A Web-based Electronic Book (eBook) for Fluid Mechanics

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Abstract

The use of electronic media has been widely recognized as an effective and efficient tool in delivering course materials. Through electronic media, interactive and visual appealing media such as texts, animations, graphics, simulations and sounds can be incorporated in the illustrations of engineering theories and concepts. The motivation of developing such media is to promote students' interest in engineering education and perhaps has a great impact on the quality of education. This paper presents an eBook in fluid mechanics delivered via the web (www.eCourses.ou.edu). This eBook is intended to cover materials for a typical introductory fluid mechanics course. It can be used as a stand-alone tool for distance learning or as a supplementary material for traditional classes. In addition, this eBook is designed and developed such that it could be a just-in-time learning tool for students and engineers who would like to learn or review a specific topic in fluid mechanics. The implementation of such an eBook in course delivery is particularly convenient for students at the University of Oklahoma since all engineering students have laptop computers with wireless network connections.

This eBook consists of 38 modules with each module further divided into 4 parts: case introduction, theory, case solution and simulation. A concerted effort has been invested in relating the theory to real world engineering applications through the case studies. Applications from different disciplines (e.g., daily experiences, mechanical and civil engineering applications) are included. The design approach of this eBook is to capture students' interest by first presenting a case study. The theories and concepts necessary for the students to solve the specific case study are then covered, and followed by a complete solution for the case study. A simulation is also included at the end of each module to engage students in constructive learning. The material of this eBook is freely open for any institution or student to use without cost or conditions.

I. Introduction

Electronic media has been widely used in education, particularly in the discipline of engineering where complex and abstract mathematical model or theory can be easily visualized through the use of appealing media such as texts, animations, graphics, simulations and sounds. As such, more educators are now engage and incorporate multimedia in their teaching. Some of the web-based course modules presently available on the web and readily for others to use include prerequisite engineering courses such as Statics[1], Dynamics[2], and Thermodynamics[3-4]. The trend in utilizing interactive and electronic media in presenting fluid mechanics materials has been increasing over the past few years as well. Just to name a few, an interactive CD (*Fluid Mechanics Phenomena*), which contains 75 short movie clips illustrating concepts of fluid mechanics, is supplemented with the distribution of a popular fluid mechanics textbook by Young et al[5]. Other CD-ROM based fluid mechanics textbooks include *Multi-Media Fluid Mechanics* by Homsy et al.[6] and *Fluid Mechanics: An Interactive Text* by Liggett and Caughey[7]. On the other hand, comprehensive web-based modules in the area of fluid mechanics are relatively scarce. In 2001, an NSF-sponsored workshop was held to find ways to improve undergraduate fluid mechanics across the curriculum[8]. One of the discussion topics was the use of multimedia technology to enhance fluid mechanics education. The panel suggested initiating and developing a central web site for fluid mechanics where universities, colleges and industries can all share the resources.

Realizing the need for a comprehensive text for fluid mechanics in electronic form was, in part, the motivation for the current project to develop a web-based Multimedia Engineering Fluid Mechanics eBook (www.eCourses.ou.edu), which is both informative and interactive. The goal is to enhance the learning experience of the student in studying fluid mechanics, and also perhaps attract more students to become enthusiastic in the field of fluid mechanics. To encourage using electronic media, the material of this eBook is freely open for any institution or student to use without cost or conditions through the Internet. This eBook can be used as a stand-alone tool for distance learning or for regular classes in which students are expected to go over and review the materials before class on their own. Instructor can then make better use of the class time to engage students in active learning and address any questions students may have had, and hence promoting interaction and discussion in class. In addition, this eBook is designed and developed such that it could be a just-in-time learning tool for students and engineers who would like to learn or review a specific topic in fluid mechanics. It can also serve as supplementary material to reinforce the lectures taught in traditional classes.

II. An Overview of the Multimedia Fluid Mechanics eBook

Fluid flow phenomenon is encountered frequently in our daily lives, and the study of fluid mechanics is broad, and it involves different engineering disciplines such as the aerospace, biomedical, chemical, civil, environmental, mechanical and petroleum engineering. Hence, a web-based Multimedia Engineering Fluid Mechanics eBook has been developed at the University of Oklahoma to cover fluid mechanics at the introductory level for cross-disciplines, and it is intended to be a shared instructional resource among universities and colleges. The Multimedia Engineering Fluid Mechanics eBook consists of a total of 38 modules with each module divided into 4 different parts: case introduction, theory, case solution and simulation. In each module, the theory part covers a particular topic in fluid mechanics. The modules are grouped into 10 different sections according to the topics, and they are accessible through the menu bar on the left from the main page (Figure 1). In addition, tables for fluid properties, common mathematical formulae and unit conversion tables are included in the appendices. As seen from the main page, all students need to view this eBook is a browser with Shockwave plug-in, which is commonly used and can be downloaded for free through the Internet.

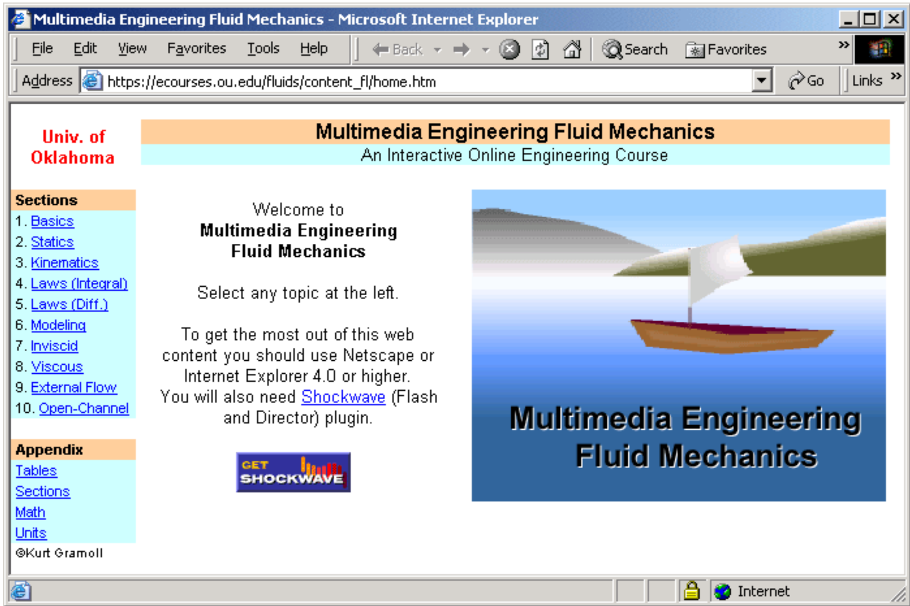

Figure 1. Main page of the Multimedia Engineering Fluid Mechanics eBook

As pointed out by Kulacki et al.[9], the contents of fluid mechanics at the introductory level have not changed for several generations. Therefore, the contents covered in this Multimedia Engineering Fluid Mechanics eBook mimic those of traditional and popular textbooks such as Young et al.[5] and White[10]. The organization of the Multimedia Engineering Fluid Mechanics eBook contents is summarized in Table 1. The emphasis and challenge of the present project is to find ways to present the materials with the aids of multimedia technology. The design approach of this eBook is to capture students' interest by first presenting a case study. The theories and concepts necessary for the students to solve the specific case study are then covered, and followed by a complete solution for the case study. A concerted effort has been invested in finding case studies related to real world engineering applications. This is to ensure that the students are trained to have an intuition on how to tackle real world problems by making adequate assumptions and hence reduce the complexity of the problem. A simulation is also included at the end of each module to engage students in constructive learning.

In a recent study, St. Clair and Baker[11] compared 10 different software programs/course modules delivering the contents in Statics. Based on their assessment report, they concluded that the Multimedia Engineering Statics eBook fulfills majority of the evaluation criteria, and it has been chosen as a supplementary material for several classes offered at Georgia Institute of Technology. The design philosophy of Multimedia Engineering Fluid Mechanics eBook is essentially the same as that of Multimedia Engineering Statics eBook, hence it has most important pedagogical features that an excellent instructional software should possess. Some of the key features of Multimedia Engineering Fluid Mechanics eBook include user-friendly navigation, attractive interface, theory related to real world applications, visual appealing multimedia technology usage, and constructive simulation. Detailed discussion of these features is given in the subsequent section.

Table 1. Contents available in the Multimedia Engineering Fluid Mechanics eBook

Section 1: Basics	***Section 2: Fluid Statics***
• Density • Ideal Gas Law • Viscosity • Surface Tension • Vapor Pressure	• Pressure Variation in a Static Fluid • Pressure Measurement • Hydrostatic Force on a Plane Surface • Hydrostatic Force on a Curved Surface • Buoyancy
Section 3: Fluid Kinematics	***Section 4: Fundamental Laws (Integral)***
• Lagrangian and Eulerian Viewpoint • Steady and Unsteady Flows • Streamlines, Streaklines and Pathlines • Velocity and Acceleration Fields • Irrotational Flow	• Conservation of Mass • Linear Momentum Equation • Moment of Momentum Equation • Conservation of Energy
Section 5: Fundamental Laws (Differential)	***Section 6: Modeling and Similitude***
• Conservation of Mass • Navier-Stokes and Euler's Equations • Conservation of Energy	• Dimensional Analysis (Buckingham Pi Theorem) • Similitude • Common Dimensionless Groups
Section 7: Incompressible and Inviscid Flow	***Section 8: Incompressible and Viscous Flow***
• Bernoulli's Equation • Flow Measurement • Superposition of Flows • Flow around a Circular Cylinder	• Flow between Parallel Plates • Couette Flow • Laminar Flow in Pipe
Section 9: External Flow	***Section 10: Open-Channel Flow***
• Drag • Lift • Boundary Layer Characteristics	• Uniform Flow • Gradually Varied Flow • Rapidly Varied Flow

Based on past experiences, both the Multimedia Engineering Statics and Dynamics eBook have gained favorable responses from the students. The implementation of such an eBook in course delivery is particularly convenient for students at the University of Oklahoma since all engineering students have laptop computers with wireless network connections. Most classrooms, lecture halls, libraries and student union are now equipped with wireless connection, and students can have instant access to the course materials practically from anytime and anywhere on campus.

III. Features of the Multimedia Engineering Fluid Mechanics eBook

In the following sections, some key features of the Multimedia Engineering Fluid Mechanics eBook are described and demonstrated in details.

(a) Case Introduction

At the beginning of each module, a case study is first introduced and presented to the students.

The case studies selected are closely related to real world engineering applications, and they are from different disciplines (e.g., daily experiences, mechanical and civil engineering applications). Assumptions needed to solve the case study are clearly stated as they serve as a hint to the students on setting up the problem. For example, Figure 2 shows a case study for the "Conservation of Energy (Integral Analysis)" module. The case study chosen for this particular module is related to hydroelectric power where students are required to determine the power generated by a turbine.

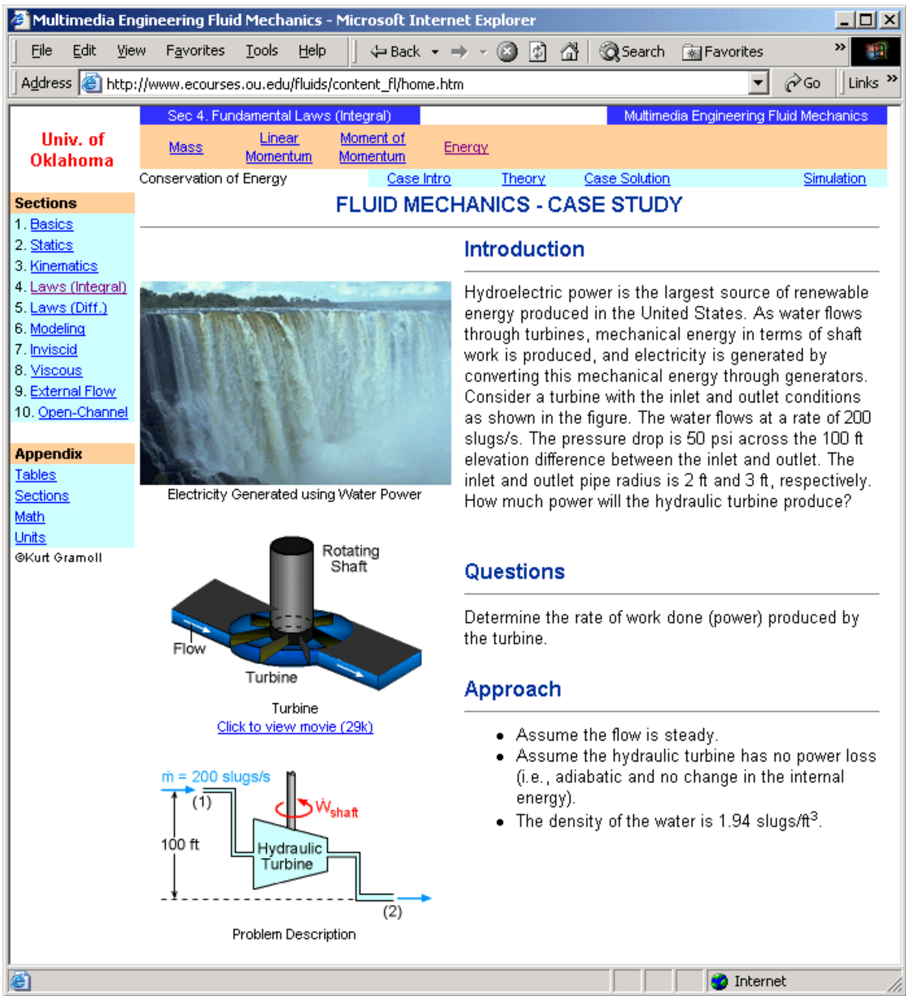

Figure 2. A typical case study interface

<u>(b) Theory</u>

After introducing the case study, the theory required for solving the case study is presented. The theory part has extensive use of the interactive media such as texts, graphics, sounds, and animations for illustration purposes. This is extremely beneficial to engineering education as complex models and abstract concepts or theories can be illustrated easily using these better visualization techniques. Figure 3 shows a typical theory page. Flow past a fixed circular cylinder is the topic of discussion in this particular module. As seen in the figure, texts, diagrams, pictures, animations and equations are all incorporated to illustrate the theory. Although each module of this eBook is written and developed as a stand-alone module, links are provided to direct students to a particular module of the eBook if they choose to review a certain topic. The materials covered in the theory section are kept in a concise and simple fashion, and detailed derivations of equations/theorem are often omitted.

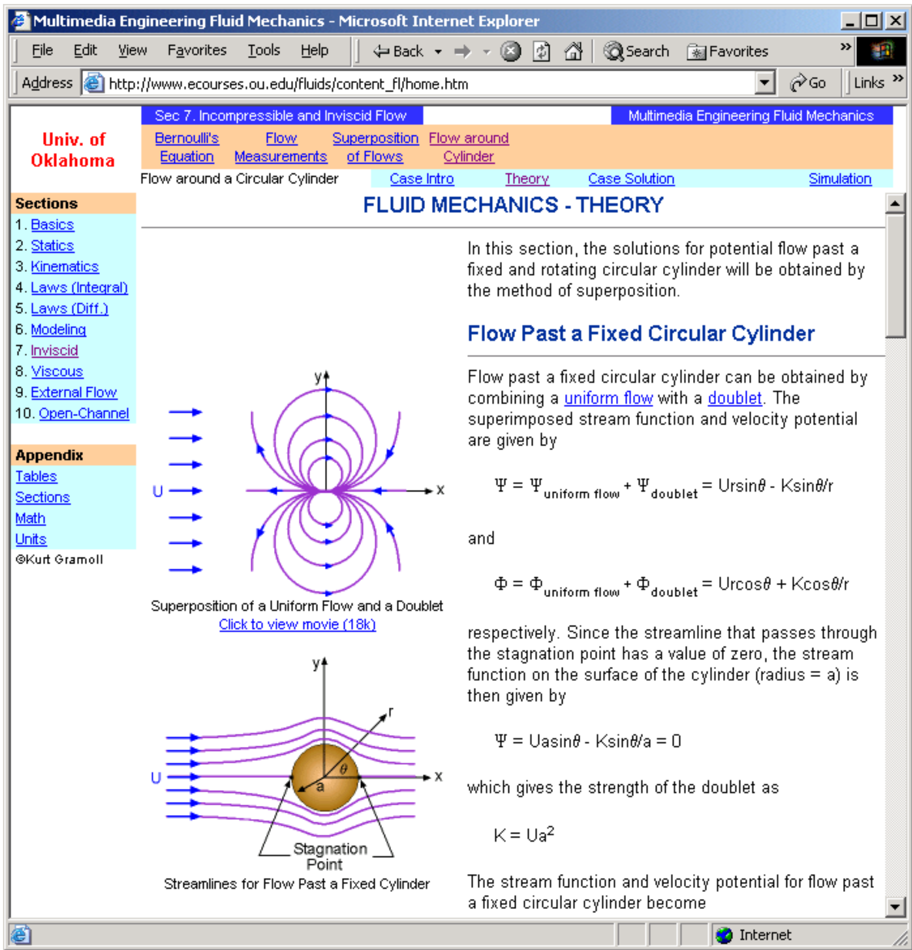

Figure 3. A typical theory interface

Animations are used throughout the eBook to help presenting a case study or illustrate a certain concept. Take the animations as shown in Figure 4 for example. Animations are used to present case studies of oil leakage from a piston-cylinder assembly and cavitation in pipe and pump. Also, fluid mechanics concepts such as the gas constant, kinetic and potential energy as well as turbulent flow can be illustrated with the aid of animation. All movies and animations included in the eBook are created using Macromedia Flash. The Flash movie files are small in file size since they are vector-based graphics (i.e., less than 100 kb with narrations) and can be downloaded easily through the Internet.

Figure 4. A typical movie/animation interface

Another advantage of electronic education media, which is often overlooked and under-appreciated, is the unlimited use of color. In fact, it presents a major advantage that electronic media has to offer over traditional textbook. Most paper textbooks have limited use of color in their illustrations in order to minimize the publication cost. Using electronic media, on the other hand, charts and diagrams such as the Moody chart and the compressibility chart are brought to life with the color usage (Figure 5). All diagrams are vector-based and they can be enlarged to see the details.

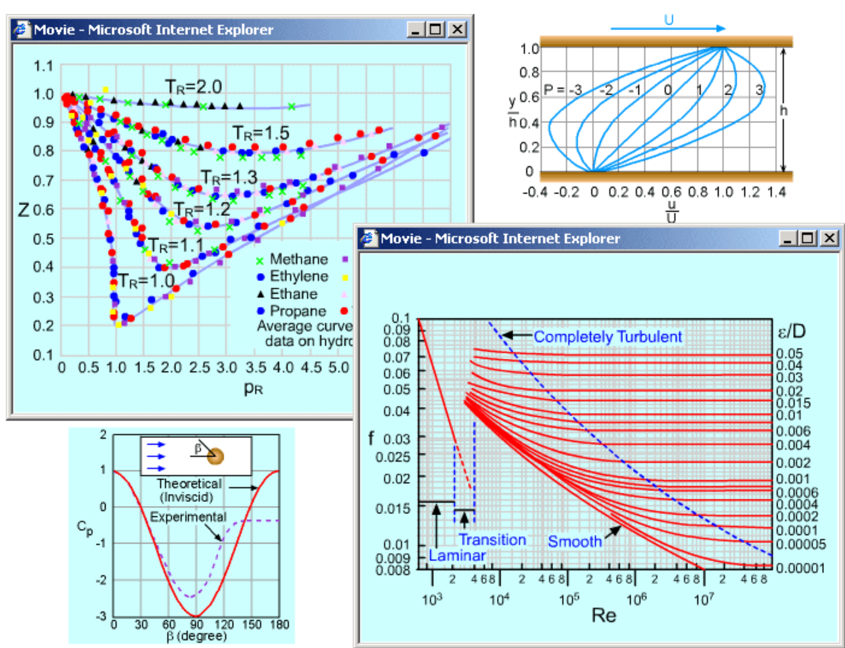

Figure 5. Different charts and diagrams

(c) Case Solutions
Once the materials required for the students to solve a case study are covered in the theory section, a complete detailed solution is given for that particular case study. To improve student's problem solving skills, a systematic approach with step-by-step solution procedure is given here. A typical case solution page is shown in Figure 6. In this particular solution page, students will learn how to determine the force components exerted on a curved surface of a spillway gate.

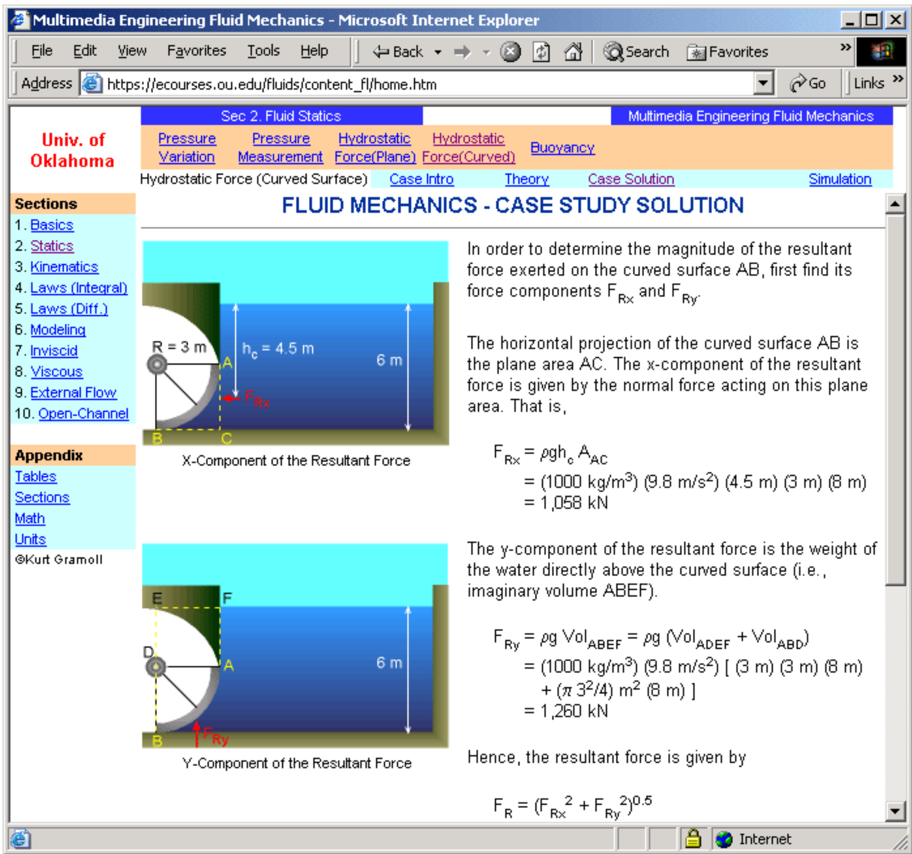

Figure 6. A typical solutions interface

(d) Simulation
One unique feature that multimedia technology has to offer is the use of interactive simulation. At the end of each module, a simulation is included to engage students in constructive learning. Students are allowed to adjust several parameters of a problem and immediately observe how these changes will affect the outcome of the results. Figure 7 shows three different simulations. The simulation for the crankshaft journal bearing (top left) will allow students to alter the rotating speed or the lubricant viscosity and observe the velocity profile of the lubricant. The stormwater sewer simulation (top right) shows how the discharge flow rate and Manning coefficient will affect the pipe size selection for a sewer system. The simulation shown at the bottom determines the mass of different gas (modeled as ideal gas) subject to different

temperature and pressure. Simulations such as these provide an active learning environment to the students. All simulations are developed using Macromedia Director and saved as shockwave format for web publication. Suggested help questions and technical help are included to guide students in using these simulations.

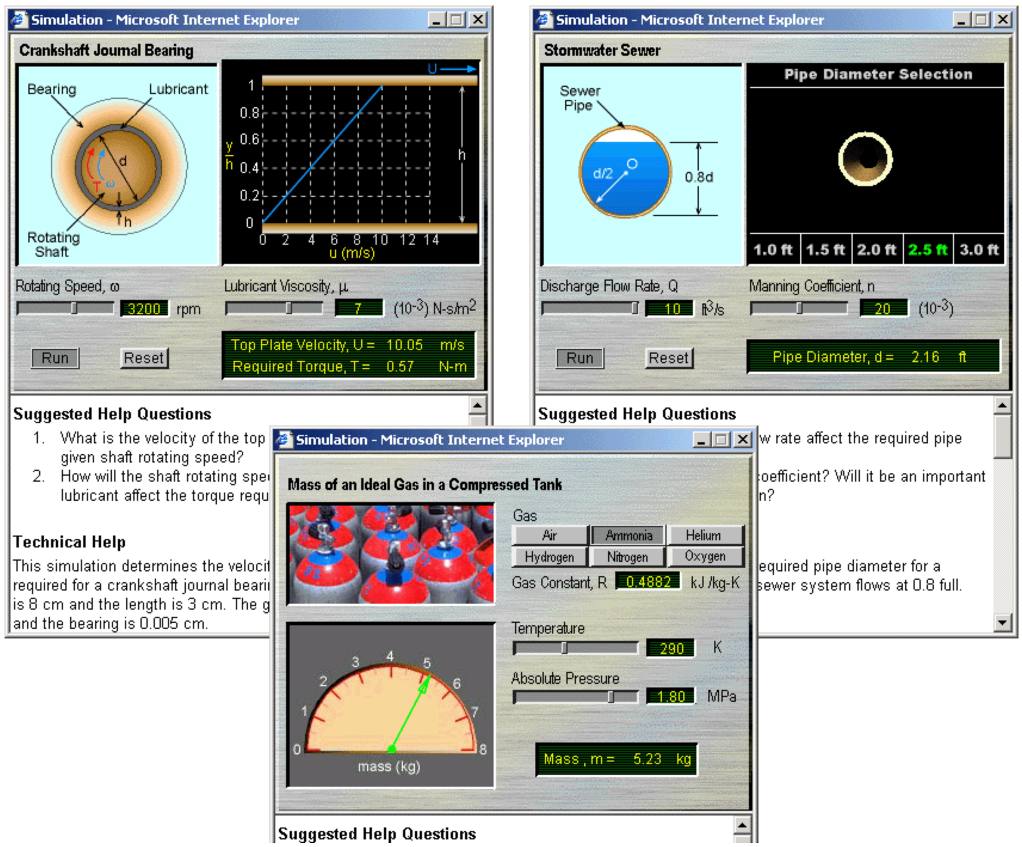

Figure 7. A typical simulation interface

IV. Summary

A web-based Multimedia Engineering Fluid Mechanics eBook has been developed with an extensive use of interactive media. This eBook can be used as a stand-alone tool for distance learning, just-in-time learning tool for review purposes, or as supplementary materials for traditional classes. This eBook is intended to be a shared instructional resource, and it is freely open for any institution or student to use without cost or conditions.

V. Acknowledgment

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Biography

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C. C. Ngo is currently a doctoral student in the School of Aerospace and Mechanical Engineering at the University of Oklahoma. He received his B.S. and M.S. degree in Mechanical Engineering from the University of Oklahoma (1997 and 1999, respectively). His research interests include heat transfer and fluid flow in porous media, and the implement of multimedia technology in online engineering education.

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