TECHNICAL AND ACADEMIC VOCABULARY IN ELECTRICAL ENGINEERING TEXTBOOKS

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A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in English Language Studies

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คำศัพท์เทคนิคและคำศัพท์วิชาการในตำราวิศวกรรมไฟฟ้า

นายสุขุม วสุนธราโศภิต

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาศิลปศาสตรดุษฎีบัณฑิต
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TECHNICAL AND ACADEMIC VOCABULARY IN ELECTRICAL ENGINEERING TEXTBOOKS

Suranaree University of Technology has approved this thesis submitted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy.

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สุขุม วสุนธราโศภิต : คำศัพท์เทคนิคและคำศัพท์วิชาการในตำราวิศวกรรมไฟฟ้า (TECHNICAL AND ACADEMIC VOCABULARY IN ELECTRICAL ENGINEERING TEXTBOOKS) อาจารย์ที่ปรึกษา : ASSOC. PROF. DR. JEREMY WILLIAM WARD, 229 หน้า.

การวิจัยครั้งนี้มีวัตถุประสงค์เพื่อศึกษาสัดส่วนของศัพท์เทคนิค ศัพท์วิชาการ และศัพท์ทั่วไปทั้งที่เป็นคำโดดและกลุ่มคำนามจากตำราวิศวกรรมไฟฟ้า และเพื่อทดสอบความรู้ศัพท์เทคนิคและศัพท์วิชาการของนักศึกษาวิศวกรรมไฟฟ้า สำหรับการศึกษาครั้งนี้คลังข้อมูลภาษาอังกฤษจำนวน 122,209 คำ ได้รวบรวมขึ้นโดยการสุ่มจากตำราวิศวกรรมไฟฟ้า 5 เล่ม ในการวิเคราะห์ข้อมูล กลุ่มคำนามจะถูกจำแนกออกจากคำโดดด้วยเกณฑ์ที่ตั้งไว้ และจำแนกศัพท์เทคนิคด้วย Rating Scale ของ Chung และ Nation (2003-2004) จำแนกศัพท์วิชาการด้วยกลุ่มคำศัพท์วิชาการ (The AWL) ของ Coxhead (2000) จำแนกศัพท์ทั่วไปด้วยกลุ่มคำศัพท์ทั่วไป (The GSL) ของ West (1953) สัดส่วนของศัพท์แต่ละประเภทเปรียบเทียบเป็นร้อยละ (percentage) สำหรับการทดสอบความรู้คำศัพท์ได้ใช้แบบทดสอบคำศัพท์แบบให้แปล โดยการสุ่มเลือกคำศัพท์เทคนิค 30 คำ ศัพท์วิชาการ 30 คำ และกลุ่มคำนามเชิงเทคนิค 30 คำ จากประเภทต่างๆ ของศัพท์ที่จำแนกได้จากคลังข้อมูลที่ศึกษา และได้ทดสอบกับนักศึกษาวิศวกรรมไฟฟ้าจำนวน 104 คน โดยแบ่งเป็น ชั้นปีที่ 2 จำนวน 35 คน ชั้นปีที่ 3 จำนวน 34 คน และชั้นปีที่ 4 จำนวน 35 คน การเปรียบเทียบค่าคะแนนเฉลี่ยจากการทดสอบของศัพท์โดยรวมและของแต่ละประเภท โดยแยกเป็นแต่ละชั้นปีและภายในชั้นปี ด้วยการวิเคราะห์ความแปรปรวน (ANOVA) และ Post Hoc Tests ของ Scheffé จากโปรแกรม SPSS for Windows

ผลการศึกษาพบว่า 1) กลุ่มคำนามมีสัดส่วนมากกว่า 20 % ของจำนวนคำทั้งหมดในคลังข้อมูล 2) กลุ่มคำนามส่วนใหญ่เป็นศัพท์เทคนิค และ 3) กลุ่มคำนามที่เป็นศัพท์เทคนิคบางส่วนมีศัพท์วิชาการประกอบอยู่ด้วย สัดส่วนของคำศัพท์แต่ละประเภทได้จากการรวมคำโดดและกลุ่มคำนามประเภทเดียวกัน (ศัพท์เทคนิค ศัพท์ทั่วไป และ ศัพท์วิชาการ) ปรากฏว่าศัพท์ทั่วไปมีสัดส่วนของคำ (Running words) มากที่สุด และศัพท์เทคนิคมีสัดส่วนมากกว่าศัพท์วิชาการ ศัพท์เทคนิคมีสัดส่วนของคำที่แตกต่างกัน (Types) มากที่สุด และศัพท์ทั่วไปมีสัดส่วนของคำที่แตกต่างกันมากกว่าศัพท์วิชาการ

ผลจากการทดสอบความรู้คำศัพท์พบว่า 1) นักศึกษามีความรู้ในศัพท์แต่ละประเภทต่างกัน และ 2) ระดับชั้นปีของนักศึกษามีผลต่อความรู้คำศัพท์ ในภาพโดยรวม นักศึกษาวิศวกรรมไฟฟ้ามีความรู้ในศัพท์เทคนิค สูงกว่าศัพท์วิชาการและกลุ่มคำนามเชิงเทคนิคอย่างมีนัยสำคัญที่ระดับ .01 และ .05 ตามลำดับ เมื่อเปรียบเทียบทุกชั้นปี 1) นักศึกษาชั้นปีที่ 4 มีความรู้คำศัพท์โดยรวมมากกว่า

นักศึกษาชั้นปีที่ 3 อย่างมีนัยสำคัญที่ระดับ .05 และ 2) นักศึกษาชั้นปีที่ 3 และ 4 มีความรู้คำศัพท์โดยรวมมากกว่านักศึกษาชั้นปีที่ 2 อย่างมีนัยสำคัญที่ระดับ .01 ในแต่ละระดับชั้นปี พบว่านักศึกษาชั้นปีที่ 2 มีความรู้ศัพท์เทคนิคมากกว่าศัพท์วิชาการ และมีความรู้ศัพท์วิชาการมากกว่ากลุ่มคำนามเชิงเทคนิคอย่างมีนัยสำคัญที่ระดับ .01 นักศึกษาชั้นปีที่ 3 และ 4 มีความรู้ศัพท์เทคนิคมากกว่าศัพท์วิชาการ และมีความรู้ศัพท์วิชาการมากกว่ากลุ่มคำนามเชิงเทคนิคอย่างมีนัยสำคัญที่ระดับ .05 ในกลุ่มของศัพท์แต่ละประเภท พบว่านักศึกษาชั้นปีที่ 4 มีความรู้ศัพท์เทคนิคมากกว่านักศึกษาชั้นปีที่ 3 อย่างมีนัยสำคัญที่ระดับ .05 นักศึกษาชั้นปีที่ 3 และ 4 มีความรู้ศัพท์เทคนิคมากกว่านักศึกษาชั้นปีที่ 2 อย่างมีนัยสำคัญที่ระดับ .01 นักศึกษาชั้นปีที่ 4 มีความรู้ศัพท์วิชาการมากกว่านักศึกษาชั้นปีที่ 3 อย่างมีนัยสำคัญที่ระดับ .01 นักศึกษาชั้นปีที่ 3 และ 4 มีความรู้ศัพท์วิชาการมากกว่านักศึกษาชั้นปีที่ 2 อย่างมีนัยสำคัญที่ระดับ .05 และ .01 ตามลำดับ และนักศึกษาชั้นปีที่ 3 และ 4 มีความรู้กลุ่มคำนามเชิงเทคนิคมากกว่านักศึกษาชั้นปีที่ 2 อย่างมีนัยสำคัญที่ระดับ .01

สาขาวิชาภาษาอังกฤษ ลายมือชื่อนักศึกษา____________________

ปีการศึกษา 2551 ลายมือชื่ออาจารย์ที่ปรึกษา_______________

SUKHUM WASUNTARASOPHIT : TECHNICAL AND ACADEMIC VOCABULARY IN ELECTRICAL ENGINEERING TEXTBOOKS. THESIS ADVISOR : ASSOC. PROF. JEREMY WARD, Ph.D., 229 PP.

TECHNICAL VOCABULARY/ACADEMIC VOCABULARY/COMPLEX NOUN PHRASE

This study aimed to identify proportions of technical, academic and general vocabulary in terms of single words and complex noun phrases from electrical engineering textbooks as well as to measure electrical engineering students' knowledge of technical and academic vocabulary. A corpus of 122,209 running words was compiled as a random sample from five engineering textbooks. Complex noun phrases were classified and separated from single words according to preset criteria. Technical vocabulary was classified according to Chung and Nation's rating scale (2003-2004). Academic vocabulary was classified with the academic word list (AWL) by Coxhead (2000). General vocabulary was identified with the general service list (GSL) by West (1953). Proportions of these vocabulary types are reported as a percentage. To measure the students' knowledge of vocabulary, a vocabulary test, translation format, was written up from randomly selected words and phrases—30 technical words, 30 academic words and 30 technical noun phrases—from the lists obtained from the corpus. The test was administered with 104 electrical engineering students: 35 second-year, 34 third-year, and 35 fourth-year students. The mean scores from the test were analyzed and compared as a whole group, among levels of subjects and within each level in terms of knowledge of vocabulary as a whole and knowledge

of each type of vocabulary, by the analysis of variance (ANOVA) and the Post Hoc test by Scheffé from SPSS for Windows.

It was found 1) that noun phrases cover around one fifth of running words in the corpus, 2) that most of the noun phrases are technical, and 3) that some technical noun phrases contain academic words. Single words and noun phrases of the same kind (technical, general, and academic) were combined to obtain total proportions of different types of vocabulary. In terms of running words and lexical tokens, general vocabulary has the highest proportion, and technical vocabulary has a higher proportion than academic vocabulary. The figures from lexical types show that technical vocabulary has the highest proportion, and general vocabulary has a higher proportion than academic vocabulary.

It was from the vocabulary test 1) that the students had different knowledge in different types of vocabulary and 2) that study levels affected their knowledge of vocabulary. Overall, it was found that the electrical engineering students knew more technical words than academic words and than technical noun phrases with a significant difference at the levels .01 and .05 respectively. Among students from different levels, it was found 1) that the fourth-year students knew more vocabulary than the third-year students with a significant difference at the level .05 and that the third and the fourth-year students know more vocabulary than the second-year students with a significant difference at the level .01. From each study level, it was found 1) that the second-year students knew more technical words than academic words and knew more academic words than technical noun phrases with a significant difference at the level .01 and 2) that the third and fourth year students knew more technical words than academic words and more academic words than technical noun phrases with a significant difference at the level .05. Lastly, it was found 1) that the fourth-year students knew more technical words than did the third-year students with a significant difference at the level .05, 2) that the third and fourth-year students knew more technical words than did the second-year students with a significant difference at the level .01, 3) that the fourth-year students knew more academic words than did the third-year students with a significant difference at the level .01, 4) that the third and the fourth-year students knew more academic words than did the second-year students with a significant difference at the level .05 and .01 respectively, and 5) that the third and the fourth-year students knew more technical noun phrases than did the second-year students with a significant difference at the level .01.

School of English | Student's Signature ________________

Academic Year 2008 | Advisor's Signature ________________

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I am indebted to the Thai Government who provided me a full scholarship to study in Thailand and Australia and to all the people in the Faculty of Humanities and

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CHAPTER 1

INTRODUCTION

1.1 General background of the study

The Faculty of Engineering at Khon Kaen University (KKU) has been offering degrees since the university was founded. As most scientific and technological knowledge, including the engineering field, comes from the western world, texts in this field are normally written in English. Though engineering classes and instruction are conducted in Thai, subject teachers still rely on original English textbooks and have their students study these texts. Inevitably, engineering students have to read engineering textbooks written in English. To prepare its engineering students for dealing with the language in these textbooks, the degree programs in the Faculty of Engineering offer 6 credits or 2 courses (3 credits per course) of Technical English for Engineering. These courses, which are the responsibility of the teachers of English in the Faculty of Humanities and Social Sciences, have been taught as English for academic and/or specific purposes consistent with the 1999 National Education Act (Foley 2005, p. 225). In the technical language classes, the teaching materials are compiled based on authentic engineering texts, including textbooks, articles, and texts from other sources (Robinson, 1991). The purpose of utilizing authentic texts is to expose engineering students to the language they must cope with during their studies, as authentic materials are a rich source for pedagogical activities (Hutchinson and Water, 1987; Johns, 1991; Wong et al., 1995; Dudley-Evans and John, 2002), and are more interesting, up-to-date, and related to everyday issues and activities (Lee, 1995). The main focus of the teaching of technical English is on linguistic knowledge like vocabulary and grammar as well as language skills like reading and writing.

As a language teacher who has taught and been responsible for the technical English courses for seven years, I have consistently observed that students have difficulties in understanding these technical engineering texts for two reasons. First, the students have a low level of engineering knowledge. I have noted that the students are quite new to the field of engineering since they are only second-year students when enrolling in the Technical English for Engineering courses. During the first year of study, engineering students are required to study general scientific knowledge, and they specialize in their second year. When they enter year two, they still might have little knowledge of the engineering contexts. Second, the students have problems with technical vocabulary. Nation (2001) classifies English vocabulary into four types: high-frequency words, academic words, technical words, and low-frequency words. *High-frequency word list* which Michael West (1953a), as cited by Nation (2001), calls *A General Service List of English words* contains around 2,000 word families. Normally, high-frequency words appear as 80 % of the running words in the normal text. *Academic vocabulary or sub-technical vocabulary* refers to those words used in different kinds of academic texts. Academic words are identified from a variety of academic texts and a new academic word list (AWL) of 570 word families introduced by Coxhead (2000). Words of this type normally cover 9 % of the running words in the text. *Technical words* are specialized words closely related to a specific area or field of study like engineering, medicine, linguistics, etc. They are purposefully used in specialized textbooks.

The literature in the field of English for Specific Purposes (ESP) and English for Academic Purposes (EAP) suggests that the language of scientific texts comprises general words, sub-technical or academic words, and technical words (Liu and Nesi, 1999 and Yang, 1986) and that technical words are different from general and sub-technical word in a number of ways and have an effect on learners' comprehension of technical texts. Chujo and Genung (2000) have found in EPS articles in engineering fields that the 15 highest frequency ESP words used in each ESP article covered 10.6% of the running words of each article. This means total technical words in those articles are higher than 10.6 % of running words. Similarly, Chung and Nation (2003) found that technical vocabulary covers 37.6% of total word types or 31.2% of running words in an anatomy text and 16.3% of total word types or 20.6% of running words in an applied linguistics text. Academic vocabulary covers 8.6% of total word types or 3.7 % of running words in the same anatomy text and 17.4% of total word types or 6.9% of running words in the applied linguistics text. The figures of technical vocabulary are quite high and can cause difficulties in comprehension. Laufer (1989) remarks that readers need 95% of lexical words in the text for comprehension. Likewise, Sutarsyah, Nation and Kennedy (1994) put out that a lack of familiarity with more than 5% of lexical words in a text can cause language learners problems for reading comprehension. As the proportion of technical vocabulary in technical or ESP texts is high, it can provide the students with difficulties in understanding the texts.

To understand the engineering texts, students need both knowledge of the field and knowledge of the language. Nation (2001) and Strevens (1973, p.228) suggest that students who know the scientific area may have little difficulty with technical terms. This means knowledge of the specific field is essential in learning the technical language of that field. However, the problem of limited knowledge of the field can be solved by contextualizing for the students the contents they are to deal with (Love, 1991) and using texts from the field which are not overly complicated (overly complicated texts can cause difficulties for both teachers and students). For the knowledge of the language, it is significant for EAP/ESP teachers to know what to include and introduce as part of language teaching, especially specific words or vocabulary.

In regard to language, students tend to have problems with technical terms rather than other types of words. Before enrolling in technical English courses, the students have studied general English for years, and they are required to take two general English courses during the first year of study. During their English classes, the students have opportunities to see a variety of English texts in different contexts. They therefore are familiar with common English or everyday language, so they come to ESP classes with at least some knowledge of general words. Farrell (1990: 29) divides words from his lemmatized list into three groups—general words, semi-technical words, and technical words—and gives a definition of general words that: "General words are defined as words which learners coming to an ESP course will in most cases already have met, as ESP courses are rarely, and probably should not be taught to complete beginners." In general English classes, students have a chance to read many text types and to learn different types of vocabulary. Kornwipa Poonpon (2002) analyzed an English book, *Inside Out*, published by Macmillan Heinemann English Language Teaching in 2000. This book was used in two general English courses for first-year students at Khon Kaen University. She found that this book contains academic words up to 257 word families, with 1,307 occurrences, from the

Academic Word List by Coxhead (*ibid.*). This proves that the students have already met in their general English courses both general words and academic words and might have learned some of them. However, they might not have met the technical language of the engineering texts which mostly appears in that specific domain (Nation, 2001). Scientific/technical English is possibly new to them as it contains single scientific words which can be new and unknown to the students, and it is used to compact information by the use of multi-word units which can provide more complications and complex meanings for a group of words. In this way, technical words are likely to cause more difficulties for the students than general and sub-technical or academic vocabulary.

However, in practice, language teachers and researchers have paid more attention to more academic vocabulary than technical vocabulary in ESP/EAP class. This can be explained by at least two factors. Firstly, academic vocabulary occurs in a wide range of academic texts across scientific fields (Farrell, 1990 and Coxhead, 2000) and this type of words covers around 8.5-10% of running words in academic texts (Coxhead and Nation, 2001 and Nation, 2001). This figure is higher than the coverage of technical vocabulary which is 5% of running words provided by Nation (2001). Secondly, most language teachers have a very low level of familiarity with the scientific context and thereby rendering technical vocabulary too difficult for them (Trimble, 1985 and Nation, 2001). These two reasons would be relatively sufficient for language teachers to focus on academic vocabulary. However, both figures of academic and technical words by Nation (*ibid.*) are remarkably untrue. The figures of technical vocabulary provided by Chung and Nation (2003) discussed above are relatively higher. These figures suggest language teachers and researchers rethink the focus of EAP vocabulary. Studying words used in technical texts, therefore, would probably help technical English teachers learn more about the use of technical language in scientific texts and make a decision whether technical vocabulary should be given more attention in ESP/EAP or not, since the study would reveal the proportion of the vocabulary and terms used in the texts. This proportion is expected to provide some implications for language pedagogy.

To turn these observations and experiences into a research study, it is important to identify the number and proportion of vocabulary used in the texts in terms of the words and complex noun phrases. It is also important that the students' knowledge of such identified vocabulary is measured. I made a decision to conduct this study with electrical engineering textbooks and students. The reason I chose the electrical engineering field was that I could apply my expertise in this field as I have a three-year certificate in electricity from Petchaburi Technical College in Thailand and I also have gained some experiences from teaching technical English for Engineering at Khon Kaen University for more than eight years. I chose engineering textbooks because they highlight the ways in which engineering knowledge is expressed in written form. Moreover, textbooks are the main source of knowledge the students have to deal with.

1.2 Rationale for the study

In learning a language, one cannot deny that learning vocabulary is essential. Knowing vocabulary is considered useful for language learners (Nation, 2001). Hence, language pedagogy invariably includes vocabulary teaching in language classes. One needs to know and recognize words in the text not only for reading, but also for other communication skills. The correlation between vocabulary and language proficiency has been the focus of several studies, e.g. Poe et al (2004, pp. 315-332). Clark and Ishida (2005) suggest that the highest correlation exists between vocabulary knowledge and reading comprehension as compared with the other skills. Meara (1996) states that learners who know more vocabulary are more proficient in language skills than those who know less vocabulary items. In essence, the beliefs held by teachers and learners of a foreign language are that vocabulary enrichment contributes to language proficiency (Lee, 2003: 537-561 and Barrow et al 1999: 223-247). It is widely accepted that it is necessary for language learners to learn vocabulary items.

Like other English courses, Technical English for Engineering as ESP and EAP needs to include the teaching of vocabulary including general, academic, and technical words so as to help the learners in comprehension. The teaching materials used in these classes are compiled mainly from engineering textbooks and partly from articles, information from the internet, magazines, leaflets, etc. The students are then exposed to authentic materials—the texts they are to deal with in their subject classes. Generally, most English academic texts contain general words, semi-technical words and technical words (Farrell, 1990); or general words, sub-technical words and technical words (Yang, 1986 and Liu and Nesi, 1999); or high frequency words, academic words, technical words, and low frequency words (Nation, 2001). As the contents are authentic and in a specific context, in this case electrical engineering, these texts contain a proportion of technical terms as well as other types. Technical terms, as Yang (1986) defines in his study, “should have fairly high frequencies of occurrence in texts where they occur, but vary dramatically from one subject matter area to another." Nation (2001) defines technical vocabulary as a word which is used in a specific field and provides specific meaning to that field. From these definitions, the two keywords 'high frequency of occurrence' and 'specific field' seem to imply that technical language learners could possibly have difficulties with technical terms in those cases where the students are newly introduced to the field. Engineering students at Khon Kaen University are required to study technical English when they are in their second year and are new to their subject area. Technical texts presented cause difficulties for them as a consequence of the high frequency of technical language in those texts. To help the engineering students deal with technical language, it is then necessary for teachers to study the target language to gain more insight into the features of the language before making a decision what to include and to focus on in language teaching in terms of vocabulary teaching. In the case of technical English which is taught as ESP and EAP, identification of technical vocabulary should be a focus since, as discussed above, students have met the other vocabulary types in their general English classes during their school years.

Technical vocabulary used in engineering texts appears in the form of both words and complex noun phrases. Martin (2001) postulates that nominal groups or noun phrases occur in all kinds of text, but are likely to be used more in academic texts. Scientific texts like those in the engineering field are written academically, and there is no doubt that technical noun phrases are used in the texts. The use of noun phrases to deliver the contents in scientific texts is one of the characteristics of scientific language. Compared with technical noun phrases, technical words might cause fewer difficulties than do the phrases, especially those which contain a group of words with variety, involve complex structures and comprise technical written texts.

For technical words, it could be easier to learn the meanings as most single technical words provide exact meaning fixed with the form and are strictly dependent on the field context. Some technical words can be found in technical dictionaries. On the other hand, noun phrases as technical terms can cause more difficulties since their meanings can rely on the relationships between or among the words in the group. In language class, language teachers normally teach words in isolation. They might skip the relationships of words in a group and thereby leave the complexities to their learners to discover. Frequently, phrases do not appear in the dictionaries. Therefore, technical noun phrases can provide more difficulties than technical words. Pueoy and Val (1996) remark that technical terms are used in technical discourse to compact information and to change the nature of more commonsense meanings. A technical term refers not to a single word but to a group of terms used to explain scientific processes and relations. This means that in the field of engineering, a scientific field, many technical terms are used. These terms provide some difficulties to language learners. To facilitate learning technical terms, it is therefore essential to study the proportion of technical terms in the text, both words and complex noun phrases. Nation (2001) states that in distinguishing such a group of words it is possible to see how they affect language learning goals, particularly the number of words that need to be known to be able to cope effectively with language in use. Similarly, Conrad (1999) postulates that studies that include statistical analyses or even frequency data can identify strong patterns in language use that teachers do not recognize intuitively—patterns that may be very helpful to discuss with students.

Corpus linguistics is a methodology encompassing the study of the nature of language. A corpus is a large collection of authentic language in a form of either archive or machine-readable form. Studies in language and vocabulary, including academic and technical terms in a corpus and corpora to identify and/or to analyze vocabulary and vocabulary lists, have been done to study proportions of words and/or behaviors of the language, as to focus on materials and vocabulary teaching (Yang, 1968; Tagliacozzo, 1975; Hass and He, 1993; Biber, Conrad and Reppen, 1994; Sutarsyah, Nation and Kennedy, 1994; Howarth, 1998; Coxhead, 2000; Chujo and Genung, 2003; Chung and Nation, 2003 and 2004; Wang, 2005; and Mudraya, 2006). Though these works have a variety of purposes, the core of these studies is to gain more insight into the features and use of the language, thereby offering implications for language pedagogy. For example, Yang (1986) used a new technique to identify technical vocabulary in scientific texts and compare the distributions of the vocabulary from different scientific texts. He identified words by their frequency of occurrence and distribution and multi-word terms by their collocational behaviors—when a word frequently co-occurs with other words. The frequency of occurrence of technical words identified using statistics can be used to describe scientific texts. Chung and Nation (2003) conducted a study entitled "Technical vocabulary in specialized texts", using anatomy and applied linguistics texts. They identified technical words in those texts by utilizing a rating scale which they had developed. The rating scale contains four steps or categories of words according to their degree of technicalness, in which Steps 1 and 2 respectively refer to function words and general words with very little or no relationship to the field of the study while Steps 3 and 4 are general words and specialized words providing technical meaning to that field. Chung and Nation (2004) compared different methods for identifying technical vocabulary from the same textbooks in order to develop a very reliable method. They concluded that the use of a rating scale is more reliable than are other methods. Chujo and Genung (2003) identified ESP vocabulary in different ESP articles and other English language materials. They found a big gap of vocabulary level between the EGP teaching materials and the general-use English language materials and ESP articles. These four studies exemplify ways to identify technical vocabulary. Yang (*ibid.*) and Chujo and Genung (*ibid.*) applied a statistical method while Chung and Nation (*ibid.*) introduced the use of a rating scale, the use of technical dictionaries, the use of clues provided in the text, and the use of a computer-based approach. The rating scale was recommended as more reliable for identifying technical vocabulary. Whatever the method, I believe that these studies relate to language pedagogy.

In terms of vocabulary teaching in ESP/EAP, there is a contrast among experts' perspectives on this discipline—to focus on teaching technical vocabulary and/or to focus on academic vocabulary. Some EFL teachers might believe that it is not necessary to teach technical words because the learners of the specific field know the words more than the teachers do, and teaching technical words is the responsibility of the subject teachers. Mudraya (2006) recommends that ESP/EAP teachers pay more attention to teaching academic vocabulary than other types of vocabulary because academic words are more frequent than technical words. However, since technical words are a part of the text, they can cause difficulties for learners in learning as well as in comprehension. Some believe that teachers should teach technical words. Yang (1986) postulates that learners need to acquire a certain number of scientific or technical terms. Therefore, this type of word should be taught in class. Liu and Nesi (1999), in a study of their master degree students' receptive knowledge of two types of vocabulary: "sub-technical" and "technical", concluded that they were having difficulties with technical words rather than other kinds of words. They then suggest that teachers pay more attention to technical words in ESP/EAP classes. Similarly, Hyland (2002) argued that ESP has become central to the teaching of English in university contexts, and effective language teaching in the universities should involve taking specificity of the language seriously and added further that teachers must go as far with technicality as they can.

It is interesting that researchers recommend teaching academic vocabulary according to the amount of coverage in the text, but not other types of proof. In fact, a higher amount of coverage does not refer to the degree to which a learner can understand a technical text, but it could be that the technical terms of the field carry most of the content information (Yang, 1986). The only study in the students' knowledge of academic and technical vocabulary was that of Liu and Nasi (1999). However, this research still has some flaws as the researchers agreed that they tested only the students' receptive knowledge—the recognition of form—by the use of yes/no test format, but not meaning and use, and that the findings reflect students' knowledge only of the group they studied but are not generalized to an entire overseas student population or all undergraduates. Further study should pay more attention to investigate the greater depth of students' knowledge as well as students' ability to produce or interpret the two types of vocabulary: academic and technical (Liu and Nesi, 1999).

From the discussion above, I believe that technical texts contain a considerable proportion of technical terms, and these technical terms provide more difficulties than academic words do. Also, technical vocabulary must be focused and taught in a technical English class for engineering. Therefore I developed this study, which is shaped from two perspectives. Firstly, the conflict of language teachers on technical vocabulary teaching—to teach or not to teach—compared with academic vocabulary. Secondly, from the review of literature, it has been found that there are studies focusing on technical vocabulary and multi-word units; however, very few studies focus on a specific field like electrical engineering. Additionally, only one study focused on the measurement of learners' knowledge of technical and academic vocabulary knowledge in order to obtain a significant indication for vocabulary teaching in terms of technical and academic vocabulary. I developed my study following Liu and Nesi's (1999) framework. To implement the study, first I created an electrical engineering corpus from electrical engineering textbooks recommended by electrical engineering teachers at Khon Kaen University. To investigate the proportion of technical vocabulary from this corpus, technical vocabulary, academic vocabulary and complex noun phrases were identified and divided into groups according to frequency of occurrence. Second, to investigate whether technical vocabulary is more difficult than academic vocabulary and if complex noun phrases are more difficult than words, I then selected a number of the identified words and complex noun phrases from the corpus on the basis of frequency of occurrence and I developed a vocabulary test from those selected words and phrases. The test aims to measure and to compare electrical engineering students' knowledge (1) between technical and academic words, (2) between technical words and technical noun phrases, and (3) among all categories of vocabulary, and to investigate the difficulties with vocabulary the students are facing.

1.3 Significance of the study

This study is based on two assumptions. Firstly, engineering texts contain technical terms with a high frequency of text coverage and this group of vocabulary is likely to cause more difficulties for students than other groups. Secondly, engineering students have learned and acquired general words and some academic terms during their years in school and in first year at university, so they tend to have more problems with technical vocabulary rather than academic vocabulary. My hypothesis is that the students know more academic vocabulary than technical vocabulary, and they know more technical words than technical noun phrases. In other words, the students get higher scores from academic vocabulary tests than from technical vocabulary tests, and they get higher scores from technical words than from technical noun phrases. The study then focuses on an identification of vocabulary in the form of both words (technical and academic) and complex noun phrases (general, technical and academic) in a corpus combined from electrical engineering textbooks as well as a test of engineering students' knowledge of the vocabulary. One objective is to reveal the proportion of technical and academic vocabulary as well as other vocabulary types in the text. A second objective is to investigate whether the engineering students know more technical than academic vocabulary and what type they have difficulties with. As a result, the findings can be used as guide to designing teaching materials focusing on the appropriate type of vocabulary to suit engineering students' language needs. Conrad (1999) suggests that the growth of corpus linguistics is helpful for language teachers to understand language use and design effective materials for their students. Moreover, Nation and Waring (1997: p. 17) assert:

> "Frequency information provides a rational basis for making sure that learners get the return for their vocabulary learning effort by ensuring that words studied will be met often. Vocabulary frequency lists which take account of range have an important role to play in curriculum design and in setting learning goals."

It is therefore expected that the findings from this study would be useful for technical language teachers as they can improve decision-making about effective teaching material design to help their students learn specialized vocabulary in technical texts effectively.

1.4 Scope and limitations of the study

Engineering is divided into many specific fields such as chemical, civil, environmental, mechanical and electrical. Each discipline has its own specificity of the language use, depending on the nature of the field. Study in several fields at the same time would be too broad and time-consuming and lead to confusion. For this reason, this study will focus only on one discipline—electrical engineering. This field is selected for the study for two reasons: firstly, because it is one of the most popular engineering fields and widely-opened in universities in Thailand as well as globally and because the researcher has expertise and experience in the field.

As the aim of the study is to serve the Technical English Courses for engineering at Khon Kaen University, a corpus for the study is created only from electrical engineering textbooks recommended by subject specialists from the university. Only textbooks are used in this study since they are main sources of the field the engineering students have to read in English. Also subject teachers mainly use textbooks or recommend them for their students to study. Other sources are also important for engineering students, but each source may have a different language use. The mix of different sources would have an effect on the study in terms of samples and the findings. It is better, therefore, to study only one source at a time to avoid distorted results. This study does not aim to compare technical language in different sources in the electrical engineering field, but to investigate and reveal the proportion of technical and academic language in the textbooks. Both the field of electrical engineering and the textbooks in this field are used in this study as a sampled research study which can be guidance for further study in other fields and sources.

Technical English for Engineering at KKU is taught as both EAP and ESP. The purpose is to reinforce the students' language ability and skills so that they can apply knowledge of the language and technical skills in their field of study. Therefore, two types of vocabulary—technical and academic—are mainly discussed and taught in ESP class. This study puts more focus on technical vocabulary as I have discussed and hypothesized that technical vocabulary causes more difficulties than does academic vocabulary. However, research on academic words needs to be conducted since a comparison between the two types is required. Therefore, more discussion on literature in this study is focused on technical vocabulary.

1.5 Purpose of the study

This research study aims:

(1) To identify the proportion of words and complex noun phrases in the corpus created from the selected electrical engineering textbooks.

(2) To identify the proportion of words (technical, academic and general vocabulary) in the electrical engineering textbooks.

(3) To identify the proportion of technical, academic and general noun phrases in the electrical engineering textbooks.

(4) To measure and compare the students' knowledge of vocabulary between technical words and academic words.

(5) To measure and compare the students' knowledge of vocabulary between technical words and technical noun phrases.

(6) To identify the type of vocabulary the students have difficulties with.

1.6 Research questions

As it is doubtful whether language teachers have focused on teaching the right words, and which group of words between technical and academic are more difficult and problematic for electrical engineering students and should be given more focus in technical English classes, three research questions with eight sub-questions are formed as follows.

(1) What proportion of the different types of vocabulary occurs in the electrical engineering corpus?

(1.1) What is the proportion of words and complex noun phrases in the electrical engineering corpus?

(1.2) What is the proportion of technical words, academic words, and general words in the electrical engineering corpus?

(1.3) What is the proportion of technical noun phrases, academic noun phrases and general noun phrases in the electrical engineering corpus?

(2) How well do the students know each type of lexical units from the electrical engineering corpus?

(2.1) Which type of lexical items between technical and academic words do the students know more?

(2.2) Which type of lexical items between technical words and technical noun phrases do the electrical engineering students know more?

(3) How do the students' study levels affect their knowledge of vocabulary?

1.7 Definitions of operational terms

There are some terms frequently used as keywords and operational terms in this study. These terms are briefly defined for consistency of use through the whole study and its report.

Electrical engineering corpus

A '**corpus**' is a large collection of authentic texts either in archive or in electronic form. The corpus used in this study is created from five electrical engineering textbooks randomly selected from five different areas/subjects in this field, contains approximately 120,000 words, and is stored as plain text (*.text). It is used for a study focused on technical vocabulary, both single-word vocabulary and multi-word units which focus only on noun phrases.

Words

The term **'word'** in this study refers to an isolated lexical unit with its own meaning and without any modifiers. A word can be a noun, a verb, an adjective, a pronoun, an article, etc., for example, current, proceed, the, with, active, it, etc. In this study, the term is normally used in the plural form as 'words' which includes **function words, general words**, **technical words**, **academic words and low frequency words**.

Phrases

The term **'phrase'** in this study refers to a **complex noun phrase** which is a group of words used as a noun to express one meaning. It contains a head word which is pre-modified by the other word(s), for example, electric plate, primary coil, synchronous motor, etc. It is counted as a lexical unit with its entire meaning relying on all the words in the group. Similar to the term 'word', the term 'phrase' is generally used in the plural form. There are three types of noun phrases**: technical noun phrases**, **academic noun phrases** and **general noun phrases**.

Technical vocabulary

Technical vocabulary refers to a word or a group of words in the form of a noun phrase used as a technical lexical unit in a specific field with specific meaning to the field (Nation, 2001). It varies according to different fields of study such as engineering, medical sciences, and applied linguistics. In this study, technical vocabulary includes both technical words and technical noun phrases used with specialized meanings in the field of electrical engineering.

Academic vocabulary

Academic word refers to a word which occurs in a wide range of academic texts from different fields of study. It is identified with frequency and range (Coxhead, 2000). In this study, academic vocabulary or academic lexical unit includes both academic words and academic noun phrases. Both are identified by the use of the Academic Word List (AWL) by Coxhead (*ibid*.)

1.8 Summary of introduction

Engineering students at Khon Kaen University are assigned to study English engineering textbooks as the original source. To meet the need to study English textbooks, the students are required to enroll in two courses of Technical English to enhance their language knowledge and skills Technical English courses have been taught as EAP/ESP and emphasize reading and writing as well as grammar and vocabulary. With the figures of academic and technical vocabulary covered in academic texts and the ignorance of the scientific context, language teachers and researchers place their focus on academic vocabulary. In fact, the coverage of technical vocabulary in some academic texts is considerably higher. Anyhow, there is a dispute among language teachers over whether technical vocabulary should be taught in language class or not, compared with academic vocabulary. From the researcher's experience, though the students complete two courses of Technical English for Engineering, they still have problems with technical language in English engineering texts, especially technical vocabulary. With regard to the contrast of the language teachers' opinions on technical vocabulary teaching and the difficulties the students are facing, this study was formed. The study focused on an identification of technical vocabulary and a measurement of learners' vocabulary knowledge (a comparison between technical and academic vocabulary). For the study, an electrical engineering corpus was created and words (technical and academic) and complex noun phrases (general, technical and academic) were identified. Some identified words from each type were randomly selected, based on their high frequency of occurrence, and these words were used as tested items to measure electrical engineering students' knowledge of technical and academic vocabulary to prove the hypothesis—the students get higher scores from academic vocabulary than from technical vocabulary tested and higher scores from technical words than from technical noun phrases.

CHAPTER 2

REVIEW OF RELATED LITERATURE

2.1 The importance of vocabulary for reading

Reading is an important language skill since a reading knowledge of a foreign language is important to academic studies, professional success, and personal development. “This is particularly true of English as so much professional, technical and scientific literature is published in English today” Alderson (1994: p. 1). There are many studies which have focused on reading and its difficulties (e.g. Brown, 1988; Cohen, Glasman, Rosenbaum-Cohen, Ferra and Fine, 1988; Ward, 2001; Williams, 1985 and Uso-Juan, 2006) as well as reading and vocabulary (Alderson, 1984; Cobb and Horst, 2001 and Marshall and Gillmour, 1993). Alderson (*ibid.*) remarks that second language readers have more problems with grammar and vocabulary. Limited by lexical knowledge, readers have difficulties with reading comprehension (Marshall and Gillmour, 1993). Cobb and Horst (*ibid.*) tried to help their learners learn more vocabulary since they were facing with lexical limitations in reading academic English.

Language learners need to learn the vocabulary of the language (Harmer, 1997) since learning vocabulary is essential, the units of vocabulary are the basic building blocks of language (Read, 2000 and Schmitt, Schmitt and Clapham, 2001) which language learners need for communication (Laufer and Nation, 1995). Similarly, Sutarsyah, Nation and Kennedy (1994: p. 49) point out that though vocabulary is only one part of language learning, it is a component that learners pay more attention to and spend more time on it. With an awareness of the importance of vocabulary, many language teachers and researchers put the focus on vocabulary studies (e.g. Chung and Nation 2003-2004; Clark and Ishida, 2005; Laufer and Nation. 1955; Laufer, 1998; Mudraya, 2006; and Nation and Hwang, 1995).

2.1.1 Receptive vocabulary knowledge

Vocabulary is learned and known to various degrees, but the well-known question "what it means to know a word" can be best described by looking at the process when receptive or passive vocabulary is applied and a text decoded and comprehended (Arnuad and Savignon, 1997). Receptive vocabulary (Nation, 2001) or passive vocabulary (Arnaud and Savignon, 1997 and Laufer, Elder, Hill, and Congdon, 2004) refers to the ability of recognition in forms and meanings including the behaviors of words and their meanings used in different contexts. As its name implies, this knowledge is then applied with receptive skills like reading and listening. Arnuad and Savignon (1997: p. 157) discuss the application of passive vocabulary in the comprehension process "Using phonetic clues present in the speech continuum, the phonological representation (*significant*) of a lexeme is accessed, which in turn permits access to the representation of its meaning (*signifie*). In other words, comprehension takes place when words in the text are recognized and their meanings are known. Based on the idea of use, Corson's (1995) passive vocabulary refers to the active vocabulary plus three other kinds of vocabulary which include words partly known, low frequency words not readily retrieved for use, and words avoided in active use (Nation, 2001).

Receptive knowledge of vocabulary has a close relationship with breadth of knowledge of vocabulary. While the receptive talks about the degree of vocabulary knowledge, the breadth of vocabulary knowledge talks about how many words are known (Nation, 2001: p. 354). According to Read (2000: p. 81) the term ‘breadth’ is used by Anderson and Freebody (1981). In essence, vocabulary knowledge, when being measured, the receptive or passive knowledge is measured as breadth. There have been studies focusing on learners’ passive knowledge of vocabulary. To measure vocabulary knowledge, researchers have designed, developed, and validated receptive vocabulary tests, for example, the Yes/No test or Checklist (Meara and Buxton, 1987; Beekmans, Eyckmans, Janssens, Dufranne and Van de Velde, 2001; Huibregtse, Admiraal and Meara, 2002 and Mochida and Harrington 2006), the Vocabulary Levels Test (Nation, 1983; Beglar and Hunt, 1999 and Schmitt, Schmitt and Clapham, 2001), and the Translation Test (Nurweni and Read,1999). With these tests, the students are to tell either they recognize word forms of the tested items or they know their meanings. The scores resulting from these test types can tell only passive vocabulary knowledge in terms of breadth—how much the students know the vocabulary being tested, but not how well they know those words. Also, the scores can yield some implications whether the learners may have problems with reading comprehension or not.

2.1.2 Vocabulary knowledge and reading

In the field of foreign-language reading where learners apply most receptive knowledge of vocabulary, vocabulary is considered essential and cannot be neglected. In fact, it is one of the focuses of language teaching. Laufer (1997: p. 20) mentions

“No text comprehension is possible, either in one’s native language or in a foreign language, without understanding the text’s vocabulary.” Furthermre, Cooper (1984) remarks that readers with inadequate vocabulary will become handicapped in their reading. Laufer (1997) asserts that the threshold for comprehension is lexical, and lexical problems, the major obstacle, can hinder comprehension. Hence, reading comprehension is strongly related to vocabulary knowledge (Marshall and Gilmour, 1993), more strongly than to the other components of reading (Laufer, 1997). Increased proficiency in high-frequency vocabulary leads to an increase in reading proficiency. Therefore, “The relationship between vocabulary knowledge and reading comprehension has been an extensive focus of investigation among reading researchers and the amount of attention paid to this area of research has clearly indicated that it is a crucial issue for learners” (Clark and Ishida, 2005: p. 226). There are research studies (e. g. Carrell, 1988; Koda, 1989 and Laufer,1992; quoted by Clark and Ishida, 2005) showing that vocabulary knowledge has a positive effect on reading comprehension.

Moreover, several research studies show the correlation of vocabulary knowledge and language proficiency (e.g., Lee, 2003 and Barrow, Nakanishi, and Ishino, 1999). This is consistent with Meara’s study (1996) that learners who know more vocabulary are more proficient in language skills than learners who know fewer vocabulary items. Not only in reading does one need to know and recognize words in the text, but also for other communication skills. How can one understand texts or produce a composition if they do not know words? This provides implications that language learners need to learn vocabulary items or, in other words, vocabulary is relatively important to reading.

2.2 Ways of classifying vocabulary

Words are classified into categories with two major criteria: (1) frequency of occurrence (West, 1953; Xue and Nation, 1984; Farrell, 1990 and Coxhead, 2000) and (2) range or meaning strict to the discipline (Nation, 2001). According to the nature of their occurrence in texts, words as so called vocabulary are classified into categories such as common and technical/scientific vocabulary (Tagliacozzo, 1975); well distributed words, subtechnical words, and scientific/technical words (Yang, 1986); general and technical vocabulary (Haas and He, 1993); general, semi-technical and technical vocabulary (Farrell, 1990); and high-frequency words, academic words, technical words, and low-frequency words (Coxhead and Nation, 2001 and Nation, 2001). In fact, from Nation's categories, high-frequency words are general/common vocabulary, and some low-frequency words can be technical words with low frequency of occurrence (Yang, 1986) or specialized words from other disciplines. With all categorizations discussed, it is preferable that vocabulary in academic/scientific texts be classified, based on need of vocabulary for comprehension, into three main categories which are general/common words, sub-technical/academic words, and technical/scientific words since in comprehension language learners need at least 95% of words in the text (Laufer, 1998) and this 95% is comprised of 80% general words, 10% academic words, and 5% technical words (Nation, 2001).

2.2.1 General vocabulary

General vocabulary or general service vocabulary consists of high-frequency words in most uses of the language and covers 80% as running words in a wide range of general texts (Nation, 2001). This group of words includes words from the *High-frequency word list* which Michael West (1953a), as cited by Nation (2001), calls *A General Service List of English Words (GSL).* This list, identified by West (1953), contains around 2,000 word families providing both semantic and frequency information drawn from a corpus of five million words created from general written texts (Carter and McCarthy, 1991). Words from this list include both function words: the, with, of, a, etc.; and content words: competition, state, present, write, etc. Buaman (2007) remarks that the actual list contains 2284 headwords (with the number of occurrence per 5 million words). Each headword represents a word family, so it does not represent a single learning unit for a learner of English. Learners who know a headword are expected to know its inflected forms. Therefore, a critical question emerges—"How many words does the GSL contain?" The GSL can be downloaded free at http://jbauman.com/gsl.html (Bauman, 2007).

There are two criticisms of the GSL widely discussed among researchers: its size and its age (Hwang and Nation, 1995). The GSL is divided into two levels: the first 1000 and the second 1000 words. The 1st 1000 words cover around 70% plus in non-fiction texts while the 2nd 1000 words covers only 4-5% in the same texts (Hwang and Nation, 1995). The figure of coverage leads to a size criticism if the 2nd 1000 is essential for language learners (Engels, 1968 quoted by Hwang and Nation, 1995). Also, as the list is old and there are constant changes in language, it does not contain some new high frequency words (Richards, 1974 quoted by Hwang and Nation, 1995). It does not matter whatever the criticisms are. The GSL is always considered essential as a basis of vocabulary knowledge to all language learners. Though the GSL is quite outdated as the corpus, collected from only written text, was created and the words were counted in the 1930s, and some new modern words are missing (Carter and McCarthy, *ibid.*). Notwithstanding, it "has had a wide influence for many years, serving as the basis for graded readers as well as other material" (Bauman, 2007: p. 1) and it is essential and appropriate for learners who are moving on to special purpose study (Hwang and Nation, 1995). Moreover, the GSL is still applicable and utilized by researchers who work on corpus analysis (Sutarsyah, Nation and Kennedy, 1994; Nation and Hwang, 1995; Ward, 1999; Coxhead, 2000 and Chung and Nation, 2003 &2004).

2.2.2 Academic vocabulary

Academic vocabulary is variously known as sub-technical vocabulary (Cooper, 1984 and Yang, 1986), semi-technical vocabulary (Farrell, 1990), and academic vocabulary (Coxhead, 2000) and is common in academic texts (Coxhead and Nation, 2001). It refers to those words that occur outside the General Service List by West (1953) and apparently used in different kinds of academic texts. This group of words is called the Academic Word List (AWL) and contains 570 word families created by Coxhead (2000). Words of this type normally cover 9 % of the running words in the text (Nation, 2001). This list can be downloaded free at http://www.vuw.ac.nz/lals/research/awl/sublists.html. In fact, before this list was generated, several studies in vocabulary needed for academic study had been conducted. Xue and Nation (1984) created the University Word List (UWL). This list was combined from the words which do not appear in the General Service List (GSL), but occur frequently in a wide range of academic texts. The UWL contains over 800 word families which cover 8.5 % of running words in academic texts. It was later replaced by the AWL (Coxhead and Nation, 2001). Coxhead (2000) remarks that the weakness of the UWL is attributed to a lack of consistent selection principles and thereby resulted in a small corpus with no wide and balanced range of topics.

Academic words in the AWL are commonly identified by their frequency and range of their occurrence across academic fields. The Academic Corpus is combined from 414 academic texts by more than 400 authors of 3,513,330 tokens or running words and 70,377 types (or different individual words) (Coxhead, 2002). The corpus is generated from 28 subject areas distributed over the four divisions, e.g. arts, commerce, law, and science (Coxhead, 2000 and Wang and Nation, 2004). Words included in the AWL are selected based on three criteria including specialized occurrence, range, and frequency (Coxhead, 2000). Specialized occurrence refers to the occurrence of words outside the first 2,000 high frequency words from the GSL by West (1953). Range is the occurrence of a word across different fields—a member of a word family must occur at least 10 times in each of the four main divisions and in 15 or more of the 28 subject areas. Frequency means that members of the word families must occur at least 100 times in the corpus. With these criteria, an academic vocabulary is identified and defined as a word which occurs generally in academic texts, outside the GSL, across a wide range of texts from different fields, and with high frequency. Since the AWL is created from a well-designed corpus, it is well-known among corpus linguists and English language teachers worldwide and used in research studies and references (see Kornwipa Poonpon, 2002; Chung and Nation, 2003; Murphy and Kandil, 2004; Morris and Cobb, 2004; Clark and Ishida, 2005; and Mudraya, 2006).

2.2.3 Technical vocabulary

Technical words are specialized words closely related to a specific area or field of study like engineering, medicine, linguistics, etc. They are commonly used in specialized textbooks. This group of words is identified by the meaning of a word strict to the field in which it occurs and its high frequency of occurrence or use in that field (Tagliacozzo, 1975; Yang, 1986; Nation, 2001) and covers about 5 % of running words in the text (Nation, 2001). Some technical words have low frequency of occurrence (Liu and Nesi, 1999). Technical vocabulary can be a common word which provides a specialized meaning different from its vernacular meaning when used in specific field. Wignell, Martin and Eggins (1993) state that the use of technical terms can be overlapped with words from other fields. Similarly, Bowker and Pearson (2002) mention that technical words and general words can have some degree of overlap.

Researchers in the technical field have provided similar definitions for technical vocabulary regarding (1) groups of specialists, (2) fields of use, (3) special meanings, (4) distinct forms or morphology, and (4) high frequency of occurrence in the specific field. For example, relying on groups of specialists, fields of use and morphology, Tagliacozzo (1975) explains that technical languages are specifically used by particular groups of people who have common specific knowledge on particular domains, and they provide forms different to common language. She compared 'technical language' to a *dialect*, giving the reason that it is the language spoken by a subgroup of people who use the 'common language.' Focusing on fields of use and the unique nature of technical vocabulary, Nation and Newton (1997) explained that technical vocabulary is used within specialized field, and it may be sensibly common in that field. That includes every field such as engineering, law, chemistry and so on and has its technical vocabulary unique to its area. Regarding fields of use and special meanings, Nation (2001) and Chung and Nation (2004) remark that technical vocabulary is a word which is common in specific area but not so common elsewhere and which is one that is specific to particular topic, field or discipline. Technical words differ from subject area to subject area and provide specialized meanings to the field they are in. Therefore, the restriction of a word and its meaning to the field determines the degree of technicalness of a word. Regarding high frequency of occurrence, Yang (1986) postulates that technical terms are words that occur in high concentration and play an important role in scientific texts. In essence, technical terms have considerably high frequencies of occurrence in texts where they are used.

With his criteria on the restriction of words to a particular subject area, Nation (2001) defines degrees of technicalness in four categories. The first two categories are included as technical vocabulary. Category 1 refers to words mostly used in the field and appearing rarely outside the field, and Category 2 is vocabulary items used both inside and outside the particular field with different meanings. The last two categories are not counted as technical vocabulary. Category 3 includes words used both inside and outside the particular field with particular meaning. The meaning of the words used inside the field is accessible through their meaning outside the field. Category 4 means the words more commonly used in a specific field than elsewhere where they may be little or no specialization of meaning, though specialists of that field know its exact meaning. Using the Rating Scale adapted from the degrees of technicalness, Chung and Nation (2003-2004) identified technical vocabulary in an anatomy textbook and an applied linguistic textbook. In their Rating Scale, Step 1 refers to "words such as function words that have a meaning that has no particular relationship with the field of anatomy, that is, words independent of the subject matter." Step 2 includes "words that have a meaning that is minimally related to the field of anatomy in that they describe the positions, movement, or features of the body." Step 3 contains "words that have a meaning that is closely related to the field of anatomy. They refer to parts, structures or functions of the body, such as the regions of the body and systems of the body. Such words are also used in general language. The words may have some restrictions of usage depending on the subject field." Step 4 combines "words that have a meaning specific to the field of anatomy and are not likely to be known in general language. They refer to structures and functions of the body. These words have clear restrictions of usage depending on the subject field."

Studies on technical vocabulary have been undertaken for years, either to find out practical methods for identification of technical vocabulary or to investigate numbers of technical words in specific domains (Yang, 1986; Hass and He, 1993; Pueyo and Val, 1996 and Chung and Nation, 2003). In his book, Nation (2001) discusses two systematic methods to identify lists of technical vocabulary: using technical dictionaries and using corpus-based frequency count. In their latest study, Chung and Nation (2004) conducted a study comparing four methods in identifying technical vocabulary in an anatomy text: the use of a rating scale, the use of technical dictionary, the use of clues provided in the text, and the use of a computer-based approach.

1. *The use of a rating scale*: In this method the researchers and the raters make a decision whether a word is technical vocabulary or not, relying on their

intuition and knowledge of the area. The scale contains 4 steps. The words that fall at steps 3 and 4 are classified as technical words, but at steps 1 and 2 are not. To test the reliability of the scale, the interrater reliability is applied. The raters should be trained using the same text used for the study.

2. *The use of a technical dictionary*: This approach relies on a specialist who compiles a technical dictionary. Unknown words from the text will be checked with the dictionary. If the words appear in the technical dictionary, they are technical words. An advantage of this method is that the word is judged by the specialist, but a weak point is that it is based on one person's intuition.

3. *The use of clues provided in the text*: In some texts, the authors provide some signals to learn and to guess the meaning of technical vocabulary. Some writers give definition to the word. Some may use typographical clues: they make the word **bold** or *italic* to state that the word is specialized. Some may put the words as labels in diagrams or illustrations. The flaws of this process are that sometimes it is difficult to find clues, and some typographical signals can refer to something else, not merely technical terms.

4. *The use of a computer-based approach*: The process in identifying terms is called automatic term extraction (Heid, 1998/1999 and Pazienza, 1998/1999), automatic term recognition (Kageura and Umino, 1996), or computer-assisted term acquisition (Gamer and Stock, 1998/1999). (Chung and Nation, 2004) This approach involves with using a software program with a corpus to identify technical vocabulary. The comparison corpus is normally bigger than the technical corpus. Sometimes, the users need to adapt the software before the real use. The extraction software comprises two different approaches: statistical and linguistic. The linguistic

approach is used to identify possible words before the statistical method is utilized to identify real technical vocabulary.

The first three methods above classify technical vocabulary with meaning strict to the field relying on intuition to judge if a word is technical while the last technique uses high frequency of occurrence in the specific field—a figure from statistics. These methods have some weak points. The use of rating scale and technical vocabulary depends much on the intuition of the researcher and the dictionary editor. The disadvantage of the use of clues is that some technical terms have no clues provided in the text, so many terms will be missing from the list. According to their study comparing the four approaches in identifying technical vocabulary, the findings turn out to be different. Out of the four methods, the rating scale is preferable since the criteria are quite well-established (see also Nation, 2003 and2004). The four scales are set up using meaning criteria with the degree of technicalness employed by Nation (2001). Chung and Nation (2004) concluded that the rating scale approach, compared with other approaches, was more reliable, valid and practical than the others, though it is time-consuming to check every word, and a well-trained inter-rater is needed to ensure for its reliability.

In conclusion, the criteria used to classify vocabulary into groups are quite practical and applicable as they are set up based on the level of difficulty for language learners, steps of language learning and need for comprehension. General words and academic words are clear-cut identified and separated from each other with the same criteria—words occur with high frequency in a wide range of general and academic texts—and they do not overlap. Therefore, the General Service List (GSL) by West (1953) and the Academic Word List (AWL) by Coxhead (2000) have been accepted and used by language teachers and researchers, though the GSL is outdated (Carter and McCarthy, 1991). However, classifying technical vocabulary is still problematic since the criteria to identify technical words are still unclear and unreliable, so identified technical words overlap with some general and perhaps academic words. If high frequency of occurrence is used, there will be some arguments since general words also occur with high frequency, and some technical words occur with low frequency. Also some general words are frequently used as technical words. In these cases, this criterion may not be reliable. The use of meaning strict to the field is possibly preferable and has been proved more reliable by Chung and Nation (2004) though some criticism has emerge stating that it relies on the intuition of the person who identifies the words. A solution to this criterion is the use of an inter-rater in the identification of the words (Chung and Nation 2003).

2.3 Complex noun phrases

In scientific language or technical discourse, it seems that multi-word vocabulary, in this case a complex noun phrase, plays an important role in carrying most contents (Martin, 2001). It is noun phrases, therefore, that characterize written English, especially those used in physical science since they are used to compact information in each clause, and the text becomes lexically dense (Halliday, 1994 and 2004). A multi-word vocabulary or multi-word term (Yang, 1986) refers to a group of two or more words which occur together and are used as a single unit or word with one meaning in the context of a discourse. A noun phrase is a type of multi-word vocabulary which, as its name implies, functions as a noun in a clause. Quirk, Greenbaum and Svartvik (1985: p. 1350) classify noun phrases into two types: simple noun phrases and complex noun phrases. Therefore, the noun phrase can be used as subject or complement (Halliday, 2004). In fact, the noun phrase is a bit different from the multi-word term in the way that while the multi-word vocabulary consists of at least two words, the noun phrase can stand alone and consist of only a head noun (Bloor and Bloor, 1995: p. 135). As the focus of this part is put on multi-word vocabulary, the nominal group which contains only one Head noun is excluded since it is not complex or not of interest in this study. Therefore, the nominal groups ranging from two words or noun phrases are the focus.

2.3.1 Word formation and structure of complex noun phrases

Nouns can be extensive; for example, two nominal groups—*a sophisticated computer* and *a computer with an external drive*—can become more expansive like *a sophisticated computer with an external drive that meets all the requirements* (Bloor and Bloor, 1995: pp. 26-27). Bauer (1983) and McCarthy (1990) discuss two ways a noun can be formed: derivation and compounding. Derivation refers to new lexical items to be created using pre-existing words but does not necessarily involve a change in their form. For example, with derivation, derivatives of *electric* can be obtained such as electricity, electric light, electrical battery, etc. (Halliday, 2004: p. 150). Compounding is a creative word-formation considered as a communicative strategy and applied when the right word cannot be found (McCarthy, ibid.). Trimble (1985) postulates that noun compounds or noun strings contain two or more nouns plus necessary adjectives that express a single concept or a single-noun idea. For example, the phrase *an advertisement in a magazine* can be formed as *a magazine advertisement* and the clause *a person (or machine) that binds books* can be formed as *a bookbinder* (see more details in Trimble, 1985: pp. 131-132). Noun compounds looks similar to noun derivatives, but the interpretation of their meaning is problematic since many noun compounds are formed and used as technical terms and cannot be directly translated word by word or logically back-formed. A compound word is a new unit and which becomes lexicalized and fixed, and its form may change. Words comprising a compound may be hyphenated to be clearly treated as a word for communicative purposes (Bauer, 1983 and Moon, 1997).

According to Thomson (1996), the functional structure of complex noun phrases can be divided into three main parts i.e. pre-modifier, head, and post-modifier. Not all complex noun phrases contain all the three parts, but the head, normally a noun, is obligatory. He adds that the pre-modifier shows more functional diversity, while the post-modifier serves only one primary function which is relatively simple in functional terms, but it is structurally extremely complex and has a capacity for apparently infinite extension. Therefore, complex noun phrases containing only the Head noun and pre-modifier are studied and discussed in this study.

A pre-modified complex noun phrase refers to a group of words which contains a noun as a head word and has a modifier or more in front of it. This type of multi-word unit includes some compound nouns, which contain two or more words, defined by Trimble (1985). Trimble (*ibid.*) defines compound nouns or noun strings as groups of two or more nouns plus necessary adjectives, each of which make up a unitary concept. A compound noun is treated as a word with a unitary meaning. Carter and McCarthy (1991: p. 19) state "…when we talk of words, we are not excluding the fact that some multi-word units,…, behave largely like single words for the purposes of examining meaning-relations in the lexicon. The word 'word' will therefore be used as convenient shorthand for lexical items of varying kinds.” Moon (1997) differentiates compounds from single words on the condition that they are composed of two or more orthographic words (tokens) and cannot be separated out. Compounds are normally hyphenated, and this is a technique by which a group of words is lexicalized and become non-compositional. The simplest form of the complex noun phrase is as follows.

Modifier + Head Noun

With this discussion, a compound noun is different from a nominal group in the way that a compound noun contains two or more nouns (perhaps plus modifier) and its meaning can be more complex and cannot be interpreted on a word-by-word basis (Moon, 1997), while in a nominal group containing a head noun plus modifier(s) the meaning of a nominal group is extended by its modifier and can be interpreted word-by word. Thus, a compound noun can be simply formed as follows.

(Additional Modifier) + Noun +Head Noun

Compound nouns, which provide more complex meaning, have been categorized by length and difficulty of paraphrasing into four groups: simple (Metal shaft), complex (Automated nozzle brick grinder), more complex (Long-term surveillance test planning), and very complex (Heterogeneous graphite moderated natural uranium fueled nuclear reactor) (See Trimble, 1985: p. 133-135).

2.3.2 Identifying and classifying pre-modified complex noun phrases

There is an unavailability of a frequency list for multi-word terms like those of the GSL and the AWL. Arnaud and Savignon (1997: p. 160) assert that “Quantitative data on the learning or use of complex (or multiword) lexical units are less advanced than the data on simple units. One reason for this is that complex units are more difficult to trace in corpora as they take more different shapes in discourse the more complex they are." With a lack of the data and the difficulties involved in identifying multi-word terms, no classifications of multi-word terms is available.

Multi-word vocabulary can be identified with some certain criteria. Yang (1986) set up presuppositions as criteria to identify multi-word terms for his work entitle 'A new technique for identifying scientific/technical terms and describing science texts'. Yang's presuppositions (1986: 100) are:

1. Multi-word terms are mainly nominals;
2. Multi-word terms cannot go across punctuation marks;
3. Verbs may be terms by themselves but no part of a multi-word term because of 1.;
4. Function words should be excluded with the exception of prepositions, because prepositions may be part of multi-word terms (e.g. 'speed OF propagation, 'revolution PER minute', etc.);
5. Adverbs may be part of multi-word term (e.g. 'VERY high frequency', 'POSITIVELY charged ions', but adverbs for text cohesion (e.g. 'subsequently', 'naturally', 'usually', etc.) should be excluded;
6. No multi-word terms can end up with an adjective or adverb;
7. S-endings should be removed for the purpose of frequency counting.

Yang's criteria focus only on nominal groups, and the terms were counted only for their frequency, to investigate the proportion of multi-word terms in his corpus.

Though Yang (*ibid.*) identified nominal groups, he did not classify them into categories as technical and non-technical.

Multi-word terms, in this case noun phrases, used as general terms and technical terms in scientific texts are created with the same principles as are nominal groups used in general texts (Sager, 1990: p. 9). A noun phrase is used and treated as a single unit or a word. In the case that individual words in a discourse can be identified and classified into categories (function, general and technical) with the Rating Scale, this method should be applicable with multi-word terms of the same discourse as a word does not occur alone but does have a relationship with word(s) close to it. That is to say, multi-word terms as noun phrases would possibly be classified into general, technical and academic categories as are individual words, considering their components and their meaning of the whole unit in the context.

2.4 The relative importance of academic and technical vocabulary

Academic and technical vocabularies are normally taught in ESP/EAP classes. ESP/EAP is an advanced language class since the learners are normally required to have knowledge of general English, and the learners may need to know 2,000 words of general English before coming to an ESP/EAP class (Coxhead and Nation, 2001). If the learners can control 2,000 words, that means, they will have an ‘access’ to learning more advanced vocabulary which, in this case, are academic and technical words. Coxhead and Nation (2001) postulate that academic vocabulary should be taught first and technical words later since 80% of running words in an academic text are general words. To comprehend a reading text, the study by Laufer (1989) reveals that learners need to know about 95% of running words. The ESP learners are expected to know 80% from general words; therefore, they can gain an additional 15%, of which 10% comes from academic words and 5% from technical words.

2.4.1 The current focus of EAP vocabulary

Coxhead and Nation (2001) and Nation (2001) discuss the importance of academic vocabulary giving four main factors. Firstly, academic vocabulary commonly occurs in a wide range of academic texts across subject areas (Cooper, 1984), but not in non-academic texts. They say that studies focusing on analysis of academic vocabulary have been done since the computers were not available, and a study by Barber (1962) triggered much thinking about English for Specific Purposes. Very few studies comparing the frequency of academic vocabulary in academic and non-academic texts have been publicized, and the one that shows a big contrast in frequency is Coxhead's (1998). Secondly, a number of academic words in academic texts, measured by looking at tokens, lemmas, and word families, are considered substantial. This substantial number can be seen from Sutarsyah, Nation and Kennedy's (1994) results found that the UWL which covers around 8.4% of the running words in the Learned and Scientific sections (Sections J) from the LOB and Wellington Corpora, and 8.7% of running words in an economic text and that the AWL (by Coxhead, 2000) covers 10.2% of the tokens of her Academic Corpus of 3,500,000 running words (Coxhead and Nation, 2001 and Nation, 2001). Thirdly, academic vocabulary is not well known by learners, compared with technical vocabulary. Nation (2001) provides an example from Cohen, Glasman, Rosenbaum-Cohen, Ferrara and Fine's study in 1988 that some academic words such as *essential*, *maintain*, and *invariable*, are more unknown than technical words because of their technical use and a lack of awareness on the part of the learners as well as an ignorance of related terms referring to the same thing and their lexical cohesion. Nation (2001) added that by the use of the Vocabulary Level Test, many learners got low scores on the UWL section. Fourthly, academic vocabulary is a kind of specialized vocabulary that language teachers can help their learners understand. Unlike, academic vocabulary, technical vocabulary provides more difficulties for language teachers. The most important thing is that the teachers might lack the background knowledge in the subject, and they may need to learn technical vocabulary in the texts for teaching materials. The other is that there is a diversity of students from different fields in the same group. That is why academic vocabulary is the core vocabulary for the mixed groups of students as it occurs across different fields. In light of the four reasons above, academic vocabulary has become a focus of vocabulary teaching for ESS/EAP while technical vocabulary has been pushed aside.

Studies in academic vocabulary discuss the number, range and frequency of occurrence, but very few focus on measuring learners' knowledge of academic vocabulary (see Marshall and Gilmour, 1993) or test its difficulties compared with the other specialized language or technical vocabulary (see Liu and Nesi, 1999). The excuse that language teachers have more difficulties with technical vocabulary rather than academic vocabulary seems acceptable in the language teaching community. This leads the language teachers to pay less attention to technical vocabulary for two reasons. Firstly, language learners know more technical words than do the language teachers and have fewer difficulties with technical vocabulary than academic vocabulary. Secondly, subject teachers deal with technical vocabulary while teaching the contents. The first claim is sensible, but there are not a sufficient number of empirical studies to prove its veracity. The second claim is doubtful, at least when considering the manner in which subject teachers get involved in language teaching in the countries where the course is taught in a language other than that used in the textbok. For example, at Khon Kaen University subject teachers give lectures in Thai, but most assign their learners to study English textbooks as original sources of knowledge. Do the subject teachers teach technical vocabulary simultaneously with the content? In the Thai context, there seems to be no empirical study to answer this question. Perhaps, the second claim may cover the situations in which the learners use English as a second language along with their native language and where learners take courses conducted in English. In these situations, subject content is taught in English and the teachers need to clarify the technical terms for their learners. To conclude, academic vocabulary is important, but the balance of both academic and technical vocabulary as a major part of academic texts and a goal of ESP/EAP should be justified, considering the real situations in which the language is used and taught. Moreover, there should be more empirical studies on both types of vocabulary.

2.4.2 Reconsideration in academic and technical vocabulary

Chung and Nation (2003) found that an anatomy text contains 20.3% general words, 8.6% academic words, 37.6% technical words, and 33.5% low frequency words and that an applied linguistics text contain 41.8% general words, 17.4% academic words, 16.3% technical words, and 24.5% low frequency words. This suggests that proportion of vocabulary type varies according to area or discipline. The question is “Can we make sure the students will have no difficulties with the anatomy text if we follow the steps of teaching from academic to technical vocabulary?" The anatomy text contains such a high proportion of technical vocabulary that it can block comprehension. Language teachers may argue that learners have some knowledge of the field, and they might know some technical words. This is true and acceptable if the ESP class is provided for field-experienced learners. However, many ESP classes in universities are provided for new learners of the field, for example, Technical English for Engineering at Khon Kaen University, which is geared to prepare the engineering students for academic study in engineering texts. With no or very little experience, the language in this field would be new to them. And what is the proportion of each type of vocabulary in engineering texts? It is still doubtful if the proportion is the same as defined by Coxhead and Nation (2001). And if technical vocabulary occurs in a higher proportion than academic vocabulary, would the focus of vocabulary teaching shift to technical words? These questions need answers from empirical studies of both from the engineering texts and engineering students.

Currently, many teachers and researchers put more focus on academic vocabulary while only a few concentrate on technical vocabulary. Many applied linguists focus on the teaching of academic vocabulary since this type of words has a wider range of use or occurrence than technical vocabulary in academic texts (Farrell, 1990; Nation, 2001; Nation and Coxhead, 2001; and Mudraya, 2006). Coxhead (2000) found that academic words occur in a wide range of academic texts from different fields and comprise 570 word families. In fact, academic words do not equally occur in different disciplines. Chung and Nation (2003) found different proportions of academic vocabulary in an applied linguistic textbook (8.6 % of running words) and an anatomy textbook (17.4 % of running words). Similarly, Hyland and Tse (2007) found that Coxhead's subcorpara contained different proportions of academic words and that some academic words are homographs (words which can provide different meanings in different contexts). Chung and Nation (2003) also found in an anatomy textbook that technical words made up higher proportion than academic words. These findings lead to some questions "Can the AWL or academic words by Coxhead be generalized to other academic areas?; Can the list be practically used for all EAP classes?; and Is academic vocabulary the main focus of EAP vocabulary teaching?

Language teachers and researchers talk about the number of academic words and suggest this group of words be taught in class, but no one talks about how many academic words ESP/EAP learners have already learned before coming to class. Indeed, the students might have learned some academic vocabulary before enrolling in ESP class. Kornwipa Poonpon (2002) studied an English book, *Inside Out,* published by Macmillan Heinemann English Language Teaching in 2000, which is used for two general English courses for the first-year science and technology students at Khon Kaen University. She found that this book contains academic words from up to 257 word families, with 1,307 occurrences, from the Academic Word List by Coxhead (2000). This finding suggests that the ESP learners who studied general English with *Inside Out* met almost half of the academic words from AWL.

There is no study showing that ESP students know more technical vocabulary before enrolling in the language course. This could be because most technical vocabulary appears in texts in its specific field and hardly occurs in general English. In fact, many studies in ESP focus on academic vocabulary while not many studies focus on technical vocabulary, and while a diverse body of recommendations exist which are focused on the teaching academic words. Very few people suggest on teaching technical vocabulary (Yang, 1986: Hyland, 2002; and Liu and Nesi, 1999). However, those who emphasize teaching academic vocabulary have the recommendations with only figures of occurrence of academic vocabulary in general study, but without any proof from empirical studies of ESP students. Only one study, by Liu and Nesi (1999), was conducted to identify learners' difficulties with technical vocabulary compared with academic vocabulary. The questions are "Which type of ESP vocabulary causes more problems/difficulties for scientific students? And what are their needs with respect to vocabulary learning?" These questions are in need of research studies to provide answers.

2.5 Learner difficulties with technical vocabulary

Technical vocabulary occurs in academic texts with high frequency (Yang, 1986; Liu and Nesi, 1999; and Nation, 2001) as well as low frequency (Liu and Nesi, 1999). Learners need to know the words since they carry most of the content in the text. This group of words then needs to be taught. Yang (1986: p. 93) states, "One of the specific features of English for Science and Technology (EST) is the high concentration of terms. Before a learner can have practical reading competence, he/she must have acquired a certain number of scientific/technical terms. Scientific/technical terms should be part of the teaching of EST, especially at the advanced level." Yang's statements have provided no direct comment on the difficulties of technical words. However, with a high proportion of technical words, they can cause difficulties for learners in significant ways. Carter and McCarthy (1991: p. 13) state, "The difficulty of a word may result, inter alia, from the relations it can be seen to contract with other words…, from its polysemy, the associations it creates,…, from the nature of contexts in which it is encountered.” From these statements, the difficulties of words come from the context in which they occurs as well as the relationship with other words. This means a word by itself and a group of words can both provide some difficulties.

Technical words, which carry the content of the discourse, occur with high frequency in academic texts (Yang, 1986). Technical vocabulary comprises indexical words, general scientific words, and loan words from common language (Wignell, Martin and Eggins, 1993). In their study, Liu and Nesi (1999) found that technical words provide more difficulties to non-native learners of English than do academic words.

Scientific texts use numerous noun phrases. Those noun phrases might contain some technical words which make the phrases technical. The technical words themselves can provide some difficulties to learners. The interpretation of a noun phrase the meaning can be problematic, especially with compound nouns. Trimble (1985) asserts that compounding is a natural process and it can provide problems for most non-native students. Learners might be able to handle a two-word compound which may have technical meaning. They might have learned how to analyze compounds and translate them into their native language. However, a great number of compounds cannot be interpreted with the procedures the learners have learned. Trimble (1985: pp. 131-132) discusses some rules for understanding and producing compounds. In fact, compound nouns are used as shorthand versions of:

1. Prepositional phrases: a differential time domain equation = the time domain *of* a differential equation.

2. String of prepositional phrases: momentum transfer experiments = experiments *of* the transfer *of* momentum.
3. Noun modified by relative clauses: automatic controller action = controller action which is automatic.
4. Noun modified by gerund phrases: a fluid bed reactor = a reactor containing a fluid reactor.
5. Combinations of the above: an air pressure device = a device *which* signals the pressure *of* air; a quiescent state fluid bed reactor = a reactor contain*ing* a fluid bed *which/that* is in a state of quiescene.

These shorthand versions of noun phrases are complex, especially with longer compound nouns. As discussed above, compound nouns are categorized by length and difficulty of paraphrasing. The complexity and difficulty of a compound noun, therefore, depends on the number of words that comprise it—the more words it contains, the more difficult it will become (Trimble, 1985)

With the difficulties technical terms provide or due to doubts whether they provide difficulties or not, there have been some studies focusing on identification of technical terms (Tagliacozzo, 1975; Yang, 1986; Liu and Nesi, 1999; and Chung and Nation, 2003) as well as tests of knowledge of technical vocabulary (Liu and Nesi, 1999). All of these studies found that scientific texts are comprised of a high proportion of technical vocabulary, even higher than that of academic vocabulary. However, most language teachers put more focus on teaching academic vocabulary, claiming that learners have fewer problems with technical words (Trimble, 1985) and giving responsibility to teach technical vocabulary to subject teachers. This might be because technical words involve subject content which is too difficult for language teachers to understand and that it has become a convenient excuse for paying more attention to academic vocabulary. Indeed, there have been very few studies to prove where the focus should lie, on technical or academic vocabulary.

Thankfully, there is a study which directly focuses on the proportion of technical and academic vocabulary as well as learners' knowledge of the two types of vocabulary. Liu and Nesi (1999) identified technical and sub-technical vocabulary from texts used in a language course, tested their overseas students' receptive knowledge of the identified technical and sub-technical vocabulary and found that their students had more difficulties with technical vocabulary. They admit that there were some flaws with their study. Firstly, the test was a checklist, a yes/no format, in which the learners tell only whether they know the tested words or not. The scores did not reflect the students' ability to produce or interpret the tested word in an appropriate context. Since the meaning of the words is not involved, it is difficult to tell whether the learners really know the words—they might have marked the words known when they were only somewhat familiar with the words. Secondly, their participants were overseas students who have some experiences in reading academic texts, so they know some academic words in a wide range of texts—the words which undergraduate students might not know. The results cannot be generalized to undergraduate students. Also, technical texts used in the study contain modules in subfields, and they might present the participants with new items which they could not have acquired by the end of the course or before they were tested. With these flaws in mind, Liu and Nesi (*ibid.*) suggest testing for a greater depth of knowledge of vocabulary of both technical and academic vocabulary and conducting the test both at the beginning and the end of the course of study.

2.6 Vocabulary test

Read (2000: pp. 1-2) said "…vocabulary can be seen as a priority area in language teaching, requiring tests to monitor the learners' progress in vocabulary learning and to assess how adequate their vocabulary knowledge is to meet their communication needs." This notion clearly emphasizes the importance of vocabulary teaching, vocabulary knowledge, and vocabulary assessment or measurement according to learners' needs for communication. Vocabulary tests have been designed and developed to measure learners' knowledge of vocabulary. Why do we need to measure this kind of knowledge? The answer could be that it is necessary to diagnose how many words particular students know because the size of vocabulary students have or students' vocabulary knowledge, is important for language learning (Read, 1988). Alderson (2005) says that it is important for teachers to know what their language learners have learned and what their learners need to learn in order to help them learn more as well as to determine what problems their learners are facing in language learning. There are some studies on vocabulary knowledge with language proficiency (see Marshall and Gilmour, 1993; Laufer, 1997; Carrell, 1988; and Koda, 1989).

2.6.1 Vocabulary test formats

A variety of studies on vocabulary tests have been conducted and test formats designed to test vocabulary knowledge of language learners. There are five well-known formats—Meara's Yes/No Checklist (Liu and Nesi, 1999), Vocabulary Levels Test (Nation, 1983 and Read, 1988), Receptive Recall Translation (Nurweni and Read, 1999 and Nation, 2001), Word Association Test (Schmitt and McCarthy, 1997 and Meara and Fitpatrick, 2000), and Interview Test (Nurweni and Read, 1999)—designed, developed and validated as reliable tools for testing vocabulary knowledge. *Checklist* or *Yes/ No Test* is an easy and effective format mostly used as a placement test. *Vocabulary Levels Test* is a matching format used to measure learners' vocabulary size—how many words the students know. *Translation Test* presents the test takers with items in context. The test taker provides the meaning in their first language. Translation can be used to test both receptive and productive knowledge of vocabulary. *Word Association Test* presents a test item with a set of words. The test takers tell a word from the set related to the test item. This test can be used to measure both breadth and depth of their knowledge of vocabulary. *Interview Test* is used to test the depth of knowledge of vocabulary. The process of the interview starts from word recognition, meaning and synonym provision and progresses to the use of the tested word. The interview test can be used to obtain greater knowledge of vocabulary to supplement other vocabulary tests.

2.6.2 Test of technical and academic vocabulary knowledge

Liu and Nesi (1999) employed a yes/no format to test Msc engineering students on their knowledge of technical and sub-technical vocabulary. The purpose was to identify which type of vocabulary the students were facing difficulties with. They found that technical vocabulary should be introduced and reinforced in the class. However, they admitted that the yes/ no or checklist format was used to test only receptive knowledge, and the results did not reveal the students' ability to produce or interpret the two types of words in contexts. Therefore, they recommended that words in context be examined and taught in greater depth with regard to the knowledge of the learners. Though the yes/no format might prove reliable, valid and practical, it is used most often to estimate learners' vocabulary knowledge and place them in the right class level. Nation (2001) argues that this test format is effective as a placement test and helps save time, but teachers and researchers still have some doubt whether it can tell if the test takers really know the word they checked as known since they do not demonstrate any knowledge of meaning for the tested words.

2.7 Summary of the literature review

Reading is a necessary skill, but many second language readers have problems with limited vocabulary and need to learn more vocabulary. As learning new words is essential, many studies focus on vocabulary. Vocabulary knowledge comprises receptive, or passive, and productive, or active, knowledge. Receptive knowledge is measured in breadth and productive in depth. It is receptive knowledge that is applied most in reading, and vocabulary knowledge correlates with reading comprehension as well as language proficiency. To date, multiple studies on vocabulary have been completed so far. Researchers classify vocabulary into levels, types or categories with similar criteria, such as frequency of occurrence and meaning exclusive to the field. Whatever type of vocabulary is classified, words can be categorized into three major groups, namely general, academic, and technical. General and academic words are classified with well-established criteria and comprise their own lists. Technical vocabulary is still problematic because the meaning of a technical word depends on its technicality—the way and the context in which it is used. Like general and academic words, technical words are identified by their high frequency of occurrence in the specific field or their meaning related to the field. There are four common approaches used to identify technical vocabulary: Rating Scale, technical dictionary, clues provided in the text, and computer software. Technical vocabulary prevails in scientific texts, and it can be a group or a multi-word unit as a noun phrase, which is a complex group of words. Noun phrases are formed in two ways, which are derivation and compounding, and have two main structures—head noun with pre-modifier and head noun with post-modifier. This study focuses on pre-modified or complex nominal groups as noun phrases. In EAP classes, technical and academic vocabularies are taught as EAP students are expected to know an exact percentage of general vocabulary and prepared to learn academic words and technical words respectively. Academic words are given more attention from language teachers for various reasons while technical vocabulary is normally out of sight. However, some studies have shown that proportion of technical words in some scientific texts is higher than that of academic vocabulary. A study on the use of vocabulary test reveals that language learners have more problems with technical vocabulary than with academic words. However, the test format used in the study has several weaknesses. The researchers then suggested using other test formats in further studies for more reliable results. There are five major vocabulary test formats which can be used for different purposes. The translation format can be used to measure both receptive and productive knowledge by examining the way that the test takers indicate or provide the meaning of the test items in their mother tongue.

CHAPTER 3

RESEARCH DESIGN AND METHODS

3.1 The design of the study

The purposes of this study were to (1) identify proportions of words (Chung and Nation (2003-2004) and complex noun phrases (Yang, 1986) from the electrical engineering corpus, and (2) to test electrical engineering students' knowledge of the identified technical and academic words from those textbooks (Liu and Nesi, 1999). Therefore, this study was divided into two main phases. To answer the questions of this study or research Questions 1, 2 and 3, all data from the two phases were analyzed and interpreted together.

3.1.1 Phase 1: Identification of words and complex noun phrases

This phase applied quantitative methods (Cresswell, 2003; Burns, 1995 and Salkind, 2006) and corpus linguistics (Biber, Conrad and Reppen, 1994; Bowker and Pearson, 2002; Conrad, 1999; Hunstun, 2002; Kennedy, 1998; Partington, 1998; and McEnery, Xiao and Tono, 2006) to identify the proportion of technical vocabulary (Chung and Nation, 2003) and academic vocabulary (Coxhead, 2000 and Farrell, 1990) in samples from electrical engineering corpus. To work with the corpus in this study, a computer, a software program, and specific criteria were utilized. Data obtained from Phase 1 were used to answer research Question 1 as follows.

(1) What proportion of the different types of words occurs in the electrical engineering corpus?

3.1.2 Phase 2: Test of engineering students' knowledge of vocabulary

This phase applied quantitative methods and a vocabulary test to measure the students' knowledge of technical and academic vocabulary (Liu and Nesi, 1999). Data from Phase 2 answers research Questions 2 and 3 as follows.

(2) How well do the students know each type of vocabulary from the electrical engineering corpus?

(3) How do the students' study levels affect their knowledge of vocabulary?

The scheme of the study can be summarized in a diagram as follows:

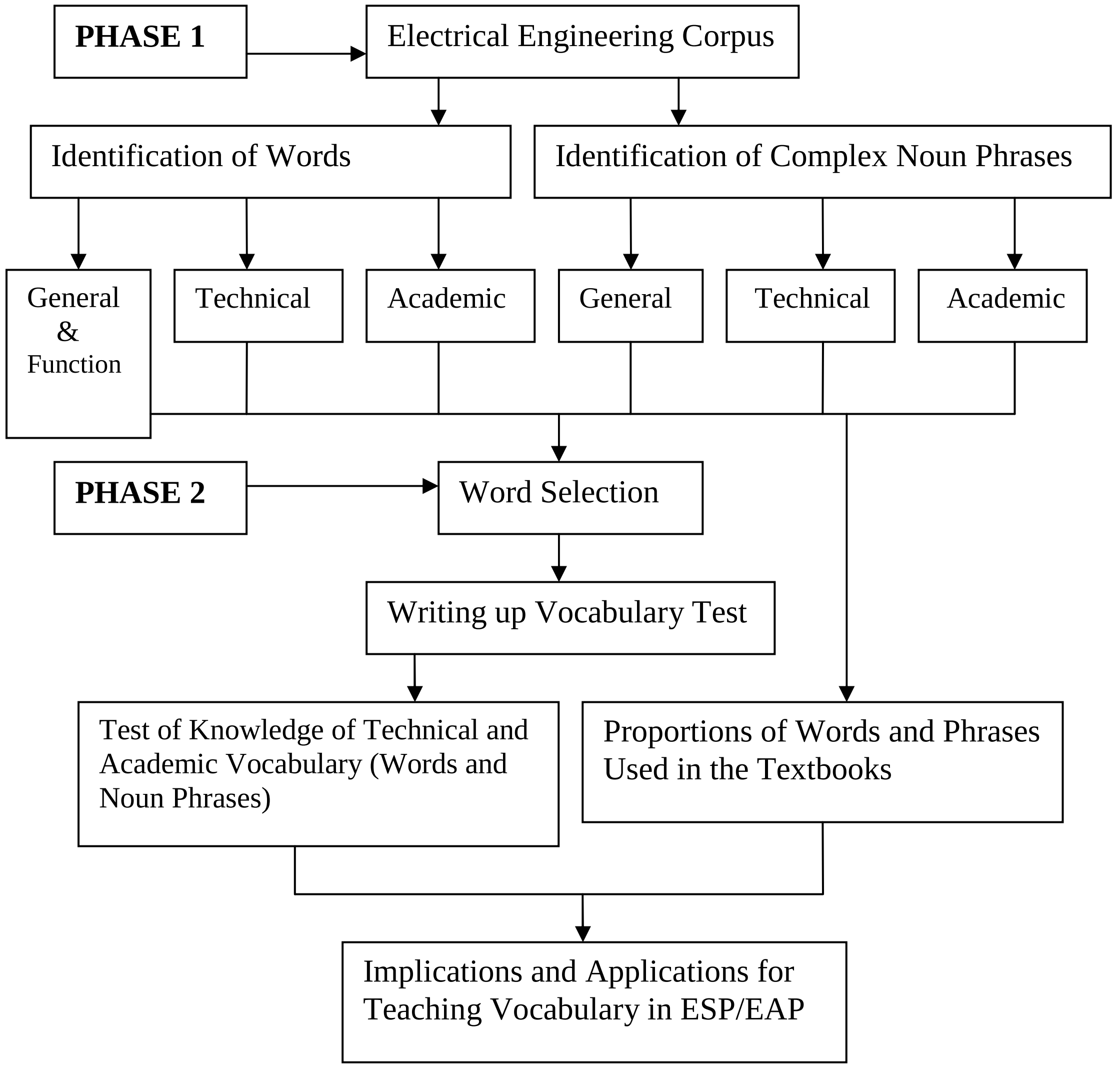

Figure 3.1 Diagram of the Study Scheme

The diagram shows that from two phases this study consisted of seven main stages in total, namely, (1) creation of the corpus, (2) identification of words and complex noun phrases, (3) identification of general, technical and academic words, (4) identification of general, technical and academic noun phrases (5) selection of words and noun phrases for the vocabulary test, (6) writing up the vocabulary test, and (7) test of students' knowledge of the vocabulary.

3.2 Research methods

3.2.1 PHASE 1: Identification of words and complex noun phrases

The first phase of this study focused on identification and classification of vocabulary from the electrical engineering corpus into categories. This phase discussed how the corpus was created, edited and processed and how the identified words and terms were counted and presented with a statistical formula.

3.2.1.1 The creation of the corpus

The selection of textbooks and the randomness: This study aimed to identify the proportions of vocabulary in electrical engineering corpus that undergraduate electrical engineering students at Khon Kaen University are to study. The whole population refered to all textbooks in this field. It would provide better findings if the whole population of electrical engineering corpus were used and the language analyzed. As it was impossible to do so; thus, "…sampling is unavoidable" (McEnery, Xiao and Tono, 2006: 13). In fact, there were many textbooks in this field found on shelves at Khon Kaen University library. But from the preliminary survey, only some textbooks were used. This means that the students and teachers prefer to use some of the books. Therefore, *purposive sampling* was applied, and samples of textbooks were obtained from the regularly used textbooks and the recommendations from electrical engineering lecturers from the Faculty of Engineering, Khon Kaen University.

The corpus for this study contained approximately 120,000 tokens or running words. The number of the running words in the corpus was limited to this number with three constraints: permission from the publisher, specialized language, and manual analysis. It was difficult to get full permission to scan the whole book and change it into a machine-readable form since the copyright is protected. The publisher allowed only some parts of the book to be scanned. This study involved five books from the same publisher, so it was even more difficult. Also, this study worked on levels of vocabulary which were manually identified. A large corpus would take a very long time for data analysis. To create the corpus for a study on language for a specific purpose, Bowker and Pearson (2002) postulate that well-designed corpora which comprise a number ranging from ten thousands to several hundred thousand words in size have proved to be exceptionally useful. In his work, Farrell (1990) analyzed a corpus of 20,000 words from English of electronics. His findings have provided relatively important contributions to corpus studies and language pedagogies as can be seen from Chung and Nation (2003), Wang and Nation (2004), and Liu and Nesi (1999). Therefore, the corpus in this study was created from five textbooks in the electrical engineering field. The books, recommended by electrical engineering teachers, exemplify the four sub-fields of electrical engineering at Khon Kaen University: Control Systems, Power Systems, Electronics, and Communications. These books are assigned for KKU electrical engineering students to study. One book was selected from each sub-field and an extra book from the common course every electrical engineering student has to study as basic knowledge. In fact, there were many more textbooks to be chosen. Only textbooks from Pearson Education were selected and used for this study because this publisher provided full permission to scan the exact pages of the textbooks, while other publishers did not. Therefore, five textbooks from Pearson Education were included in this study (see appendix A, page 188).

From each selected textbook, samples were randomly chosen to obtain approximately 100 pages which consisted of approximately 24,000 words each. The total number of words in the corpus was approximately 120,000. The random processes were carried out with a software program called ‘randomono’, a random number generator created by a mathematician colleague. The numbers obtained from each book were the exact pages used in the research study (see appendix B, page 189).

The permission from the publisher: It was necessary to scan the random pages and change them into a machine-readable form. All the books used in this study belong to Pearson Education, U.S.A and all the copyrights are reserved. A full permission from the publisher was granted only for the study (see appendix C, page 191).

The change in archive into machine-readable form: All the random pages were scanned and changed into text files. The texts received from the scanned page were checked to ensure that all the words remained the same as in the original page before they were combined with other parts to build up a corpus. This was to confirm that texts in the corpus were not distorted from the original texts.

3.2.1.2 Instruments used in the study: Phase 1

1. Oxford WordSmith 4.0 (Scott, 2004-2006)

This tool is a software program used for data creation. It is an integrated suite of programs for looking at how words behave in texts. It comprises three major tools which are WordList, Concord, and KeyWords. In this study, the WordList tool was used to make a list of all the words from the corpus, and Concord was used to select test items from the corpus.

2. The rating scale

The rating scale was developed by Chung and Nation (2003-2004) to identify technical vocabulary from an anatomy textbook and a linguistics textbook. The rating scale was used to identify technical vocabulary in this study for three reasons. Firstly, the other methods had more drawbacks than the rating scale. Secondly, the rating scale has been validated and proven to be more reliable than other methods (Chung and Nation, 2004). Thirdly, it was easily accessible and not complicated to use. The scale comprises four steps, each of which contains a specific criterion, so there are a total of four criteria for identifying technical vocabulary. The principle used to design the scale was "The rating would depend on how closely related the meaning of a word is to a particular subject area, and the scale would range from the least related meaning to the most" (Chung and Nation, 2004). The scale used in their study is illustrated as follows.

Table 3.1 The rating scale by Chung and Nation (2003-2004)

Step 1 Words such as function words that have a meaning that has no particular relationship with the field of anatomy, that is, words independent of the subject matter. Examples are: *the, is, between, it, by, adjacent, amounts, common, commonly, constantly, early,* and *especially.*
Step 2 Words that have a meaning that is minimally related to the field of anatomy in that they describe the positions, movement, or features of the body. Examples are: *superior, part, forms, pairs, structures, surrounds, supports, associated, lodge, protects.*
Step 3 Words that have a meaning that is closely related to the field of anatomy. They refer to parts, structures, or functions of the body, such as the regions of the body and systems of the body. Such words are also used in general language. The words may have some restrictions of usage depending on the subject field. Examples are: *chest, trunk, neck, abdomen, ribs, breast, cage, cavity, shoulder, girdle, skin, muscles, lungs, heart, organs, liver, breathing*. Words in this category may be technical terms in a specific field like anatomy and yet may occur with the same meaning in other fields and not be technical terms in those fields.
Step 4 Words that have a meaning specific to the field of anatomy and are not likely to be known in general language. They refer to structures and functions of the body. These words have clear restrictions of usage depending on the subject field. Examples are: *thorax, sternum, costal, vertebrae, pectoral, fascia, trachea, mammary, periosteum, hematopoietic, pectoralis*…

However, the scale needed to be adapted to suit this study. In a trial to identify technical vocabulary from a sample of about 1,990 words from an electrical engineering textbook by an application of the rating scale, there was an emergence of problems. Some scientific words which are from general sciences could not be put into one of the four steps since they did not meet any of the criteria from the scale. Those scientific words were, for example, integral, kinetic, oxide, etc. They are technical and used in scientific fields or other engineering fields but are not included in the field of electrical engineering. Based on the criteria (Nation, 2001; and Chung and Nation, 2003 and 2004) and the trial above, the criteria for identifying technical vocabulary in electrical engineering corpus is adjusted and divided into five main groups as follow:

Table 3.2 The rating scale adapted from Chung and Nation's (2003-2004)

Group 1: Words that are classified as function or grammatical words, including articles, demonstratives, prepositions, question words, auxiliaries, modals, pronouns, possessives, ordinals, cardinals, conjunctives and some adverbs. These words are, for example*, the, this, with, what, to, do, will, we, its, and, moreover, always,* and *while.*
Group 2: Content words including nouns, verbs, adjectives, and adverbs that are used both inside and outside the field of electrical engineering with no specialized meaning related to the field. They are content words i.e. nouns, verbs, adjectives, and adverbs, for example, *condition, obtain, reliable,* and *heavily*.
Group 3: Content words including nouns, verbs, adjectives, and adverbs that are used both inside and outside the field of electrical engineering with meaning related to words from Group 4 & Group 5. They describe the processes, functions, features, properties, items, and materials. When they are used in the context of electrical engineering with words from Group 1 & Group 2, their meaning is technical for example, *current, gate,* and *frequency.*
Group 4: Content words in general science or other engineering fields, including nouns, verbs, adjectives, and adverbs, which are related to the field of electrical engineering and words (forms) which are not likely to be used in general language/concept. They refer to scientific principles, items, materials, units, properties, functions, processes, and concepts. These words have clear restrictions of usage within science. Examples are *atom, sine,* and *thermal (agitation).*
Group 5: Content words including nouns, verbs, adjectives, and adverbs that provide specialized meaning and are used mostly in the field of electrical engineering. This list of words includes materials or items, apparatus, equipment, units, properties, and functions closely related to electricity and electrical engineering. Examples are *op amp, amplifier, oscilloscope, volts, pulse,* and *amplification.*

This scale has one additional group of words—Group 4—which includes general scientific words from physics, chemistry, and mathematics and some other engineering fields. These words provide technical meanings to their own field, but are not exclusive to the field of electrical engineering. These words are used in electrical engineering texts as the electrical engineering field comprises several fields of general sciences. This scale then becomes suitable criteria for identifying technical vocabulary from electrical engineering texts.

The reliability of the scale was checked with three inter-raters who are engineering teachers, one from Suranaree University of Technology and two from Khon Kaen University (Chung and Nation, 2003-2004). To check reliability, the three inter-raters were trained to use the rating scale first. Fifty words (ten from each of the five groups identified by the researcher) were randomly chosen to be used. The researcher and the raters worked and discussed together how to put the words, one by one, into groups. The training session took about 20-30 minutes. After the training, sixty randomly selected single words (12 from each group) were given to the raters to independently classify into groups. The consistency of the scores from the three raters was analyzed and compared with those from the researcher for reliability.

3. The General Service List

The General Service List (GSL) by West (1953) was used to identify general words or high-frequency words from the electrical engineering corpus.

4. The Academic Word List

The Academic Word List (AWL) by Coxhead (2000) was used to identify academic words from the electrical engineering corpus.

5. Dictionary

A dictionary is important as the researcher does not know every word in the corpus, so he needs to consult a dictionary. In this study, Dictionary.com from the website http://dictionary.reference.com/ (2007) was used. The researcher tried this online dictionary by consulting with it on some general words which are used as technical words and found that this dictionary was effective as it provides both general and technical meanings for entries. As this dictionary has been compiled from seventeen dictionaries, it also provides precise meanings for the technical words. Moreover, it is fast, convenient, and free.

6. The Criteria for identifying complex noun phrases

The criteria used to identify noun phrases in this present study are adapted from Yang's (1986). Yang set up presuppositions or criteria to identify multi-word terms for his work entitled 'A new technique for identifying scientific/technical terms and describing science texts'. Yang's presuppositions (1986: 100) are:

(1) Multi-word terms are mainly nominals;

(2) Multi-word terms cannot go across punctuation marks;

(3) Verbs may be terms by themselves but no part of a multi-word term because of 1.;

(4) Adverbs may be part of multi-word term (e.g. 'VERY high frequency', 'POSITIVELY charged ions', but adverbs for text cohesion (e.g. 'subsequently', 'naturally', 'usually', etc.) should be excluded;

(5) No multi-word terms can end up with an adjective or adverb;

(6) S-endings should be removed for the purpose of frequency counting.

From these criteria, the criteria number (6) is excluded from this study since noun phrases are compared with single words in term of 'types' or inflected forms which include singular and plural. Thus, Criteria (6) can distort the real proportions of noun phrases against single words if applied in this study.

7. The criteria for identifying general, technical and academic noun phrases

There are no established criteria for classifying complex noun phrases into categories. The criteria for this study were then formed by the use of the principles of word formation discussed in 2.4.3 that “A noun phrase is used and treated as a word.” In the case that words in a discourse can be identified and classified into categories (function, general, technical and academic) with the rating scale, this method should be applicable with complex noun phrases. Therefore, the criteria from the rating scale used to identify words could be adapted and applied as criteria for classifying complex noun phrases.

Category 1 (non-technical noun phrases) was adapted from Group 2 of the rating scale from which words belonging to this group are general or common words plus academic words. Therefore, non-technical noun phrases included general and academic noun phrases which were classified afterwards with the AWL. Category 2 (technical noun phrases) is adjusted from Groups 3-5 of the rating scale from which words belonging to these groups were counted as technical vocabulary. The criteria for classifying noun phrases into categories are:

Table 3.3 The criteria for classifying technical and non-technical noun phrases

Category 1: Non-Technical Noun Phrases Nominal groups as noun phrases which provide their meaning not related to the fields of general science and engineering are classified as non-technical noun phrases.
Category 2: Technical Noun Phrases Nominal groups as noun phrases which provide their meaning related to the fields of general science and engineering are classified as technical noun phrases. These noun phrases refer to scientific principles, items, materials, units, properties, functions, processes, and concepts.

For the reliability of these criteria, the inter-rater reliability was checked. This stage was done together with the reliability of rating scale. Twenty noun phrases (10 technical and 10 non-technical identified by the researcher) were randomly chosen to train the raters. Then, thirty phrases (15 technical and 15 non-technical) were randomly selected for the raters to classify independently (adapted from Chung and Nation, 2003-2004). The consistency in classifying was analyzed for the reliability.

3.2.1.3 Identification of non-technical and technical noun phrases

Noun phrases were identified with the criteria (Yang, 1986) discussed above. The identified noun phrases were then classified into technical and non-technical with the criteria adapted from the rating scale as discussed in **3.2.1.2** and academic noun phrases were identified as non-technical noun phrases. The procedures are:

(1) Identify and underline noun phrases in each line from the corpus.

(2) Copy the identified noun phrases to Microsoft Exel and sort them alphabetically. (The rest of the corpus is single words and kept for single-word analysis.)

(3) Count the number of words in the group for each noun phrase and mark the number of words (2, 3, 4… (words)). After finishing counting and marking, sort the data according to these numbers to classify the noun phrases into groups.

(4) Count the frequency of each noun phrase and mark the number in a different column.

(5) Delete the repeated noun phrases and keep only one from every repeated item and its number of frequency.

(6) Classify all the noun phrases into technical and non-technical.

(7) From identified non-technical noun phrases, academic noun phrases are identified with the use of the Academic Word List. The rest are counted as general noun phrases.

3.2.1.4 Identification of technical words

After the noun phrases were identified and copied to Microsoft Excel for further analysis, single words were kept and analyzed. An initial analysis of the single words in the corpus was undertaken by the use of a software program, WordSmith 4.0, to make word lists in the first instance. After word lists were made, each word from the lists was identified and put into a specific group with the use of the rating scale. This stage consists of steps which are discussed as follows.

1. The edition of the corpus and making the word lists

The texts used in this study contain figures or numbers, proper nouns, abbreviations of proper or specific nouns and equations and equation symbols. These items are not desirable for the study. Therefore, before the analysis begins, the corpus was edited according to the purposes of the study as to block them from appearing on the list. After the corpus was edited, the word lists were made.

2. Classification of words from the lists into specific groups

Each word from the list was checked against the criteria from the rating scale. According to the criteria, words which fall into Group 3, Group 4 and Group 5 were classified as technical vocabulary. Words in Group 2 can be general and academic words while words in Group 1 are only function or grammatical words. Therefore, only words in Group 3, Group 4 and Group 5 are included in technical vocabulary lists for data analysis in order to investigate a proportion of technical vocabulary in electrical engineering corpus.

3.2.1.5 Identification of academic words

To identify academic words from the corpus, all words from Group 2 were checked against the AWL (Coxhead, 2000).

3.2.1.6 Identification of general words

General words from the corpus were identified from words in Group 1 and 2 with the use of the GSL (West, 1953) to check against words from this group.

3.2.1.7 Data analysis and presentation

The data obtained from identification of words and terms were analyzed and presented to answer research Question 1. Two vocabulary levels—single words and noun phrases—were classified and identified from this corpus. After noun phrases were identified and excluded from the corpus, all individual words from both noun phrases and the rest of the corpus were separately counted.

Single words are generally counted in tokens or running words, types, lemmas and families (Nation, 2001). **Token** or **running word** means a unit of counting words which every word form is counted as one token—the sentence 'Compute the power for each element shown in the figure' contains 10 tokens. The use of token in counting words is to answer the question 'How many words are there in the electrical engineering corpus?' **Type** refers to a unit of counting words with different forms—the word 'go' and 'going' are counted as two types. The use of type to count words helps to answer the questions 'How large is the vocabulary of this corpus?' and 'How many words do electrical engineering students need to know to read this text?' **Lemma** is a unit of counting words from the same part of speech, which includes a headword and its inflected and reduced forms—the words 'go' and 'going' are counted as one lemma. Counting words in lemmas helps to see the learning burden of a word and its inflectional forms. For example, with the word 'count', learners who know the inflectional system will have no problems with its inflectional forms 'counts' 'counted' and 'counting'. While a lemma includes only derivational words from the same part of speech, a **word family**, regardless of their part of speech, combines words from a base word with its affixes and inflected and derivational forms, regardless of their meaning. Since affixes such as *-ly*, *-ness*, *un-*, are used with the base word systematically, the learning burden is greatly reduced when learners know its meaning (Nation, 2001). In this study, a word is an isolated lexical unit. To avoid some confusion with noun phrases, words were therefore counted as **lexical unit tokens, lexical unit types**, and **lexical unit lemmas**.

To compare proportion of words with that of noun phrases, it was necessary to count noun phrases in the same way as words. This can be done, as in this study a *noun phrase* refers to a lexical unit with a unique meaning as does a *word*. Therefore, words and noun phrases were then counted as lexical tokens, lexical types and lexical lemmas. **Lexical unit token** refers to a unit of counting individual word and individual noun phrases—one word is a lexical token and one noun phrase is a lexical token. **Lexical unit type** means a unit of counting words and noun phrases with different forms, for example, the words '*obtain*' and '*obtaining*' are counted as two lexical types and the phrases '*alternating voltage*' and '*alternating voltages*' are counted as two lexical types. **Lexical unit lemma** is a unit of counting the same part of speech for words and the same noun phrase regardless of singular or plural forms. For example, the words *'obtain', 'obtains', 'obtaining'* and *'obtained'* are counted as one lexical lemma. For noun phrases, the same phrases like '*alternating voltage*' and '*alternating voltages*' are included as one lexical lemma. In this study, the terms **lexical unit tokens** and **running words** were used differently in the data presentation. **Running word** was used to count every single word in the corpus, while **lexical unit token** was used to count a word or a noun phrase as a lexical unit.

In this study, lexical units are presented mostly in tokens, types and running words. Lemma is not used as noun phrases include only singular and plural forms of nouns and inflect in relatively few cases, while single words include verbal, adverbial and adjectival inflections. Also, word family is not used since it is problematic to decide on a unit, and what should be included in a word family. Wang and Nation (2004) and Hyland and Tse (2007) found word families with homographs in their studies —the same words are used with different meanings. Wang and Nation (ibid.) confirm that using word families as a unit of counting can cause problems with homographs. They suggest that, by using types and lemmas, “the amount of homography would be less because different meanings tend to be represented by different types.” Also Chung and Nation (2003) found that only one or two members of a family were technical words. The words *analyze*, *analytical*, and *analysis*, which are from the same family, are used differently across fields with semantic differences (Hyland and Tse, ibid.). Similarly, the words *frequency* and *frequent* are used with different meanings in electrical engineering texts. There are some other general words which are used in this engineering field as technical words with semantic differences when used in general text, for example, short, line, mean, excited, contact, etc. With this potential problem, only word types and lemmas are used, but word family was considered inappropriate and not involved in this study.

1. Data from the whole corpus

The proportions of words and complex noun phrases were presented in terms of lexical unit tokens, lexical unit types, and running words. The proportion of text coverage was calculated as a percentage. The data from this part answered research Question 1.1.

1. % of lexical unit tokens

= (*lexical unit tokens*) x (100) /

(*Total lexical unit tokens from the corpus*)

2. % of lexical unit types

= (*lexical unit types*) x (100) /

(*Total lexical unit types from the corpus*)

3. % of running words

= (*running words from single words or noun phrases*) x (100) /

(*Total running word from the corpus*)

2. Data from words

Data obtained from lists of words were presented in terms of lexical unit tokens, lexical unit types, lexical unit lemmas and their percentage of text coverage (Chun and Nation, 2003) to answer research Question 1.2.

1. % of lexical unit tokens from general, technical, or academic words

= (*Lexical unit tokens from general, technical, or academic words*) x (100) / (*Total lexical tokens from single words*)

2. % of lexical unit types from general, technical, or academic words

= (*Lexical unit types from general, technical, or academic words*) x (100) / (*Total lexical unit types from single words*)

3. % of running words from general, technical, or academic words

= (*Running words from general, technical, or academic words*) x (100) / (*Total running words from single words*)

3. Data from the complex noun phrases

Complex noun phrases were identified and classified into three groups: general, technical and academic. Like single words, they were presented in terms of lexical unit tokens, lexical unit types, lexical unit lemmas and running words. The proportion of noun phrases was calculated as a percentage to answer research Question 1.3.

1. % of lexical unit tokens from each kind of phrases

   = (lexical unit tokens from a kind of noun phrase) x

   (100) / (*Total lexical unit tokens from noun phrases*)

2. % of lexical unit types from each kind of noun phrase

   = (lexical unit types from a kind of noun phrase) x

   (100) / (*Total lexica unit types from noun phrases*)

3. % of running words from each kind of noun phrase

   = (running words from a kind of noun phrase) x

   (100) / (*Total running words from noun phrases*)

The percentage obtained from the calculations were analyzed, interpreted, presented and discussed.

3.2.2 PHASE 2: Engineering students' knowledge of vocabulary

This second phase of the study aimed to investigate the electrical engineering students' knowledge of technical and academic vocabulary. The purpose was to identify which type of vocabulary caused more difficulties for electrical engineering students. This part discusses participants, research instruments, data collection, and data analysis.

3.2.2.1 Participants

Engineering students choose their field of study when they are in the second year. The Department of Electrical Engineering accepts around 95-100 students each year to study in this field. Therefore, the population of the study included second, third, and fourth-year students, which numbered approximately 280. To get the samples, a consent letter asking for permission from the Faculty of Engineering and the Department of Electrical Engineering to conduct the study with their students was sent since this issue is considered ethical when doing research (Salkind, 2006: p. 59). Also, the students individually received a consent letter.

Samples of 120 students for the study were voluntarily obtained from the three study levels: 40 students from second year; 40 from third year; and 40 from fourth year. The purpose of using 40 students from each level is to obtain representatives from the school of electrical engineering students—the group which is just starting the field of study, the group which is in the middle of their study, and the group which has almost finished their studies. Also, this would help explain how knowledge of the field affects technical vocabulary learning as the students from each group have different level of knowledge of their field.

3.2.2.2 Research instruments

For testing the students' knowledge of vocabulary, the translation format test was utilized, to collect data to answer research Questions 2 and 3. The vocabulary test was administered to investigate engineering students' knowledge of technical and academic words as well as technical noun phrases. In this study, the diagnostic test (Nation, 2001) was used since the main purpose was not to measure the students' vocabulary size, but to compare their knowledge of vocabulary among technical and academic words and technical noun phrases.

a. The use of the translation test in this study

As discussed above, there are five well-known test formats—yes/no, Vocabulary Levels Test, translation, word association, and interview—used by researchers for different purposes. This study applied the translation format test (Nurweni and Read, 1999) to measure the students' knowledge of vocabulary at the form recognition and meaning level. The translation test format was selected and used for the following reasons.

Translation or receptive recall translation (Nation, 2001) is an assessment instrument of item recognition which requires learners to provide mother-tongue equivalence (Nurweni and Read 1999, p.164), and the use of translation to test word meaning is very efficient (Nation, 2001). The tested item can be presented in contexts or in isolation. Test takers are given a mark for providing mother-tongue translation that expresses a correct meaning of the tested word. The use of the first language in telling definitions to words is efficient since telling definitions in second language needs more skills and could be problematic to the test takers or the students. The purpose of the test is to test knowledge of meaning and not other skills. Translation then fulfils the purpose effectively as the students need only tell the meaning in their L1. Moreover, scoring second language definitions could be problematic because some words are difficult to define and it could be even worse if the students have low ability in L2. In this case, students might know the word, but they do not know how to explain the meaning in their L2. They might be able to provide the definition but not in a straight-forward manner. With this problem, translation is more direct and relevant. Also, translation can be used to measure both receptive and productive vocabulary knowledge. The vocabulary test format of translation used by Nurweni and Read (1999) is as follows. (Nation, 2001)

Translate the underlined words into your first language

1. You can see how the town has developed. ________
2. I cannot say much about his character. ________
3. Her idea is a very good one. ________

(Nation, 2001: p. 345)

The translation format was chosen and used instead of other test types for the study for several reasons. First, the yes/no test measures merely the recognition of form—students do not need to tell any meaning of a word. How do we know if the students really know the meaning of the word marked known? The student might have seen a word frequently and say that he knows that word, but it doesn't mean that he really knows the meaning. The student might overestimate his knowledge by marking some words familiar for which he does not know the meaning. Though some researchers put occasional imaginary words into the test to help the calculation and reduction of "mistakes" made by the students, it is still doubted by some researchers whether it really works.

Second, the Vocabulary Levels Test is in the form of a multiple choice and matching format. The choices are provided in the target language, in this case English, which might cause problems for the students—they might know the words but not know the meaning of the choices. They might apply some test strategies in order to complete the test. In this case, the test would not measure the true knowledge of the students. As the test has been validated with the use of the target language, the use of L1 for the choices could be an alternative, but it might affect the result scores. The Vocabulary Levels Test is then not selected.

Third, both the word association and the interview tests are used to measure the depth of knowledge of vocabulary. This study aims to compare the knowledge of technical and academic vocabulary in breadth. In fact, the interview test can be used to measure both breadth and depth of knowledge, but it is time consuming and cannot be conducted with a big group of students. Practically, the interview format is used to follow up the other test types, to study the students' knowledge of vocabulary in greater depth.

Fourth, some technical words are from general word lists. To test the students on the technical words, the tested item or word needs to be presented within the context so that its meaning is confined to the context and not confused with something else outside the context. Read (2000: p. 7) explains that there are two contrasting perspectives on the role of vocabulary in language assessment. One perspective is that it is sensibly acceptable to design tests to diagnose how well students know a set of words as context-independent units. The other one is that vocabulary must be measured in its surrounding context of a language-use task. From the previous discussion of test formats—Yes/No Test, Vocabulary Levels Test, Translation, Word Association, and Interview—most of them present the test items in isolation, except translation. Read (2000: p. 99) says that there is a weak point with testing vocabulary in isolation. That is, a word can have more than one meaning and be used as more than one part of speech. Nation (2001) argues that sentence context affect test scores and, with sentence contexts, tests can measure things other than vocabulary knowledge. For instance, the test takers can use some test strategies like substitution within the context sentence to eliminate the distractors from multiple-choices. Anyhow, sentence contexts can be used with some test formats such as receptive recall translation, and multiple-choice recognition tests (Nation, *ibid.*).

Lastly, translation was considered appropriate in two ways. First, the students do not have difficulties with their L1 when giving meaning in their own language. They only give the meaning of the tested word in Thai. This conforms well to the purpose of the study—testing how well they know technical and academic vocabulary. Second, the researcher is a Thai teacher of English, so he has no difficulties with the Thai language when marking. Some examples of the translation format test used for this study are shown below.

Translate the underlined words into your first language.

1. A current-controlled voltage source ________
2. The current through a particular circuit element ________
3. It is possible to write node-voltage equations. ________

b. Test items

The items for the test were taken from the corpus, and they were presented with their real context from the text in the corpus. Each item might not be presented in a full sentence, but it was accompanied by a few words to confine its meaning. The use of a few words for the context was to prevent the use of context for guessing the meaning and to avoid testing skills other than knowledge of vocabulary. Moreover, the context presented with the word was expected to help in a students' recall of meaning and a confinement of meaning suited to the context.

The study aimed to test knowledge of technical and academic words and technical noun phrases. Therefore, the test contained three types of items/words e.g. technical words, academic words and technical noun phrases. All the items in the test were all nouns selected from the top frequency from the lists of academic and technical words as well as noun phrases in Phase 1. Words and phrases with high-frequency were used in the test since they are keywords and are mainly used to express meaning of the text. Also, the students have more chance to meet these words and need to know them for comprehension. Problems with words and phrases with high-frequency would be an indication of the difficulty in understanding the texts. From each type of units/words, 30 lexical units were chosen from the top frequency of each lost and used in the test for its reliability. Nation (2001) states that a reliable vocabulary test contains around 30 items as a minimum. In total, the test contained 90 items.

c. Criteria for marking

To mark the responses or answers from the test, it was necessary for the researcher as a marker to fully know the meaning of every item. All tested items were translated into Thai with the use of the dictionary as possible answers for the answer keys. Before using them for marking the test, all of the meanings were rechecked by three electrical engineering teachers to make sure all the meanings were correct and suitable as the answer keys.

It is impossible for the students to give the correct answers exactly the same as the ones from the answer keys. Marking can be subjective and problematic, so criteria for marking were needed. When Nurweni and Read (1988) applied translation to test Indonesian students they had the criteria saying:

> "The test-takers were awarded a mark for providing
> an Indonesian word that expressed a possible meaning of the

> target English word, even if it was not the meaning that fitted the sentence in the test item. In addition, the Indonesian word did not need to belong to the same word class as the English one." (p. 164)

According to Nurweni and Read, the criteria for marking focused on any aspect of meaning of the target word, regardless of the provided context and the word class of the L1 meaning. With these criteria, Nurweni and Read (ibid.) measured the students' knowledge of vocabulary in general in a broad sense, not a given type of vocabulary. Therefore, it is understandable why the answer or the meaning that fit the test item but did not fit the sentence was awarded a score since the given context was not used to confine the meaning of the tested item. The answer was then marked either 1 or 0.

Anyhow, in the case of measuring a specific type of vocabulary like technical words, a presence of context is considered necessary as a provision for recall and a confinement of meaning, so the meaning given to a word must fit both the tested item and its context as to be marked correct. Therefore, in this study, the meaning given to a tested item by the student was awarded one point with the criteria below.

1. The Thai word expresses a possible meaning of the tested word; the meaning must fit or relate to the provided context; and the Thai word does not need to belong to the same word class as the English one; and
2. Another method e.g. synonym, picture, graphic, statement, symbol, explanation, loan word, etc. expresses a possible meaning of the target word and fits the context.

From the criteria, 'possible meaning' and 'fitting the context' are the key considerations in marking and scoring the test. The answer or the meaning provided by the students was marked only 1 or 0. In the case that the answer was not clear or still doubtful, a follow-up interview was conducted individually with the student who gave the answer.

d. Piloting the test

There might be some factors that affect language test scores and cause the test scores to vary from individual to individual. Bachman (1990) postulates that it is necessary for the test developers to identify these factors if they would like to estimate how reliable the test scores are. The test designers need to reduce the measurement errors or unreliability to maximize reliability in order to ensure the consistency of measurement. Therefore, the test was piloted with 45 fourth-year students (1) to check its reliability, (2) to find out the average time to complete the test, and (3) to identify problems with the test if there were any before the real use.

3.2.2.3 Data collection

The same test was administered to the three groups of subjects: 35 second-year, 34 third-year, and 35 fourth-year students at the date and time agreed on the students. To complete the test, the students were allowed 60 minutes for their translation responses. Nurweni and Read (1999) allowed one minute for their subjects to translate two (single) words. This test contains 60 words (30 technical and 30 academic words) and 30 technical noun phrases, so 45 minutes would be sufficient to complete the test.

3.2.2.4 Analysis of scores from the test

Numeric data need a statistical formula for the analysis, and numerical analyses of scores from the vocabulary test in this study apply the software SPSS for Windows, which provides a variety of statistical formula for social science research. This phase of the study aimed to find out the difficulties with technical words, academic words, and technical noun phrases, to answer research Questions 2 and 3. The three groups of participants were tested only once. To find the difficulties with the different types of vocabulary, comparisons were carried out using one-way analysis of variance (ANOVA).

The statistic formula was used depending on the research questions below:

(2) How well do the students know each type of vocabulary from the electrical engineering corpus?

(2.1) Which type of vocabulary between technical and academic words do the students know more?

(2.2) Which type of vocabulary between technical words and technical noun phrases do the electrical engineering students know more?

(3) How do the students' study levels affect their knowledge of vocabulary?

a. Research Question 2.1-2.2: A comparison among the mean scores from three types of vocabulary (technical words, academic words and technical noun phrases) was conducted, so ANOVA was used

(Types of vocabulary = independent variables; mean scores from each type of vocabulary = dependent variables).

b. Research Question 3: A comparison among the mean scores from the three groups of the students (second year, third year and fourth year) was conducted, so ANOVA was used (Year of study = independent variables; mean scores from each year or group = dependent variables).

3.3 The research tools and their reliability

The research tools used in this study were piloted to check their reliability. The processes to check reliability of these tools are discussed as follows.

3.3.1 The trial of the rating scale used for classifying single words

As discussed in the former section, the rating scale used in this study was adapted from Chung and Nation (2003-2004) and checked for reliability by three experts in the electrical engineering field. All the three experts, two associate professors from KKU and one associate professor from SUT, have got their PhD in electrical engineering from overseas. This means that all of them are proficient in English, have got involved with studying electrical engineering textbooks written in English, and become qualified as electrical engineering experts, to check the reliability of the rating scale. The reliability of the rating scale for each of the processes of the trial is discussed below.

3.3.1.1 The training for the raters

To have the three experts check the reliability of the rating scale, it was essential to train them how to use the scale and its criteria. The material for training was produced from the random words from each group of words identified by the researcher (see appendix D, page 193).

The training in this study was conducted three times according to the availability of the raters. It started with an explanation of the purposes of the study and the purposes of the scale. The criteria were given for the raters to study until they understood all of them. This process took around ten minutes. Then, the rater and the researcher did an exercise with 50 words shuffled together (see appendix D, page 194), rating all the words with number 1 to 5 (1 = function word, 2 = general (content) word, 3 = general word used as technical word, 4 = scientific/technical word from other fields, and 5 = technical word from the electrical engineering field). This process helped the rater to become familiar with the use of the scale and enabled him to use it independently. This exercise took about ten minutes. After this process, the rater was allowed ten minutes to work with 60 other words independently, and the scores from this part were used to calculate the reliability of the Rating Scale. All together, training and checking took around 30 minutes.

3.3.1.2 The inter-rater reliability of the rating scale

The rating scale used by Chung and Nation (2003-2004) had four steps and was checked for reliability by the use of a reliability accuracy score, to estimate the degree of agreement between the researcher's results and the rater's. In their study, only one inter-rater was involved and the items were rated in four groups. The reliability of the scale, therefore, depended on two persons only. The criteria for acceptable inter-rater reliability by Rosenthal (1987) is a raw accuracy score of 0.7. Their rating scale received 0.95, which is much higher than the determined criteria.

Though the rating scale for this study was adapted from Chung and Nation (2003-2004), it is different in that this study involved 3 inter-raters and the items were rated in 5 groups. As there were more inter-raters and more steps, the reliability of the rating scale depends on the consistency of the scores from the raters as well as from the researcher. The reliability of the rating scale for this study was carried out in a very simple way. To obtain the consistency, the scores from each item rated by the three raters were first compared to find a consistent number. The scores were deemed consistent if all the raters gave the same number or at least two of them did. To check the reliability, the number rated by the researcher was then checked against the consistent score by the experts. If consistent, the consistency score is 1. If not, the score becomes 0. (The score '1' means that the researcher classified the word into the right group, while the score '0' means that the researcher might classify the word into the wrong group or that the raters have rated the word inconsistently.) This means that the consistency score is obtained from three out of four or from the unanimity of the researcher and the raters.

The score results from the three raters are shown in Table 3.4 as follows.

Table 3.4 Inter-rater reliability of the rating scale: words classified into Groups

Raters / Words	Researcher	Rater 1	Rater 2	Rater 3	Consistency
1. AMPLIFIER	5	5	5	5	1
2. AND	1	1	1	1	1
3. ARMATURE	5	5	5	5	1
4. AS	1	1	1	1	1
5. ATOM	4	4	4	4	1
6. BANDWIDTH	5	5	5	5	1
7. BAR	3	4	2	3	0
8. BASE	3	3	3	3	1
9. BINARY	4	4	4	4	1
10. BIT	4	4	3	4	1
11. BY	1	1	1	1	1
12. CALLED	2	2	2	2	1
13. CAPACITOR	5	5	5	5	1
14. CONDUCTOR	5	5	5	5	1
15. CORRELATION	4	4	4	2	1
16. CURVE	4	3	4	3	0
17. DIODE	5	5	5	5	1
18. ELECTRON	5	5	4	4	0
19. EQUAL	2	1	2	2	1
20. EQUATION	2	4	4	3	0
21. EQUILIBRIUM	4	2	4	4	1
22. EXCITATION	3	5	3	3	1
23. FIGURE	2	3	2	2	1
24. FIND	2	2	2	2	1
25. FREQUENCY	3	5	3	3	1
26. FROM	1	1	1	1	1
27. GENERATOR	5	5	5	5	1
28. GIVEN	2	2	2	2	1

Table 3.4 (Cont.) Inter-rater reliability of the rating scale: words classified into Groups

Raters / Words	Researcher	Rater 1	Rater 2	Rater 3	Consistency
29. HARMONICS	3	5	5	5	0
30. HAVE	1	1	2	1	1
31. IF	1	1	1	1	1
32. INDUCTANCE	5	5	5	5	1
33. INERTIA	4	4	4	5	1
34. LINEAR	4	4	3	4	1
35. MACHINE	2	5	2	5	0
36. MEANS	3	2	2	3	0
37. MULTIPLYING	4	2	4	4	1
38. NOT	2	1	1	1	0
39. OF	1	1	1	1	1
40. ON	1	1	1	1	1
41. ONLY	2	2	1	2	1
42. OXIDE	4	3	4	4	1
43. POLE	3	5	4	5	0
44. RESISTOR	5	5	5	4	1
45. SAME	2	2	2	1	1
46. SECONDARY	3	2	3	3	1
47. SHORT	3	2	2	3	0
48. SIGNAL	5	5	4	5	1
49. SQUARE	4	4	3	4	1
50. SUBSTRATE	4	3	4	4	1
51. SWITCH	3	5	3	3	1
52. TABLE	3	2	2	3	0
53. TERMINAL	3	3	3	3	1
54. THAT	1	1	1	2	1
55. THIS	1	1	1	2	1
56. TO	1	1	1	1	1
57. TORQUE	5	4	4	5	0

Table 3.4 (Cont.) Inter-rater reliability of the rating scale: words classified into Groups

Raters / Words	Researcher	Rater 1	Rater 2	Rater 3	Consistency
58. TWO	2	2	2	2	1
59. VALUE	2	3	2	2	1
60. WITH	1	1	1	1	1
			Total scores		**48**
			Reliability		**48 ÷ 60 = 0.8 or 80%**

According to Table 3.4 the total number of consistent scores is 48 out of 60 and the reliability is 0.8 or 80 %. This means that 80 % of the words were correctly classified into the right groups according to the rating scale.

Interestingly, reliability is higher if the purposes of the study and the classifications of the vocabulary into categories in this study are considered. Virtually, five groups of words in the rating scale are classified into three main categories—Group 1 is classified as function words, Group 2 is general words (including academic words), and Groups 3-5 are technical words. Thus, with these classifications, the scores from items 7, 16, 18, 29, 43, and 57 in Table 3.4 could be reconsidered and counted consistent since the raters and the researcher rated them as type 3-5 which refer to technical words. Therefore, the total consistency scores become 54 (48+6) and the reliability is 90 %. See Table 3.5 below.

Table 3.5 Inter-rater reliability of the rating scale: words classified into types

Raters / Words	Researcher	Rater 1	Rater 2	Rater 3	Consistency
1. AMPLIFIER	5	5	5	5	1
2. AND	1	1	1	1	1
3. ARMATURE	5	5	5	5	1
4. AS	1	1	1	1	1
5. ATOM	4	4	4	4	1
6. BANDWIDTH	5	5	5	5	1
7. BAR	3	4	2	3	1
8. BASE	3	3	3	3	1
9. BINARY	4	4	4	4	1
10. BIT	4	4	3	4	1
11. BY	1	1	1	1	1
12. CALLED	2	2	2	2	1
13. CAPACITOR	5	5	5	5	1
14. CONDUCTOR	5	5	5	5	1
15. CORRELATION	4	4	4	2	1
16. CURVE	4	3	4	3	1
17. DIODE	5	5	5	5	1
18. ELECTRON	5	5	4	4	1
19. EQUAL	2	1	2	2	1
20. EQUATION	2	4	4	3	0
21. EQUILIBRIUM	4	2	4	4	1
22. EXCITATION	3	5	3	3	1
23. FIGURE	2	3	2	2	1
24. FIND	2	2	2	2	1
25. FREQUENCY	3	5	3	3	1
26. FROM	1	1	1	1	1
27. GENERATOR	5	5	5	5	1
28. GIVEN	2	2	2	2	1

Table 3.5 (Cont.) Inter-rater reliability of the rating scale: words classified into types

Raters / Words	Researcher	Rater 1	Rater 2	Rater 3	Consistency
29. HARMONICS	3	5	5	5	1
30. HAVE	1	1	2	1	1
31. IF	1	1	1	1	1
32. INDUCTANCE	5	5	5	5	1
33. INERTIA	4	4	4	5	1
34. LINEAR	4	4	3	4	1
35. MACHINE	2	5	2	5	0
36. MEANS	3	2	2	3	0
37. MULTIPLYING	4	2	4	4	1
38. NOT	2	1	1	1	0
39. OF	1	1	1	1	1
40. ON	1	1	1	1	1
41. ONLY	2	2	1	2	1
42. OXIDE	4	3	4	4	1
43. POLE	3	5	4	5	1
44. RESISTOR	5	5	5	4	1
45. SAME	2	2	2	1	1
46. SECONDARY	3	2	3	3	1
47. SHORT	3	2	2	3	0
48. SIGNAL	5	5	4	5	1
49. SQUARE	4	4	3	4	1
50. SUBSTRATE	4	3	4	4	1
51. SWITCH	3	5	3	3	1
52. TABLE	3	2	2	3	0
53. TERMINAL	3	3	3	3	1
54. THAT	1	1	1	2	1
55. THIS	1	1	1	2	1
56. TO	1	1	1	1	1

Table 3.5 (Cont.) Inter-rater reliability of the rating scale: words classified into types

Raters / Words	Researcher	Rater 1	Rater 2	Rater 3	Consistency
57. TORQUE	5	4	4	5	1
58. TWO	2	2	2	2	1
59. VALUE	2	3	2	2	1
60. WITH	1	1	1	1	1
			Total scores		**54**
			Reliability		**54 ÷ 60 = 0.9 or 90%**

In conclusion, the inter-rater reliability of the rating scale is 0.8 or 80 % according to the classification into groups (1-5) in the scale, and it is 0.9 or 90 % according to the classification as vocabulary types (function, general, and technical). These two figures are higher than the acceptable value (0.7) Chung and Nation (2003) used in their study. Therefore, the Rating Scale as a research tool with a reliability of 0.8 and 0.9 can be used for this research study.

3.3.2 The trial of the criteria for classifying noun phrases

Like the rating scale, the criteria used to classify noun phrases into non-technical and technical were piloted with three experts in the electrical engineering field to check their reliability, the same lecturers who checked the reliability of the rating scale. The material for training and checking the reliability can be seen in appendix E, page 196).

3.3.2.1 The training for the raters

The training started with an explanation of the purposes of the study and of the criteria to help the raters become familiar with the terms, both technical and non-technical. This process took around 3-5 minutes. After the rater understood the criteria, the rater, together with the researcher, went through an exercise (see appendix E, pages 197), rating the given noun phrases with 1 = non-technical and 2 = technical. This exercise took around 5 minutes. After the exercise was completed, the rater was allowed to classify noun phrases independently with 30 other noun phrases (see appendix E, page 198). This process took about 3-5 minutes. The scores from this part were used to find the inter-rater reliability of the criteria. Similar to the rating scale, the training was conducted three times according to the availability of the experts.

3.3.2.2 The inter-rater reliability of the criteria

The scores from the three raters were shown in Table 3.6 below. The inter-rater reliability of the criteria for classifying non-technical and technical noun phrases depends on the consistency of the scores from the raters and from the researcher, similar to that of the rating scale for single words.

Table 3.6 The inter-rater reliability of the criteria used for classifying non-technical and technical noun phrases

Raters / Noun Phrases	Researcher	Rater 1	Rater 2	Rater 3	Consistency
1. accepted tests	1	1	1	2	1
2. active power	2	2	2	2	1
3. apparent power	2	2	2	2	1
4. average duck	1	1	2	2	0
5. basic characteristics	1	1	1	1	1
6. color image	1	1	2	2	0
7. combined action	1	1	1	2	1
8. conduction band	2	2	2	2	1
9. discrete components	1	1	2	2	0
10. equivalent circuit	2	2	2	2	1
11. first stage	1	1	1	1	1
12. general purpose applications	1	1	1	1	1
13. induction motor	2	2	2	2	1
14. input signal	2	2	2	2	1
15. line current	2	2	2	2	1
16. magnetic field	2	2	2	2	1
17. major problem	1	1	1	1	1
18. minimum weight	1	1	1	1	1
19. opposite direction	1	1	1	1	1
20. phasor diagram	2	2	2	2	1
21. power quality	1	1	2	2	0
22. second stage	1	1	1	1	1
23. secondary voltage	2	2	2	2	1
24. straight line	1	1	1	1	1
25. synchronous generators	2	2	2	2	1
26. terminal voltage	2	2	2	2	1

Table 3.6 (Cont.) The inter-rater reliability of the criteria used for classifying non-technical and technical noun phrases

Raters / Noun Phrases	Researcher	Rater 1	Rater 2	Rater 3	Consistency
27. time delay	1	2	2	2	0
28. transition region	2	2	2	2	1
29. transmitted signal	2	2	2	2	1
30. voltage gain	2	2	2	2	1
			Total Scores		**25**
			Reliability		**25 ÷ 30 = 0.8333 or 83.33%**

According to Table 3.6, the total number of consistent scores is 25 out of 30 and the reliability of the criteria is 0.833 or 83.33 %. This means that the criteria used for classifying non-technical and technical noun phrases is reliable and can be used for this research study.

3.3.3 The trial of the vocabulary test

The translation test was designed with 90 items selected from the top frequency from the lists obtained from the corpus (see appendix F, page 199 and appendix G, page 206). All of these items are nouns since subjects' knowledge of technical and academic words are compared with their knowledge of technical noun phrases. Thus, the test contains 30 nouns from technical words, 30 nouns from academic words, and 30 technical noun phrases. It was piloted with 45 fourth-year electrical engineering students at Suranaree University of Technology to find its reliability before it was used with the participants of the study. Additionally, to get more information for the reliability, ten students out of 45 were interviewed for some problematic items from the test results and scores.

3.3.3.1 The criteria for marking answers from the test

The translations given by the students were checked against the answer keys which were rechecked by three electrical engineering teachers. The answers were scored 1 and 0 only. The answer which was correct or partly correct was marked 1, but the one which was totally incorrect or not answered was marked 0. Some examples are displayed in Appendix H (page 213).

Marking was done two times in two weeks to recheck whether the marker made any mistakes with any items and their score results. After the first time, the scores were left for a week before the second time.

3.3.3.2 The findings from the test

To check the internal consistency measure of the test or the test reliability, the result scores were processed with the SPSS 13.0 for Windows and Alpha Coefficient or Cronbach's alpha (α) was utilized. Cronbach's alpha is the most common internal consistency measure, calculated from the pairwise correlations between items. The alpha coefficient can range from 0.00-1.00 but an α of 0.6-0.7 is commonly acceptable as a rule of thumb to show that a test is consistent or reliable, and 0.8 or higher indicates good reliability (Cortina, 1993). The alpha coefficient can be interpreted as the percent of consistent or reliable variance in the scores on a test.

For example, the alpha value of 0.7 is then interpreted as 70 % consistent or reliable (Brown, 2005 and Fraenkel and Wallen, 1993).

In this study, the reliability estimate is based on a 45-student sample and result scores from 90 items from the test. The result from the SPSS shows that the alpha coefficient is 0.926, from which the test can be interpreted as 92.6 % reliable. Compared with the rule of thumb (0.6-0.7), this figure is higher, and higher than 0.8 (good reliability). This means that the translation test with an alpha coefficient of 0.926 is a good research tool for this study.

3.3.3.3 The findings from the interview

The findings from the pilot of the test show that some answers from the students are still doubtful. Only twenty out of forty five students gave the right answer to the word ‘equation’ and seventeen out of the whole group gave the correct answer to the word ‘equivalent circuits’. There are some more words to which a few students gave correct answers, e.g. reactive power, concepts, section, transmitted signal, terminal voltage, generated voltages, receiver, terminals and amplifier. These words occur with high frequency in electrical engineering texts and electrical engineering students need them in order to understand the texts. The doubtfulness lies on the following questions. If the students don’t really know these words, how can they understand electrical engineering textbooks? Are the test items problematic to the students? Is the test reliable?

Therefore, the findings from the pilot needed to be rechecked by the use of an interview. To do this, ten students were randomly selected for the interview, and ten items with incorrect answers from each student’s test were selected. The interviewees were asked to give meaning to the selected words again. Some follow-up questions were used to get more information from the interviewee. The interview was conducted in Thai. The information from each interviewee was recorded, transcribed and translated into English.

The results from the interview were used as an indication for the test reliability. If the findings from the interview are consistent with the findings from the test, the test has high reliability. In contrast, if the two findings are inconsistent, the test must be revised. The interview questions and the transcriptions from the interview are shown in Table 3.7 and Table 3.8 as follows.

Table 3.7 The interview questions

Questions
1. Look at these words one by one. (Show the student ten words they gave incorrect answer.) 1.1. Which one do you know? 1.2. (If yes) What does it mean in Thai? 1.3. (If no) Have you ever seen it before? (If yes) Why don't you pay attention to its meaning? 1.4. (If yes with the incorrect answer) Why couldn't you give its meaning during the test the other day?
2. Which word is used more as a loan word or as a Thai pronunciation of an English word? 2.1. Are you familiar with its Thai meaning? 2.2. Can you explain it?

Table 3.8 Findings from the interview

Student	Scores (consistent answers)	Question 1	Question 2
1	Student 1 gave consistent answers for 18 tested items. This time he gave correct answers for the items '*armature*' and '*terminal voltage*'.	He said "I have seen all the words here; I was not confident with the meaning at first and I skipped them and forgot to give their meaning."	He said, "*line-to-neutral voltages, armature, stator windings, analysis, secondary voltage, requirements, input signals, amplifier, coil, terminals, line current, errors, line, terminal voltage, generators, output voltage,* and *equation* can be used as loan words." He continued, "When we discuss among friends we use English words instead of using Thai meanings though we know them."
2	Student 2 gave consistent answers for 17 tested items. This time he gave correct answers for the items '*terminal voltage, line* and *coil*.	He said "I have seen all the words here; I was not confident with their meaning at first and I saw my friends submitting the test, so I then finished in a big hurry."	He said, "*power factor, electrons, regions, line, errors, flux, resistance, coil, amplifier, secondary voltage, analysis, capacitance, windings,* and *impedance*" can be used as loan words. He added "as they are used as English words or loan words, frequently we cannot recognize their Thai meaning sometimes."
3	Student 3 gave consistent answers for 19 tested items.	She said "I have seen all the words here; I just temporarily forgot the meaning of the word "*reactive power*" the other day."	She said, "most of the words here are used as loan words and this makes me confused with their Thai meaning sometimes."

Table 3.8 (Cont.) Findings from the interview

4	Student 4 gave consistent answers for 18 tested items.	She said "I have seen all the words here; Last time I was not confident with the meanings of the words '*gates*' and '*flux*', so I just skipped and forgot them.	She pointed out, "*impedance, cycle, gates, secondary voltage, flux, errors* and *output voltage* are normally used as loan words in class and discussion." She added "I don't know many words, but, in reading, equations and figures are more important than the Thai meanings of these words."
5	Student 5 gave consistent answers for 17 tested items.	She said, "I have seen all the words here; Last time I could not give the Thai meaning to the words 'gates', 'coil' and 'terminal' because I was not sure, so I was not confident to write down the meaning."	She said, "*armature, gates, synchronous generators, line current, flux* and *output voltage* are frequently used as loan words." She added "The teachers use them as loan words in class and so do we in. discussion among friends
6	Student 6 gave consistent answers for 17 tested items.	He said, "I have seen all the words here; I could not recognize the meaning of *equation, torque* and *resistance* last time, but I thought I didn't know them, so I just skipped them."	He said, "*phasor diagram, load, source, output voltage, transformer, systems line, torque, errors, amplifier* and *stator* are frequently used as loan words."

Table 3.8 (Cont.) Findings from the interview

7	Student 7 gave consistent answers for 15 tested items.	He said, "I have seen all the words here; I got confused with the meaning of the words '*generated voltage*' and '*terminals*'; I was not confident with the word '*converter*' though I know its meaning; for the word '*capacitance*', I confused it with the word '*capacitor*'; I know the word '*line-to-neutral-voltages*', but it is difficult for me to give its Thai meaning or to explain it in Thai; I know the word '*portion*' but mostly we use the word '*ratio*' much more."	He pointed out, "*concepts, section, line, converter, windings* and *line-to-neutral voltages* are normally used as loan words in class, so it is difficult to recognize their Thai meanings sometimes."
8	Student 8 gave the consistent answers for18 tested items. On the test, he gave the right answer for the word '*magnetic field*', but he could not recognize its meaning in the interview.	He said, "I have seen all the words here. Last time I could not recognize the meaning of the word '*secondary voltage*'; for the word '*magnetic field*'. I think I know it but cannot think of its meaning now.	He said, "*impedance, armature, stator, windings, ratio, flux, errors*, and *line* are used as loan words in class and discussion."

Table 3.8 (Cont.) Findings from the interview

9	Student 9 gave consistent answers for 16 tested items. He had a wrong reading with the word '*electrons*'. He read it as '*electone*'. He had problems with the words '*received signal*', '*terminal voltage*' and '*cores*'.	He said "I have seen all the words here; I was not confident with the word '*received signal*' and it is difficult to give the Thai meaning to the words '*terminal voltage*' and '*cores*'."	He pointed out, "*concepts, electrons, terminal voltage, flux, synchronous motors, cores, coil, amplifier* and *secondary voltage* are normally used as loan words; it is difficult to give Thai meanings to these words as we understand English words better."
10	Student 10 gave consistent answers for16 tested items. He had difficulties giving Thai meanings to the words 'electrons', 'section', 'received signal' and 'equivalent circuit'.	He said, "I have seen all the words here; I know these words, but it is difficult to give their Thai meaning, so I just skipped some words last time."	He said, "*equation, power factor, frequency, electrons, generators, received signal, electric field, distribution, receiver, amplifier, windings,* and *brushes* are used as loan words and I understand the English words better.",

Apart from the transcriptions above, the students admitted that they had seen all the words before the test, but they did not know some words and paid no attention to their meaning because those words might not be important to help them understand the electrical engineering texts they were assigned to study. In fact, they said equations and figures would play a more important role in understanding texts.

The students might have problems with some words, but these problems lie with their recognition ability. They said that they were familiar with the words but could not recognize their meaning during the test. They got stuck with the

Thai meanings because many words from the test are used as English or loan words and their Thai equivalents were rarely mentioned or used in their study, so they were more familiar with the English words than their Thai meanings. Therefore, the use of these words as loan words could make the students confused and unconfident with their Thai equivalent sometimes, and they could have problems when they need to give Thai meaning to these words.

However, it was found from the interview that most answers were consistent to those of the test. Out of 20 tested items, students 1-10 gave consistent answers respectively as 18, 17, 19, 18, 17, 17, 15, 18, 16, and 16. This is counted as 17.1 on average or 85.5 %. This means that the use of loan words and the students' recognition ability with Thai meanings have a very low effect on the results from the test. To sum up, the test has high reliability since the data from the test and from the interview are highly reliable (the reliability is 92.6 % and the consistency with the interview is 85.5 %). Therefore, this translation test can be used to collect data for this research study with high reliability.

3.4 Summary of research tools and methods

The design of this study discusses quantitative methods. The whole procedures of the study were divided into two phases. Phase 1 focused on the identification of types of vocabulary from the corpus while Phase 2 investigated the engineering knowledge of the identified vocabulary from Phase 1. For Phase 1 of the research, a specialized corpus of approximately 120,000 words was created and used as samples and subjects. General, technical and academic words as well as general, technical and academic noun phrases were identified with the applications of criteria and instruments including Oxford WordSmith Tools 4.0, the rating scale, the Academic Word List, Dictionary.com, and Yang’s presuppositions. Data obtained from the corpus were analyzed in terms of percentage of types and tokens, and frequency of occurrence. The research Phase 2 concerned the test of vocabulary knowledge. Samples were 104 electrical engineering students. The research instrument used to collect data was a vocabulary test with translation format with 120 items randomly selected from each type of vocabulary from Phase 1. The analysis of the data from the test scores was carried out by the use of one-way analysis of variance or ANOVA.

The results from the piloting of the research tools for this research study show high reliability. The Rating Scale for single words and the criteria for noun phrases were checked for inter-rater reliability with three experts. The Rating Scale has 80 % reliability when used to classify single words into five groups (function, general, general used as technical, scientific/technical from other fields, and technical from the electrical engineering field) and 90 % reliability when used to classify words into three main categories (function, general, and technical). The criteria for classifying noun phrases has 83.33 % reliability. The translation test has 92.6 % reliability. Therefore, with high reliability, these research tools were used to collect data for this study.

CHAPTER 4

FINDINGS FROM THE ELECTRICAL ENGINEERING CORPUS

4.1 The coverage of different kinds of vocabulary estimated by researchers

The estimates by researchers are that, in academic texts, the GSL covers 80 % of running words; the AWL 10 %; technical words 5 % and rare words 5 % (Nation and Waring, 1997; Coxhead, 2000; and Nation, 2001). These researchers classified different kinds of words by range and frequency or by the use of available lists such the GSL (West, 1953) and the AWL (Coxhead, 2000). To make the process for classifying words easier, Paul Nation from Victoria University of Wellington, New Zealand, has developed a software program called RANGE. This program identifies different kinds of words by running the corpus against the GSL and the AWL, which are included in the program. The program identifies and classifies words into four kinds or levels, the 1^{st} 1000, 2^{nd} 1000, AWL, and technical + rare words. The 1^{st} and 2^{nd} 1000 are words from the GSL; the AWL or academic words are words outside the GSL and occur in wide range and with high frequency; technical words are words with specialized meaning in a specific field; and rare words are words outside the GSL and the AWL and can be technical words from other specific fields (Nation, 2001).

To see if the proportions of word levels from an academic text are consistent with those estimates by researchers, the corpus in this present study which contained around 122,000 running words was run by RANGE. The findings are shown in Table 4.1 below.

Table 4.1 Proportion of different types of words from the whole corpus

Levels of vocabulary	Types	Tokens
1st 1,000 words (GSL)	1,778 (24.73 %)	84,214 (68.91 %)
2nd 1,000 words (GSL)	727 (10.11 %)	7,323 (6.00 %)
AWL	1,034 (14.38 %)	12,085 (9.89 %)
Technical + rare words	3,651 (50.78 %)	18,587 (15.20 %)
Total	**7,190 (100 %)**	**122,209 (100 %)**

Table 4.1 shows the proportions of different types of words counted in types and tokens (running words). Totally, the corpus contains 122,209 tokens which comprise 7,190 word types. In detail, GSL (1st 1,000 + 2nd 1,000 words) covers around 75 % of the tokens from the entire corpus; AWL covers 9.89 % of the tokens; and technical and rare words cover 15.20 %. From these figures, only the coverage of the AWL is close to the estimate. While the GSL is 5 % lower than the estimate, the combination of technical with rare words is more than 5 % higher.

However, this way of classifying words has some flaws which can distort the real coverage of vocabulary from different kinds or levels since some words from the GSL and AWL can provide technical meanings in different contexts and can be counted as technical words. Chung and Nation (2003) identified technical vocabulary with the rating scale based on the degree of technicalness of words in context. They found that many technical words are from common words, including words from the GSL and the AWL. Hyland and Tse (2007) found that words from the AWL can be homographs which can provide different meanings in different contexts, and these homographs should not be included as academic words. Therefore, identified by the GSL and AWL in RANGE, technical words from the corpus, which are words from the GSL and AWL, can be classified into wrong levels. In addition, an individual word can be a part of a multi-word lexical unit as a complex noun phrase. To separate individual words from a phrase would impair the actual meaning of the words when used in the phrase. Therefore, to get more real proportions of different kinds of vocabulary, individual words and multi-word items should be analyzed separately, and both of them should be identified by checking against not only the GSL and the AWL but also their meaning according to the context they are in. The rest of this chapter shows the results received from this method.

4.2 The coverage of single words and noun phrases in the electrical engineering corpus

From the whole corpus, multi-word lexical units or, in this case complex noun phrases, were identified and separated from individual (single) words. Both single words (SWs) and complex noun phrases (NPs) (i.e. all lexical units) were counted as running words, tokens, and types. A running word refers to every individual word from the corpus. An individual lexical unit in the corpus was counted as a token, for example, the SW '*motor*' is a (single word) token every time it occurs alone and the NP '*induction motor*' is also a (noun phrase) token. Thus, both *motor* and *induction motor* are counted as lexical units and as tokens. Inflected forms of SWs and/or NPs were counted as separate types, for example, the SWs ‘motor’ and ‘motors’ were counted as two types, and the NPs ‘induction motor’ and ‘induction motors’ are also counted as two types. In other words, lexical units were not lemmatised. The findings from this part answer the following research question.

Research Question 1.1: *What is the proportion of words and noun phrases in the electrical engineering corpus?*

This section presents proportion of SWs and NPs from the corpus under two headings, e.g. (1) high proportion of noun phrases; (2) high proportion of technical noun phrases.

4.2.1 High proportion of complex noun phrases in the corpus

Complex noun phrases (NPs) were separated from single words (SWs). Remember that SWs include both function words and content words, while NPs have no function words. The proportion of SWs and NPs is shown in Table 4.2 as follows.

Table 4.2 Proportion of single words and noun phrases in the electrical engineering corpus

Kinds of lexical units	**Types**	**Tokens**	**Running words**
Single words	4,689 (43.69 %)	96,780 (90.04 %)	96,780 (79.20 %)
Noun Phrases	6,043 (56.31 %)	10,707 (9.96 %)	25,429 (20.80 %)
Total	**10,732 (100 %)**	**107,487 (100 %)**	**122,209 (100 %)**

Table 4.2 shows the proportion of words in the corpus which occur as part of noun phrases. It is clear that NPs represent a large proportion of the corpus. The corpus contains 122,209 running words, of which no less than 25,429 are part of NPs; this is 20.80 % of the total running words. In short, more than one in every five running word is part of a NP.

This is, of course, not because NPs are frequently repeated; it is because there are so many different ones. This is shown by "types" column in the table. Excluding NPs, there are 4,689 different SW types in the corpus. But there are 6,043 NP types. As there are 10,707 NP tokens, this means that each NP occurs only about 1.77 times in the corpus (i.e. a type/token ratio of 1:1.77).

The figure of the SW types is somewhat distorted by the presence of function words, which are relatively few in number (150 types), but which in many cases (*the, of, in, are, etc.*) occur everywhere and often (54,550 tokens). This tends greatly to decrease the type/token ratio. If we exclude them, we are left with 42,230 SW tokens (instead of 96,780) and 4,539 SW types in stead of 4,689. This still leaves us with a type/token ratio of about 1:9 for single content words.

To summarize table 4.2; there are a relatively large number of NP types, most of which are used only once or twice; and a relatively small number of single content word types, with a much higher frequency. This means that NPs represent a relatively high learning load (since, obviously, we learn types, not tokens.)

4.2.2 High proportion of technical noun phrases

NPs were classified into three vocabulary levels i.e. general noun phrases (GNPs), technical noun phrases (TNPs) and academic noun phrases (ANPs). Since this present study focuses on technical and academic vocabularies, all of which are content words and carry meanings of the text, only content words from SWs are used to compare with other types of lexical units. Therefore, all function words are excluded since function words do not carry much meaning by themselves and can distort the proportion of general words. The findings from this part also answer the following research questions.

Research Question 1.2: *What is the proportion of technical words, academic words, and general words in the electrical engineering corpus?*

Research Question 1.3: *What is the proportion of technical noun phrases, academic noun phrases, and general noun phrases in the electrical engineering corpus?*

The proportions of different kinds of lexical units are shown in Table 4.3 below.

Table 4.3 Coverage of different kinds of lexical units in the corpus

Kinds of lexical units	Types	Tokens	Running words
General content words	2,048 (19.35 %)	25,482 (48.14 %)	25,482 (37.66 %)
Technical words	895 (8.46 %)	8,406 (15.88 %)	8,406 (12.42 %)
Academic words	898 (8.48 %)	6,172 (11.66 %)	6,172 (9.12 %)
Rare words	698 (6.60 %)	2,170 (4.10 %)	2,170 (3.21 %)
General noun phrases	295 (2.79 %)	351 (0.66 %)	757 (1.12 %)
Technical noun phrases	5,500 (51.98 %)	10,069 (19.02 %)	24,061 (35.56 %)

Table 4.3 (Cont.) Coverage of different kinds of lexical units in the corpus

Kinds of lexical units	Types	Tokens	Running words
Academic noun phrases	248 (2.34 %)	287 (0.54 %)	611 (0.90 %)
Total	**10,582 (100 %)**	**52,937 (100 %)**	**67,659 (100 %)**

Table 4.3 shows the proportions of lexical units, all of which are content words in the corpus. Clearly, technical noun phrases or TNPs represent a large proportion of the corpus. From 67,659 running words, up to 24,061 are part of TNPs. That is, TNPs make up 35.56 % of all the content words in the corpus. This means that, from every three content words, there is a word used as part of a TNP.

There are a very high number of TNPs in the corpus. The figure from the table shows that from 10,582 lexical unit types, up to 5,500 or no less than 51.98 % are TNPs. Also, the figure shows that, as there are 52,937 tokens, a TNP occurs in every five lexical unit tokens.

Table 4.4 Proportion of different types of noun phrases

Kinds of Noun Phrases	Types	Tokens	Running words
General	295 (4.88 %)	351 (3.28 %)	757 (2.98 %)
Technical	5,500 (91.01 %)	10,069 (94.04 %)	24,061 (94.62 %)
Academic	248 (4.10 %)	287 (2.68 %)	611 (2.40 %)
Total	**6,043 (100 %)**	**10,707 (100 %)**	**25,429 (100 %)**

From Table 4.4, it is quite clear that, among all kinds of noun phrases, TNPs represent the highest proportion. GNPs, TNPs, and ANPs in the corpus were classified from a total of 10,707 NP tokens. The figure in the “tokens” column shows that TNPs account for 10,069 or no less than 94.04 % of all NPs in the corpus. A type/token ratio (1:1.83) indicates that each TNP occurs 1.83 times.

To sum up Table 4.3-4.4; TNPs prevail in the corpus with a large number of NP types, leaving very few as GNPs and ANPs. On average, TNPs occur one or two times in the corpus. This means that high learning load of NPs falls much more on TNPs than on other kinds.

4.3 The coverage of different types of lexical units in the corpus

Note that technical vocabulary and academic vocabulary in this study are different from other studies as this study includes both single words and noun phrases, both of which refer to here as lexical units. Also, remember that academic words in this study are from the AWL but some are used as technical words in the electrical engineering field. In this part, proportions of technical and academic lexical units are compared and presented. Also, these two kinds of lexical units are compared with other kinds (i.e. general lexical units and rare lexical units). General lexical units (GLUs) consist of general words (GWs) and GNPs. Academic lexical units (ALUs) consist of words from the AWL or academic words (AWs) and ANPs. Technical lexical units (TLUs) consist of TWs and TNPs. Rare words (RWs) are words hardly met in the text and cannot be included with GWs, AWs, and TWs. The findings in this section answer Research Question 1 as follows.

Research Question 1: *What proportion of the different types of vocabulary occurs in the electrical engineering corpus?*

The data for this section are presented under two headings, i.e. (1) higher coverage of TLUs and (2) proportions of lexical units in detail.

4.3.1 Higher coverage of TLUs

The data from the corpus reveal different proportions of lexical-unit levels. It was found that TLUs represent larger proportion than do ALUs and GLUs. The proportions of different lexical units are shown in Table 4.5 below.

Table 4.5 Proportion of vocabulary in electrical engineering corpus

Kinds of lexical units	**Types**	**Tokens**	**Running Words**
Function words	150 (1.40 %)	54,550 (50.75 %)	54,550 (44.63 %)
General (GWs + GNPs)	2,343 (21.83 %)	25,833 (24.03 %)	26,239 (21.47 %)
Academic (AWs + ANPs)	1,146 (10.68 %)	6,459 (6.01 %)	6,783 (5.55 %)
Technical (TWs + TNPs)	6,395 (59.59 %)	18,475 (17.19 %)	32,467 (26.57 %)
Rare words	698 (6.50 %)	2,170 (2.02 %)	2,170 (1.77 %)
Total	**10,732 (100 %)**	**107,487 (100 %)**	**122,209 (100 %)**

Table 4.5 shows all proportions of vocabulary in electrical engineering corpus. It is clear that function words comprise almost half of total running words in the corpus. TLUs have a large proportion with 26.57 % of all running words, while

GLUs have 21.47 % and ALUs have only 5.55 % of the whole corpus. But when function words are excluded and only general content words are compared, the percentage of all (content) lexical units becomes much higher.

Table 4.6 Proportion of lexical units from the whole corpus

Kinds of lexical units	**Types**	**Tokens**	**Running Words**
General (GCWs + GNPs)	2,343 (22.14 %)	25,833 (48.80 %)	26,239 (38.78 %)
Academic (AWs + ANPs)	1,146 (10.83 %)	6,459 (12.20 %)	6,783 (10.02 %)
Technical (TWs + TNPs)	6,395 (60.43 %)	18,475 (34.90 %)	32,467 (47.99 %)
Rare	698 (6.60 %)	2,170 (4.10 %)	2,170 (3.21 %)
Total	**10,582 (100 %)**	**52,937 (100 %)**	**67,659 (100 %)**

Table 4.6 illustrates proportions of lexical units from different kinds of vocabulary. It can be seen from the table that TLUs have the highest coverage in the corpus. Out of 67,659 running (content) words, no less than 32,467 are part of TLUs while only 6,783 are part of ALUs. That is, TLUs cover 47.99 % of total content words, while ALUs cover 10.02 %. In other words, TLUs cover 26.97 % more of the electrical engineering corpus than ALUs. This means one from every two content words in the corpus is a TLU or part of a TLU, while one from every ten is an ALU or part of an ALU.

There are more TLUs in electrical engineering corpus than ALUs. This can be concluded from the high number of TLU types in Table 4.6. The figure from the “types” column in the table shows that TLUs make up 6,395 types or 59.60 % out of 10,582 total types. However, TLUs have lower repetition than ALUs. Each TLU occurs two or three times while each ALU occurs more than five times. This can be seen from the “types” and “tokens” columns in the table. The type/token ratio of TLUs is about 1:2.89 while that of ALUs is 1:5.63.

TLUs occur with higher proportion in the corpus than GLUs (in the case that function words are excluded). Non-function-word GLUs consist of 26,239 running words or 38.78 % while TLUs consist of 32,467 or 47.99 %. While almost one from every two content words is a TLU or part of a TLU, more than one from every three is a GLU or part of a GLU. This can find this percentage from the ratio of TLU and GLU running words to the total number of running words (i.e. 32,467/67,659 for TLUs and 26,239/67,659 for GLUs).

TLUs also occur more often in the corpus than GLUs though they have a lower number of repetitions. The higher prevalence of TLUs over of GLUs can be seen from TLU types (6,395) which are higher than GLU types (2,343). The repetition or frequency of lexical units is from the type/token ratio. The type/token ratio of GLUs is about 1:11 while that of TLUs is 1:2.89. This means each non-function-word GLU occurs 11 times on average while each TLU occurs 2.89 times.

To conclude, technical lexical units or TLUs appear at a relatively higher proportion in electrical engineering corpus than ALUs and non-function-word GLUs. TLUs cover almost a half of the content words in the text. In other words, electrical engineering corpus uses more TLUs than other kinds of lexical units. Since TLUs have a larger number of lexical unit types, they represent a much higher learning load than ALUs.

4.3.2 Proportions of lexical units in detail

Remember that lexical units include single words (SWs) and noun phrases (NPs). The proportions of TLUs and ALUs in terms of single words and noun phrases, compared with other kinds of lexical units, are shown in Table 4.7 as follows.

Table 4.7 Proportions of lexical units from the whole corpus in detail

Kind of lexical units		**Types**	**Tokens**	**Running Words**
Function (GSL)	SWs	150 (1.40 %)	54,550 (50.75 %)	54,550 (44.63 %)
General (GSL)	GWs	2,048 (19.10 %)	25,482 (23.70 %)	25,482 (20.85 %)
	GNPs	295 (2.74 %)	351 (0.33 %)	757 (0.62 %)
Academic	AWs	898 (8.36 %)	6,172 (5.74 %)	6,172 (5.05 %)
	ANPs	248 (2.31 %)	287 (0.27 %)	611 (0.50 %)
Technical	TWs	895 (8.34 %)	8,406 (7.82 %)	8,406 (6.88 %)
	TNPs	5,500 (51.25 %)	10,069 (9.37 %)	24,061 (19.70 %)
Rare	RWs	698 (6.50 %)	2,170 (2.02 %)	2,170 (1.77 %)
Total		**10,732 (100 %)**	**107,487 (100 %)**	**122,209 (100 %)**

Table 4.7 shows all proportions of lexical units which are classified into SWs and NPs. The proportion of TWs is a little higher than that of AWs. This is because TWs are more frequently used than AWs. The figures by the “tokens” column from

Table 4.7 show that TLUs are comprised of 8,406 TWs and 10,069 TNPs, while ALUs have 6,172 AWs and 287 ANPs. On average, a TW occurs more than 9 times while AWs recur about 7 times. These frequencies are from a type/token ratio, i.e. 1 : 9.4 for TWs and 1 : 6.9 for AWs. This means that both TWs and TNPs have higher coverage than AWs and ANPs and that they represent a heavy learning load for EAP learners.

Technical words (TWs) cover 895 types and 8,406 tokens. In fact, these figures are combined from three groups of technical words, i.e. common words used with technical meaning, scientific/technical words from other fields, and indexical words or words mainly found in the electrical engineering field. Three groups of technical words with their proportions are shown in Table 4.8 as follows.

Table 4.8 Different types of words comprising technical words in the corpus

Words used as technical vocabulary	Types	Tokens
Common words	289 (32.29 %)	2,836 (33.74 %)
Scientific words	273 (30.50 %)	1,414 (16.82 %)
Indexical words	333 (37.21 %)	4,156 (49.44 %)
Total	**895 (100 %)**	**8,406 (100 %)**

It is obvious that indexical words have the highest coverage and frequency. Over one third of the total number of TWs are indexical words. That is, a TW occurs every thirty running words (122,209/4,156 equals 29.40) and each word form occurs more than 12 times on average in the corpus (a type/token ratio is 1:12.48).

Interestingly, “common” (= technical common) words also have a high occurrence, taking up more than one third of the entire TWs. A technical common word occurs every 44 running words (122,209/2,836 equals 43.09). On average, one common word is recycled around 9 to 10 ten times (a type/token ratio is 1: 9.8). This means that not only indexical words but also common words with technical meanings provide a learning load to learners. Scientific words are less common, although they are still a significant presence.

4.4 The coverage of words from the AWL used in technical noun phrases

Some words from the AWL are used with technical meanings, especially when they occur with other words as noun phrases. To see the proportion of technical noun phrases containing words from the AWL, these noun phrases were used to check against the AWL. The findings are shown in Table 4.9 as follows.

Table 4.9 Proportion of TNPs with AWs

Technical noun phrases	Types	Tokens
With academic words	2,032 (36.94 %)	3,721 (36.96 %)
Without academic words	3,468 (63.06 %)	6,348 (63.04 %)
Total	**5,500 (100 %)**	**10,069 (100 %)**

Table 4.9 shows the proportion of TNPs which contain words from the AWL. It is clear that more than one third of TNPs contain at least one word from the AWL. It was found that 3,721 out of 10,069 NP tokens contain academic words. This means that a substantial number of words from the AWL are used with technical meaning in

TNPs. To see the proportion of words from the AWL, all words from TNPs were run by RANGE (to check against the AWL and the GSL). The coverage of words from the AWL used in TNPs can be seen in Table 4.10 below.

Table 4.10 Coverage of AWs in TNPs

Levels of vocabulary	**Types**	**Tokens**
Words from the GSL	437 (35.47 %)	1,648 (32.43 %)
Words from the AWL	357 (28.98 %)	2,285 (44.97 %)
Technical + Rare Words	438 (35.55 %)	1,148 (22.59 %)
Total	**1,232 (100 %)**	**5,081 (100 %)**

According to Table 4.10, it is obvious that though they are technical noun phrases, they comprise a very large proportion of words from the AWL which are frequently repeated. That is, 2,285 tokens in TNPs are words from the AWL but are accounted as technical vocabulary. From the type/token ratio, each type of these words occurs more than 6 times, while each type of words from the GSL can be found around 4 times and each technical word appears about 3 times. This means that there are a number of words from the AWL used as TNPs (perhaps with technical meaning) which add to the learning load for electrical engineering students. The examples of TNPs containing words from the AWL are illustrated in Table 4.11 as follows. All *italic* words in the table are words from the AWL.

Table 4.11 Examples of technical noun phrases containing academic words

No. of academic words in a noun phrase		
1	**2**	**3**
reactive power	*transition region*	*parallel enable* PE *input*
power *factor*	*transfer function*	*complex* combinatorial *logic functions*
unity power *factor*	*transfer function* magnitude	*individual transfer function* magnitudes
average *normalized* power	cross-*sectional area*	*uniformly distributed random* variable
small-signal *equivalent* circuit	*reverse-biased* collector junction	*communication* system *analysis* and *design*
squirrel-cage *induction* motor	per-*phase equivalent* circuit	*input* and *output image* tables
binary and four-*symbol* systems	*conduction* band equi-*energy* surfaces	balanced *positive sequence* wye connected 60Hz three *phase* source
bitline-to-cell capacitance *ratios*	*stable* line-to-*neutral* voltages	-
two-sided average *normalized* power spectrum	single-*phase* unity power *factor* load	-
shell-type and a *core*-type transformer	three-*phase*, unity power *factor* synchronous motor	-

Table 4.11 exemplifies some TNPs containing words from the AWL which are technically used with technical meanings. From these examples, it can be seen that words from the AWL are not limited to providing meanings which are common to all academic texts. Many of them are homographs whose meanings vary according to context. These words occur with other type of words and become technical such as *reactive* power, *induction* motor, *bias* current, etc. Some are used together with words

in their groups and become technical, for examples, *transfer function*, *transition region*, *potential source*. To sum up Table 4.11, many words from the AWL can provide technical meaning when used together with other words as technical noun phrases.

4.5 Summary of findings from the corpus

When the corpus was analyzed and run with RANGE, the proportion of academic vocabulary was close to the estimate by researchers. However, this proportion became much lower when SWs and NPs were separated and classified with their meanings in the electrical engineering context. With this method, it was found that NPs, most of which are technical, made up a very high proportion. TNPs had much higher coverage than ANPs. Similarly, TWs occur as a higher proportion than AWs. Therefore, with a combination of lexical units from TWs and from TNPs, TLUs made up a high proportion, 26.57 % of running words. In the same way, when lexical units from AWs were combined with those from ANPs, ALUs fell to a very low proportion with 5.55 %. In terms of lexical unit types, TLUs can be found in the highest proportion at 59.59%, while ALUs stand at 10.68 %. These percentages become much higher when function words are excluded and only content words are compared. Among all (content) running words in the corpus TLUs comprise 47.99 %. Therefore, TLUs represent a very large proportion of the vocabulary in electrical engineering corpus and fill out the learning load for electrical engineering students.

It was found that technical words or TWs are comprised of three kinds of words used with technical meaning in the electrical engineering context, i.e. common words (including words from the GSL and AWL), scientific words, and indexical words. Among these three types, indexical words have the highest proportion, while scientific have the lowest. Common words also have high coverage. Interestingly, it was also found that there were a large number of words from the AWL used in TNPs. These findings indicate that many words from the GSL and AWL can provide technical meanings to electrical engineering context.

CHAPTER 5

FINDINGS FROM THE VOCABULARY TEST

5.1 Administering the translation test, marking and analyzing scores

The vocabulary test was meant to be administered with 120 electrical engineering students as subjects at Khon Kaen University: 40 from second year, 40 from third year, and 40 from fourth year. In practice, only 104 students showed up and took the test: 35 from second year, 34 from third year, and 35 from fourth year. The test started at 1.30 p.m. and finished by 2.30 p.m., but most subjects were able to finish it in 50 minutes on average. The marking was done two times as discussed in Chapter 3, to get the raw scores. The subjects' test scores were processed with the SPSS for Windows to compare means. The analysis of variance (ANOVA) was then used and the Post Hoc Test by Scheffé was utilized to see if there was a significance difference of means from each group of subjects and each type of vocabulary.

5.2 Results from the test scores

Data from the test were statistically analyzed and the findings were used to answer research Questions 2 and 3 as follows.

(2) How well do the students know each type of lexical item from the electrical engineering textbooks?

(2.1) Which type of lexical items between technical and academic words do the students know more?

(2.2) Which type of lexical items between technical words and technical noun phrases do the electrical engineering students know more?

(3) How do the students' study levels affect their knowledge of vocabulary?

To answer these questions, the test scores were analyzed under four headings: (1) electrical engineering students' knowledge of different types of vocabulary, (2) vocabulary knowledge of electrical engineering students from different years, (3) knowledge of different types of vocabulary of electrical engineering students within the same year and (4) knowledge of different types of vocabulary of electrical engineering students from different years. The findings from (1) were used to answer research Question 2, while the findings from (2) and (3) were used to answer research Question 3.

5.2.1 Electrical engineering students' knowledge of different types of vocabulary

The subjects' scores from three types of vocabulary—technical words, academic words, and technical noun phrases—were analyzed and compared. The results are shown in Table 5.1-Table 5.2.

Table 5.1 Subjects' mean scores from different types of vocabulary

Types of vocabulary	N	Mean	Std. Deviation	Minimum	Maximum
Technical words	104	20.6442	6.10255	7.00	30.00
Academic words	104	18.2692	6.16950	4.00	30.00
Technical noun phrases	104	16.6058	7.40168	3.00	30.00
Total	**312**	**18.5064**	**6.77046**	**3.00**	**30.00**

Table 5.1 shows the details of minimum, maximum and mean scores from 104 electrical engineering students. The scores were obtained from three types of vocabulary: technical words, academic words, and technical noun phrases. The minimum scores from technical words, academic words and technical noun phrases are 7, 4 and 3 respectively. The maximum score from all three types is 30 or the full score. The total mean score is 18.5064, and the mean scores of technical words, academic words and technical noun phrases are 20.64, 18.26 and 16.60 respectively. The mean scores from the three types are different. To see if there is a significant difference between these mean scores, further analysis was done with an analysis of variance (ANOVA). To see which one the students know more, each pair of the mean scores were compared with the Post Hoc tests by Scheffé. The results are shown in Table 5.2 as follows.

Table 5.2 Subjects' knowledge in different types of vocabulary

Student's knowledge of vocabulary	Mean Difference	Sig.
Technical words > Academic words	2.37500*	.035
Technical words > Technical noun phrases	4.03846*	.000
Academic words > Technical noun phrases	1.66346	.192

*The mean difference is significant at the .05 and .01 level.

Table 5.2 shows the results from multiple comparisons of the mean scores from technical words, academic words, and technical noun phrases. According to the figures of significance, only two pairs of the mean scores have a significant difference: between technical words and academic words (.035); and between technical words and technical noun phrases (.000). Since the mean score from technical words is higher than the one from academic words and from technical noun phrases, this means the subjects knew more technical words than academic words with the significant difference at the .05 level and they knew more technical words than technical noun phrases with the significant difference at the .001 level. The subjects knew more academic words than technical noun phrases, but the mean difference is not significant (.192).

5.2.2 Vocabulary knowledge of electrical engineering students from different levels

Since all the subjects of this study were electrical engineering students from different levels or years of study, it was interesting to know whether or not the students from a higher level might have more knowledge of vocabulary than those from lower one. To check this, the test scores from different years of study were analyzed and compared. The findings are shown in Table 5.3 – Table 5.4 as follows.

Table 5.3 Mean scores from different levels of subjects

Students	**N**	**Mean**	**Std. Deviation**	**Minimum scores**	**Maximum scores**
2nd year	35	38.6857	11.82662	15.00	65.00
3rd year	34	59.1765	16.57210	24.00	84.00
4th year	35	68.8000	12.48481	41.00	87.00
Total	**104**	**55.5192**	**18.60785**	**15.00**	**87.00**

Table 5.3 shows details of minimum, maximum and mean scores of the test results from the subjects from different years. The numbers of subjects from years 2, 3 and 4 are 35, 34 and 35 respectively. The minimum score, 15, is from the second year while the maximum score, 87, is from the fourth year. The three mean scores are different. The fourth year students got the highest mean score with 68.80, while the second year students got the lowest mean score with 38.68. The mean score of the third year students is lower than that of the fourth years but higher than that of the second years. The findings in significant difference of these mean scores by an analysis of variance (ANOVA) and further analysis was done with multiple comparisons of the mean scores by Scheffé. The results are shown in table 5.4 below.

Table 5.4 Vocabulary knowledge of the subjects from different levels

Vocabulary knowledge from different levels	Mean Difference	Sig.
3nd year > 2rd year	20.49076*	.000
4th year > 2nd year	30.11429*	.000
4th year > 3rd year	9.62353*	.017

*The mean difference is significant at the .01 and .05 level.

Table 5.4 shows the results from the post hoc tests by Scheffé. According to the figures, there was a significant difference (.000) between the mean score from the third-year students and the second-years, a significant difference (.000) between the mean score from the fourth-year and that from the second-year students, and a significance difference between means (.017) from the fourth-year and the third-year students. As shown in Table 5.3, the mean scores from the second, third and fourth year students are 38.68, 59.17 and 68.80 respectively. Therefore, the third year students knew more vocabulary than did the second year students with a significant difference at the .01 level; the fourth year students knew more vocabulary than did the second year students with a significant difference at the .01 level, and more than the third year students with significant difference at the .05 level.

5.2.3 Knowledge of different kinds of vocabulary of the subjects within the same levels

Tables 5.3-5.4 present how different the scores are for the subjects from each group on the test as a whole. To see more details on how well each group of students knew different types of vocabulary, further analysis was undertaken. The findings are shown in the following tables.

Table 5.5 Mean scores from different types of vocabulary compared within the same level of subjects

Level	Types of Vocabulary	N	Mean	Std. Deviation	Min.	Max.
2nd year	Technical Words	35	14.6857	3.87125	7.00	25.00
	Academic Words	35	14.3429	5.15034	4.00	29.00
	Technical Noun Phrases	35	9.6571	4.22139	3.00	18.00
	Total	105	12.8952	4.97092	3.00	29.00
3rd year	Technical Words	34	22.2941	5.21960	9.00	28.00
	Academic Words	34	18.2059	5.94306	6.00	28.00
	Technical Noun Phrases	34	18.6765	6.66843	4.00	28.00
	Total	102	19.7255	6.19191	4.00	28.00
4th year	Technical Words	35	25.0000	3.54799	15.00	30.00
	Academic Words	35	22.2571	4.71757	14.00	30.00
	Technical Noun Phrases	35	21.5429	5.08945	10.00	30.00
	Total	105	22.9333	4.70120	10.00	30.00

Table 5.5 shows the mean scores from different types of vocabulary from each level of the subjects. According to the table, all three levels got the highest mean score from technical words. The second year and fourth year students got the lowest mean score from technical noun phrases, while the third year students got the lowest

mean score from academic words. Since each group of subjects got different mean scores from each type of vocabulary, further analysis by analysis of variance (ANOVA) was done to see if there was significant different between these mean scores.

Table 5.6 Subjects' knowledge of different types of vocabulary compared within the same level of study

Levels	**Students' knowledge of vocabulary**	**Mean Difference**	**Sig.**
2nd year	Technical words > Academic words	0.29412	.964
	Technical words > Technical NPs	5.0285(*)	.000
	Academic words > Technical NPs	4.6857(*)	.000
3rd year	Technical words > Academic words	4.0882(*)	.022
	Technical words > Technical NPs	3.6176(*)	.049
	Technical NPs > Academic words	0.47059	.949
4th year	Technical words > Academic words	2.7428(*)	.043
	Technical words > Technical NPs	3.4571(*)	.007
	Academic words > Technical NPs	0.73529	.800

* The mean difference is significant at the .01 and .05 levels.

Table 5.6 shows the results from multiple comparisons of mean scores from different types of vocabulary. The findings from the second-year students show a significant difference (.000) between the mean scores from technical words and technical noun phrases and a significant difference (.000) between the mean scores from academic words and technical noun phrases. This means that the second-year students knew more technical words and academic words than technical noun phrases with the significant difference at the .01 level. The second-year students knew more technical words than academic words, but the mean difference is not significant (.964).

For the third-year students, there is a significant difference (.022) between the mean scores from technical words and that from academic words and a significant difference (.049) between the mean score from technical words and the one from technical noun phrases. This indicates that the third-year students knew more technical words than academic words and technical noun phrases with the significant difference at the .05 level. The third-year students knew more technical noun phrases than academic words, but the mean difference is not significant (.949).

Like the results from third-year students, the figures from the fourth-year students show that there are a significant difference (.043) between the mean scores from technical words and academic words and a significant difference of mean scores (.007) from technical words and technical noun phrases. This indicates that the fourth-year students knew more technical words than academic words with the significant difference at the .05 level and technical noun phrases with the significant difference at the .01 level. The fourth-year students knew more academic words than technical noun phrases, but the mean difference is not significant (.800)

5.2.4 Knowledge of different types of vocabulary of the subjects among different levels

The findings show that, overall, students from different levels had different knowledge of vocabulary. Since this study was conducted with mixed level electrical engineering students, it might have useful implications for vocabulary teaching, to see whether the students from different years know different types of vocabulary. Therefore, further analysis was conducted focusing on different types of vocabulary. The findings are presented in Table 5.7 and 5.8 as follow.

Table 5.7 Mean scores from different types of vocabulary and different levels of the subjects

Types of Vocabulary	Students	N	Mean	Std. Deviation
Technical Words	2nd year	35	14.6857	3.87125
	3rd year	34	22.2941	5.21960
	4th year	35	25.0000	3.54799
	Total	104	20.6442	6.10255
Academic Words	2nd year	35	14.3429	5.15034
	3rd year	34	18.2059	5.94306
	4th year	35	22.2571	4.71757
	Total	104	18.2692	6.16950
Technical Noun Phrases	2nd year	35	9.6571	4.22139
	3rd year	34	18.6765	6.66843
	4th year	35	21.5429	5.08945
	Total	104	16.6058	7.40168

Table 5.7 presents the mean scores from different types of vocabulary obtained from the students from different levels, a total of 104 students. For all three kinds of vocabulary the second year students got minimum scores, while the fourth year students got maximum scores. Similarly, for the mean scores from all three types, the second year students got the lowest, while the fourth year students got the highest. For technical vocabulary, the mean scores from second year, third year and fourth year students are 14.68, 22.29 and 25.00 respectively and the grand total mean score is 20.64. The mean scores of academic words are respectively 14.34, 18.20 and

22.25 and the grand total is 18.26. The mean scores of noun phrases are respectively 9.65, 18.67 and 21.54 and the grand total is 16.60. These mean scores were compared by analysis of variance, to see whether there was a significant difference between groups of students and types of vocabulary. The findings are shown in Table 5.8.

Table 5.8 Subjects' knowledge of different types of vocabulary and different levels of study

Types of Vocabulary	**Students' knowledge of vocabulary**	**Mean Difference (I-J)**	**Sig.**
Technical Words	3rd year > 2nd year	7.60840*	.000
	4th year > 2nd year	10.31429*	.000
	4th year > 3rd year	2.70588*	.035
Academic Words	3rd year > 2nd year	3.86303*	.012
	4th year > 2nd year	7.91429*	.000
	4th year > 3rd year	4.05126*	.008
Technical Noun phrases	3rd year > 2nd year	9.01933*	.000
	4th year > 3rd year	2.86639	.094
	4th year > 2nd year	11.88571*	.000

* The mean difference is significant at the .01 and .05 levels.

Table 5.8 presents the results from multiple comparisons of means between groups of students. In terms of technical words, there are a significant difference of means (.000) from the third-year students and the second-year students, a significant difference of mean scores (.000) from the fourth-year and the second-year students, and a significant difference of mean scores (.035) from the fourth-year and the third-year students. This indicates that the fourth-year students knew more technical words than did their second-year counterparts with a significant difference at the .01 level and the third-year students with a significant difference at the .05 level and that the third-year students knew more technical words than did the second-year students with significant difference at the .01 level.

For academic words, there is a significant difference of mean scores (.012) from the third-year and the second-year students, a significant difference of means (.000) from the fourth-year and the second-year students, and a significant difference of mean scores (.008) from the fourth-year and the third-year students. This means that the fourth-year students knew more academic words than did the second-year and the third-year students with significant difference at the .01 level and that the third-year students knew more academic words than did the second-year students, with significant difference at the .05 level.

In terms of technical noun phrases, there is a significant difference of mean scores (.000) from the third-year students and the second-year students and a significant difference of means (.000) from the fourth-year students and the second-year students. This means the fourth-year and the third-year students knew more technical noun phrases than did the second-year students with a significant difference at the .01 level. The fourth-year students knew more technical noun phrases than the third-year students, but the mean difference is not significant (.094).

5.3 Summary of findings from the vocabulary test

The vocabulary test was conducted with 104 electrical engineering students. The result scores from the test were analyzed by the Analysis of Variance from SPSS for Windows. All mean scores were compared and statistically analyzed with a significant difference at the .01 and .05 level. The findings were that overall the subjects knew more technical words than academic words and technical noun phrases. In terms of study levels, the fourth year students knew more vocabulary than did the third year and the second year students, and the third year students knew more vocabulary than did the second year students. In terms of different types of vocabulary and different study levels, it was found that the second-year students knew more technical words and academic words than technical noun phrases. The third-year students knew more technical words than academic words and technical noun phrases. The fourth-year students knew more technical words than academic words and technical noun phrases. In terms of different types of vocabulary, the third-year and the fourth-year students knew more technical words, academic words, and technical noun phrases than did the second-year students. The fourth-year students knew more technical words and academic words than did the third-year students. The third-year students knew more technical words, academic words and technical noun phrases than did the second-year students.

CHAPTER 6

DISCUSSION

6.1 Discussion of findings from the corpus

This corpus study counts occurrence and frequency of vocabulary, separately in terms of single words (*amplifier, ratio, power, etc*.) and multi-word units (*reactive power, potential problems, film reel, etc.*) as, in this case, noun phrases. Both single words and noun phrases are classified into three groups: general, academic and technical. With these classifications, single words are classified as general words (GWs), academic words (AWs) and technical words (TWs). Noun phrases are classified as general noun phrases (GNPs), academic noun phrases (ANPs) and technical noun phrases (TNPs). As vocabulary in this study refers to a word and/or a noun phrase, the unit of vocabulary used for calling and counting both single words and noun phrases is the *lexical unit* (LU). Therefore, GWs and GNPs are general lexical units (GLUs); AWs and ANPs are academic lexical units (ALUs); and TWs and TNPs are technical lexical units (TLUs). For examples, the word '*amplifier*' is a lexical unit (LU), and as it is a technical word (TW), it becomes a technical lexical unit (TLU). The noun phrase '*potential problem*' is a lexical unit (LU) and as the word '*potential*' is a word from the AWL, it becomes an academic lexical unit (ALU) and an academic noun phrase (ANP).

With the identification and classification of single words and noun phrases by their meanings according to their context, this study reveals more real proportions of kinds of vocabulary since words of the same forms or homographs can be used with different or special meanings in different contexts (Wang and Nation, 2004 and Hyland and Tse, 2007). In many research studies, words were individually studied and classified into kinds or levels (Farrell, 1990; Sutarsyah, Nation and Kennedy, 1994; Coxhead, 2000; Chujo and Genung, 2003; Chung and Nation, 2003-2004). In this way, the researchers paid attention to the forms of words only and ignored their meanings in context, especially the meanings formed from relationships of words. Therefore, the studies, which separate words from a phrase and ignore the real meaning of words in context, distort a large number of technical lexical units. Hyland and Tse (2007: 247) remark "By breaking into single words items which may be better learnt as wholes, vocabulary lists simultaneously misrepresent discipline-specific meanings and mislead students."

Findings from the real proportions reveal some perspectives on vocabulary in electrical engineering corpus and some implications for language pedagogy. In fact, more than 45 % of running words in the corpus are function words encompassing little or no information. Yang (1986) points out that 45 % per cent of function words does not indicate that 45 per cent can be extracted from the text, because the main subject information depends on multi-word units. What is interesting is that the proportion of noun phrases, in terms of number of types, is higher than that of single words (see Table 6.1 below). Most of these noun phrases are technical, resulting in, as a whole, a remarkably high proportion of technical vocabulary, when combined with individual technical words. In contrast, as shown in Table 6.1, academic vocabulary comprises only a low proportion in electrical engineering corpus. These findings provide helpful implications for teaching-material designers as well as EAP/ESP teachers for vocabulary teaching. This section aims to discuss proportions of vocabulary and potential for difficulty. The findings are discussed under two main headings, i.e. (1) high coverage of TLUs and potential for difficulties and (2) academic vocabulary: an overestimate by researchers.

Table 6.1 Proportion of different kinds of lexical units in the corpus

Types of Vocabulary		**Lexical unit types**	**Lexical unit tokens**	**Running Words**
Function (GSL)	Words	150 (1.40 %)	54,550 (50.75 %)	54,550 (44.63 %)
General content (GSL)	Words	2,048 (19.10 %)	25,482 (23.70 %)	25,482 (20.85 %)
	NPs	295 (2.74 %)	351 (0.33 %)	757 (0.62 %)
Technical	Words	895 (8.34 %)	8,406 (7.82 %)	8,406 (6.88 %)
	NPs	5,500 (51.25 %)	10,069 (9.37 %)	24,061 (19.70 %)
Academic	Words	898 (8.36 %)	6,172 (5.74 %)	6,172 (5.05 %)
	NPs	248 (2.31 %)	287 (0.27 %)	611 (0.50 %)
Rare	Words	698 (6.50 %)	2,170 (2.02 %)	2,170 (1.77 %)
Total		**10,732 (100 %)**	**107,487 (100 %)**	**122,209 (100 %)**

6.1.1 High coverage of TLUs and potential for difficulties

Technical lexical units (TLUs) have high coverage in electrical engineering corpus, and their high proportion in electrical engineering corpus can result in problems or difficulties to the electrical engineering students, especially for reading comprehension. It has been estimated that technical vocabulary covers around 5 % of the running words in academic texts when all individual words in the texts are counted, and language teachers can ignore this small proportion and leave it for subject teachers (Nation, 2001). This study proves that the coverage of technical vocabulary may be seriously underestimated. According to our count with lexical unit tokens (an individual word or SW is a lexical unit token and a noun phrase or NP is a lexical unit token), technical vocabulary covers 17.19 % of lexical unit tokens from the whole corpus. Counted with running words, technical vocabulary covers 26.57 % of running words in the same corpus. With both ways of counting, the proportion of technical vocabulary is higher than the estimate.

Remember that TLUs in this study are a combination of TWs with TNPs. TWs include all types of single words technically used in electrical engineering contexts. Similarly, TNPs include all noun phrases used with technical meaning in the engineering context. In the corpus from electrical engineering corpus, TLUs cover 59.59 % of types and 26.57 % of running words (see Table 6.2 below). These figures include GSL words and AWL words technically used in the context of engineering.

Table 6.2 Proportion of vocabulary in electrical engineering corpus

Kinds of lexical units	**Types**	**Tokens**	**Running Words**
Function words	150 (1.40 %)	54,550 (50.75 %)	54,550 (44.63 %)
General (GSL + General NPs)	2,343 (21.83 %)	25,833 (24.03 %)	26,239 (21.47 %)
Academic (AWs + ANPs)	1,146 (10.68 %)	6,459 (6.01 %)	6,783 (5.55 %)

Table 6.2 (Cont.) Proportion of vocabulary in electrical engineering corpus

Kinds of lexical units	Types	Tokens	Running Words
Technical (TWs + TNPs)	6,395 (59.59 %)	18,475 (17.19 %)	32,467 (26.57 %)
Rare words	698 (6.50 %)	2,170 (2.02 %)	2,170 (1.77 %)
Total	**10,732 (100 %)**	**107,487 (100 %)**	**122,209 (100 %)**

Assume that to understand a reading text, one needs to know 95 % of running words in the text (Laufer, 1989). From the "running words" column in Table 6.2, the combination of general vocabulary (including function words) (66.11 %) with academic vocabulary (5.55 %) is about 71 % which is not sufficient for understanding, so for understanding the text learners need to know more at least 24 % from technical vocabulary. With its high proportion, if learners do not know the meanings of technical vocabulary or TLUs, they cannot decode meaning from the text. Therefore, both TWs and TNPs have potential for difficulties which are discussed under the following two headings: (1) potential for difficulties from single technical words and (2) potential for difficulties from technical noun phrases.

6.1.1.1 Potential for difficulties from single technical words (TWs)

Though TWs make up 6.88 % of running words from the whole corpus (see Table 6.1), they can cause difficulties for language learners since TWs are comprised of different types of words (Chung and Nation, 2004) and occur with high frequency (Tagliacozzo, 1975; Yang, 1986; and Nation, 2001). Some common words such GWs and AWs from everyday language can be used with technical meanings in specialized texts. This can yield more problems if the learners ignore a TW which occurs with high frequency in the text. They may not only lose some information but potentially misunderstand the text as a whole. The details are discussed under the two headings below.

A. Difficulties from common words with technical meaning

According to this study, TWs include general/common words, scientific words, and indexical words (Martin,1989). The last two kinds of words are technically fixed in form and meaning to their disciplines while common words with technical meanings are words from everyday language (including words from the GSL and words from the AWL). Trimble (1985) includes this type of word as 'sub-technical vocabulary' as these common words vary their meanings according to the context, and discusses that this type of word can cause problems to language learners. For instance, the word '*line*' from the sentence '*The current in the line drops quickly*' is a word from the GSL but is used as a TW referring to electric wire. In their dictionaries, language learners might not find the technical meaning of this common word that suit the context. As a result, they might ignore some section with the unidentified word and lose the information of the text. Common words can provide different (technical) meanings when used in different contexts and the prevalence of these words can create more difficulties for learners than do scientific and indexical words (Kennedy and Bolitho, 1984; Higgins, 1985 and Liu and Nesi, 1999).

Table 6.3 Technical words (TWs) in the corpus

Words used as technical vocabulary	Types	Tokens
Common words	289 (32.29 %)	2,836 (33.74 %)
Scientific words	273 (30.50 %)	1,414 (16.82 %)
Indexical words	333 (37.21 %)	4,156 (49.44 %)
Total	895 (100 %)	8,406 (100 %)

From Table 6.3, it is clear that common technical words occur with a high proportion in the corpus. The entire list of TWs contains 895 types and 8,406 tokens. According to our 3-part classification of TWs, general (technical) words make up 289 types and 2,836 tokens; scientific words make up 273 types and 1,414 tokens; and indexical words make up 333 types and 4,156 tokens. The numbers of types do not vary greatly but those of tokens do. A type/token ratio from these three groups of technical words indicates that each common word occurs about 10 times; each scientific words 5 times; and each indexical words 12.5 times. Some examples of TWs are shown in Table 6.4 as follows.

Table 6.4 Examples of technical words which are general, scientific, and indexical

Common words	**Freq.**	**Scientific words**	**Freq.**	**Indexical words**	**Freq.**
load	210	calculate	178	voltage	405
phase	189	system	129	current	388
frequency	154	bit	107	motor	332
output	100	curve	46	circuit	182
input	99	probability	44	electron	148
line	98	angle	28	transformer	145
terminal	88	binary	26	generator	143
rate	87	oxide	26	signal	137
mean	81	multiply	24	coil	111
gate	72	quadrant	24	capacitor	85

Table 6.4 shows some examples of TWs in terms of common, scientific and indexical words. Each type is exemplified by the ten most frequently found words in the corpus. From the ten common words in the table, six words (*load, frequency, line, rate, mean* and *gate*) are high frequency words from the GSL; three words (*input, out put* and *phase*) are AWs from the AWL; and only one word (*terminal*) is from rare words, as it cannot be found in either the GSL or the AWL. For examples from Dictionary.com (2007), the word '**line**' can refer to '*a mark or stroke long in proportion to its breadth, made with a pen, pencil, tool*' for laymen, but can refer to '*a wire circuit connecting to two or more pieces of apparatus*' for electrical engineering specialists. The word '**phase**' may have '*a stage in a process of change or development*' as a general meaning, but might have '*the fractional part of*

the period through which the time has advanced, measured from some arbitrary origin often expressed as an angle (phase angle), the entire period being taken as 360°'' as a specific meaning to the electrical engineering field.

B. Difficulties from high frequency of TWs

TWs carry the meaning of the text and occur with high frequency; as a result, they can cause difficulties for the electrical engineering students. What makes TWs high in proportion is the nature of a specialized/scientific text. As electrical engineering is a specialized discipline, a specialized/technical vocabulary is used and recycled to carry meanings of the content of the field. To make it clear proportions of single words in terms of content words are compared in Table 6.5 below. Remember that NPs are not included here.

Table 6.5 Proportions of content words in the corpus

Kinds of Vocabulary	Types	Tokens
General Content Words (GSL)	2,048 (45.12 %)	25,482 (60.34 %)
Academic Words (AWL)	898 (19.78 %)	6,172 (14.62 %)
Technical Words (Common + Scientific + Indexical Words)	895 (19.72 %)	8,406 (19.90 %)
Rare Words	698 (15.38 %)	2,170 (5.14 %)
Total	4,539 (100 %)	42,230 (100 %)

From Table 6.5, among individual content words, words from the GSL have the highest proportion. Apart from the GWs, TWs have a higher proportion than other kinds in terms of tokens. This means that, except GWs, TWs are used more frequently than AWs in electrical engineering corpus. A type/token ratio of TWs is 1: 9.4; this is, one inflected form or type of TW occurs more than 9 times on average. To clarify this more, the most frequent ten TWs with high frequency are selected for exemplification. Similarly, AWs, GWs and rare words are also selected as examples and to compare with TWs. Note that we have excluded all function words such as *the, of, a, to in,* etc. which carry the non-specific meaning of the text. The examples of these types of words with a high frequency of occurrence from electrical engineering corpus are illustrated in Table 6.6 as follows.

Table 6.6 Examples of single words with high frequency

General words	**Freq.**	**Technical words**	**Freq.**	**Academic words**	**Freq.**	**Rare words**	**Freq.**
figure	596	voltage	405	equation	240	junction	86
show	580	current	388	source	165	series	85
use	576	motor	332	assume	143	magnitude	67
many	332	load	210	require	138	absorb	51
example	270	phase	189	energy	111	plot	32
value	235	circuit	182	device	107	column	28
same	220	calculate	178	obtain	96	slot	27
time	210	frequency	154	constant	87	versus	27
power	208	electron	148	section	87	typically	26
find	204	transformer	145	channel	85	drain	25

Anyhow, general content words are still higher in frequency than other types of words. Though GWs occur with high frequency, they are not intended to carry the information of electrical engineering corpus. This type of word, which would be less likely to cause problems to the engineering students, is not the focus of this study. In contrast, used to carry meanings of the text and recycled with high frequency, TWs which are new or unknown to the students tend to cause more difficulties than words of other kinds.

6.1.1.2 Potential for difficulties from TNPs

TNPs are frequently found in electrical engineering corpus and are likely to cause difficulties for engineering students. They are composed of two or more words, and composed of a head word and its modifier (Modifier + Head word). TNPs are multi-word lexical items which are also collocations (Moon, 1997). A collocation is a word combination or a word that co-occurs with another word more frequently than random (Gairns and Redman, 1986; Nattinger and DeCarrico, 1992; and Willis, 2003). There is no exact criterion about frequency of co-occurrence of words as collocations. Moon (1997) counted phrases as collocations per 1-4 million words. Based on Moon (ibid.), Ward (2007) uses the frequency basis—three times of occurrence from the corpus of 380,000 words—to count noun phrases as collocations. If this criterion is applied with this study, it would be found that out of 10,069 technical NP tokens, more than 49.5 % (4,984 tokens) are collocations. Multi-word lexical units and collocations are still problematic even to advanced foreign language learners (see Bahns and Eldaw, 1993; Moon, 1997; and Nesselhauf, 2003) because of their technicality, which includes specialization and difficulty (Ward, 2007) as well as the grammatical structure (nominalization) of its individual word (Pueyo and Val, 1996). In this section, potential for difficulties from TNPs will be discussed in terms of their frequency, semantic opacity, and grammatical structure.

A. High coverage of TNPs and potential for difficulties

The proportion of TNPs indicates that noun phrases frequently occur throughout the texts and can be problematic to engineering students as shown in Chapter 6. With frequent use in the textbooks, if the students do not know these TNPs, they cannot comprehend the text in the textbooks. The findings show that around 90 % of the entire NPs from the corpus are TNPs, leaving very few used as GNPs and ANPs. Like that of TWs, the proportion of TNPs is high since TNPs are intended to express technical meaning in the electrical engineering textbooks. Complex noun phrases are formed and used as technical terminology as a consequence of the inadequacy of single words with complex or scientific/technical meanings. The creation of new terms through the use of complex noun phrases is therefore an alternative way to compensate for this insufficiency (Pueyo and Val, 1996), and TNPs are frequently recycled in electrical engineering corpus.

Table 6.7 Technical noun phrases (TNPs) with high frequency of occurrence

TNPs	Frequency
reactive power	91
phasor diagram	60
power factor	57
induction motor	47
output voltage	42
equivalent circuit	38
received signal	38
transmitted signal	35

Table 6.7 (Cont.) Technical noun phrases (TNPs) with high frequency of occurrence

TNPs	Frequency
electric field	30
terminal voltage	30
Total	**468**

Table 6.7 shows ten examples of TNPs which are multi-word units and collocations, with the top-ten frequency in the electrical engineering corpus, out of 5,124 TNPs. The phrase '*reactive power*' is technical and occurs with the highest frequency (of collocations) in the corpus. Interestingly enough, neither of the individual words from this phrase is of itself technical though the phrase is technical. Similarly, the phrase '*power factor*' contains two non-technical words. While the word '*power*' is a general word, the word '*factor*' is an AW. These terms show that a new terminology can be created from a combination of words as an NP and that GWs and AWs, when used or combined with other words in an electrical engineering context, can provide technical meanings.

B. The potential for difficulties from semantic opacity of TNPs

The semantic opacity of a TNP can cause difficulties to engineering students. Semantic opacity is the obscurity of meaning of a lexical unit. A word or a phrase is opaque when its meaning cannot be directly decoded from the individual word, but depends on the context in which it occurs. Though the head word of a noun phrase provides the main information of the phrase, decoding meaning from the whole phrase might not be done on a word-by-word basis but as a whole since the meaning of a TNP relies on its technicality (Pueyo and Val, 1996) which can result from its context and/or the relationship of its individual words (Carter and McCarthy, 1991). As with TWs, TNPs may comprise GWs, AWs, rare words, scientific words and indexical words. For example, the TNP '*average normalized power*' contains three individual words from which two words (*average* and *power*) are high frequency words from the GSL and one word (*normalized*) is a word from the AWL. The phrase '*torque speed characteristics*' also has three single words—two words (*speed* and *characteristics*) are words from the GSL while the third (*torque*) is an indexical word. From these examples, the head words of the two phrases (*power* and *characteristics*) are GWs, but these two phrases are technical because of their modifiers, which make the meanings of the phrases technical. The meaning of individual words from each phrase, if directly decoded, does not make sense to the whole phrase or to the text. This indicates that technical meaning of GWs and AWs relies on its relationship with other word(s) and the context in which they occur.

The TNPs containing GWs and AWs above are examples of multi-word lexical units which can provide semantic opacity. According to the criteria for distinguishing multi-word lexical items from other kinds of strings discussed by Moon (1997: 44), TNPs fall into institutionalisation and non-compositionality both of which represent collocations. A TNP as institutionalization refers to the one which recurs and is considered to be a unit by the language community (engineering), for example, *output voltage, electric field, voltage gain*, etc. A TNP with non-compositionality is one which can not be interpreted on a word-by-word basis but has specialized meaning, for examples, *reverse bias, reactive power, power factor*, etc. These TNPs are semantically opaque. To unpack these TNPs or these collocations which are more specialized than individual words, the students need experience or knowledge of the specific discipline (Ward, 2007: 26).

C. Grammatical structure of TNPs and a potential for difficulties

Apart from the relationship of words in a TNP that can cause difficulties to readers, grammatical structure, in this case nominalization, can also be problematic to the readers. Individual words in a TNP are often created by nominalization. Pueyo and Val (1996) remark that technical terms themselves might not be the cause of language difficulty, but the complex relationships that words have between them as technicality and the grammatical structure that they hold can make language difficult. Some nouns can be a product of the nominalization of propositions (Halliday, 1988 and 1993) or the creation of a new term with technical meaning for specific use in a specialized field (Martin, 2001). It was found from this study that some nouns come from nominalization such as *suspension*, *specification, transmission* and *violation*. In fact, these nouns are nominalizd from verbs *suspend, specify*, *transit*, and *transmit*. These verbs are from the AWL but nominalized and used with other types of words as TNPs like *suspension* insulators, system *specification*, *transition* region width, and code *violations*. To deal with this type of TNPs, readers need to be familiar with the grammatical structure of the words or the process of nominalization which can be problematic.

6.1.2 Academic vocabulary: an overestimate by researchers

Academic vocabulary in electrical engineering corpus consists of AWs and ANPs, and its proportion in these textbooks is only 10.68 % of lexical unit types and 5.55 % of running words. In detail, AWs contain 8.36 % of lexical unit types and 5.05

% of running words, and ANPs have 2.31 % of lexical unit types and 0.50 % of running words. The total proportion of AWS with ANPs in term of running words is close to that of Chung and Nation (2004) with 3.7 % in an anatomy text and 6.9 % in an applied linguistics text. However, these figures are quite low, compared with the study by Coxhead (2000) who created the AWL and claimed that words from the AWL cover around 10 % of running words in academic texts. This 10 % of coverage is the overestimate which appears in many studies. This present study proves that the AWL cannot be generalized, as a common core of words in academic texts, to textbooks in the electrical engineering discipline especially since Coxhead did not include engineering texts in her AWL corpus. Thus, the use of the AWL in vocabulary teaching for EAP electrical engineering can be an inappropriate focus since there are many words from the lists which the electrical engineering students do not need. The small proportion of academic vocabulary in electrical engineering corpus can be discussed under two headings, i.e. (1) problems with homographs from the AWL and (2) different distributions across disciplines.

6.1.2.1 Problems with homographs from the AWL

Generally, words from the AWL have their common meaning when used in a general context, but can provide technical meanings in electrical engineering. A word which can provide two or more different meanings is a homograph. Words as homographs can confuse language learners with their meanings when used in different contexts. Hyland and Tse, (2007) postulate that the potential homographs of AWL words reveal a considerable amount of semantic variation across fields and some word families in the AWL are homographs from different disciplines. This implies that the meanings of some words from the AWL can be opaque and that these words cannot be grouped as academic vocabulary. Words from the AWL can be used as a head noun or a modifier. For examples, power *factor,* voltage *regulation*, and frequency *domain* are formed by AWs which are in *italics* and used as head nouns while *input* voltage, *output* impedance, and *phase* detector are formed by AWs (in italic) and used as modifiers.

Collocation of an AW with a GW, an AW with an AW, or an AW with a TW can form a TNP. Some AWs collocate with some GWs and become TNPs in the electrical engineering field. For example the words '*reactive*' and '*factor*', which collocate with the GW 'power' and become '*reactive* power' and 'power *factor*.' Some AWs collocate with other AWs and become TNPs such as '*reverse bias*', '*contact potential*,' '*neutral region*', '*nomalized energy*', '*phase ratio*', etc. Some AWs collocate with some TWs and become TNPs, for example, '*induced* voltage', '*equivalent* circuit', and '*complex* impedance'. Though these orthographic words belong to the AWL, their meaning becomes technical, being specific to the field of electrical engineering. This suggests that AWs can provide their meaning by their collocational and semantic behaviors, relying on their field of occurrence. In this case, Hyland and Tse (2007) agree with Trimble (1985) that academic vocabulary can have an extension of meaning in a technical context and can have different meanings when used in different disciplines.

Since some words from the AWL are homographs, different criteria and methods to identify and classify AWs can affect the proportion of academic vocabulary. Coxhead (2000) classified academic vocabulary from its wide range and high frequency, paying no attention to the real meaning of a word. Every single word out of the GSL is counted as an AW with the condition that it occurs in a wide range of disciplines and with predetermined high frequency, no matter if it is used with a technical meaning. With this method, the proportion of academic vocabulary would become higher since homographs were included with the AWL. In contrast, this present study and the study by Chung and Nation (2004) classify technical words according to their technicalness defined by the rating scale, and academic words are identified afterwards with the AWL. However, this present study is different from Chung and Nation's in the way that all complex noun phrases in this study are excluded from the corpus before the rest or all single words are classified into groups. With the rating scale, words are classified into groups based on their meanings and the degree of technicalness (Nation, 2001 and Chung and Nation, 2003-2004). By the criteria from the rating scale, some GWs and AWs used with technical meaning in the context are grouped as TWs. This results in a lower proportion of academic vocabulary. The other factor that causes a low proportion of academic vocabulary is the low proportion of ANPs. In fact, many words from the AWL occur in the corpus but most are used in NPs as TNPs. To sum up, the inclusion of homographs from the AWL as academic vocabulary by Coxhead can results in an overestimate and the teaching of words with wrong meanings (inappropriate to the context) to language learners. Therefore, the AWL may need to be reconsidered by EAP/ESP teachers as to whether it is appropriate for their courses.

6.1.2.2 Different distributions across disciplines

Distribution of AWs varies according to disciplines or registers. Chen and Ge (2007) found that though academic vocabulary covers around 10 % of medical research articles, conforming to Coxhead's findings, around 292 AWL word families or 51 % were frequently recycled while the rest were not. Findings from science, engineering, and social science subcorpora by Hyland and Tse (2007) reveal a good overall coverage of AWs with 10.6 %, and 85 % when combined with words from the GSL, conforming to the results of Coxhead's (2000). However, looking at the distributions across subcorpora, they found that merely 36 word families from the AWL were remarkably evenly distributed across all the three subcorpora from their work, that 27 % of all the AWL families have very low occurrence in a subcorpus, and that the students have very low chance of encountering these words. They also found that the distribution of AWs in the sciences is lower than that of other fields. Similarly, Coxhead (2000) found from her subcorpora (commerce) that AWs occur more, up to 12 %, while the other three subcorpora (arts, law, and sciences) had around 9 % occurrence. This implies that the occurrence of words in the AWL differs or varies according to different disciplines, and that the lists from the AWL cannot be equally applicable to all academic disciplines.

AWs do not have an equal number of uses in all kinds of texts, so the 10 % coverage of AWL by Coxhead (2000) cannot be applied to the electrical engineering field in which academic vocabulary covers only 5.55 %—a very low proportion. The AWL is not the common core of words in all kinds of academic texts, and a generalization of the AWL to all EAP disciplines would mislead all practitioners of language teaching and learning. Practically, the proportion of AWs should be determined for an individual field as needed, resulting in a better understanding of the occurrence of AWs and leading to more practical language pedagogy in terms of vocabulary needs for an EAP or ESP course.

To sum up, the coverage of academic vocabulary in academic texts has been overestimated and used as a reference all over the world. The AWL by Coxhead (2000) may not be used in language teaching for all classes, but in some disciplines with care. ALUs (AWs and ANPs) overall, have low coverage in electrical engineering corpus. On average, a running word from ALUs occurs in the corpus every 18 words. Some words from the AWL are homographs and can be used with a technical meaning, and they are not equally used in all disciplines. In an electrical engineering context, many AWs are found being used in TNPs. This leaves a very small proportion of ANPs. The low proportion of ALUs, therefore, can be from AW homographs as well as different disciplines. This implies that we should learn meaning of words and phrases from the context they occur. Though the coverage of ALUs from this study is quite low, this study does not mean to dilute the AWL or say that the AWL is useless. The AWL is still useful and valuable for studies in academic vocabulary as well as for language pedagogy (Coxhead, 2000). However, the use of the AWL must be undertaken with care, as discussed, especially with an individual discipline.

6.2 Discussion of findings from the vocabulary test

Overall, subjects know more TWs than AWs and they know more AWs than TNPs. This result is contrasted to that of Liu and Nesi (1999) whose subjects knew more AWs than TWs. The difference of these two studies is that Liu and Nesi did not include TNPs in their test, so we do not know if their subjects had problems with NPs or not. The factor causing the contrast could be from the difference of learners as subjects for these two studies. This study focuses on Thai undergraduates while Liu and Nesi's study looked at graduate students who were studying abroad. Those students might have studied English for living and studying overseas for a period of time and learned some more AWs, so they got higher scores with this type of words. TWs, therefore, became more problematic for them. Though the subjects from this study know more TWs than AWs, they know more AWs than TNPs. This means that TNPs are still difficult for them.

Apart from showing the subjects' different knowledge of vocabulary, the results show that the subjects from higher levels have higher knowledge in vocabulary than those from lower levels. The findings are discussed in details under two headings, "knowledge in different kinds of vocabulary" and "effect of study levels on knowledge of vocabulary" as follows.

6.2.1 Subjects' knowledge of different kinds of vocabulary

The subjects know more TWs than other types of vocabulary (see Tables 7.8 and 7.9 below), perhaps, as a consequence of involvement with the engineering context as well as technical texts in their field and of the high frequency of TWs in this kind of text. TWs have more repetition than AWs and TNPs. As a result, the students gain more knowledge in TWs than other kinds of lexical units. In fact, TNPs occur with higher proportion in all cases (lexical unit tokens, types, and lemmas) than do TWs. However, the frequency or the repetition of TNPs is lower than TWs. This could cause the students to acquire fewer TNPs than TWs.

The electrical engineering students need to study English engineering texts which lead them to repeatedly come across TWs in the discourse. Practically, students tend to acquire items they need rather than the ones taught in sequence (Hyland and

Tse, 2007). With this notion, the students would incidentally acquire vocabulary from reading their course books, and repetition of single words used in those books can result in gaining word knowledge (Webb, 2007).

Table 6.8 Subjects' mean scores from different types of vocabulary

Types of vocabulary	N	Mean	Std. Deviation	Minimum	Maximum
Technical Words	104	20.6442	6.10255	7.00	30.00
Academic Words	104	18.2692	6.16950	4.00	30.00
Technical Noun Phrases	104	16.6058	7.40168	3.00	30.00
Total	**312**	**18.5064**	**6.77046**	**3.00**	**30.00**

Table 6.9 Subjects' knowledge in different types of vocabulary

Student's knowledge of vocabulary	Mean Difference	Sig.
Technical words > Academic words	2.37500*	.035
Technical words > Technical noun phrases	4.03846*	.000

*The mean difference is significant at the .05 and .01 level respectively.

AWs, in contrast, are used and recycled in electrical engineering text in much lower numbers, referring to the findings from the corpus. Importantly, they are not the ones carrying the major meanings of the texts. In essence, they are not the word focus of the texts. In fact, the students might be able to construct the meaning of the text from technical and other high-frequency words, so they might ignore or pay less attention to AWs. (This assumption would need further research.) With low proportion and non-essential meaning in an electrical engineering text, it is not, therefore, surprising that the students know fewer AWs than TWs and got lower scores in this type of word than from TWs.

Among three types of vocabulary, TNPs would be more difficult for the electrical engineering students. Table 6.8 shows that the mean score from TNPs is the lowest. This result from the test is consistent to other research studies which indicate that complex noun phrases can cause more problems to learners than single words (Trimble, 1985; Yang, 1986 and Peuyo and Val, 1996).

6.2.2 The effect of subjects' levels on knowledge of vocabulary

Subjects' levels of study have an effect on their knowledge of vocabulary. The subjects from higher levels know more vocabulary than those from the lower ones, with a significant difference (see Tables 7.10 and 7.11 below). This implies that the subjects from higher levels would likely gain their knowledge of vocabulary along with the time and with their study in the subject area. In fact, the third and fourth-year students have no more English courses to enroll, but they need to study electrical engineering corpus (written in English). In the case that they have lower knowledge of vocabulary than 95 % of running words, they need to check, study or guess meanings of unknown words which repeatedly occur, so they can implicitly learn new words from their reading. This implicit learning is "strongly affected by repetition" (Nation, 2001: p. 34). To elaborate, the students read English textbooks in their field and learn TWs and TNPs from their reading (for meaning). The second-year students have just entered the field, so they know the least and got the lowest scores. The fourth-year counterparts have spent longer time than others, so they learn more vocabulary than do others.

Table 6.10 Mean scores from different levels of the subjects

Students	N	Mean	Std. Deviation	Minimum scores	Maximum scores
2nd year	35	38.6857	11.82662	15.00	65.00
3rd year	34	59.1765	16.57210	24.00	84.00
4th year	35	68.8000	12.48481	41.00	87.00
Total	**104**	**55.5192**	**18.60785**	**15.00**	**87.00**

Table 6.11 Vocabulary knowledge of the subjects from different levels

Vocabulary knowledge from different levels	Mean Difference	Sig.
3nd year > 2rd year	20.49076*	.000
4th year > 2nd year	30.11429*	.000
4th year > 3rd year	9.62353*	.017

*The mean difference is significant at the .01 and .05 level.

Compared with the third-year and the fourth-year students, the second year students have got less experience in their subject area, so they have learned fewer TWs and TNPs than their seniors. The findings also show that the second-year students' knowledge of TWs and AWs have no significant difference since the mean scores from both kinds are quite close, while the other two levels do (see Tables 7.12 and 7.13 below). Also, the second-year students know more AWs than TNPs with a significant difference, while the other higher levels do not. Therefore, the teaching of vocabulary in EAP for the second-year students needs to include TWs and TNPs.

Table 6.12 Mean scores from different types of vocabulary compared within the same level of the subjects

Level	Types of Vocabulary	N	Mean	Std. Deviation	Min.	Max.
2nd year	TWs	35	14.6857	3.87125	7.00	25.00
	AWs	35	14.3429	5.15034	4.00	29.00
	TNPs	35	9.6571	4.22139	3.00	18.00
	Total	**105**	**12.8952**	**4.97092**	**3.00**	**29.00**
3rd year	TWs	34	22.2941	5.21960	9.00	28.00
	AWs	34	18.2059	5.94306	6.00	28.00
	TNPs	34	18.6765	6.66843	4.00	28.00
	Total	**102**	**19.7255**	**6.19191**	**4.00**	**28.00**
4th year	TWs	35	25.0000	3.54799	15.00	30.00
	AWs	35	22.2571	4.71757	14.00	30.00
	TNPs	35	21.5429	5.08945	10.00	30.00
	Total	**105**	**22.9333**	**4.70120**	**10.00**	**30.00**

Table 6.13 Subjects' knowledge in different types of vocabulary compared within the same level of students

Levels	**Students' knowledge of vocabulary**	**Mean Difference**	**Sig.**
2nd year	Technical words > Technical NPs	5.0285(*)	.000
	Academic words > Technical NPs	4.6857(*)	.000
3rd year	Technical words > Academic words	4.0882(*)	.022
	Technical words > Technical NPs	3.6176(*)	.049
4th year	Technical words > Academic words	2.7428(*)	.043
	Technical words > Technical NPs	3.4571(*)	.007

* The mean difference is significant at the .01 and .05 levels.

6.3 Implications for EAP/ESP course/material designers, language teachers and electrical engineering students

This corpus-based study does not aim to validate any kind of word lists or vocabulary teaching methodologies. Instead, it was conducted to gain more insight on the occurrences of types of vocabulary in context as well as to raise language teachers and material designers' awareness of vocabulary teaching in EAP/ESP for electrical engineering students. Also, the findings from the test provide implications for the electrical engineering students to realize their knowledge of vocabulary so that they know which vocabulary to study and learn more.

6.3.1 Course/material designers

The findings from the corpus are vocabulary lists and their proportion. This can be guidance for course and material designers. They can make use of the vocabulary lists from this study and include them in EAP/ESP course and teaching materials, especially the list which have high proportion and potential for difficulties for electrical engineering students. As the findings from the test show that overall the students had the problems with technical noun phrases, that the second-year students, who are required to enroll in EAP courses, did not know technical words significantly than academic words and that both technical noun phrases and technical words occur with high proportion in the electrical engineering textbooks, course and material designers should emphasize both technical noun phrases and technical word and put them in the course/ teaching materials for electrical engineering students.

6.3.2 Language teachers

The findings from this study contribute some insight to EAP teachers to some extent. At least, the teachers know that technical lexical units have a very high proportion in the electrical engineering corpus while academic lexical units have a very low coverage in the same corpus and that the second-year engineering students had problems with technical lexical units. These findings can be applied in EAP course for the students in question, to help the students improve and reinforce their knowledge of the vocabulary as well as their ability in reading comprehension. The teaching of EAP vocabulary will be discussed in detail in 6.4.

6.3.3 Electrical engineering students

The findings from the test show that the students have more problems with technical noun phrases. This indicates that they should pay more attention on learning these noun phrases, not only what they mean but how they are interpreted. Also, they need to pay attention to homographs from the AWL. In this case they need to learn both the common meaning as well as the technical meaning of these homographs according to the electrical engineering context. Also, they must be aware that some general words from the GSL can provide technical meaning when used in electrical engineering.

Lists from this study are merely an example of different types of vocabulary for the electrical engineering students though these lists tell only type of vocabulary, not meaning. However, the students can check their meaning by using a specialized dictionary and/or by asking for meaning from both their subject and EAP teachers.

6.4 Implications for EAP/ESP vocabulary teaching

The results from the study reveal some implications for vocabulary teaching. However, the findings from the corpus suggest what to focus on while the findings from the test suggest a different focus at different levels of study.

6.4.1 Implications for teaching technical vocabulary

In teaching vocabulary, words with high frequency are a focus of learners' attention (Nation and Newton, 1997). As EAP courses are intended to reinforce students' ability to deal with their English textbooks (for engineers), TWs and TNPs, should receive more attention than AWs and ANPs based on their high coverage. In fact, general vocabulary in this present study has the highest proportion in tokens and running words (see Table 6.1). However, it includes all function words with 150 types, most of which are high frequency words. If the function words are excluded from GWs, general (content) words will remain 2,048 types. Technical vocabulary including TWs and TNPs, therefore, covers a higher proportion than those of other kinds, with 6,395 types and 32,467 running words (see Table 6.2).

With its high proportion and high frequency in electrical engineering corpus, both language teachers and material designers should include technical vocabulary in the process of language teaching in EAP/ESP classes for the engineering students. Since difficulties seem to emerge more from multi-word lexical units than single words, in vocabulary teaching, relationships of words in context should be given more attention. Yang (1986) suggests that in syllabus design multi-word terms should be emphasized more than isolated single words.

To help learners deal with TWs, Chung and Nation (2003) recommend that learners be helped in TW recognition and TW learning. They suggest that language teachers help the students learn the skills to deal with TWs by recognizing TWs, interpreting meaning, relating sense to a core meaning, and learning word parts. To recognize a TW, learners can observe clues such as definition, special letter formats, specialized use in diagram. Examples of clues are as follows.

- Semiconductors are a group of materials having electrical conductivities intermediate between metals and insulators. (definition)
- The combination of the winding resistance is called the *equivalent resistance*, and the combination of the leakage reactances is called the *equivalent reactance*. (special letter format)

Apart from clues, learners can also recognize TWs from repetition of words as TWs occur more frequently in specialized text. The following excerpt exemplifies the repetition of the word '*current*' and the noun phrase '*independent current source*' which are TLUs in electrical engineering.

> *An ideal independent* ***current*** *source forces a specified* ***current*** *to flow through itself. The symbol for an independent* ***current*** *source is a circle enclosing an arrow that gives the reference direction for the* ***current.*** *The* ***current*** *through an independent* ***current*** *source is independent of the elements connected to it and of the voltage across it.*

Learners can learn new words by checking their meaning from the dictionary. In the case that it is a general or an AW but technically used, they may check if the technical meaning relates to the common core meaning of the words. However, it is common that learners cannot find a meaning which makes technical sense in the context from a general dictionary. If so, learners need to guess its meaning from the context. Some learners may be able to do this, but some may not and may ignore them as well as lose the information the word and the context can give them. Therefore, it would be worthwhile and helpful for learners to purchase a reputable dictionary in their field (Trimble, 1985). Another way to learn a single word is to establish the meaning based on its relationship with other words or as collocations by the use of concordances. With concordance lines, learners have a greater chance to see words used in the context and to induce their meaning and to learn their grammatical patterns from them. Using this method, learners can learn words productively (Chung and Nation, 2004).

In terms of complex noun phrases as TNPs, learners may need help with recognition of the relationship of words and their grammatical structure to unpack information from groups of words. Pueyo and Val, (1996) remark that learners will be able to better understand the complexity of technical language in specialized texts if they can unpack the information technical terms hold through the different lexico-grammatical structures. They suggest that nominalization processes be introduced to learners—how a single name is changed to a nominalization and how nominalizations are turned back into processes. With more complex nominal groups, identification of head nouns and important modifiers are good practice for learners. Knowledge of grammatical structures of noun phrases would help develop learners understanding of how nominalizations and nominal groups are used in technical text (Pueyo and Val, *ibid.*).

To unpack information from noun phrases, Trimble (1985) proposes a useful way with the individualized assignment approach. Learners are asked to bring with them some subject-matter reading excerpts with noun phrases or compounds for class discussion on translating and paraphrasing. When phrases are too technical to deal with in language classes, one way to help learners with those TNPs is to have learners ask for meanings from subject teachers. Trimble (1985: 136) argues that non-native language learners “are hesitant to show their ignorance before subject-matter teachers (but not before English teachers).” He recommends that language teachers have lists of noun phrases and ask for clarification of meanings from appropriate (subject) teachers. This approach is useful for making a file which can be used with future classes (Trimble, *ibid*).

An alternative way is to introduce learners to collocations and involve them with noun phrases as collocations. To multi-word items as collocations, Moon (1997) adds “Their non-compositionality, whether syntactic, semantic or pragmatic in nature, means that they must be recognized, learned, decoded and encoded as holistic units.” She points out that frequency is “a useful criterion for judging which items should be taught”—very frequent items should be prioritized in language teaching while infrequent ones might be taught as receptive vocabulary (p. 61). What is more, multi-word items must be classified by subject area and advanced learners should be made aware of the range of types of multi-word items and the differing degrees of transparency and opacity (Gläser, 1988: 264; quoted by Moon, 2007: 61).

In terms of language teaching, Ward (2007) discusses teaching collocations in two parts: teaching individual collocations, and teaching collocations as a class. In term of individual collocations, he confirms involvement of active elaboration of the items or *rich instruction* by Nation (2001) and redundant exposure to target word or *reading plus* by Paribakht & Wesche (1996) and Wesche and Paribakht (2000).

Teaching collocations as a class has two steps: raising students' awareness of the existence and frequency of collocations and teaching the process of reading collocations as chunks. Learners' knowledge of collocations does not develop in parallel with their knowledge of general vocabulary. In reality, English language learners know more general vocabulary than collocations. In language teaching collocations have been neglected, and language learners do not realize that collocations can pose potential problems in language learning. Therefore, collocations should be taught in EFL contexts (Bahns and Eldaw, 1993).

For language teachers, teaching technical vocabulary can be problematic. Chung and Nation (2003) argue that language teachers know nothing or very little about technical subjects. In EAP classes authentic materials cannot be avoided. It is doubtful how language teachers can improve reading comprehension and check learners' understanding if they themselves do not really know about the content. With the use of authentic texts, language teachers can learn, in time, some content and TWs while they are teaching and working with EAP/ESP; otherwise they will not know what they are dealing with. Study of the content before teaching can be accomplished by consulting an engineering encyclopedia and/ or with engineering specialists. However, this could be more problematic if language teachers are not selective in using authentic texts with technical content far beyond their capability. Language teachers, therefore, need to be careful with text selection for EAP/ESP classes.

6.4.2 Implications for teaching academic vocabulary

The words contained in the AWL are unlikely to be of equal value to all students, and many words will be of almost no use to students at all (Hyland and Tse, 2007). They add that teachers have to recognize that students in different disciplines need different ways of using language and so teachers cannot depend on a list of academic vocabulary. The AWL seems most useful to students in computer sciences, where 16 % of the words are covered by the list (Hyland and Tse, 2007), but it is not very useful to the electrical engineering students because many words from the AWL are used with technical meaning in this field. Though the proportion of AWs in electrical engineering corpus is quite low and the AWL would likely become invalid for this study field, totally ignoring this type of word would spoil learners' vocabulary knowledge. The electrical engineering students may need to study texts from other related fields, which might contain more AWs, as the nature of engineering is an applied science.

However, the teaching of academic vocabulary should be conducted with care since some AWs provide different meaning in technical contexts. Wang and Nation (2004) argue that polysemes should have a common underlying meaning and the central concept behind a variety of uses should be emphasized. They added that this should also be done with AWs used as technical terms. There are two ways suggested for language teaching by having learners study from entries and sub-entries in dictionaries and learn from concordances. Through the use of a dictionary, learners try to identify the common core, or unifying definition, by relating sub-entries to each other. For example, suppose the entry "*phase*" as a noun (from Dictionary.com) has 6 sub-entries:

1. any of the major appearances or aspects in which a thing of varying modes or conditions manifests itself to the eye or mind.
2. a stage in a process of change or development: Each phase of life brings its own joys.
3. a side, aspect, or point of view: This is only one phase of the question.

4. a state of synchronous operation: to put two mechanisms in phase.
5. (Chemistry) a mechanically separate, homogeneous part of a heterogeneous system: the solid, liquid, and gaseous phases of a system.
6. (Physics) a particular stage or point of advancement in a cycle; the fractional part of the period through which the time has advanced, measured from some arbitrary origin often expressed as an angle (phase angle), the entire period being taken as 360°.

From these sub-entries, the students may work individually or in pairs to find the core meaning of the word "*phase*".

By concordances, learners may internalize words and a variety of their meanings by looking at clues to different meaning from concordance lines and studying from word type and collocations as well as the relationships of words in context. For example, the concordance lines of the word "*phase*" are shown below.

1	munication systems is the *phase*-locked loop , whic
2	main job is to track the *phase* of the carrier of
3	mpairments to the carrier *phase* and frequency. Acc
4	uctuations in the carrier *phase* and frequency be r
5	amplitude, frequency, and *phase* of the input signa
6	we select the appropriate *phase* detector. The outp
7	umption is related to the *phase* detector, whose ma
8	he difference between the *phase* of the input signa
9	d the output signal . The *phase* detector can have
10	lysis, we will consider a *phase* detector whose out
11	on of What is the maximum *phase* deviation for ? Wh
12	e T (t) as represents the *phase* error, which is th
13	he difference between the *phase* of the input signa
14	a perfect tracking of the *phase* of the input signa
15	s a representation of the *phase* error in the compl
16	tion is the output of the *phase* detector. Figure s
17	Figure shows one type of *phase* detector, called a
18	tector, called a sawtooth *phase* detector. This pha
19	ooth phase detector. This *phase* detector has a lin
20	Note, however, if the *phase* difference suddenl

From these concordance lines, the students can learn the word '*phase*' used in the real context and at least they will see that this word occurs regularly with '*detector*'. Thurstun and Candlin (1998) confirm that the use of concordances provide learners with "experience of the language with insights into collocations…linked to opportunities to develop students' analytical abilities" and the use of concordances is valuable for both a teacher-mediated workshop format and for independent study. However, they argue that too much exposure to concordance lines or dependence merely on deduction from concordances can bore the learners.

6.4.3 Implications for teaching learners from different levels

EAP/ESP engineering classes are offered to second-year students who have met the requirements of general English courses. The score results of the second-year students reveal that the mean scores between TWs and AWs have no significant difference but the mean scores of both AWs and TWs show a significant difference with the mean scores of TNPs (see Tables 7.8 and 7.9). This implies that the second year students still have problems with all types of vocabulary, especially with TNPs.

However, the findings give two perspectives for EAP/ESP classes. The first perspective is for the EAP/ESP beginners like the second-year students. In term of lexical units, this group may need to learn more EAP/ESP lexical units apart from words from the GSL. EAP/ESP vocabulary includes AWs and TWs as well as ANPs and TNPs. ALUs are not problematic to language teachers as this type of word can be found in dictionaries, unlike those used as TLUs. TLUs could be more difficult for language teachers to deal with as their meanings are bound with the context in which they occur. Some TWs can be found in normal dictionaries, but most of them can only be found in specialized dictionaries. However, the use of dictionaries is only one way to help the students learn new words. There are some other ways to teach new words, for example, the use of concordances, word cards, word parts, etc. A good method for language teachers is to consult with the subject teachers. Language teachers can learn a lot from subject teachers and can apply the knowledge to future classes.

The second perspective is for advanced level EAP/ESP classes like the fourth-year students or the first-year master degree students. This group knows more TWs and AWs and even TNPs, so vocabulary teaching may not be the main focus, in contrast with beginner classes. The students may need to learn other language skills in order to deal with advanced textbooks, research journals, research studies and other related printed materials. When teaching this level, needs analysis should be implemented and conducted with the students. At the least, language teachers should talk to the subject teachers to determine their focus.

6.5 Limitations of the study

This research study applied the Rating Scale and the manual analysis, both of which revealed limitations of use and might have an effect on the research findings to some extent. The use of both methods, therefore, must be handled with care.

6.5.1 The use of the rating scale

The Rating Scale is considered more reliable than other methods, for identifying technical vocabulary (Chung and Nation, 2003-2004), but this method must be used with care. To identify TWs and to classify them into groups with the Rating Scale requires the researcher’s intuition or the researcher’s knowledge of the discipline and its related fields. To put the words in groups according to the degree of technicalness can be problematic if the researcher does not really know where the words belong. Though the use of a dictionary is helpful, it is tedious and time-consuming to check every word against the dictionary.

The use of the researcher's intuition can be a flaw of this research tool in terms of reliability. To raise its level of reliability, the inter-raters, who are experts in the field, are involved by checking whether the rated words by the researchers are put in the right groups (depending on each expert's intuition). The consistency of intuitions would indicate the reliability of the Rating Scale. However, the inter-rater reliability is normally checked after the analysis has been done by the researcher. The consistency or the reliability cannot be 100 %, and this means some words are put into the wrong groups. For example, in this study, the consistency of the Rating Scale from three inter-raters and the researcher is 90 %. The other 10 % is not actual errors. It is the inconsistency of intuition among the inter-raters and the researcher. This means that from 100 words, the researcher classified 90 words into the right groups for sure but the other 10 can be into the right or wrong groups or categories. To conclude, the use of the Rating Scale needs a high level of intuition or knowledge on the part of the researcher.

6.5.2 The manual analysis of the corpus

The identification of noun phrases was done manually with the predetermined criteria. This process was especially time-consuming since the researcher needed to go through the corpus line by line searching for complex noun phrases and taking them out of the corpus. These noun phrases were analyzed separately from single words. As this manual analysis is time-consuming, it limits the size of the corpus for a study with a limited amount of time. The corpus in this study contains 122,209 running words. The researchers needed to look through all these words for noun phrases. The classification of words into categories was also conducted manually after the single words are made lists by the use of a software program. The researchers needed to check every word from the lists against the criteria from the Rating Scale. The lists would be longer and the analysis would take a longer time if the size of the corpus were bigger. In essence, manual analysis of the corpus can limit the corpus size for a study with time constraints.

6.6 Suggestions for further research

This research study was conducted on a small scale and restricted to the electrical engineering field. It was limited by the use of manual analysis which leads to a small corpus. However, this study offers some suggestions for further research.

1. Replication of the present study can be done on a larger scale, and electrical engineering corpus from other publishers should be included.

2. Replication of the present study can be done with other engineering fields or with other EAP/ESP classes. The findings would enable language teachers to effectively manage their EAP/ESP classes.

3. Extension to other aspects of language apart from vocabulary can be conducted. Practically, needs analysis of language for EAP/ESP should be done for guidance in language teaching so that the teachers focus on teaching what learners really need.

6.7 Conclusion

The use of corpus linguistics to study the proportions of vocabulary in electrical engineering corpus results in insights for language teachers on the perspectives of types of vocabulary in a specialized text as well as implications for

EAP/ESP pedagogy. The first insight involves the proportion of technical vocabulary. This type of word was estimated at only 5 % of running words in academic texts (Nation, 2001). In fact, the percentage of technical vocabulary varies according to disciplines. For example, in electrical engineering corpus, technical vocabulary occurs in 26.57 % of running words. This indicates that technical vocabulary is found in a very high proportion in these textbooks and cannot be ignored. The second insight involves academic vocabulary. Academic vocabulary has been estimated at around 10 % of running words in academic texts (Coxhead, 2000 and Nation, 2001), and made out to be the ideal focus of vocabulary teaching. Like that of technical vocabulary, the proportion of academic vocabulary varies according to fields or areas of study (Hyland and Tse, 2007). In electrical engineering corpus, academic lexical units make up only 5.55 % of running words. This finding indicates that those experts have overestimated the proportion of academic vocabulary and mistakenly put the focus of vocabulary teaching on this type. In fact, the teaching of academic vocabulary should be effected with care since some AWs are used as technical terms. In essence, some AWs have homographs with technical meanings.

The third insight involves the presence of words which do not occur alone but in groups. This study, with classification of words and phrases, reveals more realistic proportions of vocabulary. Complex noun phrases provide meaning based on words in their groups. Two or more common words, including academic vocabulary, can be used together as a technical term with a meaning unique to the context. Separating a noun phrase into individual words impairs understanding of the real meaning of that phrase. This study separated single words from noun phrases and found that noun phrases made up 20.80 % of the corpus or 25,429 running words, and 94.62 % or

24,061 of these running words were used as technical terms. Therefore, studies conducted looking at individual words only distort the real proportion of technical vocabulary since most noun phrases are used as technical terms. This is misleading for language teaching in EAP/ESP classes. In practice, materials designers and language teachers should include (technical) noun phrases in teaching materials since this type of vocabulary is considered more problematic to language learners.

The vocabulary test also provides some insights on learners from different levels with different knowledge of vocabulary. The hypothesis from this study that engineering students know more academic vocabulary than technical vocabulary proved untrue since the results show that they know more TWs than academic ones. The other hypothesis that the students know more TWs than TNPs held true. Still, the findings from the test reveal that students from higher levels know more vocabulary than those from lower ones. This suggests that learners from different levels have different language needs. While the second-year students may need to learn more technical vocabulary, the third and fourth-year students may need some other language skills to deal with more advanced texts. Both findings from the corpus and the vocabulary test yield some implications for EAP/ESP pedagogy. Technical vocabulary, including TNPs should be included in language teaching, especially for second-year students who are beginners in EAP/ESP classes.

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APPENDIX A

The Electrical Engineering Textbooks Used in the Study

ISBN	AUTHOR	TITLES	No. of pages
0-13-040268-0	Harold P.E. Stern, Samy A. Mahmoud, and Lee Elliott Stern, 2004	Communication Systems: Analysis and Design	90 pages
0-13-098637-2	Theodore Wildi, 2002	Electrical Machines, Drives, and Power System	94 pages
0-13-061070-4	Allan R. Hambley, 2002	Electrical Engineering: Principles and Applications	91 pages
0-13-080182-8	Timothy L., 2001	Electrical Power and Controls	88 pages
0-13-026101-7	Ben G. Streetman and Sanjay Banerjee, 2000	Solid State Electronic Devices	94 pages

APPENDIX B

The Numbers of Random Pages from the Textbooks

Communication Systems: Analysis and Design: 1, 12, 24, 27, 33, 44, 49, 52, 54, 61, 84, 97, 98, 106, 124, 125, 126, 128, 134, 143, 149, 153, 155, 156, 164, 166, 167, 172, 174, 182, 188, 192, 197, 198, 206, 207, 212, 214, 222, 238, 243, 246, 247, 249, 257, 259, 264, 268, 270, 307, 308, 309, 320, 328, 333, 342, 345, 360, 362, 363, 366, 367, 370, 374, 376, 380, 388, 395, 400, 403, 405, 409, 414, 421, 424, 428, 429, 448, 450, 456, 459, 463, 464, 465, 471, 479, 491, 501, 502, 505 = **90 pages**

Electrical Machines, Drives, and Power System: 3, 6, 13, 18, 24, 30, 38, 51, 54, 57, 69, 70, 76, 79, 84, 91, 95, 109, 115, 116, 123, 127, 139, 145, 146, 161, 166, 172, 178, 200, 204, 206, 223, 224, 229, 230, 239, 254, 260, 290, 299, 308, 320, 334, 341, 345, 352, 354, 362, 363, 367, 369, 382, 395, 396, 420, 439, 443, 444, 448, 463, 466, 469, 471, 476, 512, 513, 517, 520, 528, 530, 534, 554, 557, 586, 619, 622, 623, 631, 648, 649, 655, 673, 701, 706, 708, 709, 732, 740, 756, 774, 775, 779, 783, 790 = **94 pages**

Electrical Engineering: Principles and Applications: 26, 38, 64, 70, 79, 83, 84, 88, 105, 112, 113, 116, 123, 125, 151, 168, 184, 187, 189, 197, 200, 201, 212, 216, 217, 229, 245, 251, 262, 265, 275, 283, 305, 323, 325, 330, 346, 351, 354, 395, 412, 418, 420, 448, 466, 472, 477, 494, 502, 504, 512, 515, 523, 531, 542, 548, 551, 554, 557, 558, 572, 579, 581, 587, 589, 592, 605, 610, 621, 626, 628, 639, 640, 646, 656, 658, 661, 673, 675, 710, 714, 720, 730, 739, 741, 756, 761, 767, 779, 790, 794 = **91 pages**

Electrical Power and Controls: 8, 15, 18, 27, 31, 43, 50, 53, 68, 70, 75, 91, 93, 97, 106, 108, 109, 111, 114, 117, 118, 122, 127, 131, 133, 135, 137, 150, 155, 157, 174, 179, 180, 182, 183, 184, 188, 198, 200, 202, 210, 223, 227, 230, 237, 242, 247, 254, 259, 263, 271, 276, 278, 282, 286, 295, 300, 301, 305, 311, 322, 323, 338, 340, 341, 343, 344, 347, 351, 360, 363, 374, 375, 376, 382, 386, 388, 389, 392, 408, 411, 424, 425, 427, 429, 432, 453, 454, 458 = **88 pages**

Solid State Electronic Devices: 1, 7, 38, 39, 41, 44, 47, 50, 51, 53, 70, 72, 75, 86, 101, 106, 115, 128, 134, 144, 148, 152, 156, 161, 163, 168, 172, 174, 180, 183, 187, 190, 193, 201, 207, 215, 221, 225, 232, 234, 242, 245, 247, 248, 253, 255, 263, 267, 271, 272, 279, 283, 285, 288, 292, 308, 315, 325, 327, 328, 331, 335, 339, 352, 381, 382, 386, 398, 401, 404, 409, 415, 416, 417, 418, 423, 425, 443, 445, 453, 454, 458, 459, 460, 467, 468, 476, 482, 485, 491, 502, 508, 513, 515 = **94 pages**

APPENDIX C

Letter of Permission from Pearson Education

Pearson Education

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MARY ANN BROADNAX

March 1, 2006
Mr. Sukhum Wasuntarasophit
Suranaree University of Technology
111 University Avenue, Muang District
Nakhon Ratchasima 2230000
Thailand

Dear Mr. Wasuntarasophit:

You have our permission to include in your research study on technical vocabulary in electrical engineering textbooks, random words from our books: **Communication Systems:Analysis and Design 1/e by Stern and Mahmoud ISBN#0-13-040268-0, Electrical Machines, Drives, and Power System 5/e by Wildi ISBN#0-13-093083-0, Electrical Engineering:Principles and Applications 1/e by Hambley ISBN#0-13-061070-4, Electrical Power and Controls 1/e by Skvarenina and DeWitt ISBN#0-13-080182-8 and Solid State Electronic Devices 5/e by Streetman and Banerjee ISBN# 0-13-025538-6.**
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Skvarenina, Timothy L.; DeWitt, William E.; Electrical Power and Controls 1/e ISBN#0-13-080182-8©2001

Streetman, Ben.; Banerjee, Sanjay.; Solid State Electronic Devices 5/e ISBN#0130255386

Sincerely,
Mary Ann Broadnax
Permissions Administrator

APPENDIX D

Interrater Reliability

The Rating Scale for Identifying Technical Vocabulary

Group 1: Words that are classified as function or grammatical words, including articles, demonstratives, prepositions, question words, auxiliaries, modals, pronouns, possessives, ordinals, cardinals, conjunctives and some adverbs. These words are, for examples, the, this, with, what, to, do, will, we, its, and, moreover, always, and while.
Group 2: Content words including nouns, verbs, adjectives, and adverbs that are used both inside and outside the field of electrical engineering with no specialized meaning related to the field. They are content words i.e. nouns, verbs, adjectives, and adverbs, for examples condition, obtain, reliable, and heavily.
Group 3: Content words including nouns, verbs, adjectives, and adverbs that are used both inside and outside the field of electrical engineering with meaning related to words from Group 4 & Group 5. They describe the processes, functions, features, properties, items, and materials. When they are used in the context of electrical engineering with words from Group1 & Group2, their meaning is technical for examples, current, gate, and frequency.
Group 4: Content words in general science or other engineering fields, including nouns, verbs, adjectives, and adverbs, which are related to the field of electrical engineering and words (forms) which are not likely to be used in general language/concept. They refer to scientific principles, items, materials, units, properties, functions, processes, and concepts. These words have clear restrictions of usage within science. Examples are atom, sine, and thermal (agitation).
Group 5: Content words including nouns, verbs, adjectives, and adverbs that provide specialized meaning and are used mostly in the field of electrical engineering. This list of words includes materials or items, apparatus, equipment, units, properties, and functions closely related to electricity and electrical engineering. Examples are op amp, amplifier, oscilloscope, volts, pulse, and amplification.

1. Classify the words below using the criteria from the table above by putting numbers 1-5 in the column next to the words. (The interrater works with the researcher.)

1. A	
2. AN	
3. ANGLE	
4. ARE	
5. AT	
6. BRUSH	
7. COULD	
8. CHARGE	
9. CIRCUIT	
10. CONVERTER	
11. DIAMETER	
12. EXAMPLE	
13. FILTER	
14. FLUX	
15. FOR	
16. GAIN	
17. GATE	
18. GROUND	
19. IMPEDANCE	
20. IN	
21. INTEGRATOR	
22. IS	
23. IT	
24. LINE	
25. LOAD	

26. MATRIX	
27. MORE	
28. ONE	
29. POINTER	
30. POWER	
31. PROBABILITY	
32. QUADRANT	
33. RATE	
34. RECEIVER	
35. ROTOR	
36. SCALE	
37. SHOWN	
38. SOURCE	
39. SPECTRUM	
40. STATOR	
41. SYSTEM	
42. THE	
43. TIME	
44. TRANSFORMER	
45. TRANSISTOR	
46. USE	
47. VOLTAGE	
48. WE	
49. WINDING	
50. ZERO	

2. Classify the words below using the criteria from the table above by putting numbers 1-5 in the column next to the words. (The interrater works alone.)

1. AMPLIFIER	
2. AND	
3. ARMATURE	
4. AS	
5. ATOM	
6. BANDWIDTH	
7. BAR	
8. BASE	
9. BINARY	
10. BIT	
11. BY	
12. CALLED	
13. CAPACITOR	
14. CONDUCTOR	
15. CORRELATION	
16. CURVE	
17. DIODE	
18. ELECTRON	
19. EQUAL	
20. EQUATION	
21. EQUILIBRIUM	
22. EXCITATION	
23. FIGURE	
24. FIND	
25. FREQUENCY	
26. FROM	
27. GENERATOR	
28. GIVEN	
29. HARMONICS	
30. HAVE	

31. IF	
32. INDUCTANCE	
33. INERTIA	
34. LINEAR	
35. MACHINE	
36. MEANS	
37. MULTIPLYING	
38. NOT	
39. OF	
40. ON	
41. ONLY	
42. OXIDE	
43. POLE	
44. RESISTOR	
45. SAME	
46. SECONDARY	
47. SHORT	
48. SIGNAL	
49. SQUARE	
50. SUBSTRATE	
51. SWITCH	
52. TABLE	
53. TERMINAL	
54. THAT	
55. THIS	
56. TO	
57. TORQUE	
58. TWO	
59. VALUE	
60. WITH	

APPENDIX E

Inter-rater Reliability

Criteria for identifying Non-technical and Technical Noun Phrases

Category 1: Non-Technical Noun Phrases Nominal groups as noun phrases which provide their meaning not related to the fields of general science and engineering are classified as non-technical noun phrases.
Category 2: Technical Noun Phrases Nominal groups as noun phrases which provide their meaning related to the fields of general science and engineering are classified as technical noun phrases. These noun phrases refer to scientific principles, items, materials, units, properties, functions, processes, and concepts.

1. Classify noun phrases below into non-technical and technical noun phrases using the criteria in the table above by putting numbers 1-2 in the column next to the noun phrases. (The interrater works with the researcher.)

average lifetime	
basic building blocks	
basic structure	
clockwise direction	
connection points	
design team	
developed power	
electric field	
generated voltage	
heater element	
induced voltage	
output voltage	
power factor	
previous section	
reactive power	
real part	
received signal	
service entrance	
synchronous motor	
voltage drop	

2. Classify noun phrases below into non-technical and technical noun phrases using the criteria in the table above by putting numbers 1-2 in the column next to the noun phrases. (The inter-rater works alone.)

accepted tests	
active power	
apparent power	
average duck	
basic characteristics	
color image	
combined action	
conduction band	
discrete components	
equivalent circuit	
first stage	
general purpose applications	
induction motor	
input signal	
line current	
magnetic field	
major problem	
minimum weight	
opposite direction	
phasor diagram	
power quality	
second stage	
secondary voltage	
straight line	
synchronous generators	
terminal voltage	
time delay	
transition region	
transmitted signal	
voltage gain	

APPENDIX F

Vocabulary Test: Format A

แบบทดสอบคำศัพท์

ชื่อ__________________________________ ชั้นปีที่ _______ โทรศัพท์____________

<u>คำสั่ง</u>: ข้อสอบมีจำนวน 6 หน้า 90 ข้อ ให้นักศึกษาแปลเฉพาะ**<u>คำที่ขีดเส้นใต้</u>**ให้เป็นภาษาไทย หรืออธิบายความหมายของคำที่ขีดเส้นใต้ด้วยวิธีใดก็ได้ เพื่อแสดงว่านักศึกษารู้ความหมายของคำ และความหมายของคำต้องสอดคล้องกับบริบท (คำหรือข้อความโดยรอบคำที่ขีดเส้นใต้) ที่ให้มาด้วย

1. possible **<u>voltages</u>** for the original analog signal

____

2. Substituting these terms into **<u>equation</u>** 2-3 as follows

____

3. This means that a converter absorbs **<u>reactive power</u>** from the ac system

____

4. **<u>Current</u>** flows relatively freely in the forward direction of the diode

____

5. the **<u>concepts</u>** developed in this section will be used extensively

____

6. the **<u>phasor diagram</u>** is shown in Figure 5.10a

____

7. Let R represent the resistance of a particular **<u>load</u>**

____

8. only one **source** is readily available

---

9. Find the **power factor** when the motor operates at rated conditions

---

10. inexpensive integrated **circuits** with a wide variety of user-adjustable ranges

---

11. in the form of heat, 80 percent of the **energy** it receives

---

12. a three-phase **induction motor** drives a load such as a pump

---

13. the average normalized power at **frequency** f_0 is related only to X_1

---

14. Numerical **data** can be represented in decimal

---

15. by shifting the brushes the **output voltage** decreases

---

16. the random motion of **electrons** within electronic devices

---

17. this **section** will be used extensively in the analyses of diodes

---

18. we now proceed to develop the **equivalent circuit** of the transformer

---

19. variable dc voltages were obtained from dc **generators**

---

20. There are other **devices** available to improve power quality

---

21. the **received signal** will be corrupted by noise

---

22. **Transformers** and motors are particularly important for nonelectrical engineers

---

23. diffusion capacitance as a **function** of forward bias in long and short diodes

24. the channel will attenuate the **transmitted signal**

25. the corresponding average normalized power spectrum for a typical **signal**

26. the **regions** above and below the two magnets

27. the **electric field** W must just balance the product Vx

28. Two low-voltage **systems** are provided

29. allow the induction motor to operate over a wide **range** of speeds

30. The resulting **terminal voltage** is a flat-topped wave

31. by casting molten aluminum into slots cut into the **rotor**

32. There is a **distribution** of energies

33. The value of the **induced voltage** is proportional to the rate of change of flux

34. a prediction algorithm can be implemented using a tapped-delay **line**

35. These **codes** are called pseudo-random

36. the inductor is storing more energy in its **magnetic field**

37. the **torque** produced by the motor versus speed

38. allow the receiver to detect **errors**

---

39. All five **generated voltages** end at the same horizontal line

---

40. the resulting magnetic **flux** changes

---

41. for a junction with an **area** of about 1 cm^2

---

42. There are six equivalent X valleys in the **conduction band**

---

43. little **resistance** between the ends of the channel and the electrodes

---

44. you have more than one **component** within a block

---

45. the **line current** drops from 5 A to 3.6 A

---

46. many thousands of transistors, diodes, resistors, and **capacitors** to be included in a chip of semiconductor

---

47. describe the **sequence** of events that takes place

---

48. The **active power** absorbed by the motor

---

49. the farther the **receiver** is out of synchronization

---

50. this is a good **assumption**

---

51. they are called **synchronous motors**

---

52. the current through two **terminals** can be controlled

---

53. such as **cores** that lack symmetry and those with multiple coils

54. **Synchronous generators** are the backbone of the electric power system

55. Regulation curves are plotted with the field **excitation** fixed

56. motors in industry actually operate as generators for brief **periods**

57. the p side diffuses to the **transition region**

58. time-varying magnetic flux linking a **coil** induces voltage across the coil

59. the **ratio** of the highest frequency to the lowest

60. The constant Av is called the **voltage gain** of the amplifier

61. improper design or over driving an electronic **amplifier**

62. The second term on the right-hand side of equation 10-5 contains the **factor** j

63. the **input signals** contained only a few components

64. This means that a **converter** absorbs reactive power from the ac system

65. they meet all the **requirements** in the previous section

66. the **secondary voltage** of a practical transformer decreases

67. the minimum **bandwidth** of the channel

68. Figure 14-19 shows a **portion** of the I/O image tables

69. find the **input impedance** to the transformer

70. the **gates** are the same in each half of the channel region

71. we begin our **analysis** by developing the following notation

72. the diffusion current is usually negligible for **reverse bias**

73. the small signal semiconductor **capacitance** is given by the same formula

74. The duration of one **cycle** is T seconds

75. loads operate at near **unity power factor**

76. The rotor **windings** of a three-phase induction machine can take two forms

77. Calculate the total harmonic distortion, using both **definitions**

78. consider the **torque-speed characteristics** for a three-phase induction motor

79. the **brushes** short-circuit the coils in which the voltage is momentarily zero

80. but it introduces **distortion**

81. The **small-signal equivalent circuit** for the amplifier is shown

82. The starting current in both the **stator** and rotor is high

83. Describe the **principles** of operation of the DC machine

84. for periodic signals and **average normalized power**

---

85. the corresponding **armature** current is negligible

---

86. the **accuracy** of the induction motor model has limitations

---

87. Draw a phasor diagram showing the **line-to-neutral voltages**

---

88. because inductors and capacitors add to the **impedance** of the circuit

---

89. the **construction** and size of the diode

---

90. the **locked-rotor current** I_s lags considerably behind the applied voltage E

APPENDIX G

Vocabulary Test: Format B

แบบทดสอบคำศัพท์

ชื่อ________________________________ ชั้นปีที่ _______ โทรศัพท์ ___________

คำสั่ง: ข้อสอบมีจำนวน 6 หน้า 90 ข้อ ให้นักศึกษาแปลเฉพาะ**คำที่ขีดเส้นใต้**ให้เป็นภาษาไทย หรืออธิบายความหมายของคำที่ขีดเส้นใต้ด้วยวิธีใดก็ได้ เพื่อแสดงว่านักศึกษารู้ความหมายของคำ และความหมายของคำต้องสอดคล้องกับบริบท (คำหรือข้อความโดยรอบคำที่ขีดเส้นใต้) ที่ให้มาด้วย

1. the **locked-rotor current** I_s lags considerably behind the applied voltage E

____

2. the **construction** and size of the diode

____

3. because inductors and capacitors add to the **impedance** of the circuit

____

4. Draw a phasor diagram showing the **line-to-neutral voltages**

____

5. the **accuracy** of the induction motor model has limitations

____

6. the corresponding **armature** current is negligible

____

7. for periodic signals and **average normalized power**

____

8. Describe the **principles** of operation of the DC machine

---

9. The starting current in both the **stator** and rotor is high

---

10. The **small-signal equivalent circuit** for the amplifier is shown

---

11. but it introduces **distortion**

---

12. the **brushes** short-circuit the coils in which the voltage is momentarily zero

---

13. consider the **torque-speed characteristics** for a three-phase induction motor

---

14. Calculate the total harmonic distortion, using both **definitions**

---

15. The rotor **windings** of a three-phase induction machine can take two forms

---

16. loads operate at near **unity power factor**

---

17. The duration of one **cycle** is T seconds

---

18. the small signal semiconductor **capacitance** is given by the same formula

---

19. the diffusion current is usually negligible for **reverse bias**

---

20. we begin our **analysis** by developing the following notation

---

21. the **gates** are the same in each half of the channel region

---

22. find the **input impedance** to the transformer

---

23. Figure 14-19 shows a **portion** of the I/O image tables

---

24. the minimum **bandwidth** of the channel

---

25. the **secondary voltage** of a practical transformer decreases

---

26. they meet all the **requirements** in the previous section

---

27. This means that a **converter** absorbs reactive power from the ac system

---

28. the **input signals** contained only a few components

---

29. The second term on the right-hand side of equation 10-5 contains the **factor** j

---

30. improper design or over driving an electronic **amplifier**

---

31. The constant Av is called the **voltage gain** of the amplifier

---

32. the **ratio** of the highest frequency to the lowest

---

33. time-varying magnetic flux linking a **coil** induces voltage across the coil

---

34. the p side diffuses to the **transition region**

---

35. motors in industry actually operate as generators for brief **periods**

---

36. Regulation curves are plotted with the field **excitation** fixed

---

37. **Synchronous generators** are the backbone of the electric power system

---

38. such as **cores** that lack symmetry and those with multiple coils

---

39. the current through two **terminals** can be controlled

---

40. they are called **synchronous motors**

---

41. this is a good **assumption**

---

42. the farther the **receiver** is out of synchronization

---

43. The **active power** absorbed by the motor

---

44. describe the **sequence** of events that takes place

---

45. many thousands of transistors, diodes, resistors, and **capacitors** to be included in a chip of semiconductor

---

46. the **line current** drops from 5 A to 3.6 A

---

47. you have more than one **component** within a block

---

48. little **resistance** between the ends of the channel and the electrodes

---

49. There are six equivalent X valleys in the **conduction band**

---

50. for a junction with an **area** of about 1 cm^2

---

51. the resulting magnetic **flux** changes

---

52. All five **generated voltages** end at the same horizontal line

---

53. allow the receiver to detect **errors**

---

54. the **torque** produced by the motor versus speed

---

55. the inductor is storing more energy in its **magnetic field**

56. These **codes** are called pseudo-random

57. a prediction algorithm can be implemented using a tapped-delay **line**

58. The value of the **induced voltage** is proportional to the rate of change of flux

59. There is a **distribution** of energies

60. by casting molten aluminum into slots cut into the **rotor**

61. The resulting **terminal voltage** is a flat-topped wave

62. allow the induction motor to operate over a wide **range** of speeds

63. Two low-voltage **systems** are provided

64. the **electric field** W must just balance the product Vx

65. the **regions** above and below the two magnets

66. the corresponding average normalized power spectrum for a typical **signal**

67. the channel will attenuate the **transmitted signal**

68. diffusion capacitance as a **function** of forward bias in long and short diodes

69. **Transformers** and motors are particularly important for nonelectrical engineers

70. the **received signal** will be corrupted by noise

---

71. There are other **devices** available to improve power quality

---

72. variable dc voltages were obtained from dc **generators**

---

73. we now proceed to develop the **equivalent circuit** of the transformer

---

74. this **section** will be used extensively in the analyses of diodes

---

75. the random motion of **electrons** within electronic devices

---

76. by shifting the brushes the **output voltage** decreases

---

77. Numerical **data** can be represented in decimal

---

78. the average normalized power at **frequency** f_0 is related only to X_1

---

79. a three-phase **induction motor** drives a load such as a pump

---

80. in the form of heat, 80 percent of the **energy** it receives

---

81. inexpensive integrated **circuits** with a wide variety of user-adjustable ranges

---

82. Find the **power factor** when the motor operates at rated conditions

---

83. only one **source** is readily available

---

84. Let R represent the resistance of a particular **load**

---

85. the **phasor diagram** is shown in Figure 5.10a

---

86. the **concepts** developed in this section will be used extensively

---

87. **Current** flows relatively freely in the forward direction of the diode

---

88. This means that a converter absorbs **reactive power** from the ac system

---

89. Substituting these terms into **equation** 2-3 as follows

---

90. possible **voltages** for the original analog signal

APPENDIX H

Examples of Marking Answers from the Test

Word/Phrase	Right answer	Correct answers (1 point)	Incorrect answers (0 points)
armature	ขดลวดในส่วนที่เป็นแกนหมุนของไดนาโมหรือมอเตอร์ไฟฟ้ากระแสตรง	- ขดลวดในมอเตอร์ - ขดลวด armature - ส่วนที่หมุนได้, rotor - ส่วนที่หมุนของมอเตอร์ ดี.ซี - อยู่ในมอเตอร์ ทำหน้าที่จ่ายหรือรับกระแส	- ขนาดใหญ่ - ขดลวดที่มีการจ่ายกระแสให้ - อาร์เมเจอร์
torque	แรงบิด (ขณะมอเตอร์เริ่มหมุน)	- แรงบิด - T = FR	- แรงทางกล - อัตราการหมุน
Line current	กระแสไฟฟ้าในสาย	- กระแสไฟฟ้าในสายส่ง - กระแสในสาย - กระแสในสายไฟ - กระแสในสายส่ง - กระแสของสาย	- สายไฟฟ้า - สายไฟที่มีกระแสสลับไหล - สายกระแส - กระแสที่เดินทางเป็นเส้นตรง - เส้นกระแสไฟฟ้า
Equivalent circuit	วงจรสมมูล (เป็นวงจรที่เขียนขึ้นเปรียบเทียบกับวงจรไฟฟ้าจริง โดยใช้สัญลักษณ์ในการเขียน ทำให้เห็นลักษณะของวงจรดูง่ายขึ้น)	- วงจรสมมูล - วงจรเสมือน - วงจรเสมือน ใช้ปรียบเทียบ - วงจรจำลอง - วงจรทีสามารถหาค่าหรือเขียนเป็นสมการได้โดยง่าย	- สมการวงจร - วงจร - วงจรรวม

APPENDIX I

Examples of Single Words from the Electrical Engineering Textbooks (Word / Frequency)

A. High Frequency Words

Function Words

the / 12637
be / 4832
of / 4128
a / 3770
to / 3018
in / 2897
and / 2703
for / 1319
that / 1259
we / 1156
as / 1110
by / 999
can / 830
this / 743
at / 710
with / 684
from / 605
it / 591
on / 565
will / 499
or / 455
if / 399
which / 387
when / 310
thus / 264
not / 256
than/ 255
each / 244
between / 236
other / 232

must / 204
because / 198
so / 195
have / 188
also / 184
its / 180
into / 179
these / 177
all / 174
then / 166
but / 164
such / 158
however / 154
through / 144
may / 140
where / 139
they / 135
across / 131
what / 131
very / 125
since / 119
how / 116
do / 115
any / 109
no / 101
both / 99
therefore / 98
shall / 95
during / 93
some / 91

per / 85
our / 79
their / 78
while / 74
over / 73
about / 72
out / 69
due / 67
up / 67
either / 63
next / 62
another / 61
several / 61
you / 61
within / 59
after / 58
us / 58
under / 55
before / 51
off / 51
above / 49
although / 48
always / 48
below / 46
down / 46
without / 44
even / 43
them / 40
rather / 34
along / 32

upon / 31
those / 30
still / 24
whose / 24
whether / 22
around / 21
every / 20
toward / 18
whenever / 17
your / 17
behind / 16
itself / 14
until / 14
quite / 13
beyond / 12
inside / 12
though / 11
throughout / 9
neither / 8
against / 5
among / 5
everything / 5
nor / 5
anything / 4
he / 4
onto / 4
unless / 4
front / 3
nothing / 3
something / 3

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be / 2875
figure / 596
show / 580
use / 576
have / 538
many / 332
example / 270
two / 245
value / 235
one / 226
same / 220
time / 210
power / 208
find / 204
high / 189
increase / 188
call / 174
change / 166
connect / 163
machine / 163
give / 160
only / 155
apply / 150
large / 150
low / 143
produce / 143
equal / 142
result / 142
type / 140
operate / 136
consider / 134
speed / 134
see / 133
zero / 133
small / 129
represent / 128
little / 127
determine / 125
follow / 124
term / 118
deliver / 116
side / 115
now / 112
make / 111
case / 110
reduce / 109
number / 106
become / 104
provide / 104
let / 103
flow / 100
first / 98
form / 96
draw / 95
need / 95
know / 94
three / 94
turn / 94
refer / 92
depend / 89
point / 88
cause / 87
hole / 83
add / 82
effect / 82
note / 81
include / 78
much / 78
problem / 78
describe / 77
discuss / 75
important / 75
noise / 75
operation / 75
way / 74
second / 72
contain / 70
loss / 70
move / 70
supply / 70
state / 69
solution / 67
develop / 66
drive / 66
take / 66
write / 66
direction / 65
material / 65
allow / 63
usually / 63
unit / 60
lead / 58
limit / 58
place / 57
start / 57
suppose / 57
build / 56
decrease / 56
do / 56
efficiency / 56
often / 56
compare / 55
total / 54
end / 53
explain / 53
part / 53
possible / 53
control / 52
expression / 52
field / 52
run / 52
set / 51
great / 50
close / 48
good / 48
sample / 48
application / 47
level / 47
new / 47
fact / 46
long / 46
carry / 45
notice / 44
relate / 44
solve / 44
well / 44
cost / 43
measure / 43
standard /43
appear / 42
order /42
pass / 42
size / 42
step / 41
temperature / 41
useful / 41
heat / 40
leave / 40
reason / 40
say / 40
difference / 39
four / 39
late / 39
remain / 39
understand / 39
why / 39
again / 38
go / 38
hand / 38
look / 38
few / 37
near / 37
simple / 37
yield / 37
like / 36
list / 36
receive / 36
store / 36
third / 36
drop / 35

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Indexical Words

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motor / 332
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transformer / 145
generator / 143
signal / 137
coil / 111
capacitor / 85
rotor / 84
resistance / 83
flux / 80
torque / 79
amplifier / 75
winding / 72
transistor / 67
volt / 67
converter / 57
conductor / 51
diode / 51
bandwidth / 47
capacitance / 45
semiconductor / 39
resistor / 38
stator / 37
impedance / 36
armature / 35
inverter / 35
inductor / 32
phasor / 32
pulse / 32
band / 27
inductance / 27
amplitude / 24
transmitter / 22
battery / 19
emitter / 18
insulation / 18
collector / 17
rectifier / 17
chip / 15
equalizer / 15
synchronization / 15
ampere / 14
commutator / 14
demodulate / 13
insulator / 13
relay / 12
thyristor / 12
cathode / 11
encoder / 10
pixel / 10
reactance / 10
sinusoid / 10
compensator / 9
conductivity / 9
watt / 9
accumulator / 8
alias / 8
alternator / 8
contactor / 8
discriminator / 8
heterojunction / 8
hysteresis / 8
node / 8
overexcited / 8
amplification / 7
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arc / 7
electrical / 7
electronic / 7
proton / 7
synchronize / 7
waveform / 7
wavelength / 7
autotransformer / 6
breaker / 6
cycloconverter / 6
demodulation / 6
electrically / 6
electricity / 6
electrode / 6
ohm / 6
sinusoidal / 6
wave / 6
amp / 5
amplified / 5
electric / 5
measurand / 5
sensor / 5
synchronous / 5
transconductance / 5
turbine / 5
wye / 5
baseband / 4
cable / 4
capacitive / 4
coulomb / 4
digital / 4
digitally / 4
henry / 4
insulated / 4
kilowatt / 4
microprocessor / 4
milliampere / 4
resistivity / 4
rheostat / 4
snubber / 4
stepped / 4
synchronism / 4
synchroscope / 4
underexcited / 4
watthourmeter / 4
waveshape / 4
windage / 4
commutating / 3
decoder / 3
electromagnet / 3
farad / 3
mesh / 3
orthogonal / 3
photodetector / 3
photodiode / 3
radio / 3
reheater / 3
resistive / 3
resonance / 3
shunt / 3
software / 3
underflow / 3
acceptor / 2
ammeter / 2
analog / 2
array / 2
bandgap / 2
bandpass / 2
bandstructure / 2
bitline / 2
bushing / 2
calculators / 2
centerline / 2
circuitry / 2
commutative / 2
compressor / 2
condenser / 2
conductance / 2
demodulator / 2
differentiator / 2
electrocardiograph / 2
equivalents / 2
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calculate / 178
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bit / 107
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angle / 28
binary / 26
oxide / 26
multiply / 24
quadrant / 24
spectrum / 24
atom / 22
square / 22
substrate / 20
matrix / 19
equilibrium / 18
diameter / 15
calculation / 13
meter / 13
pointer / 13
scale / 12
axis / 11
copper / 11
inertia / 11
subtract / 11
coefficient / 10
correlation / 10
integrator / 10
flywheel / 9
joule / 9
linear / 9
aluminum / 8
inch / 8
integer / 8
iron / 8
mathematically / 8
newton / 8
oxidation / 8
rectangular / 8
kilogram / 7
magnet / 7
photon / 7
exponentially / 6
horsepower / 6
internet / 6
linearly / 6
mechanical / 6
neutron / 6
nucleus / 6
quantized / 6
radius / 6
sine / 6
thermally / 6
triangle / 6
decibels / 5
furnace / 5
graph / 5
gravity / 5
hydrogen / 5
kinetic / 5
minus / 5
momentum / 5
perpendicular / 5
algorithm / 4
alloy / 4
automobile / 4
bearings / 4
digits / 4
gas / 4
gradient / 4
graphically / 4
mica / 4
miniaturization / 4
molecule / 4
multiple / 4
multiplexed / 4
octave / 4
plasma / 4
polysilicon / 4
processor / 4
radian / 4
sapphire / 4
silicon / 4
vector / 4
zeroing / 4
asbestos / 3
chassis / 3
combustion / 3
constants / 3
correlate / 3
denominator / 3
deuterium / 3
geometrically / 3
hoist / 3
isotope / 3
mechanically / 3
metallization / 3
metering / 3
nonlinearity / 3
nonzero / 3
quantum / 3
satellite / 3
saws / 3
velocity / 3
algebra / 2
ammonia / 2
anisotropic / 2
atomic / 2
aught / 2
barrel / 2
bolted / 2
buffer / 2
cents / 2
condense / 3
cosine / 2
entropy / 2
factoring / 2
gauge / 2
immune / 2
ion / 2
ionize / 2
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laboratory / 2
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logarithm / 2
magnetic / 2
mathematics / 2
multiplication / 2
multiplier / 2
octal / 2
parabolic / 2
postmultiplied / 2
quantization / 2
syndrome / 2
thermodynamics / 2
thermometer / 2
valence / 2
vertex / 2
angstrom / 1
anisotropy / 1
asymptotes / 1
atomized / 1
blueprints / 1
bolts / 1
burners / 1
calculator / 1
carbon / 1
cardiologist / 1
casting / 1
centimeter / 1
convection / 1
correlator / 1
cubic / 1
cursor / 1
damascene / 1
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diagonally / 1
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interconnect / 9
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inverse / 8
inversion / 8
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invert / 7
plant / 7
plate / 7
reactor / 7
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commutation / 6
die / 6
engineers / 6
friction / 6
header / 6
impurity / 6
interconnection / 6
laser / 6
plugs / 6
ratings / 6
fabrication / 5
inductive / 5
intercept / 5
interrupt / 5
notch / 5
offset / 5
receptacle / 5
reciprocal / 5
sensitive / 5
tap / 5
window / 5
board / 4
controller / 4
integrate / 4
intersection / 4
jumper / 4
nominal / 4
rectified / 4
bipolar / 3
breakdown / 3
bridge / 3
delta / 3
detectors / 3
disc / 3
divider / 3
film / 3
installation / 3
interruptions / 3
intersect / 3
inversely / 3
net / 3
saturate / 3
sensitivity / 3
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blower / 2
boiler / 2
emit / 2
exciter / 2
fitter / 2
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increment / 2
interfere / 2
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pinch / 2
sputtering / 2
stray / 2
undoped / 2
avalanche / 1
bounds / 1
bucking / 1
bulbs / 1
caked / 1
chamber / 1
clamped / 1
collar / 1
conditioning / 1
conjugate / 1
conjunction / 1
contraction / 1
cooler / 1
cutoff / 1
degenerate / 1
disk / 1
drum / 1
ellipsoid / 1
emission / 1
evaporation / 1
feedwater / 1
fusion / 1
hashed / 1
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hop / 1
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icons / 1
implantation / 1
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industrial / 1

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derive / 30
factor / 30
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involve / 30
sequence / 30
establish / 29
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minimum / 26
potential / 26
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technique / 25
ensure / 24
evaluate / 24
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maintain / 24
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approximately / 22
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couple / 20
definition / 20
hence / 20
image / 20
label / 20
remove / 20
maximum / 19
variance / 9

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appropriate / 18
approximate / 18
enable / 18
exceed / 18
transform / 18
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conduct / 17
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normally / 15
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specification / 14
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adjust / 13
data / 13
distribution / 13
implement / 13
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shifts / 13
structure / 13
automatically / 12
complex / 12
computer / 12
detect / 12
accurately / 4

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feature / 12
identify / 12
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concentration / 10
conversely / 10
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integrated / 10
integration / 10
location / 10
obviouslyv / 10
percentage / 10
previously / 10
restrict / 10
specific / 10
valid / 10
variation / 10
category / 9
consumed / 9
eventually / 9
extract / 9
integral / 9
major / 9
plus / 9
primarily / 9
prior / 9
summary / 9
status / 4

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displaced / 8
fundamental / 8
implication / 8
investigate / 8
mode / 8
phenomenon / 8
predict / 8
respond / 8
response / 8
significant / 8
specify / 8
utility / 8
volume / 8
alter / 7
apparent / 7
assign / 7
briefly / 7
bulk / 7
constitute / 7
decade / 7
demonstrate / 7
distort / 7
expand / 7
identical / 7
isolate / 7
nevertheless / 7
physically / 7
release / 7
role / 7
subsequently / 7
sufficient / 7
transition / 7
attain / 6
capacity / 6
comment / 6
communication / 6
consistent / 6
duration / 6
enhance / 6
equipped / 6

consumer / 8
displaced / 8
fundamental / 8
implication / 8
investigate / 8
mode / 8
phenomenon / 8
predict / 8
respond / 8
response / 8
significant / 8
specify / 8
utility / 8
volume / 8
alter / 7
apparent / 7
assign / 7
briefly / 7
bulk / 7
constitute / 7
decade / 7
demonstrate / 7
distort / 7
expand / 7
identical / 7
isolate / 7
nevertheless / 7
physically / 7
release / 7
role / 7
subsequently / 7
sufficient / 7
transition / 7
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capacity / 6
comment / 6
communication / 6
consistent / 6
duration / 6
enhance / 6
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alternatively / 4
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brief / 4
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challenge / 4
compensate / 4
concentrate / 4
conclusion / 4
convention / 4
depressed / 4
derivative / 4
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emphasize / 4
encounter / 4
environment / 4
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external / 4
file / 4
flexibility / 4
fluctuate / 4
guarantee / 4
impose / 4
incorporate / 4
inherently / 4
instructive / 4
job / 4
manipulation / 4
maximize / 4
monitor / 4
obvious / 4
occupy / 4
periodic / 4
precisely / 4
proportionate / 4
reconstruct / 4
regulate / 4
rely / 4
retain / 4

strategy / 4
sufficiently / 4
triggered / 4
adequate / 3
alternated / 3
aspects / 3
confined / 3
contribute / 3
contribution / 3
conversion / 3
derivation / 3
dimensions / 3
displacement / 3
evolution / 3
expansion / 3
exposed / 3
formula / 3
inspection / 3
instruction / 3
interactive / 3
isolation / 3
majority / 3
margin / 3
minority / 3
mutually / 3
odd / 3
participate / 3
precise / 3
proportion / 3
proportionality / 3
random / 3
randomness / 3
reactive / 3
reliable / 3
reversible / 3
scope / 3
stabilize / 3
stable / 3
stress / 3
target / 3
technology / 3

D. Low Frequency Words

junction / 86
series / 85
channel / 83
magnitude / 67
information / 63
absorb / 51
plot / 32
column / 28
slot / 27
versus / 27
typically / 26
drain / 25
barrier / 24
dissipate / 24
characteristic / 23
recombination / 23
drift / 22
rotate / 22
inject / 21
rotation / 19
diffuse / 18
peak / 18
sketch / 16
align / 15
typical / 15
designate / 14
diagram / 14
recall / 14
trellis / 14
unlike / 14
simplify / 13
attenuate / 12
modulate / 12
plane / 12
tunnel / 12
brake / 11
hint / 11
injection / 11
overheat / 11
associated / 10
alert / 2

defect / 10
exert / 10
module / 10
segment / 10
substation / 10
theorem / 10
vice versa / 10
accelerate / 9
accomplish / 9
additive / 9
conduction / 9
continuous / 9
deposit / 9
etch / 9
attenuation / 8
brakes / 8
cancel / 8
clockwise / 8
dopant / 8
imperfections / 8
recombine / 8
simultaneously / 8
acceleration / 7
characterize / 7
crystal / 7
lamination / 7
rack / 7
reluctance / 7
reset / 7
subscript / 7
suite / 7
withstand / 7
cascade / 6
compression / 6
despreads / 6
destination / 6
disconnect / 6
donor / 6
energize / 6
irrespective / 6
jurisdiction / 2

mind / 6
shift / 6
symmetric / 6
threshold / 6
uncertainty / 6
click / 5
continually / 5
counterclockwise / 5
depletion / 5
diffusivity / 5
encode / 5
interchanged / 5
million / 5
objectives / 5
orbital / 5
permeability / 5
postulate / 5
pulley / 5
rearranged / 5
sealed / 5
spark / 5
stack / 5
standstill / 5
stationary / 5
upward / 5
verify / 5
wherein / 5
absorption / 4
architect / 4
buried / 4
circulates / 4
continuously / 4
corrupt / 4
cumulatively / 4
depleted / 4
discard / 4
downward / 4
fraction / 4
port / 4
redundancy / 4
surveyors / 2

resemble / 4
ripple / 4
symmetry / 4
tripled / 4
aircraft / 3
bombard / 3
capture / 3
chopped / 3
compromise / 3
decomposing / 3
depicted / 3
ensemble / 3
equiprobable / 3
expended / 3
generalize / 3
huge / 3
instantaneously / 3
intuitively / 3
likewise / 3
millimeter / 3
millisecond / 3
optimize / 3
optimum / 3
packet / 3
preset / 3
probe / 3
revolves / 3
stall / 3
standby / 3
stringent / 3
superimpose / 3
surmount / 3
symmetrical / 3
tank / 3
tendency / 3
tolerate / 3
trench / 3
abbreviated / 2
activate / 2
actuate / 2
barleycorns / 1

altitude / 2
amenable / 2
associative / 2
asymmetric / 2
backfill / 2
background / 2
campus / 2
cancellation / 2
carefully / 2
clip / 2
compress / 2
concentrations / 2
counterpart / 2
crest / 2
decoded / 2
deenergized / 2
degradation / 2
degrade / 2
density / 2
departure / 2
designation / 2
determination / 2
dial / 2
drastically / 2
dump / 2
elementary / 2
embedded / 2
extrinsic / 2
fluid / 2
generically / 2
horn / 2
immersed / 2
impractical / 2
indistinguishable / 2
inefficient / 2
interpret / 2
intrude / 2
intuition / 2
intuitive / 2
laminated / 2
latched / 2
layout / 2
lesser / 2
lubricate / 2
mainstay / 2
merit / 2
mirror / 2
nonperiodic / 2
optically / 2
orbit / 2
overhead / 2
overshoot / 2
oxygen / 2
pancake / 2
parentheses / 2
peer / 2
penalty / 2
polled / 2
preclude / 2
premium / 2
profile / 2
punch / 2
ramp / 2
recloses / 2
redraw / 2
remainder / 2
renamed / 2
resort / 2
reverts / 2
sags / 2
schedule / 2
serially / 2
specs / 2
spontaneously / 2
strain / 2
substantial / 2
substantially / 2
superscripts / 2
susceptibility / 2
symmetrically / 2
technologist / 2
tedious / 2
tolerances / 2
traffic / 2
tremendous / 2
troubleshooting / 2
undergoes / 2
underground / 2
vacuum / 2
valve / 2
vertically / 2
via / 2
vicinity / 2
abeled / 1
aboard / 1
abreast / 1
abrupt / 1
accessories / 1
accrue / 1
administration / 1
advent / 1
aforementioned / 1
airstream / 1
albeit / 1
alleviate / 1
anchors / 1
annihilating / 1
announces / 1
anomaly / 1
anymore / 1
apparatus / 1
appliances / 1
applicable / 1
apposite / 1
astronomers / 1
backbone / 1
barely / 1
beware / 1
bid / 1
blast / 1
blenders / 1
bombardment / 1
bottlenecks / 1
breakthroughs / 1
burden / 1
calibrate / 1
ceramic / 1
choppy / 1
clients / 1
clumsy / 1
clustered / 1
cocktail / 1
collectively / 1
collide / 1
combat / 1
comma / 1
compactly / 1
competitive / 1
completeness / 1
concatenation / 1
conditional / 1
configured / 1
conservation / 1
conservatively / 1
consideration / 1
constricted / 1
continuity / 1
continuum / 1
controllable / 1
conversing / 1
cornerstone / 1
corollary / 1
corrosive / 1
counterintuitive / 1
dashed / 1
decelerated / 1

APPENDIX J

Examples of Complex Noun Phrases from

Electrical Engineering Textbooks

A. General Noun Phrases

opposite direction / 7
time delay / 5
accepted tests / 4
first stage / 4
average lifetime / 3
power quality / 3
second stage / 3
service entrance / 3
straight line / 3
average duck / 2
basic characteristics / 2
clockwise direction / 2
combined action / 2
connection points / 2
different characteristics / 2
different connection / 2
different messages / 2
different times / 2
film reel / 2
important considerations / 2
important result / 2
independent set / 2
ordered form / 2
original machine / 2
positive feedback / 2
possible combinations / 2
power level / 2
proper operation / 2
room temperature / 2
short description / 2
shorthand way / 2
additional levels / 1
amusement parks / 1
apartment buildings / 1
applicable conditions / 1
approved materials / 1
architectural firm / 1
average depth / 1
average distance / 1
average size / 1
average velocity / 1
average weight / 1
basic connections / 1
basic facts / 1
basic operation / 1
basic understanding / 1
building classification / 1
building location / 1
campus substation / 1
capital letters / 1
certain application / 1
certain time / 1
clear picture / 1
clockwise rotation / 1
clothes dryers / 1
colored lines / 1
commercial buildings / 1
common practice / 1
complete explanation / 1
complete solution / 1
complicated form / 1
compressed air / 1
concrete surface / 1
convenient reference / 1
counterclockwise direction / 1
critical importance / 1
desirable characteristics / 1
desirable property / 1
desired result / 1
desired temperature / 1
different combinations / 1
different effects / 1
different locations / 1
different machines / 1
different metals / 1
different places / 1
different points / 1
different temperatures / 1
different types / 1
direct application / 1
direct connection / 1
dotted circles / 1
downward ramp / 1
dumb-bells / 1
dusty atmospheres / 1
electric bill / 1
elegant solution / 1
elemental materials / 1
engineering disciplines / 1
equal brightness / 1
equal lengths / 1
excellent characteristics / 1
experimental arrangement / 1
extreme cases / 1
falling stone / 1
general characteristics / 1

air conditioners / 1
given amount / 1
heavy industry / 1
high performance / 1
holding companies / 1
human eye / 1
human heart / 1
human interface / 1
immense amounts / 1
immense quantities / 1
important application / 1
important limitation / 1
increased temperature / 1
increasing speed / 1
industrial buildings / 1
industrial control / 1
information content / 1
intuitive sense / 1
lab bench / 1
landscape architect / 1
large advantage / 1
last stage / 1
leading direction / 1
leading edge / 1
left side / 1
level change / 1
light bulbs / 1
light flash / 1
lightning protection / 1
liquid drops / 1
loaded train / 1
low speeds / 1
main advantage / 1
main characteristics / 1
mass production / 1
material limitations / 1
metal object / 1
microphone results / 1
muscle contractions / 1
negligible effect / 1
numerous physicists / 1
cooling problem / 1
original mass / 1
original suggestion / 1
particular level / 1
particular message / 1
particular product / 1
particular user / 1
perfect crystal / 1
permissible limits / 1
personnel protection / 1
population densities / 1
power business / 1
power changes / 1
practical difficulty / 1
practical material / 1
practical problems / 1
practical situations / 1
prescribed distance / 1
probabilistic tendencies / 1
problem statement / 1
proper direction / 1
proper match / 1
proper performance / 1
proper protection / 1
proper relationship / 1
protective overcoat / 1
public airwaves / 1
punctuation characters / 1
rapid acceleration / 1
rapid advances / 1
rapid growth / 1
rapid stop / 1
real surfaces / 1
received information / 1
receiver's point / 1
red lamp / 1
red light / 1
relative injection / 1
relative probabilities / 1
relative strengths / 1
remaining terms / 1
general solution / 1
respective ends / 1
rise time / 1
routine work / 1
same resin / 1
second law / 1
second number / 1
separate locations / 1
Separate solutions / 1
service agreements / 1
service life / 1
several reasons / 1
severe fines / 1
shipboard use / 1
shooting gallery / 1
shooting guide / 1
shopping centers / 1
short distance / 1
short segment / 1
side effect / 1
simple rule / 1
simple tests / 1
Simplified view / 1
single turn / 1
single unit / 1
single user / 1
small appliances / 1
soldered interconnections / 1
solid particles / 1
solid piece / 1
space considerations / 1
special consideration / 1
special purpose / 1
speed limit / 1
speed times / 1
spiral wrapping / 1
spread message / 1
standard instruments / 1
standard machine / 1
standard markings / 1
standard way / 1

B. Technical Noun Phrases

(Note: Words with *italic* format are academic words from the AWL)

reactive power / 91
phasor diagram / 60
power *factor* / 57
induction motor / 47
output voltage / 42
equivalent circuit / 38
received signal / 38
transmitted signal / 35
electric field / 30
terminal voltage / 30
induced voltage / 29
magnetic field / 28
generated voltage / 27
conduction band / 26
developed power / 26
line current / 26
voltage drop / 26
active power / 25
synchronous motor / 24
transition region / 23
full load / 23
synchronous generators / 23
voltage gain / 23
input signal / 22
op amp / 22
secondary voltage / 22
apparent power / 21
circuit breaker / 21
power system / 21
input impedance / 20
reverse bias / 20
field current / 20
synchronous speed / 20
voltage source / 20
phase angle / 19
synchronous machine / 19
bit *period* / 18
depletion *region* / 18
transmission line / 17
unity power *factor* / 17
copper loss / 17
load current / 17
short circuit / 17
bit *error* / 16
transfer function / 16
carrier signal / 16
current source / 16
rated voltage / 16
real power / 16
torque-speed curve / 16
core loss / 15
voltage *regulation* / 15
applied voltage / 15
flip flop / 15
power supply / 15
valence band / 15
right hand side / 15
input voltage / 14
small-signal *equivalent* circuit / 14
armature current / 14
magnetic flux / 14
starting torque / 14
ideal op amp / 14
torque-speed characteristic / 14
kinetic *energy* / 13
output impedance / 13
primary voltage / 13
average *normalized* power / 13
line-to-*neutral* voltage / 13
frequency band / 13
gate oxide / 13
truth table / 13
input resistance / 12
source voltage / 12
average power / 12
base speed / 12
lowpass filter / 12
mechanical power / 12
minority carriers / 12
peak voltage / 12
locked-rotor current / 12
bias current / 11
equivalent reactance / 11
integrated circuit / 11
wave *function* / 11
carrier frequency / 11
collector current / 11
cost path / 11
drain current / 11
electrical power / 11
flux density / 11
leakage flux / 11
leakage reactance / 11
original signal / 11
rated current / 11
rated load / 11
thermal noise / 11
voltage level / 11
logic gate / 10
mutual flux / 10
output signal / 10
bandpass filter / 10
harmonic current / 10
infinite bus / 10
magnetomotive force / 10
maximum value / 10
operating point / 10
resistive load / 10
sine wave / 10
torque angle / 10
power spectral density / 10
base *region* / 9
electrical *energy* / 9
input power / 9

sub-band / 6
voltage equation / 6
voltage regulator / 6
voltage transformers / 6
direct-current generator / 6
left-hand side / 6
minority carrier concentration / 6
open circuit voltage / 6
active *region* / 5
circuit *symbol* / 5
complex impedance / 5
construction features / 5
digital *format* / 5
dynamic range / 5
energy bands / 5
frequency *components* / 5
front *panel* / 5
independent *source* / 5
induction machine / 5
input terminal / 5
instantaneous current / 5
instantaneous voltage / 5
interrupting *capacity* / 5
inversion *region* / 5
logic circuit / 5
logic function / 5
neutral zone / 5
nonlinear *distortion* / 5
output variable / 5
phase ratio / 5
positive charge / 5
primary winding / 5
scanning *cycle* / 5
series field / 5
service *factor* / 5
stored *energy* / 5
surface *potential* / 5
thermal *energy* / 5
time *domain* / 5
probability density *function* / 5
series resonant circuit / 5
transformer *equivalent* circuit / 5
primary and secondary windings / 5
squirrel-cage *induction* motor / 5
two-sided average *normalized* power spectrum / 5
amplifier circuit / 5
armature winding / 5
binary system / 5
coil side / 5
commutating poles / 5
Conductor size / 5
current gain / 5
diffusion length / 5
drain characteristics / 5
drift current / 5
effective value / 5
electric power / 5
electrical circuit / 5
electrical machine / 5
electrical system / 5
excess carriers / 5
field excitation / 5
gate current / 5
gate electrode / 5
half load / 5
harmonic voltage / 5
ladder diagram / 5
logical rack / 5
magnetic contactor / 5
magnetisation curve / 5
leading power *factor* / 5
probability density *function* / 5
series resonant circuit / 5
transformer *equivalent* circuit / 5
primary and secondary windings / 5
squirrel-cage *induction* motor / 5
two-sided average *normalized* power spectrum / 5
amplifier circuit / 5
negative charge / 5
negative feedback / 5
no load / 5
nominal rating / 5
nominal voltage / 5
optimal receiver / 5
particular application / 5
phasor voltage / 5
power dissipation / 5
power triangle / 5
present sample / 5
quantum number / 5
rated frequency / 5
recombination rate / 5
reference direction / 5
rotor winding / 5
semiconductor material / 5
stator field / 5
sub-collector / 5
temperature rise / 5
time constant / 5
trade-off / 5
universal motor / 5
voltage waveform / 5
armature circuit resistance / 5
eddy current losses / 5
electron-hole pairs / 5
op-amp circuit / 5
original analog signal / 5
pull-out torque / 5
rated armature current / 5
run-length coding / 5
two-wire control / 5
open-circuit voltage gain / 5
accumulated value / 4
analog *format* / 4
bank *ratio* / 4
bias error / 4
channel noise / 4

C. Academic Noun Phrases

major problem / 6
basic structure / 3
color image / 3
design team / 3
discrete components / 3
heater element / 3
minimum weight / 3
previous section / 3
accurate standards / 2
approximate value / 2
basic principles / 2
complete cycle / 2
component image / 2
cross section / 2
different designs / 2
different sources / 2
direct proportion / 2
discrete devices / 2
effective area / 2
energy level / 2
error control / 2
error correction / 2
fire detection / 2
fundamental component / 2
individual device / 2
individual stages / 2
infinite period / 2
logic expression / 2
logical product / 2
potential problem / 2
sufficient energy / 2
basic construction features / 2
accuracy requirements / 1
accurate representation / 1
accurate values / 1
additional complexity / 1
additional contribution / 1
additional restriction / 1
alternative expressions / 1
appreciable amount / 1
appropriate averages / 1
appropriate limits / 1
appropriate materials / 1
appropriate packages / 1
approximate form / 1
architectural design / 1
audio components / 1
average energy / 1
basic approaches / 1
basic components / 1
basic concepts / 1
basic construction / 1
basic definitions / 1
basic elements / 1
basic requirements / 1
beneficial effect / 1
brick portion / 1
building design / 1
building features / 1
certain concentration / 1
commercial establishments / 1
common approach / 1
common links / 1
common method / 1
common technique / 1
communication capabilities / 1
complex process / 1
complex quantities / 1
complex structure / 1
comprehensive guidelines / 1
comprehensive review / 1
computer size / 1
considerable concentrations / 1
consumer products / 1
continuous process / 1
convenient methods / 1
convenient technique / 1
conventional definition / 1
cooling methods / 1
correct recovery / 1
corresponding term / 1
corresponding word / 1
definite purpose / 1
design coordinator / 1
desired task / 1
device properties / 1
device size / 1
different approaches / 1
different methods / 1
different participants / 1
different principle / 1
different styles / 1
different symbols / 1
difficult process / 1
direct contact / 1
discrete form / 1
distinct disadvantage / 1
dominant term / 1
dramatic improvement / 1
economical approach / 1
economical level / 1
economy's sake / 1
electric utilities / 1
elegant method / 1
energy transformations / 1
engineering topics / 1
entire image / 1
environmental factors / 1
equal components / 1
equipment protection / 1
error-detecting / 1
excellent isolation / 1
extra component / 1
federal government / 1
final check / 1
final product / 1
financial penalties / 1
fixed period / 1
flexible operation / 1
foundation design / 1

fundamental principle / 1
fundamental properties / 1
fundamental understanding / 1
general design / 1
generated minority / 1
good approximation / 1
heating element / 1
humid environment / 1
illuminated area / 1
illustrative purposes / 1
important components / 1
important feature / 1
important specification / 1
important version / 1
improper design / 1
individual dwellings / 1
individual components / 1
individual customers / 1
individual ducks / 1
Institutional buildings / 1
instructive way / 1
interior designer / 1
intermediate position / 1
loaded vehicle / 1
Local authorities / 1
logical introduction / 1
louder version / 1
main function / 1
major advantage / 1
major directions / 1
material selection / 1
maximum temperature / 1
normal conditions / 1
normal course / 1
normal direction / 1
normal incidence / 1
normal operation / 1
open areas / 1
original image / 1
original objective / 1
overwhelming majority / 1
personal computer / 1
philosophical point / 1
physical characteristics / 1
physical component / 1
physical dimensions / 1
physical laws / 1
physical separation / 1
physical shape / 1
popular approach / 1
power requirements / 1
practical approach / 1
practical benefit / 1
practical criterion / 1
practical implementation / 1
preceding section / 1
precise definitions / 1
preferred structure/ 1
principal choices / 1
principal components / 1
principal ways / 1
priority level / 1
project manager / 1
proper design / 1
proper maintenance / 1
pseudo-random / 1
real portion / 1
receiver's design / 1
red component / 1
registered trademarks / 1
relative concentrations / 1
required disciplines / 1
residential customers / 1
restricted space / 1
safety feature / 1
same sequence / 1
second symbol / 1
series term / 1
short periods / 1
significant implications / 1
significant improvement / 1
starting period / 1
sufficient information / 1
temporary state / 1
total energy / 1
Troubleshooting section / 1
typical residence / 1
unstable condition / 1
unstable state / 1
useful devices / 1
usual approximation / 1
Various implementations / 1
visible light / 1
visual observations / 1
annual electric bill / 1
average power consumption / 1
building design process / 1
certain minimum standards / 1
consulting engineering firms / 1
corresponding decrease / 1
electric utility bill / 1
given average energy / 1
given geographical region / 1
industrial manufacturing facility / 1
industrial manufacturing process / 1
major loss categories / 1
manufacturers' web sites / 1
new-generation communication / 1
per-unit approach / 1
properly designed structures / 1
standard English text / 1
start-up period / 1
typical image / 1
tremendous technological challenge / 1
building design team's work / 1
starting period / 1
economic and environmental impact / 1
experimental and theoretical work / 1
gas distribution and control / 1
real and imaginary parts / 1
specific connection / 1
states and the federal government / 1

CURRICULUM VITAE

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