Literature Review

Introduction

In terms of a literature review, "the literature" means the works you consulted in order to understand and investigate your research problem. Re-view (or look again) is a process of systematic, meticulous, and critical summary of the published literature in your field of research. How others have dealt with topics in your research subject and of what knowledge they have acquired?

The following are some definitions which explain the meaning, purposes and functions of literature review:

F. Cardesco and E.M. Gatner (1986): "A literature review is a self-contained unit in a study which analyzes critically a segment of a published body of knowledge through summary, classification, and comparison of prior research studies and theoretical articles."

P. Haywood and E.C. Wragg (1996): "A literature review is the process of locating, obtaining, reading and evaluating the research literature in the area of your interest."

N. Walliman (2010): "A literature review (or overview) is a summary and analysis of current knowledge about a particular topic or area of enquiry."

Review of literature is, thus, an essential part of all research studies. It is a way to discover what other research in the area of your problem has uncovered. A critical review of the literature helps you to develop a thorough understanding and insight into previous research works that relates to your study. It is also a way to avoid investigating problems that have already been definitely answered.

Example: A social scientist is interested to study the impact of social mobilization program on poverty alleviation. From his or her knowledge and experience in the field, he or she knows that a body of knowledge exists about the methods and policies of social mobilization, but he or she also knows that the boundaries of this body of knowledge are constantly expanding. Other social scientists have worked in the same area and have, no doubt, contributed new information to the field. Therefore, he or she seeks to identify these new contributions and add them to the established body of knowledge before he or she conducts his or her own investigation.

Purpose of Literature Review

Scientific research must be based on past knowledge. The previous studies cannot be ignored because they provide the foundation to the present study and provide you with a handy guide to a particular topic. The primary purposes of literature review are: to learn how others have defined and measured key concepts; to identify data sources that other researchers have used; to identify potential relationships between concepts; and to identify researchable hypotheses. The literature review enables you to know:

- What research has been done in the subject?
- What others have written about the topic?
- What theories have been advanced?
- What approaches were taken by other researchers?
- What were the areas of agreement or disagreement?
- Whether there are gaps that can fill through the proposed research?

The purpose of literature review is, thus, to find out what research studies have been conducted in your chosen field of study, and what remains to be done. No matter what topic you choose, chances are that someone has already done research on it. If so, then conducting your research as originally planned would be a waste of time and resource. The purposes of literature survey are as follows:

- To give continuity in research.
- To place the research in a historical context to show familiarity with state-of-the-art developments.
- To synthesize and gain new perspective, get more insight into the topic and know about the knowledge status of the proposed subject.
- To draw a theoretical framework and define the research parameters.
- To discover important variables relevant to the topic.
- To generate hypotheses.
- To identify the methodology and techniques of research.

The literature survey provides the foundation for developing a comprehensive theoretical framework from which hypothesis can be developed for testing.. Another advantage of reviewing the literature applies to the design phase of your project. Designing a study involves several decisions as to what variables to include and how to measure them, what techniques to use, what procedures to follow, and so on. A literature review provides you with a rich source for addressing these important design questions.

Need of literature review:

- It demonstrates that you know the field. This means more than reporting what you have read and understood. Instead, you need to read it critically and to write in such a way that shows you have a feel for the area; you know what the most important issues are and their relevance to your work; you know the controversies and things that are neglected.
- It justifies the reason for research. This is closely connected with demonstrating that you know the field. It is the knowledge of your field which allows you to identify the gap which your research could fill.
- It allows you to establish your theoretical framework and methodological focus. Even if you are proposing a new theory or a new method, you are doing so in relation to what has been done.

Types of Literature Review

There are different types of literature review that can be undertaken, depending on the purpose of the research. The main kinds of literature review are as follows:

- **Historical review:** This type of literature review traces the issues, concepts or events over time.
- **Methodological review**: This kind of review assesses and evaluates methodological techniques used and the strengths of different studies.
- **Theoretical review:** This type of review focuses on the theories or concepts related to the research issue under study.
- **Integrative review:** This type of review summarizes and integrates the current state of knowledge on the topic under study.

  These kinds of literature reviews are not mutually exclusive. These are often mixed together. In the case of academic research, all these types of literature review need to be undertaken.

Functions of Literature Review

The review of literature accomplishes the following functions:

- Ensures that you are not "reinventing the wheel".
- Gives credit to those who have laid the groundwork for your research.
- Demonstrates your knowledge of the research problem.

- Demonstrates your understanding of the theoretical and research issues related to your research.
- Shows your ability to critically evaluate relevant literature information.
- Indicates your ability to integrate and synthesize the existing literature.
- Convinces your readers that your proposed research will make a significant and substantial contribution to the literature.

Encyclopedias

■ ***Encyclopedia Britannica***: It is an excellent introduction to almost any field. It includes features and relatively long articles, which may be relied upon for authenticity and scholarly quality. The original British version of the encyclopedia is sometimes reflected in the fuller treatment given certain English topics. If an American orientation is desired, the Encyclopedia Americana should be consulted. Both these encyclopedias offer extensive bibliographies.

■ ***Britannica Online:*** This is an online version of Encyclopedia Britannica. Now with the online version, the task of locating materials, events and bibliographies has become much quicker and simpler.

■ ***Encyclopedia of the Social Sciences:*** It is the first comprehensive encyclopedia covering all fields of social sciences. Though it is international in scope, its emphasis is on English-speaking and Western European nations. It includes signed articles by specialists with adequate bibliographies. This encyclopedia is a good source for biographical articles.

■ ***International Encyclopedia of the Social Sciences***: International Encyclopedia of the Social Sciences is not meant to replace the earlier Encyclopedia of the Social Sciences. Instead, they should be used together with the International Encyclopedia emphasizing recent developments and an analytic comparative approach to a subject (e.g. "Comparative Politics"). Once again, articles are written by specialists and contain up-to-date bibliographies.

■ ***Encyclopedia of Education:*** Authoritative articles are included covering the history and theory of education, structure of education, structure of educational systems in various countries, research in education, important people and educational institutions, etc. This encyclopedia should be used in conjunction with the detailed index (Vol. 10). Its orientation is based primarily on education in the US; however, a number of articles treat international or comparative topics.

• ***McGraw-Hill Encyclopedia of Science and Technology:*** Clearly written articles, intelligible to the non-specialist, treat the basic subject matter of natural sciences, including their major technological applications in engineering, agriculture, forestry, etc. Articles are profusely illustrated and have short bibliographies.

■ ***Business Encyclopedia and Legal Adviser.*** This encyclopedia includes articles written by professionals in accounting, banking, journalism, commerce and industry and explains the concepts significant to business, including the legalities invol***ved.***

- ***Internet***

Today Internet is a very easy and quick source of Review of Literature. Internet sites are very useful for providing easy access to original writings by important researchers. They also provide such an updated information on the topic that ordinarily is not available in the library. Internet sites also provide for useful bibliographies related to a particular researcher. Search on Internet also reveals some relevant professional societies and academic associations which can provide a lot of support to the studies in the concerned area. Sometimes, the Internet sites include articles extracted from encyclopedias which can also be very useful and informative as background reading. However, they are not normally suitable for citing in a report.

Difference between Reference and Bibliography

While writing an assignment, article or book, the writer often looks for the sources to generate an idea or data. In this context, students usually misinterpret bibliography for reference, but they are different, in the sense that you give **reference** to the sources, that you have quoted in-text, in the research report or assignment. But on the other hand, in the **bibliography**, you create a list of all the sources you have gone through to conceive the idea.

Reference Vs Bibliography Comparison Chart

BASIS FOR COMPARISON	REFERENCE	BIBLIOGRAPHY
Meaning	Reference implies the list of sources, that has been referred in the research work.	Bibliography is about listing out all the materials which has been consulted during the research work.
Based on	Primary Sources	Both Primary and Secondary Sources
Arrangement	Alphabetically and numerically	Numerically
Includes	Only in-text citations, that have been used in the assignment or project.	Both in-text citations and other sources, that are used to generate the idea.
Supporting argument	A reference can be used to support an argument.	A bibliography cannot be used to support an argument.
Used for	Thesis and Dissertation	Journal Papers and Research work

Definition of Reference

Reference can be understood as the act of giving credit to or mentioning the name of, someone or something. In research methodology, it denotes the items which you have reviewed and referred to, in the text, in your research work. It is nothing but a way to acknowledge or indirectly showing gratitude, towards the sources from where the information is gathered.

Definition of Bibliography

At the end of the research report, bibliography is added, which contains a list of books, magazines, journals, websites or other publications which are in some way relevant to the topic under study, that has been consulted by the researcher during the research. In finer terms, it comprises of all the references cited in the form of footnotes and other important works that the author has studied.

Key Differences Between Reference and Bibliography

The difference between reference and bibliography can be drawn clearly on the following grounds:

1. Reference implies referring to someone or something, that means it provides the list of sources, whose text is used in the assignment or research work. Conversely, bibliography represents the list of all the sources, from which the research has gained some information about the topic, irrespective of the work cited or not.
2. References are based on primary sources, whereas bibliography is created on the basis of primary and secondary sources.
3. References used in the assignment can be arranged alphabetically or numerically. On the contrary, list of sources used in the bibliography is arranged numerically.
4. The bibliography is used to list out everything you go through to obtain the information relating to the assignment, no matter if you specifically cite it in your assignment or not. Now coming to references, it only takes into account those sources which have been cited in the assignment.
5. The main objective of adding a reference at the end of the document is to improve credence or support an idea or argument. As against, the bibliography is not used for supporting an argument.
6. While reference is used in thesis and dissertation. On the other hand, bibliography is used in case of journal paper and research work.

Research Design

Introduction

. A research design is the plan of attack: What approach to the problem will be taken? What methods will be used? What strategies will be most effective?

Definition

Fred N. Kerlinger (1986): "Research design is the plan, structure, and strategy of investigation conceived so as to obtain answers to research question. The plan is the overall scheme or program of the research. It includes an outline of what the investigator will do from writing the hypotheses and their operational implications to the final analysis of data".

John W. Creswell (2011): "Research designs are plans and the procedures for research that span the decision from broad assumptions to detailed methods of data collection and analysis."

William Zikmund (2013): "Research design is a master plan specifying the methods and procedures for collecting and analyzing the needed information".

Essential elements of a research design

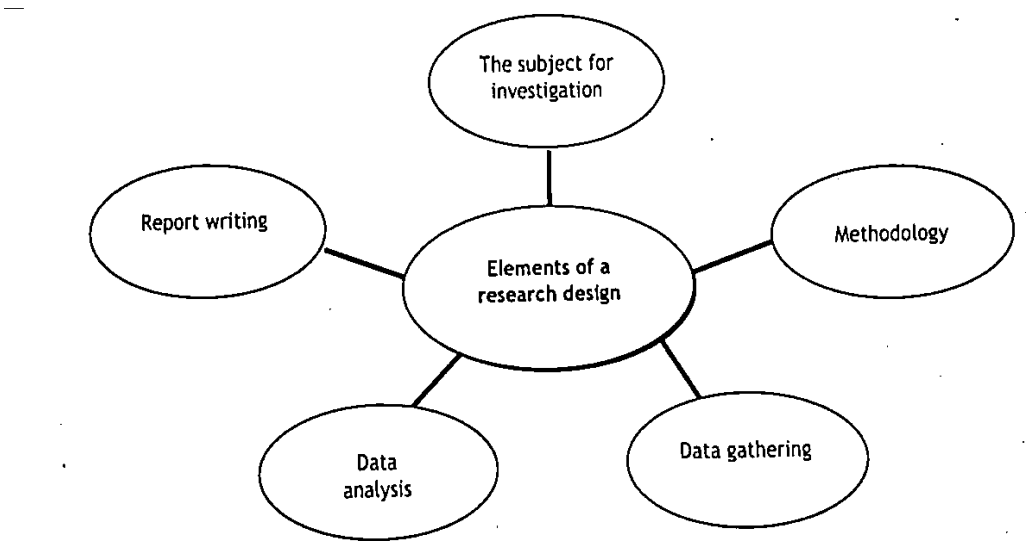
- A research design is an *overall plan* for the activities to be undertaken during the course of a research study.
- The research design serves as a *framework for the study*, guiding the collection and analysis of the data, the research instruments to be utilized, and the sampling plan to be followed.
- It is an *organized and integrated system* that guides the researcher in formulating, implementing, and controlling the study.
- The research design is a *blueprint* specifying the method to be adopted for gathering and analyzing data.

- The research design is a *strategy* of obtaining information for the purpose of conducting a study and making generalizations about the population.

In planning a research investigation, choices have to be made about research strategy (experimental vs non-experimental), research setting (laboratory vs natural setting), measures (questionnaires, observations, interviews), the data analysis strategies (descriptive vs inferential statistics), and a host of other factors. A research design thus includes all these essential factors of an investigation.

Elements of a Research Design

The basic elements of a research design are (a) the problem, (b) the methodology, (c) data gathering, (d) data analysis, and (e) report writing. These elements of research design have been shown in figure. A good research design considers all these elements. The first element of a research design is to answer the research question or test research hypothesis.



Every research work usually requires an explanation of the methodology and the sample description. What methods were used to choose the sample? Why these methods were chosen and how they were applied? Next, there should be an explanation of what the variables are in the hypothesis and how they were measured. Furthermore, the details of the data collection must he explained and a discussion on the reliability and validity of the measurements included. Finally, it is necessary to explain how the data were analyzed.

Preparation of the Research Design

A research design is a clearly planned procedure for carrying out the research. Many things need to be planned in advance. The design generally incorporates answers to the following kinds of questions (Oliver, 2011):

- What sort of data do I need to collect in order to test the hypothesis and/or achieve research aims?
- Where will I collect the data?
- How will I collect the data?
- What type of data-collection instruments and procedures will I use?
- Who will provide me the data?
- Do I need to ask permission before trying to collect data?
- When will I collect the data?
- How will the data be analyzed?
- Will I use a particular theoretical frame in order to interpret the data?

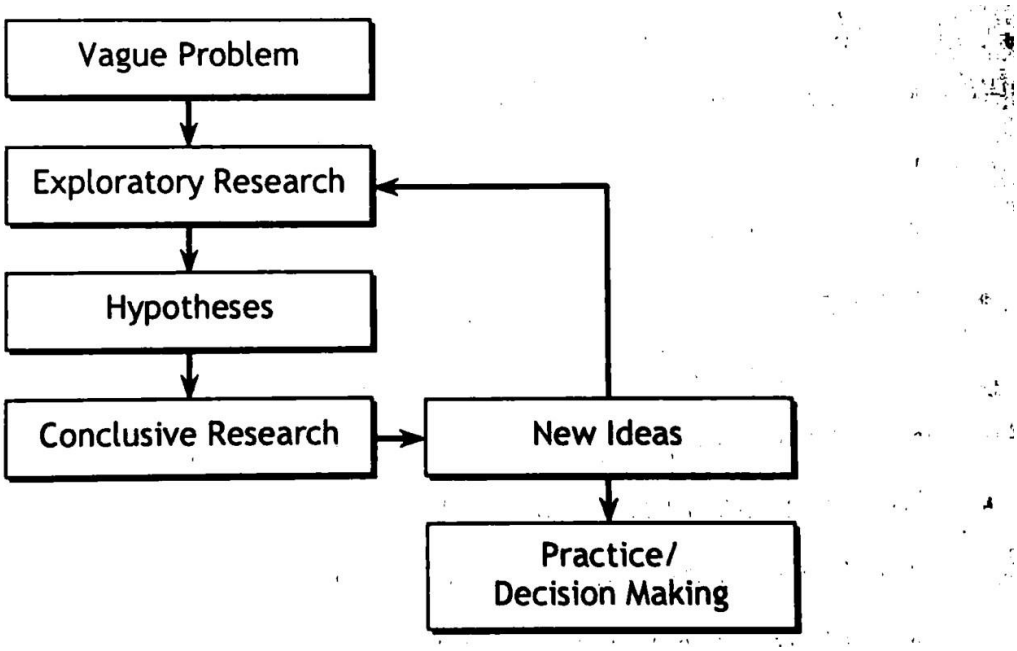
Exploratory Research Design

When searching for hypotheses, exploratory designs are appropriate. When hypotheses have been established and are to be tested, conclusive research designs are needed. Figure given below, highlights the sequence of research activities, from vague problem to new idea generation. First, let us define exploratory research.

An exploratory research is defined as "a study undertaken in areas where very little prior knowledge or information is available on the subject under investigation". It is thus the initial research conducted to study and define the nature of a problem. An exploratory study is undertaken when we do not know much about the situation at hand. In such cases, extensive preliminary work needs to be done to gain familiarity with the phenomenon in the situation.

. There are three purposes for exploratory research:

- Diagnosing a situation
- Screening alternatives
- Discovering new ideas



An exploratory study is undertaken to orient the researcher and the study. It is, therefore' a important method of finding out what is happening, to see new insights, to ask questions, and assess phenomena in a new light. It is particularly useful if you wish to clarify your understanding of a problem. In such study, the focus is initially broad and becomes progressively narrower in the research progresses.

Characteristics of Exploratory Research Design

■ There is no set method of conducting exploratory research. The key requirements for this research are: imagination and flexibility. It is less structured and more flexible.

■ Exploratory research studies are not characterized by formal research design. Hence, they are not very scientific in nature.

■ The researcher may utilize any number of informal approaches in attempting to define the problem and gather the data.

■ Exploratory research provides low-risk form of research that may result in good outcomes. A clear picture of the situation can emerge leading to hypothesis formulation.

■ Exploratory research provides direction for a more formal research effort.

Descriptive Research Designs

Descriptive research describes phenomena as they exist. Such studies involve the systematic collection and presentation of data to give a clear picture of a particular situation. These studies attempt to obtain a complete and accurate description of a situation. These studies can be classified in the following five categories:

(a) Historical

(b) Descriptive

(c) Developmental

(d) Survey

(e) Case Study.

These five types of descriptive research designs are not mutually exclusive. A combination of all these could also be used in some research projects.

(a) Historical Research

History is a meaningful and an organized record of past events. It is not merely a list of events arranged chronologically, but a valid integrated account of social, cultural, economic, and political forces that had operated to produce a historical event.

Historical research is concerned with past phenomena. It can be defined as "the systematic and objective location, evaluation, and synthesis of evidence in order to establish facts and draw conclusions about past events."

Historical research is thus a process of collecting, evaluating, verifying, and synthesizing past evidence systematically and objectively to reach a conclusion. Historical research may also attempt to discern trends in the past and reconstruct the origin and development of those events. The main purpose of conducting historical research is to show the relevance of past events to the present. In other words, the purpose is to arrive at an accurate account of the past so as to gain a clearer perspective of the present.

Accuracy of gathered information is the main ingredient of success in historical research. There are two main sources from where past evidences can be found. One is the primary source, where you were a direct observer of the recorded event and the other is the secondary source, where you are reporting the observations of others. In most cases, you have to depend upon the data observed by others rather than by yourself. At the same time, you must also be aware that inappropriate and biased information results in faulty conclusions and findings.

Characteristics of Historical research

- Good historical data result from painstaking detective work which analyzes the authenticity, accuracy, and significance of source material.
- Historical research must be rigorous, systematic and exhaustive.
- Historical research depends upon two kinds of data: primary sources where the author was a direct observer of the recorded event and secondary sources where the author is reporting the observations of others and is one or more times removed from the original event. Of the two primary sources carry the authority of firsthand evidence and have priority in data collection.
- This critical evaluation of the data is what makes true historical research so rigorous - in many ways, more demanding than experimental methods.
- While historical research is similar to the, "reviews of the literature" which precede other forms of research, the historical approach is more exhaustive, seeking out information from a larger array of sources.

(b) Descriptive Research

It is a type of study, which is generally conducted to assess the opinions, behaviors, or characteristics of a given population and to describe the situation and events occurring at present. Descriptive research is a process of accumulating facts. It does not necessarily seek to explain relationships, test hypotheses, make predictions or get at meanings and implications of a study. Hence, a descriptive research is an extension of an exploratory research.

Descriptive research can be either quantitative or qualitative. This research involves gathering data that describes events and then organizes, tabulates, depicts, and describes the data collection. Descriptive statistics is used to reduce the data to manageable form. Descriptive

research is unique in the number of variables employed:

- Descriptive research, like other types of research, can include multiple variables for analysis.
- Descriptive research might simply report the percentage summary on a single variable.

Descriptive studies thus simply portray an accurate profile of organizations, events, or situation. Investigators collect, classify, and correlate data to describe what exists. However, they do not fully analyze and explain why phenomena behave as they do. They do not put the relationships they describe to crucial experimental tests. Although descriptive research cannot predict and control conditions and events, it contributes to science primarily by building a foundation of facts upon which exploratory hypotheses may be constructed, by checking the validity of existing theories, and by directing attention toward alternative hypotheses which better fit the facts (Van Dalen, 1973). In a descriptive research, it is necessary to have a clear picture of the phenomena on which you wish to collect data prior to the collection of data. Isaac (1978) identifies the characteristics and steps in a descriptive research as follows:

Characteristics

- Descriptive research is used in the literal sense of describing situation or events.
- It is accumulation of a database that is solely descriptive - it does not necessarily seek or explain relationship, test hypotheses, make predictions, or get at meanings and implications, although research aimed at these more powerful purposes may incorporate descriptive methods.

Purposes of Descriptive Studies

- To collect detailed factual information that describes existing phenomena.
- To identify problems or justify current conditions and practices.
- To make comparisons and evaluations.
- To determine what others are doing with similar problems or situations and benefit from their experience in making future plans and decisions.

(c) Developmental Research

Developmental research is conducted for the purpose of predicting future trends. It concentrates on the study of variables, their rates of change, directions, sequences and other inter-related factors over a period of time. There are several methods of developmental research.

(1) **Longitudinal Study**

It is a research where phenomena are studied over time either continuously or repeatedly. This type of study measures the nature and rate of change in a sample at different stages of development. This occurs when the data are collected at two or more points in time from the same group of individuals. Because data are gathered at two different points in time, it is not a cross-sectional or a one-shot study, but it is a study carried longitudinally across a period of time. Longitudinal studies are mostly quantitative.

(1.i)**Trend Study**

The trend study is probably the most common longitudinal study among others. When the data are collected at intervals spread over a period of time, it is called a trend study. It is designed to establish patterns of change in the past in order to predict future patterns or conditions. A trend study thus provides information about net changes at an aggregate level. It can establish a pattern over time to detect shifts and changes in some event. Marketing firms, for example, compile trend studies that chart fluctuations in consumption level for a certain product.

This type of study is particularly used to obtain and analyze social, economic, and political data to identify trends and to predict what is likely to take place in the future. Frequently regression analysis is used for trend studies.

(1.ii)Cohort Study

A cohort is a group of people who share a common characteristic or experience within a defined period. Thus, cohort study is a study of a specific group, such as those born on a day or in the particular period, say in the year 2003. This group then forms a birth cohort or a kindergarten cohort. Similarly, a group of students graduating from college in a year form a student cohort. There are many other kinds of cohorts, including disease, education, employment, housing, family formation, and the like.

A sample of the selected cohort group is then studied at different points of time. A cohort study s thus a systematic follow-up of a group of people for a defined period of time or until a specified event. To form cohort studies, data are compiled for the same population over time. Such studies are therefore rare because of the difficulty of maintaining contact with members of the cohort from year to year.

(1.iii) Panel Study

A panel is a group of individuals that have agreed to provide information to a researcher over period of time. In panel study we take the same people and study their attitudes towards particular phenomenon over time. Panel studies are most useful when studying change. These studies allow the researcher to find out why changes in the population are occurring. They measure the same sample of respondents at different points in time. For example, if we were interested in finding out the general attitude towards single parenthood, we would take a group of people and interview them at periodic intervals on the same subject and over a number of years.

(2.0) **Cross-sectional Study**

This type of study is also known as cross-sectional analysis. It involves observation of some items of the population all at the same time. This study basically measures the rates of changes by drawing samples from a cross-section of society. It focuses on comparing and describing groups.

In this study, data are gathered just once, perhaps over a period of time, in order to answer a research question. Such studies are also known as one-shot studies. Cross-sectional studies often employ the survey strategy. The fundamental difference between a cross-sectional study and longitudinal study is that a cross-sectional study takes place at a single point of time and that a longitudinal study Involves a series of measurements taken over a period of time

Characteristics of developmental Research

- Developmental research focuses on the study of variables and their development over a period of months or years. It asks, "What are the patterns of growth, their rates, their directions, their sequences, and the interrelated factors affecting these characteristics?"
- The sampling problem in the longitudinal method is complicated by the limited number of subjects it can follow over the years; any selected factor affecting attrition biases the longitudinal study.
- Once underway, the longitudinal method does not lend itself to improvements in techniques without losing the continuity of staff and financial support over an extended period of time and typically is confined to university or foundation centers that can maintain such an effort.
- Cross-sectional studies usually include more subjects, but describe fewer growth factors than longitudinal studies. While the latter is the only direct method of studying human development, the cross-sectional approach is less expensive and faster since the actual passage of time is eliminated by sampling different subjects across age ranges.
- Sampling in the cross-sectional method is complicated because the same children are not involved at each age level and may not be comparable.

(d) Survey Research

A survey is a means of gathering information about the characteristics, actions, or opinions of a large group of people, referred to as a population. A survey research is thus defined as "the Systematic gathering of information from respondents for the purpose of understanding and/or predicting some aspect of the behavior of the population of interest". If conducted scientifically this type of research can contribute to the advance of knowledge.

A Survey study may be done in the field - an example would be a survey of employee attitudes toward a new compensation policy- or it may take in a library, where a survey of secondary literature is conducted. In survey research, the researcher selects a sample of respondents from a population and administers a standardized questionnaire to them. Hence, using surveys it is possible to collect data from large or small populations.

Types of Survey Research

- Exploratory survey research. This type of survey research takes place during the early stages of research. It provides the basis for more in-depth surveys. Sometimes, this kind of survey is carried out using data collected in previous studies.
- Confirmatory (theory-testing or explanatory) survey research. In this type of survey, data collection is done with specific aim of testing the theory or hypothesis.
- Descriptive survey research. This type of survey research describes the distribution of the phenomenon in a population. Through facts described, it can provide useful hints both for theory building and for theory refinement.

The aim of survey research is to measure certain attitudes or behavior of a population or a sample. The attitudes might be opinions about the services provided by a business firm or feelings about certain issues or practices. Most often respondents are asked for information. Surveys come in a wide range of forms and can be distributed using a variety of media: written surveys, oral surveys, or electronic surveys. The questionnaire, or survey, can be a written document that is completed by the person being surveyed, on online questionnaire, a face-to-face interview, a mail survey, or a telephone interview. Some forms of survey research by telephone or Internet may be completely automated. Using surveys, it is possible to collect data from large or small population.

(e) Case Study Research

Case studies are written summaries or synthesis of real-life cases based upon data and research. A case study is thus defined as *"a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within a real-life context using multiple sources of evidence".*

Yin (1994) defines the case study research as *"an empirical inquiry that investigates contemporary phenomenon within its real-life context"* (p.79). Rather than using samples to examine a limited number of variables, case study methods involve in in-depth, longitudinal examination of a single instance or event (case). This research thus views a social or study unit as a whole in its real-life context. This study phenomenon could be a person, a family, a social group, an institution, a community, or even an entire culture.

A case study not only uses the sources and techniques of historical story but also employs several techniques and sources of data for examining current aspects of the phenomenon under study. A case study could be conducted in the field as well as a non-field setting (Shah,1972, p.11).

The investigator gathers pertinent data about the present status, past experiences and environmental forces that contribute to the individuality and behavior of the unit. After analyzing the sequences and inter-relationships of these facts he or she conducts a comprehensive study of the social unit as it functions in society.

Case studies need to be both comprehensive and systematic. That is, as much data as possible need to be collected in a way that ensures as little as possible is missed. Jensen and Rodgers (2001) set forth a typology of case studies as follows:

■ *Snapshot case studies are the detailed study of one unit.*

■ *Longitudinal case studies are studies of the same unit at multiple time points.*

■ *Pre post ease studies are undertaken at two time points separated by a critical event.*

■ *Cross-cut studies are studies of multiple case studies for the purpose of comparison.*

When selecting a case for a case study, researchers often use information-oriented sampling, as opposed to random sampling. This is because the typical case is often not the richest in information. Information-oriented cases may be distinguished as: extreme cases, critical cases, and exemplar cases. Extreme cases reveal more information because they activate more basic mechanisms and more actors in the situation studied.

It is sometimes impossible for us to handle the whole social reality; at other times, the conceptual basis for understanding some aspects of social reality is not available. In such cases, you may first want to explore the social reality before you formulate and test specific hypotheses. But you must recognize that a case does not represent the total reality. It is just one example of the social reality. Hence, a case study may be an intensive, integrated and insightful method of studying the social phenomena. It can also be used to illustrate a theory by providing an example.

In recent years, there has been increased attention to implementation of case studies in a systematic manner which increases the validity of associated findings. However, although case study research may be used in its own right, it is more often recommended as part of a multi- method approach (triangulation).

Characteristics

■ Case studies are in-depth investigations of a given social unit resulting in a complete, well- organized picture of that unit.

■ Compared to a survey study which tends to examine a small number of variables across a large sample of units, the case study tends to examine a small number of units across a large number of variables and conditions.

■ Because case studies are intensive, they bring to light the important variables, processes and interactions that deserve more extensive attention. They pioneer new ground and often are the source of fruitful hypotheses for further study.

■ Because of their narrow focus on a few units, case studies do not allow valid generalizations to the population from which their units came until the appropriate follow-up research is accomplished, focusing on specific hypotheses and using proper sampling methods.

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Limitations of Case Study

- A case study is more expensive because of its exploratory nature.
- A generalization drawn from a single case cannot be applied to all cases in a given population
- There is some element of subjectivity. You must guard against permitting personal biases and standards to influence your interpretation.

Analytical Research Design

Analytical Research designs can be experimental or observational and each type has its own features. A study design is critical to the research study because it determines exactly how we will collect and analyze our data. If we aim to study the relationship between two variables, then an analytical study design is the right choice. It's necessary to have a clear plan before we begin data collection. Analytical study designs can be experimental or observational and each type has its own features.

A study design is a systematic plan, developed so we can carry out our research study effectively and efficiently. Having a design is important because it will determine the right methodologies for our study. Using the right study design makes our results more credible, valid, and coherent.

Descriptive vs. analytical Research

Study designs can be broadly divided into either descriptive or analytical.

Descriptive studies describe characteristics such as patterns or trends. They answer the questions of what, who, where, and when, and they generate hypotheses. They include case reports and qualitative studies.

Analytical study designs quantify a relationship between different variables. They're used to test hypotheses and make predictions**.**

Experimental and observational

Analytical study designs can be either experimental or observational. In experimental studies, researchers manipulate something in a population of interest and examine its effects. These designs are used to establish a causal link between two variables.

In observational studies, in contrast, researchers observe the effects of a treatment or intervention without manipulating anything. Observational studies are most often used to study larger patterns over longer periods.

Experimental Research Method

The experimental method of research is used as the classical method in physical sciences. It is based on observation or experiments. It deals with actual experiments to determine the relationship between cause and effect of various experimental treatments. It is defined as 'the research method in which a researcher objectively observes phenomenon which is made to occur in a strictly controlled situation where one or more variables are varied and others are kept constant'.

The purpose of experimental research is to investigate cause and effect relationship by exposing one (or more) experimental groups to one (or more) treatment conditions & comparing the result to one (or more) control groups not receiving the treatments. In this method, the researcher undertakes control or manipulation (vary) of various variables under study. The usual approach is to hold all variables constant except one in controlled condition. By varying this one variable,

the out puts (the effects) are studied and documented.

Actually, in social sciences, in natural sciences, in biological phenomena and the human behavior control of variable is hardly possible. However, in physical sciences and experimental technology the investigation in controlled condition is highly acceptable.

Experiment is a test of a casual proposition, such as:

i) Do changes in variable 'A' cause changes in variable 'B' keeping other variables constant?

ii) How the changes in the value of one variable (called independent variable) affect another variable (called dependent variable)?

The mathematical form of the experimental method is given below: If x_1, x2, x3, x4... xn are n independent variables taken as the inputs of the process and y is the output of the process (a dependent variable), then y is defined as a function x and denoted by,

$y = f(x)$

Where,

x means x_1, x_2, x_3, x_4.....x_n and f denotes the function

Suppose for an example, yield (y) of a product in an agricultural field is influenced by the following four different independent variables:

x_1 - seed quality (qualitative variable say, Si, S2),

x_2 - amount of fertilizer (quantitative variable, in kg),

x_3 - irrigation scheme (categorical variable say, I_1, I_2,I_3)

x4 - labor input (quantitative variable say, in number)

The production or yield, which depends upon these four variables, can be related mathematically as

$Y = f(x)$

Or $Y= f(x_1, x_2, x_3, x_4)$

By taking any three (say x_1, x_2, x_3) constant one can observe the effect of x_4 in Y; x_4 may vary as researchers will, so it is said to be a controlled variable.

The various factors in an experiment are divided into two groups: independent variables and dependent variables. The first sets of a factor or factors are called an experimental group and the second sets of factors are called control group. Control group is also known as a group of individuals, items or objects used as a standard for comparison or accepted norm.

To make the experimental method of research effective and distinct from normal activity the method of local control (blocking) and statistical control methods are used. Control is necessary to reduce variations. In some experiments, some variables may be eliminated.

Types of Experiment

Experiment is the scientific investigation in which an investigator manipulates and controls one or more independent variables and observes the dependent variables for variation concomitant to the manipulation of the independent variable. There are four different types of experiments.

1. Positive and Negative Experiment If the subject of an experiment is such that i) the phenomenon and ii) its cause both are present, the experiment is said to be positive. For example, a bell rings in the air. Here both the sound and cause of its propagation are present; but if, on the other hand, a bell is rung in a vacuum, there will be no phenomenon of a sound because the cause of the propagation, namely air is absent. Such experiment is called negative experiment.

2. Natural Experiment These experiments are to be observed in natural phenomenon. In most of the natural state experiments, the controlling of variable is unnecessary to obtain, the real information about the phenomena. In such case, the whole phenomenon is divided into control group and experimental group to study the effects of seen and unseen variables.

3. Laboratory Experiment These are the experiments performed in physical sciences with full control of external conditions. A laboratory experiment is an artificially created situation in which the researcher controls one or more variables while manipulating other variable at will. The method of lab experiment is used in the experiments, mainly related to the physical, chemical, microbiological, clinical and such other sciences. If, it is difficult to conduct an experiment out-side or in the field or in the society then one tries to carry out it in the laboratories.

4. Field Experiment Field experiments are the experiments conducted in the field or in natural setting. Research study in a realistic situation in which one or more independent variables are manipulated by the experimenter under carefully controlled conditions as the situation will permit. In the social, managerial, agricultural, environmental researches, the method of field experiment is widely used. Some of the field experiments like agricultural or business field the controlling of the variable is possible but in the careful condition

Purposes of Experimental Method

a. To determine the effect of various treatments and to compare the differences of effects as significant or non-significant.

b. To estimate the interaction effects of various treatments and to compare them

c. To establish the mathematical relationship between various treatments and their effects.

Problem in Experimentation

- To single out one factor from the phenomena

It is always difficult to single out one factor from a social phenomenon for the purpose of measurement, because in any event there may be many factors interacted.

- Controlling the factors

Control of factors sometimes is not possible, because some factors may be unknown and uncontrollable. It is better to select several random samples as experimental and control groups. One solution here is the adoption of the control group technique.

- To get data from the control groups

There are difficulties in getting data from the control groups. The remedy may be found in matching the control and experimental groups on as many points as possible.

- To assign the level of significance

The determination of the required level of significance of the differences between the experimental and control groups is also fraught with difficulty. What difference can be taken as fraught with difficulty? What difference can be taken as significant? There is the problem of value judgment. But the scientific criterion is the determination of the statistical test of significance. However, this requires a reliable and valid socio-metric scale.

- Change in response of people

In field experiment related with human behaviors (society and clinical setup), when data collected through human interaction due to changes in time, situation, environment and types of questions to be asked people often changes their responses.

- Change in theme of trialing

Due to change in behavior of the respondents and unsatisfactory management of the investigator theme of trialing of the area under experiment (in social and clinical setup) may change at the end of the experiment from what it was started. Because of the changes made by experimentation may give different responses which may lead wrong conclusion.

- Problem of handling or operation

In social setup and to the medical trials, if the people under study area is not aware, attentive and responsive about the inquiry, true response cannot be possible.

Steps in Experimental Methods

Statement of the problem, research questions and the objectives

The first step in the application of field techniques is related in mentioning of problem, research questions and specific objective. The hypothesis, at this stage, should be stated explicitly in general terms.

Examination of possible outcomes and events through literature

The second step consists in setting up the field experiment by thorough reading of the available literature. The factors to be controlled must be assessed, the cooperation between the researcher and the subject must be set up.

Design of experiment

The next step is the choice of experimental design regarding its size, material, control groups etc. The choice of material should be based on the criterion of maximum possible accuracy. The basic problem of design relates to control. Control and experimental groups should be matched on all important factors.

Performing experiment

The next step of this method is to performing experiment in predefined circumstances. The principles of randomization, replication and blocking should be implemented as can as possible. The sensitiveness of experiments can be augmented by neutralizing the biases through random choice, by increasing the replication, improving the quantitative technique and by refinements of techniques.

Analysis of experimental out comes statistically

The analysis of the experimental data should be done starting from stating the descriptive nature of the data, measuring relationship between them and modeling data into some mathematical models. The analysis of variance permits a study of complex interrelationship, which is not possible by simpler designs. It permits more reliable conclusions about more hypotheses with fewer cases than if hypotheses were tested in separate design.

Drawing conclusions by measuring reliability

For an experimental research the conclusions are drawn based on the statistical significance testing. The tests can be performed as required level of design by the use of different statistical techniques. The results obtained then are put to test their reliability and the conclusions are made.

Testing the validity of the conclusion

The validity of the results should be measured before disseminating the results and reports. The validity of the experimental results is checked by the comparing with other similar phenomenon or to the standards.

Evaluation of the entire investigation through practice

The success of the experimental study can be measured only through putting into practice the experiments many times. If the repeated experiments give similar or better results, then the experimental results may be considered satisfactory.

Ethical Issues in Experimental Research Design

- The following practices are considered unethical:
  - Putting pressure on individuals to participate in experiments through coercion, or applying social pressure.
  - Deceiving subjects by deliberately misleading them as to the true purpose of the research.
  - Exposing participants to physical or mental stress.
  - Not allowing subjects to withdraw from the research when they want to.
  - Using the research results to disadvantage the participants, or for purposes not to their liking.
  - Not explaining the procedures to be followed in the experiment.
  - Not debriefing participants fully and accurately after the experiment is over.
  - Not preserving the privacy and confidentiality of the information given by the participants.
  - Withholding benefits from control groups.

Research Guides

Research Guides are **librarian-curated pathways to information, videos, databases, and other resources for your discipline**. That is, they pull many different types of resources on a subject or topic together in one place.

Hand Book

A handbook is a compilation of miscellaneous information in a compact and handy form. It contains data, procedures, principles etc. Tables, Graphs, diagrams and illustrations are provided. Scientists and technologists use handbooks in their fields.

A treaties on a special subject; often nowadays a simple but all-embracing treatment, containing concise information, and being small enough to be held in the hand; but strictly, a book written primarily for practitioners and saving for constant revision or reference. Also called a 'Manual'.
Example:

- Britain, 1948/49-, an official handbook, London, stationery Office, 1948-, Annual.
- Handbook of Chemistry and Physics: A ready reference book of Chemistry and Physical data, 52nd ed, Cleveland, Ohio, Chemical Rubber, 1971**.**

CITATION

A "citation" is **the way you tell your readers that certain material in your work came from another source**. It also gives your readers the information necessary to find the location details of that source on the reference or Works Cited page. A citation must include a set of parentheses.

For APA, IEEE and other reference style follow the web-link given below

APA

APA is the style of documentation of sources used by the American Psychological Association. This form of writing research papers is used mainly in the social sciences, like psychology, anthropology, sociology, as well as education and other fields.

IEEE

The Institute for Electrical and Electronics Engineers (IEEE) is a professional organization supporting many branches of engineering, computer science, and information technology. In addition to publishing journals, magazines, and conference proceedings, IEEE also makes many standards for a wide variety of industries.

IEEE citation style includes in-text citations, numbered in square brackets, which refer to the full citation listed in the reference list at the end of the paper. The reference list is organized numerically, not alphabetically

https://pitt.libguides.com/citationhelp/apa7

Citation Index

Citation indexes allow researchers to trace the impact of an article upon later publications. Besides including the bibliographic information about an article (author, article title, journal title, date, etc.), citation indexes also provide each article's references or bibliography (the list of sources cited).

For citation Index follow the web link: **https://www.isko.org/cyclo/citation**

SCIFinder

SciFinder is a database focused on the literature in chemistry. It is produced and published by CAS: Chemical Abstracts Service, a division of the American Chemical Society. CAS has, as its objective, "to find, collect and organize all publicly disclosed chemical substance information."

Follow the link **: https://library.ulethbridge.ca/scifinder/overview#s-lg-box-wrapper-9172764**

SCOPUS

Scopus Indexed Journals are considered better sources for citation as compared to other databases. Scopus publications enjoy a good reputation among peer researchers due to their rigid selection procedure that ensures high-quality content and reliable data. In addition, the journal database is recognized by scholars in research and academia.

Follow the link: **https://www.aimlay.com/scopus-indexed-journals/**

Science direct:

ScienceDirect is **a website which provides subscription-based access to a large database of scientific and medical research**. It contains the world's largest electronic collection of full-text and bibliographic information on science, technology and medicine

Follow the link: **https://cscitconf.cikd.ca/an-introduction-to-sciencedirect/**

Impact Factor

In any given year, the two-year journal impact factor is the ratio between the number of citations received in that year for publications in that journal that were published in the two preceding years and the total number of "citable items" published in that journal during the two preceding years:

$$\mathrm{IF}_y = \frac{\mathrm{Citations}_y}{\mathrm{Publications}_{y-1} + \mathrm{Publications}_{y-2}}.$$

For example, *Nature* had an impact factor of 41.577 in 2017

$$\mathrm{IF}_{2017} = \frac{\mathrm{Citations}_{2017}}{\mathrm{Publications}_{2016} + \mathrm{Publications}_{2015}} = \frac{74090}{880 + 902} = 41.577.$$

Follow the link: **https://en.wikipedia.org/wiki/Impact_factor**

H-Index

The *h*-index is defined as the maximum value of *h* such that the given author/journal has published at least *h* papers that have each been cited at least *h* times

Follow the link: **https://en.wikipedia.org/wiki/H-index#Calculation**

APA STYLE: SEVENTH EDITION

These guidelines follow the 2020 7th edition of the American Psychological Association's *Publication Manual*, which is widely used in the health and social sciences. They focus on documentation, but the manual addresses issues from abbreviations to layout and should be consulted for further information. In an APA-style paper, you'll identify the author and year of each source any time you use it. That information directs readers to more detailed entries on a reference list at the paper's end.

■ Citing Sources in Your Paper

Your readers can't know where any word, idea, or information in your sentence comes from unless you tell them. It could be your own idea, or from the source you just mentioned, or from a completely different source. That's why you need to tell them! Once you've told them, they may want to find out more about that source. To help them, your citation will always include the first word(s) of your reference page entry--usually the name of the person(s) or group considered the "author" of the work. Direct quotations require page or paragraph numbers, but paraphrases usually don't. Both can be cited **narratively** (author's name as part of the sentence) or **parenthetically** (author's name in parentheses after the sentence).

		Narrative Citation	**Parenthetical Citation**
DIRECT QUOTATION	**One author**	Sendak (2015) contended that "imagination is crucial" (p. 2).	Clearly, "imagination is crucial" (Sendak, 2015, p. 2).
	Two authors	According to Sendak and Wise (2010), "Imagination is crucial" (pp. 112-113).	It is true that "imagination is crucial" (Sendak & Wise, 2010, pp. 112-113).
	Three+ authors	"Imagination is crucial," Sendak et al. (2001) reflected (para. 5).	"Imagination," however, "is crucial," (Sendak et al., 2001, para. 5).
	Group author, first reference	The American Library Association (ALA; 2005) has insisted that "imagination is crucial" (para. 2).	Perhaps "imagination is crucial" (American Library Association [ALA], 2005, para. 2).
	Group author, late rreference	The ALA (2005) has insisted that "imagination is crucial" (para. 2).	Perhaps "imagination is crucial" (ALA, 2005, para. 2).
	Author unknown	The author of "Feeding Young Minds" (2010) noted that "imagination is crucial" (p. 5).	One article (2010) claimed that "imagination is crucial" ("Feeding," 2015, p. 5).
PARAPHRASE	**One author**	Sendak (2015) argued that children must develop imagination.	Children must develop imagination (Sendak, 2015).
	Two authors	Sendak and Wise (2015) believed that children must develop imagination.	Children must develop imagination (Sendak & Wise, 2015).
	Three+ authors	Children must develop imagination, observed Sendak et al. (2015).	Children must develop imagination (Sendak et al., 2015).
	Group author, first reference	Children must develop imagination, the American Library Association (ALA, 2015) has explained.	Children must develop imagination (American Library Association [ALA], 2015).
	Author unknown	In "Feeding Young Minds" (2015), the author suggested that children must develop imagination.	Children must develop imagination ("Feeding," 2015).

1. **Dates**. APA includes the year of publication in every parenthetical citation and in the first narrative citation of each source in any paragraph (although some teachers require it in all narrative citations). Only the year of publication goes in your in-text citation, even if the reference page entry includes a month. *Manual*, p. 262.

2. **Page numbers**. APA requires specific page, paragraph, or location numbers for all direct quotations. Specific page numbers are rarely included for paraphrases and most teachers don't allow them, although APA does.

   List all digits in every page number. For written sources without page numbers, use "para.," the paragraph number, and, when possible, the section heading. Put document-specific headings in quotation marks and shorten them if needed. For video or audio sources, use the timestamp; for PowerPoint presentations, use the slide number. *Manual,* p. 264.

   (Drew, 2002, para. 4)
   (Marvin, 2009, Introduction, para. 12)…
   (Fayne, 2013, "Idaho Dentists Find," para. 3)

   Major classical works like the Qur'an, *The Odyssey,* and *Macbeth* have standard numbering systems that cross all editions and translations, so use those systems instead of page numbers. *Manual,* p. 274.

   (Shakespeare, 1623/2003, 1.5.45-60)
   (*King James Bible*, 1769/2017, 2 Sam. 12:1-10)

3. **Names**. The body of an APA paper typically uses last names only, even on first reference. Endings like "Jr." and academic degrees are not included. *Manual,* p. 262.

   Garland and Wilder (2013) found that…
   Other research suggests that this model may be inadequate (Garland & Wilder, 2013).

   APA doesn't use first names or initials in citations unless that's the only way of distinguishing between two sources. However, be aware that some fields like English may expect first and last names on first narrative reference. *Manual,* p. 262.

4. **No author.** When you don't know the name of your source's author, use the first words of its title. Italicize the title of a periodical, book, or report; use quotation marks for an article. *Manual,* p. 265.

   Book: (*Eating Disorders*, 2018) or the book *Eating Disorders* (2018)
   Article: …benefits have been demonstrated ("Holistic Approach," 2002)

5. **Multiple authors**. If your source has two authors, cite both every time. If it has three or more authors, use the first author's name with "et al." Note that "et al." is not italicized and that there is a period after "al." If you name two authors in a narrative citation, write out the "and" between their names. In a parenthetical citation, use "&." *Manual,* p. 266.

   One study of peer relationships… (Granger & Patil, 1997).
   A later study of peer relationships… (Longbottom et al., 1999).

6. **Group authors.** When the author of your source is an organization, its name is spelled out in full on first reference. If it's well-known or will be used at least two more times, an abbreviation (in parentheses) follows the full name and replaces the full name later. Don't go back and forth between the full name and the abbreviation. *Manual,* p. 268.

7. **One author, multiple works**. If you're citing two works written by the same author(s) in different years, cite them as you normally would. If you have two works written by the same author(s) in the same year, however, those works will be listed alphabetically by title on your reference page, where they'll be labeled (YYYYa) and (YYYYb). *Manual,* p. 267.

    Cisneros (2011a) found….
    …..direction for future research (Cisneros, 2011a).

8. **One citation, multiple sources**. If you refer to several sources within the same parentheses, put them in the same order in which they appear in your reference list and separate them with a semicolon. *Manual,* p. 263.

    (Andrews et al., 1996; Gillis, 2017; Gillis, 2019; Shirley & Blythe, 2013)

9. **One paragraph, multiple references to same source.** If all the information in a paragraph comes from one part of one source, identify its author and date at the beginning. If you use transitional phrases and pronouns like "these findings" to show that each following sentence paraphrases material in the same source, you won't have to repeat the citation unless your teacher requires it. *Manual,* pp. 269-270.

    If you cite a source by putting the author's name in your sentence, you don't have to include the date again in other sentences within the same paragraph (although some teachers will expect you to). You do have to include the date in any parenthetical citations. *Manual,* p. 265.

    Travers (2006) found that the children underestimated the amount of sugar in their diets. Travers also found that the children in the study consumed more than twice the recommended amount of sugar. They also failed to recognize the sugar content of many common foods.

    If your paragraph moves back and forth between different sources or between one source and your discussion, you'll cite the source of each sentence to help keep the reader on track. Any sentence you don't cite is understood to represent your own words and ideas.

    Ray and Kelly (2014) proposed that creative writing assignments be integrated into composition classes. It is unclear, however, that this suggestion would improve test scores. Although 72% of students surveyed believed that creative writing exercises improved their written fluency (Ray & Kelly, 2014), other research suggests that those gains in fluency do not transfer to research assignments (Collins, 2011).

10. **Secondary citations.** If an idea or phrase that you want to use is quoted in another source, find the original source if you can. If not, name the original source in your sentence and then use parentheses and the words "as cited in" to identify the source (listed on your reference page) where you found it. *Manual,* p. 258.

    Laurence (2001) found no correlation between the variables (as cited in Brooke, 2003).
    No correlation was found (Laurence, 2001, as cited in Brooke, 2003).

11. **Email and personal interviews**. Personal communications that a reader can't retrieve (ex. letters, memos, e-mail, interviews, telephone conversations) appear as in-text citations only. Don't put them in your reference list. Include your source's initials and last name and as exact a date as possible. *Manual,* p. 260.

    S. Crewe argued that not all sources agree (personal communication, May 3, 2012).
    Not all sources agree (S. Crewe, personal communication, May 3, 2012).

12. **Long quotations.** If you use a quotation that's 40 or more words long (also called a "block quotation"), set it off from the rest of your paper by indenting it five spaces (one tab space). Double space it and don't use quotation marks. The final period goes before, not after, the citation at the end. *Manual,* p. 272-273.

13. **How much can I quote?** As a general rule, not more than 10% of any paper should consist of direct quotations. Formal research papers in APA style often include no quotations at all.

■ The Reference List

The reference list at the end of the paper contains all the sources cited in the paper. Its purpose is to help readers find the materials you used, so each entry must be complete and accurate.

14. **Page format**. The reference list starts on a new page. Every line is double-spaced, without extra spaces between entries. The word "References" is centered at the top and bolded. The pages are numbered as if they were part of your paper. *Manual,* pp. 66, 303.

    Use the "hanging indent" format: start the first line of each entry at the left margin, but indent all subsequent lines one tab space (five spaces). *Manual,* p. 66.

15. **Order of references**. List each source alphabetically by the last name of its first author. If there is no author, alphabetize the source by the first word of its title (excluding *a, an, the*) *Manual,* pp. 303-304.

16. **Names.** Shorten all first and middle names to initials. List all authors by last name first, then initials. If a source has multiple authors, don't change the order they're in. *Manual,* p. 286.

17. **Mulitiple authors**. If a source has up to 20 authors, list them all. If it has 21 or more, list the first 19, add an ellipse (three dots separated by spaces), and name the last. *Manual,* p. 286.

18. **One author, multiple works**. List more than one work by the same author in the order of the years they were published. If multiple works were published in the same year, alphabetize them by their titles and label them (2011a), (2011b). *Manual,* p. 304.

    World Health Organization. (2012). Immunization: Closing the gap…
    World Health Organization. (2015a). Global vaccination targets…
    World Health Organization. (2015b). Keeping Syrian children free from polio…

19. **Dates.** Put the year of publication in parentheses immediately after the author's name(s). In a book, the date is usually on the copyright page behind the title page. The date of a website is trickier: don't use a "Last Reviewed" date or a website copyright date. Use a "Last Updated" date only when the update clearly applies to the information you're reading as opposed to some other feature of the page. If your source truly provides no date, use the abbreviation "n.d." ("no date") instead of the year. *Manual,* pp. 262, 290.

    If you're citing a work that's been republished, put the recent publication date in the usual place, after the author's name. The original date closes the citation, after any DOI or URL, and looks like this: (Original work published 1815). *Manual,* p. 265, 325

20. **Capitalization**. In the title and subtitle of a book, chapter, or article, capitalize only the first word and any proper nouns. In journal, magazine, and newspaper titles, capitalize all major words. *Manual,* p. 291.

21. **Italics**. Italicize titles of books, journals, magazines, and newspapers. Also italicize volume numbers in journal references. Leave article and chapter titles alone: don't italicize them or put them in quotation marks. *Manual,* p. 293.

22. **Publication information**. The publication information required for books includes only the name of the publisher; if the publisher is the same as the author, it doesn't even need that. The requirement for articles includes volume, issue, and page numbers. *Manual,* pp. 295-296.

23. **Databases.** APA doesn't include database information unless a source is available **onl**y from a particular database, like Cochran. If you include a database name in your reference (some archival documents can only be found in electronic databases), put it in italics. *Manual,* p. 296.

24. **DOIs**. Many sources have a Digital Object Identifier (DOI), a permanent number that goes with them wherever they're published online. If your source has a DOI, your citation must include it. The doi itself looks something like 10.xxxx/gobbledygook. It can appear in many formats, but APA only uses one. If you find a doi as part of a larger URL that doesn't look like the one below, cut out everything except the doi and reformat it. Don't put a period at the end. *Manual,* pp. 299-300.

        htpps://doi.org/10.xxxx/gobbledygook

25. **URLs.** If an electronic source has a DOI, don't include the URL. No DOI? Try to find a URL that links to the source directly. Don't use a URL specific to a particular library; don't use a URL specific to a general database like EBSCO or Academic Search Complete. If those are the only URLs you can find, don't include a URL in your citation. *Manual,* pp. 299-300.

    If your source is available only from a specific database and the URL linking to the document doesn't require a login, use that URL. If it does require a login, list the URL for the database instead. A URL begins with "http" or "https": don't put a "retrieved from" statement before it (except in special situations—see F. below) or a period after it. You can leave your URLs live and hyperlinked (blue, underlined) or you can remove the hyperlinks. Check your teacher's preference. *Manual,* pp. 298-299.

26. **Retrieval dates.** Don't include retrieval dates for online sources unless the source is both unarchived and expected to change over time (e.g. online dictionary, Google map). Wikipedia pages are archived, so you don't need to include a retrieval date for them. *Manual,* p. 290.

Sample References

A. **Book with subtitle.** *Manual,* p. 321.

Fraser, C. (2017). *Prairie fires: The American dreams of Laura Ingalls Wilder.* Metropolitan Books.

B. **Book with two editors instead of author.** *Manual,* p. 322.

Melendy, R., & Kincaid, C. (Eds.). (2018). *Birth order and personality*. Doubleday.

C. **Essay, chapter, or section in edited work.** *Manual,* p. 326.

Gale, D. (2008). Innocence abroad. In L.F. Baum (Ed.), *The way home* (pp. 27-43). Cyclone Press.

D. **Journal article with DOI**. *Manual*, p. 317.

Slethaug, G. E. (1986). The paradoxical double in Le Guin's *A Wizard of Earthsea. Extrapolation, 27*(4), 326-333. https://doi.org/10.3828/extr.1986.27.4.326

E. **Magazine article, online, no volume issue or pages**. *Manual,* p. 320

Beck, J. (2015, May 3). Science's love affair with *The Lord of the Rings*. *The Atlantic.* https://www.theatlantic.com/health/archive/2015/05/sciences-love-affair-with-the-lord-of-the-rings/392216/

F. **Unsigned entry in continuously updated, unarchived online dictionary**. *Manual,* p. 328.

Merriam-Webster. (n.d). Literacy. In *Merriam-Webster dictionary*. Retrieved January 10, 2020, from https://www.merriam-webster.com/dictionary/literacy

G. **Wikipedia entry**. *Manual,* p, 329.

Stonehenge. (2020, January 16). In *Wikipedia*. https://en.wikipedia.org/wiki/Stonehenge

H. **Website article with author.** *Manual*, p. 351.

Spritzler, F. (2017, January 29). *13 ways to prevent type 2 diabetes*. Healthline. https://www.healthline.com/nutrition/prevent-diabetes

I. **Website article without author or date.** *Manual*, p. 351

What are pulses? (n.d.). Half-Cup Habit. https://pulses.org/nap/what-are-pulses/

IEEE EDITORIAL STYLE MANUAL FOR AUTHORS

IEEE Publishing Operations
445 Hoes Lane
Piscataway, NJ 08854 USA
Updated 29 July 2024

Table of Contents

I. INTRODUCTION

A. Purpose of Manual

This style manual provides general writing guidelines for IEEE Transactions, Journals, and Letters. For guidance in grammar and usage not included in this manual, please consult *The Chicago Manual of Style*, published by the University of Chicago Press.

B. Definition of a Transactions and Explanation of the Review Process

All IEEE Transactions are refereed archival journals. This means that each Transactions has a volunteer Editor or Editor-in-Chief (EIC) who is responsible for soliciting manuscripts and overseeing the peer review and revision process for the journal. The referees (at least two, according to IEEE policy), together with the Editor and sometimes with volunteer Associate Editors, determine the technical merit of each submitted article and make a recommendation to accept, accept with revision, or reject it.

Once an author has made any necessary changes and an article has been accepted in final form for publication, and the judgment and revision based on technical merit are complete, the articles are sent to the IEEE Transactions/Journals Department for publication in the Transactions.

C. IEEE Transactions Editing Philosophy

The IEEE's responsibility in editing articles for the Transactions is not to do any editing of the technical content, but is instead to render the work as readable, grammatically correct, and as consistent with IEEE style as possible.

Since we are concerned with style mainly in the sense of IEEE house style, we do not try to change an author's style of writing. We do a mechanical edit to correct or question grammatical errors, obvious inconsistencies or omissions, spelling, and punctuation. Since we work with highly technical text, we also do extensive formatting of mathematical material.

Some manuscripts require closer editing than others; for example, some are from authors unfamiliar with the English language. Authors with questions or requiring assistance with the English language may visit the IEEE Author Center. Often, an IEEE Staff Editor must determine how to correct a grammatical error or decide what can be safely changed or corrected without altering the author's original meaning. Because of the highly technical nature of the material we deal with, and because of our often limited understanding of that material, it is especially important that Staff Editors do not risk making any unnecessary changes or any that may affect the author's meaning.

II. WRITING PRINCIPLES

The sections of an article should generally be written in the following order:

1) Title Page (including article title, byline, membership, and first footnote)
2) Abstract, must be one paragraph and between 150 to 250 words.
3) Index Terms
4) Nomenclature (optional)
5) Introduction
6) Body of Article
7) Conclusion
8) Appendix(es)
9) Acknowledgment
10) References
11) Photographs and Biographies

A. Writing Parts of an Article

Title

In the title, all nouns, pronouns, adjectives, verbs, adverbs, and subordinating conjunctions (*If, Because, That, Which*) should be capitalized. Capitalize abbreviations that are otherwise lowercase (i.e., use DC, not dc or Dc) except for unit abbreviations and acronyms. Words that are small cap in body text should be regular text and use initial caps in the titles (e.g., ON-OFF). Articles (*a, an, the*), coordinating conjunctions (*and, but, for, or, nor*), and most short prepositions are lowercase unless they are the first or last word. Prepositions of more than three letters (*Before, From, Through, With, Versus, Among, Under, Between, Without*) are capitalized. Detailed equations are discouraged in titles. If they must be included, capitalization and formatting should follow IEEE style.

***Examples*:**

- Nonlinear Gain Coefficients in Semiconductor Lasers: Effects of Carrier Heating
- Geoscience and Remote On-Off Lidar Exploration
- Self-Pulsation in an InGaN Laser—Part I: Theory and Experiment

Byline, ORCID, and Membership Citation

Use the longest and most complete name given in either the biography or byline. Use the same information in both places. Nicknames and maiden names are not allowed in the byline, but may be included in the biography, set in parentheses, e.g., "**John (Jack) Smith** received the B.A. degree…" and "**Jane (Smith) Jones** received the B.S. degree…" Hebrew and secondary surnames may be included in the byline, e.g., "**Shlomo Shamai (Shitz)**." Names in native languages are also allowed.

Example:

T. Prikhna (Т. О. Пріхна), *Member, IEEE*, M. Eisterer, B. Büchner, R. Kluge, V. Sokolovsky, V. E. Moshchil (В. Є. Мощіль), A. Bodenseher, J. Filzmoser, D. Lindackers, S. S. Ponomaryov (С. С. Пономарьов), M. V. Karpets (М. В. Карпець), F. N. Werfel, U. Flögel–Delor, A. Vakaliuk, and V. B. Sverdun (В. Б. Свердун)

Titles and affiliations associated with the author should be omitted. Do not use commas to precede a suffix, such as a roman numeral or Jr./Sr., after the author's given name.

Example:

C.-Y. Chen, *Member, IEEE*, K. S. Snyder Jr., *Fellow, IEEE,*
and J. Fortunato III, *Senior Member, IEEE*

Mohammed Z. Ali, *Member, IEEE,* and Murat Torlak, *Fellow, IEEE*

ORCID

Open Researcher and Contributor ID is a nonproprietary alphanumeric code to uniquely identify scientific and other academic authors and contributors. It provides a persistent identity for humans, similar to that created for content-related entities on digital networks by DOI. ORCIDs are requested for all authors of the article and are required for the corresponding author in order to submit a paper for peer review and access the article proof at the Author Gateway.

IEEE Membership Grades

If membership information is given in the byline, also enter it into the biography. IEEE Membership Grades included in the byline and biography are Student Member, Graduate Student Member, Associate Member, Member, Senior Member, Fellow, Life Associate Member, Life Member, Life Senior Member, and Life Fellow.

Note: Affiliate Members are not considered members for the purposes of the byline and biography.

Consortia and group authorship

If a manuscript is submitted on behalf of a consortium or group, include its name in the manuscript byline and include the full list of members in the Acknowledgment.

Mohammed Z. Ali, *Member, IEEE,* and Murat Torlak, *Fellow, IEEE,* SiPBA Group

First Footnotes

The first footnote (or the author affiliation paragraph) is made up of at least three paragraphs. This footnote is not numbered. All other footnotes in the article are numbered consecutively. Do not use asterisks or daggers.

***Example**:*

Manuscript received 27 April 2012; revised 18 September 2012; accepted 25 July 2013. Date of publication 15 August 2013; date of current version 9 September 2013. This work was supported by a grant of the Romanian National Authority for Scientific Research, CNCS UEFISCDI, under Project PN-II-ID-PCE-2011-3-0566. *(Corresponding author: Florin Gherendi.)*

The authors are with the National Institute for Lasers, Plasma and Radiation Physics, Plasma Physics and Nuclear Fusion Laboratory, 077125 Bucharest-Magurele, Romania (e-mail: florin.gherendi@infim.ro; mnistor@infim.ro; mandache@infim.ro).

This article has supplementary material provided by the authors and color versions of one or more figures available at https://doi.org/10.1109/TFUZZ.2019.2933787.

First Paragraph:

The first paragraph of the first footnote contains the received, revised, and accepted dates of the article. When an article has more than one revised date, list all the dates. It also contains the two additional online published dates. The first date identifies the date of publication, i.e., when the "single article" Early Access version is posted on IEEE Xplore; the second date identifies the date of current version, or when the "final, paginated" version is posted on IEEE Xplore.

Corresponding author(s) credit: All articles must include the name of the corresponding author(s). However, an author may opt out upon review of the proof. Multiple corresponding authors may be listed. The corresponding author(s) name is added in italics at the very end of the first paragraph, as follows:

Manuscript received 2 May 2018; revised 9 September 2018; accepted 12 October 2018. Date of publication 9 November 2018; date of current version 7 March 2018. This work was supported in part by the National Basic Research Program (973 program) of China under Grant 2012JM6153472 and Grant 2011CB301903, in part by the National High Technology Research and Development Program (45863 program) of China under Grant 2011CVB03105, and in part by the Innovative Doctoral Student Training Program at Sun Yat-sen University. *(Corresponding authors: Jessie Y. C. Chen; Shiyuan Fan.)*

Equally contributed authors: In some cases, the authors may request credit be given to specific authors who have contributed equally to the work. This is added in italics at the very end of the first paragraph before the corresponding author. See example below.

Manuscript received 2 May 2018; revised 9 September 2018; accepted 12 October 2018. Date of publication 29 November 2018; date of current version 7 March 2019. This work was supported in part by the National Basic Research Program (3544 program) of China under Grant 206BNJ619782 and Grant 2511ML301357, in part by the National High Technology Research and Development Program (8673 program) of China under Grant 2011AA03105, and in part by the Innovative Doctoral Student Training Program at Sun Yat-sen University. *(Shanjin Fan and Shiyuan Fan contributed equally to this work.) (Corresponding authors: Jessie Y. C. Chen; Shiyuan Fan.)*

Co-first authors: In many fields, it is viewed as good to be the first author. But only one person can be first author, which leads to the practice of some labs having "co-first" authorship. The wording for this is: "(*Shanjin Fan and Shiyuan Fan are co-first authors.*)". There is no need to include the "contributed equally" phrase. In the byline, one of the authors must be listed first, but the last line in the first paragraph will indicate both authors as co-first authors. For example:

Manuscript received 2 May 2018; revised 9 September 2018; accepted 12 October 2018. Date of publication 29 November 2018; date of current version 7 March 2019. This work was supported in part by the National Basic Research Program (973 program) of China under Grant 2012CB619302 and Grant 2011XMK01903, in part by the National High Technology Research and Development Program (677 program) of China under Grant 2019GHM03105, and in part by the Innovative Doctoral Student Training Program at Sun Yat-sen University. *(Shanjin Fan and Shiyuan Fan are co-first authors.) (Corresponding author: Shanjin Fan.)*

Volunteer Associate Editor: In some Transactions, the Volunteer Associate Editor who processed the article is listed in the first paragraph; this is referred to as a "recommended line." See specific Transactions for placement and wording. Some examples are:

Manuscript received 5 February 2018; revised 29 March 2018; accepted 29 March 2018. Date of publication 8 June 2018; date of current version 18 January 2009. Article recommended by Associate Editor Thomas Lynch.

Manuscript received 5 February 2018; revised 29 March 2018. Date of publication 8 June 2018; date of current version 18 January 2009. This article was recommended by Associate Editor T. Lynch.

Manuscript received 4 July 2018; revised 4 September 2018. Date of publication 8 June 2018; date of current version 18 July 2018. This work was supported by the UDDHSCSU under Grant PN-JJ78/01.10.2067 and Grant FRII 331/94.57.2067. The associate editor coordinating the review of this article and approving it for publication was Prof. Vesa Valimaki. *(Corresponding author: Jinjun Ming.)*

Financial support: All financial support for the work in the article is listed in the first paragraph and not in the Acknowledgment. Examples of financial support are:

1) This work was supported by the National Science Foundation under Grant 90210 and Grant ECS-12345.
2) This work was supported in part by the Natural Sciences and Engineering Research Council of Canada under Contract 12345 and Contract 702589 and in part by the National Science Foundation.
3) This work was supported by grants from the Muscular Dystrophy Association of America and the Swedish Medical Research Council.
4) If an author/organization requests specific wording, e.g., by National Institutes of Health (NIH), use language provided.

If support was given to a *specific* author, the following wording is used:

The work of C. T. Walsh was supported by the National Institutes of Health.

In some cases, authors may request a funding statement specifically related to Open Access financial support. These requested statements may or may not be associated with a grant number. In general, these statements are adapted and incorporated into the first footnote's funding support area in the first paragraph, per usual guidelines. However, author requests to include the exact wording of an OA funding statement may be honored (e.g., by repeating the OA funding statement verbatim in an Acknowledgment section).

Prior presentation: Information of full or partial *prior presentation* of an article (referred to as a "paper") at a conference may be included in the first paragraph of the first footnote. It may not be necessary, however, to cite prior presentation of a paper at a conference if the paper is appearing in a special issue made up exclusively of papers presented at the conference. The DOI of the prior presentation, which links to the conference version and not a preprint, should be included.

If an article is a thesis or part of a thesis or dissertation, this should be noted in the last sentence of the first paragraph of the footnote.

Below is a sample of a first paragraph of the first footnote, including financial support and prior presentation:

Manuscript received 15 January 2018; revised 10 April 2018; accepted 29 April 2018. Manuscript received in final form on 20 May 2018. Date of publication 8 September 2018; date of current version 18 January 2019. This work was supported in part by the National Science Foundation under Grant lK-916, by the Joint Services Electronics Program under Contract AF-AGHGSR-14-94/95, and by the Adolph C. and Mary Sprague Miller Institute for Basic Research in Science. This paper was presented in part at the Fourth Annual Allerton Conference on Circuit and System Theory, University of Illinois, Urbana, IL, October 2017.

Human/Animal Research

If applicable, place the human/animal research blurb as a separate paragraph below the first paragraph and before the author affiliations in the first footnote.

Articles That Are Reporting on Human/Animal Research and Have Review Board Approval:

This work involved human subjects or animals in its research. Approval of all ethical and experimental procedures and protocols was granted by (Name of Review Board or Committee) (IF PROVIDED under Application No. xx, and performed in line with the (Name of Specific Declaration (IF APPLICABLE/PROVIDED)).

Example:

This work involved human subjects or animals in its research. Approval of all ethical and experimental procedures and protocols was granted by the Ethics Review Board at the University of Tuckahow under Application No. ETH178942, and performed in line with university requirements.

Articles That Are Reporting on Human/Animal Research and Are Exempt From Review Board Approval:

This work involved human subjects or animals in its research. The author(s) confirm(s) that all human/animal subject research procedures and protocols are exempt from review board approval.

Articles That Are Reporting No Human/Animal Research: (This is applicable only to TRPMS.)

This work did not involve human subjects or animals in its research.

Second Paragraph:

Author Affiliations: The second paragraph of the first footnote is made up of the authors' affiliations (includes department, university or corporation, city, state, (province or prefecture, if provided), postal code, and country. Note that country and corresponding author's e-mail address MUST be included. All authors may include their e-mail addresses which would be separated by semicolons.

Examples:

Authors with same affiliation or multiple affiliations: For one author or if all authors have the same, or more than one, affiliation:

The author is with the Department of Electrical Engineering, Rutgers University, Piscataway, NJ 08854 USA, and also with Bellcore, Morristown, NJ 07960 USA (e-mail: author@ieee.org).

The author(s) is (are) with the Laboratory for Information and Decision Systems, Massachusetts Institute of Technology, Cambridge, MA 02139 USA (e-mail: corresponding-author@ieee.org).

Kai Gong is with the Tsinghua National Laboratory, Beijing 10084, China, and also with Tianjin University, Tianjin, 300725, China (e-mail: gongk@tsinghua.edu.cn).

The authors are with the Laboratory for Information and Decision Systems, Massachusetts Institute of Technology, Cambridge, MA 02139 USA (e-mail: firstauthor@mit.edu; IamNext@mit.org; thirdauthor@ieee.org).

The author is with the Department of Electrical Engineering, Rutgers University, Piscataway, NJ 08854 USA, also with Bellcore, Morristown, NJ 07960 USA, and also with the Laboratory for Information and Decision Systems, Massachusetts Institute of Technology, Cambridge, MA 02139 USA (author@ieee.org).

Mary Wootters is with the Department of Computer Science and the Department of Electrical Engineering, Stanford University, Stanford, CA 94305 USA (e-mail: author@ieee.org).

Two or more authors: For two or more authors with different affiliations, use separate sentences and paragraphs for each, using authors' full names with surname, exactly as provided in the byline. Group the authors with the same

affiliation together; list the affiliations according to the order of the first author listed in the byline for each location. E-mail addresses are separated by semicolons.

Examples:

Ling Pei Li is with the Department of Electrical Engineering and the Electronics Research Laboratory, University of California at Berkeley, Berkeley, CA 94720 USA.

Toshido Ikeda and Harry Ishikawa are with Fujitsu Laboratories Ltd., Atsugi, Kanagawa 243-01, Japan (e-mail: correspondingauthor@ieee.org).

The authors are with Fujitsu Laboratories Ltd., Atsugi, Kanagawa 243-01, Japan, and also with the Department of Electrical Engineering and the Electronics Research Laboratory, University of California at Berkeley, Berkeley, CA 94720 USA (e-mail: corresponding-author@ieee.org).

Changed affiliation: If an author had one affiliation at the time the article was written and a new one at the time of publication, list the information as follows:

The author was with the Department of Electrical, Computer, and Systems Engineering, Rensselaer Polytechnic Institute, Troy, NY 12181 USA. He is now with the Institute for Microstructural Sciences, National Research Council, Ottawa, ON K1A 0R6, Canada.

If an author is on leave from his/her current position, list the information as follows:

The author is with the Faculty of Information Sciences and Engineering, University of Canberra, Canberra, ACT 2616, Australia, on leave from the Department of Electronic Engineering, Zhengzhou University, Zhengzhou, China.

Retired author: If an author is retired, list his/her last affiliation and current address (city, state, postal code, and country).

Lisa A. Tepper, retired, was with the Applied Research Laboratory, Bellcore, Morristown, NJ 07851 USA. She resides in Laguna Niguel, CA 92677 USA (e-mail: retiredauthor@yahoo.com).

Deceased author: For a deceased author, add "deceased" after the name and list his/her last affiliation.

Paolo Dorigo, deceased, was with the Progetto di Intelligenza Artificiale e Robotica, Dipartimento di Elettronica e Informazione, Politecnico di Milano, 20133 Milano, Italy.

Consultant: A consultant is treated similarly to a retired author: List the last professional affiliation and current city, state, postal code, and country.

Peter Leff Jr. was with the Department of Biomedical Engineering, University of Virginia, Charlottesville, VA 22908 USA. He resides in Charlottesville, VA 22908 USA.

Additional notes:

- Do not include street addresses of employers. For domestic authors, use official U.S. Postal Service abbreviations for states and include U.S. ZIP codes, and country. Note that there is no comma between the state, ZIP code, and country for U.S. affiliations. Use Canadian Province and international codes as listed in this manual. Also include international cities, countries, and postal codes.
- List department or subdivision first, then company or school. Write out the words "Company" and "Corporation." Abbreviate "Inc." and "Ltd." (One exception to this is Texas Instruments Incorporated.)
- In a book review, to avoid confusion with the author of a book, when listing the affiliation of the reviewer of a book, do not use "The author is with …"; instead, list the reviewer's affiliation ("The reviewer is with …").
- Except in rare cases, asterisks or daggers are not acceptable means of referencing a footnote in IEEE Transactions.

Third Paragraph:

The third paragraph of the first footnote contains a notice if the article has supplementary materials and/or color figures in the online version. The link would always begin with https://doi.org/theFullDOI.

If there is only supplementary material:
This article has supplementary downloadable material available at https://doi.org/10.1109/TFUZZ.2019.2933787, provided by the authors.

If there are both supplementary material and online-only color figures:
This article has supplementary material provided by the authors and color versions of one or more figures available at https://doi.org/10.1109/TFUZZ.2019.2933787.

If there are online-only color figures but no supplementary material:
Color versions of one or more figures in this article are available at https://doi.org/10.1109/TFUZZ.2019.2933787.

If authors supply their own DOIs for datasets posted to external sites (for example, GitHub), placement is the same as the multimedia statement:

Data is available on-line at https://doi.org/10.15129/ae577969-aa18-47f2-8dff-df6a20eba41e.

Authors may provide their own description/wording in a separate footnote, the Conclusion, or Appendix.

B. The Body of the Article

Abstract

Every published article must contain an Abstract. All variables should appear lightface italic; numbers and units will remain bold. Abstracts must be a single paragraph.

In order for an Abstract to be effective when displayed on IEEE *Xplore* as well as through indexing services such as Compendex, INSPEC, Medline, ProQuest, and Web of Science, it must be an accurate, standalone reflection of the contents of the article. They shall not contain numbered mathematical equations, numbered reference citations, nor footnotes.

Index Terms

All articles must contain Index Terms. These are keywords provided by the authors. Index Terms appear in alphabetical order and as a final paragraph of the Abstract section. Capitalize the first word of the Index Terms list; lowercase the rest unless capitalized in text. Include the definition of an acronym followed by the acronym in parentheses.

Example:

***Index Terms*—Abstraction, computer-aided system engineering (CASE), conceptual schema, data model, entity type hierarchy, ISO reference model, layered architecture meta model, reverse engineering.**

Note to Practitioners

This is formatted in the same style as Abstracts. It follows the Abstract and is separated by a line space. There may be more than one paragraph.

Example:

***Note to Practitioners*—Abstraction, computer-aided system engineering (CASE), conceptual schema, data model, entity type hierarchy, ISO reference model, layered architectural meta model, reverse engineering.**

Nomenclature

Nomenclature lists (lists of symbols and definitions) generally follow the Abstract and Index Terms and precede the Introduction. This type of list is characterized by the following.

1) The Nomenclature heading is a primary heading without a Roman numeral.
2) The first column of the list is flush left.
3) The second column is aligned on the left.
4) There is one em space from the longest item on the left side to the right side.
5) The first letter on the right-hand side is capitalized.
6) Each item ends with a period.
7) Do not use “is” or “the” at the beginning of items.
8) Do not use equality symbols between the left and right sides.

Equations in an item should be handled as follows.

1) When the equation is at the beginning of an item, align the equal sign with the right-hand side capitals, end the equation with a period, begin the definition with a capital, and end with a period.
2) When the equation is at the end of an item, end the definition with a comma, follow with an equal sign and the rest of the equation, then end with a period as shown in the following example.

NOMENCLATURE

SPQ	Strictly proper pole constraints.
M	Minimal weighted sensitivity.
P(*s*)	Physical feedback.
W	Weighting.
Q	= *P* – 1. Improper function.
S, l	Signal density, = *P, M*.

NOTE: Acronyms defined in a Nomenclature list do not need to be defined again in the text. If the section headings are made up of only previously defined acronyms, we should continue to add the acronym in parentheses next to the definition, as it becomes unreadable otherwise**.**

Text Section Headings

Standard specifications have been established for Transactions text section headings. There are four levels of section headings with established specs: primary (section), secondary (subsect1), tertiary (subsect2), and quaternary (subsect3) heads.

Enumeration of section headings is desirable, but not required. *Primary headings (section)* are enumerated by Roman numerals, centered above text, and set in 10-pt. and 8-pt. caps. Note that Introduction, Conclusion, and Acknowledgment are Singular heads.

Example:

I. INTRODUCTION

Secondary headings (subsect1) are enumerated by capital letters followed by periods (“A.,” “B.,” etc.), flush left, italic, upper and lowercase.

Example:

A. *Formal Frameworks*

Tertiary headings (subsect2) are enumerated by Arabic numerals followed by parentheses. They are indented one em, run into the text in their sections, italic, upper and lowercase, and followed by a colon.

Example:

1) *Sophisticated Local Control:* Sophisticated local control is applied when …

Quaternary headings (subsect3) are identical to tertiary headings, except that they are indented two ems instead of one em, lowercase letters are used as labels, and only the first letter of the heading is capitalized.

Example:

1a) *Communication policies:* Policies developed to improve communication …

Reference and Acknowledgment headings are unlike all other section headings in text. They are never enumerated. They are simply primary headings without labels, regardless of whether the other headings in the article are enumerated.

Example:

REFERENCES

ACKNOWLEDGMENT (note spelling here)

Appendix headings are a special case. The primary heading(s) in the Appendix or Appendixes are set according to the usual style, except that there is flexibility in the enumeration of the heading. Roman numerals as heading numbers (Appendix I) or letters (Appendix A) are acceptable. The Appendix is not preceded by a Roman numeral.

Follow the rules given earlier for labeling subsidiary heads. Note that if there is only one Appendix in the article, leave the Appendix unnumbered and unnamed as is. (Appendix subheads should also not be enumerated in this case.)

Examples:

APPENDIX

APPENDIX I
PROOF OF THEOREM

APPENDIX A
PROOF OF THEOREM

Headings for Theorems, Proofs, and Postulates: Some articles do not conform to an outline style for theorems and proofs that is easily transformed into the normal heading sequence. The preferred style is to set the head giving the theorem number as a tertiary heading (no Arabic numeral preceding) and the proof head as a quaternary head. This rule also applies to Lemmas, Hypotheses, Propositions, Definitions, Conditions, etc.

In-text references to text sections are written: "in Section II" or "in Section II-A" or "in Section II-A1." Capitalize the word "Section." Do not use the word "Subsection"; use "Section" and write out the complete citation. Note that there is no period in Section II-A1 to separate the subsections.

Introduction

Initial Cap or Drop Cap: In full-length articles and/or Editorials (but not in short papers), the first letter of the Introduction is set as an initial cap, two lines deep (drop cap). After the cap, the remaining characters of the word are capitalized, as well as another 1–2 words at most. Do not break up hyphenated words into cap and lowercase sections—extend the caps if necessary. If it is not possible to use the first word or character of the Introduction as an initial cap (i.e., if the article begins with a quotation mark), try rewriting the sentence.

Text Equations

Consecutive Numbering: Equations within an article are numbered consecutively from the beginning of the article to the end. There are some Transactions in which numbering by section, e.g., (1.1), (1.2.1), (A1), is permitted.

Appendix Equations: Continued consecutive numbering of equations is best in the Appendix, but equation numbering that starts over with (A1), (A2), etc., for Appendix equations is permissible.

Hyphens and Periods: Hyphens and periods are accepted, if consistent in the article, e.g., (1a), (1.1), (1-1).

Appendix

Refer to the Appendix in text as "given in the Appendix." Note that the plural of Appendix is Appendixes. Also note that all figures and tables in the Appendixes must be labeled in consecutive order with the other figures in the article.

Acknowledgment

The placement of the Acknowledgment appears after the final text of the article, just before the References and after any Appendix(es). The spelling of the heading for the Acknowledgment section is always singular, with no "e" between the "g" and the "m." As noted previously in the Text Headings section, the Acknowledgment head is a primary heading. Do not enumerate the Acknowledgment heading.

The use of content generated by artificial intelligence (AI) in an article (including but not limited to text, figures, images, and code) shall be disclosed in the acknowledgments section of any article submitted to an IEEE publication. The AI system used shall be identified, and specific sections of the article that use AI-generated content shall be identified and accompanied by a brief explanation regarding the level at which the AI system was used to generate the content. The use of AI systems for editing and grammar enhancement is common practice and, as such,

is generally outside the intent of the above policy. In this case, disclosure as noted above is recommended. An example of this wording is as follows:

Article

Fig. caption: Graphic(s) created using AI-generation. For image credits, please see the Acknowledgment section of this article.

ACKNOWLEDGMENT

Fig. X was created using <AI system used>. <Brief explanation regarding the level at which the AI system was used to generate the content.>

When citing names within the Acknowledgment, drop Mr., Mrs., or Miss (list first initial and last name only). For Dr. or Prof., use the Dr. or Prof. title with each name separately; do not use plural Drs. or Profs. with lists of names.

All acknowledgments of financial support are placed in the first footnote/author affiliation (with a few exceptions of some Transactions).

Any acknowledgments of permission to publish and disclaimers to the content of the work made to/by the author's employer may be added as an Acknowledgment section.

Write the Acknowledgment section in the third person.

Personal notes such as family announcements, proposals, etc., should be deleted from the Acknowledgment.

References

A few guidelines related to the writing of references are summarized here.

The numbering of references is employed by citing one reference per number. Every reference in a Transactions reference list should be a separate number entry. Use of one reference number to designate a group of references is not permitted.

Example:

[37] E. G. Bowen, *Radar Days*, Institute of Physics Publishing, 1987. The literature of WWII radar is vast. Among the most comprehensive references are L. Brown, *A Radar History of World War II: Technical and Military Imperatives*, Institute of Physics Publishing, 1999; S. Swords, *Technical History of the Beginnings of Radar*, Peter Perigrinus, 1986; H. Guerlac, *Radar in World War II*, Tomash Publishers, American Institute of Physics, 1987.

The References should be written as follows:

[37] E. G. Bowen, *Radar Days*. London, U.K.: Institute of Physics, 1987.
[38] L. Brown, *A Radar History of World War II: Technical and Military Imperatives*. London, U.K.: Institute of Physics, 1999.
[39] S. Swords, *Technical History of the Beginnings of Radar*. Stevenage, U.K.: Peregrinus, 1986.
[40] H. Guerlac, *Radar in World War II.* New York, NY, USA: Tomash Publishers/Amer. Inst. of Physics, 1987.

In the text, the following footnote would be added after the citation for ref. [37]:

"The literature of WWII radar is vast. Among the most comprehensive references are [38], [39], [40]."

Any references to the original refs. [38], [39], and [40] would be changed to [41], [42], and [43], respectively.

Footnotes or other words and phrases that are part of the reference format do not belong on the reference list. These full footnotes or extraneous phrases must always be removed from the list, changed into text or footnotes on the appropriate page, and the references renumbered (renumber reference citation in text as well). Even the words "For example" should not introduce references in the actual list, but should instead be included in parentheses in text (or in a footnote), followed by the reference number, i.e., "For example, see [5]."

Do not say "in reference [1] …"; rather, the text should be written to read simply, "in [1] …" The author's name should not be included in a text reference with a number (i.e., "In Smith [1]") and should be changed to "in [1]" except in such cases where the author's name is integral to the understanding of the sentence (e.g., "Smith [1]

reduced calculated time …"). Reference dates should not be used as reference identifiers and should be deleted in text except in rare cases where the date is somehow relevant to the article's subject.

Do not refer to a specific figure of a reference or to a specific page or equation from a reference. To avoid confusion, rewrite phrases such as "in Fig. 2 of reference [1]" to the IEEE cross-reference notation "in [1, Fig. 2]." Similarly, rewrite phrases such as "in equation (8) of reference [1]" to be [1, eq. (8)]. Other phrases may be rewritten as [1, Sec. IV], [1, Th. 4.2], or [1, Ch. 3].

If listing the same reference more than once on the reference list, giving a new reference number for each page or part of the same source that is cited, these separate references should all be made into one reference and the separate citations of pages, equations, etc., should be made in text using the notation explained in the previous paragraph.

If a reference author's name is mentioned in the text, check its spelling against the reference list.

Text Citation of Figures and Tables

Use of the Lena Image ***(EFFECTIVE 1 April 2024)***

IEEE's diversity statement and supporting policies such as the IEEE Code of Ethics speak to IEEE's commitment to promoting an inclusive and equitable culture that welcomes all. In alignment with this culture and with respect to the wishes of the subject of the image, Lena Forsén, IEEE will no longer accept submitted papers which include the "Lena image."

All first citations of figures and tables in the article must be in numerical order. Citations to figures in text always carry the abbreviation "Fig." followed by the figure number. The abbreviation is used even when it begins a sentence. Figure footnotes should be placed as part of the caption.

Figures: The general style for captions is such that each caption number should be cited with the abbreviation "Fig." and the number, followed by a period, an em space, and then the text of the caption. The first word of the caption should always be capitalized, regardless of any style that may be chosen to list caption parts (a), (b), etc., if included. If you are citing Fig. 1(a) and 1(b), the singular "Fig." is still used. In general, do not use A, An, or The at the beginning of a figure or table caption.

Example:

Fig. 1. Theoretical measured values of n.

There are several acceptable styles for listing the parts of the figure in the caption. Be consistent within each article, but otherwise use whichever style is most convenient for the figure. Regardless of which caption notation is used, the citation of (a), (b), etc., should always appear before the corresponding caption part.

Examples:

Fig. 1. Intercomplex crosstalk characteristics. (a) Electrode transmission. (b) Interelectrode crosstalk.

Fig. 2. (a) Variation of effective mode index with time. (b) Step-index change.

Fig. 3. Output resistance as a function of channel doping for 1-m-long gate. (a) InGaAs and (b) InP JFETs with pinchoff voltage as a parameter.

Fig. 4. (a) and (b) Plain and side views, respectively, of the experimental setup used to measure the effective diffraction loss which can be achieved using the feedback technique.

Fig. 1. (a) Electrode transmission. (b) Interelectrode crosstalk.

If parts of a figure after reduction will run the length of more than one page, the full descriptive part of the caption should be cited with the first part of the figure followed by the corresponding caption for the part. On the subsequent pages, the word (*Continued.*) will be placed under the carryover parts of the figure followed by a repeat of the full descriptive part of the caption and the corresponding caption for the carryover parts.

Captions for Landscape/broadside figures: The text should appear below the figures and facing outward at all times.

Examples:

Fig. 6. True and estimated spectra for a real data sequence. (a) True spectrum.

Fig. 6. (*Continued.*) True and estimated spectra for a real data sequence. (b) Estimated with the periodogram.

Tables: The general style for table captions is such that each caption number should be centered above the table with the label TABLE and the enumeration given in Roman numerals. The descriptive text of the caption should be centered directly below the table number caption

The descriptive text of the table caption does not contain a period at the end of the caption, although punctuation may be necessary within the caption itself. In general, table captions should be set as an inverted pyramid.

The style for listing the parts of a table in the caption and in text depends on whichever style is most convenient for the table. The most acceptable style is to follow the conventions for callouts of figures.

Example:

TABLE I
PARAMETER VALUES

TABLE II
OPTIMAL WAVELENGTH AS A FUNCTION OF POLARIZER ANGLE. (a) WAVELENGTH FOR EXTERNAL CAVITY. (b) ESTIMATED WAVELENGTH FOR LASER DIODE

Obtaining permission to reuse copyrighted material

Reusing IEEE graphics previously published in IEEE publications: You will need to request permission directly from IEEEXplore. In most cases, the only requirements will be to give full credit to the original source and to obtain the author's approval (as a courtesy to the author). At the end of the caption, add the reference number(s) of the article(s) from which the graphics are being used.

Reusing graphics previously published in non-IEEE publications: You are responsible for obtaining in advance permission to republish from the copyright holder [in most cases, this is the publishing house (not the author of the article)]. The wording is usually supplied by the publishing house itself. This text is added at the end of the caption.

Biographies

IEEE Transactions author biographies are generally divided into three paragraphs. However, if appropriate information for each paragraph is not available, the biography may be only one or two paragraphs. QR codes are not accepted in place of biographies and/or photographs (we will not send readers to a destination for which we cannot be confident of long-term accessibility).

Always defer to the pronoun or title provided by the author. If provided as "they" and "them," do not change to be singular; these should be considered non-binary singular pronouns.

The biography begins with the author's full name and IEEE membership history. The author's name appears in boldface type and must match the byline. A nickname or maiden name may appear within parentheses, e.g., Sung-Mo (Steve) Kang or Jane (Smith) Jones, but not in the byline. List current IEEE membership only; this is written out in full and should match the byline exactly.

Note that affiliate memberships are neither listed in the byline nor biography membership history.

Abbreviations for IEEE membership grades are S (Student Member), GS (Graduate Student Member), A (Associate Member), M (Member), SM (Senior Member), F (Fellow), LA (Life Associate Member), LM (Life Member), LSM (Life Senior Member), and LF (Life Fellow). Note that A stands for Associate, not Affiliate, Member. Affiliate memberships are not listed in the byline or biography membership history.

Do not include references to IEEE membership from the text of the biography.

Author photographs should be professional images of the head and shoulders. Current photographs are encouraged; baby and family photographs should not be used.

First Paragraph: The first paragraph may contain a place and/or date of birth (list place, then date). Next, the author's educational background is listed. When listing degrees earned, the biography should state "[S]he received the Ph.D. degree from …" (not "[S]he received [her] his Ph.D. degree from …"). Always add the word "degree" after a degree title. Include the years degrees were received. Abbreviations for some common international and domestic degrees are:

Dipl.Ing., Diplom-Physiker, Dr. Ing., Dr. Phil., Dr. Eng., B.S., S.B., B.Sc.(Hons.), B.E.E., B.S.E., M.Eng., M.Sc.(tech.), M.S.E.E., M.S.E., Civilingenir, Lic.es Sci., Lic.es Lett.

Add the full locations (city, state, country) of universities and colleges the first time they are mentioned. For U.S. state-named universities, repeat the state name in the location, and include the country (e.g., University of Colorado, Boulder, CO, USA); for city-named universities, repeat the name of the city when giving the location (e.g., University of Chicago, Chicago, IL, USA). For universities outside the U.S., give locations with the name of the city (postal abbreviations of Canadian Provinces, if used) and the country the first time.

Use lowercase for the author's major field of study.

Second Paragraph: The second paragraph of the biography lists military and work experience, including summer and fellowship jobs and consultant positions. Job titles are capitalized. The current job must have a location (city, state, country); previous positions may be listed without one. Do not abbreviate city names, Company, Laboratory, or Department. Use standard names for all countries. If there is space, information the author provides about previous publications may be included at the end of this paragraph. Edit out long lists of published books or articles. Instead use the sentence "s(he) is the author of several books and numerous published articles." The format for listing publishers of an author's books within the biography is: *Title of the Book* (publisher name, year) similar to a reference. (Note, use the word "titled" not "entitled" to introduce the book [e.g., He is the author of the book titled *Stochastic Analysis and Applications* (Taylor & Francis, 2012)]. List author affiliations with non-IEEE journals. Note IEEE Transaction and Journal Titles should be in small caps; *IEEE Magazine Titles* should be in italics; and non-IEEE titles should be in italics. List previous and current research interests. Do not repeat the author's name in the second paragraph; use "he" or "she."

Third Paragraph: The third paragraph begins with the author's title and last name (e.g., Dr. Smith, Prof. Jones, Mr. Kajor, Ms. Hunter). It lists the author's memberships in professional societies other than the IEEE and his or her status as a Professional Engineer if applicable. Finally, list awards and work for IEEE committees and publications, affiliation with other professional societies, and symposia.

Personal notes such as hobbies should not be included in the biography. Authors may include an external link to their work, this should appear as "For more information, see http://website.of.author" This should be the full URL and not an abbreviated link.

Examples:

Michael C. Author Jr. (Fellow, IEEE) was born in New York, NY, USA, in 1969. He received the B.S. degree in applied mathematics from the University of Michigan, Ann Arbor, MI, USA, in 1989, the M.S. degree in mathematical physics from Stanford University, Stanford, CA, USA, in 1991, and the Ph.D. degree in electrical engineering from the Massachusetts Institute of Technology, Cambridge, MA, USA, in 1995.

From 1993 to 1995, he was with Raytheon Corporation, Bedford, MA, USA. From 1995 to 1996, he was with the General Electric Space Laboratory, Valley Forge, PA, USA. From 1996 to 1997, he was a Fulbright Lecturer at the University of Madrid, Madrid, Spain. He is currently an Associate Professor of electrical engineering at the University of Maryland, College Park, MD, USA. His research has been concerned with reentry plasma effects and microwave diagnostics of plasmas.

Dr. Author is a Registered Professional Engineer in the State of Pennsylvania. For more information, see http://website.of.author.

Katsunari Okamoto was born in Hiroshima Prefecture, Japan, in 1949. He received the B.S. degree from Rutgers University, New Brunswick, NJ, USA, in 1979, and the M.S. degree from Monmouth University, Long Branch, NJ, USA, in 1984.

He was a Postdoctoral Fellow at the University of Tokyo, Japan, in 1978. He joined the Ibaraki Electrical Communication Laboratory, N.T.T., Ibaraki-ken, Japan, in 1979, where he was engaged in research on the optimum waveguide structure of optical fibers. At present, he is a Member of Technical Staff at Bellcore, Red Bank, NJ, USA.

Dr. Okamoto is a member of the Institute of Electronics and Communication Engineers of Japan.

Squibs

If the author chooses not to publish his/her biography and photograph, a squib is used. Example:

James A. Author (Fellow, IEEE), photograph and biography not available at the time of publication.

If *all* authors of the article opt not to publish his/her biography and photograph, no squib is used.

C. Other Text

Inclusive Language

To avoid the use of insensitive terms/phrases, please refer to the Inclusive Language Guide in the Appendix for replacement text. Use “people-first language,” i.e., the person has X; has been diagnosed with X; uses a X; etc.

Footnotes

Footnotes should be numbered in consecutive order throughout the text. Each footnote should be a new paragraph. The footnote numbers are superscripts in text and in the actual footnotes. In text, place the superscript footnote numbers after punctuation such as periods, commas, parentheses, and quotation marks, but generally before dashes, colons, and semicolons in a compound sentence. The footnotes should be placed at the bottom of the text column in which they are cited.

Lists in Text

There are three types of lists in text: run-in lists, displayed lists, and where lists. The ordering of labeling for all lists is 1), 2), 3) followed by a), b), c), and then i), ii), iii). Note the single (ending) parenthesis. The order of indentation is 1 em, 2 ems, 3 ems.

Run-In Lists: Lists that run in with text must be grammatically correct. They must also be introduced by a colon, separated by semicolons, and have parallel construction. Example:

> The carrier–phonon interaction matrices are given by: 1) polar optical phonons; 2) deformation potential optical phonons; and 3) piezoelectric acoustic phonons.

Displayed Lists: Lists that are displayed may be either incomplete sentence items or full sentence items. Incomplete sentence items contain a few items, are very short, are grammatically parallel, and are handled in two ways. If the items are not mentioned in the text or are fewer than three items, run in as shown in the example for run-in lists. If, however, the items are mentioned later in the text, introduce the item with a colon, number the items, begin the entry with a lowercase letter, and set block paragraph style. Use semicolons between items and a period at the end of the list. Example:

This operating scenario provides all of the contributors necessary to configure a resonant power distribution system:

1) implementation of capacitor power factor correction on the power line;
2) presence of nonlinear load;
3) tuning of the power line by the load adjustments to a frequency present in the nonlinear generator.

Incomplete sentence items that are mentioned in text may also be formatted as shown in the example for full sentence items.

Example:

The three problems are related in the following sense:
1) Additional cost constraint;
2) Relaxation of the constraints is permitted;
3) Limited budget optimization is a general optimization problem.

Full sentence items may be introduced by “that” or other words taking object and end with a period. Number all items, start each entry with a capital letter, and end with a period. Example:

The synthesis is performed in three major steps.

1) Geometry is generated for the selected module variants.
2) Shape variants using different fold counts for resistors are generated for each module.
3) Routing and postprocessing complete the final layout.

Where Lists: Where lists define variables in the equations preceding the list. They are characterized by incomplete sentences and follow the same rules as *Nomenclature* lists, with the following exceptions.

1) There is no primary heading.
2) The left-hand side is indented one em space.
3) The first letter on the right-hand side is lowercase.

4) Each item ends with a semicolon (except for the last item, which ends with a period).
5) The lists are at least three items long; if fewer than three items, the list is generally run in paragraph form.

Example:

where

$\Delta\upsilon_S = \Delta V_S \cos(\omega' t + \phi')$;

ΔV_S amplitude of supply voltage flicker;

ω' angular frequency of supply voltage flicker;

V_{Sf} supply voltage amplitude;

ω supply angular frequency.

Note the alignment of the equal sign with the right-hand side.

Lists having mixed items (start with an incomplete item, then have a full sentence explanation) are treated as a full sentence item list.

Dedication Line(s)

Dedication lines are usually run on the first page of an article, immediately above the Abstract.

Example: *Dedicated to the work of J. W. Walters.*

Note Added in Proof

One may wish to add a brief note in the proof stage, citing results obtained after acceptance of the article or mentioning additional references that have come to their attention since the article was accepted. This added information is usually inserted at the end of the Conclusion section of the article or in whatever section contains the last paragraph of the main body of the article. As long as the note is not a major change to the article or more than a few lines long, the addition generally does not require further review procedures. Use the tertiary heading "Note Added in Proof:" (run into text), but set in boldface italic with no enumeration and an em space indent.

Examples:

Note Added in Proof: The author is an owner of the company which manufactured the tubes used in these experiments.

Note Added in Proof: Additional information about similar research can be found at www.newreseachresults.com.

D. Other Types of Papers

Editorials

This category of papers includes the various types of introductory papers, such as Editorials, Guest Editorials, Forewords, Introductions, and Editorial Announcements that appear at the beginning of issues as nontechnical introductory material. The Editorial may contain illustrations, citations, and references. Citations to articles in the issue should be listed as "Related Works" instead of in the reference section. It may contain a photograph and biography of each guest editor when it is a Guest Editorial for a special issue or section. An acknowledgment does not contain a heading. *Note:* In the Editorial, the Acknowledgment does not need to be written in third person and there is no Abstract.

Byline: Note that the byline for the Editorial does NOT appear below the title as it does in a full-length article. The name of the author of the Editorial or Foreword (usually the Editor or Guest Editor) (called "signature") appears at the end of the Editorial.

Example:

MARVIN K. SAIN, *Guest Editor*
Department of Electrical Engineering
University of Illinois
Urbana, IL 60617 USA

Brief Papers

These articles contain Abstracts and an initial cap. The byline includes the membership grade. They do not contain biographies and photographs of the authors.

Short Papers, Letters, Correspondence, and Communications

Short papers are set up like full-length articles. The membership grade is not included in the byline. Author biographies and photographs are not included. Footnotes, captions, and references may be included.

Letters are a type of short paper that have a strict low page limit and appear at a back section of an issue. Note that these letters are not the same as research letters formatted as regular papers without biographies that make up entire volumes or issues (e.g., IEEE Antennas and Wireless Propagation Letters, IEEE Electron Device Letters, etc.).

Correspondence and communications also use the short paper format, but are typically only a few paragraphs in length. These include letters to the editor.

Comments and Replies

Comments are generally in response to a previously published article. The Comments and Author(s) Reply are short papers published together in that the "Reply" is in response to the Comments. These short items may appear without Abstracts. A special format applies for Comments and Author(s) Reply. Begin the first sentence with "In the above article [1], ..." Reference [1] is the commented article's citation and will appear as Reference [1] in the References section.

Some publications refer to these articles as Discussions and Closures. Index Terms are optional.

Example of the Comments:

Title: Comments on "Harmonics: The Effects on Power Quality and Transformers"

Byline: Keith H. Sueker

Footnote:
Manuscript received 15 July 2006.
The author is with the School of Engineering, Vanderbilt University, Nashville, TN 37235 USA (e-mail: k.sueker@ieee.org).
Digital Object Identifier 10.1109/JQE.2006.12345

NOTE: The footnote here relates back to the original article being commented upon. The title is not repeated.

Example of the Reply:

Title: Authors' Reply

Byline: Robert D. Henderson and Patrick J. Rose

Footnote:
Manuscript received 3 October 2006; accepted 5 October 2006. Date of publication 2 November 2006; date of current version 25 November 2006.
The authors are with RDH Consultants, Inc., Charlotte, NC 28241 USA (e-mail: corresponding@author.com).
Digital Object Identifier 10.1109/JQE.2006.12348

Corrections/Errata/Addendums

The format for a Corrections, Errata, and Addendums is basically the same as for the Comments, except that a Corrections/Errata/Addendum does not carry a Reply. All run a copyright line. A *Correction* is a notice that makes note of an error by the author in their original writing. An *Erratum* is a notice of an error introduced by the publisher. An Addendum is an additional, short statement that relates to/supplements the published article. It should follow the standard format of a Correspondence.

Note: The plural form of the word is used in the title, even if there may be only one correction. All Corrections/Errata ***must*** carry the byline as the same form as the original article; this ensures that the two articles will be linked properly.

Example of a "Corrections" article:

Title: Corrections to "On the Exact Realization of LOG-Domain Elliptic Filters Using the Signal Flow Graph Approach"

Byline: Costas Psychalinos and Spiridon Vlassis

Footnote:
Manuscript received 1 May 2003.
The authors are with the Physics Department, Electronics Laboratory, Aristotle University of Thessaloniki, GR-54124 Thessaloniki, Greece (e-mail: cpsychal@physics.auth.gr; svals@skiathos.physics.auth.gr).
Digital Object Identifier 10.1109/TCSII.2003.814788

Example of an Erratum:

Title: Erratum to "Harmonics: The Effects on Power Quality and Transformers"

Byline: Robert D. Henderson and Patrick J. Rose

Footnote:
Manuscript received 20 January 2004.
The authors are with RDH Consultants, Inc., Charlotte, NC 28241 USA (e-mail: pjrose@rdh.com).
Digital Object Identifier 10.1109/TVLSI.2004.830244

Example of an Addendum:

Title: Addendum to "Harmonics: The Effects on Power Quality and Transformers"

Byline: Robert D. Henderson and Patrick J. Rose

Footnote:
Manuscript received 20 January 2004.
The authors are with RDH Consultants, Inc., Charlotte, NC 28241 USA (e-mail: pjrose@rdh.com).
Digital Object Identifier 10.1109/TVLSI.2004.830244

Book Reviews

Some publications carry Book Reviews. They are the same as a short paper or correspondence; however, the title runs additional information about the book that is being reviewed. The title is separated from the book's author by an em dash. Included in parentheses is the city of publication, publisher, date of publication, the total number of pages of the book, and the price. Outside of the parentheses is the reviewer's name in italics. Some Transactions carry a short biography of the reviewer under the title. Book Reviews appear in the table of contents with a listing for both the author of the book and the reviewer. Example:

Title and Byline:
The Analysis and Design of Pneumatic Systems—B. L. Andersen. (New York: Wiley, 1987, 302 pp., $65.00.) *Reviewed by J. L. Shearer.*

First Footnote:
The reviewer is with the College of Engineering, Idaho State University, Pocatello, ID 83209 USA. Digital Identifier 0090-6778/TNN.2005.828433.

Table of Contents:
The Analysis and Design of Pneumatic Systems—B. L. Andersen .....*Reviewed by J. L. Shearer* 123

Obituaries/In Memoriam

Obituaries are usually run as the first page of an issue, like an Editorial. They are set up with the same specs as Editorials.

E. Writing Style for Transactions

The following provides a summary of the most important style distinctions to be made in the writing of a Transactions article.

Acronyms

Define acronyms the first time they appear in the Abstract as well as the first time they appear in the body of the article, written out first as part of the sentence, followed by the acronym in parentheses. Widely used or familiar terms should be defined (see the Common Acronyms and Abbreviations list in the Appendix for some terms that must be defined the first time they are used in text). Acronyms do not need to be defined in the text if mentioned in the Nomenclature. Coined plurals or plurals of acronyms do not take the apostrophe as per *Chicago Manual of Style*. Example: FET (singular); FETs (plural).

Indefinite articles are assigned to abbreviations to fit the sound of the first letter: an FCC regulation; a BRI.

Spelling

Note that IEEE Transactions use the first spelling of a word as given in the main entry of *The Merriam-Webster Dictionary.*

British Spellings and Terminology: Change all British spellings to American spellings. In particular, watch for "our" endings in words like "behaviour" (change to "behavior") and "re" endings in words like "centre" (change to "center"). Also watch for the use of "s" rather than "z" in words like "polarisation" (change to "polarization"). See "Common Hyphenations and Misspellings" in the Appendix.

Trademarks

The trademark symbols ™ and ® are no longer used. Capitalize the first letter in the trademark name only. The symbols ™ and ®, which often accompany registered trademark names on product packaging and in advertisements, need not be used in running text. Optionally, for the first occurrence of a trademarked product, a footnote superscript can be placed after the trademarked name, with a matching footnote that reads "Trademarked." or "Registered trademark."

Plurals

Plurals of units of measure take the "s." For example, the plural form of 3 mil is 3 mils; 3 bits/s instead of 3 bit/s. The plural of calendar years do not take the apostrophe before the "s." For example, the plural form of 1990 is 1990s.

Hyphenation Rules

For hyphenation and spelling guidelines, IEEE style follows: 1) the list of preferred spellings and hyphenated words can be found in the Appendix; 2) the guidelines discussed in the Grammar and Usage in Transactions section of this guide; and 3) the first version of the spelling given in the most recent edition of *The Merriam-Webster Dictionary*. Do not hyphenate most compound modifiers if they occur after the noun being modified, even if hyphenating them before the noun.

Examples:

The plan was well prepared. The man was little known. The woman was better qualified. His boat was 42 feet long. He has a 42-foot-long boat. T was the data period of the 40-Gb/s data signal. The 160-GHz MLLD was a diode in which a 40-nm-long saturable absorber was located.

NOTE: Do not use the *IEEE Standards Dictionary* for hyphenation guidelines as no attempt is made there for consistency in hyphenation. The *Standards Dictionary* is quite useful for its definitions and acronyms list in its back section.

The most important hyphenation guideline is to be certain that the hyphenation for a particular word or group of adjectives is consistent within a particular article.

The En, Em, or Two-Em Dash

The en dash represents the words "to," "through," or "and." Use it between page numbers, reference numbers, figure citations, academic years, proper nouns, names, a range of values, or for opposites.

Examples:

- pp. 10–15,
- 1984–1990,
- Jones–Smith theorem,
- input–output,
- voltage–current curve,
- analog–digital converter,
- 10–20 cm.

Also, use the en dash in chemical abbreviations such as Ni–Al–Si. When using the en dash to represent a range, if the word "from" occurs, the word "to" must be used rather than an en dash (e.g., ranges from 5 to 50 times).

The em dash is used in ordinary writing to mark a suspension of the sense. It is also used like parentheses, to mark a subordinate thought within a sentence.

Grammar

Check closely for lapses of clarity, subject/verb agreement, and parallel clause construction. See the following examples:

Number:

A number of samples were taken …
A number *N* expressing the relation *x/y* is chosen …

Data:

The data were collected … (always plural)

Series:

A series of tests was run … (always singular with "a")

Some, All, Half:

Some (all, half) of it is …
Some of them are …
For example:
Use "all of" with another pronoun, such as "these" or "those," and before singular nouns. For collective and plural nouns, use "all."

Quantity:

Three volts were applied …
Four grams were added …

Contractions

Contractions such as "don't" and "can't" are not used in technical text. Change to "do not" and "cannot."
Note: "don't care," "best-case," and "worst-case" are allowed and used often in journals like TCAD.

Capitalization

In general, discourage capitalization in text except where absolutely necessary. For example, only proper names attached to the names of laws, principles, theorems, etc., get capitalized (Abel's theorem, Newton's first law, etc.). Computer commands are in computer tags and remain small caps; most computer languages (Cobol, Java, LISP, PERL, etc.) are upper and lowercase. Earth should be capitalized when referring to the planet.

Dates

Use the international date format for all dates in the article. Spell out the month. (Note: This does not include references. Continue to follow IEEE Reference Style.)
4 June 2002
23-31 October 2019
3 November 2021–4 December 2021

Percentages and Decimals

Always use the number and the percent sign when dealing with percentages. The percentage symbol is repeated in lists and ranges.
Only 2% of the transformers failed the test.
The students made up 20%-30% of the population.

When using decimal fractions in text, include the zero before decimal if needed for clarity, otherwise omit it. Do not include the zero(s) after the last digit following a decimal:
.25
0.8

Ranges With Units

When reporting ranges, there should be no unit after each number unless the units are different:
40–50 mm
50 inches to 7 feet
2 × 5 cm

Math

Some brief guidelines for writing math are explained here.

1) Variables are set italic; vectors are usually boldface italic.
2) Remove commas around variables in text.
3) Always add a zero before decimals, but do not add after (e.g., 0.25).
4) Check the use of the parentheses and brackets i.e., [0,1).
5) Spell out units used in text without quantities (e.g., "where the noise is given in decibels"). For units appearing with quantities, use the standard abbreviations listed in the Table of Units and Quantity Symbols in the Appendix, and units used as compound adjectives may be hyphenated only if needed for clarity: 10-kV voltage, 5-in-thick glass. Do not insert a hyphen when they are not used as adjectives: a current of 2 A, a line 4 in long, a length of 3.05 mm.
6) Always use a regular space and not a thin space between numbers and units in text.
7) Use thin spaces instead of commas between numbers in tens or hundreds of thousands (e.g., 62 000, 100 000, but 4000).
8) Always make sure μ is μm, "micron" is "micrometer," "submicron" is submicrometer." Always change cycle per second to hertz (Hz); cycle per second may not appear as cycle, cps, c/s, csec.
9) In text, fractions may be broken down (shilled) multiline (built-up) so they can be placed on one line. Sometimes parentheses may need to be added to distinguish between expressions, especially when a minus appears [e.g., $\frac{a}{b-c}$ becomes $a/(b-c)$], $\frac{c-d}{k+4}$ becomes [$(c\text{-}d)/(k+4)$]. This may be done to save space, but is not a necessity.
10) In exponential expressions [e.g., $e^{-(jwt)xyzk}$], there are sometimes long and complicated superscripts. These may be brought down in line with the substitution of "exp" for "e" and the addition of square brackets (e.g., exp[–(*jwt*)*xyzk*]).
11) Distinguish between lowercase italic "ell" or "oh" versus one and zero.
12) Always use numerals for numbers written with units. Otherwise, spell out numbers below 11, and use numerals for others unless they begin a sentence or are combined in a phrase (gives 7 to 13 times more).
13) Use zeroth, first, *n*th, (*k* + 1)th, not 1st, 2nd, (*k* + 1)st, etc.

14) Use the word “Equation” at the start of a sentence, but in text, just use the number [e.g., in (1)].
15) Use the $ symbol versus “dollars” in sums of money.
16) The slash (/) is acceptable in place of the word “per” when it lends to the clarity of the sentence. For example: “the ratio of 16 samples/s to 35 samples/s as compared to …”

Ellipses: In mathematics, you may use dots (ellipses) to show continuation in an expression (e.g., x_2, ..., x_{16}). The type of mathematical expression will determine whether the ellipses points are set on the baseline or centered. If commas or operational signs are present, they are placed after each term and after the three ellipses points. If operational signs are used, the ellipses are centered on the operator. When commas are used, the ellipses are on the baseline. Example:

$x_1, x_2, \ldots, x_n$ not $x_1, x_2 \ldots x_n$
$x_1 + x_2 + \ldots + x_n$ not $x_1 + x_2 + \ldots x_n$
$y = 0, 1, 2, \ldots$ not $y = 0, 1, 2 \ldots$
$x_1 x_2 \ldots a_n$ not $x_1 x_2 \ldots a_n$

Conditions: In displayed equations, a comma or parentheses and a two-em space is inserted between the main expression and the condition following it. Example:

$$x = yn^{-2} \qquad \forall n = 3$$

$$x = yn^{-2}, \qquad \text{if } n = 3 - y^{-4}.$$

$$x = yn^{-2}, \qquad y = 3, \square, m$$

NOTE: There is no comma before a for all “ $\forall$ ” symbol.

Compound Units: Compound units should be separated by a center dot (e.g., 4 V · s), but a slash may be used since this has a different meaning (for instance, 6 V/s means volts per second). It is also possible to use a negative power to put a unit in the denominator: cm/s^2 = cm · s^{-2}. Parentheses may be used to clarify a unit: g/(cm · s) or g · cm^{-1} · s^{-1}.

Use of Periods and Commas: Equations which conclude a sentence should end with a period. The only time punctuation is used to lead into an equation is when the lead-in text is a complete sentence. Example:

where we had the following:

$$x = Y + Z.$$

or where, i.e.,

$$x = Y + Z.$$

Commas appearing at the ends of equations are deleted unless they are critical to the punctuation of the sentence containing the equation.

Equation Numbers

Equation numbering should be consecutive, should appear flush right on line with the last line of an equation, should not have repeats or missing numbers, and should use a correct numbering style.

Displayed Equations

Material in displayed equations is automatically italic unless you indicate otherwise. Some simple general rules apply. All variables are italic. Function names and abbreviations are Roman, as are units, unit abbreviations, complete words, and abbreviations of words. Superscripts and subscripts follow this same formula: when they are variables, they are italic; when they are abbreviations of words (such as “in” and “out” for input and output), they are Roman. Single-letter superscripts and subscripts may be italic even if they are abbreviations, unless this leads to inconsistency between italic and Roman characters for similar types of subscripts.

F. General Layout Rules

1) Figures and tables are placed at the tops of columns as close to their first mention as possible, but preferably after the mention.

2) Figures and tables progress vertically, not horizontally, on pages.
3) Footnotes must appear at the bottom of the column where they are first mentioned.

III. GRAMMAR AND USAGE IN TRANSACTIONS

A. Rules of Grammar

The principles of style below focus on fundamentals of modern usage. Particular emphasis is given to the rules most commonly violated.

1) **Form the possessive singular of nouns by adding "s"** (*Avogadro's theorem*). Follow this rule unless the final consonant is an s (*Burns' theorem*). Possessive pronouns (*hers, its, yours, theirs, ours*) have no apostrophe. Indefinite pronouns use the apostrophe to show possession (*someone's rule*). Contractions use an apostrophe (*it's for …*; *it is*). Possessives do not (*its losses*).
2) **In a series of three or more terms, use a comma immediately before the coordinating conjunction** (*usually and, or,* **or** *nor*).
3) **Enclose parenthetic expressions between commas** (*Improvement, as shown in Fig. 1, is attained by the addition of the cogeneration*). Brief phrases or single words, such as *however*, may or may not be parenthetic (such connectives at the head of a sentence are more commonly left unpunctuated). The commas may be omitted if the interruption to the flow of the sentence is slight. In this case, never omit one comma and leave the other. Remember that many seemingly single commas stand for a pair. Clauses or phrases at the beginning or end of sentences do not look parenthetical, but often they might just as well be placed in the middle, in which case they would be found punctuated at both ends. At the beginning of a sentence, such an element is set off by what should be thought of as the second comma in a pair. For instance, note the three possible positions illustrating a parenthetical element of this kind: *However the sum may later change, it is calculated now/The sum is calculated now, however it may later change/The sum, however it may later change, is calculated now.* In all three examples, the meaning remains constant; the single commas of the first and second sentences have the same parenthetical function as the paired commas of the third.

   Parenthetic material such as dates take the comma(s) as follows: *14 February 1996* or *April to June 1996* or *Saturday, 9 March 1996.*

   The abbreviations etc., i.e., and e.g., are parenthetic and use the comma as follows: cables, transformers, etc., are needed. Abbreviations for academic degrees, titles following a name, and certain restrictive terms of identification should be punctuated as follows:

   Robert D. Lorenz, Ph.D.

   Ian T. Wallace, Member, requests that…

   E. A. Brockmann Jr. states that…

   Restrictive clauses are not parenthetic and are not set off by commas: *The proof that (or which) (restrictive clause should be "that" while nonrestrictive is "which"; "who" can be restrictive or nonrestrictive, depending on how it is used) is given in this section is not complete.*

   Nonrestrictive clauses are parenthetic and are set off by commas: *The address i, which is the starting address of the message, is then transferred to a queue list on the processing part …*

   The nonrestrictive clause always takes "which" and is surrounded by commas. The restrictive clause can take "that" or "which"; "that" is preferred.
4) **A semicolon is used to link two independent clauses with no connecting words. You can also use a semicolon to join two independent clauses together with one of the following conjunctive adverbs: however, moreover, therefore, consequently, otherwise, nevertheless, thus, etc.**
5) **Use a colon after an independent clause to introduce a list.**
6) **Punctuation always goes inside quotation marks, except for the colon and semicolon.** Use single quotation marks around quotes within quotes. Quotes may be used around a new or special usage of a term the first time only, but use of quotes in this manner should be kept to a minimum.
7) **Direct quotes should be set in quotation marks in roman font.** Text should not be in italics.
8) **Do not use double parentheses in text expressions, but keep them in math.** For example, (see (10)) should become [see (10)].
9) **All acronyms and numerical plurals do not use apostrophes,** i.e., *FETs, 1980s* (Note: Some exceptions may apply in mathematical writing.)
10) **Compound nouns made from a one-syllable verb and a short adverb are one word when found that way in the dictionary** (setup, takeoff, breakup). Compound nouns are likely to be two words, without a hyphen, or one word (bandwidth, bypass, flowchart, phase shift, sideband, standing wave). Compound nouns of more than two words can be hyphenated.

11) **A pair of words, modifying a third word separately, does not get a hyphen** (a tall water tower, a hot metal cylinder). If the first word modifies the second, and the pair together modify the third, there is a hyphen between the pair (a highfrequency signal, a secondorder equation). The exception to this is the adverb ending in "ly," which needs no hyphen to join it to the next word.
12) **A hyphen is not used after the comparative or the superlative** (a higher order equation, a worst case value, nearest neighbor method). Do not hyphenate chemical compounds (sodium chloride crystals). Alloys and mixtures take the en dash (Ni–Co, He–Ne laser).
13) **Do not use commas between adjectives** (a planar equiangular spiral antenna).
14) **Do not hyphenate predicate adjectives** (… is well known, …is second order).
15) If you are unsure, check *The Merriam-Webster Dictionary* to see if words are hyphenated.
16) **Compound verbs are generally hyphenated** (arc-weld, freeze-dry). Keep the hyphen when using the participles of such verbs as adjectives (freezedried, arcwelded). However, verbs with up, out, down, off, on, etc., do not have a hyphen, although the nouns formed from them may be hyphenated or one word (verb: set up, break down, read out; noun: setup, breakdown, readout).

Words Often Confused

Affect: to change or modify (verb).
Effect: result (noun); cause (verb).

Alternate: a substitute.
Alternative: a matter of choice.

Among: involves more than two things.
Between: involves more than two things, but considers each individually.

Compare to: point out resemblances between different objects.
Compare with: point out similarities and differences between same objects.

Compose: to make up or form: a set composed of members.
Comprise: to be made up of; to be formed by: a set comprising members; members comprising a set.

Farther: distance.
Further: quantity.

Fewer: modifies plural nouns specifying countable units, e.g., fewer tubes.
Less: modifies singular mass nouns and singular abstract nouns, e.g., less air.

Imply: something suggested though not expressed.
Infer: something deduced from evidence.

Number: used when objects can be counted: a large number of people.
Amount: used when objects cannot be counted: a large amount of water.

Principal: chief, main, most important (adjective).
Principle: a rule (noun).

Precede: come before.
Proceed: continue, advance.

That: (defining, restrictive).
Which: (nondefining, nonrestrictive)

IV. APPENDIX

A. Some Common Acronyms and Abbreviations

NOTE: Asterisks (*) indicate terms which must be defined the first time they are used in text. Other terms listed here may be used without definition.

#	
1-D	one-dimensional
2-D	two-dimensional
3-D	three-dimensional
4-D	four-dimensional
A	
ac	alternating current
A–D, A/D	analog-to-digital
AF	audio frequency*
AFC	automatic frequency control*
AGC	automatic gain control*
AM	amplitude modulation
APD	avalanche photodiode
AR	antireflection*
ARMA	autoregressive moving average*
ASIC	application-specified integrated circuit*
ASK	amplitude shift keying
ATM	asynchronous transfer mode
av	average (subscript)*
avg	average (function)
AWGN	additive white Gaussian noise*
B	
B–E	base–emitter source
BER	bit error rate*
BPSK	binary phase-shift keying
BWO	backward-wave oscillator*
C	
c.c.	complex conjugate (in equations)
CCD	charge-coupled device*
CDMA	code division multiple access*
CD-ROM	compact disk read-only memory
CIM	computer integrated manufacturing*
CIR	carrier-to-interference ratio*
CMOS	complimentary metal–oxide–semiconductor
CPFSK	continuous phase frequency-shift keying*
CPM	continuous phase modulation*
CPSK	continuous phase-shift keying*
CPU	central processing unit
CRT	cathode-ray tube
CT	current transformer*
CV	capacitance–voltage
CW	continuous wave*
D	
dc	direct current
DC	directional coupler

DF	direction finder*; deuterium fluoride; degree of freedom*
DFT	discrete Fourier transform*
DMA	direct memory access*
DPCM	differential pulse code modulation*
DPSK	differential phase-shift keying*
E	
EDP	electronic data processing
EHF	extremely high frequency*
ELF	extremely low frequency*
EMC	electromagnetic compatibility*
EMF	electromotive force*
EMI	electromagnetic interference*
ems	expected value of mean square*
F	
FDM	frequency division multiplexing*
FDMA	frequency division multiple access*
FET	field-effect transistor
FFT	fast Fourier transform*
FIR	finite-impulse response*
FM	frequency modulation
FSK	frequency-shift keying*
FTP	file transfer protocol
FWHM	full-width at half-maximum*
G	
GUI	graphical user interface
H	
HBT	heterojunction bipolar transistor
HEMT	high-electron mobility transistor
HF	high frequency
HTML	hypertext markup language
HV	high voltage
HVdc	high voltage direct current
I	
IC	impedance compensation*; integrated circuit
ID	inside diameter; induced draft*; interdigital*
IDP	integrated data processing*
IF	intermediate frequency
IGFET	insulated-gate field-effect transistor
i.i.d.	independent identically distributed*
IM	intermediate modulation
IMPATT	impact ionization avalanche transit time (diode)
I/O, I–O	input–output
IR	infrared
IR	current-resistance
ISI	intersymbol interference
I–V	current–voltage
J	
JFET	junction field-effect transistor
JPEG	Joint Photographers Expert Group
L	
LAN	local area network
LC	inductance–capacitance
LED	light-emitting diode

LHS	left-hand side*
L–I	light output–current
LMS	least mean square
LO	local oscillator*
LP	linear programming*
LPE	liquid phase epitaxy*
LR	inductance–resistance
M	
MESFET	metal–semiconductor field-effect transistor
MF	medium frequency*
MFSK	minimum frequency-shift keying
MHD	magnetohydrodynamics
MIS	metal–insulator–semiconductor
MLE	maximum-likelihood estimator*
MLSE	maximum-likelihood sequence estimator*
MMF	magnetomotive force
MMIC	monolithic microwave integrated circuit*
MoM	method of moments*
MOS	metal–oxide–semiconductor
MOSFET	metal–oxide–semiconductor field-effect transistor
MOST	metal–oxide–semiconductor transistor
MPEG	Motion Pictures Expert Group
N	
NA	numerical aperture*
NIR	near infrared response*
NMR	nuclear magnetic resonance*
n-p-n	(diode)
NRZ	nonreturn to zero*
O	
OD	outside diameter
OEIC	optoelectronic integrated circuit*
OOP	object-oriented programming
P	
PAM	pulse-amplitude modulation*
PC	personal computer
PCM	pulse-code modulation*
pdf	probability density function*
PDM	pulse-duration modulation*
PF	power factor*
PID	Proportional-integral differential
p-i-n, p-n-p	(diode)
PLL	phase-locked loop*
PM	phase modulation*
PML	perfectly matched layer
pp, p–p	peak-to-peak*
PPM	pulse-position modulation*
PRF	pulse-repetition frequency*
PRR	pulse-repetition rate*
PSK	phase-shift keying*
PTM	pulse–time modulation
p.u.	per unit*
PWM	pulse width modulation*
Q	

Q	quality factor; figure of merit
QoS	quality of service
QPSK	quaternary phase-shift keying
R	
RAM	random access memory
RC	resistance–capacitance
R&D	research and development
RF	radio frequency
RFI	radio frequency interference*
RHS	right-hand side*
RIN	relative intensity noise*
RL	resistance–inductance
rms	root mean square
ROM	read-only memory
RV	random variable
S	
SAW	surface acoustic wave*
SGML	standard generalized markup language
SHF	super high frequency*
SI	International System of Units; severity index*
SIR	signal-to-interference ratio
S/N, SNR	signal-to-noise ratio
SOC	system-on-a-chip*
SSB	single sideband*
SW	short wave*
SWR	standing-wave ratio*
TDM	time-division modulation*; time-division multiplexing*
TDMA	time-division multiple access*
TE	transverse electric
TEM	transverse electromagnetic
TFT	thin-film transistor*
TM	transverse magnetic
TVI	television interference*
TWA	traveling-wave amplifier*
U	
UHF	ultrahigh frequency
UV	Ultraviolet
V	
VCO	voltage-controlled oscillator*
VHF	very high frequency*
V–I	voltage–current
VLF	very low frequency*
VLSI	very large scale integration*
W	
WAN	wide area network
WDM	wavelength division multiplexing*

B. Common Hyphenations and Misspellings

A
a posteriori
a priori
Abelian
accommodate
acknowledgment
acoustoelectric
acoustooptical
ad hoc
ad hoc networks
adder
aerospace
aftereffect
airborne
all-pass (adj)
Alnico
alphameric
alphanumeric
analog (not analogue)
appendixes
arc-back (n, adj)
arc-over (n, adj)
axle
B
back EMF
back-end (adj)
backscatter
band-limited (adj)
bandpass
band-shared (adj)
bandwidth
bang-bang
base–emitter [en dash]
base–collector [en dash]
baseband
baseline
Bayes' rule
beamwidth
Bernoulli polynomial
Bessel function
bimetallic
biomedical
blackbody
Boltzmann's constant
Boolean algebra
broadband
bulk–source [en dash]
bus (not buss)
bypass
C
C-band
Cartesian
Cascade
cascode
Cauchy's inequality
Chebyshev (not Tchebbycheff)
chi-square
Clebsch–Gordan coefficient
coauthor (also, coworker)
coax (coaxial)
collinear (not colinear)
continuous-time (adj)
coset
costate
Coulomb wave function
counterclockwise
counterexample
coworker
coupled-mode (adj)
cross correlation
crossover
cross section
cross-sectional (adj)
crosstalk
cutoff
cybersecurity
D
database
deadtime (or dead time)
debug, debugged
Debye temperature
Dewar
diagramed
dielectric
diesel
digamma function
Dirac
discretization
discusser
Doppler
drain–source [en dash]
dropout
dyadic
E
eccentricity
eigenfunction
eigenvalue
eigenvector
elastance
elastooptical
electrooptic
elliptical coordinates
elliptic integrals
emitter–bulk [en dash]
end-effector
endfire
endpoint
et al.
Euler function
exponentiate
F
fan-in
fan-out
far-field (adj)
fast Fourier transform
feedback
feedback-free (adj)
first-order (adj)
flat-band
flip-flop
flowchart
flowmeter
flowthrough
fold (twofold, *n*-fold)
foreword
formulas (not formulae)
forward scatter
4-vector
front-end (adj)
Fresnel
G
gate–source [en dash]
gate–drain [en dash]
gauge (not gage)
Gaussian distribution
Gegenbauer

gimbaled
gradient
(the) Green’s function
Gudermannian
H
half-angle
half-plane
half-space
half-wave
halfway
Hankel function
Heaviside
Hermite
Hermitian
Hertzian
higher order (adj)
high-order (adj)
high-pass (adj)
hookup
hydroelectric
I
iff (if and only if)
imbalance (n)
inasmuch as
indexes (plural of index)
indices (plural used in math)
infrared
inhomogeneous
input, inputted
input–output [en dash]
in situ
insofar as
in vitro
in vivo
integer
integral
integrand
integrator
integro-differential
Internet
Itô
J
Jacobian
Jacobi’s polynomials
K
Ka-band
Kronecker delta
L
L-band

Lagrange
Lagrangian
Laguerre polynomial
Lame’s transform
Laplace transform
Laplacian
Laurent series
left-hand side
leftmost
Legendre
Leibnitz (or Leibniz)
leveled
lightweight
like (suffix, close up)
line shape
lineup
linewidth
lockout
log-likelihood (adj)
lookup table
loudspeaker
lower order (adj)
low-order (adj)
low-pass (adj)
Lur’e
Lurie
Lyapunov (not Liapunov)
M
macro (noun)
magnetohydrodynamics
magnetooptic
main lobe
makeup
manhole
man-hour
man-made
manpower
Markov process
m-ary
Mathieu’s equation
matrices
mean-square
mid (prefix) close up
midband
midline
midplane
midpoint
miniscule
missile

modem
modulo (mod)
modulus
monotonic
monotonically
monotonicity
Mossbauer
m-sequence (noun)
multi (prefix) usually one word
multithreshold
Mylar
N
narrowband (adj)
n-ary
nearby
near-field (adj)
neoprene
Neumann
n-junction
n-layer
non (prefix) one word
non-Euclidean
non-Gaussian
non-Hermitian nonnegative
non-Stokes’
nonzero
NP-hard
*n*th-order (adj)
n-tuple
n-type
n-well
O
ohmmeter
one-dimensional (adj)
ORed, ORing
ON-OFF
output, outputted
overall (adj)
P
parameterization
particle
passband
percent
Permalloy
Perspex
phaselength
phase shift

phasewidth
photoelectric
photoetch
photoresist
pickup
piecewise linear
piezoelectricity
p-i-n
pinchoff
p-junction
Planck’s constant
p-n junction
p-n-p (not PNP)
p^+-n-p^++
Poisson distribution
positive definite
postmultiplication
pothead
potline
powerhouse
power plant
preceding
premultiplication
printout
proceeding
programmed
proof (suffix) one word
propagation
pseudo (prefix) one word
pseudorandom
p-type
pull-in
pull-out
pulselength
pulse shape
pulsewidth
punchthrough
p-well
Q
quadratic
quarter-wave
quartic
quasi- (prefix) hyphen
quaternary
Q value
R
radioactive
radio-astronomic
radio astronomy
radio frequency
random access (adj)
readback
READ head
readin (noun)
readout (noun)
real-valued (adj)
reentry
reexamine
Riccati
Riemann
right-hand side
rise time
root-mean-square (adj)
roundoff (adj)
Runge–Kutta
S
saddle point
scalar (magnitude)
scaler (machine)
scalor (rare)
self- (prefix) hyphen
self-adjoint
semi (prefix) usually one word
semi-infinite
servo (servomechanism)
servo amplifier
-shaped (hyphen)
sideband
sidelobe
signaling
slip ring
slow wave
so-called
solid-state (adj)
space-time
special-purpose (adj)
spirule
state of the art (noun)
state-variable (adj)
step-down
step-up
Stirling numbers
Stokes’
stopband
straightforward
strain gauge
Struve’s function
Sturm–Liouville [en dash]
suboptimum
subproblem
succeeding
successive
summable, asummable
supercoding
supermartingale
supersede
switchgear
switchyard
T
table lookup
takeoff
Taylor expansion
Tchebbyscheff (use Chebyshev)
Teflon
Teletype
teletypewriter
tensor
thin-film (adj)
threefold
3-space
throughput
time dependence
time-varying (adj)
tradeoff
traveling
two-port (or 2-port)
two’s complement
-type (hyphen)
U
ultrahigh frequency
ultrasonic
ultraviolet
unbalance (verb)
V
Van de Graaf
van der Waals
vector
versus
vertical
vertices
W
watthour meter
wattmeter
waveband
waveform

wavefront
wave function
waveguide
wavelength
wavenumber
wave shape
wave vector
wideband
wide-sense (adj)
widespread
wise (suffix) one word
worldwide
worst case (adj)
WRITE head

X
x-axis
X-band
x-direction
X-ray (adj)
xy plane
Y
Yagi
Z
Zener diode
zero-input (adj)
zero-sum (adj)
zeroth-order (adj)
z transform

C. Table of Units and Quantity Symbols

NOTE: Asterisks (*) indicate SI units, preferred multiples of SI units, or other units acceptable for use with SI.

Unit	**Unit Symbol**	**Sometimes Occur as: (do not use)**	**Applications and Notes**	**Quantity Symbol (for use as variables, etc.)**
*ampere	A	amp, a	SI unit of electric current.	*I* *U* *F*
ampere-hour	Ah	amp-hr	Also A · h.	
*ampere (turn)	A	At	SI unit of magnetomotive force.	*F*
*ampere per meter	A/m		SI unit of magnetic field strength.	*A* *H*
ångström	Å	Å	Å $\underline{\Delta}$ 10^{-10} m. Deprecated (see ANSI/IEEE Std 268-1992).	
atmosphere, standard	atm		atm $\underline{\Delta}$ 101 325 Pa. Deprecated (see ANSI/IEEE Std 268-1992).	
atmosphere, technical	at		at $\underline{\Delta}$ kgf/cm^2. Deprecated (see ANSI/IEEE Std 268-1992).	
*atomic mass unit (unified)	u		The (unified) atomic mass unit is defined as one-twelfth of the mass of an atom of the carbon-12 nuclide. Use of the old atomic mass unit (amu), defined by reference to oxygen, is deprecated.	
*atto	a		SI prefix for 10^{-18}.	
*attoampere	aA			
bar	bar	b, barye	bar $\underline{\Delta}$ 100 kPa. Use of the bar is strongly discouraged (see ANSI/IEEE Std 268-1992). Except for limited use in meteorology.	

barn	b		b $\underline{\Delta}$ 10^{-28} m^2.	
barrel	bbl		bbl = 42 gal_{US} = 158.99 L. This is the standard barrel used for petroleum and petroleum products. Different standard barrels are used for other commodities.	
barrel per day	bbl/d			
baud	Bd	baud (w/prefix)	In telecommunications, a unit of signaling speed equal to one element per second. The signaling speed in bauds is equal to the reciprocal of the signal element length in seconds.	$1/\tau$
bel	B	b		
*becquerel	Bq		SI unit of activity of a radionuclide.	
billion electronvolts	GeV	bev, BeV	The name *gigaelectronvolt* is preferred for this unit.	
bit	b		In information theory, the bit is a unit of information content equal to the information content of a message, the *a priori* probability of which is one-half. In computer science, the name bit is used as a short form of *binary digit.*	
bit per second	b/s			
British thermal unit	Btu			
byte	B		A byte is a string of bits, usually eight bits long, operated on as a unit. A byte is capable of holding one character set.	
calorie (International Table)	cal_{IT}		$\underline{\Delta}$ cal_{IT} 4.1868 J. Deprecated (see ANSI/IEEE Std 268-1992).	
calorie (thermochemical)	cal		$\underline{\Delta}$ cal 4.1840 J. Deprecated (see ANSI/IEEE Std 268-1992).	
*candela	cd		SI unit of luminous intensity.	*I*
candela per square inch	cd/in^2		Use of the SI unit cd/m^2 is preferred.	
*candela per square meter	cd/m^2	nit	SI unit of luminance.	*L*
candle	cd		The unit of luminous intensity has been given the name *candela*. Use of the name *candle* for this unit is deprecated.	
*centi	c (prefix)		SI prefix for 10^{-2}.	
*centimeter	cm			
centipoise	cP		cP $\underline{\Delta}$ mPa · s. The name centipoise is deprecated (see ANSI/IEEE Std 268-1992).	
centistokes	cSt		cSt $\underline{\Delta}$ mm^2/s. The name centistokes is deprecated (see ANSI/IEEE Std 268-1992).	
*circular mil	cmil		cmil $\underline{\Delta}$ $(\pi/4) \cdot 10^{-6} in^2$.	
*coulomb	C	c	SI unit of electric charge.	Q
*cubic centimeter	cm^3	cc	Volume. (Preferred SI unit multiple.)	
cubic foot	ft^3			
cubic foot per minute	ft^3/min	cfm		
cubic foot per second	ft^3/s			
cubic inch	in^3			
*cubic meter	m^3			
*cubic meter per second	m^3/s			

cubic yard	yd^3			
curie	Ci	C	Ci $\underline{\Delta}$ 3.7 x10^{10} Bq. A unit of activity of a radionuclide. Use of the SI unit, the becquerel, is preferred.	
cycle per second	Hz	c/s, cps, c/sec, cycle	See hertz.	
darcy	D		D $\underline{\Delta}$ cP·(cm/s)·(cm/atm) = 0.986923 μm^2. A unit of permeability of a porous medium. By traditional definition, a permeability of one darcy will permit a flow of 1 cm^3/s of fluid of 1 cP viscosity through an area of 1 cm^2 under a pressure gradient of 1 atm/cm. Deprecated (see ANSI/IEEE Std 268-1992).	
day	d		day $\underline{\Delta}$ 24 h.	
deci	d (prefix)		SI prefix for 10^{-1}.	
decibel	dB	db, DB		
degree (plane angle)	…°	deg		
degree (temperature)				
degree Celsius	°C	degree centigrade	SI unit of Celsius temperature. The degree Celsius is a special name for the kelvin, used in expressing Celsius temperatures or temperature intervals.	*t*
degree Fahrenheit	°F		Note that the symbols for °C, °F, and °R are comprised of two elements, written with no space between the ° and the letter that follows. The two elements that make the complete symbol are not to be separated.	
degree kelvin	K		See kelvin.	
degree Rankine	°R			
deka	da		SI prefix for 10.	
dyne	dyn	dyne	dyn $\underline{\Delta}$ 10^{-5} N. Deprecated (see ANSI/IEEE Std 268-1992).	*F*
*electronvolt	eV	ev		
erg	erg		erg $\underline{\Delta}$ 10^{-7} J. Deprecated (see ANSI/IEEE Std 268-1992).	
exa	E		SI prefix for 10^{18}.	
exbi	Ei		Prefix for 2^{60}.	
*farad	F	f, fd	SI unit of capacitance.	*C*
*femto	f		SI prefix for 10^{-15}.	
femtometer	fm			
foot	ft		ft $\underline{\Delta}$ 0.3048 m.	
foot of water	ftH_2O		ftH_2O = 2989.1 Pa. (ISO).[1]	
foot per minute	ft/min	fpm		
foot per second	ft/s	fps, ft/sec		
foot per second squared	ft/s^2			
foot pound-force	ft · lbf			
footcandle	fc		fc $\underline{\Delta}$ lm/ft^2. The name *lumen per square foot* is also used for this unit. Use of the SI unit of illuminance, the lux (lumen) per square meter, is preferred.	

footlambert	fL		fL $\underline{\Delta}$ $(1/\pi)$ cd/ft^2. A unit of luminance. One lumen per square foot leaves a surface whose luminance is one footlambert in all directions within a hemisphere. Use of the SI unit, the candela per square meter, is preferred.	
gal	Gal		Gal $\underline{\Delta}$ cm/s. Deprecated (see ANSI/IEEE Std 268-1992).	
gallon	gal		1 gal$_{UK}$ = 4.5461 L. 1 gal$_{US}$ $\underline{\Delta}$ 231 in^3 = 3.7854 L.	
gauss	G		The gauss is the electromagnetic CGS unit of magnetic flux density. Deprecated (see ANSI/IEEE Std. 268-1992).	*B*
gibi	Gi		Prefix for 2^{30}.	
*giga	G	kM	SI prefix for 10^9.	
gigabyte	GB		GB $\underline{\Delta}$ 10^9 B.	
*gigaelectronvolt	GeV	bev, BeV		
*gigahertz	GHz	kMHz, KMC, Gc/s		
			[1]The term "(ISO)" means that the definition is from ISO 31.	
gilbert	Gb		The gilbert is the electromagnetic CGS unit of magnetomotive force. Deprecated (see ANSI/IEEE Std 268-1992).	
grain	gr		gr $\underline{\Delta}$ lb/7000.	
*gram	g	gm		*m*
gram per cubic centimeter	g/cm^3			
*gray	Gy		SI unit of absorbed dose in the field of radiation dosimetry.	
*hecto	h		SI prefix for 10^2.	
*henry	H	Hy, hy	SI unit of inductance.	*L* *P*, P_m
*hertz	Hz	cps, c/s, cycle	SI unit of frequency.	f, v *B*
horsepower	hp		hp $\underline{\Delta}$ 550 ft · lbf/s = 746 W. The horsepower is an anachronism in science and technology. Use of the SI unit of power, the watt, is preferred.	
*hour	h	hr		
inch	in	in.	in $\underline{\Delta}$ 2.54 cm.	
inch of mercury	inHg		inHg = 3386.4 Pa (ISO).	
inch of water	inH_2O		inH_2O = 249.09 Pa (ISO).	
inch per second	in/s	ips		
*joule	J		SI unit of energy, work, and quantity of heat.	*E* *W* *Q*
*joule per kelvin	J/K		SI unit of heat capacity and of entropy.	*S*
kelvin	K		In 1967, the CPGM gave the name *kelvin* to the SI unit of temperature, which had formerly been called *degree kelvin*, and assigned it the symbol K (without the symbol °).	
kibi	Ki		Prefix for 2^{10}.	

*kilo	k		SI prefix for 10^3. The symbol k shall not be used for kilo. The prefix kilo shall not be used to mean 2^{10} (that is, 1024).	
*kilobit per second	kb/s			
*kilobyte	kB		kB $\underline{\Delta}$ 1000 bytes.	
kilogauss	kG		Deprecated (see ANSI/IEEE Std 268-1992).	
*kilogram	kg		SI unit of mass.	
kilogram-force	kgf		Deprecated (see ANSI/IEEE Std 268-1992). In some countries the name kilopond (kp) has been used for this unit.	
*kilohertz	kHz			
*kilohm	kΩ			*R*
*kilometer	km			
*kilometer per hour	km/h			
kilopound-force	klbf		Kilopound-force should not be misinterpreted as kilopond (see kilogram-force).	
*kilovar	kvar			*Q*
*kilovolt	kV			
*kilovoltampere	kVA	KVA, kva		
*kilowatt	kW			
kilowatthour	kWh		Also kW·h.	
knot	kn		kn $\underline{\Delta}$ nmi/h. 0.514 m/s.	
lambert	L		L $\underline{\Delta}$ $(1/\pi)$cd/cm^2. A CGS unit of luminance. One lumen per square centimeter leaves a surface whose luminance is one lambert in all directions within a hemisphere. Deprecated (see ANSI/IEEE Std 268-1992).	
*liter	L		L $\underline{\Delta}$ 10^{-3} m^3. In 1979, the CGPM approved L and l as alternative symbols for the liter. Because of frequent confusion with the numeral 1, the letter symbol l is not recommended for U.S. use (see Federal Register notice of December 20, 1990, vol. 55, no. 245, p. 52242). The script *l* shall not be used as a symbol for liter.	*V, v*
liter per second	L/s			
*lumen	lm		SI unit of luminous flux.	Φ
lumen per square foot	lm/ft^2		A unit of illuminance and also a unit of luminous exitance. Use of the SI unit, lumen per square meter, is preferred.	
*lumen per square meter	lm/m^2		SI unit of luminous exitance.	*M*
*lumen per watt	lm/W		SI unit of luminous efficacy.	*K(λ)* *K, K$_t$*
*lumen second	lm·s		SI unit of quantity of light.	*Q*
*lux	lx		1x/lm $\underline{\Delta}$ /m^2. SI unit of illuminance.	*E*
maxwell	Mx		The maxwell is the electromagnetic CGS unit of magnetic flux. Deprecated (see ANSI/IEEE Std 268-1992).	
mebi	Mi		Prefix for 2^{20}.	
*mega	M		SI prefix for 10^6. The prefix mega shall not be used to mean 2^{20} (that is, 1 048 576).	

megabit per second	Mb/s			
*megabyte	MB		MB $\underline{\Delta}$ 1 000 000 bytes.	
*megaelectronvolt	MeV			
*megahertz	MHz			
*megohm	MΩ	M		
*meter	m		SI unit of length.	*L*
metric ton	t		t $\underline{\Delta}$ 1000 kg. Use of the name *tonne* is deprecated in the U.S. (see ANSI/IEEE Std 268-1992).	
mho	S		Ω^{-1}. The name *mho* was formerly given to the reciprocal ohm. Deprecated; see siemens (S).	
*micro	μ		SI prefix for 10^{-6}.	
*microampere	μA			
*microfarad	μF			
*microgram	μg			
*microhenry	μH			
microinch	μin			
*microliter	μL		See note for liter.	
*micrometer	μm	μ		
micron	μm	μ	The name micron is deprecated. Use micrometer.	
*microsecond	μs			
*microwatt	μW			
mil	mil		mil $\underline{\Delta}$ 0.001 in.	
mile (statute)	mi		mi $\underline{\Delta}$ 5280 ft = 1609 m.	
mile per hour	mi/h	mph	Although use of mph as an abbreviation is common, it should not be used as a symbol.	
*milli	m		SI prefix for 10^{-3}.	
*milliampere	mA			
millibar	mbar		Use of the bar is strongly discouraged in ANSI/IEEE Std 268-1992, except for limited use in meteorology.	
*milligram	mg			
*millihenry	mH			
*milliliter	mL		See liter.	
*millimeter	mm			
millimeter of mercury	mmHg		mmHg = 133.322 Pa. Deprecated (see ANSI/IEEE Std 268-1992).	
millimicron	nm		Use of the name millimicron for the nanometer is deprecated.	
*millipascal second	mPa · s		SI unit-multiple of dynamic viscosity.	
*millisecond	ms			
*millivolt	mV			
*milliwatt	mW			
*minute (plane angle)	′			
*minute (time)	min		Time may also be designated by means of superscripts as in the following example: $9^{h}46^{m}30^{s}$.	

*mole	mol		SI unit of amount of substance. The mole is the amount of substance of a system that contains as many elementary entities as there are atoms in 0.012 kg of carbon 12. When the mole is used, the elementary entities shall be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles.	
month	mo			
*nano	n		SI prefix for 10^{-9}.	
*nanoampere	nA			
*nanofarad	nF			
*nanometer	nm			
*nanosecond	ns			
nautical mile	nmi		nmi $\underline{\Delta}$ 1852 m.	
*neper	Np			
*newton	N		SI unit of force.	
*newton meter	N · m			
*newton per square meter	N/m^2		SI unit of pressure or stress. See pascal.	
oersted	Oe	oe	The oersted is the electromagnetic CGS unit of magnetic field strength. Deprecated (see ANSI/IEEE Std 268-1992).	
*ohm	Ω		SI unit of resistance.	
ounce (avoirdupois)	oz		oz $\underline{\Delta}$ 1/16 lb = 28.350 g.	
*pascal	Pa		Pa $\underline{\Delta}$ N/m^2. SI unit of pressure or stress.	
*pascal second	Pa · s		SI unit of dynamic viscosity.	
pebi	Pi		Prefix for 2^{50}.	
*peta	P		SI prefix for 10^{15}.	
phot	ph		ph $\underline{\Delta}$ lm/cm^2. CGS unit of illuminance. Deprecated (see ANSI/IEEE Std 268-1992).	
*pico	p		SI prefix for 10^{-12}.	
*picofarad	pF			
*picowatt	pW			
pint	pt		pt (U.K.) = 0.568 26 L. pt (U.S. dry) = 0.550 6 L. pt (U.S. liquid) = 0.473 18 L.	
poise	P		Deprecated (see ANSI/IEEE Std 268-1992).	
pound (avoirdupois)	lb		lb $\underline{\Delta}$ 0.453 592 37 kg.	
pound per cubic foot	lb/ft^3			
pound-force	lbf		lbf = 4.4482 N.	
pound-force foot	lbf · ft			
pound-force per square foot	lbf/ft^2			
pound-force per square inch	lbf/in^2	psi	Although use of the abbreviation psi is common, it should not be used as a symbol.	
poundal	pdl		pdl $\underline{\Delta}$ lb · ft/s^2 = 0.1383 N	
quart	qt		qt (U.K.) = 1.1365 L. qt (U.S. dry) = 1.1012 L. qt (U.S. liquid) = 0.946 35 L.	
rad	rd		rd $\underline{\Delta}$ 0.01 Gy. A unit of absorbed dose in the field of radiation dosimetry. Use of the SI unit, the gray, is preferred.	

*radian	rad		SI unit of plane angle.	
rem	rem		rem $\triangleq$ 0.01 Sv. A unit of dose equivalent in the field of radiation dosimetry. Use of the SI unit, the sievert, is preferred. 1 rem = 0.01 Sv.	
revolution per minute	r/min		Although use of rpm as an abbreviation is common, it should not be used as a symbol.	
revolution per second	r/s			
roentgen	R		A unit of exposure in the field of radiation dosimetry.	
*second (plane angle)	″		$1'' = 4.848 \cdot 10^{-6}$ rad.	
*second (time)	s		SI unit of time.	
*siemens	S		S $\triangleq \Omega^{-1}$. SI unit of conductance.	
*sievert	Sv		SI unit of dose equivalent in the field of radiation dosimetry.	
slug	slug		slug $\triangleq$ lbf $\cdot$ s^2/ft = 14.594 kg.	
square foot	ft^2			
square inch	in^2			
*square meter	m^2			
*square meter per second	m^2/s		SI unit of kinematic viscosity.	
*square millimeter per second	mm^2/s		SI unit-multiple of kinematic viscosity.	
square yard	yd^2			
*steradian	sr		SI unit of solid angle.	
stilb	sb		sb $\triangleq$ cd/cm^2. A CGS unit of luminance. Deprecated (see ANSI/IEEE Std 268-1992).	
stokes	St		Deprecated (see ANSI/IEEE Std 268-1992).	
tebi	Ti		Prefix for 2^{40}.	
*tera	T		SI prefix for 10^{12}.	
terabyte	TB		TB $\triangleq 10^{12}$ B.	
*tesla	T		T $\triangleq$ N/(A $\cdot$ m)^2 $\triangleq$ Wb/m^2. SI unit of magnetic flux density (magnetic induction).	
therm	thm		thm $\triangleq$ 100 000 Btu.	
ton (short)	ton		ton $\triangleq$ 2000 lb.	
ton, metric	T		t $\triangleq$ 1000 kg. Use of the *tonne* for this unit is deprecated in the U.S. (see ANSI/IEEE Std 268-1992).	
torr	torr		A unit of pressure equal to 0.001316 atmosphere; named after Torricelli.	
*(unified) atomic mass unit	u		The (unified) atomic mass unit is defined as one-twelfth of the mass of an atom of the carbon- 12 nuclide. Use of the old atomic mass unit (amu), defined by reference to oxygen, is deprecated.	
*var	var		IEC name and symbol for SI unit of reactive power.	
*volt	V		SI unit of voltage.	
*volt per meter	V/m		SI unit of electric field strength.	
*voltampere	VA	va	IEC name and symbol for SI unit of apparent power.	
*watt	W		SI unit of power.	
*watt per meter kelvin	W/(m $\cdot$ K)		SI unit of thermal conductivity.	

*watt per steradian	W/sr		SI unit of radiant intensity.	
*watt per steradian square meter	$(W/sr \cdot m^2)$		SI unit of radiance.	
watthour	Wh			
*weber	Wb		Wb $\underline{\Delta}$ V·s. SI unit of magnetic flux.	
yard	yd		yd $\underline{\Delta}$ 0.9144 m.	
year	a		Also W·h.	
yobi	Yi		Prefix for 2^{80}.	
yocto	y		SI prefix for 10^{-24}.	
yotta	Y		SI prefix for 10^{24}.	
zebi	Zi		Prefix for 2^{70}.	
zepto	z		SI prefix for 10^{-21}.	
zetta	Z		SI prefix for 10^{21}.	

D. Miscellaneous Alphabetical Abbreviations, Acronyms, and Symbols

NOTE: Key: fn—function name (roman); s—symbol (italic); u—unit abbreviation (roman); *—acronyms that must be defined in text.

A	
A	(s) Hermitian conjugate of *A*
Å	(u) angstrom
ab	(prefix) denotes absolute system of (CGS) units. Abampere, abcoulomb, abvolt, abohm, abfarad, abmho, abhenry (use not recommended, see units list)
abs	absolute
ABS	air-bearing surface
Ac	alternating current
ACB	air circuit breaker*
ACSR	steel-reinforced aluminum cable*
AD	attention display*
A–D, A/D	analog-to-digital
ADF	automatic direction finder*
a.e.	almost everywhere (in equations)
AEW	airborne early warning*
AF	audio frequency*
AFB	Air Force Base
AFC	automatic frequency control*
AFM	atomic force microscopy
AGC	automatic gain control*
AGFM	alternating gradient force magnetometer
AGM	arithmetical–geometric mean*
A·h (u)	ampere hour
Ai (fn)	Airy integral
AM	amplitude modulation

A.M.	ante meridiem (morning)
ama	automatic message accounting*
AND	(small caps) logical AND operation
ANI	automatic number identification
ANN	artificial neural network*
antilog (fn)	antilogarithm
AOGM	accelerated optimum gradient method*
AOPT	air-operated press type*
APD	avalanche photodiode
API	air position indicator*
AQL	acceptable quality level
AR	antireflection*; autoregressive*
arcsin arccos arctan arccot arcsec arccsc	(fn) inverse trigonometric functions
arg	(fn) argument
ARMA	autoregressive moving average*
a.s.	almost surely (in equations)
ASE	amplified spontaneous emission*
ASIC	application specified integrated circuit*
ASK	amplitude-shift keying
ASW	antisubmarine warfare* (note: for acoustic surface wave use SAW)
at (u)	technical atmosphere: 1 kgf/cm
At (u)	ampere turn (note: no longer in use; change to A)
ATM	asynchronous transfer mode*
atm (u)	atmosphere
ATR	antitransmit receive*
ATT	avalanche transit time*
av	average (subscript)
AVC	automatic volume control*
avg (fn)	average (use av as subscript)
AWE	asymptotic wave evaluation*
AWG	American wire gauge
AWGN	additive white Gaussian noise*
B	
bar (u)	bar
barye (u)	barye: microbar (use not recommended; see units list)
bbl (u)	barrel (see units list)
bcc	body-centered cubic (of crystals)
BCD	binary coded decimal
BCH	Bose–Chaudhuri–Hocquenghen (codes)

BCT	bushing current transformer*
Bd (u)	baud* (see units list)
B–E	base–emitter source
Be	Baume
bei, ber (fn)	Kelvin forms of Bessel function
BEM	boundary-element method
BER	bit error rate*
BeV, bev (u)	use GeV
BFO	beat-frequency oscillator*
B–H B–H curve:	curve of magnetic induction (magnetic flux–density) versus magnetic intensity (field intensity) B–H relationship. B–H loop: hysteresis loop
Bhp	brake horsepower*
Bi (fn)	Airy integral: (u) bit: = 10 A*
BIL	basic impulse insulation level*
BJT	bipolar junction transistor*
BMEP	brake mean effective pressure*
bpi (u)	bit per inch: use b/in
bps (u)	bit per second: use b/s
BPSK	binary phase-shift keying
BRA	biased rectifier amplifier*
BS	breaking strength*
BS	British Standards*
B&S	Brown and Sharpe gauge*
BSF	bulk shielding facility*
BSL	basic switching surge insulation level*
BTU	(u) British thermal unit
BWG	Birmingham wire gauge*
BWK	Brillouin–Wentzel–Kramers (method)*
BWO	backward-wave oscillator*
BWR	boiling water reactor*
C	
C (u)	coulomb
°C (o)	degree Celsius
c (u)	cycle: use Hz; centi- (prefix to unit abbreviation)
c (s)	speed of light in a vacuum
cal (u)	calorie (use not recommended; see units list)
CATV	community antenna television system
cc (u)	cubic centimeter: use cm^3
c.c.	complex conjugate (in equations)
CCB	coin collecting box (British telephones)*
CCD	charge-coupled device*
CCR	closed-cycle refrigerator*
cd (u)	candela

cdf	cumulative distribution function*
CDMA	code division multiple access*
CDO	community dial offices*
CD-ROM	compact disk read-only memory
cdrx	external critical damping resistance: use caps*
CEMF	counterelectromotive force*
cf.	compare
cfm (u)	cubic feet per minute: use ft^3/min
cfs (u)	cubic feet per second: use ft^3/s
CGS	centimeter-gram-second (system of units)
Ci (fn)	cosine integral; (u) curie
CIM	computer integrated manufacturing*
CIR	carrier-to-interference ratio*
ckVA	capacitive kilovoltamperes (write out)
cmil (u)	circular mil
CMOS	complementary metal–oxide–semiconductor
CNN	cellular neural network
COP	coefficient of performance*
cos cosec cosh cot coth covers	(fn) cosine (fn) cosecant: use csc (fn) hyperbolic cosine (fn) cotangent (fn) hyperbolic cotangent (fn) coversine
cP (o)	centipoise (see units list)
CPFSK	continuous phase frequency-shift keying*
CPM	continuous phase modulation*
CPSK	continuous phase-shift keying; coherent phase-shift keying*
CPU	central processing unit
CRO	cathode-ray oscilloscope
CRS	cold-rolled steel*
CRT	cathode-ray tube
c/s (u)	cycle per second: use Hz
csc (fn)	cosecant
csch (fn)	hyperbolic cosecant cs (u) centistokes: use cSt or write out (see units list)
CSP	completely self-protected
cSt (u)	centistokes (see units list)
CSV	corona-starting voltage
CT	current transformer*
CTC	centralized traffic control
ctn (fn)	cotangent: use cot
curl (fn)	curl
CV	capacitance–voltage
CVD	chemical vapor deposited
CW	continuous wave*

D	
DA	design automation
dB (u)	decibel
dc	direct current (DC at start of sentence or in article title)
DC	directional coupler
DDA	digital differential analyzer*
DDD	direct distance dialing*
DE	disruptive effect*
det (fn)	determinant
DF	direction finder*; deuterium fluoride; degree of freedom*
DFB	distributed feedback
DFT	discrete Fourier transform*
diag	(diagonal)
diam	diameter
DIC	Diploma of membership in Imperial College of Science and Technology
div (fn)	divergence; division (u) in charts
DMA	direct memory access*
DME	distance-measuring equipment*
DOD	diameter over dielectric; Department of Defense
DOF	degree of freedom (unit)
DP	dial pulse*
DPCM	differential pulse code modulation*
DPDT	double-pole double-throw switch*
DPH	diamond pool hardness*
DPQSK	differential quadrature phase-shift keying*
DPSK	differential phase-shift keying*
DRCPR	differential reactive current protective relay*
DRO	destructive readout*; doubly resonant oscillator
DS	dielectric strength*; direct sequence*
DSB	double sideband*
DSP	digital signal processor
DVP	differential vapor pressure*
DWT	discrete wavelet transform*
dyn (u)	dyne
E	
EB	emergency bank*
EC	eddy current; electrical conductivity* (grade of Al)
ECG	electrocardiogram
ECL	emitter-coupled logic*
ECM	electronic countermeasures
ECT	eddy current testing
ED	enforced draft

EDFA	erbium-doped fiber amplifiers*
EDP	electronic data processing
EDS	energy dispersive spectrometer
EDX	energy dispersive X-ray
EEG	electroencephalogram
EHD	electrohydrodynamic*
EHF	extremely high frequency*
EHIPS	extra heavy iron pipe size*
EHV	extra high voltage
Ei (fn)	exponential integral
ELF	extremely low frequency*
EM	electromagnetic*
EMC	electromagnetic compatibility*
EMF	electromotive force*
EMI	electromagnetic interference*
ems	expected value of mean square*
EMU	electromagnetic units
EOF	end of file
erf (fn)	error function
erfc (fn)	complementary error function
erg (u)	erg
ERP	effective radiated power*
ESS	electrical sheet steel*
ESU	electrostatic units
eV (u)	electronvolt
EXOR	EXCLUSIVE-OR circuit (small caps)
exp (fn)	exponential function
exsec (fn)	exsecant
F	
f (*f*-stop, f/22)	ratio of focal length to aperture
F (u)	farad
°F (u)	degree Fahrenheit
FA	forced-air-cooled transformer*
fcc	face-centered cubic (of crystals)
FCC	Federal Communications Commission
FD	flux density*
FDA	finite difference approximations*
FDM	frequency-division multiplexing*
FDMA	frequency-division multiple access*
FDTD	finite-difference time domain*
FEA	finite-element analysis
FET	field-effect transistor
ff.	following pages

FFT	fast Fourier transform*
FIFO	first-in first-out
FIM	field intensity meter*
FIR	finite-impulse response*
fL (u)	footlambert
FL	full load
FM	frequency modulation
FMFB	FM feedback receiver*
FMR	frequency of maximum reliability*; ferromagnetic resonance
FPGA	field-programmable gate array*
fpm, fps (u)	feet per minute: use ft/min; feet per second: use ft/s
FS	full scale
FSK	frequency-shift keying*
FSM	finite-state machine*
ft (u)	foot
FTL	flat tie-line*
FTP	file transfer protocol
FW	full wave
FWHM	full-width at half-maximum*
FWM	four-wave mixing*
G	
G	giga- (prefix to unit abbreviations) = 10^9
G (u)	gauss
g	acceleration of gravity, “gee force”; use as unit with metric prefix, as in 3 mg
G (s)	gravitational constant
Gal (u)	gal (gravitational unit)
gal (u)	gallon
Gb (u)	gilbert
GCA	ground-controlled approach*
gcd	greatest common denominator (may be function name)
GenAI	generative artificial intelligence
GLB	greatest lower bound*
GMD	geometric mean distance*
GMEC	generalized minimum effort control*
GMF	geometric mean frequency
GMR	geometric mean radius
GMT	Greenwich mean time
gpd (u)	gallon per day: use gal/day
GPS	Global Positioning System
GPU	graphical processing unit, General Public Utilities*
grad (fn)	gradient
GSE	ground support equipment*
GTD	geometrical theory of diffraction

GUI	graphical user interface
GW	ground wire
H	
h (s)	Planck's constant
H (u)	henry
H (s)	magnetic intensity; magnetic field strength
hav, havers (fn)	haversine
HBT	heterojunction bipolar transistor
hcp	hexagonal close-packed (of crystals)
HD	hard-drawn*
HDBC	hard-drawn bare copper*
HDC	hard-drawn copper*
HDD	hard disk drive
HDT	hard-drawn tubing*
HEMT	high-electron mobility transistor
HF	high frequency; hydrogen fluoride
HFET	heterojunction FET
HG	mercury
hipot	high potential (write out)
hp (u)	horsepower
HTC	high-tension cable*
HTML	hypertext markup language
HV	high voltage
HVdc	high voltage direct current
Hz (u)	hertz
I	
I (s) current (fn)	imaginary part of: use Im
IACS	International Annealed Copper Standard*
IC	impedance compensation*; integrated circuit
ICW	interrupted continuous wave*
ID	inside diameter; induced draft*; interdigital*
IDP	integrated data processing*
IF	intermediate frequency
iff	if and only if
IFT	interfacial tension*
IGFET	insulated-gate field-effect transistor
i.i.d.	independent identically distributed*
IIR	infinite-impulse response
ILS	instrument landing system*
Im (fn)	imaginary part of
IM	intermediate modulation
IMPATT	impact ionization avalanche transit time (diode)

INE	irredundant normal equivalent*
inf (fn)	infimum
int (fn)	integer value of
I/O, I–O	input–output
IoT	Internet of Things*
IP	Internet Protocol
ips (u)	inch per second: use in/s
IPS	iron pipe size; international pipe standard*
IR	infrared
IR	current–resistance
ISB	independent sideband*
ISE	integral of squared error*
ISI	intersymbol interference
itae	integral of time-multiplied absolute value of error
ITI	inter-track interference
I–V (s)	current–voltage (characteristic or curve)
IVA	induced voltamperes
IX	current–reactance (drop)
IZ	current–impedance
J	
J (u)	joule
JFET	junction field-effect transistor
JPEG	Joint Photographers Expert Group
K	
k	kilo (prefix to unit abbreviations) = 10^3
K (u)	Kelvin
Kayser (u)	= cm^{-1} (wavenumber)
kbps (u)	kilobits per second: use kb/s
KCL	Kirchhoff's current law
kcm, KCM (u)	thousand circular mils: use kcmil
kg (u)	kilogram
KGO, KGOe, KGoe, KgOe (u)	use kO·Oe
kgp (u)	kilogrampois (French): use kg
kG.Oe (u)	kilogauss oersted
kip	thousand pounds
kn (u)	knot (nautical mile per hour)
KOH	potassium hydroxide
kp (u)	kilopound (German): use kg
kt (s)	Boltzmann's constant × time
KVL	Kirchhoff's voltage law
kVp (u)	kilovolt peak*

L	
l (u)	liter
L (u)	lambert
LAN	local area network
lb (u)	pound
lbf (u)	pound-force
LC	inductance–capacitance
lcm	least common multiple (may be function name)
LCR	inductance–capacitance–resistance
LCS	load current substation*
LDC	line drop compensator*; load division circulation
LED	light-emitting diode
LF	low-frequency
LHP	left-half plane*
LHS	left-hand side*
Li (fn)	logarithmic integral
lim (fn)	limit
l.i.m. (fn)	limit in the mean
L–L	line to line*
lm (u)	lumen
LMLT	locus of major loop tips*
LMS	least mean square
LMT	local mean time*
ln (fn)	natural logarithm (base *e*)
L–N	line to neutral*
LNA	low noise amplifier
LO	local oscillator*
log, $\log_n$ (fn)	logarithm, logarithm base *n* (where *n* = 2, 10, etc.)
LP	linear programming*
LPE	liquid phase epitaxy*
LR	inductance–resistance
LRC	load ratio control*
LSB	least significant bit
LSI	large-scale integration*; large-scale integrated*
LST	local standard time
LTC	load tap-changing*
LTE	long-term evolution
LTS	laser-triggered switching*
LUF	lowest usable frequency*
lx (u)	lux
M	
m (u)	meter; milli- (prefix to unit abbreviations) = 10^{-3}

M	mega- (prefix to unit abbreviations) = 10^6; mole
MAG	maximum available gain
MAP	maximum *a posteriori*
max (fn)	maximum; also used as subscript
MC	Monte Carlo
mcm, MCM (u)	thousand circular mils: use kcmil
mc/mM (u)	millicuries per millimole: use mCi/mM
MCS	multicircuit substation*
MCT	movable core transformer*
MCW	modulated continuous wave*
MDF	manual direction finder*
MDS	minimum detectable signal
MEMS	micro-electromechanical systems
MESFET	metal–semiconductor field-effect transistor
MEW	microwave early warning*
MF	medium frequency*
MFM	magnetic force microscopy
MFSK	minimum frequency-shift keying
MGO (u)	megagauss oersted: use MG·Oe
MG·Oe (u)	megagauss oersted
MHD	magnetohydrodynamics
mho (u)	mho (also Ω^{-1})
mi (u)	mile
MIM	metal–insulator–metal
MIMO	multi-in multi-out*
mio (fn)	minimum; also used as subscript
MIS	metal–insulator–semiconductor*
MKS	meter–kilogram–second (system of units)
ml	milliliter
MLE	maximum-likelihood estimation*
MLSD	maximum-likelihood sequence detector
MLSE	maximum-likelihood sequence estimator*
MMF	magnetomotive force
mmHg (u)	millimeter of mercury
MMIC	monolithic microwave integrated circuit*
mm_2O (u)	millimeter of water
mmse	minimum mean square error
MOCVD	metal–organic chemical vapor deposition*
mod	modulo
MOKE	magnetooptic Kerr effect
MoM	method of moments*
MOS	metal–oxide–semiconductor
MOSFET	MOS field-effect transistor
MOST	MOS transistor

MOVPE	metal–organic vapor phase epitaxy*
MPEG	Moving Pictures Expert Group
MPIE	mixed potential integral equation
MRAM	magnetic random access memory
MRI	magnetic resonance imaging
MSB	most significant bit
mse	mean square error
MSIC	medium scale integrated circuits*
MTBE	mean time between explosions
MTBF	mean time between failures*
MTI	multiple target indicator*; moving target indicator
MTJ	magnetic tunnel junction
MTL	multiconductor transmission line
MU	multiple unit*
MUF	maximum usable frequency*
MVQE	minimum variance quantum estimator
Mx (u)	maxwell
MZI	Mach–Zehnder interferometric*
N	
n	nano (prefix to unit abbreviations) = 10^{-9}
N (u)	newton
NA	numerical aperture*
NAND	NOT-AND circuit (small caps)
nat (u)	nat
NC	diode negative-conductance diode*
NDRO	nondestructive readout
NDT	nondestructive testing*
NIC	negative impedance converter*
NIR	near infrared response*
nit (u)	nit
Nkw-hr (u)	net kilowatthour: use net kW·h
NL	no load
nmi (u)	nautical mile
NMR	nuclear magnetic resonance*
NOR	NOT-OR circuit (small caps)
NP	nameplate (rating)
Np (u)	neper
n-p-n	semiconductor forms: Roman, lowercase, hyphens
NRZ	nonreturn to zero*
NTC	negative temperature coefficient*
NWP	network protector
O	

OCB	oil circuit breaker*
OCR	oil circuit recloser*
OD	outside diameter
Oe (u)	oersted
OEIC	optoelectronic integrated circuit*
OFDA	optical-fiber frequency-domain analysis*
OGM	optimum gradient method
OOK	on–off keying
OOP	object-oriented programming*
opt (fn)	optimum: also used as subscript
OR	OR circuit (small caps)
OSM	omni spectra miniature
OTDM	optical time-division multiplexing*
O-wave	ordinary-wave (ionogram)
OZ (u)	ounce
P	
p	pico- (prefix to unit abbreviations) = 10^{-12}
P (u)	poise
Pa (u)	pascal
PAE	power-added efficiency
PAM	pulse-amplitude modulation*
PAX	private automatic exchange*
PBX	private branch exchange*
pc (u)	parsec
PC	personal computer
PCM	pulse-code modulation*; pulse-count modulation*
PD	potential difference*
pdf	probability density function*
pdl (u)	poundal (see units list)
PDM	pulse-duration modulation*
P_e (s)	probability of error
PER	probability of error
PES	position error signal
PF	power factor*
ph (fn)	phase
pH	power of hydrogen (acidity or alkalinity of solution)
PI	polarization index
PID	proportional–integral–differential*
PILC	paper-insulated lead-covered*
PIN	use p-i-n for diodes, etc.
p-i-n	semiconductor forms: Roman, lowercase, hyphens
PL/1	a programming language
PLC	power line carrier*

PLL	phase-locked loop*
PM	phase modulation*
P.M.	post meridiem (small caps)
PML	perfectly matched layer
PMMA	polymethyl methacrylate*
PMR	perpendicular magnetic recording
p-n-i-p	semiconductor forms: Roman, lowercase, hyphens
p-n-p	semiconductor forms: Roman, lowercase, hyphens
POD	para-operational device*
POW_p (u)	picowatts psophometrically weighted at a point of zero relative level*
pp, p-p	peak to peak*
PPI	plan-position indicator*
ppm (u)	parts per million; pulse per minute*
PPM	pulse-position modulation*
pps (u)	pulse per second*
Pr (fn)	probability (appears as Pr $x \mid x = \mathrm{U}$)
PRA	pulse relaxation amplifier
PRF	pulse-repetition frequency*
PRML	partial response maximum likelihood
Prob.,	P, x|· use Pr (usually)
PRR	pulse-repetition rate*
PSD	power spectral density
PSF	power separation filter*
psi (u)	pounds per square inch: change to $\mathrm{lb/in^2}$ unless paper also contains psia and/or psig
psia (u)	pound-force per square inch absolute (stet)
psig (u)	pound-force per square inch gauge (stet)
PSK	phase-shift keying*
PTM	pulse–time modulation
p.u.	per unit
PVC	polyvinyl chloride*
PWL	piecewise linear
PWM	pulse width modulation*
PWR	pressurized water reactor*
PZT	lead zirconate titanate
Q	
Q	quality factor; figure of merit
QAM	quadrature-amplitude modulation*
Q.E.D.	quod erat demonstrandum (end of proof) (set flush right)
QoS	quality of service
QP	quasi-peak*
QPSK	quaternary phase-shift keying
QW	quantum well*

R	
R (u)	roentgen
R (fn)	real part of: use Re
°R (u)	degrees Rankine
rad (u)	radian
RAM	random access memory
RB	circuit transient blocking relay circuit*
RC	resistance–capacitance
RCF	radar cross section*
R&D	research and development
Re (fn)	real part of: use Re (be sure of this meaning before changing)
redox	reduction–oxidation
rem (u)	Roentgen equivalent, man
RF	radio frequency
RFI	radio frequency interference*
RFU	reclosing fuses*
RH	relative humidity*
RHS	right-hand side*
RI	radio interference*
RIFI	radio interference and field intensity*
RIL	radio interference level*
RIN	relative intensity noise*
RL	resistance–inductance
RMI	radiomagnetic indicator*
rms	root-mean-square (error); root mean square
ROM	read-only memory
rpm (u)	revolution per minute: use r/min
rps (u)	revolution per second: use r/s
RSG	recurrent surge generator*
RTD	resistance temperature detectors
RV	random variable
RX	resistance–reactance
S	
s (u)	second
S (u)	siemens
SAR	specific absorption rate
SATT	Strowger Automatic Toll Ticket*
SAW	surface acoustic wave*
SC	switched-capacitor*(adj)
SCA	steel-reinforced aluminum cable*
SCC	signal component control*
scfm	standard cubic feet per minute*

SCL	space-charge limited*
scr	short-circuit ratio*
SCR	silicon-controlled rectifier
sec (fn)	secant; (u) second: use s; second of arc*
sech (fn)	hyperbolic secant
SEM	scanning electron microscope
SF	single frequency*
SGML	standard generalized markup language
sgn (fn)	signum function
SHF s	upper high frequency*
SI	severity index*; Systeme International d'Unites (International System of Units)
Si, si (fn)	sine integral
sin (fn)	sine
sinc (fn)	sinc $x = (\sin x) / x$
sinh (fn)	hyperbolic sine
SINR	signal-to-interference-plus-noise ratio*
SIR	signal-to-interference ratio
SISO	single-in, single-out*
SLAR	side looking airborne radar
SLG	single line to ground
SMSA	standard metropolitan statistical area
S/N	signal-to-noise ratio
SNR	signal-to-noise ratio
SoC	system-on-chip*
SPDT	single-pole double-throw (switch)*
SPICE	Simulation Program with Integrated Circuit Emphasis
SPT	single-pole type
sq square:	if on a unit, change to ^{2}
SQUID	superconducting quantum interference device
sr (u)	steradian
SR	saturable reactor*
SS	subsystems*
SSB	single sideband*
s.t.	subject to
St (u)	stokes
sterad (u)	steradian: use sr
SUL	soft underlayer
SUMT	sequential unconstrained minimization techniques
sup (fn)	supremum
sus	Saybolt universal seconds (oil viscosity)*
sw	sine wave*
SW	short wave*
SWG	standard wire gauge*
SWR	standing-wave ratio*

T	
t (u)	tonne
T (u)	tesla
tan (fn)	tangent
tanh (fn) hyperbolic tangent	
TCUL	tap-changing under load*
TDM	time-division modulation*; time-division multiplexing*
TDMA	time-division multiple access*
TE	transverse electric (appears as TE^0_{01} and TE_{01})
TEFC	totally enclosed fan-cooled*
Telex	teleprinter exchange*
TEM	transverse electromagnetic
TFT	thin-film transistor*
tg (fn)	tangent: use tan
th (u)	thermie
TIF	telephone influence factor*
TLM	transmission-line matrix
TM	transverse magnetic
tof	thermal ohms per foot (spell out)
torr (u)	torr
tpc (u)	turns per centimeter: turns/cm
TPC	turns per coil*
tr (fn)	trace
Tr	transpose
TSS	time sharing system
TTL	transistor–transistor logic
TTY	teleprinter
tu	traffic units*
TVI	television interference*
TWA	traveling-wave amplifier*
TWM	traveling-wave maser*
TWP	traveling-wave phototube*
TWT	traveling-wave tube
U	
UHF	ultrahigh frequency
ult (fn)	ultimate
UPS	uninterruptible power system*
	uniform *RC* sections (stet overbar)
URL	uniform resource locator
XRD	X-ray diffraction
UT	universal time

UTS	ultimate tensile strength
UV	ultraviolet
V	
V (u)	volt
V (s)	voltage
VA (u)	voltampere; Viterbi algorithm*
var (u)	var
VCL	varnished-cambric lead-covered*
VCO	voltage-controlled oscillator*
VCW	type V copper weld*
VDS	voltage divider switching*
ver, vers (fn)	versine
VF	voice frequency*
VFO	variable-frequency oscillator*
VHF	very high frequency*
V–I	voltage–current (characteristic of curve)
VLF	very low frequency*
VLSI	very large scale integration*
VOR	very high-frequency omnidirectional radio
VR	voltage regulator*
VSB	vestigial sideband*
VSWR	voltage standing-wave ratio
VTB	voltage time to breakdown*
VTVM	vacuum-tube voltmeter
vu	volume units*
W	
W (u)	watt
WAN	wide area network
Wb (u)	weber
WDM	wavelength-division multiplexing*
WDMA	wavelength-division multiple access*
WKB	Wentzel–Kramer–Brillouin*
wpl, w.p.l.	with probability 1*
wrt, w.r.t.	with respect to
WT	watertight*
wt%	weight percent
X	
XPM c	ross-phase modulation
XOR	EXCLUSIVE-OR circuit (small caps)
X-wave	extraordinary-wave (ionogram)

Y	
YAG	yttrium aluminum garnet
yd (u)	yard
YIG	yttrium iron garnet

Factor by Which the Unit Is Modified	Prefix	Symbol
$1000000000000 = 10^{12}$	tera	T
$1000000000 = 10^{9}$	giga	G
$1000000 = 10^{6}$	mega	M
$1000 = 10^{3}$	kilo	k
$100 = 10^{2}$	hecto	h
$10 = 10^{1}$	deka	da
$0.1 = 10^{-1}$	deci	d
$0.01 = 10^{-2}$	centi	c
$0.001 = 10^{-3}$	milli	m
$0.000001 = 10^{-6}$	micro	μ
$0.000000001 = 10^{-9}$	nano	n
$0.000000000001 = 10^{-12}$	pico	p
$0.000000000000001 = 10^{-15}$	femto	f
$0.000000000000000001 = 10^{-18}$	atto	a

For prefixes indicating powers of 2, see Table 7 at the NIST site.

E. Inclusive Language Guide

Overall recommendations:

- Use “people-first language,” i.e., the person has X; has been diagnosed with X; uses a X; etc.
- Do not spell out the acronyms LGBTQIA+, LGBT, LGBTQ, LGBTQIA.

Insensitive Term/Phrase	Replace With	Definition/Background	Additional Notes
A.D. (when referencing history/time)	C.E., common era	Abbreviation of the Latin phrase anno Domini, translated as “the year of the Lord.” Traditionally, it is used to date years after the birth of Jesus	This contradicts AP style.
Able-bodied	non-disabled/does not have a disability		

Afro-American/Negro/ Colored/Nigger (in reference to race)	Avoid in all instances; African American*; Black†	People of African descent have widely varied cultural backgrounds, family histories, and family experiences. Some will be from Caribbean islands, Latin America, various regions in the United States, countries in Africa, or elsewhere. Some American people of African ancestry prefer "Black," and others prefer "African American"; both terms are acceptable.	* Specific to people of specific African descent; not to be used as an umbrella for people of African ancestry worldwide. † Widely accepted to encompass multiple ethnicities and/or national origins.
B.C. (when referencing history/time)	B.C.E., before common era	Literally, before Christ or the Christian era.	This contradicts AP style.
Black box	Closed box		Preferred term from IEEE Thesaurus
Blacklist; black list	Blocklist; block list	The Hollywood blacklist was instituted by the House Un-American Activities Committee in 1947 to block screenwriters and other Hollywood professionals who were purported to have Communist sympathies from obtaining employment. A list or compilation that identifies entities that are denied, unrecognized, or ostracized. The term's racist connotations derive from the idea that black equates to negative; this view can be controversial.	Preferred term from IEEE Thesaurus
Blind	blind*; limited vision; low vision; partially sighted†	According to the American Foundation for the Blind, the term "legally blind" denotes a person with 20/200 visual acuity or less. Therefore, "blind" or "legally blind" is acceptable for people with almost complete vision loss. Many people with vision loss are not considered blind.	* Use only with people who are "legally blind" (a person with 20/2000 visual acuity or less) † Used most often in British publications
Blind channel estimation	Source signal equalizers		Preferred term from IEEE Thesaurus
Blind equalizers	Source signal equalizers		Preferred term from IEEE Thesaurus
Blind signal separation	Mix source separation		Preferred term from IEEE Thesaurus
Blind source separation	Mix source separation		Preferred term from IEEE Thesaurus
Caretaker	caregiver	A caregiver is an individual who assists another, including a person with a disability, with his or her daily life, according to Merriam-Webster.	Caretaker denotes taking care of property; Caregiver denotes giving care to people.

Caucasian	European American*; White	The use of the term “Caucasian” as an alternative to “White” or “European” is discouraged because it originated as a way of classifying White people as a race to be favorably compared with other races. As with all discussions of race and ethnicity, it is preferable to be more specific about regional (e.g., Southern European, Scandinavian) or national (e.g., Italian, Irish, Swedish, French, Polish) origin when possible.	* Adjust as needed for location (i.e., European, European American, European Australian, etc.)
Chairman	chairperson		
Committed suicide	died by suicide		
Crazy/loony/mad/ psycho/nuts/deranged/ insane/insanity/ mentally deranged/ psychopathology	mental illness*; mental disorder*; psychopathology(ical)	Once commonly used to describe people with mental illness; commonly used informally to denote mental instability or mental illness.	* Except in a quote or when referring to a criminal defense.
Cripple	Avoid in all instances*; use people first language and their diagnosis, i.e., “person with X”	Merriam-Webster defines the noun “cripple” as “a lame or partly disabled person or animal” and as “something flawed or imperfect.” It is also used as a verb. The word dates back to Old English, where it was related to words that meant to creep or bend over.	
Deaf	D(d)eaf*; hard of hearing	Having total or partial hearing loss.	* NCDJ Recommendation: Lowercase when referring to a hearing-loss condition or to a deaf person who prefers lowercase. Capitalize for those who identify as members of the Deaf community or when they capitalize Deaf when describing themselves. “D(d)eaf” should be used as an adjective, not as a noun; it describes a person with profound or complete hearing loss. Other acceptable phrases include “woman who is deaf” or “boy who is hard of hearing.” When quoting or paraphrasing a person who has signed their responses, it’s appropriate on first reference to indicate that the responses were signed. It’s acceptable to use the word “said” in subsequent references. Per the National Association of the Deaf, "D(d)eaf" is acceptable.

Deformed/deformity (when referencing a person)	Avoid in all instances*; refer to specifics description rather than generalized term of deformity	Merriam-Webster defines as a part of the body that does not have the typical or expected shape	
Dumb (mute)	non verbal	Once widely used to describe a person who could not speak and also implied the inability to express oneself; however, someone who does not use speech still may have the ability of expression.	
Dwarf/vertically challenged/midget	Dwarf*; short stature; little person	Dwarfism is a medical or genetic condition that results in a stature below 4’10,” according to Little People of America. The terms “little people” and “little person” refer to people of short stature and have come into common use since the founding of the Little People of America organization in 1957.	* Use only when applied to a medical diagnosis or in a quote.
Gay marriage/same-sex marriage	Marriage*		* When writing about the inability to legally marry, use “exclusion from Marriage” or “denial of marriage.”
Handicap	Use people first language; refer to the person's condition	The Oxford English dictionary defines a handicap as “a condition that restricts a person’s ability to function physically, mentally or socially.”	
Homesexual/Gay	gay*; lesbian, bi(sexual)†	Short form term to reference gay, lesbian, and bisexual orientations, though not transgender people or gender identity. Anti-gay activists use “homosexual” as a slur to stigmatize gay people by reducing their lives to purely sexual terms.	* Only when used as an adjective (ie, gay people); † Use bisexual as an adj. and as needed on first reference for clarity, otherwise default to bi.
Indian (when referencing Indigenous People)	Indigenous People; specific tribe	The Oxford English dictionary defines Indian in two ways: 1) a native or inhabitant of India;* and 2) a member of any of the indigenous peoples of North, Central, and South America, especially those of North America.	* Acceptable use for Indian in this instance
Invalid (noun: in·va·lid)	Avoid in all instances*; use people first language and their diagnosis, ie, “person with X”	The Oxford English dictionary defines an invalid as “a person made weak or disabled by illness or injury.” It is probably the oldest term for someone living with physical conditions that are considered seriously limiting.	* Except when used in a direct quote
Lame	“difficulty walking”	Commonly used to describe difficulty walking as the result of an injury to the leg.	

LGBT (when talking with those who are unfamiliar with the issues or are not supportive of the issues)	Gay and transgender; lesbian, gay, bisexual, and transgender*	Per "The Ally's Guide to Terminology": Reference sexual orientation and gender identity when talking about issues pertaining to both. (See Transgender for more information.) The abbreviation "LGBT" can be confusing and alienating for those who are unfamiliar with the issues or not yet supportive—though it is essential when talking to LGBT and strongly supportive audiences. Use the term that allows your audience to stay focused on the message without creating confusion about your intended meaning.	* If needed for clarity
Master/Slave	leader/follower; parent/child; primary/secondary; main/secondary*		* Preferred term from IEEE Thesaurus
Mentally ill/ emotionally disturbed	Person with a psychiatric disability		
Minorities	People of color*; underrepresented groups†	The use of "minority" may be viewed pejoratively because it is usually equated with being less than, oppressed, or deficient in comparison with the majority (i.e., White people).	* POC (people of color). † When possible, use the specific name of the group or groups to which you are referring.
Normal People	Person without X		
Oriental (when referencing race)	Asian*; Asian American†	"Orientals" is considered pejorative; be more specific by providing nation and region of origin (Japanese, Chinese, Vietnamese, etc.).	* For people from Asia; † People of Asian descent in North America

Retarded/Slow learner	Learning disability*	According to the University of Kansas Research & Training Center on Independent Living: "...describes a neurologically based condition that may manifest itself as difficulty learning and using skills in reading (called dyslexia), writing (dysgraphia), mathematics (dyscalculia) and other cognitive processes due to differences in how the brain processes information. Individuals with learning disabilities have average or above average intelligence, and the term does not include a learning problem that is primarily the result of another cause, such as intellectual disabilities or lack of educational opportunity."	* Only when the condition has been medically diagnosed
Schiophrenic/Schizo	Person with schizophrenia		
Sex change (operation)	Transition	Per hrc.org: The process by which some people strive to more closely align their internal knowledge of gender with its outward appearance. Some people socially transition, whereby they might begin dressing, using names and pronouns, and/or be socially recognized as another gender. Others undergo physical transitions in which they modify their bodies through medical interventions.	Transition is the accurate term that does not fixate on surgeries, which many transgender people do not or cannot undergo. Terms like "pre-op" or "postop" unnecessarily fixate on a person's anatomy and should be avoided.
Sexual identity/ transgender identity	Gender identity/gender expression	Gender identity is one's internal sense of gender. Gender expression is how a person outwardly expresses their gender. (Terms are not interchangeable.)	Many transgender people identify as male or female and not simply transgender. Pronouns express this identity: He/him; She/her; They/them.
Sexual Preference/Gay lifestyle/homosexual lifestyle/same-sex attractions/sexual identity	sexual orientation	"Sexual preference" is used by anti-gay activists to suggest that being gay is a choice; therefore, being gay can be changed. Using "lifestyle" insinuates much the same and stigmatizes gay people suggesting their lives should be viewed strictly as sexual.	
Transgendered/ a transgender (n.)/ transgenders (n.)/ transvestite/tranny	Transgender	Transgender is an adjective, not a noun. "Trans" as shorthand is often used within the LGBTQ+ community, but not generally understood by general audiences.	Always use a transgender person's chosen name. Also, a person who identifies as a certain gender should be referred to using pronouns consistent with that gender (he/him, she/her, they/them).
Unmanned aerial vehicles	Autonomous aerial vehicles		Preferred term from IEEE Thesaurus

Unmanned automobiles or cars	Autonomous automobiles		Preferred term from IEEE Thesaurus
Unmanned underwater vehicles	Autonomous underwater vehicles		Preferred term from IEEE Thesaurus
Unmanned vehicles	Autonomous vehicles		Preferred term from IEEE Thesaurus
Unsuccessful suicide	Attempted suicide		
Wheelchair-bound	Wheelchair user/Uses a wheelchair		
White box	Glass box		Preferred term from IEEE Thesaurus
Whitelist; white list	Access list	A whitelist (or white list) is a list or register of entities that, for one reason or another, are being provided a particular privilege, service, mobility, access or recognition. This can be a controversial view for some.	Preferred term from IEEE Thesaurus

Manuscript preparation

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- **Author(s) name(s):** The names should be in the order: initials of first and middle names and then surname (family name), (Examole, M. Abdel-Aty[1], H. Servistava[2] and M. Ahmed[3]), Check that all names are spelled correctly.

- **Author(s) affiliations:** Full designation, professional address with postal code, country name and mobile number of all the authors (Example, [1]*Mathematics Department, Faculty of Science, 82524 Sohag, Sohag University, Egypt*)
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- **Short running title:** only of 4 or 5 words (Example, Fixed-Time Analysis of ……)
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Introduction

Quantum entanglement is at the heart of quantum information processing and quantum computation [1–4]. In recent years, many efforts have been devoted to the study of the evolution of joint systems formed by two qubits [5–15]. In particular, Yu and Eberly [5, 6] have found out that ……

On the other hand, the long-lived entanglement in cavity QED or solid state systems was investigated by several authors [18–22]. In [18], the authors ……

In the present paper, we investigate the entanglement dynamics and coherence of a quantum system formed by two two-level atoms within two spatially separated …….

The present paper is organized as follows. In section 2, we obtain an explicit analytical solution of one atom interacting with a dissipative cavity in the dispersive limit. In section 3, we consider a quantum system consisting of two atoms within two spatially separated cavities. In section 4, the entanglement dynamics and coherence of the two two-level atoms are investigated by employing the concurrence and linear entropy, respectively. Finally, we summarize our results in section 5.

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  - ❖ 2. Materials and Methods
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Example:

Professor Mahmoud Abdel-Aty completed his doctorate in quantum optics at Max-Plank Institute of Quantum Optics, Munch, Germany in 1999. He received the D. Sc. (Doctor of Science), in 2007. His current research interests include quantum resources, optical and atomic implementations of quantum information tasks and protocols. He has published more than 240 papers in international refereed journals, 14 book chapters and 2 books. Abdel-Aty's research has been widely recognized and he has received several local and international awards. In 2014 he has been elected as a vice-president of the African Academy of Science.

Dr. Susan Jing completed her doctorate in economic at University of Reggio Calabria. She was the Founder and Director of MEDAlics, Research Canter of Mediterranean Relations and Vice Rector at University Dante Alighieri of Reggio Calabria. She is referee and Editor of several international journals in the frame of pure and applied mathematics, applied economics. Her main research interests are: dynamical systems, patterns of growth and sustainable development, economics, game theory, applied economics, differential geometry and applications, geometric dynamics and applications.

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