# Interactive Homework Problems for the Internet

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## Introduction

The Electric Circuits Workout (ECW) is a computer tool designed to aid in both teaching and learning about electric circuits. The ECW consists of HTML documents containing Java applets and so is ideally suited to the Internet.

 The Electric Circuits Workout provides students an opportunity to develop and practice circuit analysis skills. It does so by presenting exercises similar to quiz or exam problems. The Electric Circuits Workout poses a problem, then accepts and checks the user's answer. Students are provided with immediate feedback regarding the correctness of their work. Student learning is further supported by extensive help, in the form of worked example problems, available from within the Electric Circuits Workout. The Electric Circuits Workout chooses parameter values somewhat randomly and so provides a seemingly endless supply of problems. This pairing of a solution to a particular problem with an endless supply of similar problems is an important feature of the Electric Circuits Workout. Providing both a detailed solution to a problem and an opportunity to practice similar problems is an effective way to help students learn about electric circuits.

The Electric Circuits Workout has been class tested for several years. This paper presents the lessons learned from that testing.

## Some History

The objective of the Electric Circuits Workout is to provide a set of homework problems that are graded automatically and immediately. The Electric Circuits Workout is a modern version of an earlier program called the Linear Circuits Tutor [2]. The Linear Circuits Tutor also provided automatically graded homework problems, but, being 15 years old, has a user interface that seems clumsy when compared to modern programs.

Modern computer languages, like Java, provide the tools required to build a Graphical User Interface (GUI). The Electric Circuits Workout uses a GUI to present a homework problem that is interactive. Each problem consists of an interactive picture and a question. The picture provides the circuit diagrams, plots, tables of data and equations required to pose the problem. The user interacts with the picture using the computer keyboard or mouse. Figure 1 shows the user interface of the Electric Circuit Workout. The plot and equations shown in Figure 1 are features of the Electric Circuit Workout that were not available in the Linear Circuits Tutor.

The author's experience using the Linear Circuits Tutor guided design of the Electric Circuits Workout. In particular, the pop-up calculator and the "Show Answer" feature respond to student comments regarding the perceived shortcomings of the Linear Circuits Tutor. Similarly, the help screens were added in response to student comments regarding an early version of the Electric Circuits Workout.

Electric Circuits Workout is posted on the Internet [4]. Both the Linear Circuits Tutor and the Electric Circuits Workout were the subjects of the "Personal Computer Programs for Electrical Engineering" column in the "IEEE Circuits and Devices Magazine [2,3]. The ECW was originally part of a larger package, The Electronic Teaching Assistant (ETA). The ETA was described previously [1]. The ETA is published with a textbook about electric circuits [5]. Numerous examples from the Electric Circuits Workout are incorporated into that text. The ECW has been the most popular part of the ETA and has grown while other parts of the ETA have not. The ECW now dominates the ETA.
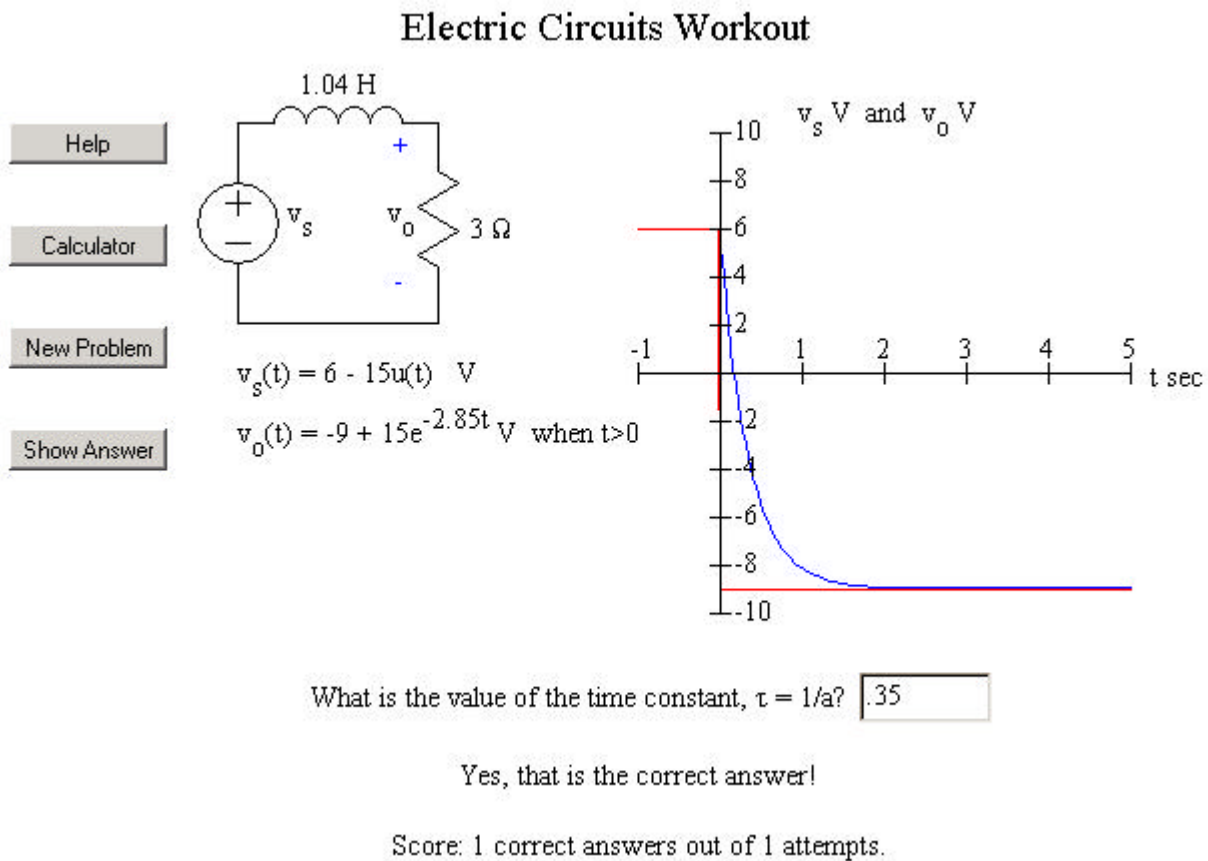
## Electric Circuits Workout

$v_s(t) = 6 - 15u(t)$ V

$v_o(t) = -9 + 15e^{-2.85t}$ V when t>0

What is the value of the time constant, $\tau = 1/a$? .35

Yes, that is the correct answer!

Score: 1 correct answers out of 1 attempts.

**Figure 1** A screen from the Electric Circuits Workout

**Helping Students**

The Electric Circuits Workout poses a problem, then accepts and checks the user's answer. In order for such a program to be useful to students it must accomplish three things. It must be accurate, it must provide adequate feedback and it must pose the right problems.

First, consider accuracy. It would be hard to over emphasize the importance of accuracy. Inaccurate feedback is worse than no feedback at all. Students need to know that the Electric Circuits Workout is correct when it says that an answer is wrong. It is very frustrating for students to search for an error in their work when there is no error. On the other hand, the program reinforces misconceptions if it accepts wrong answers as being correct. Obviously, careful testing is required to insure that the feedback provided by the Electric Circuits Workout is accurate. Yet, as more and more problems are added to the Electric Circuits Workout it becomes more likely that an error will occur. The author has found it helpful to tell students when a new module is introduced so that an error in that module will not cause students to loose confidence in the entire Electric Circuits Workout.

Next, consider providing adequate feedback. The Electric Circuits Workout provides feedback by accepting and checking the user's answer. In the Electric Circuits Workout, an answer is the value of a single real number. That real number could represent the value of a particular voltage or current or resistance, the amplitude of a sinusoid, the time constant of a first order circuit or a particular coefficient in a partial fraction expansion. The feedback provided by the Electric Circuits Workout indicates only whether an answer is correct or not. This feedback is adequate for problems solved by writing and solving a single equation.  If the answer is wrong, the student knows where to look for the error. Longer problems, those requiring a series of calculations, require more feedback. To provide additional feedback, the Electric Circuits Workout presents longer problems as a series of steps, with feedback provided at each step. Figure 2 provides an example. In this example, students are led through a series of three steps, shown in parts *a*, *b* and *c* of Figure 2.  In each step the Electric Circuits Workout poses a problem, checks the answer and provides feedback. Further, the correct answer from the previous step is incorporated into the problem statement of the next step. Once again, enough feedback is provided so that if an answer is wrong, the student knows where to look for the error.

Finally, consider the issue of posing the "right problems". The "right problems" are problems that are similar to those problems that will be used to evaluate student performance. That is, the "right problems" are problems that could be quiz or exam problems. Those are the problems that students want to practice. Two things have been done to insure that the Electric Circuits Workout poses the "right problems".
- The problems have been selected to be typical of the problems posed by popular textbooks for introductory courses on electric circuits [5, 6, 7]. Hopefully, if the problems generated by the ECW are similar to textbook problems they will also be similar to exam problems.
- An instructor's version of the Electric Circuits Workout is provided to make it easy to "cut and paste" problems from the Electric Circuits Workout into Word documents for quizzes and exams. ECW problems are more likely to be exam problems if there is a convenient way for instructors to put them into exams.
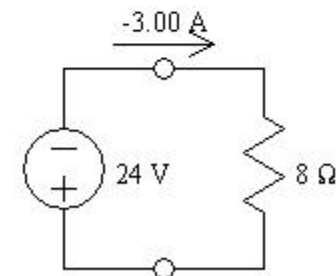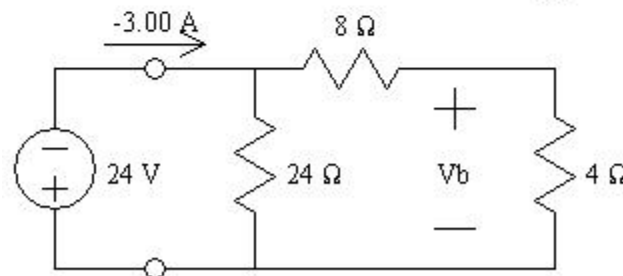
These two circuits are equivalent.
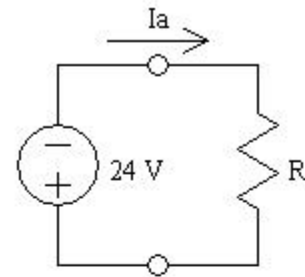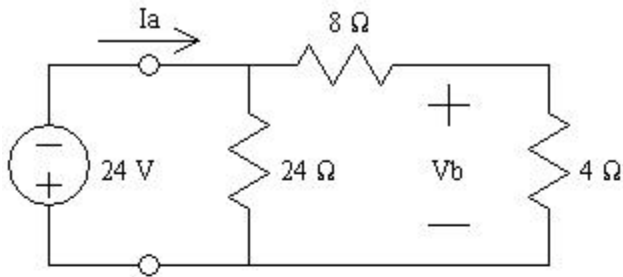


What is the value of the resistance R in Ω? ☐

*(a)*
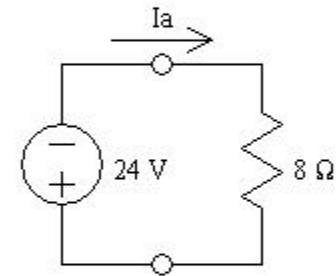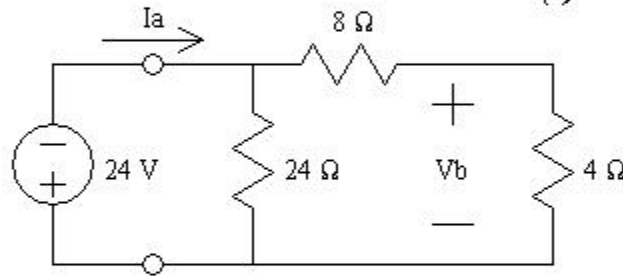


What is the value of the current, Ia, in A? ☐

*(b)*



What is the value of the voltage, Vb, in V? ☐

*(c)*

**Figure 2** These three screens from the Electric Circuits Workout present a problem in three steps, *(a)*, *(b)* and *(c)*, in order to provide adequate feedback to students.

**Helping Instructors**

The Electric Circuits Workout saves instructor's time by helping to prepare and/or grade homework, quizzes and exams.

The Electric Circuits Workout provides a set of homework problems, with solutions, that don't need to be graded, because the Electric Circuits Workout checks the student's answer. The Electric Circuits Workout includes problems sets on a variety of topics that span a typical two-semester sequence of courses in introductory electric circuits. The ECW has problem sets on the following topics.

1. Ohm's and Kirchhoff's Laws: Simple Circuits
2. Ohm's and Kirchhoff's Laws: Circuits with Dependent Sources
3. Voltage and Current Division, Series and Parallel Resistors
4. Equivalent Resistance
5. Equivalent Circuits
6. Mesh and Node Equations: Simple Circuits
7. Mesh and Node Equations: More Complex Circuits
8. Mesh and Node Equations: Circuits with Dependent Sources
9. Superposition
10. Thevenin and Norton Equivalent Circuits
11. Op Amp Circuits: Inverting and Noninverting Amplifiers
12. Op Amp Circuits: Node Equations
13. Capacitors and Inductors
14. Complete Response of Simple 1st Order Circuits
15. Complete Response of 1st Order Circuits
16. Voltage Division for AC Circuits
17. KCL and KVL for AC Circuits
18. AC Power
19. Frequency Response: Simple Circuits
20. Frequency Response: Circuits with Dependent Sources
21. Frequency Response: Circuits with Op Amps
22. Partial Fraction Expansion
23. Step and Impulse Response: Simple Circuits
24. Step and Impulse Response: Circuits with Op Amps

Each of these problem sets contains 8-12 different problems with variations of those problems due to random selection of circuit parameters. (In some cases the random variations change more than values. For example, reference direction of voltage and current sources and the location of the dots for coupled coils are selected randomly.) That's a lot of problems. For the last two years, the author has used the ECW as the primary source of problems for a two-semester sequence of courses on introductory electric circuits. There has been no shortage of problems.

Today's students expect that solutions to some, or all, homework problems will be provided as study aids. Providing such solutions incurs the risk that less sophisticated students will confuse being able to read the solutions with being able to do the problems. The ECW provides very

detailed solutions to problems that are slightly different than those that students are being asked to solve. To get the solution of the assigned problem, students must work through to example solution, changing the numbers as necessary. This requires a more active reading than would be needed if students were provided solutions to the assigned problems.

The Instructor's version of the Electric Circuits Workout makes it easy to include problems from the ECW in quiz or exams. The error checking built into the Electric Circuits Workout reduces the error checking needed to write the exam. Further, the Electric Circuits Workout will produce several versions of a problem, each with different parameter values, and each with the correct answer. This feature saves a lot of time when multiple versions of an exam must be prepared. Students appreciate the fairness of incorporating problems into exams that are similar to the problems that they have practiced.

The Electric Circuits Workout has also been used to collect grades remotely using the Internet [1]. Remote grading requires a java servlet to receive and record the grades and also a modified applet that can send grades to the servlet. The servlet and modified applet were successfully used to collect grades for a single quiz in a class of 250 students.

## Conclusion

The Electric Circuits Workout (ECW) is a computer tool designed to aid in both teaching and learning about electric circuits. The Electric Circuits Workout provides students an opportunity to develop and practice circuit analysis skills. It does so by presenting exercises similar to quiz or exam problems. The Electric Circuits Workout poses a problem, then accepts and checks the user's answer. Students are provided with immediate feedback regarding the correctness of their work.

References

[1] Svoboda, J.A. "Teaching Electric Circuits via the Internet", 2001 ASEE Annual Conference Proceedings.

[2] Huelsman, L.P. Personal Computer Programs for Electrical Engineering. *IEEE Circuits and Devices Magazine*. vol. 6, no. 1, pp.3-6, January 1990.

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