Dr. P. Narayana Reddy

Elements of Electrical Networks

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ELEMENTS OF ELECTRICAL NETWORKS

(A Textbook for Engineering Students)

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PREFACE

This book deals with the fundamental principles of Electrical Circuits. This subject is generally the first course for all Electrical and Electronics Engineering students. This is then followed by a rigorous course of Network Theory. This book is a result of teaching Electrical Circuits for a number of years.

The book is evolved in such a manner that a student wil himself or herself be able to understand the subject if he or shel goes through this book in an orderly manner. Only a very fundamental knowledge of Electricity is assumed.

All electrical apparatuses are ultimately reduced to simple or complex networks depending on the accuracy of the analysis required. Hence a thorough knowledge of Electrical Circuits is very essential for all Electrical and Electronics Engineering students. This book aims at making the student clearly understand and appreciate the concepts of Electric Circuit Theory.

Enough number of worked examples are given along with the theory so as to enable the student to use the book easily even for self studies.

The author would very much appreciate the comments and criticism from the readers and fellow teachers for further improvement of the book.

DR. P. NARAYANA REDDY

Bangalore
March 1981

DEDICATED TO

Dr. A.S. Adke

former Vice-Chancellor,
Karnatak University, Dharwad.

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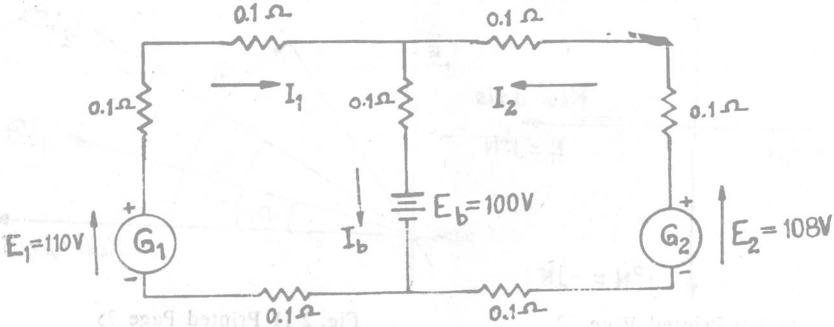

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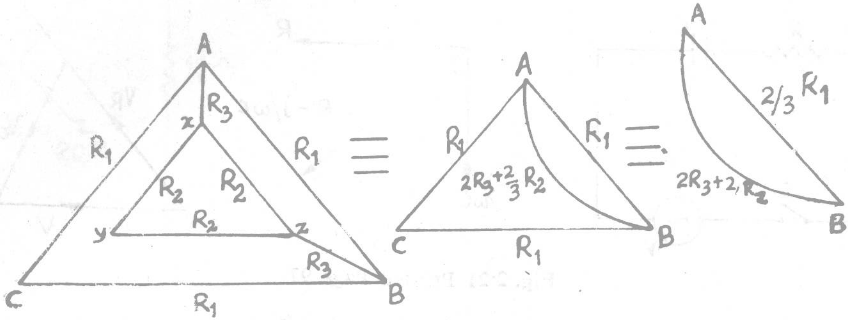

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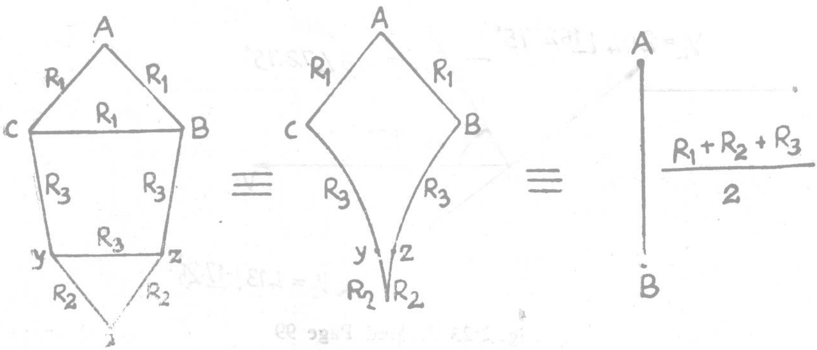

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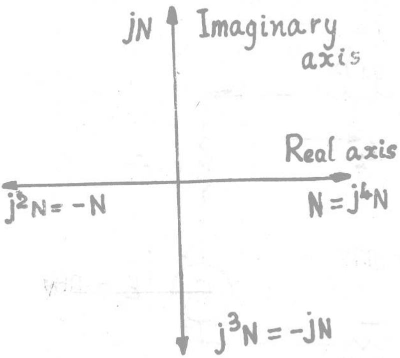

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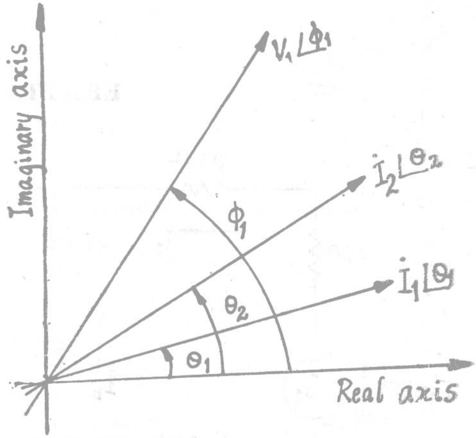

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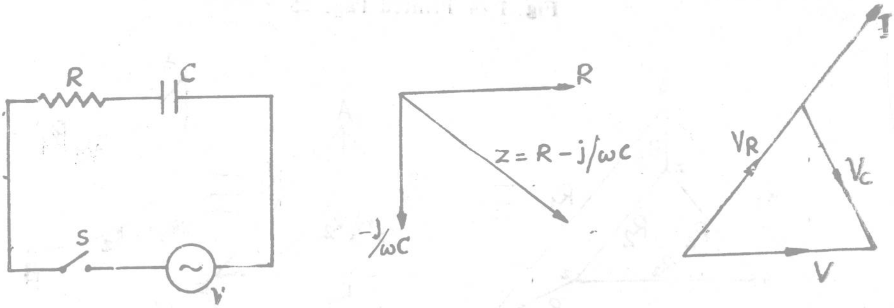

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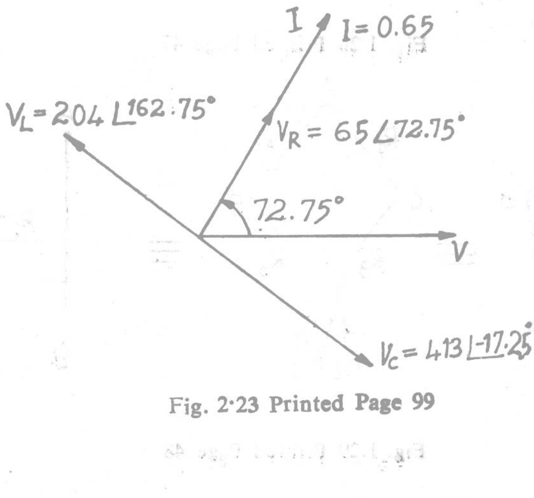

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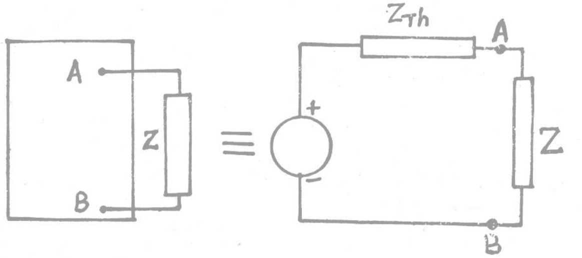

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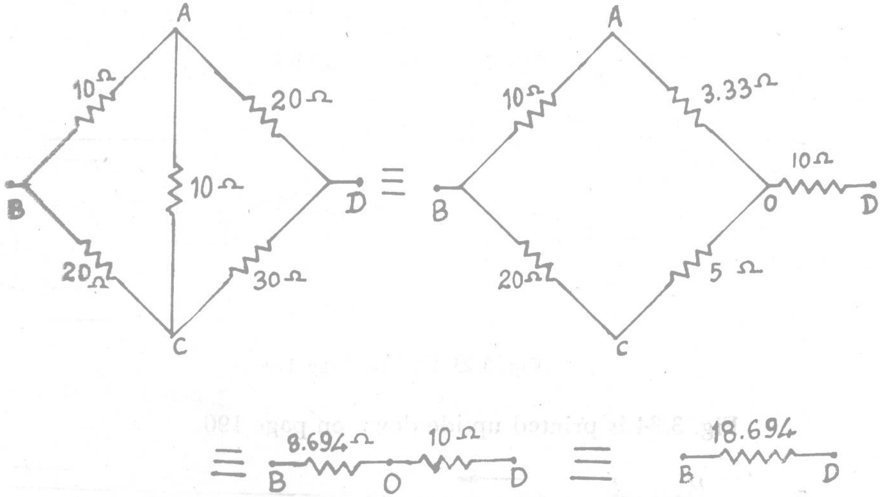

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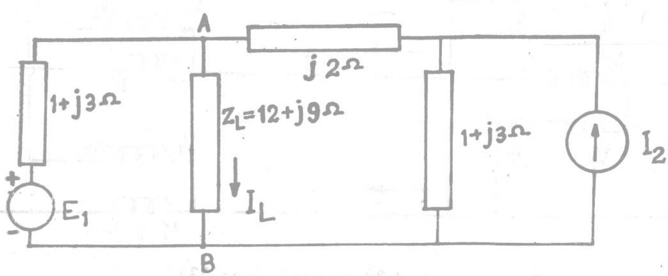

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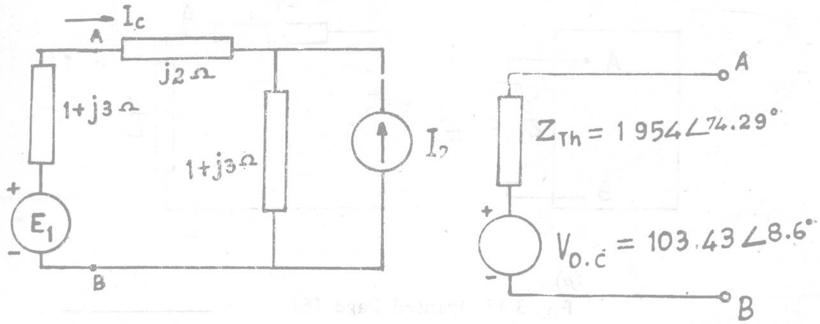

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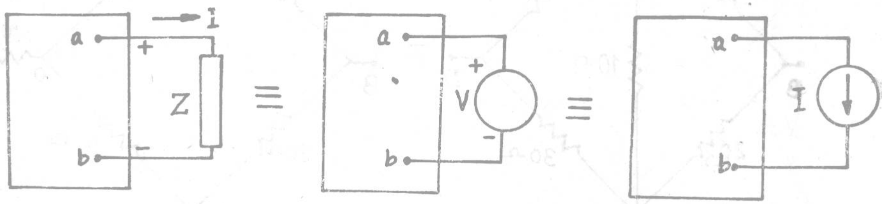

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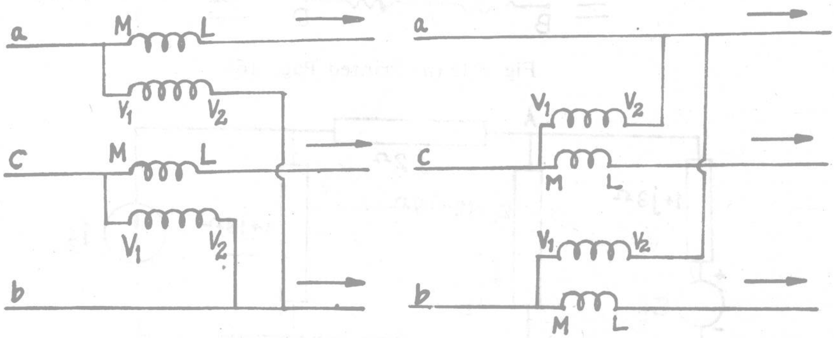

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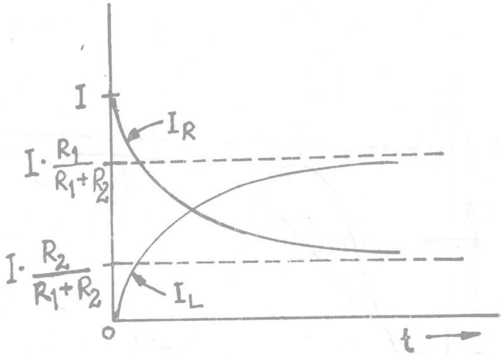

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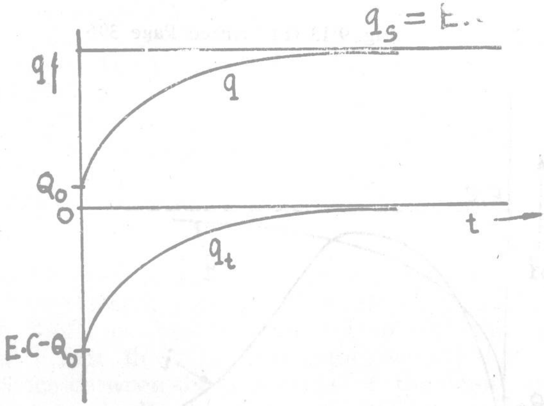

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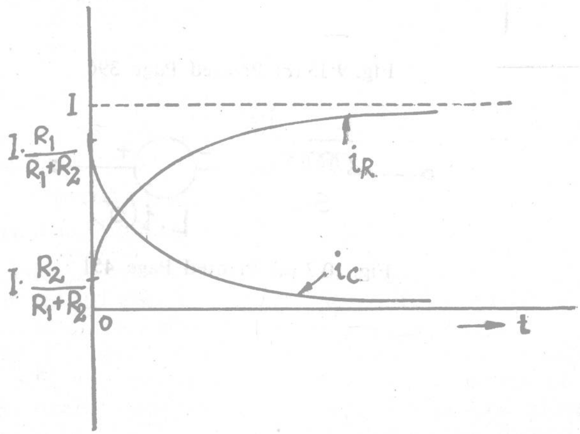

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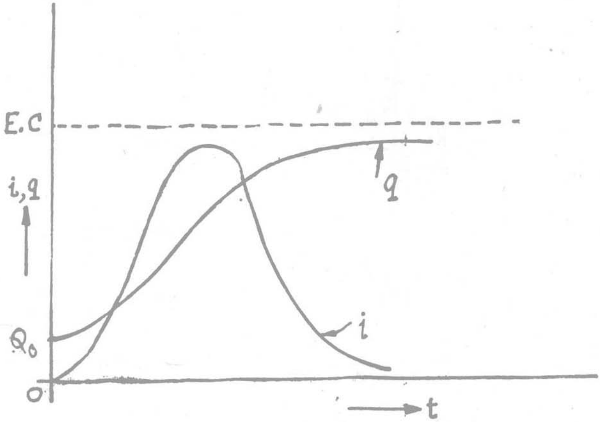

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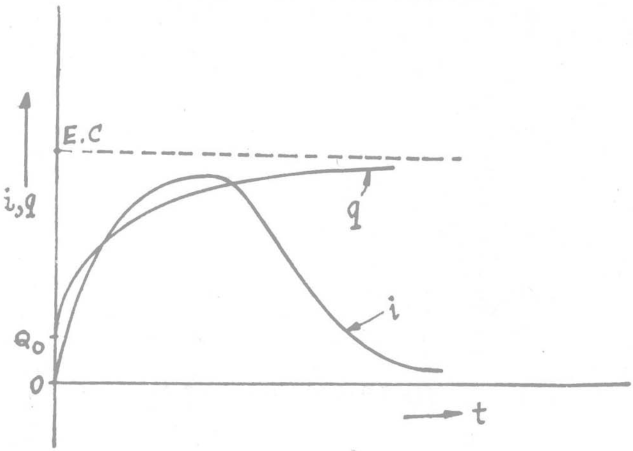

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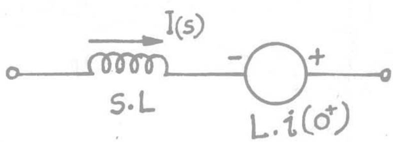

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Direct Current Circuits

Electric current in any conductor is due to the movement of electrons. Each electron has a charge e equal to $1{\cdot}602\times10^{-19}$ coulombs. This charge by convention is assumed to be negative. The electic current is the rate of flow of positive charge and hence the direction of the current is opposite to that of flow of electrons. If N is the number of electrons moving in a conductor per second in a given direction, then the current i which is the rate of flow of positive charge q is

$$i=\frac{dq}{dt}=N.e \text{ amp} \qquad ...(1{\cdot}1)$$

the direction of electric current being opposite to that of movement of electrons.

The electric current is the result of electric pressure across a conductor. This electric pressure is more accurately called *Electro Motive Force* or briefly emf. Due to the influence of emf, when a current flows in conductor, we say that there is a potential difference between the two ends of the conductor. The more common term is voltage. The unit of voltage is *Volt* and normally suggests the difference of potential between two points. The voltage across a conductor suggests the existence of a force that tends to create electric current in the conductor. The unit of electric current is *Ampere*.

1·1. Direct Current

In our study of electric circuits, we mainly deal with two kinds of currents.

(*i*) Direct current and

(*ii*) Alternating current.

A direct current is an unidirectional current whereas an alternating current alternates in direction. In the case of alternating current, the current also may change from instant to instant. As shown in Fig. 1·1, the current is in one direction say positive for 0 to T_1 sec and of opposite direction say negative for T_1 to T_2 sec. This means that the current has changed direction during the period of T_2 sec. This change in direction is repeated every T_2 sec. The current variation with respect to time can be of any form and need not be as shown in Fig 1·1.

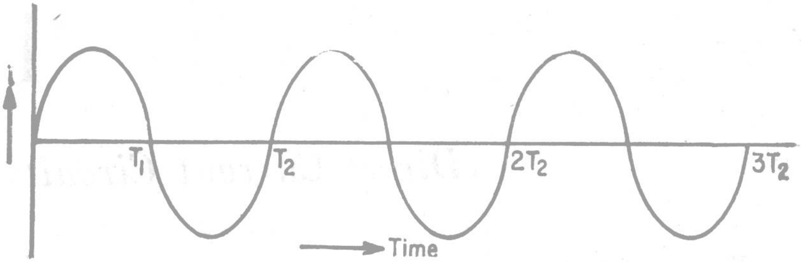
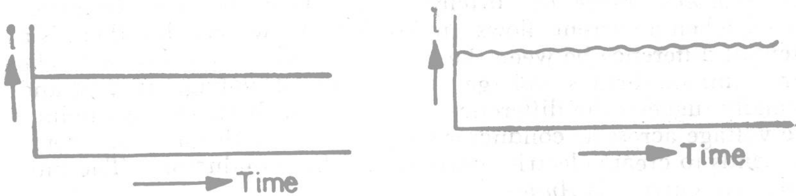


Fig. 1·1. Alternating current.

The direct current is unidirectional. This may be of constant magnitude or there may be slight variations in the instantaneous value of the current as shown in Fig. 1·2. The current of constant magnitude can be obtained by direct current batteries and is called *Direct Current Continuous*. If the magnitude of the direct current has slight variations, then the direct current is called *Direct Current Unidirectional*. This is the type of current obtained from direct current generators. This current is equivalent to a direct current of constant magnitude and a small amount of alternating current superimposed on it. By direct current, we normally mean the average value which is equal to the current of constant magnitude.



(*a*) Direct current continuous. (*b*) Direct current unidirectional.

Fig. 1·2. Direct current.

International Ampere. A direct current unit is *International Ampere* which is defined as an unvarying current that deposits 0·0118 gram of silver per second when passed through an electrolytic cell of standard dimensions.

1·2. Onm's Law

Ohm's law is the most fundamental in the field of electrical engineering. This is a *Law of science* which is found to be true in *nature*. Experimentally, OHM found that electric current in any given conductor is proportional to the voltage (potential difference) applied across the conductor. So *Ohm's law* can be stated as :

The electric current in a conductor is directly proportional to the voltage across the conductor. That means,

$$i \propto v \, ; \, i = G.v \qquad ...(1\cdot2)$$

where G is the constant of proportionality and is called the *conductance* of the element. The conductance of an element suggests its ability to conduct electric current. The above equation can be written as

$$v = R.i \qquad ...(1\cdot3)$$

where $R = 1/G$ is the *resistance* of the element. *Resistance* of an element suggests its ability to resist the flow of current. The unit of resistance is Ohm (Ω) and the unit of conductance is Mho (℧). The resistance of an element is also called the *ohmic value*.

International Ohm. The international Ohm is defined as the resistance of a column of mercury of uniform cross-section, having a length of 106·3 cm and a mass of 14·4521 grams, at zero degree Celsius.

This definition of *Ohm* suggests that the resistance of a conductor depends on

(*i*) the material of the conductor
(*ii*) the length of the conductor
(*iii*) the cross-sectional area of the conductor and
(*iv*) the temperature.

The resistance of most of the materials in Nature increases with temperature at a reasonably uniform rate.

If a homogeneous element of uniform cross-section is taken, then the resistance R at a given temperature is

proportional to length l,

proportional to reciprocal of cross-section $1/a$,

So $$R \propto l/a \, ; \, R = \rho.l/a \qquad ...(1\cdot4)$$

where ρ is the constant of proportionlity and is called *resistivity* of the material. The above equation suggests that the resistance of an element of a given material depends on the *geometrical configuration* of the element. Resistance is the geometrical property of an element. Those elements whose resistive properties are utilised, are called *resistors*. The resistivity of a material is its *physical property* and depends on the material. Most of the heavy metals are good conductors of electricity. The most commonly used material as a conductor of electricity is *copper*.

Consider a cube of side 1 cm. What is the resistance of this cube ? The question has no meaning unless it is clearly mentioned the points or the surfaces between which the resistance is to be