Module-10

**Electric current**

An **electric current** is the rate of flow of [electric charge](https://en.wikipedia.org/wiki/Electric_charge) past a pointor region. An electric current is said to exist when there is a net flow of electric charge through a region. In [electric circuits](https://en.wikipedia.org/wiki/Electric_circuit) this charge is often carried by [electrons](https://en.wikipedia.org/wiki/Electron) moving through a [wire](https://en.wikipedia.org/wiki/Wire). It can also be carried by [ions](https://en.wikipedia.org/wiki/Ion) in an [electrolyte](https://en.wikipedia.org/wiki/Electrolyte#Electrochemistry), or by both ions and electrons such as in an ionized gas ([plasma](https://en.wikipedia.org/wiki/Plasma_(physics))).

The [SI](https://en.wikipedia.org/wiki/International_System_of_Units) unit of electric current is the [ampere](https://en.wikipedia.org/wiki/Ampere), which is the flow of electric charge across a surface at the rate of one [coulomb](https://en.wikipedia.org/wiki/Coulomb) per second. The ampere (symbol: A) is an SI base unit Electric current is measured using a device called an [ammeter](https://en.wikipedia.org/wiki/Ammeter).

Electric currents cause [Joule heating](https://en.wikipedia.org/wiki/Joule_heating), which creates [light](https://en.wikipedia.org/wiki/Light) in [incandescent light bulbs](https://en.wikipedia.org/wiki/Incandescent_light_bulbs). They also create [magnetic fields](https://en.wikipedia.org/wiki/Magnetic_fields), which are used in motors, generators, inductors, and [transformers](https://en.wikipedia.org/wiki/Transformer).

The moving charged particles in an electric current are called [charge carriers](https://en.wikipedia.org/wiki/Charge_carrier). In [metals](https://en.wikipedia.org/wiki/Metal), one or more electrons from each atom are loosely bound to the atom, and can move freely about within the metal. These [conduction electrons](https://en.wikipedia.org/wiki/Conduction_electron) are the charge carriers in metal conductors.

## Ohm's law

Ohm's law states that the current through a conductor between two points is directly [proportional](https://en.wikipedia.org/wiki/Proportionality_(mathematics)) to the [potential difference](https://en.wikipedia.org/wiki/Potential_difference) across the two points. Introducing the constant of proportionality, the [resistance](https://en.wikipedia.org/wiki/Electrical_resistance), one arrives at the usual mathematical equation that describes this relationship:

I = V R {\displaystyle I={\frac {V}{R}}}

where *I* is the current through the conductor in units of [amperes](https://en.wikipedia.org/wiki/Ampere), *V* is the potential difference measured *across* the conductor in units of [volts](https://en.wikipedia.org/wiki/Volt), and *R* is the [resistance](https://en.wikipedia.org/wiki/Electrical_resistance) of the conductor in units of [ohms](https://en.wikipedia.org/wiki/Ohm). More specifically, Ohm's law states that the *R* in this relation is constant, independent of the current.

Application of Ohms law:

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| [Ohm's Law with Voltage source TeX.svg](https://en.wikipedia.org/wiki/File:Ohm's_Law_with_Voltage_source_TeX.svg)  Fig.1 A simple electric circuit, where current is represented by the letter *i*. The relationship between the voltage (V), resistance (R), and current (I) is V=IR; this is known as [Ohm's law](https://en.wikipedia.org/wiki/Ohm%27s_law). | |
| **Common symbols** | I |
| [**SI unit**](https://en.wikipedia.org/wiki/SI_unit) | [ampere](https://en.wikipedia.org/wiki/Ampere) |
| **Derivations from other quantities** | I = V R , I = Q t {\displaystyle I={V \over R}\,,I={Q \over t}} |
| [**Dimension**](https://en.wikipedia.org/wiki/Dimensional_analysis#Definition) | **I** |

## Series Resistance circuits

**Series circuits** are sometimes referred to as *current*-coupled or [daisy chain](https://en.wikipedia.org/wiki/Daisy_chain_(electrical_engineering))-coupled. The [current](https://en.wikipedia.org/wiki/Electric_current) in a series circuit goes through every component in the circuit. Therefore, all of the components in a series connection carry the same current.

A series circuit has only one path in which its current can flow. Opening or breaking a series circuit at any point [causes the entire circuit to "open" or stop operating](https://en.wikipedia.org/wiki/Single_point_of_failure). For example, if even one of the light bulbs in an older-style string of [Christmas tree lights](https://en.wikipedia.org/wiki/Christmas_tree_lights) burns out or is removed, the entire string becomes inoperable until the bulb is replaced.

### CurrentI = I 1 = I 2 = ⋯ = I n {\displaystyle I=I\_{1}=I\_{2}=\cdots =I\_{n}}

In a series circuit, the current is the same for all of the elements.

### Voltage

In a series circuit, the voltage is the sum of the voltage drops of the individual components

V = V 1 + V 2 + ⋯ + V n {\displaystyle V=V\_{1}+V\_{2}+\dots +V\_{n}}

### Resistance

The total resistance of resistance units in series is equal to the sum of their individual resistances:

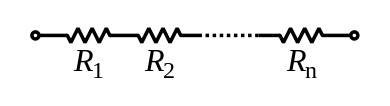
[](https://en.wikipedia.org/wiki/File:Resistors_in_series.svg)

Fig.2 Resistance units in series R total = R s = R 1 + R 2 + ⋯ + R n {\displaystyle R\_{\text{total}}=R\_{\text{s}}=R\_{1}+R\_{2}+\cdots +R\_{n}}

Rs=>Resistance in series

## Parallel Resistance circuits

If two or more components are connected in parallel, they have the same difference of potential ([voltage](https://en.wikipedia.org/wiki/Voltage)) across their ends. The potential differences across the components are the same in magnitude, and they also have identical polarities. The same voltage is applied to all circuit components connected in parallel. The total current is the sum of the currents through the individual components, in accordance with [Kirchhoff's current law](https://en.wikipedia.org/wiki/Kirchhoff%27s_circuit_laws#Kirchhoff's_current_law_(KCL)).

### Voltage

In a parallel circuit, the voltage is the same for all elements.

V = V 1 = V 2 = … = V n {\displaystyle V=V\_{1}=V\_{2}=\ldots =V\_{n}}

### Current

The current in each individual resistor is found by [Ohm's law](https://en.wikipedia.org/wiki/Ohm%27s_law). Factoring out the voltage gives

I t o t a l = V ( 1 R 1 + 1 R 2 + ⋯ + 1 R n ) {\displaystyle I\_{\mathrm {total} }=V\left({\frac {1}{R\_{1}}}+{\frac {1}{R\_{2}}}+\cdots +{\frac {1}{R\_{n}}}\right)}.

To find the total [resistance](https://en.wikipedia.org/wiki/Electrical_resistance) of all components, add the [reciprocals](https://en.wikipedia.org/wiki/Multiplicative_inverse) of the resistances R i {\displaystyle R\_{i}} of each component and take the reciprocal of the sum. Total resistance will always be less than the value of the smallest resistance:

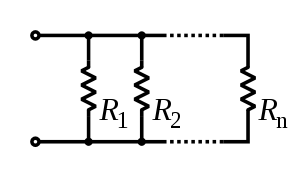
[](https://en.wikipedia.org/wiki/File:Resistors_in_parallel.svg)

Fig.3 Resistance units in parallel

1 R t o t a l = 1 R 1 + 1 R 2 + ⋯ + 1 R n {\displaystyle {\frac {1}{R\_{\mathrm {total} }}}={\frac {1}{R\_{1}}}+{\frac {1}{R\_{2}}}+\cdots +{\frac {1}{R\_{n}}}} .

For only two resistances, the unreciprocated expression is reasonably simple:

R t o t a l = R 1 R 2 R 1 + R 2 . {\displaystyle R\_{\mathrm {total} }={\frac {R\_{1}R\_{2}}{R\_{1}+R\_{2}}}.} 

This sometimes goes by the mnemonic *product over sum*.

For *N* equal resistances in parallel, the reciprocal sum expression simplifies to:

1 R t o t a l = N 1 R {\displaystyle {\frac {1}{R\_{\mathrm {total} }}}=N{\frac {1}{R}}} .

and therefore to:

R t o t a l = R N {\displaystyle R\_{\mathrm {total} }={\frac {R}{N}}} .

To find the [current](https://en.wikipedia.org/wiki/Current_(electricity)) in a component with resistance R i {\displaystyle R\_{i}} , use Ohm's law again:

I i = V R i {\displaystyle I\_{i}={\frac {V}{R\_{i}}}\,}.

The components divide the current according to their reciprocal resistances, so, in the case of two resistors,

I 1 I 2 = R 2 R 1 {\displaystyle {\frac {I\_{1}}{I\_{2}}}={\frac {R\_{2}}{R\_{1}}}}.

## Series and Parallel Resistors: Examples with Detailed Solutions

|  |
| --- |
| Example 1 Find the current I passing through and the voltage across each of the resistors in the circuit below.  Resistors in series in example 1 [Pin it!Share on Facebook](http://www.problemsphysics.com/electricity/series-and-parallel-resistors.html) The three resistor in series have a resistance Req given by the sum of the three resistances. Hence Req = 100 + 400 + 200 = 700 Ω The current I passing through R1, R3 and R3 is the same and is calculated as follows: I = 7 v / 700 Ω = 0.01 A The voltage across each resistance is calculated using [Ohm's law](http://www.problemsphysics.com/electricity/ohms-law-examples.html) as follows: The voltage across 100Ω: VR1 = 100 × I = 100 × 0.01 = 1 v The voltage across 400Ω: VR2 = 400 × I = 400 × 0.01 = 4 v The voltage across 200Ω: VR3 = 200 × I = 200 × 0.01 = 2 v  Example 2 Find current I in the circuit below and the current passing through each of the resistors in the circuit.  Resistors in parallel in example 2 Solution to Example 2 The three resistors are in parallel and behave like a resistor with resistance Req given by 1 / Req = 1 / 100 + 1 / 400 + 1 / 200 Multiply all terms by 400 and simplify to obtain 400 / Req = 4 + 1 + 2 Solve for Req to obtain Req = 400 / 7 Ω The main current I is given by I = 7 / Req = 7 / (400 / 7) = 49 / 400 A We now use Ohm's law to find the current passing through each resistor. The current through the resistor of 100 Ω: I1 = 7 / 100 A The current through the resistor of 400 Ω: I2 = 7 / 400 A The current through the resistor of 200 Ω: I3 = 7 / 200 A As an exercise; check that the sum of the three currents above is equal to the current I = 49 / 400 A.  Example 3 Find current I in the circuit below.  Series and Parallel Resistors in example 3[Pin it!Share on Facebook](http://www.problemsphysics.com/electricity/series-and-parallel-resistors.html)Solution to Example 3 The two resistors that are in series are grouped as Req1 in the equivalent circuit below and their resistance is given by the sum Req1 = 100 + 400 = 500 Ω The two resistors that are in parallel are grouped as Req2 in the equivalent circuit below and their resistance is given by the equation 1 / Req2 = 1 / 100 + 1 / 200  Solution for Series and Parallel Resistors in example 3[Pin it!Share on Facebook](http://www.problemsphysics.com/electricity/series-and-parallel-resistors.html) Solve to obtain Req2 = 200 / 3 Ω Req1 and Req2 are in series and therefore are equivalent to R given by the sum R = Req1 + Req2 = 500 + 200 / 3 = 1700 / 3 Ω We now use Ohm's law to find current I. I = 6 / R = 6 / (1700 / 3) = 18 / 1700 A  Example 4 What resistance x in parallel with resistances 100 Ω and 200 Ω gives an equivalent resistance of 50 Ω? Solution to Example 4 Let x be the resistance to be found. The equivalent resistance of the all three resistor in parallel is known. We use the equation that gives the equivalent resistance of resistors in parallel as follows 1 / 50 = 1 / 100 + 1 / 200 + 1 / x which gives 1 / x = 1 / 50 - 1 / 100 - 1 / 200 Set all fractions on the right to the common denominator 200 and rewrite the above equation as 1 / x = 4 / 200 - 2 / 200 - 1 / 200 = 1 / 200 solve for x to obtain x = 200 Ω  Example 5 Show that if the resistors with resistances R1, R2 ,..., Rm are in parallel, then the equivalent resistance Req is always smaller than R1, R2, ..., Rm. Solution to Example 5 The equivalent resistance Req is given by the equation 1 / Req = 1 / R1 + 1 / R2 + ... + 1 / Rm Since R1, R2, ... Rm are positive quantities, we can write that 1 / Req > 1 / Ri , where Ri is any of the resistances. Multiply all terms of the inequality above by (Req × Ri) and simplify to obtain Ri > Req or Req < Ri , i = 1, 2, ... m. |

## Kirchhoff's current law

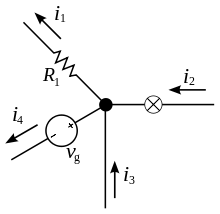
[](https://en.wikipedia.org/wiki/File:KCL_-_Kirchhoff's_circuit_laws.svg)

Fig.4 The current entering any junction is equal to the current leaving that junction. *i*2 + *i*3 = *i*1 + *i*4

This law is also called **Kirchhoff's first law**, **Kirchhoff's point rule**, or **Kirchhoff's junction rule** (or **nodal rule**).

This law states that, for any node (junction) in an [electrical circuit](https://en.wikipedia.org/wiki/Electrical_circuit), the sum of [currents](https://en.wikipedia.org/wiki/Current_(electricity)) flowing into that node is equal to the sum of currents flowing out of that node; or equivalently:

**The algebraic sum of currents in a network of conductors meeting at a point is zero**.

Recalling that current is a signed (positive or negative) quantity reflecting direction towards or away from a node, this principle can be succinctly stated as:

∑ k = 1 n I k = 0 {\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.

The law is based on the [conservation of charge](https://en.wikipedia.org/wiki/Charge_conservation) where the [charge](https://en.wikipedia.org/wiki/Electric_charge) (measured in coulombs) is the product of the current (in amperes) and the time (in seconds). If the net charge in a region is constant, the current law will hold on the boundaries of the region. This means that the current law relies on the fact that the net charge in the wires and components is constant.

## Kirchhoff's voltage law

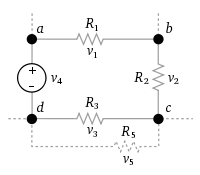
[](https://en.wikipedia.org/wiki/File:Kirchhoff_voltage_law.svg)

Fig.5 The sum of all the voltages around a loop is equal to zero

The sum of all the voltages around a loop is equal to zero  
v1 + v2 + v3 +v4 = 0

This law is also called **Kirchhoff's second law**, **Kirchhoff's loop** (or **mesh**) **rule**, and **Kirchhoff's second rule**.

This law states that

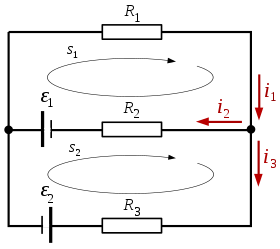
**The directed sum of the** [**potential differences**](https://en.wikipedia.org/wiki/Potential_difference) **(voltages) around any closed loop is zero.**

Similarly to Kirchhoff's current law, the voltage law can be stated as:

∑ k = 1 n V k = 0 {\displaystyle \sum \_{k=1}^{n}V\_{k}=0}

Here, *n* is the total number of voltages measured.

## Example

[](https://en.wikipedia.org/wiki/File:Kirshhoff-example.svg)

Assume an electric network consisting of two voltage sources and three resistors.

According to the first law:

i 1 − i 2 − i 3 = 0 {\displaystyle i\_{1}-i\_{2}-i\_{3}=0\,} 

Applying the second law to the closed circuit *s*1, and substituting for voltage using Ohm's law gives:

− R 2 i 2 + E 1 − R 1 i 1 = 0 {\displaystyle -R\_{2}i\_{2}+{\mathcal {E}}\_{1}-R\_{1}i\_{1}=0} 

The second law, again combined with Ohm's law, applied to the closed circuit *s*2 gives:

− R 3 i 3 − E 2 − E 1 + R 2 i 2 = 0 {\displaystyle -R\_{3}i\_{3}-{\mathcal {E}}\_{2}-{\mathcal {E}}\_{1}+R\_{2}i\_{2}=0} 

This yields a [system of linear equations](https://en.wikipedia.org/wiki/System_of_linear_equations) in i 1 , i 2 , i 3 {\displaystyle i\_{1},i\_{2},i\_{3}} :

{ i 1 − i 2 − i 3 = 0 − R 2 i 2 + E 1 − R 1 i 1 = 0 − R 3 i 3 − E 2 − E 1 + R 2 i 2 = 0 {\displaystyle {\begin{cases}i\_{1}-i\_{2}-i\_{3}&=0\\-R\_{2}i\_{2}+{\mathcal {E}}\_{1}-R\_{1}i\_{1}&=0\\-R\_{3}i\_{3}-{\mathcal {E}}\_{2}-{\mathcal {E}}\_{1}+R\_{2}i\_{2}&=0\end{cases}}}

which is equivalent to

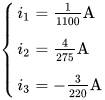
{ i 1 + ( − i 2 ) + ( − i 3 ) = 0 R 1 i 1 + R 2 i 2 + 0 i 3 = E 1 0 i 1 + R 2 i 2 − R 3 i 3 = E 1 + E 2 {\displaystyle {\begin{cases}i\_{1}+(-i\_{2})+(-i\_{3})&=0\\R\_{1}i\_{1}+R\_{2}i\_{2}+0i\_{3}&={\mathcal {E}}\_{1}\\0i\_{1}+R\_{2}i\_{2}-R\_{3}i\_{3}&={\mathcal {E}}\_{1}+{\mathcal {E}}\_{2}\end{cases}}} 

Assuming

R 1 = 100 Ω ,   R 2 = 200 Ω ,   R 3 = 300 Ω {\displaystyle R\_{1}=100\Omega ,\ R\_{2}=200\Omega ,\ R\_{3}=300\Omega } 

E 1 = 3 V , E 2 = 4 V {\displaystyle {\mathcal {E}}\_{1}=3{\text{V}},{\mathcal {E}}\_{2}=4{\text{V}}}

the solution is

{ i 1 = 1 1100 A i 2 = 4 275 A i 3 = − 3 220 A {\displaystyle {\begin{cases}i\_{1}={\frac {1}{1100}}{\text{A}}\\[6pt]i\_{2}={\frac {4}{275}}{\text{A}}\\[6pt]i\_{3}=-{\frac {3}{220}}{\text{A}}\end{cases}}} 

The current i 3 {\displaystyle i\_{3}} has a negative sign which means the assumed direction of i 3 {\displaystyle i\_{3}} was incorrect and i 3 {\displaystyle i\_{3}} is actually flowing in the direction opposite to the red arrow labeled i 3 {\displaystyle i\_{3}} . The current in R 3 {\displaystyle R\_{3}} flows from left to right.

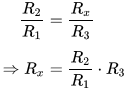
**Wheatstone bridge**

A **Wheatstone bridge** is an [electrical circuit](https://en.wikipedia.org/wiki/Electrical_circuit) used to measure an unknown [electrical resistance](https://en.wikipedia.org/wiki/Electrical_resistance) by balancing two legs of a [bridge circuit](https://en.wikipedia.org/wiki/Bridge_circuit), one leg of which includes the unknown component. The primary benefit of the circuit is its ability to provide extremely accurate measurements (in contrast with something like a simple [voltage divider](https://en.wikipedia.org/wiki/Voltage_divider)).[[1]](https://en.wikipedia.org/wiki/Wheatstone_bridge#cite_note-1) Its operation is similar to the original [potentiometer](https://en.wikipedia.org/wiki/Potentiometer_(measuring_instrument)).

## Operation

In the figure, R1R x {\displaystyle \scriptstyle R\_{x}} , R2, R3 resistancevalues are the fixed and known, RX is to resistance to be measured. TR 1 , {\displaystyle \scriptstyle R\_{1},} TThe resistance R2 R 2 {\displaystyle \scriptstyle R\_{2}} is adjustable. The resistance R2R 2 {\displaystyle \scriptstyle R\_{2}} is adjusted until the bridge is "balanced" and no current flows through the [galvanometer](https://en.wikipedia.org/wiki/Galvanometer) V g {\displaystyle \scriptstyle V\_{g}}VG. At this point, the [voltage](https://en.wikipedia.org/wiki/Voltage) between the two midpoints (**B** and **D**) will be zero. Therefore the ratio of the two resistances in the known legs DA and AB ( R 2 / R 1 ) {\displaystyle \scriptstyle (R\_{2}/R\_{1})}DADDDDequal to the ratio of the two resistances in the unknown leg DC and CB( R x / R 3 ) {\displaystyle \scriptstyle (R\_{x}/R\_{3})} . If the bridge is unbalanced, the direction of the current VG indicates whether R 2 {\displaystyle \scriptstyle R\_{2}} is too high or too low.

At the point of balance,

R 2 R 1 = R x R 3 ⇒ R x = R 2 R 1 ⋅ R 3 {\displaystyle {\begin{aligned}{\frac {R\_{2}}{R\_{1}}}&={\frac {R\_{x}}{R\_{3}}}\\[4pt]\Rightarrow R\_{x}&={\frac {R\_{2}}{R\_{1}}}\cdot R\_{3}\end{aligned}}} 

Detecting zero current with a [galvanometer](https://en.wikipedia.org/wiki/Galvanometer) can be done to extremely high precision. Therefore, if R 1 , {\displaystyle \scriptstyle R\_{1},}  R 2 , {\displaystyle \scriptstyle R\_{2},}  and R 3 {\displaystyle \scriptstyle R\_{3}}  are known to high precision, then R x {\displaystyle \scriptstyle R\_{x}}  can be measured to high precision. Very small changes in R x {\displaystyle \scriptstyle R\_{x}}  disrupt the balance and are readily detected.

Alternatively, if  R 1 , {\displaystyle \scriptstyle R\_{1},}  R 2 , {\displaystyle \scriptstyle R\_{2},} and  R 3 {\displaystyle \scriptstyle R\_{3}} are known, but  R 2 {\displaystyle \scriptstyle R\_{2}} is not adjustable, the voltage difference across or current flow through the meter can be used to calculate the value of R x , {\displaystyle \scriptstyle R\_{x},} using [Kirchhoff's circuit laws](https://en.wikipedia.org/wiki/Kirchhoff%27s_circuit_laws). This setup is frequently used in [strain gauge](https://en.wikipedia.org/wiki/Strain_gauge) and [resistance thermometer](https://en.wikipedia.org/wiki/Resistance_thermometer) measurements, as it is usually faster to read a voltage level off a meter than to adjust a resistance to zero the voltage.

## Derivation

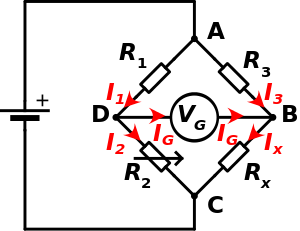
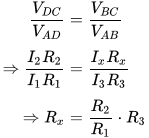
[](https://en.wikipedia.org/wiki/File:Wheatstonebridge_current.svg)

Fig. 6 Wheatstone bridge

Directions of currents arbitrarily assigned

#### Quick derivation at balance

At the point of balance, both the [voltage](https://en.wikipedia.org/wiki/Voltage) and the [current](https://en.wikipedia.org/wiki/Electric_current) between the two midpoints (**B** and **D**) are zero. Therefore, I 1 = I 2 {\displaystyle I\_{1}=I\_{2}} ,  I 3 = I x {\displaystyle I\_{3}=I\_{x}} , V D = V B {\displaystyle V\_{D}=V\_{B}} and:



V D C V A D = V B C V A B ⇒ I 2 R 2 I 1 R 1 = I x R x I 3 R 3 ⇒ R x = R 2 R 1 ⋅ R 3 {\displaystyle {\begin{aligned}{\frac {V\_{DC}}{V\_{AD}}}&={\frac {V\_{BC}}{V\_{AB}}}\\[4pt]\Rightarrow {\frac {I\_{2}R\_{2}}{I\_{1}R\_{1}}}&={\frac {I\_{x}R\_{x}}{I\_{3}R\_{3}}}\\[4pt]\Rightarrow R\_{x}&={\frac {R\_{2}}{R\_{1}}}\cdot R\_{3}\end{aligned}}}

#### Full derivation using Kirchhoff's circuit laws

First, [Kirchhoff's first law](https://en.wikipedia.org/wiki/Kirchoff%27s_first_law) is used to find the currents in junctions **B** and **D**:

I 3 − I x + I G = 0 I 1 − I 2 − I G = 0 {\displaystyle {\begin{aligned}I\_{3}-I\_{x}+I\_{G}&=0\\I\_{1}-I\_{2}-I\_{G}&=0\end{aligned}}} 

Then, [Kirchhoff's second law](https://en.wikipedia.org/wiki/Kirchhoff%27s_circuit_laws#Kirchhoff's_voltage_law_(KVL)) is used for finding the voltage in the loops **ABD** and **BCD**:

( I 3 ⋅ R 3 ) − ( I G ⋅ R G ) − ( I 1 ⋅ R 1 ) = 0 ( I x ⋅ R x ) − ( I 2 ⋅ R 2 ) + ( I G ⋅ R G ) = 0 {\displaystyle {\begin{aligned}(I\_{3}\cdot R\_{3})-(I\_{G}\cdot R\_{G})-(I\_{1}\cdot R\_{1})&=0\\(I\_{x}\cdot R\_{x})-(I\_{2}\cdot R\_{2})+(I\_{G}\cdot R\_{G})&=0\end{aligned}}} 

When the bridge is balanced, then *IG* = 0, so the second set of equations can be rewritten as:

I 3 ⋅ R 3 = I 1 ⋅ R 1 (1) I x ⋅ R x = I 2 ⋅ R 2 (2) {\displaystyle {\begin{aligned}I\_{3}\cdot R\_{3}&=I\_{1}\cdot R\_{1}\quad {\text{(1)}}\\I\_{x}\cdot R\_{x}&=I\_{2}\cdot R\_{2}\quad {\text{(2)}}\end{aligned}}} 

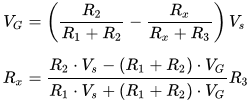
Then, equation (1) is divided by equation (2) and the resulting equation is rearranged, giving:

R x = R 2 ⋅ I 2 ⋅ I 3 ⋅ R 3 R 1 ⋅ I 1 ⋅ I x {\displaystyle R\_{x}={{R\_{2}\cdot I\_{2}\cdot I\_{3}\cdot R\_{3}} \over {R\_{1}\cdot I\_{1}\cdot I\_{x}}}} 

Due to: *I*3 = *Ix* and *I*1 = *I*2 being proportional from Kirchhoff's First Law in the above equation *I*3 *I*2 over *I*1 *I*x cancel out of the above equation. The desired value of *Rx* is now known to be given as:

 R x = R 3 ⋅ R 2 R 1 {\displaystyle R\_{x}={{R\_{3}\cdot R\_{2}} \over {R\_{1}}}}

On the other hand, if the resistance of the galvanometer is high enough that *IG* is negligible, it is possible to compute *Rx* from the three other resistor values and the supply voltage (*VS*), or the supply voltage from all four resistor values. To do so, one has to work out the voltage from each [potential divider](https://en.wikipedia.org/wiki/Potential_divider) and subtract one from the other. The equations for this are:

 V G = ( R 2 R 1 + R 2 − R x R x + R 3 ) V s R x = R 2 ⋅ V s − ( R 1 + R 2 ) ⋅ V G R 1 ⋅ V s + ( R 1 + R 2 ) ⋅ V G R 3 {\displaystyle {\begin{aligned}V\_{G}&=\left({R\_{2} \over {R\_{1}+R\_{2}}}-{R\_{x} \over {R\_{x}+R\_{3}}}\right)V\_{s}\\[6pt]R\_{x}&={{R\_{2}\cdot V\_{s}-(R\_{1}+R\_{2})\cdot V\_{G}} \over {R\_{1}\cdot V\_{s}+(R\_{1}+R\_{2})\cdot V\_{G}}}R\_{3}\end{aligned}}}

where *VG* is the voltage of node D relative to node B.

References:

1. “Text book of Physics-I & II” by K.N. Barik, N. Barik and L. K. Das, Kalyani Publisher,2008.

2. sites.google.com

3. en.wikipedia.org

4. www.ukessays.com

Question Banks

1. Define Electricity and writ down its SI unit.

2. Write Ohms Law.

3.Write and explain Kirchhoff’s Laws.

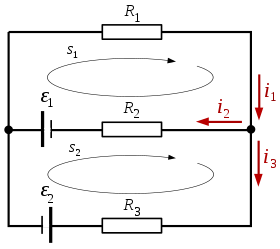
4.Explain application of Kirchhoff’s Laws to Wheatstone Bridge.

5.What resistance x in parallel with resistances 400 Ω and 300 Ω gives an equivalent resistance of 50 Ω?

6. Find the current I passing through and the circuit having voltage source 200v in series with 500ῼ,100 ῼ and 750 ῼ .

7.Find the value of current I3 and I2 , where R1 =100, ῼ ,R2 =200, ῼ, R3 =200, ῼ, 100v and

200v.

[](https://en.wikipedia.org/wiki/File:Kirshhoff-example.svg)