DEVELOPMENT AND VALIDATION OF A DIRECT CURRENT CIRCUIT ANALYSIS POST-TEST IN ELECTRONIC ENGINEERING TECHNOLOGY

By

MARION RONALD FOX

Bachelor of Science
Oklahoma State University
Stillwater, Oklahoma
1965

Master of Education
University of Illinois
Urbana, Illinois
1969

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Thesis Adviser

Dean of the Graduate College

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CHAPTER I

INTRODUCTION, RATIONALE, AND STATEMENT OF THE PROBLEM

Statement of the Problem

The development and validation of an achievement post-test in DC (Direct Current) electrical circuit analysis is necessary to conduct research on new and existing teaching techniques in electronic engineering technology. A search of the literature reveals that there is no test which has been developed and validated in DC Circuit Analysis. Several tests have been validated at a lower math and science level than that normally taught in engineering technology programs, but none were found at the engineering technology level. The validity of future research in DC Circuit Analysis is subject to being questioned if a test used has not been validated.

Purpose of the Research

The purpose of this study was to develop and validate a DC electrical circuit analysis post-test at the engineering technology level (hereafter referred to as Fox DC Test). Development included determining the content of the test by a jury of experts chosen from various schools in Kansas, Missouri, and Texas. Validation included establishing the construct validity, content validity, and reliability of the instrument. The development and validation of the Fox DC Test should enable persons to conduct further research in such areas as teaching techniques and curriculum.

Statement of the Need

One factor which creates a need for improvement of the curriculum in electronic engineering technology is the increase in knowledge or information. As the amount of information increases the educational institutions need to be more efficient. Cross discusses this problem with regard to adult learners (Cross, 1981). This increase in knowledge also necessitates an almost constant reevaluation of the curricula. This is particularly true in engineering technology, because of the fact that technology is on the leading edge of new developments.

Another factor which necessitates a well designed curriculum is the fact that some teachers in electronic engineering technology have little or no formal schooling in educational methods (Annual Report, 1986). In addition, they do not have time to prepare and validate tests to determine if their methods are fulfilling the goals they have set. A validated test would enable them to make refinements in such things as teaching techniques and curriculum. If a valid test existed, it could be used to help the teacher to determine particular areas in which his teaching methods or curriculum were deficient.

Research Questions

The following questions set forth the basis of the research conducted by this researcher:

Question One: What topics should be covered in a comprehensive post-test in DC Circuit Analysis?

Question Two: Do the questions written in the test adequately cover the topics chosen for the test?

Question Three: Does the test exhibit evidence of construct validity?

Question Four: Does the test have internal consistency?

Question Five: Are the test items homogeneous?

Question Six: Is the test reliable?

Question Seven: What is the difficulty level of each question?

Question Eight: What is the item discrimination index of each question?

Assumptions

Several assumptions were made in this research project. First, it was assumed that the faculty who participated in the test construction were a valid representation of experts in the field of DC Circuit Analysis. Second, it was assumed that the students from the schools which did not participate in this study would score at the same level as those who participated. And third, it was assumed that the test administrators administered the tests according to the instructions given to them. The researcher received verbal confirmation that the third assumption was correct.

Limitations of the Study

This test is limited to a two-year post-secondary electronic engineering technology program, taught on the same level as TAC/ABET (Technology Accreditation Commission/Accrediting Board for Engineering and Technology) accredited programs. Since this test was administered during the first semester of a normal four semester curriculum it is not representative of students graduating from these programs. Since this test is administered at or near the end of the first semester of the two year program it is not representative of beginning students in these programs.

Definitions

<u>ABET</u>: Accrediting Board for Engineering and Technology (Annual Report, 1986).

<u>Achievement Test</u>: "A test designed to measure a student's grasp of some body of

knowledge or proficiency in certain skills (Ebel and Frisbie, 1986, p. 347)."

Aptitude Test: "A test that is used to determine how well a person will do in some future situation (Ghiselli, Campbell, and Zedeck, 1981, p. 473)."

Black-White Fallacy: Sometimes referred to as black-white thinking. "Thinking in extremes; because a sentence is false, it is inferred that some very contrary sentence is true (Barker, 1980, p. 320)."

Comfortable Time: ". . . the amount of time required for 90 percent of the persons to complete a test under power conditions (Nunnally, 1967, p. 565)".

Composition, Fallacy of: This fallacy is committed when a person argues that what is true of the individual is also true of the whole group (Barker, 1980).

Construct Validity: The expression "construct validity" is really a type of validity evidence, not true validity. Ebel and Frisbie associated the proof of content validity with appealing to a consensus of experts (Ebel and Frisbie, 1986).

Content Validity: "Is evidence which is judgmental information gathered by a test user to demonstrate that the tasks in a particular test are appropriate measures of the abilities the user wishes to measure (Ebel and Frisbie, 1986, p. 348)."

Distracter: A distracter is an answer that is plausible if the examinee does not understand some aspect of the material being tested (Hopkins and Antes, 1985). Some authors refer to a distracter as a foil.

Empirical Keying: "A technique whereby items are selected for inclusion on a test based on their validities in predicting an external criterion. Items incorporate into an empirical key have high correlations with the external criterion and low intercorrelations (Ghiselli, Campbell, and Zedeck, 1981, p. 476)."

Engineering Technology:

> Engineering technology is that part of the technological field which requires the application of scientific and engineering knowledge and methods combined with technical skills in support of engineering activities; it lies in the occupational spectrum between the craftsman

> and the engineer at the end of the spectrum closest to the engineer (Annual Report, 1986, p. 5).

Factor Analysis:

> Any of several methods of analyzing the intercorrelations or covariances among variables by constructing hypothetical factors, which are fewer in number than the original variables. It indicates how much of the variation in each original measure can be accounted for by each of the hypothetical factors (Standards for Educational and Psychological Testing, 1985, p. 91).

Homogeneous: "If the scores on the various items comprising a test intercorrelate positively, the test is homogeneous, and all items can be said to measure a common characteristic (Weston, 1986, p. 51)."

Independence of Items: Independence of Items: "assumes, for a person of a given ability, a response to one item is independent of a response to any other item; that is, a correct response to one item cannot depend on a correct response to any other item (Isaac and Michael, 1985, p. 113)."

Internal Consistency: "We are generally concerned here with the inter-item correlations, i.e., the degree to which items measure the same thing (Payne, 1968, p. 128)."

Item Analysis:

> Item analysis is a procedure to increase the reliability and validity of a test by separately evaluating each test item to determine whether or not that item *discriminates* in the same way the overall test is intended to discriminate (Isaac and Michael, 1985, p. 116).

Item Difficulty:

> The difficulty of an item is the percentage of persons who answer the item correctly (percent pass). It is computed using the formula: DIFF = (C/N) x 100, where: C = number of students who answer the item correctly N = total number of students in the group (Berk, 1984, p. 109).

Item Discrimination: "Item discrimination in its simplest form refers to the relation of the performance on each item to performance on the total test." (Payne, 1968, p. 145) "Item discrimination has been defined as the degree to which an item

differentiates the high achievers from the low achievers (Payne, 1968, p. 152)."
". . . the discrimination index provides an index of how an item correlates with the total test (Erickson and Wentling, 1976, p. 263)."

Modified Delphi Technique: This technique consists of using the Delphi technique without obtaining a total consensus from the experts.

Obtained Score Versus True Score: An obtained score is the raw score or number of points a student receives on the test. The true score is a hypothetical value that best represents the true knowledge of the student. "The *correlation* between obtained and true scores can be estimated by taking the square root of the reliability coefficient (Sax, 1980, p. 258)."

Power Test: A test that is intended to measure the level of maximum achievement or ability of a student. (Hopkins and Antes, 1985)

> *Power tests* are tests designed to assess the full range of a student's skills or abilities, which place little or no emphasis on time limits. Students are allowed adequate time to consider carefully and respond to all items included in a power test. The items included in a power test range from very easy to very difficult (Erickson and Wentling, 1976, p. 65).

Reliability: Reliability refers to the accuracy (consistency and stability) of measurement by a test (Isaac and Michael, 1985). ". . . *reliability* may be thought of as a special type of correlation that measures consistency of observations or scores (Sax, 1980, p. 259)."

Specific Determiner: "A word or characteristic in a selected-response item that gives the test taker an unintended clue to the correct response (Hopkins and Antes, 1985, p. 478)."

Speed Test:

> A pure *speed test* is one in which individual differences depend entirely on speed of performance. Such a test is constructed from items of uniformly low difficulty, all of which are well within the ability level of the persons for whom the test is designed. The time limit is made so short that no one can finish all the items. Under

these conditions, each person's score reflects only the speed with which he worked (Anastasi, 1976, p. 122).

TAC: Technology Accreditation Commission (Annual Report, 1986).

Timed Test: A test in which there are time limits placed upon the examinees.

Validity: ". . . *validity* refers to the degree to which a particular test or instrument is useful in measuring that which it was designed to measure (Erickson and Wentling, 1976, p. 22)." "Traditionally, the various means of accumulating validity evidence have been grouped into categories called *content-related, criterion-related,* and *construct-related evidence of validity* (Standards for Educational and Psychological Testing, 1985, p. 9)."

Summary

This research project entailed the development and validitation of an achievement post-test for DC Circuit Analysis taught at the engineering technology level. Two year programs accredited by TAC/ABET, in Arkansas, Kansas, Missouri, and Texas were chosen as target programs for the development and validation of the Fox DC Test. This project began in February 1989 and ended in January 1990. The Fox DC Test was developed and validated because no prior test had been developed and validated for DC Circuit Analysis at the engineering technology level. This project had three phases: (1) the identification of the topics to be included in the test, (2) the development of the test, and (3) the validation of the test.

CHAPTER II

REVIEW OF RELATED LITERATURE

Introduction

The literature was divided into four basic categories: (1) books, monographs, periodicals, reports, and research articles; (2) dissertations, theses, and papers presented at professional meetings; (3) general integrative reviews; and (4) a summary of the literature reviewed. Each of these four categories was studied in order to determine how to conduct the research in this project.

Historical Background

Mitchell (1983) does not list a test which has been validated in the area of DC electricity at the engineering technology level. An ERIC search failed to discover a study which had been conducted in this area. Searches of various technical handbooks failed to discover a validated test in this area of study.

No dissertations were found which directly related to development of an electronics test in DC Circuit Analysis at the engineering technology level. A wider search of the literature, by the researcher, did not discover a dissertation which directly related to a validation of a test in any area of electronic engineering technology. A wider search revealed one thesis which related to the validation of a placement pre-test in electronic engineering technology had been written (Grulick, 1987).

Research Studies Which Develop and Validate a Test

McCurdy (1985) investigated the curriculum characteristics of all 74 TAC/ABET accredited bachelor level electronic engineering technology programs in the United States. His study revealed that the TAC/ABET programs were of a higher level than other programs. This higher level was especially evident in the areas of circuit analysis and mathematics. From this it must be concluded that tests developed for lower math/science levels of electronics technology are not suitable for ABET accredited schools. Brenner (1968) employed three different tests in DC Circuit Analysis in his experiment concerning different styles of teaching laboratory exercises in DC Circuit Analysis. Brenner did not conduct a rigorous validation of the tests employed in his research. The tests are of a lower math and science level than that employed in engineering technology. The levels of Brenner's tests were for the traditional industrial arts programs.

Weston (1986) developed an instrument to assess teacher's knowledge of behavior modification. To develop and validate the test, Weston used: analysis of covariance, correlational procedures, factor analysis, and item analysis. Weston used the Kuder Richardson KR_{20} and KR_{21} tests to determine the internal consistency of the test. Nunnally (1967) listed several reasons for not constructing tests on the basis of factor analysis. Nunnally said:

> One important reason for not beginning test construction with factor analysis is that such analyses are seldom highly successful. . . . Another reason for not beginning the construction of tests with factor analysis is that such analysis is that such analysis of test items is extremely laborious. . . . To prevent taking advantage of chance, a minimum standard (not an ideal) in a factor analysis is that there be at least ten times as many subjects as variables (Nunnally, 1967, pp. 255-256).

Cangelosi (1988) developed and validated a test for underprepared mathematics teacher assessment. Cangelosi used a panel of eight experts to determine the test content. He then wrote the test questions and used panels of experts to help to refine the test items or questions. The third stage of his research included a field test (pilot test) of the examination. The fourth stage of his research included a field test of the examination in which he determined the reliability and established the validity of the test.

Carlson (1985) developed and validated a test for religious education. His project consisted of three phases: (1) Identification of the goals, (2) development of the test, and (3) validation of the test. In identifying the goals, he used a jury of experts to determine the goals (test content). Carlson (1985) developed questions to fulfil each goal and the jury of experts evaluated each question to determine if it fulfilled the goals. Validation of the test involved an analysis of item quality, item difficulty, reliability, readability, and content validity. The reliability was determined by the KR_{20} formula.

Multiple Choice Tests Versus Essay Tests

In developing a test it becomes important to determine how to construct the test items. Often, technology instructors object to multiple-choice questions as not being able to test adequately. Frederiksen and Satter (1953) compared the completion format with the multiple-choice format in mathematics. The completion format is commonly called the essay format. They compared the difficulty levels of these formats and found them to be comparable. Rimland and Zwerski (1962) compared the frequency that distracters were chosen in the multiple-choice and the completion formats. They found that the distracters were chosen at comparable rates in these two formats. These studies justified the researcher's usage of a multiple-choice test instead of a completion test.

Hogan (1981) traced the history of the development of multiple-choice tests. He concluded:

> Contrary to widely held beliefs about choice-type tests, the studies indicate that the two types of tests do generally measure the same traits or abilities. To the extent that there are minor differences, the choice-type measures tend to be more valid; and the use of

> choice-type measures does not seem to have adverse effects on study habits. (Hogan, 1981, p. iv).

Neither was the ease of scoring a test one of the original reasons for choosing a multiple-choice test, nor was the passion to engage in the testing of large numbers a reason for developing multiple-choice tests (Hogan, 1981). In fact reliability and more extensive content coverage were the main motives for developing multiple-choice tests (Hogan, 1981).

Hogan (1981) concluded that the choice-type formats (multiple-choice, true-false, etc.) were more reliable than the free response (essay) type test and were certainly easier to score. This greater reliability should cause it to become more prevalent in testing.

Some have argued that choosing an answer by the process of elimination of the distracters is not good testing. Ebel and Frisbie (1986) argued that the production of an answer is not necessarily more complex than the choosing of the correct answer from several options.

Harke, Herron, and Lefler (1972) compared the performance of students on a multiple-choice format test and a written solution test in physics and obtained a reliability coefficient r of .92. They concluded that the multiple-choice format is a proper substitute for a written solution test.

Hogan (1981) cited a number of authors whose studies demonstrated that the multiple-choice format tested the same material that had an $r \geq .85$. In spite of their empirical studies, these authors still recommended the essay format as superior to the multiple-choice format. Hogan (1981) concluded that bias exists against multiple-choice tests and also bias exists in favor of essay type tests, in spite of the evidence that multiple-choice tests are more reliable.

Construction of Multiple-Choice Tests

A number of questions need to be answered concerning how to construct a multiple-choice test. One question is, should the problems be grouped by topic or should they be randomized? Schriesheim, Kopelman, and Solomon (1989) determined that the results of their study did not support the usefulness of grouping questionnaire items. They did suggest that further research be conducted in this area. The research conducted by Balch (1989) disagreed with the conclusions of Schriesheim, Kopelman, and Solomon (1989). Balch concluded that the order of the questions does cause a significant difference in the scores of the examinees. Balch relates his research to the usage of alternate forms of a test.

College students do not generally follow directions (Marks, 1962). Because of this, it is important to design the test in such a manner that the attention of the examinees will be obtained. This problem probably lies ". . . in the poor visual quality of the material presented to them (Marks, 1962, p. 169)." Because of this problem, this researcher conducted a pilot study to facilitate the design and modification of the test instructions.

The research conducted by Bresnock, Graves, and White (1989) concluded that when a larger number of correct answers were in the "A" position in contrast to the "D" position on a test it caused the examinee to have a statistically significant difference in the scores on the test. This research entailed a four choice multiple-choice test with options of A, B, C, and D. With "A" being the first option and "D" being the last option.

Dix (1987) studied the number of options (choices) per item and drew the conclusion that when ability level is disregarded the two and four choice formats were equivalent in reliability and were both superior to the three choice format. It should be noted that Dix added additional questions to the two option format in addition to the questions of the four question format. For example, if Dix had ten questions with a four option format, when he went to the two option format, he had twenty questions. The research of Straton and Catts (1980) did not agree with that of Dix. Straton and Catts concluded that the three item format was superior to the two item format and was at least equal to the four item format. Straton and Catts pointed out that the time required to complete a test is not directly proportional to the number of alternatives per item. Lord (1977) pointed out that high ability students tend to do very little guessing and therefore profit from a longer test whereas low ability students tend to profit from a test with more choices. In accordance with the findings of Straton and Catts, if the test was changed from a four item test to a two item test by doubling the number of questions, it more than doubled the amount of time required to complete the test. This may change a power test into a speed test, and adversely affect both the reliability and validity. Erickson and Wentling (1976) warned that this can happen.

Hopkins and Antes (1985) pointed out that the construction of high-quality multiple-choice test items are time consuming and are difficult to write. They also pointed out that it requires a great amount of skill to write multiple-choice test items. They listed 19 suggestions for improving the quality of multiple-choice test items. Some objections to the usage of multiple-choice tests may be the result of experience with poorly constructed multiple-choice tests. Those who object to all multiple-choice tests because they have observed some multiple-choice tests that were poorly constructed are guilty of the fallacy of ambiguity, specifically the fallacy of composition.

In a multiple-choice format the correct answer should be randomly assigned to a position on the answer key. For example, in a four-choice format the answer "A" should be chosen about 25 percent of the time and the other three answers should each be chosen about 25 percent of the time (Ebel and Frisbie, 1986).

Berk (1984) listed three criteria for evaluating a choice response pattern:

(1) Each distracter should be selected by more students in the uninstructed (or incompetent) group than in the instructed (or competent) group. (2) At least a few uninstructed (or incompetent) students (5-10 percent) should choose each distracter. (3) No distracter should receive as many responses by the instructed (or competent) group as the correct answer.

Administration of Tests

Fuchs and Fuchs (1986) discussed the biases which can be introduced by improper test procedures. They listed several factors which can affect the performance of the examinee on a test: examinees' interpretation of the purpose of testing, their comprehension of test instructions, their test-wiseness, their pretest contact with examiners, the examiners' personality, reinforcement, their attitudes about the legitimacy of testing, the order in which they administer tests of varying difficulty, and their choice of test location. The examinees of the study of Fuchs and Fuchs were all under the age of 16 years old.

Lee, Moreno, and Sympson (1986) discussed testing procedures which helped to obtain results which were valid. This research related to two different methods of administering the test. One method was with a pencil and paper test and the other was with a computerized test. (While this did not relate directly to the research conducted in the study conducted by this researcher, it demonstrated that different testing procedures can affect the results of a test.)

The examinees should be instructed to respond to every question (Cronbach, 1950) recommended this approach because the random error introduced will create less noise than that introduced if some examinees guess and others do not. In addition, most psychometric models assume that the examinees responded to all the questions. The research conducted by Fischer (1988) examined the effects of rewards for not guessing, penalties for guessing, and different types of directions on the guessing behavior of students on multiple-choice tests. The only significant difference found by Fischer was in the scores of those who had been given more detailed directions about the procedure. Fischer (1988, p. 8) said:

> . . . it would seem that the penalty or reward clauses in written test instructions did not differentially influence a child's guessing behavior, but that the child's understanding of those instructions does influence this behavior.

Sherriffs and Boomer (1954) found that certain personality factors affect the amount of guessing when a penalty is used. From this it was concluded that penalties for guessing biased the results of a test toward those with certain personality traits, and lowered the content validity of a test. The test would then be measuring these personality traits as well as the topics the test was designed to cover. Ghiselli, Campbell, and Zedek (1981) stated that correction for guessing is a form of weighing the test items and suggested that if the test has more than 15 items (test questions) it is not necessary to weigh each item.

Thorndike (1971, p. 192) quoted Clemans who pointed out that ". . . the factors involved in speed of performance may be quite different from those involved in similar tasks under no-time-limit conditions." Myers (1952) suggested that time limits may present barriers to the measurement of the variables the examiner wishes to measure. In addition to this, adults tended to perform more poorly when they were subjected to a speed test than when they do not have time limits (Cross, 1981). Since most technology programs have a large number of adult students, a speed test may not yield the best results. Allen and Hays (1984) found that the most intelligent persons actually took longer to solve complex problems, such as trouble shooting systems, than less intelligent persons. They made fewer errors in solving the problems but took longer. It appeared that they reflected on the problems more. This may point to the necessity to have a test with complex problems on it, given with a time limit that allows the examinee a generous amount of time to complete the test. Payne (1968, p. 9) suggested that "For achievement tests, speed generally should *not* be allowed to play a significant role in determining a score, and sufficient time should generally be allowed for all or at least most examinees to finish the test." Cross (1981) said that adults should be given generous time limits when taking tests.

Ebel and Frisbie (1986) suggested that the teacher aid the students in pacing themselves by announcing, to the examinees, the amount of time left to complete the test. This could help to remove some of the test anxiety experienced by the students.

According to Cashen and Ramseyer (1969) older students (third grade and above) recorded their answers on a separate answer sheet without affecting their scores. Younger students should have their answers on the test paper, not on a separate sheet. Harris (1986) concluded that different answer sheet formats, one vertical and the other horizontal, did not have significant differences in the scores of the examinees.

"The testing environment should be one of reasonable comfort and with minimal distractions (Standards for Educational and Psychological Testing, 1985, p. 83)." "Testing materials should be readable and understandable. . . Noise, disruption in the testing area, extremes of temperature, inadequate work space, illegible materials, and so forth are among the conditions that should be avoided in testing situations (Standards for Educational and Psychological Testing, 1985, p. 83)." Erickson and Wentling (1976) suggested that a sign, warning of a test in progress, should be placed on the door of the testing room.

Factors such as order of the questions, locations of response space, gender, or test anxiety did not seem to have as much effect upon the performance of a student as time limitations (Blaugher, Melton, and Myers, 1968). Ebel and Frisbie (1986) asserted that if time limits for achievement tests were generous, the order of presentation of the items had little effect on student scores.

Wlodkowski (1985, p. 136) stated ". . . when adults work and learn in circumstances that are continually boring, their motivators tend to be fear, pressure, and extrinsic goals. . ." Adults need to be motivated to perform well on a test. Wlodkowski (1985, p. 140) further stated: "If the consequences of the learning task have no meaning for adults, they will feel apathetic." It is important that all examinees be motivated to perform as well as possible on the test.

Determination of Reliability of Tests

Kuder and Richardson (1937) developed the theory of estimation of test reliability. They compared their method to the test-retest method and the split-half method. Balian (1982) recommended that item analysis be used with the KR_{20} measure to establish the reliability of a test. Ebel and Frisbie (1986, p. 77) stated "Conceptually, K-R20 is the average correlation achieved by computing all possible split-halves correlations for a test." Ebel and Frisbie (1986, p. 78) stated that the K-R20 ". . . is actually a special case of the alpha procedure. . . .When Alpha is used to estimate the reliability of a test that is scored dichotomously (1 or 0), the result will be exactly the same as that calculated using K-R20." The Kuder-Richardson formula Number 20 is:

$r_{tt} = [k/(k - 1)][(S_x^2 - \Sigma pq)/S_x^2]$

k = the number of items in the test

p = proportion of examinees answering item correctly (or the proportion responding in a specified direction)

q = 1 - p

S_x^2 = the variance of the total raw scores.

Gucken (1986) constructed and validated a diagnostic test in high school mathematics. Gucken constructed the test, established the reliability of the test, and factor analyzed the responses of the examinees. It was suggested that teachers need training in how to use diagnostic test information in their college/university instruction.

In order to establish the validity of a test, it must first be demonstrated that the test is reliable. "*Reliability* describes the extent to which measurements can be depended on to provide consistent, unambiguous information. Measurements are *reliable* if they reflect 'true' rather than chance aspects of the trait or ability measured (Sax, 1980, pp. 255-256)." "In order for a test to be highly valid, it must be highly reliable also. High reliability is a *necessary* but not *sufficient* condition for high validity (Nunnally, 1959, p. 95)."

Payne links the internal consistency of a test with the KR_{20} method of establishing the reliability of a test (Payne, 1968).

Determination of Construct Validity of Tests

Several studies have been conducted which set forth the method of validation of achievement tests. Halpin and Halpin (1987) used a panel of experts to establish the content validity of a test. They also established the predictive validity of the test.

The construct-related category relates primarily to the test score as a measure of the characteristic.

> Evidence for the construct interpretation of a test may be obtained from a variety of sources. Intercorrelations among items may be used to support the assertion that a test measures primarily a single construct. Substantial relationships of a test to other measures that are purportedly of the same construct and the weaknesses of relationships to measures that are purportedly of different constructs support both the identification of constructs and distinctions among them. (Standards for Educational and Psychological Testing, 1985, p. 10)

Messick (1981) listed two aspects of construct validation, substantive coverage and response consistency. Messick (1981) and Tenopyr (1977) claimed that substantive coverage and response consistency are interdependent.

Anastasi (1976) listed the demonstration of internal consistency as a factor in demonstrating the construct validity of a test. Anastasi set forth two methods of demonstrating internal consistency of a test. The first method was to group the examinees into two groups, one group of those whose test score was above the median test score (the high group), and the other group of those whose test score was below the median test score (the low group). Any item that the "high" group missed more often than the "low" group was considered invalid. The second method was to group the test into subtests, relating to various topics, and any item the "high" group misses more often than the "low" group was considered invalid. Anastasi considered internal consistency correlations to be measures of homogeneity. Anastasi warned that if the test is not homogeneous, the rejection of test items on the basis of its lack of internal consistency may lower the validity of the test. This would be particularly true if the first method was employed, and can be eliminated as a problem if the second method was employed.

Determination of Content Validity of Tests

Isaac and Michael (1985) suggested the following steps in the item analysis of a multiple choice achievement test: (1) Rank order the distribution of test scores from high to low, (2) Divide these ranked scores into two contrasting groups, (3) Calculate the chi square (χ^2) value of the resulting proportions, and (4) If χ^2 is significant, it can be concluded that a dependable difference exists in the proportion of high and low scoring subjects who gave correct answers. Items that meet this criterion should be retained; items that fail to meet it should be discarded.

The content-related category is associated with:

> . . . the degree to which the sample of items, tasks, or questions on a test are representative of some defined universe or domain of content. The methods often rely on expert judgments to assess the relationship between parts of the test and the defined universe, but certain logical and empirical procedures can also be used. For example, the major facets of a domain of academic subject matter can be specified, and experts in that subject can be asked to assign test items to the categories defined by those facets. The representativeness of the sample of items can then be judged (Standards for Educational and Psychological Testing, 1985, p. 10).

Messick (1975) related that content validity is the primary concern in achievement testing and that construct validity, which has been neglected needs to be given more attention. In light of the fact that the behaviorist psychologist stresses the content validity and the cognitive psychologist stresses the construct validity, Messick (1975) adopted the more reasonable course. One is guilty of the black-white fallacy when he views the problem as one of either having content validity or construct validity. Messick (1981) set forth two aspects of test development for content validity, content relevance, and content coverage. Messick (1981) defined content relevance as the rules that define whether a given item is a member of the universe of items. Messick defined content coverage as the rules for sampling items from the universe of items in a representative fashion.

General Integrative Reviews

One work which provided a comprehensive discussion of educational measurement was edited by Thorndike (1971). This volume was divided into four parts: (1) test design, development, administration, and processing; (2) special types of tests; (3) measurement theory; and (4) application of tests to educational problems. This book provides a good integration of the various topics. It has many helpful suggestions for each aspect of test development, validation, and application.

There are several steps for test developers: (1) define the universe of the content that the test is intended to represent, (2) determine the degree to which the format and response properties of the sample of items are representative of the universe, (3) determine the item format and method of scoring the test (Standards for Educational and Psychological Testing, 1985).

Erickson and Wentling (1976) set forth a eight step plan for developing a standardized test in the area of occupational education. The first step was to define the purpose of the test. The second step was to develop a subject matter index or listing of all the knowledge and understanding related to the subject to be covered by the test. The third step was to develop a table of specifications for the test. The table of specifications was the plan or blueprint for the test. This plan or blueprint included a listing of the subject areas to be covered by the test and the number of test items to be devoted to measuring a specific level of knowledge, skill, or understanding for each subject area. The fourth step was to prepare each individual test item. The fifth step was to administer the test to a sampling of examinees who represent a sample of the population to be tested. The fifth step was to administer the test to a sampling of examinees who represent a sample of the population to be tested. The sixth step was to administer the test to a large sample of individuals representing the group for whom the test was being prepared. The seventh step was to determine the reliability and validity of the test and to establish norms for the test. The eighth step was to develop a manual or set of instructions for the test administrators and for the examinees.

Summary of the Literature Reviewed

A search of the literature failed to discover a validated test in the area of DC Circuit Analysis at the engineering technology level. The process of development and validation of a test was determined from dissertations, research articles, periodicals, and books. The various works consulted provided a fivefold division of the problem undertaken in this research study: identification of the content of tests, design of tests, validation of tests, administration of tests, and application of the tests.

The literature revealed that ABET accredited programs were taught at a higher math-science level than other engineering technology programs. No validated test was found for DC Circuit Analysis taught at the level of ABET accredited programs.

The literature revealed that tests are constructed and validated by: (1)

identifying the topics to be covered in a test (establishing the content validity of the test), (2) constructing the test, and (3) establishing the construct validity of the test by administering the test to a group of examinees.

The literature revealed that properly constructed multiple-choice tests are more reliable than essay type tests. In addition the literature revealed that the construction of high quality multiple-choice tests is difficult and time consuming. The literature revealed a number of factors which may affect the results of a test. These factors included such things as time limits, atmosphere, examinee attitude, test administrator attitude, clarity of test instructions, penalties for guessing, and rewards for not guessing.

CHAPTER III

METHODOLOGY

Introduction

This research project entailed the development and validation of a post test in DC Circuit Analysis for electronic engineering technology. The research methodology employed in this study was both a modified Delphi technique to establish the content validity of the test and correlational to establish the construct validity of the test. The reliability of the test was determined by the Kuder-Richardson KR_{20} test.

Delphi Study to Determine Content of Test

Instructors in electronic engineering technology were surveyed from nine TAC/ABET accredited schools in Kansas, Missouri, and Texas. These instructors were asked to list all topics which should be included in a comprehensive post-test in DC Circuit Analysis (Appendix A). These instructors responded by listing a total of 37 topics from DC Circuit Analysis (Appendix B). They were then asked to rank the topics by order of importance (Appendix B). The topics were ranked according to the order of Appendix C. After construction of the test, and from the time the group of 10 students took the test (hereafter referred to as the Fox DC test), it was determined by the researcher that the top 19 topics would be used in the Fox DC test and the other topics would be omitted. This was done because of the additional time required to complete a test covering all 37 topics. The same instructors were sent copies of the questions to be used in the test (Appendix D). The instructors were asked to select the topics which the examinee was required to know in order to answer each question (Appendix D).

The Fox DC test (Appendix J) was designed to cover the following topics from DC electricity: (1) Ohm's law, (2) Kirchhoff's voltage law, (3) Kirchhoff's current law, (4) Power, (5) Parallel resistor circuit analysis, (6) Series-parallel resistor circuit analysis, (7) Series resistor circuit analysis, (8) Scientific notation and metric prefixes, (9) The current divider rule, (10) The definition of current ($I = Q/t$), (11) The voltage divider rule, (12) Conductance, (13) Thevenin's theorem, (14) Mesh analysis, (15) Capacitance, (16) Coulomb's law, (17) DC meter movements, (18) Definition of energy ($P = W/t$), and (19) Capacitor static DC circuit.

This researcher developed the Fox DC test, based upon the top 19 topics chosen by a panel of experts from schools accredited by TAC/ABET, which was designed to cover the material normally taught in a two-year post-secondary engineering technology program in DC electrical circuit analysis, by means of a modified Delphi technique. The content was validated by seven experts in the field of electronic engineering technology in three states bordering Oklahoma (Texas, Kansas, and Missouri). These experts were provided with a copy of the Fox DC test (Appendix D) to determine that it covered the material normally taught in DC Circuit Analysis. This researcher attempted to obtain one expert from each two-year ABET accredited electronic engineering technology program in these three states. The department heads of these departments were asked to suggest one of their faculty members who could serve as an expert to aid in developing the Fox DC test. This researcher used a four-point Likert scale to determine whether or not they agreed with the Fox DC test content and development. In addition, they were asked to provide suggestions of any material which might be needed in the Fox DC test. Balian (1982) suggested that experts in the field be used to assess the test items.

After the content validity was established, the Fox DC test was administered as a post-test to students in two-year post-secondary ABET accredited electronics engineering technology programs in Texas, Kansas, and Missouri. The reliability of the test was determined by the KR_{20} (Kuder-Richardson 20) technique.

Factor analysis was not employed in the development and validation of the Fox DC test because it was not possible to obtain ten times as many subjects as test items as was recommended by Nunnally (1967). Another reason that factor analysis was not employed is: "Properly done, from start to finish it may take over three years to complete the job, and it will be an expensive operation (Nunnally, 1967, p. 257)."

The Fox DC test was limited to electronic engineering technology which is taught at a higher math and science level than most electronics technology programs (McCurdy, 1985). It was decided to choose programs which were accredited by ABET. Because of the expense of conducting this research on a nationwide scale, it was decided to conduct the research in the region around Oklahoma. The electronic engineering technology programs accredited by ABET were chosen from the ABET directory with Kansas, Arkansas, Texas, and Missouri as target schools to administer the Fox DC test. All ABET accredited schools in these four states, who teach DC Circuit Analysis in the spring, were chosen as targets for administration of the Fox DC test. The University of Arkansas at Little Rock chose not to participate in the research. Because of delays in preparation of the Fox DC test, it was administered to students in the fall of 1989. Since most schools which teach electronic engineering technology have larger classes in the fall, this provided a larger pool of students to whom the Fox DC test could be administered. In addition to this, all the schools targeted in this study have classes in DC Circuit Analysis in the fall and only about half of them had classes in the spring.

Pilot Study

A pilot study was conducted at Rose State College, in Midwest City, Oklahoma, with approximately 80 students who had completed a course in DC Circuit Analysis. The

Fox DC test questions were arranged in a random order. These 80 students were timed to determine the time that was required for 95 percent of the students to complete the Fox DC test. Ten minutes were added to this time; this was the time limit set for the completion of the Fox DC test. All questions asked by these students were written down and incorporated into the Fox DC test instructions. All questions about the Fox DC test were used to modify the wording and structure of the Fox DC test questions and instructions. Berk (1984) suggested that this can be done to improve a test. Berk (1984, pp. 108-109) said:

> Specific test weaknesses such as item ambiguity and cuing, miskeyed answers, inappropriate vocabulary, and unclear item and test directions can be revealed by asking leading questions pertinent to the item content and structure, test directions, and test format. Such questions may include the following: 1. Did any of the items seem confusing? 2. Did you find any item with no correct answer? 3. Did you find any item with more than one correct answer? 4. Were there any words in the items that you did not know? 5. Did you have any difficulty understanding what to do as you worked through the test?

In the pilot study the students were given a completion test and were asked to work the problems. Upon completion of the test they were given a copy of the test with multiple choice answers. They were instructed not to erase their incorrect answers, but to circle them on the original test. They were then allowed to rework the test if they could not find the answer they had on their first copy of the test. This provided the researcher with potential distracter answers. This is in accordance with the recommendations of Erickson and Wentling (1976). Each distracter answer was chosen by at least one of the examinees in the pilot study.

The purposes of the pilot study were to: (1) identify weaknesses in the Fox DC test instructions, (2) determine the length of the Fox DC test, (3) identify distracters that are not chosen by anyone and eliminate them from the Fox DC test, and (4) identify potential distracters.

Construction of the Test

All Fox DC test items were designed to be independent of each other. Independence of Items: assumes, for each examinee, the response to one item is independent of a response to any other item; that is, a correct response to one item will not depend on a correct response to any other item (Isaac and Michael, 1985). Independence is associated with the reliability of the test (Cronbach, 1950). In development of the Fox DC test, no item was dependent on the answer of any other item.

In accordance with the suggestions of Guttman and Schlesinger (1967) the researcher wrote distracters which represented different types of errors. Bejar and Weiss (1977) suggested that large gains in both reliability and validity can be made by writing distracters which represent different types of errors.

The questions were not arranged in any particular order, in accordance with the findings of Schriesheim, Kopelman, and Solomon (1989). Since the study conducted by Balch (1989) involved alternate forms of a test, and the study conducted by this researcher did not involve alternate forms, this researcher decided not to place the questions in any particular order.

Ebel and Frisbie (1986) suggested that a separate cover page be included on a test in order to emphasize the directions. This was done by this researcher. In addition, the Fox DC tests were only printed on one side of the page in order to eliminate the potential problem of the examinee missing one side of the page. The researcher personally examined each Fox DC test to be certain that it contained all the pages of the test and was printed legibly.

The correct answer was assigned to each of the four positions (A, B, C, or D) by a truly random manner. A die was rolled in order to choose the position of the correct answer, A = 1, B = 2, C = 3, D = 4, and a 5 or 6 was rolled again. In the pilot study the examinees gave four different wrong answers to the questions. This supplied the researcher with four different distracters. In this instance, a roll of five was used to select an option of E. This provided no discernible pattern to the choice of the correct answers. This researcher chose the four and sometimes five option format, rather than the three option format, because the majority of time in answering any question on the Fox DC test was spent in solving the problems and it was desired to have the greatest item discrimination possible. The reduction of the number of options per question would require additional questions to be added to the Fox DC test and create a time problem in test administration. In accordance with the finding of Lord (1977) it was decided that this researcher did not want the Fox DC test to unduly discriminate between the high and low level student, except in the area of their knowledge of DC Circuit Analysis.

The reading level of the Fox DC test was measured with the Gunning-Fog reading test (Klare, 1963) and was determined to be 8.6 and the reading level of the instructions was determined to be 9.9. Since the Fox DC test was administered to freshman level college students, who should be reading at a 13.0 level or above, the reading level is acceptable for this group of students. This was done in order to have the reading level as low as possible in order to have the examinees being tested over DC Circuit Analysis and not over reading skills. Carlson (1985) designed his test to have a reading level below that of the examinees.

By usage of the Fox DC test, teachers may be able to evaluate the curriculum. "Item analysis data can help teachers evaluate areas of a curriculum or unit that need improvement (Sax, 1980, p. 203)." Part of the design of the Fox DC test was to enable teachers to make effectual curriculum revisions. In addition, teachers may be able to evaluate their teaching techniques by usage of the Fox DC test.

Administration of the Test

A pilot study was used to determine the time required for 95 percent of the examinees to finish the Fox DC test. Over 95 percent of the examinees completed the Fox DC test in 65 minutes, in the pilot study. An additional ten minutes were added to the time required for 95 percent of the examinees to finish the Fox DC test. The examinee was given 75 minutes to complete the Fox DC test. In the Fox DC test directions the examinee was informed of this fact (Appendix J). Erickson and Wentling (1976) suggested that time limits should be based upon a trial run of the test. Nunnally (1967) stated that a pure power test would require about twice the comfortable time of the test.

The examinees were familiar with the examiners in every instance of administration. This was in accordance with the studies of Fuchs and Fuchs (1986).

The researcher attempted to control the test location and other physical surroundings in accordance with the recommendations of Fuchs and Fuchs (1986). The examiners were instructed to choose a quiet room and to insure that the room remained free from distractions (Appendix F). A sign was placed on the door of the test room in order to prevent disturbances (Appendix G). This was in accordance with the recommendations of Erickson and Wentling (1976). The examiners were instructed to have a large clock in the front of the test room and to announce when there was 30 minutes left for completion of the Fox DC test and again when there was 5 minutes left (Appendix F). This is in accordance with the recommendations of Ebel and Frisbie (1986).

Other factors which may bias the results of the Fox DC test, such as the personality of the examiner, were not controlled by the researcher. Some of these factors, mentioned by Fuchs and Fuchs (1986) were beyond the control of this researcher. All administrators verbally stated that they would follow the test directions.

This researcher had the examinees to record their answers on a separate score sheet. This was in accordance with the findings of Cashen and Ramseyer (1969), that students in the third grade or older can record their answers on a separate sheet without affecting their scores.

The examinees were informed that there was no penalty for guessing (Appendix H). Sherriffs and Boomer (1954) found that certain personality factors affected the amount of guessing done by an examinee. For this reason, this researcher did not assess a penalty for guessing or a reward for not guessing. Another reason for not assessing a penalty for guessing, or rewarding the examinee for not guessing, is that the student may make an educated guess and demonstrate partial knowledge of the subject. If a student knows that one or more of the three distracters is wrong he has at least partial knowledge of the topic in question. The allowance of guessing may give the student partial credit for this partial knowledge. By eliminating one or more of the distracters his probability of guessing correctly is raised, which effectively rewards him for his partial knowledge. The benefit of this is that the partial credit is not subjectively applied by a scorer, but is objectively supplied by an increased probability of getting the correct answer. Alder and Roessler (1964, p. 52) defined the probability of an event happening as: "If an event can happen in s ways and fail to happen in f ways, and if each of these $s + f$ ways is equally likely to occur, the probability of success (the event happening) in a single trial is $p = s/(s + f)$." If an examination question has four options (three distracters and one correct answer) the probability of getting the right answer by guessing is: $p = 1/(1 + 3) = .25$ (25%). If the examinee eliminates one distracter his probability of getting the right answer by guessing is: $p = 1/(1 + 2) = .333$ (33.3%). Some have objected to multiple-choice tests because they do not provide partial credit for partial knowledge. It is evident that with the increase in the probability of getting the correct answer the examinee is given partial credit for partial knowledge. This argument was made by Ghiselli, Campbell, and Zedeck (1981).

Validation of the Test

The Kuder-Richardson technique KR_{20} was chosen to establish the reliability of the test. This method ". . . is determined from a single administration of a test (Sax, 1980, p. 264)." This technique ". . . assumes that the test is designed to measure power rather than speed (Sax, 1980, p. 266)." "Kuder-Richardson reliabilities also assume that items measure the same trait, factor, or attribute (Sax, 1980, p. 267)." This method ". . . applies when items are scored 1 for correct answers and 0 for wrong answers (Cronbach, 1984, p. 171)." The Kuder-Richardson technique was chosen because: the validity of the Fox DC test was to be established by the administration of the test one time; the test was a power test; the test was scored with a 1 for correct answers and a 0 for wrong answers; and the items measure the same material. Item analysis was used in conjunction with the KR_{20} measure. Balian (1982) suggested the usage of item analysis in order to establish the validity of the Fox DC test.

This researcher developed the Fox DC test which was designed to cover the material normally taught in a two-year post-secondary engineering technology program in DC electrical circuit analysis. The content was validated by a panel of experts in the field of electronic engineering technology in three different states, by a modified Delphi technique and a survey. The first stage of this process involved a modified Delphi technique, in which the experts were asked to list all topics which should be included in an achievement test in DC Circuit Analysis (Appendix A). The second stage of this process involved a survey of these experts where they ranked the topics in order of importance (Appendix C). The third stage of this process involved a survey of these experts to determine if the Fox DC test covered the topics selected in the second phase of the project. These experts were provided with a copy of the proposed Fox DC test (Appendix D) to determine that it covered the material normally taught in DC Circuit Analysis.

This researcher used a modified Delphi technique to establish the content validity of the Fox DC test. The third stage of this process involved the administration of the Fox DC test to students who had just completed DC Circuit Analysis in an ABET accredited school.

CHAPTER IV

ANALYSIS OF DATA

Introduction

The purpose of this study was to develop and validate a Direct Current Circuit Analysis post-test in electronic engineering technology (Fox DC test). This was accomplished by using the Delphi Technique to determine the topics which should be covered in a comprehensive test in DC Circuit Analysis (Fox DC test), having the experts to rank the topics in order of importance, constructing the Fox DC test, and administering the Fox DC test to determine its reliability and validity.

Results

The names of schools surveyed are shown in Table 1. Some schools participated in all phases of the project, some in select phases of the project. A total of nine instructors participated in the first phase of the project, the identification of the topics which needed to be covered in a valid post-test in DC Circuit Analysis. These nine instructors were sent the letter and questionnaire (Appendix A). The topics chosen in this part of the survey are recorded in Table 2. These topics were arranged in alphabetical order (Appendix B) and the experts were asked to rank them in the order of their importance (Appendix B).

The second phase of the project entailed the ranking of the topics chosen in the first phase of the project into their order of importance (Appendix B). This was accomplished by seven of the original nine experts. Two of the experts did not reply to the survey. Later, one expert informed the researcher that he was ill during this period

TABLE 1

THE NAMES OF ABET ACCREDITED SCHOOLS PARTICIPATING IN THE DC CIRCUIT ANALYSIS TEST DEVELOPMENT AND VALIDATION

Kansas State Technical College at Salina, Kansas
DeVry Institute of Technology at Kansas City, Missouri
Florissant Valley Community College at St. Louis, Missouri
Longview Community College at Lee's Summit, Missouri
Amarillo College at Amarillo, Texas
Del Mar College at Corpus Christi, Texas
Devry Institute of Technology at Irving, Texas
Houston Community College at Houston, Texas

TABLE 2

RANK ORDER OF TOPICS IN DC CIRCUIT ANALYSIS AS SELECTED BY EXPERTS

Topic	Rank
Ohm's law	1
Kirchhoff's voltage law	2
Kirchhoff's current law	3
Power	4
Resistor circuit analysis, parallel	5
Resistor circuit analysis, series-parallel	6
Resistor circuit analysis, series	7
Scientific notation, metric prefixes	8
Current divider rule	9
Current, definition of ($I = Q/t$)	10
Voltage divider rule	11
Conductance	12
Thevenin's theorem	13
Mesh analysis	14
Capacitance	15
Coulomb's law	16
DC meter movements	17
Energy, definition of ($P = W/t$)	18
Capacitor static DC circuit	19
Temperature dependence of resistivity	20
Norton's theorem	21
Millman's theorem (source transformation)	22
Nodal analysis	22
Superposition theorem	22
Resistivity and current carrying capacity of standard wire sizes.	22
Inductor static DC circuit	27
Energy, definition of ($E = Q/V$)	27
Capacitor transient response in a DC circuit	28
Loop analysis	28
Faraday's law	30
Efficiency (η)	31
Inductor transient response in a DC circuit	31
Voltage regulation (%)	31
Fields, electric	34
Magnetic fields and circuits	35
Wheatstone Bridge	36
Delta-Wye conversions	37

of time and unable to reply. However, this expert did participate in all other phases of the project. The results of this phase of the project are recorded in Table 2. This researcher chose the top 19 topics for the Fox DC test. Additional time would have been required of students to work problems from all topics. The time allowed for students to respond to the Fox DC test was based upon information identified in the pilot study. These 19 topics are recorded in Table 3.

The scores on the Fox DC test ranged from 8 to 30, with an mean score of 21.48 and a median score of 22. The standard deviation of the Fox DC test scores was 4.73. The standard error of measurement of the Fox DC test was 2.09. The standard error of measurement is sometimes called the standard error of the test (Anastasi, 1976). Anastasi (1976, page 128) gives the following formula for the standard error of measurement:

$$\sigma_{meas} = \sigma_1\sqrt{1 - r}$$

Where σ_1 = the standard deviation of the test scores, r = the reliability coefficient (both computed on the same group, and σ_{meas} = standard error of measurement.

The number of minority examinees was insufficient to determine whether or not the Fox DC test had any racial bias. In addition, the number of female examinees was insufficient to determine whether or not the Fox DC test had any gender bias.

The demographic background of the examinees is given in Table 3. The examinees were 71.7 percent Caucasian American, 8.7 percent black American, 4.3 percent oriental American, 10.7 percent Hispanic American, and 4.3 percent from other races and nationalities. No American Indians were represented in the study. In addition, both genders were represented. The age of the examinees ranged from 18 to 54, with the average age being 25.68 and the median age being 22.

Research Question One: What topics should be covered in a comprehensive post-test in DC Circuit Analysis? A panel of nine experts selected a total of 37 topics to be covered in a comprehensive test in DC Circuit Analysis. Six of the original nine

TABLE 3

DISTRIBUTION OF RACIAL, GENDER, AND AGE CHARACTERISTICS OF EXAMINEES

Age in years	Cauc A. * F	Cauc A. * M	Black A.* F	Black A.* M	Oriental A.* F	Oriental A.* M	Hispanic A.* F	Hispanic A.* M	Other F	Other M
18		4								
19	1	5		3				1		
20		1				1		1		
21		2	1					1		
22		3								
23	1	2								
24		1								
25										1
26		1						1		
28		2								
30		3								
32										1
33								1		
35	1	1								
36		1				1				
40		1								
42	1									
43		1								
54		1								
Totals	4	29	1	3	0	2	0	5	0	2

* The letter A means "American"
(The category "other" included one black African male and one Arabic male)
F = female, M = male

members of the panel of experts ranked the topics in the order presented in Table 2.

Research Question Two: Do the questions written in the Fox DC test adequately cover the topics chosen for the test? (Does the Fox DC test exhibit evidence of content validity?) A four point Likert scale was used in the questionnaire of Appendix D. Each response was scored: Strongly agree = 4, agree = 3, disagree = 2, and strongly disagree = 1. The results of this survey are recorded in Table 5. The experts all expressed their agreement that the Fox DC test properly covered the 19 topics selected. All the experts either agreed or strongly agreed that each of the 19 topics was adequately covered by the Fox DC test. This provided evidence of the content validity of the Fox DC test. The mean values of the responses are recorded in Table 5.

Research Question Three: Does the Fox DC test exhibit evidence of construct validity? The Fox DC test scores were ranked from high to low, the top 12 scores and the bottom 12 scores were tested with the Fisher Exact Probability Test. The Fisher Exact Probability Test was used because the number of subjects was small enough to cause a χ^2 test to be invalid. "If any expected frequency is less than five for χ^2 with 1 *df*, more data may be gathered or Fisher's Exact Test may be used (Linton and Gallo, 1975, p. 62)." Table 5 lists the probabilities of there being a significant difference between the scores of the high group and the low group. In all instances, except one, the high group answered more of each item correctly. In one instance the examinees all answered the question correctly. According to Anastasi (1976) this also gives evidence of the construct validity of the Fox DC test.

Research Question Four: Does the Fox DC test have internal consistency? The Pearson product-moment correlation coefficients range from .07 to .98. The correlation coefficients for each Fox DC test item are listed in Table 6. None of the Fox DC test items demonstrated a negative correlation. The correlation coefficients are a measure of the correlation of each test item with the whole Fox DC test.

TABLE 4

SUMMARY OF EXPERTS' OPINIONS REGARDING TOPICS COVERED BY DC CIRCUIT ANALYSIS TEST

Topic	Rating
Ohm's law	3.67
Kirchhoff's voltage law	3.67
Kirchhoff's current law	3.67
Power	3.67
Resistor circuit analysis, parallel	3.67
Resistor circuit analysis, series-parallel	3.67
Resistor circuit analysis, series	3.67
Scientific notation, metric prefixes	3.33
Current divider rule	3.50
Current, definition of ($I=Q/t$)	3.33
Voltage divider rule	3.17
Conductance	3.33
Thevenin's theorem	3.17
Mesh analysis	3.50
Capacitance	3.50
Coulomb's law	3.17
DC meter movements	3.33
Energy, definition of ($P=W/t$)	3.33
Capacitor static DC circuit	3.50

Ranking: 4 = Strongly agree, 3 = agree, 2 = disagree, and 1 = strongly disagree
(All responses by the experts were statistically significant, at the .05 level)

TABLE 5

A LIST OF PROBABILITIES THAT THERE IS A SIGNIFICANT DIFFERENCE BETWEEN THE HIGH SCORING EXAMINEES AND LOW SCORING EXAMINEES BY QUESTION

N = 46 df = 1

Question Number	Fisher's Exact Test Probability
1	.71
2	1.00
3	.99
4	.996
5	1.00
6	.91
7	1.00
8	.98
9	.90
10	.94
11	1.00
12	1.00
13	1.00
14	1.00
15	.99
16	.96
17	1.00
18	(All examinees in the upper and lower quartiles answered this question correctly)
19	1.00
20	.98
21	.996
22	.87
23	1.00
24	1.00
25	.996
26	.76
27	1.00
28	1.00
29	.99
30	1.00
31	.98
32	1.00
33	.98
34	1.00

TABLE 6

A SUMMARY OF INTERCORRELATION BETWEEN EACH TEST QUESTION AND THE TEST

N = 46 df = 44

Question	Mean Correlation	Std. Dev.
1	.05	.43
2	.37	.36
3	.36	.50
4	.34	.51
5	.55	.40
6	.18	.43
7	.51	.36
8	.32	.44
9	.07	.48
10	.12	.50
11	.42	.49
12	.58	.38
13	.25	.25
14	.51	.43
15	.30	.48
16	.39	.31
17	.36	.21
18	.02	.21
19	.48	.28
20	.29	.49
21	.18	.47
22	.10	.43
23	.59	.21
24	.44	.15
25	.52	.41
26	.10	.50
27	.63	.39
28	.36	.25
29	.33	.50
30	.60	.42
31	.42	.42
32	.70	.49
33	.33	.48
34	.62	.43

Correlation coefficients must be ≥ .29 to be significant at the .05 level

Research Question Five: Are the Fox DC test items homogeneous? Homogeneity was demonstrated for most Fox DC test items (Table 6). Since some items measured different topics in DC Circuit Analysis, it is not necessary to have a high degree of homogeneity. In fact Anastasi (1976) says that increasing homogeneity may lower the reliability of the test. Ghiselli, Campbell, and Zedeck (1981) contrasted homogeneous scaling and empirical keying:

> In contrast, choice of items based on item validity is referred to as *empirical keying*. Items are selected because they have high correlations with the external criterion and at the same time low intercorrelations Thus both item validity and internal consistency are considered.... This approach is not useful for temporal predictions, when we are interested in predicting performance on an external criterion (page 436).

Since the Fox DC test related to an external criterion the proof of homogeneity was not as critical as conformity to the criterion.

Research Question Six: Is the Fox DC test reliable? The reliability of the Fox DC test was determined to be .8044 from the Kuder-Richardson KR_{20} test. Payne (1968) stated that a reliability coefficient greater than .70 was acceptable and that a coefficient of .86 provided a relatively high degree of confidence. Erickson and Wentling (1976) stated that reliabilities of .75 possessed moderately high degrees of reliability. The Fox DC test developed by this researcher was therefore reliable. In order to raise the level of the reliability coefficient it would be necessary to remove the Fox DC test items (questions) with low levels of discrimination, make the Fox DC test more homogeneous, test a group which was more homogeneous in nature, and increase the number of Fox DC test items (Ebel and Frisbie, 1986). "The general Spearman-Brown formula is used to predict the new reliability expected from increasing (decreasing) the length of a test of known reliability by adding (subtracting) items similar to the original ones. (Ebel and Frisbie, 1986, p. 76)." The Spearman-Brown formula is:

$r_n = [n(r)]/[(n - 1)r + 1]$

r = the reliability of the original test

n = the number of times the original test is lengthened

Solving the equation for n yields:

$n = r_n(r - 1)/[r(r_n - 1)]$

From this equation it can be determined that in order to increase the reliability of the Fox DC test by adding test questions covering the same material and of the same basic nature would require multiplying its' length by n = 2.1885 which would raise the number of questions to 75. At that rate the Fox DC test would require about three hours to complete, which could lower the reliability because of other factors, such as fatigue (Ebel and Frisbie, 1986).

Research Question Seven: What is the difficulty level of each question? The difficulty level (Item Difficulty) of each question was determined by the formula DIFF = (C/N), where C = number of students who answer the item correctly N = total number of students in the group (12). Kelley (1939) determined that the optimum value of the upper and lower groups is 27 percent. Because 27 percent of 46 is 12 this researcher selected the upper 12 and lower 12 scores as the group from which to perform the item analysis. The values of the difficulty level of each question are recorded in Table 7.

Research Question Eight: What is the item discrimination index of each question? This index is calculated by dividing the examinees into two groups, the highest scorers and the lowest scorers. These two subgroups are chosen based upon their total scores. Each subgroup has the same number of individuals in the subgroup (12). The discrimination index is DI = $(C_{high} - C_{low})/N$. Where C_{high} = the number of high scoring individuals who answered the Fox DC test item correctly and C_{low} = the number of low scoring individuals who answered the Fox DC test item correctly and N = the number of individuals in one of the subgroups. Each subgroup had the same number of individuals (12). These values are recorded in Table 7. "In general, it will be found that extremely difficult or extremely easy items will show very little discrimination (Payne, 1968, p. 154)." The Fox DC test

TABLE 7

A SUMMARY OF ITEM DIFFICULTY INDEX AND ITEM DISCRIMINATION INDEX BY QUESTION

N = 46

Question	Discrimination Index	Difficulty level
1	.083	.24
2	.333	.85
3	.417	.57
4	.417	.48
5	.500	.80
6	.250	.24
7	.417	.85
8	.333	.24
9	.167	.35
10	.250	.46
11	.667	.61
12	.500	.83
13	.083	.93
14	.583	.76
15	.417	.65
16	.167	.89
17	.167	.96
18	.083	.96
19	.333	.91
20	.500	.35
21	.417	.33
22	.083	.74
23	.250	.93
24	.167	.96
25	.417	.78
26	.167	.41
27	.583	.80
28	.250	.07
29	.417	.54
30	.583	.11
31	.333	.76
32	.916	.61
33	.417	.63
34	.667	.74

was a power test which normally contain items which range from very easy to very difficult (Erickson and Wentling, 1976). This lowered the discrimination index for the very easy and very difficult questions. Ghiselli, Campbell, and Zedeck (1981) suggested that the discrimination index is evidence of internal consistency.

Problems Encountered

This researcher encountered some resistance to the usage of the multiple-choice format for the Fox DC test from instructors in three of the colleges targeted in this study. These schools did not administer the Fox DC test for this study. Two instructors expressed doubts about the usage of the multiple-choice format in this study, but still administered the Fox DC test. The effects of the attitude of the examiners toward multiple-choice tests upon the examinees Fox DC test scores is unknown. Fuchs and Fuchs (1986) point out that the scores can be affected by such factors as the attitudes about the legitimacy of the test. One instructor, from the panel of experts, expressed his surprise that the Fox DC test questions had covered the higher levels of learning from Blooms taxonomy (Bloom, Englehart, Furst, Hill, and Krathwohl, 1956). The researcher attempted to construct questions which measured higher levels of learning, rather than the usual knowledge questions which are frequently asked in multiple-choice format tests.

CHAPTER V

SUMMARY AND RECOMMENDATIONS

Summary

The purpose of this study was the development and validation of a DC Circuit Analysis post-test in electronic engineering technology. The content of the DC Circuit Analysis post-test (Fox DC test) was determined by choosing a panel of experts from all the ABET accredited schools in Kansas, Missouri, Arkansas, and Texas. A modified Delphi technique was employed to determine the Fox DC test content. The panel of experts selected 37 topics in the initial phase of the research. These experts were asked to rank the topics by order of importance. This researcher timed the students in a pilot study at Rose State College in Midwest City, Oklahoma in order to be able to keep the Fox DC test length within reasonable limits. It was found that a test covering all 37 topics would require about 2 1/2 hours to complete. This forced this researcher to limit the number of test topics. The top 19 topics identified by the experts were chosen in order to have a reasonable length of time for the administration of the Fox DC test. The survey of the experts provided evidence of the content validity of the test.

The content of the Fox DC test was determined by the modified Delphi technique. The same panel was surveyed to determine if the Fox DC test questions written by the researcher properly covered the content determined from the modified Delphi study. It was the judgment of the panel of experts that the Fox DC test questions properly covered the 19 topics determined by the modified Delphi study (Table 4).

This study also included establishing the reliability of the Fox DC test. This was accomplished by demonstrating that the Fox DC test was reliable and that it had evidence of construct validity. The reliability was determined to be .8044 from the Kuder-Richardson KR_{20} test. The construct validity of the Fox DC test was demonstrated by demonstrating the internal consistency of the Fox DC test. The examinees were grouped into two groups, the high group which included the examinees who scored in the upper 27 percent, and the low group which included the examinees who scored in the lower 27 percent. These two groups were compared with the Fisher's Exact Test. This method was suggested by Anastasi (1976) to demonstrate the construct validity of a test.

The Fox DC test was administered to 46 students in five ABET (Accrediting Board for Engineering and Technology) accredited schools in three states (Missouri, Kansas, and Texas). The Fox DC test consisted of 34 questions taken from the top 19 topics from 37 topics ranked by a panel of experts chosen from the faculty of these schools. The Fox DC test instructions had a reading level of 9.9 and the Fox DC test had a reading level of 8.6, according to the Gunning-Fog Readability Index. Klare (1963) set forth the Gunning-Fog Readability Index. The examinees had a mean score of 21.48, a range from 8 to 30, a standard deviation of 4.73, and a standard error of measurement of 2.09.

Recommendations

The first recommendation is that the Fox DC test be used for research in education in the area of electronic engineering technology. The Fox DC test can be used to conduct research in such areas as new teaching techniques and new curriculum in electronic engineering technology.

The second recommendation is that the Fox DC test be administered to a larger group of examinees in order to provide more information on the validity of the Fox DC test. Factor analysis could be employed if the Fox DC test was administered to a minimum of 340 subjects. Nunnally (1967) recommended that factor analysis not be employed unless there was at least ten times as many subjects as test items.

The third recommendation is that a study be conducted to determine if the Fox DC test is free of racial and gender bias. It was not possible to collect and analyze this data because of the low number of examinees.

The fourth recommendation is that a study be conducted, by a panel of experts, to determine if the distracters can be used to detect misunderstandings of various electrical principles. "By examining the *incorrect* options selected by examinees, teachers can detect misunderstandings or lack of knowledge. . . .To be most useful for diagnostic purposes, each option should measure a plausible source of student misunderstanding (Sax, 1980, pp. 199-200)."

> The multiple-choice item also has the advantage of providing input to the diagnosis of instruction and the diagnosis of student growth. The analysis of item responses, that is, which alternatives were chosen as being correct when, in fact, they were incorrect, can help to identify misconceptions or misunderstandings on the part of a student or a group of students (Erickson and Wentling, 1976, p. 91).

This researcher designed each option to be plausible if the examinee misunderstood some law or principle of electricity.

The fifth recommendation is that a longitudinal study be conducted to determine if the Fox DC test can be used as a predictor of success in later courses in electronic engineering technology. Anastasi (1976) suggests that this can be done with achievement tests. According to Anastasi this would validate the Fox DC test as an aptitude test.

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APPENDIXES

APPENDIX A

LETTER AND QUESTIONNAIRE FOR DELPHI SURVEY TO DETERMINE TEST CONTENT

January 16, 1989

Dear Sir:

I am pursuing my doctorate of education degree at Oklahoma State University; Stillwater, Oklahoma. I have chosen for my dissertation the task of developing and validating a test in DC electricity at the engineering technology level. I have chosen to conduct this research at schools accredited by TAC/ABET; which grant an associate degree in Oklahoma, Texas, Kansas, Missouri, and Arkansas.

I would appreciate it if you would help me in this research. I would appreciate your suggesting one of your faculty members who could help me with this work. His part would be to help me with three aspects of this work: (1) help me determine the content of the test, (2) act as an expert to determine the content validity of the questions after I construct the test, and (3) administer the test to your classes in DC Circuit Analysis after it is constructed.

I realize that some of the TAC/ABET accredited institutions may not teach DC circuit analysis in the spring. I would still appreciate it if you could help with the first two parts of this work, if you are able to do so.

I have enclosed a questionnaire with a return envelope for your convenience. Please feel free to make any suggestions you feel might be helpful in this effort. If you could help me in this matter, would you please pass this on to one of your faculty members?

Sincerely yours,

Marion R. Fox
4004 Twisted Trail
Oklahoma City, Oklahoma 73150-9722

QUESTIONNAIRE FOR INSTRUCTORS OF DC CIRCUIT ANALYSIS IN TAC/ ABET ACCREDITED TWO-YEAR INSTITUTIONS OF HIGHER EDUCATION.

Instructions: Please list all laws, techniques, and theorems which should be covered in a DC Circuit Analysis test.
Name:
School:
Address:

Telephone number: ______-_____-____________
Does your school teach DC Circuit Analysis in the springtime?_________

1______________________________

2______________________________

3______________________________

4______________________________

5______________________________

6______________________________

7______________________________

8______________________________

9______________________________

10______________________________

11______________________________

12______________________________

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29 ______________________________

30 ______________________________

31 ______________________________

32 ______________________________

33 ______________________________

34 ______________________________

35 ______________________________

APPENDIX B

SECOND LETTER AND QUESTIONNAIRE FOR RANKING OF TOPICS BY IMPORTANCE

April 12, 1989

Dear Sir:

I appreciate your response to my last questionnaire. This follow up questionnaire will not take as much of your valuable time. In order to refresh you memory, I am developing a test in DC electricity at the Engineering Technology level. The questionnaire contains all responses from those who responded to the questionnaire. These responses may be helpful to you in writing course outlines. This should give you an idea of what other TAC/ABET accredited schools are teaching.

Because of time constraints I am forced to omit some of the topics from this list. It becomes necessary to select the most important topics. I am requesting that you rank the topics in order of importance.

I have enclosed a self addressed envelope for your convenience. Please feel free to make any suggestions that you feel might be helpful in this effort. Your consideration to the above request is greatly appreciated.

I would appreciate it if you could return this questionnaire within 10 days.

Sincerely Yours,

Marion R. Fox
4004 Twisted Trail
Oklahoma City, Oklahoma 73150-9722
Tel-405-732-1050

RESULTS OF SURVEY: The following topics include all responses from those surveyed in the first questionnaire.

Instructions: Please rank the following topics for a DC Circuit Analysis post-test. List the topics in order of their importance, as you perceive them. (List the most important topic as number 1, the second most important topic as number 2, etc. in the blank labeled RANK.) Please read all options before you rank any of them, there are two pages.

Capacitance RANK ( )

Capacitor static DC circuit RANK ( )

Capacitor transient response in a DC circuit RANK ( )

Conductance RANK ( )

Coulomb's law RANK ( )

Current, definition of (I=Q/t) RANK ( )

Current divider rule RANK ( )

Delta-Wye conversions RANK ( )

DC meter movements RANK ( )

Efficiency RANK ( )

Energy, definition of (E=Q/V) RANK ( )

Energy, definition of (P=W/t) RANK ( )

Faraday's law RANK ( )

Fields, electric RANK ( )

Inductor static DC circuit RANK ( )

Inductor transient response in a DC circuit RANK ( )

Kirchhoff's voltage law RANK ( )

Kirchhoff's current law RANK ( )

Loop analysis RANK ( )

Magnetic fields and circuits RANK ( )

Mesh analysis RANK ( )

Millman's theorem (source transformation) RANK ( )

Nodal analysis RANK ( )

Norton's theorem RANK ( )

Ohm's law RANK ( )

Power RANK ( )

Resistivity and current carrying capacity of standard wire sizes. RANK ( )

Resistor circuit analysis, parallel RANK ( )

Resistor circuit analysis, series-parallel RANK ( )

Resistor circuit analysis, series RANK ( )

Scientific notation, metric prefixes RANK ( )

Superposition theorem RANK ( )

Temperature dependence of resistivity RANK ( )

Thevenin's theorem RANK ( )

Voltage divider rule RANK ( )

Voltage regulation (%) RANK ( )

Wheatstone Bridge RANK ( )

APPENDIX C

LIST OF ALL TOPICS AS RANKED BY PANEL OF EXPERTS

THE FOLLOWING LIST IS THE RANK ORDER OF TOPICS IN DC CIRCUITS AS PERCEIVED BY THE PANEL OF EXPERTS.

Topic RANK
Ohm's law RANK (1)
Kirchhoff's voltage law RANK (2)
Kirchhoff's current law RANK (3)
Power RANK (4)
Resistor circuit analysis, parallel RANK (5)
Resistor circuit analysis, series-parallel RANK (6)
Resistor circuit analysis, series RANK (7)
Scientific notation, metric prefixes RANK (8)
Current divider rule RANK (9)
Current, definition of $(I=Q/t)$ RANK (10)
Voltage divider rule RANK (11)
Conductance RANK (12)
Thevenin's theorem RANK (13)
Mesh analysis RANK (14)
Capacitance RANK (15)
Coulomb's law RANK (16)
DC meter movements RANK (17)
Energy, definition of $(P=W/t)$ RANK (18)
Capacitor static DC circuit RANK (19)
Temperature dependence of resistivity RANK (20)
Norton's theorem RANK (21)
Millman's theorem (source transformation) RANK (22)
Nodal analysis RANK (22)
Superposition theorem RANK (22)
Resistivity and current carrying capacity of standard wire sizes. RANK (22)
Inductor static DC circuit RANK (27)
Energy, definition of $(E=Q/V)$ RANK (27)
Capacitor transient response in a DC circuit RANK (28)
Loop analysis RANK (28)
Faraday's law RANK (30)
Efficiency (η) RANK (31)
Inductor transient response in a DC circuit RANK (31)
Voltage regulation (%) RANK (31)
Fields, electric RANK (34)
Magnetic fields and circuits RANK (35)
Wheatstone Bridge RANK (36)
Delta-Wye conversions RANK (37)

APPENDIX D

THIRD LETTER WITH SAMPLE TEST AND QUESTIONNAIRE TO DETERMINE CONTENT VALIDITY OF TEST

May 8, 1989

Dear Sir:

I appreciate your help in determining the topics for the achievement test in DC Circuits. I have enclosed a draft of the achievement test for your consideration. I would appreciate it if you would be able to give me your expert opinion on this test.

I have enclosed a copy of the order of topics as ranked by the panel of seven instructors of DC Circuit Analysis in ABET accredited schools in Kansas, Missouri, and Texas. This might be helpful to you in preparing course syllabi. If I can be of any help to you please feel free to call upon me.

I have also enclosed two questionnaires which will help me to determine the content validity of this test. If you would complete these questionnaires and return them to me, the test will be copyrighted and all participants will be given written permission to utilize this test.

Thank you for your continued support.

Sincerely yours,

Marion R. Fox
4004 Twisted Trail
Oklahoma City, Oklahoma 73150-9722

INSTRUCTIONS FOR COMPLETION OF THE QUESTIONNAIRES

There are two questionnaires to be completed. This is the last part of the test construction project. Please complete and return both questionnaires within 10 days. You will receive a copy of the completed test and an abstract of the results when this study is complete. If you include your name and address you will receive written permission to use this test. It will be copyrighted.

When filling out the achievement test questionnaire: check the appropriate topic(s) covered by each question. (Some questions may relate to more than one topic.) For example, if the question relates to Ohm's law, Kirchhoff's voltage law, and the definition of current you should check the boxes under these topics.

When filling out the questionnaires use your professional judgment to answer the questions. Do not work the questions, unless you feel it is necessary.

QUESTIONS:

1-Would it be possible for you to give this test to your students this semester?__________

2-If so, what is the last date you can administer it to them?______________

3-If you answered "yes" to question number 1, do you teach DC circuits in the summer?_________

Example:

Please list your name and address below:

Name:____

Address:______________________________________

____

TOPIC QUESTIONNAIRE

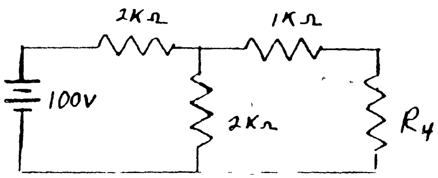
Please complete, by checking each question, and return this questionnaire.

This topic was adequately covered on this test.	Strongly agree	Agree	Disagree	Strongly disagree
Capacitance				
Capacitor static DC circuits				
Conductance				
Coulomb's law				
The definition of current (I=Q/t)				
The current divider rule				
DC meter movements				
The definition of energy (P=W/t)				
Kirchhoff's voltage law				
Kirchhoff's current law				
Mesh analysis				
Ohm's law				
Power				
Resistor circuit analysis (parallel)				
Resistor circuit analysis (series)				
Resistor circuit analysis (series-parallel)				
Scientific notation and metric prefixes				
Thevenin's theorem				
The voltage divider rule				

ACHIEVEMENT TEST FOR DC CIRCUIT ANALYSIS

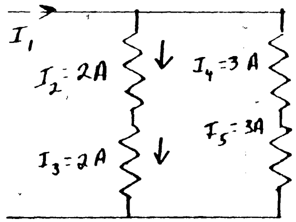
Please complete and return this questionnaire
Please check all principles that apply to each circuit in the spaces provided.

1-The power dissipated by resistor R_4 will be maximum when R_4 equals ______

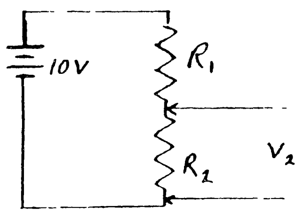


2-The value of the current I_1 equals

______



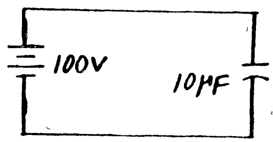
3-The voltage V_2 is measured with an ideal voltmeter and is determined to be 0 volts. What is probably the cause of this reading?______



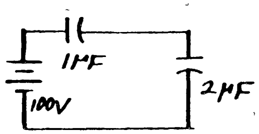
Question	Capacitance	Capacitor static DC circuit	Conductance	Coulomb's law	Current definition of (I=Q/t)	Current divider rule	DC meter movements	Energy definition of (P=W/t)	Kirchhoff's voltage law	Kirchhoff's current law	Mesh analysis	Ohm's law	Power	Resistive circuit analysis parallel	Resistive circuit analysis series	Resistive circuit analysis series-parallel	Scientific notation metric prefix	Thevenin's theorem	Voltage divider rule
1																			
2																			
3																			

Please check all principles that apply to each circuit in the spaces provided.

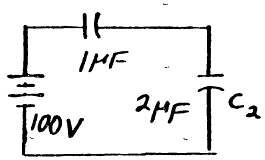
4-Calculate the charge on the following capacitor._______



5-The value of the total capacitance in the following circuit is:____________



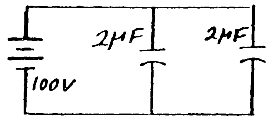
6-The value of the steady state voltage across the capacitor C_2 is:______________



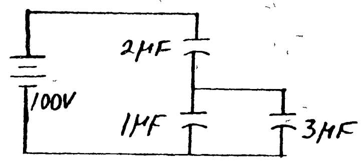
Capacitance	Capacitor state DC circuit	Conductance	Coulomb's law	Current definition of (I = Q/t)	Current divider rule	DC meter movements	Energy definition of (P = W/t)	Kirchhoff's voltage law	Kirchhoff's current law	Mesh analysis	Ohm's law	Power	Resistive circuit analysis, parallel	Resistive circuit analysis, series	Resistive circuit analysis, series-parallel	Scientific notation, metric prefix	Thevenin's theorem	Voltage divider rule

Please check all principles that apply to each circuit in the spaces provided.

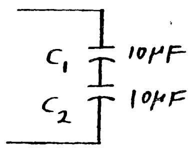
7-The value of the total capacitance of the following circuit is:____________



8-The voltage across the 3 microfarad capacitor in the circuit below equals:_______



9-Two capacitors (cf. circuit below) are connected in series and C_1 has a leakage resistance R_{leak} = 10 KM ohms and C_2 has a leakage resistance R_{leak} = 20KM ohms. Which capacitor is most likely to be damaged by excessive voltage?



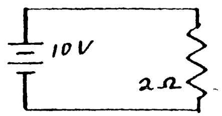
Capacitance	Capacitor use in DC circuit	Conductance	Coulomb's law	Current definition of (I = Q/t)	Current divider rule	DC meter movements	Energy definition of (P = W/t)	Kirchhoff's voltage law	Kirchhoff's current law	Mesh analysis	Ohm's law	Power	Resistor circuit analysis, parallel	Resistor circuit analysis, series	Resistor circuit analysis, series-parallel	Scientific notation, metric prefix	Thevenin's theorem	Voltage divider rule

Please check all principles that apply to each circuit in the spaces provided.

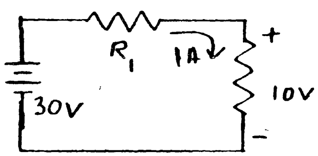
	Capacitance	Capacitor static DC circuit	Conductance	Coulomb's law	Current, definition of (I = Q/t)	Current divider rule	DC meter movements	Energy, definition of (P = W/t)	Kirchhoff's voltage law	Kirchhoff's current law	Mesh analysis	Ohm's law	Power	Resistive circuit analysis, parallel	Resistor circuit analysis, series	Resistive circuit analysis, series-parallel	Scientific notation, metric prefix	Thevenin's theorem	Voltage divider rule
10-How much current flows when 3 millicoulombs move past a point in a circuit in 430 microseconds?_______																			
11-How much time is required to deposit 18 coulombs if 20 milliamps flows?_________																			
12-What is the conductance of a 47 K ohm resistor?___																			

Please check all principles that apply to each circuit in the spaces provided.

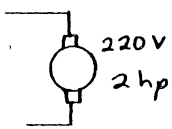
13-What is the value of the current in the following circuit?__________



14-The value of R_1 is:____________



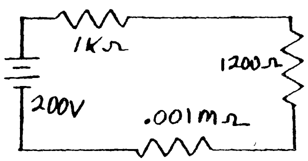
15-The value of P_t is:______________



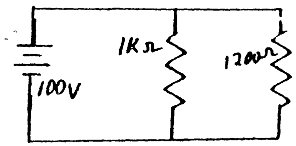
	Capacitance	Capacitor state DC circuit	Conductance	Coulomb's law	Current definition of (I = Q/t)	Current divider rule	DC motor movements	Energy definition of (P = W/t)	Kirchhoff's voltage law	Kirchhoff's current law	Mesh analysis	Ohm's law	Power	Resistive circuit analysis, parallel	Resistive circuit analysis, series	Resistive circuit analysis, series-parallel	Scientific notation, metric prefix	Thevenin's theorem	Voltage divider rule
13																			
14																			
15																			

Please check all principles that apply to each circuit in the spaces provided.

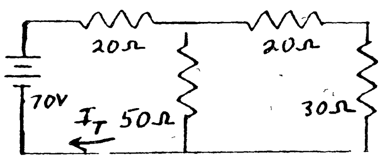
16-The value of R_t is ______________



17-The value of R_t is: ______________



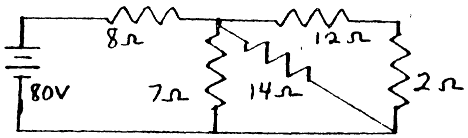
18-The value of I_t is: ______________



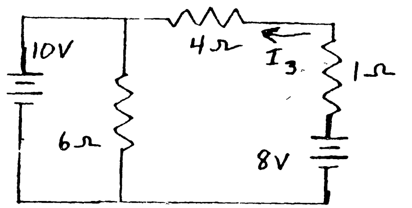
Capacitance	Capacitor static DC circuit	Conductance	Coulomb's law	Current definition of (I = Q/t)	Current divider rule	DC meter movements	Energy definition of (P = W/t)	Kirchhoff's voltage law	Kirchhoff's current law	Mesh analysis	Ohm's law	Power	Resistive circuit analysis, parallel	Resistive circuit analysis, series	Resistive circuit analysis, series-parallel	Scientific notation, metric prefix	Thevenin's theorem	Voltage divider rule

Please check all principles that apply to each circuit in the spaces provided

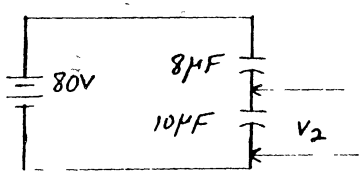
19-The value of R_t is:____________________



20-The value of I_3 is:____________________



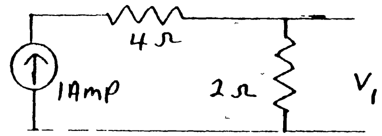
21-The value of V_2 is:____________________



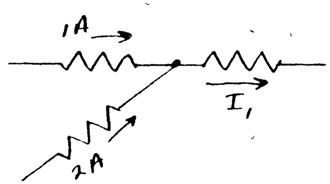
	Capacitance	Capacitor static DC circuit	Conductance	Coulomb's law	Current definition of (I = Q/t)	Current divider rule	DC meter movements	Energy definition of (P = W/t)	Kirchhoff's voltage law	Kirchhoff's current law	Mesh analysis	Ohm's law	Power	Resistive circuit analysis, parallel	Resistive circuit analysis, series	Resistive circuit analysis, series-parallel	Scientific notation, metric prefix	Thevenin's theorem	Voltage divider rule
19																			
20																			
21																			

Please check all principles that apply to each circuit in the spaces provided.

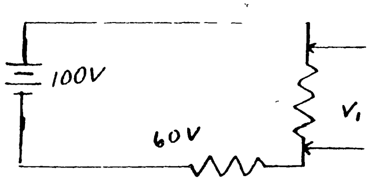
22-The value of V_1 is:________________



23-The value of I_1 is:________________



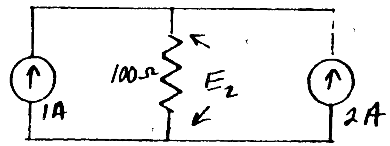
24-The value of V_1 is:________________



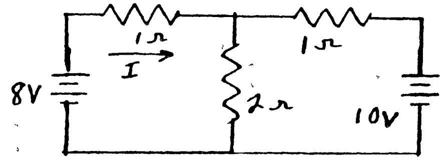
Capacitance	Capacitor state DC circuit	Conductance	Coulomb's law	Current definition of (I = Q/t)	Current divider rule	DC meter movements	Energy: definition of (P = W/t)	Kirchhoff's voltage law	Kirchhoff's current law	Mesh analysis	Ohm's law	Power	Resistor circuit analysis, parallel	Resistor circuit analysis, series	Resistor circuit analysis, series-parallel	Scientific notation, metric prefix	Thevenin's theorem	Voltage divider rule

Please check all principles that apply to each circuit in the spaces provided.

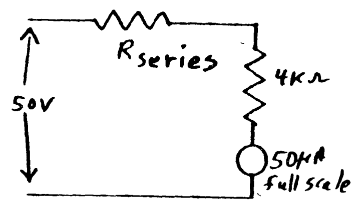
25-The value of E_2 is.__________________



26-The value of I is:__________________



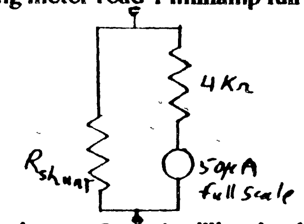
27-What series resistor is required to make the following current meter read 50 volts full scale?__________



Question	Capacitance	Capacitor in a DC circuit	Conductance	Coulomb's law	Current, definition of (I = Q/t)	Current divider rule	DC meter movements	Energy, definition of (P = W/t)	Kirchhoff's voltage law	Kirchhoff's current law	Mesh analysis	Ohm's law	Power	Resistive circuit analysis, parallel	Resistive circuit analysis, series	Resistive circuit analysis, series-parallel	Scientific notation, metric prefix	Thevenin's theorem	Voltage divider rule
25																			
26																			
27																			

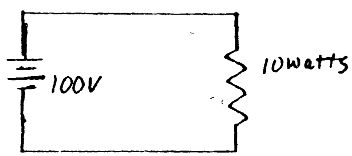
Please check all principles that apply to each circuit in the spaces provided.

28-What shunt resistor is required to make the following meter read 1 milliamp full scale? ____________



29-Two charges $Q_1 = 4$ millicoulombs and $Q_2 = 8$ millicoulombs are separated by 2 micrometers. What is the force of repulsion between Q_1 and Q_2? ____________

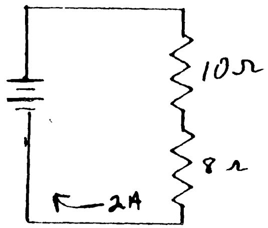
30-What is the value of the current in the following circuit? ____________



	Capacitance	Capacitor static DC circuit	Conductance	Coulomb's law	Current definition of (I = Q/t)	Current divider rule	DC meter movements	Energy: definition of (P = W/t)	Kirchhoff's voltage law	Kirchhoff's current law	Mesh analysis	Ohm's law	Power	Resistor circuit analysis, parallel	Resistor circuit analysis, series	Resistor circuit analysis, series-parallel	Scientific notation, metric prefix	Thevenin's theorem	Voltage divider rule
28																			
29																			
30																			

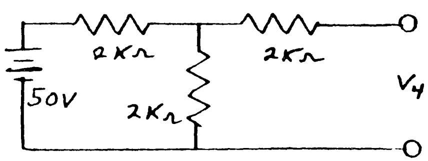
Please check all principles that apply to each circuit in the spaces provided.

31-What is the value of the power consumed in the following circuit?_______________



32-What is the cost of operating an electric range which dissipates 15,000 watts if it is used 1 hour/day for a year (365 days)? (Assume electricity costs 5 cents/ KWH)_______________

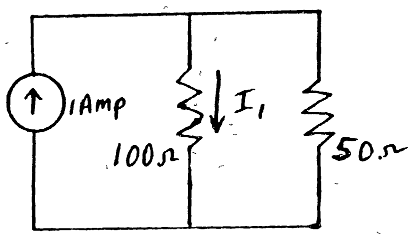
33-What is the value of the voltage V_4?_______



	Capacitance	Capacitor basic DC circuit	Conductance	Coulomb's law	Current definition of (I=Q/t)	Current divider rule	DC meter movements	Energy, definition of (P=W/t)	Kirchhoff's voltage law	Kirchhoff's current law	Mesh analysis	Ohm's law	Power	Resistive circuit analysis, parallel	Resistive circuit analysis, series	Resistive circuit analysis, series-parallel	Scientific notation, metric prefix	Thevenin's theorem	Voltage divider rule
31																			
32																			
33																			

Please check all principles that apply to each circuit in the spaces provided.

34-The value of the current I_1 is.



Capacitance	Capacitor with DC circuit	Conductance	Coulomb's law	Current, definition of (I = Q/t)	Current divider rule	DC meter movements	Energy, definition of (P = W/t)	Kirchhoff's voltage law	Kirchhoff's current law	Mesh analysis	Ohm's law	Power	Resistive circuit analysis, parallel	Resistive circuit analysis, series	Resistive circuit analysis, series-parallel	Scientific notation, metric prefix	Thevenin's theorem	Voltage divider rule

APPENDIX E

INSTRUCTIONS GIVEN TO EXAMINEES

PRIOR TO TEST

HAND OUT FOR STUDENTS TO BE GIVEN AT LEAST ONE DAY PRIOR TO THE TEST

1-The examinee is allowed to use an electronic calculator on the test.

2-The examinee should bring two # 2 lead pencils with erasers and three sheets of scratch paper to the test room.

3-The examinee will not be given any formulas during the test.

4-The exam will be administered at: ______________ in Room__________________

on______________, ____________, ____________. __________________ will be in charge of the examination.

5-The examination is a 34 question multiple-choice test, with only one right answer for each question. Most of the wrong answers will be plausible, if you do not understand some electrical principles.

6-The test will cover the following topics from DC electricity:

Capacitance
Capacitor static DC circuit
Conductance
Coulomb's law
Definition of current ($I=Q/t$)
The current divider rule
DC meter movements
The definition of energy ($P=W/t$)
Kirchhoff's current law
Kirchhoff's voltage law
Maximum power transfer theorem
Mesh analysis
Ohm's law
Power
Resistor circuit analysis (parallel)
Resistor circuit analysis (series)
Resistor circuit analysis (series-parallel)
Scientific notation and metric prefixes
Thevenin's theorem
The voltage divider rule

APPENDIX F

INSTRUCTIONS GIVEN TO TEST ADMINISTRATOR

INSTRUCTIONS TO THE TEST ADMINISTRATOR

1-Choose a classroom which will have a minimum of distractions.

2-Have the examinees seated in a room with a large clock at the front of the room, if possible.

3-Tape the "EXAM IN PROGRESS, DO NOT DISTURB" sign on the door.

4-Close the door to remove distractions.

5-Have the examinees to sign the release of information form.

6-Provide the examinees with a copy of the test instructions, three minutes prior to administering the test.

7-Make sure that the students do not have any formulas on their scratch papers.

8-Read aloud the instructions to the examinees.

9-You may not interpret any questions for the examinees or provide the examinee with any formulas.

10-The examinees may use an electronic calculator to work the problems.

11-Provide the examinees with a copy of the test, face down; after all examinees have a copy tell them to open the test and begin. Begin taking time at this time.

12-Ask the examinees to examine the test to determine if it is defective.

13-In the event that any test is defective the examinee should be given another copy and the defective copy should be retrieved.

14-Announce to the examinees when they have 30 minutes till the end of the test.

15-Announce to the examinees when they have 5 minutes till the end of the test.

16-First, retrieve all answer sheets from the examinees.

17-Then, retrieve all test booklets from the examinees

18-The test should be taken up after 75 minutes; most students will complete it before the 75 minutes are completed.

APPENDIX G

SIGN PLACED ON DOOR OF TESTING ROOM

TEST IN PROGRESS

DO NOT ENTER

APPENDIX H

INSTRUCTIONS GIVEN TO EXAMINEE WITH THE TEST

INSTRUCTIONS TO THE EXAMINEE

1-You may use an electronic calculator on this test.

2-You may not ask the proctor to interpret any questions for you.

3-You may not ask the proctor to provide you with any formulas.

4-You have 75 minutes to work the test.

5-The proctor will announce when you have 30 minutes left to complete the test and again announce when you have 5 minutes to complete the test.

6-Over 95% of the examinees who have previously taken this test have completed it within 65 minutes.

7-There is no penalty for guessing, therefore the examinee should fill in all unanswered questions prior to handing the test in to the proctor.

8-Use a number 2 pencil to fill in the computer score sheets.

9-Fill in the computer score sheets according to the format below.

[ ] (Be sure to totally blacken each box, if you make a mistake thoroughly erase it.)

10-This is an achievement test in DC electricity.

11-You may not leave the classroom for any reason during the test. Therefore, you should get a drink, use the rest room, or take care of any other necessity prior to taking the test.

12-You are allowed to have three sheets of scratch paper.

13-Write your name on the test and on the answer sheet. Answer all questions on the first page of the test booklet.

Today you will complete an examination which is designed to determine your achievement in DC electricity. This exam will enable your instructors to evaluate your progress and provide them with information which may be helpful in curriculum revision, modification of teaching styles, and other changes in the educational process. Comparisons will be made between your scores and the scores of other students in other schools.

In order to make proper comparisons you are encouraged to do your best on this test. Failure to do your best will provide an improper picture of your abilities and achievement.

APPENDIX I

ANSWER KEY TO ACHIEVEMENT TEST

Question	Correct Answer	Question	Correct Answer
1	A	18	B
2	E	19	D
3	C	20	A
4	C	21	A
5	A	22	D
6	A	23	B
7	C	24	C
8	A	25	D
9	B	26	B
10	B	27	C
11	A	28	D
12	C	29	C
13	B	30	C
14	B	31	D
15	C	32	D
16	D	33	D
17	C	34	A

APPENDIX J

ACHIEVEMENT TEST IN DC CIRCUIT ANALYSIS

ACHIEVEMENT TEST FOR DC CIRCUIT ANALYSIS QUESTIONNAIRE

[All information given on this sheet will be kept *strictly confidential*]

NAME____

SCHOOL____

DATE: month________________, day_________, year________________

AGE_______________

GENDER_____________________

RACE/ETHNIC BACKGROUND (For statistical purposes only): [please check one]

American Indian__________

Black American____________

Caucasian American___________

Oriental American______________

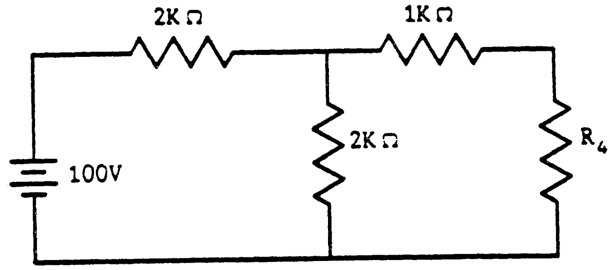
Spanish-surnamed American___________

Other____________

ACHIEVEMENT TEST FOR DC CIRCUIT ANALYSIS

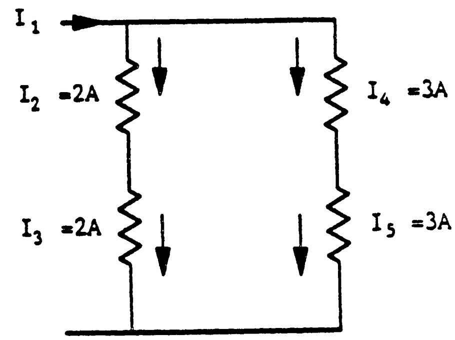
1-The power dissipated by resistor R_4 will be maximum when R_4 equals ______

a) 2 kΩ
b) 1 kΩ
c) 2.667 kΩ
d) 5 kΩ
e) 100k Ω



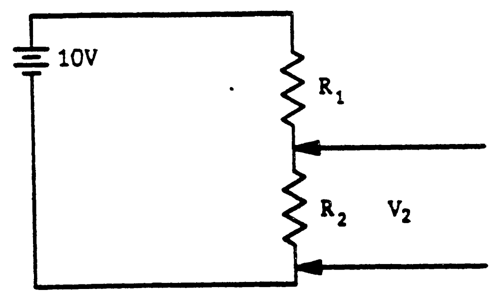
2-The value of the current I_1 equals __________.

a) 2 A
b) 3 A
c) 6 A
d) 10 A
e) 5 A



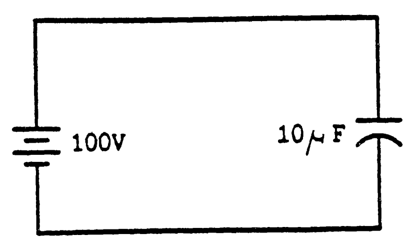
3-The voltage V_2 is measured with an ideal voltmeter and is determined to be 0 volts. What is probably the cause of this reading?_____

a) R_1 shorted
b) R_2 open
c) R_1 open
d) power supply voltage too high



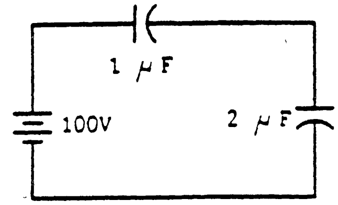
4-Calculate the charge on the following capacitor._______

a) 10 μ coulombs
b) 100 μ coulombs
c) 1000 μ coulombs
d) 1000 millicoulombs



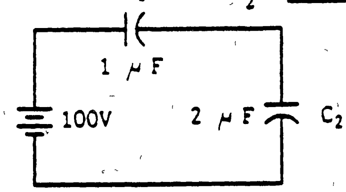
5-The value of the total capacitance in the following circuit is:__________

a) .667 μ farads
b) 1.667 μ farads
c) 2 μ farads
d) 3 μ farads



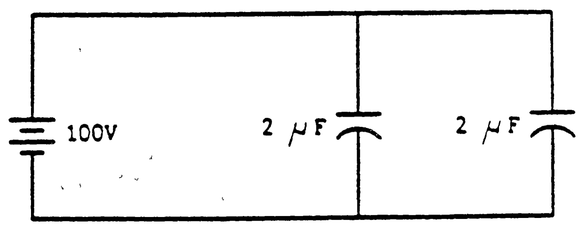
6-The value of the steady state voltage across the capacitor C_2 is:__________

a) 33.33 volts
b) 50 volts
c) 66.67 volts
d) 100 volts



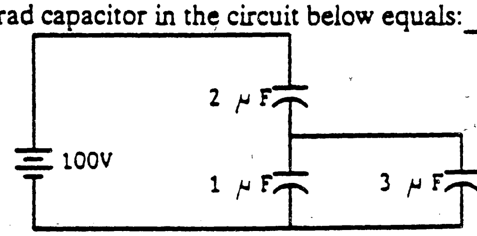
7-The value of the total capacitance of the following circuit is:__________

a) 1 μ farad
b) 2 μ farad
c) 4 μ farad
d) 400 μ farad



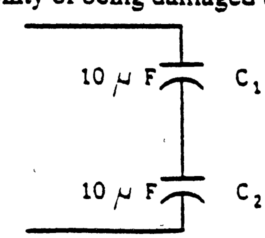
8-The voltage across the 3 microfarad capacitor in the circuit below equals:______

a) 33.33 volts
b) 50 volts
c) 66.67 volts
d) 100 volts



9-Two capacitors (cf. circuit below) are connected in series and C_1 has a leakage resistance R_{leak} = 10 kM ohms and C_2 has a leakage resistance R^1_{leak} = 20kM ohms. Which capacitor is most likely to be damaged by excessive voltage? (assume both have the same working voltage rating)

a) C_1
b) C_2
c) Neither, both will have the same probability of being damaged by excessive voltage.



10-How much current flows when 3 millicoulombs move past a point in a circuit in 430 microseconds?______

a) 6.98 milliamps
b) 6.977 amps
c) .6977 amps
d) 6.98 μ amps

11-How much time is required to deposit 18 coulombs if 20 milliamps flows?_________

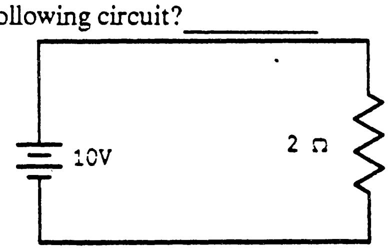
a) 900 seconds
b) .9 seconds
c) 1.11 milliseconds
d) 360 milliseconds

12-What is the conductance of a 47 K ohm resistor?_____

a) 21.277 $\mu\,\Omega$
b) 2 1277 μ Siemens
c) 21.277 μ Siemens
d) 21.277 Ω

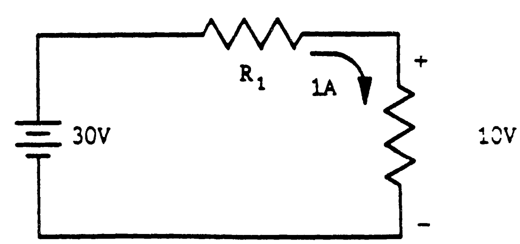
13-What is the value of the current in the following circuit?_________

a) 20 A
b) 5 A
c) 2 A
d) .2 A



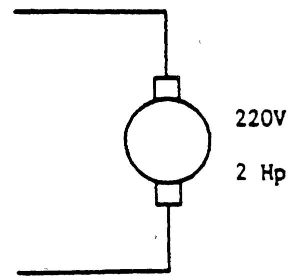
14-The value of R_1 is:____________

a) 1 Ω
b) 20 Ω
c) 10 Ω
d) 30 Ω



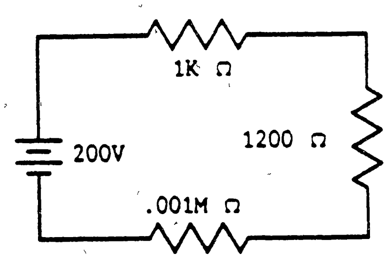
15-The value of P_t is·________________

a) 110 watts
b) 440 watts
c) 1492 watts
d) 746 watts



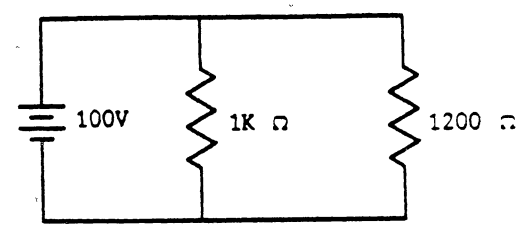
16-The value of R_t is:________________

a) 32 kΩ
b) 2 201 kΩ
c) 2.2 kΩ
d) 3 2 kΩ



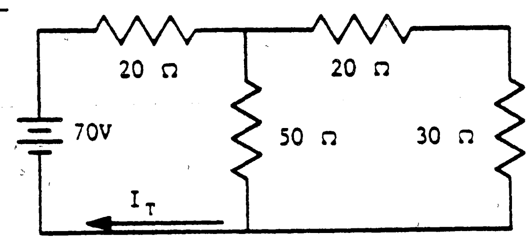
17-The value of R_t is·________________

a) 748 Ω
b) 2200 Ω
c) 545 Ω
d) 220 Ω



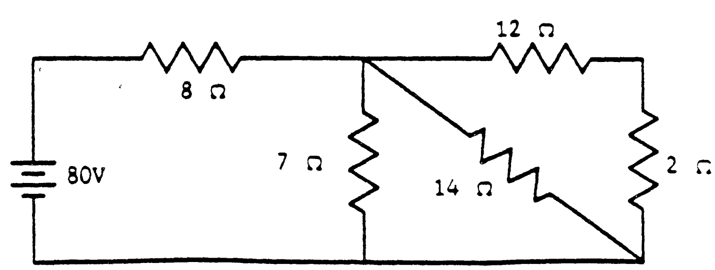
18-The value of I_t is.________________

a) 6.429 A
b) 1.556 A
c) 1556 A
d) 6429 A



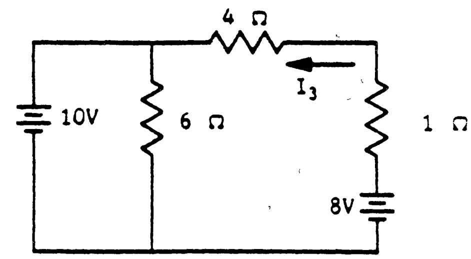
19-The value of R_t is:________________

a) 19 5 Ω
b) 43 Ω
c) 35 Ω
d) 11 5 Ω



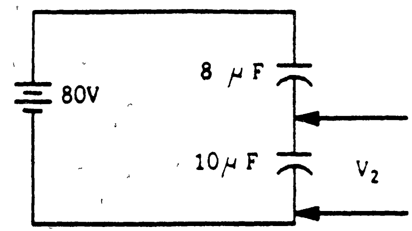
20-The value of I_3 is:________________

a) .4 A
b) 1.667 A
c) -1.6 A
d) -1 667 A
e) 8 A



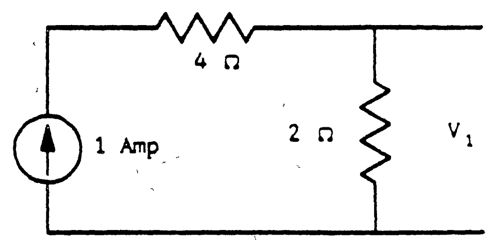
21-The value of V_2 is:________________

a) 35 56 V
b) 800 V
c) 80 V
d) 44 44 V
e) 100 V



22-The value of V_1 is ________________

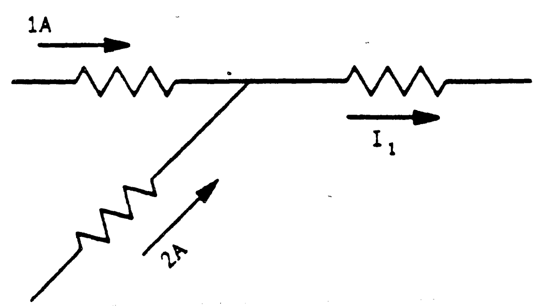
a) 20 V
b) 4 V
c) 6 V
d) 2 V



V_1

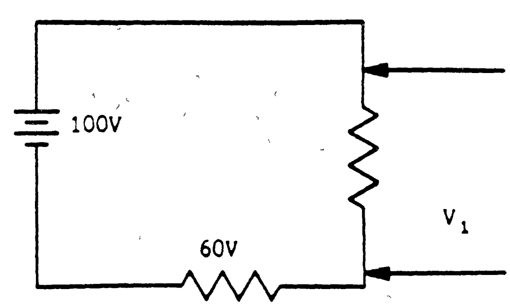
23-The value of I_1 is ________________

a) 2 A
b) 3 A
c) 1 A
d) -3 A



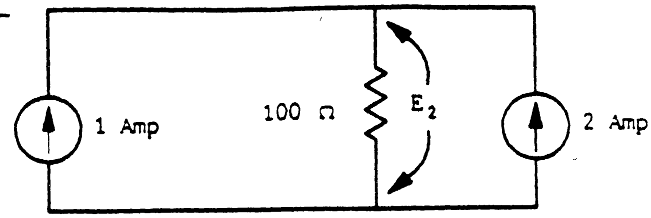
24-The value of V_1 is:________________

a) 100 V
b) 50 V
c) 40 V
d) 60 V



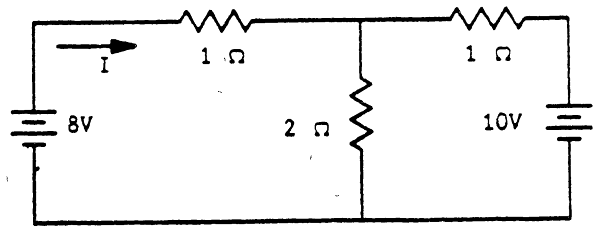
25-The value of E_2 is:______________

a) 0 V
b) 100 V
c) 200 V
d) 300 V



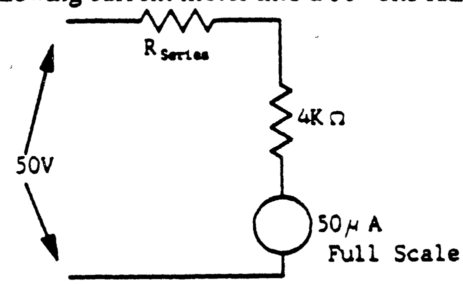
26-The value of I is:______________

a) 1.25 A
b) .8 A
c) 9 A
d) 18 A
e) 2.8 A



27-What series resistor is required to make the following current meter into a 50 volts full scale voltmeter?________

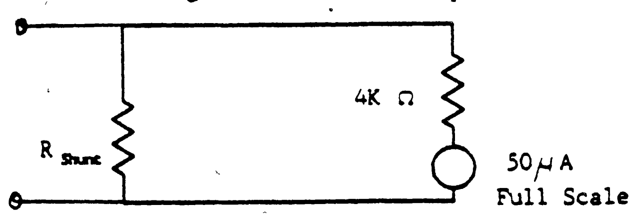
a) 20 k Ω
b) 1000 k Ω
c) 996 k Ω
d) 1004 k Ω



28-What shunt resistor is required to make the following meter read 1 milliamp full scale?

____

a) 200 Ω
b) 4 k Ω
c) cannot be done
d) 210.52 Ω

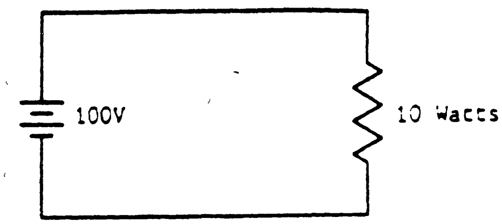


29-Two charges Q_1 = 4 millicoulombs and Q_2 = 8 millicoulombs are separated by 2 micrometers. What is the force of repulsion between Q_1 and Q_2?____________

a) 7 2 x 10^{28} newtons
b) 7.2 x 10^{10} newtons
c) 7.2 x 10^{16} newtons
d) 73,000 newtons

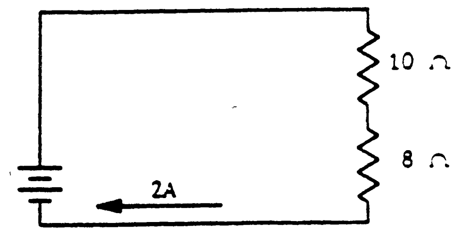
30-What is the value of the current in the following circuit?________________

a) 1 milliamp
b) 10 amps
c) .1 amps
d) 1000 amps
e) 10 milliamps



31-What is the value of the power consumed in the following circuit?____________

a) 13.8 milliwatts
b) 36 volts
c) 36 watts
d) 72 watts
e) 9 watts

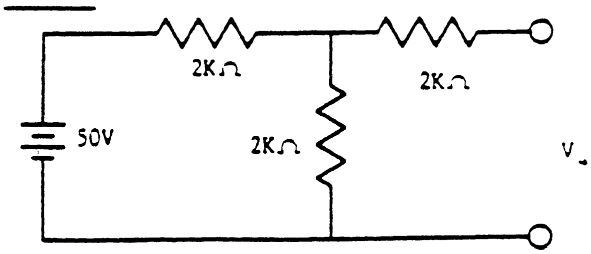


32-What is the cost of operating an electric range which dissipates 15,000 watts if it is used 1 hour/day for a year (365 days)? (Assume electricity costs 5 cents/KWH)__________

a) $365.30
b) $36.53
c) $27.38
d) $273.75
e) $750.00

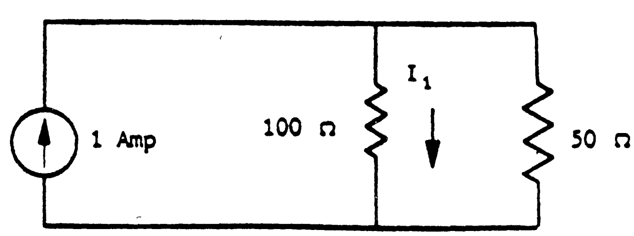
33-What is the value of the voltage V_4?______

a) 16.6 V
b) 0 V
c) 50 V
d) 25 V
e) 12.5 V



34-The value of the current I_1 is:

a) 333 Amps
b) 667 Amps
c) 1 Amp
d) 6.67 milliamps
e) 3.33 milliamps



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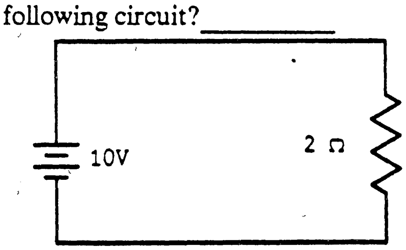

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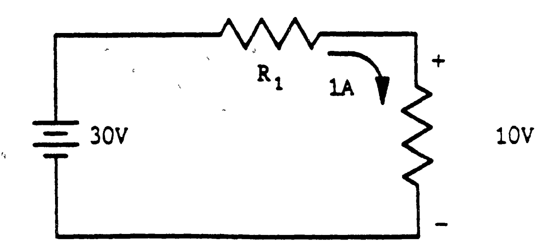

May 1972-June 1973; Instructor, Electronics Engineering Technology Department, Rose State College, Midwest City, Oklahoma January 1980-present.