

## Electric Circuits via the Internet: Sharing and Extending

Robert (Bob) M. Anderson Jr., Eric A Cheek, Sr.  
Iowa State University/North Carolina A & T State University

### Abstract

In fall 1997, Iowa State University (ISU) began to create instructional material on introductory electric circuits for delivery and administration using Mallard®. This effort has continued to this day; four semesters of experience will be available by June 1999.

In fall 1998, ISU shared its instructional material with North Carolina A & T (NCAT) and made the ISU web server available to NCAT faculty and students. Additionally, engineers at Hewlett-Packard facilities in Fort Collins and Colorado Springs, Colorado have begun a "formal audit" of this instructional material. The National Technological University will offer this course during the summer 1999.

The purposes of this paper are:

1. To share the lessons learned, over four semesters, during the development, delivery (to on-campus and off-campus students) and administration of instruction via Mallard® and the Internet. Such lessons include: those associated with the development of Mallard® problems, legal issues, student reactions, *etc.*
2. To share the lessons learned during our sharing of instructional materials and web server with faculty and students at another university. Such lessons include start-up challenges, remote access, required collaboration, *etc.*
3. To invite others to collaborate in the development and use of introductory electric circuits instruction via Mallard® and the Internet. We offer to share the body of material that has been developed to date.

### I. Introduction and Background

Today, most of the state-of-the-art discussion about delivering and administering instruction via the Internet is found under the broad heading of asynchronous learning networks (ALN)<sup>1,2,3</sup>.

Over the spring and summer of 1997, Bob Anderson and an *ad hoc* group of Iowa State University (ISU) faculty and staff reviewed a dozen, or more, software systems available for computer based instruction via the Internet. He selected Mallard®<sup>4</sup> as the system to use to support his teaching of the introductory electric circuits course at ISU.

This choice was made primarily because Mallard® offers the capability to have random numbers in the problems that are to be solved by the students. Thus, each student generally has a different set of parameter values in each circuit problem. With this situation, we encourage students to help each other with their homework; the help is focused on how to solve the problem rather than on copying the numerical answer from one student to another.

Additional useful features of Mallard® include automatic and instantaneous grading, due dates,

flexible grading schemes, ability to upload exam/lab/etc. student grades, secure access of individual students to their grades only and to class averages/standard deviations/etc., as the instructor may decide.

To illustrate Mallard® features from a student perspective, several screen shots of a typical Mallard problem are included below.

In Figure 1, we see that Mallard® is accessible using a standard web browser. The access is secured using an assigned login name and password together with 128-bit encryption of the communications between the user and the web server. We have chosen to allow our students to submit their solutions to each problem 10 times with no penalty. The 11<sup>th</sup> try is penalized 10%, the 12<sup>th</sup> 20%, etc. Solutions are due at a time and date that the instructor sets; we have chosen to assess a 20% per day penalty for late submissions.

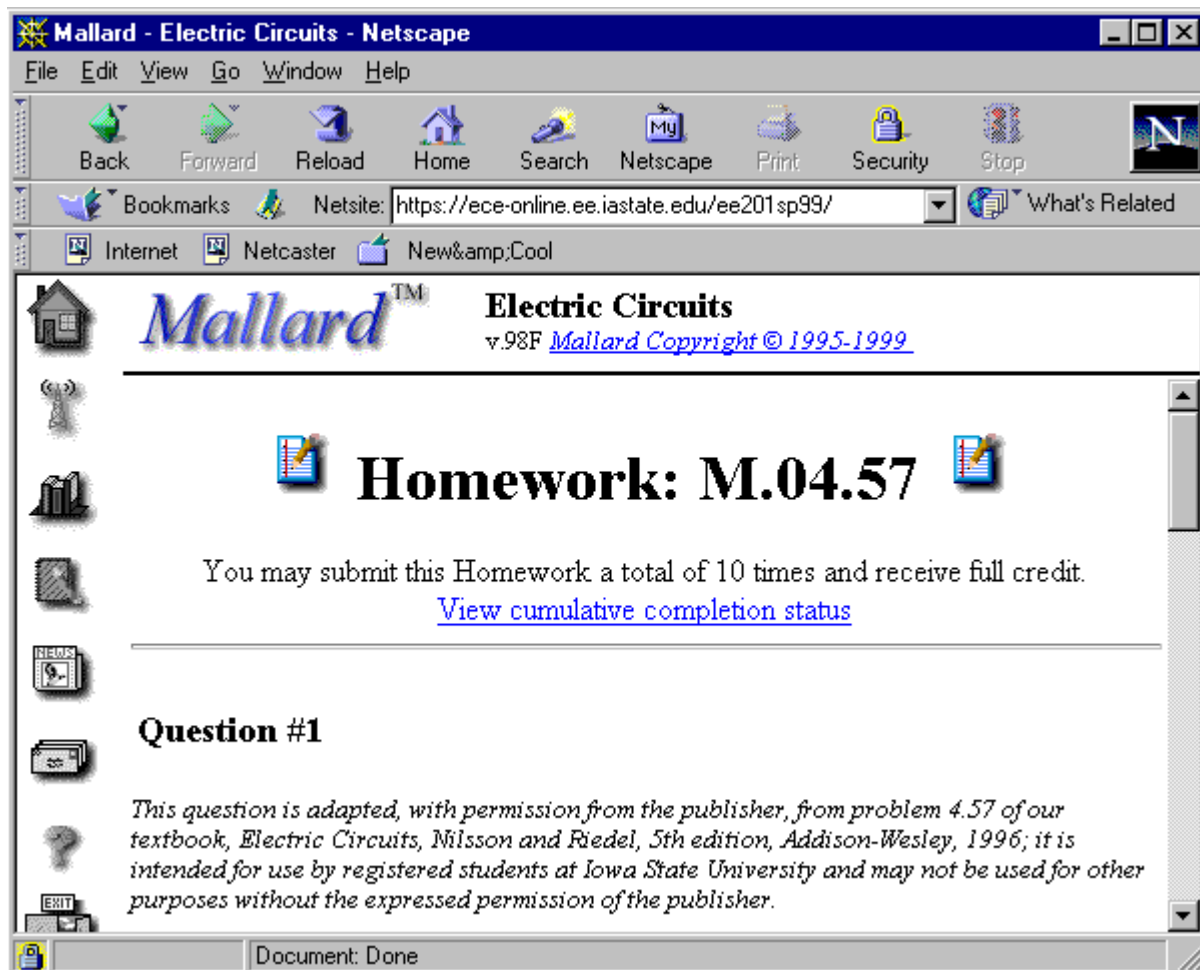


Figure 1 Screen Shot Top of Typical Problem (M.04.57)

Also shown above is the "permission statement" that Addison-Wesley and we have agreed that we would include. Note however, that Addison-Wesley has given us permission to share these Mallard® coded versions of problems from their text with specific other faculty at specific other universities.

We have adopted a convention in which circuit parameters are specified symbolically in the schematic; then, circuit parameters that are "fixed" are given above the schematic and circuit parameters whose values are "random" are given below the schematic. See Figure 2 for the "fixed parameter" values and the schematic.

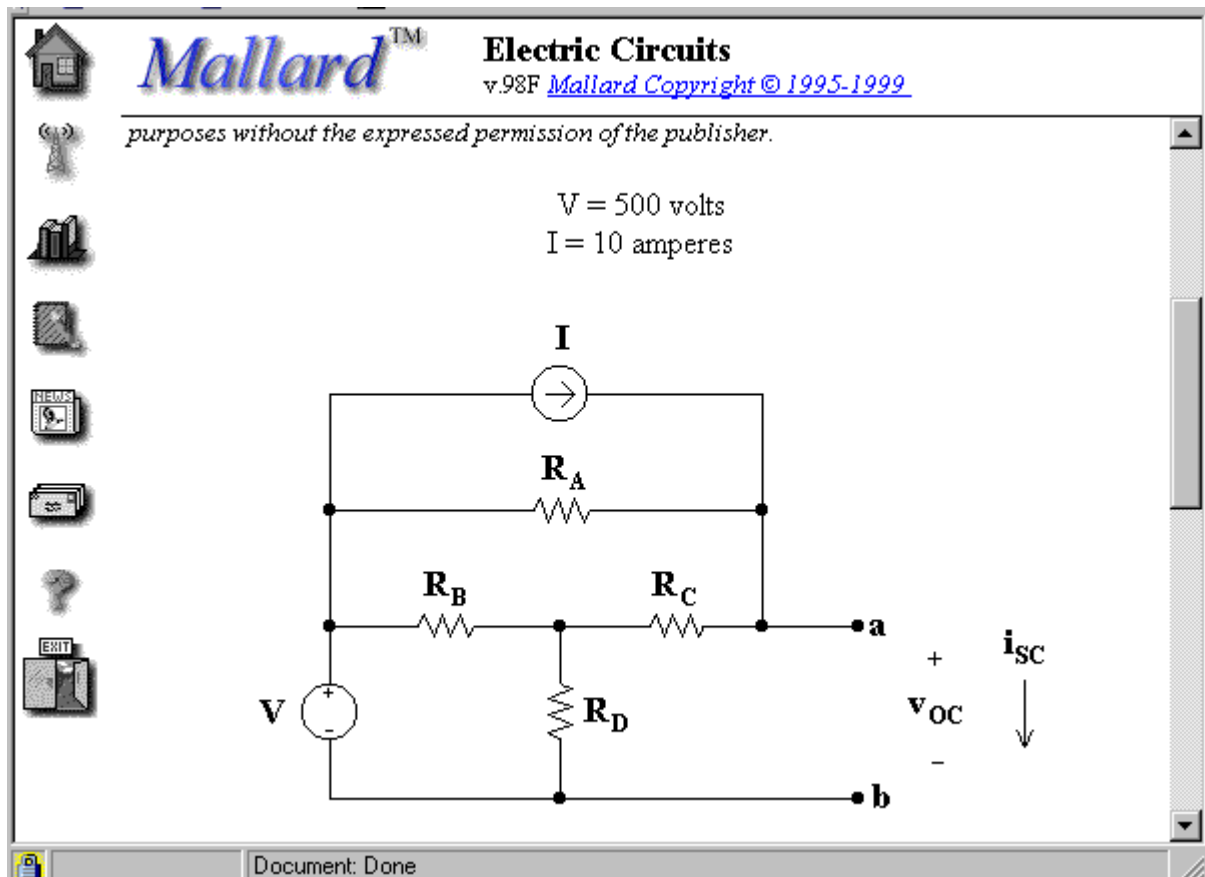


Figure 2 Screen Shot Showing "Fixed" Circuit Parameters and the Schematic

Figure 3 shows the "random values" of the remaining circuit parameters and the first two of four questions that we have posed in this problem.

**Mallard<sup>TM</sup> Electric Circuits**  
v.98F [Mallard Copyright © 1995-1999](#)

Circuit Diagram: A voltage source  $V$  is connected in series with a resistor  $R_D$ . The circuit is open at terminals  $b$ . The open circuit voltage is labeled  $v_{OC}$ .

Random Values:

- $R_A = 35$  ohms
- $R_B = 20$  ohms
- $R_C = 11$  ohms
- $R_D = 22$  ohms

Questions:

1. Find the short circuit current,  $i_{SC}$ .  
 amperes.
2. Find the open circuit voltage,  $v_{OC}$ .  
 volts.

Document: Done

Figure 3 Screen Shot Showing "Random Value" Circuit Parameters and Two Questions

Figure 4 shows all four questions we have asked in this problem and the link for the students to submit their solutions for Mallard® grading.

The screenshot shows a software window titled "Mallard™ Electric Circuits". The window has a menu bar with icons for Home, Help, and Exit. The main area contains four numbered questions, each with a text input field and a unit label. A "Submit for Grading" button is at the bottom. The footer includes copyright information for Mallard and Iowa State University.

**Mallard™ Electric Circuits**  
v.98F [Mallard Copyright © 1995-1999](#)

1. Find the short circuit current,  $i_{SC}$ .  
 amperes.
2. Find the open circuit voltage,  $v_{OC}$ .  
 volts.
3. Find the Thevenin resistance with respect to the terminals a and b.  
 ohms.
4. Find the Thevenin voltage with respect to the terminals a and b.  
 volts.

[Mallard Copyright © 1995-1999](#)  
Course Material Copyright 1997, 1998, 1999 Iowa State University

Document: Done

Figure 4 Screen Shot Showing All the Questions of Typical Problem

Figure 5 shows the response from Mallard® after the student has submitted his/her answers. Correct and incorrect answers are marked appropriately. As instructors, we have the opportunity to provide some suggestions when incorrect answers are submitted; we have chosen to not use this opportunity.

Also shown below is the notation that correct answers are within +/- 2% of the answer that Mallard® computes using about 20 significant figures. The allowable tolerance for "correct" answers is one of the variables that is set in the coding of each question within the problem.

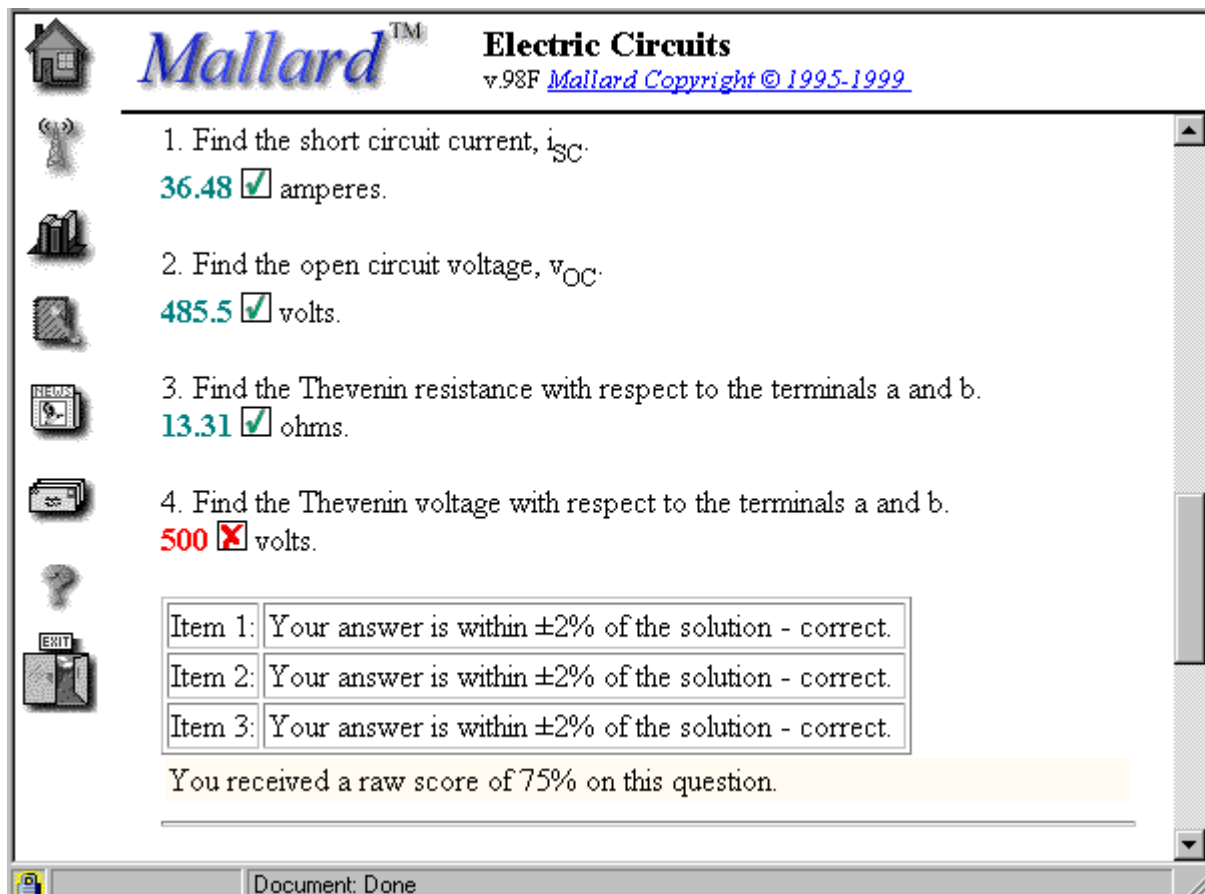


Figure 5 Screen Shot Showing Mallard Grading of Typical Problem

Figure 6 shows the grading summary for this typical problem. The raw score is shown, the extent of late penalties (with a link to get an explanation of such penalties), the adjusted score, the minimum allowed passing score (a parameter instructors set for each class of problems created in Mallard®), and finally the grade that Mallard® has recorded for the student for this problem.

The screenshot shows a web browser window with the title "Electric Circuits" and version "v.98F". The main heading is "Homework Grade Summary". A table displays the following data:

Raw score	75%
Penalties:	<a href="#">explain</a>
Late (30 days)	-100%
Adjusted score	0%
Minimum passing score	0%
Grade for this submission	0%
<b>Cumulative Grade</b>	<b>0%</b>

Below the table is a "NEW Quiz" button. The footer includes "Mallard Copyright © 1995-1999" and a status bar showing "Document: Done".

Figure 6 Screen Shot Showing Mallard Grading Summary of Typical Problem

If the student wishes to correct the mistake made on part four of this problem, we have set the Mallard® parameters for this class of problem to allow students to use the "back" button of the browser to return to the problem statement with previously submitted answers, and, most importantly, with the same values for the random values within the problem. Thus, students can correct their mistake(s) and resubmit with minimum effort. If the student wishes to have a new set of random values for the circuit parameters, he/she can use the "NEW Quiz" link shown at the bottom of the graded page.

The Mallard® code for this problem is included in this manuscript as Appendix A.

In fall 1997, Bob Anderson began teaching the introductory electric circuits course using Mallard® to deliver and administer the homework; he has continued to teach this course and to use Mallard® each semester since then. After two semesters, he reported<sup>5</sup> on his initial experience. By June 1999, he will have four semesters of experience. To see the entire introductory circuits course from the perspective of a student, point your browser to <https://ece-online.ee.iastate.edu/ee201sp99/> then for the requested login, use student and for the requested password, use student.

In fall 1998, Bob began a collaboration with Eric Cheek. Bob set up an electric circuits course on the ISU Mallard® server for Eric's use; Bob copied about 180 Mallard® electric circuits problems from his template course to Eric's Mallard® course. During fall 1998, Eric made doing the Mallard® problems an optional portion of his course. As one would expect, after the initial excitement wore off, most of his students stopped doing the Mallard® problems. Toward the end of the semester, Eric increased his emphasis on Mallard® homework and most of his students began to these problems. When final course grades were determined a clear collation between high course grade and effort on Mallard® homework was evident. Eric now has a Mallard® license for one of his servers for use during the spring 1999.

Additionally, in fall 1998, seven (7) engineers at a Hewlett-Packard (HP) facility in Fort Collins, CO officially began auditing a special version of this course and will finish in June 1999. In spring 1999, four (4) other HP engineers at a Colorado Springs, CO facility began to audit a copy of the other HP version of the course; they will finish in December 1999.

Finally, in spring 1999, Bob set created a Mallard® electric circuits course on the ISU Mallard® server for use by Professor Jennifer Ross of the University of the Pacific. Jennifer has about 10 students in her course; Mallard® homework is required and we hope to be able to report on her experience as a part of our oral presentation.

## II. Lessons Learned

### A. Development of Instructional Materials

When we began to develop homework problems at ISU in the fall 1997, our Mallard® staff consisted of a server administrator (a "techie" to handle all aspects of the Unix server, *per se*), a professor (Bob Anderson), an instructor (graduate student), and 4 undergraduate students. Initially, Bob and the instructor created new problems and the undergraduates coded them into Mallard.

We quickly learned that it was more difficult than we had thought it would be to create and to code problems that were "perfect." The slightest error in coding would cause Mallard® to tell the student that his/her answer was incorrect when in reality the student's solution was correct. Hence significant effort was required to quality assure and to quality control the development of the Mallard® problems. Since time was (and is always) a scarce commodity, we asked the publisher of our text, Electric Circuits 5<sup>th</sup> edition, Nilsson & Riedel, Addison Wesley, 1996, for permission to adapt problems from the text into Mallard®. Permission was granted and about 150 problems (of the total of about 180 problems) have been adapted from the fifth and fourth editions of Nilsson and Riedel.



To begin with a problem from a text, for which a solution is available, to adapt the problem by introducing random variables for some of the parameters of the problem, to create the schematic image, to code the problem, and to verify that the computer generated solution is valid under all allowed values of the random variables, usually requires about five (5) person-hours of a skilled Mallard® programmer. At this point, we have a "perfect" Problem that can be assigned as homework to the students.

After a "perfect" problem is developed, then "hints" are added to the problem that enable the student to display the correct answer to each part of the problem. We call this version of the problem a "Drill Problem." Problems that are not assigned as homework are made available to the students as drill problems. The effort required to add the "hints" is modest; perhaps 15 to 30 minutes per problem on average. By June 1999, we will have the drill problem versions available for all problems.

Finally, after a perfect problem is developed, then comments, equations, etc., are added to the problem code to create a "Solution" of the problem. Nominally about one (1) hour per problem is required by the professor to transform a Problem into a Solution. Solutions to homework Problems can be made available after the homework due date and/or solutions to problems not assigned as homework can be made available as tutorial material. By June 1999, we expect to have solutions available for the majority (but probably not all) of the problems. Use of these solutions will be restricted to off-campus students. Our view is that off-campus students are geographically disperse and thus, it is unlikely that a student "file" of Mallard® homework solutions will be developed that future students could access.

Thus, by June 1999, we expect to have available about 180 perfect problems, with the corresponding 180 drill problem version and about 150 solutions in the Mallard® electric circuits template course. Then for each individual offering of electric circuits a new Mallard® course is created and all problems, drill problems, and solutions are copied to the new course. The instructor then has only to select which problems will be assigned as homework, which will be used as drill problems and which solutions he/she will make available to students.

## B. Legal Issues

Mallard® must be licensed from the University of Illinois. The annual license fee is a function of the maximum number of users registered to use Mallard® course work during the year. ISU has a license for an unlimited number of users on a single server (the fee for this license is \$1,000 per year).

If problems are adapted from material that is copyrighted, formal permission to do must be received. Each of the problems that we have adapted from Addison Wesley material contains a "permission" statement at the top of the problem.

Addison Wesley has given us permission to share these adapted problems for use at other universities.

We have copyrighted all our Mallard® materials in the name of Iowa State University; however, we have freely granted permission for others to use the materials that we have developed.

Perhaps it is significant to note that Professor Hans Kuehl at the University of Southern California is adapting electric circuit problems from a Prentice Hall text by Thomas and Rosa; but, Prentice Hall has refused to grant Professor Kuehl permission to share any of these materials with others<sup>6</sup>.

### C. Student Reactions

At the end of each semester, the Mallard® students at ISU have completed an evaluation of Mallard® delivered and administered homework.

Invariably, students like 1)our homework policy of allowing ten tries on each problem without penalty, 2)the instant grading, 3)ability to rework homework problems with different numbers as a review for examinations, and 4)access to all their course grades.

Student dislikes have shifted from semester to semester. Generally, students are very unforgiving if any problem is found to have a coding error or to be ambiguously worded. Students also dislike waiting for more than a few seconds for the server to respond. Some students object to being graded on being able to get the correct answer only; *i.e.*, not receiving points for using a correct method of solution. Finally, the occasional student (even in electrical and computer engineering) doesn't like working with/on a computer and wants to do everything with paper and pencil.

One of the evaluation items is "I think that Mallard® should be continued and expanded to other courses in the ECpE Department." Students are asked to respond to this item using the standard "Strongly Agree," "Agree," "Neutral," "Disagree," "Strongly Disagree." Using five points for "Strongly Agree," the table below gives the number of students responding, the percentage of "Strongly Agree" and of "Strongly Disagree" and the numerical score for each of the three semesters complete as of this writing.

Semester	Number Responding	"Strongly Agree"	"Strongly Disagree"	Score/5.0
Fall 1997	56	30.3%	12.5%	3.68/5.0
Spring 1998	37	45.9%	5.4%	4.08/5.0
Fall 1998	51	23.5%	7.8%	3.75/5.0

### III. Sharing Instructional Development and Instructional Materials

To date, the great bulk of the instructional materials available among the collaborators has been developed at ISU. Nevertheless, we remain optimistic about the future of sharing the effort required to develop Mallard® instructional materials.

By June 1999, we will have invested almost a man-year of effort in the development of about 180 problems, the associated drill problems, and the solutions to these problems in introductory electric circuits. In spring 1999 we are beginning the effort to develop Mallard® problems in the second course of our introductory sequence, circuits and systems.

If ALN approaches are to be used more pervasively throughout higher education, then, we must find ways to spread the development effort across multiple creators. Only in this way, can we avoid adding to the real cost of adopting this new instructional delivery and administration method.

The alternative to shared development of ALN instructional materials is for such materials to be developed in a proprietary fashion where access to them is strictly on the basis of a fee. Invariably any such fee would be passed directly to the student(s).

#### IV. Invitation to Join in Creating and Sharing Electric Circuits Mallard® Based Materials

Eric and Bob invite any and all others who are interested in joining in the development of Mallard® based problems and other instructional materials in electric circuits. We are eager to form a consortium of colleagues around the country that will share in the development and use of these materials.

Ultimately, we believe that we can document that student learning is increased through the use of such Mallard® instructional materials.

Ultimately, we are convinced that remote student access to high quality instruction in electric circuits will be dramatically increased when more perfect Mallard® instructional materials are developed and become available for broad use.

#### Appendix A Mallard Code for Typical Problem M-04-57

```
<question>
<i>
<font size=-1>
This question is adapted, with permission from the
publisher, from problem 4.57 of our textbook, Electric
Circuits, Nilsson and Riedel, 5th edition, Addison-Wesley,
1996; it is intended for use by registered students at Iowa
State University and may not be used for other purposes
without the expressed permission of the publisher.
</font>
</i>
<p>

<center>
V = 500 volts
<br>
I = 10 amperes
<br>

<br>
```

$R_A = \langle \text{random name=Ra type=int range=20-40} \rangle \text{ ohms}$   
 $R_B = \langle \text{random name=Rb type=int range=4-20} \rangle \text{ ohms}$   
 $R_C = \langle \text{random name=Rc type=int range=2-15} \rangle \text{ ohms}$   
 $R_D = \langle \text{random name=Rd type=int range=5-25} \rangle \text{ ohms}$

1. Find the short circuit current,  $i_{SC}$ .

$$10 \cdot \left( \frac{R_C \cdot R_B \cdot R_A + 50 \cdot R_B \cdot R_C + 50 \cdot R_C \cdot R_D + 50 \cdot R_B \cdot R_D}{R_A \cdot R_B + R_A \cdot R_C + R_A \cdot R_D + R_B \cdot R_C + R_B \cdot R_D + R_C \cdot R_D} \right)$$

2. Find the open circuit voltage,  $v_{OC}$ .

$$10 \cdot \left( \frac{50 \cdot R_A \cdot R_D + R_B \cdot R_D \cdot (R_A + R_C) + R_B \cdot R_C \cdot (R_A + R_D)}{R_A \cdot R_B + R_A \cdot R_C + R_A \cdot R_D + R_B \cdot R_C + R_B \cdot R_D + R_C \cdot R_D} \right)$$

//</hint>

<p>

3. Find the Thevenin resistance with respect to the terminals a and b.

<br>

<input type=arith tolerance=2%>

</input>

<answer>

<eval name=answer3>

<var name=voc>/<var name=isc>

</eval>

</answer>

ohms.

//<hint height=half width=half>

//The answer is : <var name=answer3> ohms.

//</hint>

<p>

4. Find the Thevenin voltage with respect to the terminals a and b.

<br>

<input type=arith tolerance=2%>

</input>

<answer>

<var name=voc>

</answer>

volts.

//<hint height=half width=half>

//The answer is : <var name=voc> volts.

//</hint>

<p>

</question>

## Bibliography

1. The best reference to learn about asynchronous learning networks is to browse the web of Asynchronous Learning Networks. See: <http://www.aln.org/>

2. For an excellent historical review of using computers to teach electrical circuits, see: B. Oakley, A Virtual Classroom Approach to Learning Circuit Analysis, IEEE Transactions on Education, vol. 39, pp.287-296, 1996.

3. For an excellent review of using ALN techniques in engineering education, see: John R. Bourne, A. J. Brodersen, J. O. Campbell, M. M. Dawant, and R. G. Shiavi, A Model for On-Line Learning Networks in Engineering Education, Journal of Asynchronous Learning Networks, vol. 1, no. 1, pp.72-96, March 1997. Available at [http://www.aln.org/alnweb/journal/jaln\\_Vol1issue1.htm](http://www.aln.org/alnweb/journal/jaln_Vol1issue1.htm)

4. Mallard® is a registered trademark of the University of Illinois. Mallard® was developed by Professor Donna Brown and her associates in the Department of Electrical and Computer Engineering at Urbana IL; it is in widespread use at the University of Illinois and increasingly at other universities. For additional information, see: <http://www.cen.uiuc.edu/Mallard/>

5. Robert "Bob" M. Anderson, Jr., A First ALN Experience: Issues, Lessons, and Emotions, Session 2432, Proceedings for the Annual Conference and Exposition, American Society for Engineering Education, June 28-July 1, 1998.

6. Private Communication, Hans Kuehl, Dec. 18, 1998.

**ROBERT (BOB) M. ANDERSON, JR.**

Bob Anderson is a Professor of Electrical and Computer Engineering at Iowa State University. He has been the Vice Provost for Extension at ISU, the Manager of Corporate Technical Education for the General Electric Company, the Ball Professor of Engineering, Director of Continuing Engineering Education, Professor, Associate Professor, and Assistant Professor of Electrical Engineering at Purdue University. He is a PE in Indiana, and has all his degrees from the University of Michigan (Ph.D. 1967, MS-Physics 1965, MSEE 1963, BSEE 1961).

**ERIC A. CHEEK SR.**

Eric Cheek is an Associate Dean in the College of Engineering and an Adjunct Associate Professor of Electrical Engineering at North Carolina A&T State University, Greensboro, NC. He is active in the ASEE and is a regular contributor to the Annual Conference