Online Interactive Multimedia for Engineering Thermodynamics

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Abstract

This paper describes the development, implementation, and functionality of an interactive multimedia, online eBook designed to enhance the learning experience of students studying basic concepts in engineering thermodynamics. The eBook is case-based and covers the same material addressed in a typical engineering thermodynamics textbook. It is comprised of 42 case problems. Each case covers a specific concept in engineering thermodynamics and is presented in four parts: Case Introduction, Theory, Case Solution, and Simulation. The first three parts introduce a case to students, present required concepts to solve the case problem, and apply the concepts to solve the case problem. Graphics, diagrams, animations, sounds, and hypertext are used to present these materials in a rich interactive and dynamic method. The fourth part provides an opportunity for students to experience a simulation by modifying parameters of the case problem. The eBook is published through the Internet at www.eCourses.ou.edu and any instructor or engineering student can access the material without cost or conditions. The content can be used as a stand-alone tool for distance learning, a supplementary material for traditional classes, or a just-in-time learning tool for those who want to review a specific topic in engineering thermodynamics.

Introduction

Many topics in engineering are abstract and difficult to visualize. Generally, with traditional paper-based classes, concepts are taught by developing abstract mathematical models and fundamental physical principles with just 2D graphics and text, and then employing them to solve practical problems. This kind of teaching module can result in a situation where engineering students sometimes learn theory that they cannot transfer to real situations, or have experiences that they cannot explain with the knowledge they have already obtained. With advancements in multimedia technology, educators can improve the quality of engineering education with integrated media with 3D graphics, video, diagrams, sounds, animations and hypertext.

The basic concepts of engineering thermodynamics have not changed significantly for decades, and engineering thermodynamics is still a fundamental course for all engineering students. In recent years, efforts have been expended to develop and utilize multimedia in teaching engineering thermodynamics. Cobourn and Lindauer[1] at the University of Louisville present a

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thermodynamics course on the web using a slide-show format. Ngo and Lai [2][3][4] at the University of Oklahoma have also built modules for teaching specific topics in engineering thermodynamics. Their modules, which are lecture-based, contain lecture notes, interactive simulations, animations, examples, and workshops for thermodynamic property tables. There are other thermodynamic materials published on the web, but most only cover part of the basic concepts using only text, equations, and diagrams. For example, Frank L. Lambert at Emeritus Occidental College [5] published some ancient questions about "things going wrong" in daily lives due to violating the second law. Taftan Data [6] presents basic concepts such as heat, work, and system, and gives brief definitions about laws of thermodynamics and specific processes.

Multimedia Engineering Thermodynamics is one of the Multimedia eCourses developed in the Engineering Media Lab (EML) at the University of Oklahoma. Multimedia Engineering Statics[7] and Multimedia Engineering Dynamics[8] have been used for a number of years, and three other eBooks for Multimedia Engineering Fluid Mechanics, Multimedia Engineering Mechanics, and Multimedia Engineering Mathematics are under development.

In a recent study, St. Clair and Baker [9] compared 10 different software programs and course modules delivering content in Statics such as Multimedia Engineering Statics and MDSolids. They found Multimedia Engineering Statics was the only program that fulfills the major requirements outlined by instructors and supported by learning theory, and it was chosen for use in a number of classes at Georgia Tech as supplementary instructional material. The Multimedia Engineering Thermodynamics has the same structure as Multimedia Engineering Statics. Both use real-world cases to introduce theory, guide students to solve the real-world case, and invoke students thinking with simulations.

This paper describes the development, implementation, and functionality of the interactive multimedia eBook designed to enhance the learning experience of students in studying basic concepts in engineering thermodynamics. The eBook is available at www.eCourses.ou.edu at no charge for both faculty and engineering students. It can be used as a stand-alone tool for distance learning, supplementary material for traditional classes, or a just-in-time learning tool for those who wants to review a specific topic in engineering thermodynamics. In addition to standard text and graphics, the eBook uses the Macromedia Shockwave plug-in for both Flash animations and Director simulations. These plug-ins are widely used and can easily be downloaded for free through the Internet.

Overview

The Multimedia Engineering Thermodynamics eBook is case-based, and covers the same material addressed in a typical undergraduate engineering thermodynamics textbook (Figure 1). It is comprised of 42 topics, and grouped into 10 sections as listed in Table 1. Each topic covers a specific concept, and is presented in four parts: Case Introduction, Theory, Case Solution, and Simulation. The first three parts introduce a case to the student, present required concepts to solve the case problem, and apply the concepts to solve the case problem. Graphics, diagrams, animations, sounds, and hypertext are used to present the materials in a rich interactive and dynamic method. The fourth part provides the opportunity for student to modify various parameters of the case with a computer simulation.

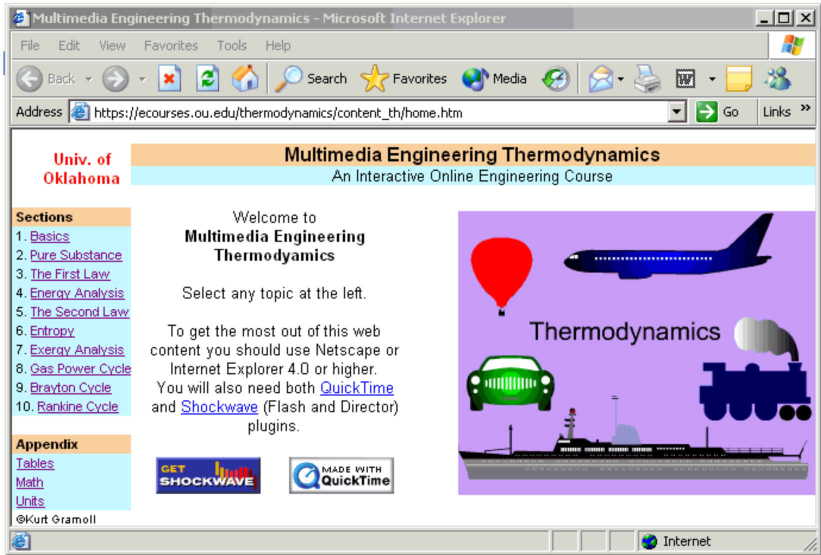

Figure 1. Main page of the thermodynamics eBook

Table 1. Thermodynamics eBook content

Section 1 Basics	Section 2 Pure Substance
1. System, State, Process and Cycle	1. Phase and Phase Change Property
2. Pressure, Temperature and the Zeroth Law of Thermodynamics	2. Diagrams for Phase-change Processes
3. Heat and Work	3. Property Tables
4. Energy	4. Ideal Gas
Section 3 The First Law	**Section 4 Energy Analysis**
1. Conservation of Mass	1. Steady-flow Process
2. Conservation of Energy	2. Nozzles, Diffusers, and Throttling Devices
3. Energy Analysis of Solids and Liquids	3. Turbines, Compressors, and Mixing Chambers
4. Energy Analysis of Ideal Gas	4. Heat Exchangers, Pipe and Duct Flow
Section 5 The Second Law	**Section 6 Entropy**
1. Heat Engine	1. Entropy
2. The Second Law	2. Tds Relations
3. The Carnot Cycle	3. Entropy Change
4. Carnot Heat Engine	4. Isentropic Process
5. Carnot Refrigerator and Heat Pump	5. Isentropic Efficiency
	6. Entropy Balance
	7. Entropy Balance for Control Volume
	8. Reversible Steady-flow Work
Section 7 Exergy Analysis	**Section 8 Gas Power Cycle**
1. Exergy	1. Otto Cycle
2. Exergy Transfer and Exergy Change	2. Diesel Cycle
3. Exergy Balance(1): Closed System	
4. Exergy Balance(2): Control Volume	
Section 9 Brayton Cycle	**Section 10 Rankine Cycle**
1. Brayton Cycle	1. Rankine Cycle
2. Brayton Cycle with Intercooling, Reheating	2. Rankine Cycle with Reheating
	3. Regeneration Rankine Cycle
	4. Rankine Cycle with Cogeneration

Multimedia Formats Used

Movies, diagrams, graphics, and tables play an important role in this eBook to help visualize and simplify abstract thermodynamics concepts such as enthalpy, entropy, or exergy, which are hard to understand by students.

(a) Movies

Movies are used throughout this eBook to present a case study, to explain the procedure of a case solving method, to demonstrate how a device works, to teach how to use a thermodynamic property table, to supplement a theory, to visualize a concept, and to illustrate a certain thermodynamic process. Figure 2 shows examples of animations, which include, cooling a computer by a fan, entropy increase when boiling eggs, hydroelectric turbine operations, use of tables to find water properties, supplementing the energy balance theory, visualizing a closed system, and illustrating the reversible isothermal expansion process of the Carnot Cycle. All movies and animations were created using Macromedia Flash and they include sound narrations. Using Flash helped in keeping all movies small (most less than 100 kilobytes, including narration). Another advantage of Flash is all movies are resizable without losing resolution. This is useful when the student or instructor needs to zoom in to view a particular detail. The Macromedia Shockwave plug-in is required to view the Flash movies but it is pre-installed with Windows Internet Explorer or can be downloaded through the Internet for free if needed.

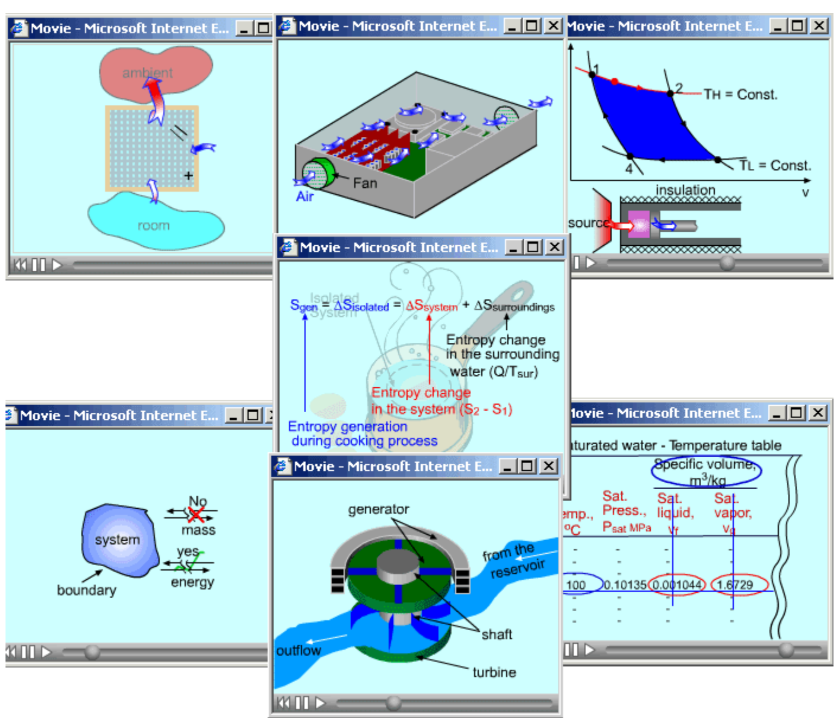

Figure 2. Examples of movies and animations in the eBook

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(b) Diagrams and Graphics

In addition to animations and movies, diagrams and graphics are excellent tools to help illustrate the technical concepts. Figure 3 shows examples of diagrams and graphics used in the eBook. Examples include, visual definition of convection, solar pond case, and a hydroelectric power plant. All the diagrams and some of the graphics are constructed using Macromedia Freehand, which is a vector-based drawing tool. In some cases, graphics from clip-art collections [10] were used and edited with Adobe Photoshop.

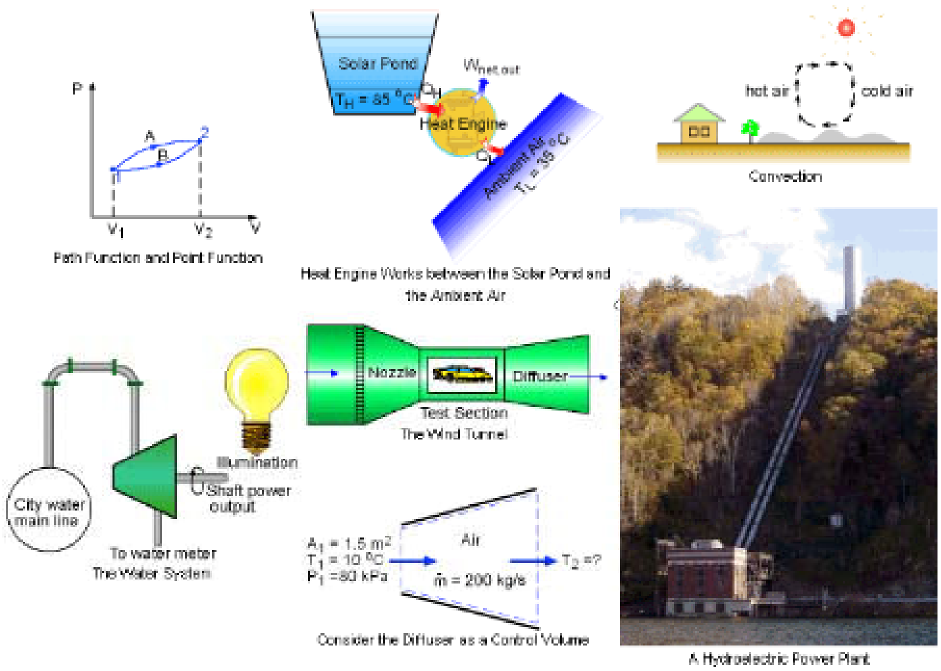

Figure 3. A collection of diagrams and graphics

(c) Tables

In the study of engineering thermodynamics, finding thermodynamic properties from tables is an essential skill that students need to acquire. In the eBook, students can access tables with links to the table where they are introduced or used. Movies, which demonstrate how to use these tables, are provided. Figure 4 shows a typical interface of the property tables. All tables are also available in the appendix of the eBook and students can access them directly from the main menu.

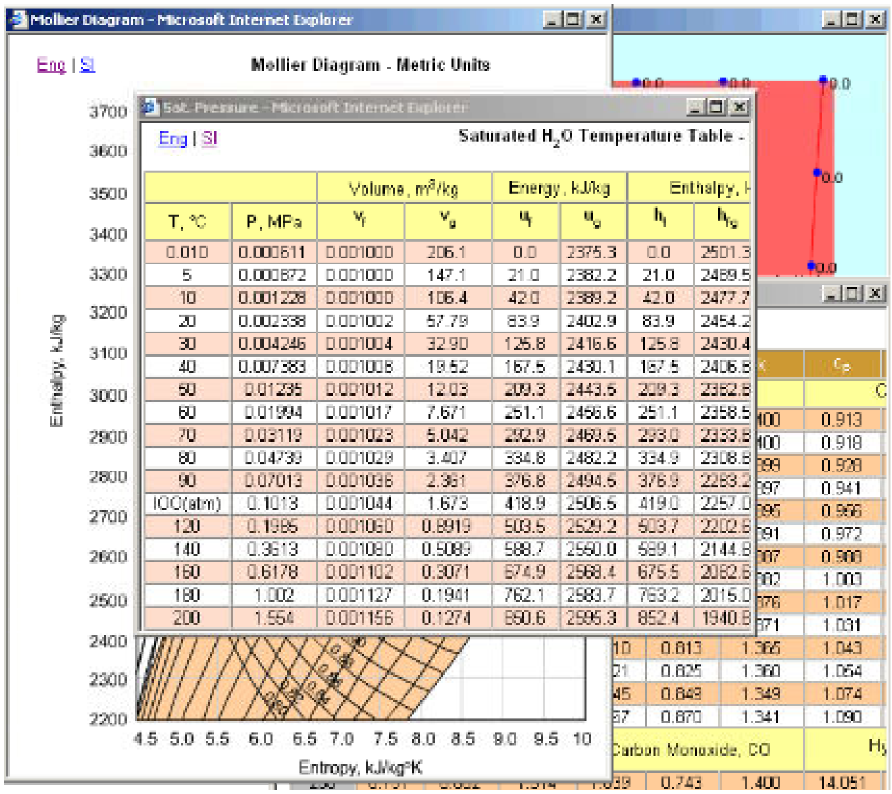

Figure 4. A collection of tables and diagrams for thermodynamic properties

Presentation of a Typical Case

Each case problem is designed to cover one particular concept in engineering thermodynamics. It is split into four parts: Case Introduction, Theory, Case Solution and Simulation. The first three pages are presented in a rich multimedia format with the use of hypertext, diagrams, graphics, animations, equations, and sounds. The interface provides navigation buttons, which allow the students to access each of the four pages at any time.

(a) Case Introduction

In the introduction page, a selected case is presented. Students are required to answer the stated questions but an approach to solve the problem is also given, as shown in Figure 5 for the "Hydroelectric Power Plant" case. This case states that a hydroelectric power plant is planned to be constructed in a mountainous region. A designer has ordered several 0.5-m-diameter-pipes but needs the engineer to specify the exact number of intake pipes. To help the student start solving the case, it is suggested that reversible steady-flow work approach be used. Two movies are available to help introduce the case including one movie to present the problem and another one to demonstrate how hydroelectric turbine generates power. Two graphics are also shown on this page to provide the dimensional information for the case.

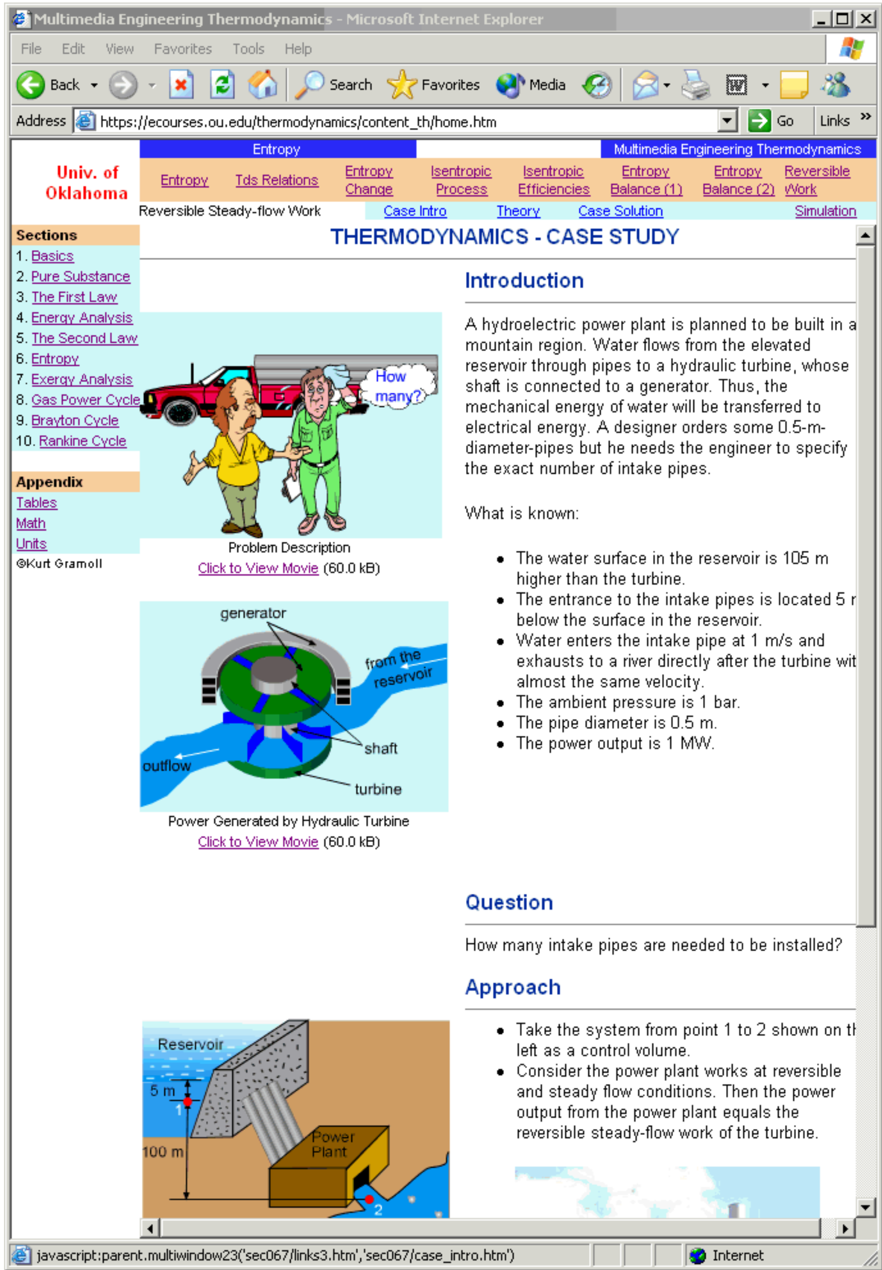

Figure 5. Typical case study interface

(b) Theory

After the case problem is introduced, it is expected that the students will want to review the theory. The theory page gives detail information on reversible steady-flow work, which is required to determine the number of the intake pipes. Similar to the introduction page, hypertext, diagrams, graphics, animations, equations, and narrations are used to introduce the reversible steady-flow work. Examples include a nozzle diagram to show a control volume with one inlet and one exit; a movie of hydroelectric turbine to illustrate the real case which runs in a steady-flow process with incompressible fluid as the working fluid; and another movie of water flowing through pipes helps present the definition of Bernoulli equation (Figure 6). Links are provided throughout the theory page for students to review a particular concept introduced in other topics.

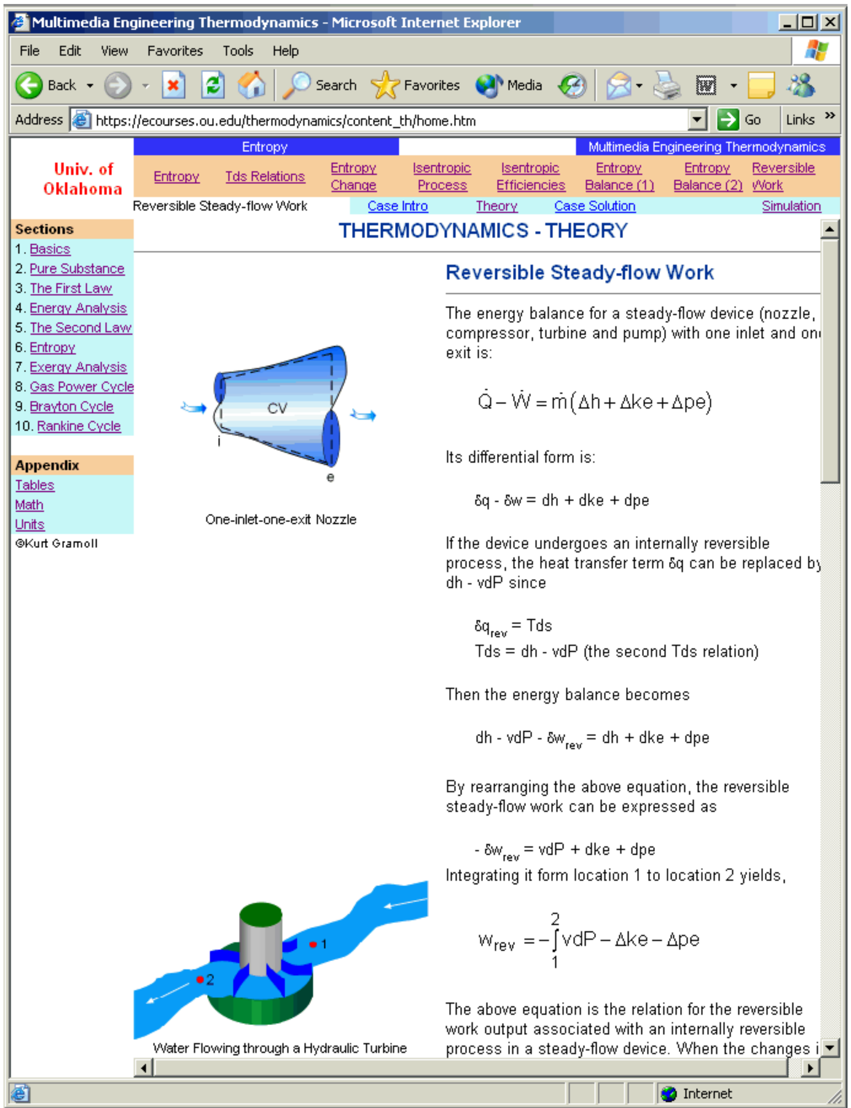

Figure 6. Typical theory interface

(c) Case Solutions

The solution page gives step-by-step solution of case. The solution procedure includes listing assumptions, specifying systems, giving general equations, simplifying the equations according to the assumptions, and substituting given data to yield the results. This procedure can help students understand how to use engineering equations to solve complex real-word problems. Table links, diagrams, and movies are also used to supplement the solution procedures. Figure 7 is the case solution page for the Hydroelectric Power Plant case.

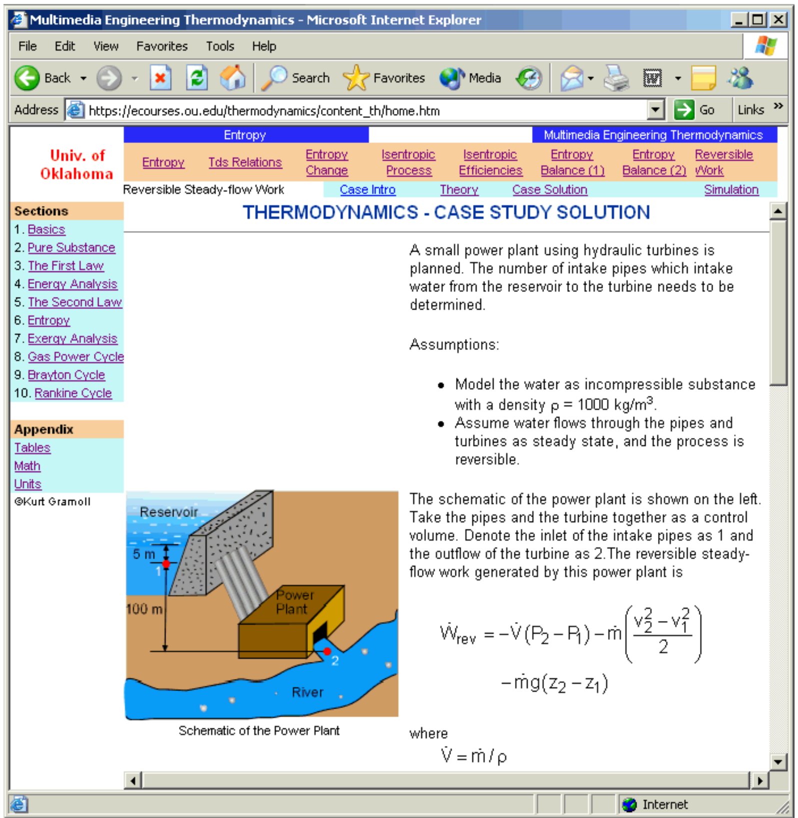

Figure 7. Typical case solution interface

(d) Simulation

The simulation page provides students the opportunity to engage in design-like activities by modifying case parameters. Graphics and diagrams are again used to help visualize what happens when the parameters are changed. In this case, elevation of the pipe inlet, pipe diameter, and power output of this power plant can be changed by moving the sliders as shown in Figure 8. The number of pipes needed to be installed between the water reservoir and the power plant is determined accordingly. Suggested help questions and technical help are provided to help guide the students in using the simulation. Simulations are created in Multimedia Director using the Lingo scripting language. Director is a robust program that allows the development of complex simulations which can be accessed through a web page. The Director Shockwave files are also small which minimizes downloading time (most simulations are less than 100 kilobytes).

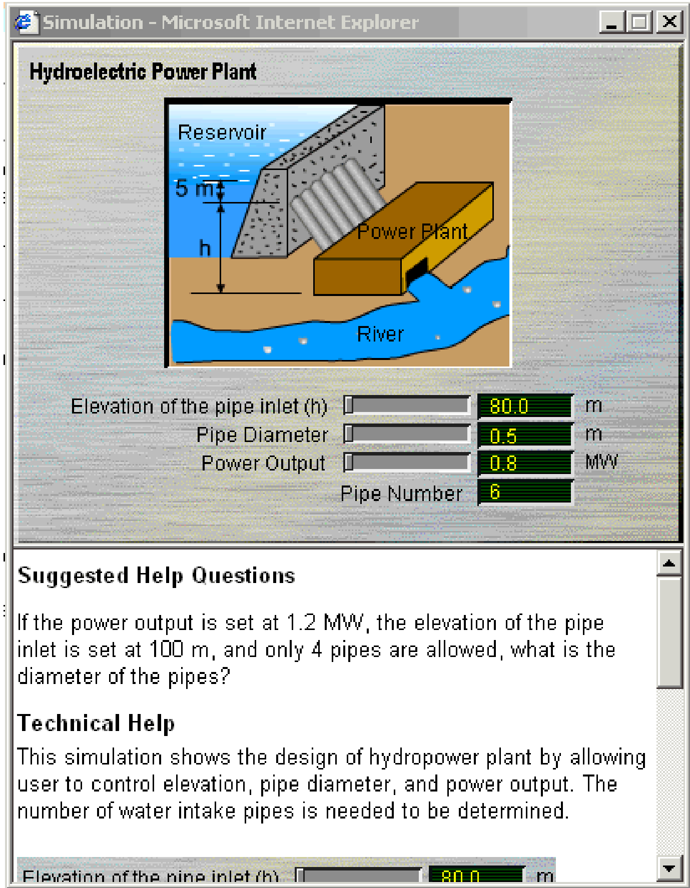

Figure 8. Typical simulation interface

Appendices

There are three appendices, including tables, math and units. The table appendix contains major tables used in engineering thermodynamics such as the water property table, Mollier diagram, and the ideal gas properties table. The math appendix gives a listing of common mathematical equations that are useful for problem solving. The unit appendix lists basic conversion factors between SI and US systems. A unit calculator is also included.

Conclusion

A case-based Multimedia Engineering Thermodynamics eBook has been developed and published through the Internet. A rich multimedia format with the use of hypertext, diagrams, graphics, animations, simulations, and sounds are incorporated in the eBook. The material covers all the major concepts and topics addressed in a typical engineering thermodynamics textbook. It can be used as a stand-alone tool for distance learning, a supplementary material for traditional classes, or a just-in-time learning tool for those who wants to review a specific topic in engineering thermodynamics. The eBook open to anyone on the Internet and only requires Flash and Director Shockwave plug-ins, which can be downloaded for free.

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Biography

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Meirong Huang is currently a doctoral student in the School of Aerospace and Mechanical Engineering at the University of Oklahoma. She received her B.E. degree and a M.E. degree in Heating, Ventilation and Air Conditioning from SWJT University in China (1994, 1997 respectively) and a M.S. degree in Mechanical Engineering from the University of Oklahoma in 2002. She is working on EHD enhanced heat and mass transfer and implementation of multimedia technology in online engineering education. She also has experience on teaching in university, HVAC design, railway tunnel ventilation simulation, and railway tunnels pressure transient computation.

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Kurt Gramoll is the Hughes Centennial Professor of Engineering and Director of the Engineering Media Lab at the University of Oklahoma. He has developed and published CDs and web-based sites for engineering education, K-12 instruction, and industrial training. Dr. Gramoll received his B.S. degree in Civil Engineering and M.S. degree in Mechanical Engineering, both from the University of Utah. He received his Ph.D. in Engineering Science and Mechanics from Virginia Tech. Previously, he has taught at University of Memphis and Georgia Tech.