button, it quickly discharges, releasing all its stored current at once to create a bright flash.

KCL and KVL are two fundamental laws used to analyze how electricity behaves in circuits. They help us find the unknown voltages and currents in a circuit.

1. Kirchhoff's Current Law (KCL)

The Rule: KCL states that the total current flowing **into** a junction (or node) must equal the total current flowing **out of** that junction.

- **Analogy:** Imagine a busy T-junction for water pipes. If 10 gallons of water per minute flow into the junction from one pipe, and 4 gallons per minute flow out from another, then the third pipe must have 6 gallons per minute flowing out. Water doesn't just disappear! The same principle applies to electrical current, which is the flow of charge. The charge entering a point must leave it.
- **Real-life example:** In your home's electrical wiring, a single power

line comes into a junction box and then splits to power several different outlets or lights. The total current flowing into that junction box is equal to the sum of all the currents flowing out to each device.

- **Memory Tip: KCL** is like a **C**onversation about **C**urrents: what goes in must **C**ome out.

2. Kirchhoff's Voltage Law (KVL)

The Rule: KVL states that the total voltage around any closed loop in a circuit must add up to zero.

- **Analogy:** Imagine a hiking trail that forms a complete loop. If you start at a specific point, hike up a hill (a voltage gain), and then walk down two valleys (voltage drops), you must end up at the exact same elevation you started at. The total change in elevation for the entire loop is zero. Similarly, in a circuit, as you "travel" around a closed loop, the voltage rises from sources (like a battery) are canceled out by the voltage drops across components (like resistors).
- **Real-life example:** A simple circuit with a battery and two light bulbs

connected in series. The voltage provided by the battery is completely "used up" or dropped across the two light bulbs. If the battery provides 9V, and the first bulb drops 4V, the second bulb must drop 5V to make the total change around the loop zero (

$9V-4V-5V=0$

).

- **Memory Tip: KVL** is about **V**oltage **L**oops. Think of going on a **V**acation **L**oop: you must return to where you started.

In a circuit, **series** refers to a way of connecting components so that they form a single, continuous path for the current to flow. Think of it as a single-lane road where all the cars (electrons) must pass through each stop (component) one after the other.

The Rules of a Series Circuit

1. **Current is the same everywhere:** The electricity has no other path to take, so the same amount of current flows through every component. If you measure the current at the beginning, middle, or end of the series, it will be the same.

2. **Voltage is divided:** The total voltage from the power source is split among all the components in the series. Each component "consumes" a portion of the total voltage. The sum of the voltage drops across all the components equals the total source voltage.
3. **Resistances add up:** To find the total resistance of a series circuit, you simply add up the resistance of each individual component.

Real-Life Example: Old Christmas Lights

A classic example of a series circuit is an old string of Christmas lights.

- The lights are wired one after the other in a single loop.
- When you plug the string in, the electricity flows through the first bulb, then the second, and so on, all the way to the end.
- **Problem:** If one bulb burns out, it creates a break in the single path. The circuit is "open," and no electricity can flow. The entire string of lights goes out. This is a key characteristic of series circuits.

Memory Tip

Think of a **S**ingle file **S**eries. The components are lined up one after the other, and the current has a **s**ingle path to follow.

In a circuit, **parallel** refers to a way of connecting components so that they are placed side-by-side, creating multiple paths for the current to flow. Think of it like a highway with multiple lanes, where cars (electrons) can choose which lane to travel in.

The Rules of a Parallel Circuit

1. **Voltage is the same everywhere:** The voltage across each parallel branch is identical and equal to the source voltage. If you measure the voltage across any component in a parallel circuit, you'll get the same value.
2. **Current is divided:** The total current from the power source splits up, with some of it flowing through each parallel branch. The amount of current that goes through each branch depends on its resistance. The sum of the currents in all the branches equals the total source current.
3. **Resistances combine differently:** The total resistance of a parallel circuit is always less than the smallest individual resistance. The formula for total resistance is more complex, but the key takeaway is that adding more paths for the current actually decreases the

overall resistance.

Real-Life Example: Your House Wiring

The electrical outlets and lights in your home are wired in a parallel circuit.

- The main power line comes into your home and then splits into multiple parallel branches, each leading to a different outlet, light fixture, or appliance.
- **Benefit:** If one device, like a lamp, stops working or you turn it off, the other devices on the same circuit continue to work just fine. The other parallel paths for the current are not affected.
- This is why if you unplug your toaster, the lights in the kitchen don't go out.

Memory Tip

Think of a **P**arallel circuit as having **Pl**enty of paths. The components are side-by-side, like a **P**arking lot, giving the current options on where to go.

A **series-parallel combination** is a circuit that combines both series and parallel connections. It's like a multi-lane highway (parallel) that then merges into a single-lane road (series), or vice versa. Many real-world circuits are a mix of both to perform specific functions.

How It Works

To understand a series-parallel circuit, you have to break it down into smaller, simpler parts. You first analyze the parallel sections and simplify them, and then you analyze the series sections.

Imagine a circuit with a power source, and then the current flows through a resistor, and after that, the path splits to go through two other resistors that are side-by-side.

- The **first resistor** is in **series** with the rest of the circuit.
- The **two other resistors** are in a **parallel** configuration.

To solve this circuit, you would first find the equivalent resistance of the two parallel resistors. Then, you would treat that equivalent resistance as a single component and add it to the first series resistor to find the total resistance of the entire circuit.

Real-Life Example: Your Car's Wiring 🚙

Your car's electrical system is a great example of a series-parallel combination.

- The main **car battery** is in **series** with the entire electrical system. If the battery is dead, nothing works.
- However, the different electrical components of the car—like the headlights, the radio, and the dashboard lights—are all connected in **parallel** to each other.
- This is why you can turn on the headlights without having to also turn on the radio. The current from the battery splits into separate paths to power each device independently. If a headlight burns out, the radio and other lights still work because they are on different parallel paths.

Memory Tip

Think of a **S**eries-**P**arallel circuit as having **S**ome **P**arts that are a one-way street, and **S**ome **P**arts that are a multi-lane highway. You have to solve the multi-lane parts first before you can figure out the one-way street.

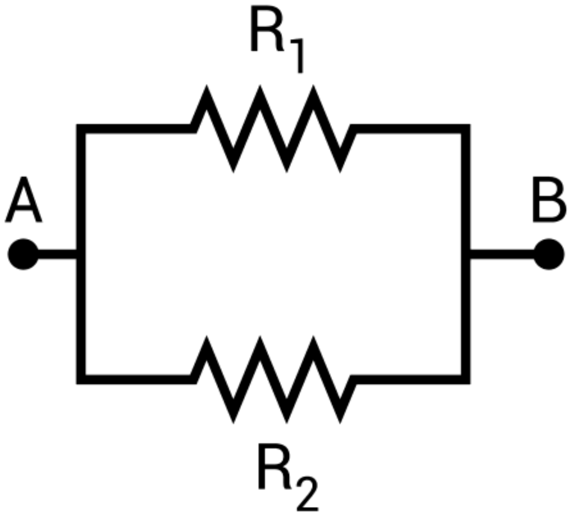
Determining whether resistors are in series or parallel in a circuit diagram can be tricky, but you can follow a few simple rules and visual cues to figure it out. The key is to trace the path of the current.

1. Identifying Resistors in Series

Rule: Resistors are in series if they are connected end-to-end with **no other paths** for the current to branch off in between them.

Visual Cues:

- **A Single Path:** The easiest way to spot series resistors is to follow the wire. If you can go from one resistor to the next without passing any junctions or "forks in the road," they are in series.
- **One after the other:** They are arranged in a straight line, one immediately following the other.



$$\frac{R_1 R_2}{R_1 + R_2}$$

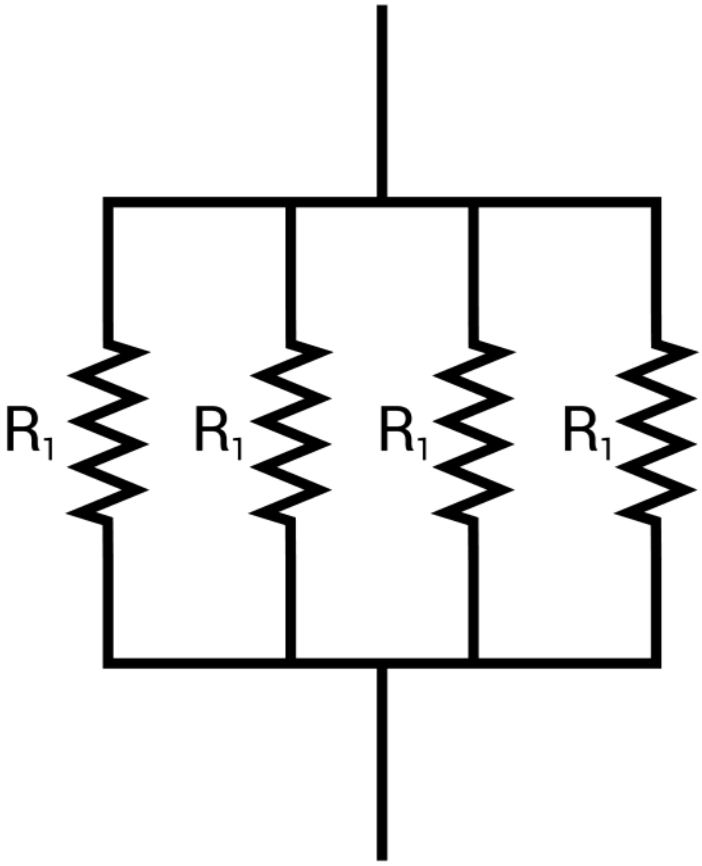
2. Identifying Resistors in Parallel

Rule: Resistors are in parallel if they are connected to the same two points (or nodes) in the circuit, creating **multiple paths** for the current to flow through.

Visual Cues:

- **Sharing Both Ends:** To be in parallel, both ends of each resistor must be connected to the exact same points as the other resistors in the group.

- **Side-by-side:** They are often drawn vertically or horizontally next to each other, with wires connecting their ends.



The **Superposition Theorem** is a powerful tool for analyzing circuits with more than one power source (like batteries or current sources). It states that the total current or voltage in a circuit is the sum of the currents or voltages produced by **each power source acting alone.** This means you can break down a complex problem into several simpler ones.

The Basic Idea

Imagine you have two people pushing a shopping cart. The total speed and direction of the cart is a combination of each person's push. The Superposition Theorem lets you figure out what would happen if only the first person pushed, then what would happen if only the second person pushed, and then you just add the two results together to find the final outcome.

How to Use the Superposition Theorem

You follow a simple step-by-step process to solve a problem. Let's use an example to illustrate.

Problem: Find the current flowing through the 3Ω resistor in the following circuit.

1. **Deactivate all but one source:** Choose one power source to keep active. You must "turn off" all other sources.
   - To turn off a **voltage source**, replace it with a **short circuit** (a plain wire).
   - To turn off a **current source**, replace it with an **open circuit** (a break in the wire).
2. **Analyze the simplified circuit:** With only one source active, solve the

circuit using your usual methods (like Ohm's Law, series/parallel combinations). Calculate the current or voltage you need.

3. **Repeat for each source:** Go back to the original circuit and repeat step 1 for each of the other power sources. For each source, you will have a new simplified circuit to solve.
4. **Add the results:** Once you have a result for each source acting alone, add them up. **Pay close attention to the direction of the current.** If the currents from different sources are flowing in the same direction through the resistor, you add them. If they are flowing in opposite directions, you subtract them. The final result is the total current.

Solved Problem Example

Let's solve the problem shown in the diagram. We want to find the current through the 3Ω resistor.

Step 1: Consider only the 10V source.

- We replace the 20V source with a short circuit.
- Now we have a simple series-parallel circuit. The 6Ω and 3Ω resistors are in parallel. Their combined resistance is:

$(6×3)/(6+3)=18/9=2Ω$

.

- This 2Ω equivalent resistance is in series with the 4Ω resistor. The total resistance of the circuit is

  $4Ω+2Ω=6Ω$

  .

- The total current from the 10V source is:

  $I_{total}=V/R_{total}=10V/6Ω=1.67A$

  .

- This current splits between the 6Ω and 3Ω resistors. We can use the current divider rule to find the current through the 3Ω resistor:

  $I_{3Ω(1)}=I_{total}×(6Ω/(6Ω+3Ω))=1.67A×(6/9)=1.11A$

  .

- **Direction:** The current flows downwards through the 3Ω resistor.

Step 2: Consider only the 20V source.

- We replace the 10V source with a short circuit.
- The 4Ω and 6Ω resistors are in parallel. Their combined resistance is:

$(4\times6)/(4+6)=24/10=2.4\Omega$

.

- This 2.4Ω equivalent resistance is in series with the 3Ω resistor. The total resistance is:

  $3\Omega+2.4\Omega=5.4\Omega$

  .

- The total current from the 20V source is:

  $I_{total}=V/R_{total}=20V/5.4\Omega=3.7A$

  .

- This current splits between the 4Ω and 6Ω resistors. We use the current divider rule to find the current through the 6Ω resistor (which is on the same path as the 3Ω resistor). Oh wait, let's just find the voltage across the 3 ohm resistor, since we know all the current from the 20V source must pass through it!
- The current through the 3Ω resistor is just the total current from the 20V source:

  $I_{3\Omega(2)}=3.7A$

  .

- **Direction:** The current flows upwards through the 3Ω resistor.

Step 3: Combine the results.

- From Step 1, the current from the 10V source (

  $I_{3\Omega(1)}$

) is 1.11A flowing downwards.
- From Step 2, the current from the 20V source (

  $I_{3\Omega(2)}$

) is 3.7A flowing upwards.
- Since the currents are in opposite directions, we subtract them:

  $I_{Total} = I_{3\Omega(2)} - I_{3\Omega(1)} = 3.7A - 1.11A = 2.59A$

  .
- The net current is 2.59A, flowing upwards (in the direction of the larger current).

Final Answer: The total current through the 3Ω resistor is **2.59A** flowing upwards.

Real-Life Analogy and Memory Tip

- **Real-Life Analogy:** Think of an air conditioning system and a heater in a room. The final temperature of the room is the sum of the cooling effect of the AC and the heating effect of the heater. The Superposition Theorem lets you calculate each effect separately and then combine them to find the final temperature.

- **Memory Tip: S**uperposition helps you **S**plit a problem with multiple **S**ources into **S**everal **S**impler ones.

The **Superposition Theorem** is a powerful tool for analyzing circuits with more than one power source (like batteries or current sources). It states that the total current or voltage in a circuit is the sum of the currents or voltages produced by **each power source acting alone.** This means you can break down a complex problem into several simpler ones.

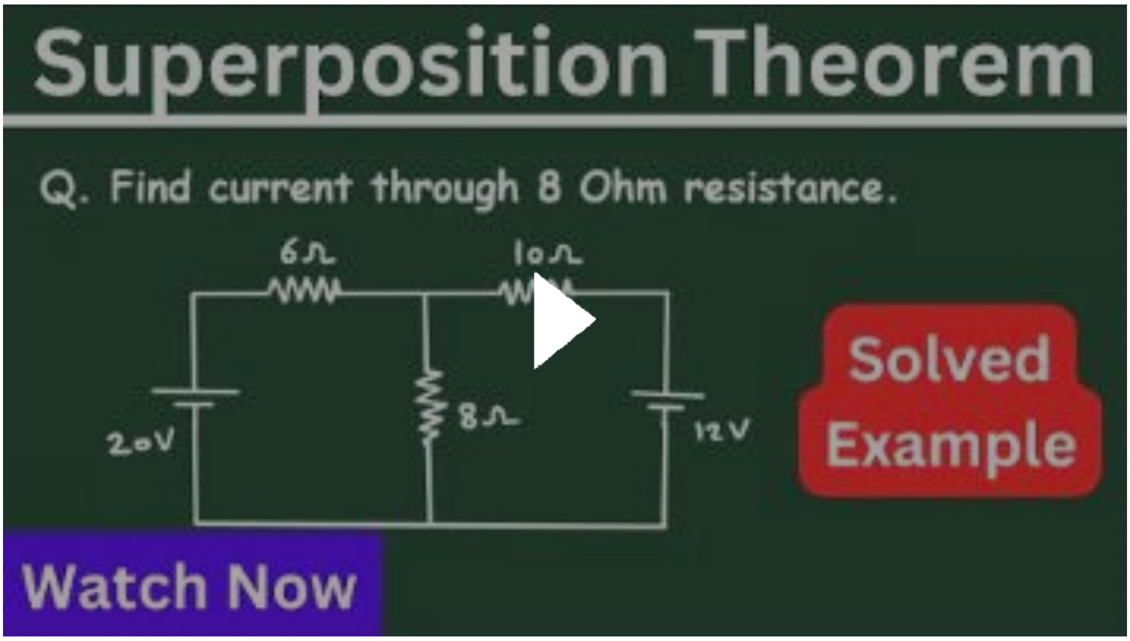
The Basic Idea

Imagine you have two people pushing a shopping cart. The total speed and direction of the cart is a combination of each person's push. The Superposition Theorem lets you figure out what would happen if only the first person pushed, then what would happen if only the second person pushed, and then you just add the two results together to find the final outcome.

ALSO CHECK :

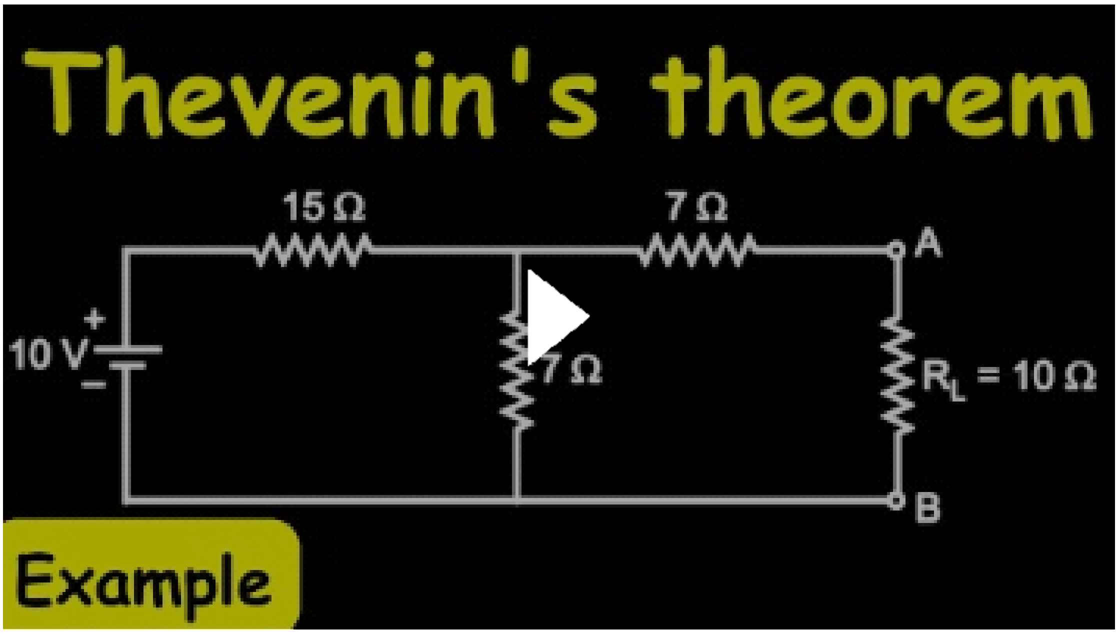
1. SUPERPOSITION THEOREM (SIMPLE PROBLEM)

superposition theorem bee 1st year | Superposition Theorem | Electrical Engineering



1. THEVENINS THEOREM (SIMPLE PROBLEM)

Thevenin's Theorem Circuit Solved Example | Easy Step By Step | Circuit Analysis



3.NORTON THEOREM (SIMPLE PROBLEM)

[Hindi : Norton's Theorem Example | Electric Circuits | Network Analysis | Network Theory]