Appendix 3B

High School Appropriate Fluid Mechanics Tables

For

HIGH SCHOOL APPROPRIATE ENGINEERING CONTENT KNOWLEDGE IN THE INFUSION OF ENGINEERING DESIGN INTO K-12 CURRICULUM

(Under the General Topic of "Engineering Design in Secondary Education" and of "Vision and Recommendations for Engineering-Oriented Professional Development")

Summer 2009 (Completion Date: Thursday, July 9, 2009)

College of Education, University of Georgia

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Notes on How to Use This Appendix

The whole Research Project and this Appendix constitute the groundwork for a proposed four-round five-point Likert Scale survey study, with five major steps in its research design:

1. Preliminary selection of high school appropriate fluid mechanics topics;
2. Presentation of data to faculty advisors for review;
3. Presentation of data to a panel of university faculty for validation and endorsement;
4. 4-round Delphi study using 5-point Likert Scale;
5. Comparative analysis of the results from the 4-round Delphi study, for the creation of a formal list of high school appropriate engineering topics.

Participants in the "4-round Delphi study using 5-point Likert Scale" might include the following groups of stakeholders in engineering and technology education:

- Group 1 (University Engineering and Technology Faculty);
- Group 2 (University K-12 Technology Education Faculty);
- Group 3 (University Undergraduate Senior-Year Engineering Students);
- Group 4 (K-12 Technology and STEM Teachers and Administrators);
- Group 5 (Practicing Engineers and Technicians).

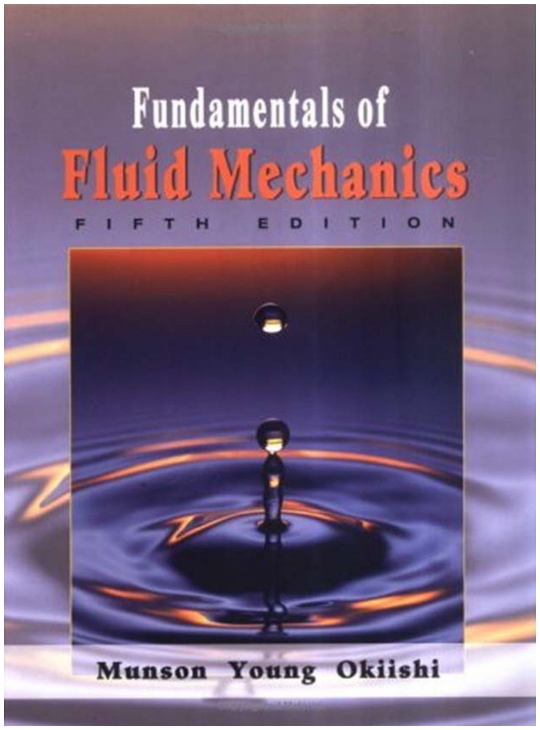

Figure 1A. The main textbook where the fluid mechanics related engineering analytic and predictive principles and computational formulas are extracted.

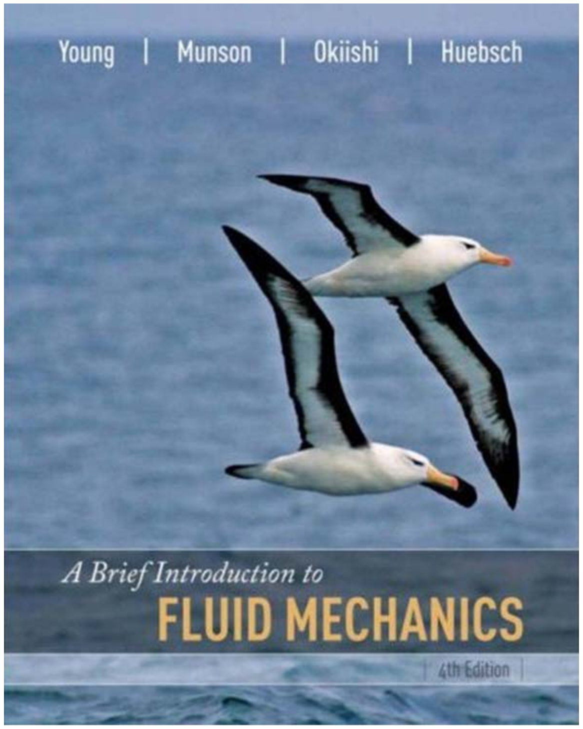

Figure 1B. The abridged version of the textbook by the same authors and used in California State University Los Angeles when I took the course. This book has been used as a reference during this research project.

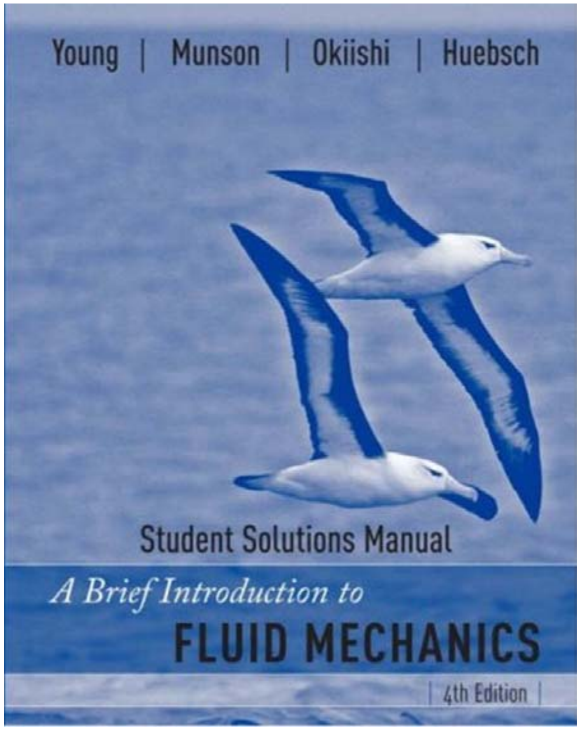

Figure 1C. The Student Solution Manual for the main textbook used to double-check for the mathematics and physics principles and computational skills needed for the study of various topics of fluid mechanics contained in the main textbook.

Textbook Information

	Main Textbook	Reference Book	Student Solution Manual
Title	Fundamentals of Fluid Mechanics Mechanics, 5th Edition	A Brief Introduction to Fluid Mechanics, 4th Edition	A Brief Introduction to Fluid Mechanics, Student Solutions Manual, 4th Edition
Authors	Bruce M. Munson, Donald F. Young, Theodore H. Okiishi	Donald F. Young, Bruce R. Munson, Theodore H. Okiishi, Wade W. Huebsch	Donald F. Young, Bruce R. Munson, Theodore H. Okiishi, Wade W. Huebsch
Publisher	John Wiley & Sons, Inc.	John Wiley & Sons, Inc.	John Wiley & Sons, Inc.
Year	2006	2007	2007
ISBN	0-471-67582-2	978-0470039625	978-0470099285

This Appendix contains tabulated information on the initial determination of high school (at 9th Grade level) appropriate engineering analytic and predictive principles and computational formulas for the subject of fluid mechanics; this determination is based on the satisfaction of pre-requisite mathematics and science (namely, physics and chemistry) education, as mandated by Georgia Performance Standards established by the State of Georgia Department of Education (available at https://www.georgiastandards.org/Pages/Default.aspx). The above-mentioned principles and computational formulas have been extracted from one of the most popular university undergraduate lower-division textbook on fluid mechanics; associated reference books have been used as well (see *Figures 1A*, *1B*, and *1C*). The Appendix contains the following:

- **Part One – Initial Determination of High School (9th Grade) Appropriate Fluid Mechanics Topics**: This Part covers the 1st, 2nd and 3rd of the above-listed 5 major steps of the proposed study (i.e., "preliminary selection of high school appropriate engineering topic," "presentation of data to faculty advisors for review," and "presentation of data to a panel of university faculty for validation and endorsement"); and it contains the *Fluid Mechanics Topic List (Engineering Topics Mathematics and Science Pre-requisite Completion Chart for the Subject of Fluid Mechanics)*, on pages 14-86. As shown in *Figures 2A* and *2B*, on the tabulated list, the columns listing the mathematics and physics/chemistry pre-requisites for the study of each fluid mechanics topic are listed on the right of the column containing the titles of the chapters and sections with associated formulas, which are symbolic representations of engineering analytic and predictive principles. The list will serve two purposes:

1. **For data review and validation**: The list will be submitted to Dr. Robert Wicklein, Dr. John Mativo, and Dr. Roger Hill at the College of Education, the University of Georgia, for review, and for validation of the findings at technical level, in terms of validity of pre-requisite sequence and of high school students' preparedness for learning the engineering knowledge content identified therein. Dr. Robert Wicklein is a veteran educator profoundly and broadly experienced in teaching both K-12 and university students engineering design and technology. Dr. John Mativo has strong academic background and long history of professional practice in both mechanical and electrical engineering, and over 15 years of working experience in university engineering instruction as well as in the development of K-12 appropriate engineering curriculum. Dr. Roger Hill is a veteran professor in the area of workforce education and is very knowledgeable about K-12 education process. All of them possess great expertise in making judgment on the feasibility of infusing specific engineering knowledge content into K-12 curriculum. To facilitate such review and validation, proposed procedures are available on pages 8-13. After Dr. Robert Wicklein, Dr. Roger Hill and Dr. John Mativo complete the review and validation process, the list would be edited to make corrections to all possible errors and mistakes; and if necessary and possible, the corrected list might be submitted to a panel of university faculty for additional validation and endorsement; and the potential members of this panel would be selected among engineering processors with experience teaching fluid mechanics course for at least three semesters in an ABET-accredited undergraduate engineering program, from four-year universities granting master's and/or doctoral degrees in mechanical and civil engineering.

2. **As part of the 1st round of the proposed four-round five-point Likert Scale Delphi study**: The expert opinions on the relative importance of each topic of fluid mechanics (with analytic principles and computational formulas), collected from the review and validation process conducted by the above professors will be counted as part of the data for the first round of the Delphi study and statistically analyzed and processed accordingly, so as to prepare for the second round of the proposed Delphi survey with the above-mentioned five Groups of Participants.

- **Part Two – 1st Round of Delphi - Five-Point Likert Scale Survey Forms**: This Part prepares for the 4th of the above-listed 5 major steps of the proposed study; and it contains two survey forms (i.e., the first round of the "4-round Delphi study using 5-point Likert Scale"). The Survey Forms will be presented to the above-mentioned five Groups of Participants for the first round of the proposed Delphi survey. To facilitate the survey, detailed information on how to fill out survey forms are available on pages 87-92.

1. *Fluid Mechanics Survey Form A (1st Round of Delphi - Likert Scale Questionnaire on the Importance of Various Fluid Mechanics Topics Selected for High School Engineering Curriculum (For the Pre-calculus Portion)*: As the name implies, this list covers only the fluid mechanics topics with computational formulas requiring no calculus related skills. (pp. 93-127).

2. *Fluid Mechanics Survey Form B (Delphi - Likert Scale Questionnaire on the Importance of Various Fluid Mechanics Topics Selected for High School Engineering Curriculum (For the Calculus Portion)*: As the name implies, this list covers only the fluid mechanics topics with computational formulas requiring calculus related skills. (pp. 128-164).

- **Part Three – Findings from the Research Project**: This Part contains tabulated lists showing the results of this research project, which might be used as reference in the future endeavors to infuse fluid mechanics related engineering analytic and predictive principles and computational skills into a potentially viable high school engineering and technology curriculum, which shall be based on the organic and seamless integration of solid mastery of engineering analytic and predictive principles and innovative application of engineering design process.

  - *List 1A. Pre-Calculus Based Fluid Mechanics Topics That Possibly Could Be Taught at 9th Grade*: The statistic summary of data at the end of this list (pp. 166-170) indicates that a significant portion of fluid mechanics knowledge content covered in the selected undergraduate level textbook could possibly be taught to high school students. 62.2% of all Sections, and 51.0% of the volume in the selected textbook is based on pre-calculus mathematics and on principles of physics students are supposed to learn before or by 9th Grade, according to Georgia Performance Standards (p. 170).

  - *List 1B. Pre-Requisite Mathematics and Science Topics to Be Reviewed Before Teaching the Pre-Calculus Portion of Fluid Mechanics Topics to 9th Grade Students*: This list includes 24 sets of mathematics principles and skills, as well as 29 sets of physics/chemistry principles and skills that are needed as pre-requisites or as important topics to be reviewed for the effective learning of fluid mechanics topics initially determined as appropriate for 9th Grade students (p. 171).

  - *List 2A. Calculus Base Fluid Mechanics Topics for Post-Secondary Engineering Education*: Topics of fluid mechanics on this list are either recommended for post-secondary engineering education, or for inclusion as application problems in 11th or 12th Grade Advanced Placement Calculus course (pp. 172-174).

  - *List 2B. Pre-Requisite Math and Science Topics to Be Reviewed Before Teaching the Calculus Portion of Fluid Mechanics Topics*: This list includes 34 sets of mathematics principles and skills, as well as 33 sets of physics principles and skills that are needed as pre-requisites or as important topics to be reviewed for the effective learning of fluid mechanics topics initially recommended either for university engineering students or for high school 11th or 12th Grade students enrolled in Advanced Placement Calculus courses (p. 175).

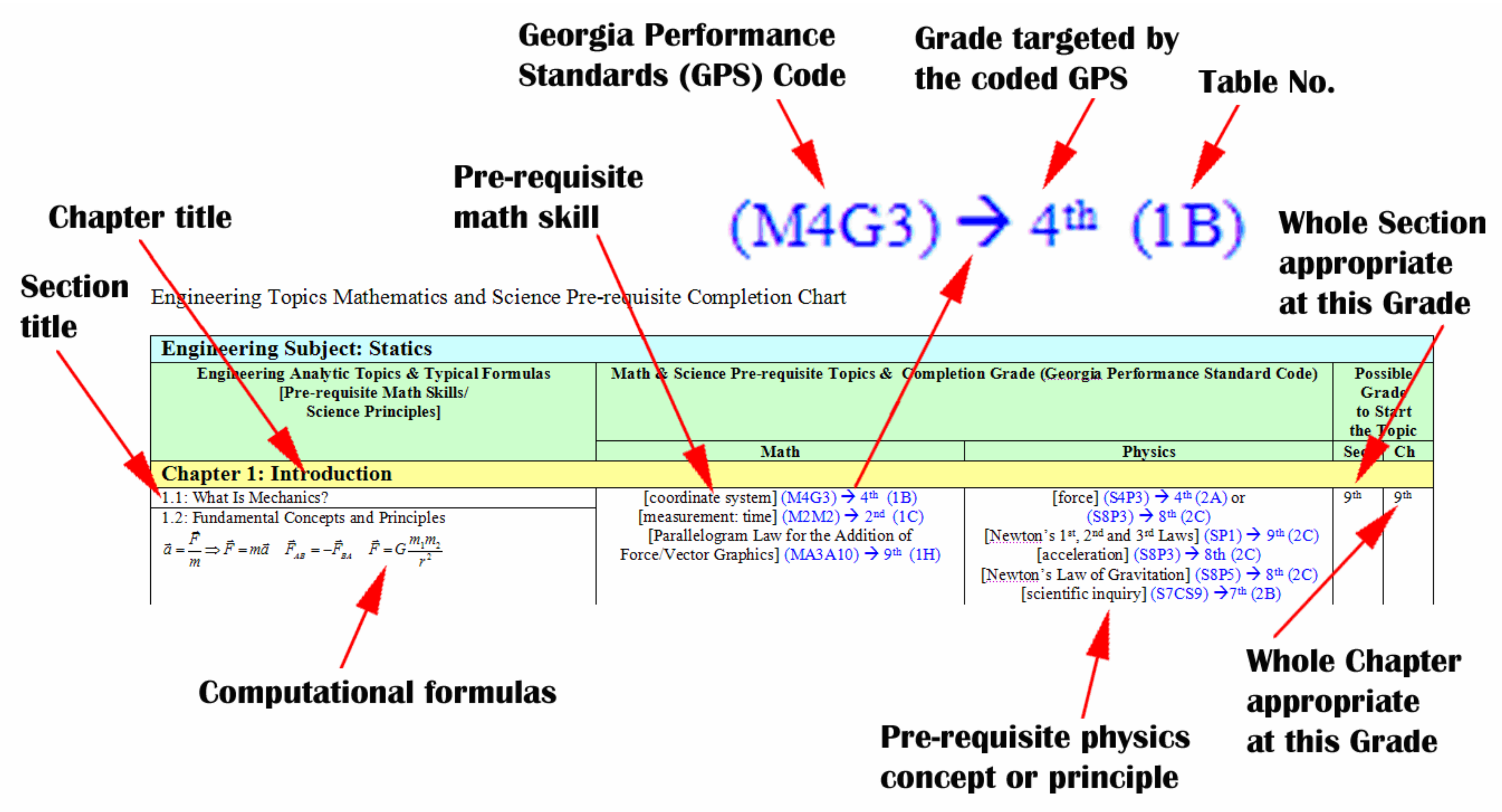

Figure 2A. Engineering Topics Mathematics and Science Pre-requisite Completion Chart for the Subject of Statics.

Engineering Subject: Statics				
Engineering Analytic Topics & Typical Formulas [Pre-requisite Math Skills/ Science Principles]	Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)		Possible Grade to Start the Topic	
	Math	Physics	Sec	Ch
Chapter 8: Friction (Continued)				
8.10: Belt Friction $\ln\frac{T_2}{T_1} = \mu_s\beta \quad \frac{T_2}{T_1} = e^{\mu_s\beta}$ (For other formulas, refer to pp. 451-452)	[summation/addition] (M6N1) → 6th (2A) [four operations] (M1N3) → 1st (2A) + (M2N3) → 2nd (2A), or (M7N1) → 7th (2A) [trigonometric functions] (MA2G2) → 10th (2F) → To be taught as a special math topic [logarithmic functions] (MA2A4) → 10th (2E) → To be taught as a special math topic [integration] → 12th (to be taught) [differentiation] → 12th (to be taught)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C)	PS	PS

Whole chapter apropriate for university undergraduate statics course

Integration and differentiation covered at Grade 12

Figure 2B. Notation for undergraduate level appropriate statics topics.

Part One: Initial Determination of High School (9th Grade) Appropriate Fluid Mechanics Topics

Proposed Procedures for Review and Validation

To facilitate review and validation of the initial selection of fluid mechanics topics that could be possibly taught to students at 9th or above Grade, as listed in the *Fluid Mechanics Topic List*, the following procedures are hereby proposed:

1. Look at the formulas listed under the **Engineering Analytic Topics & Typical Formulas** column, and check the mathematics and science pre-requisite items under the **Math** and **Physics/Chemistry** columns; verify if there are necessary pre-requisite that are missing; if so, write a note in either the **Math** or **Physics/Chemistry** column; and if any listed item is not really needed, cross it out with a horizontal strikethrough (as shown on *Figure 3A*);

2. Rate the importance of each Section as a topic in a potentially viable 9th or above Grade fluid mechanics subject, and write a number representing its "importance" value (*Figure 3A*), using the five-point Likert Scale (*Figure 3B*);

3. Check the formulas listed under the **Engineering Analytic Topics & Typical Formulas** column, and use symbols shown in *Figure 3B* to indicate your expert opinion and advice about each formula;

4. Add your comment and advice on the Grade at which the topic should be taught to pre-collegiate students;

5. Add your general comments and advice in the empty space.

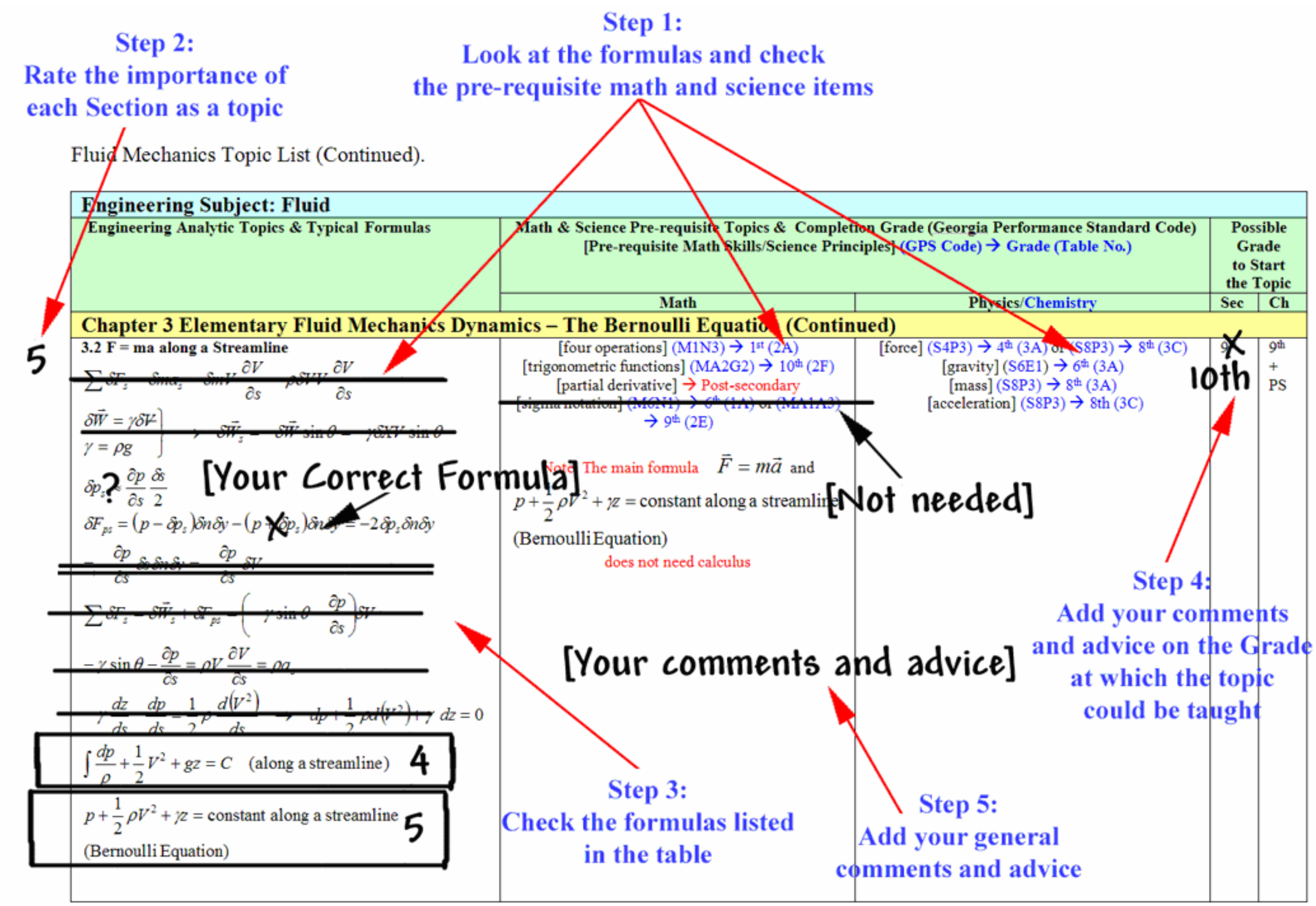

Figure 3A. Step-by-step procedures proposed for the review and validation of data.

Likert Scale (Score of Importance) for Engineering Analysis Topics/Formulas				
Totally Unimportant	Not So Important	Might Be Important	Important	Very Important
1	2	3	4	5

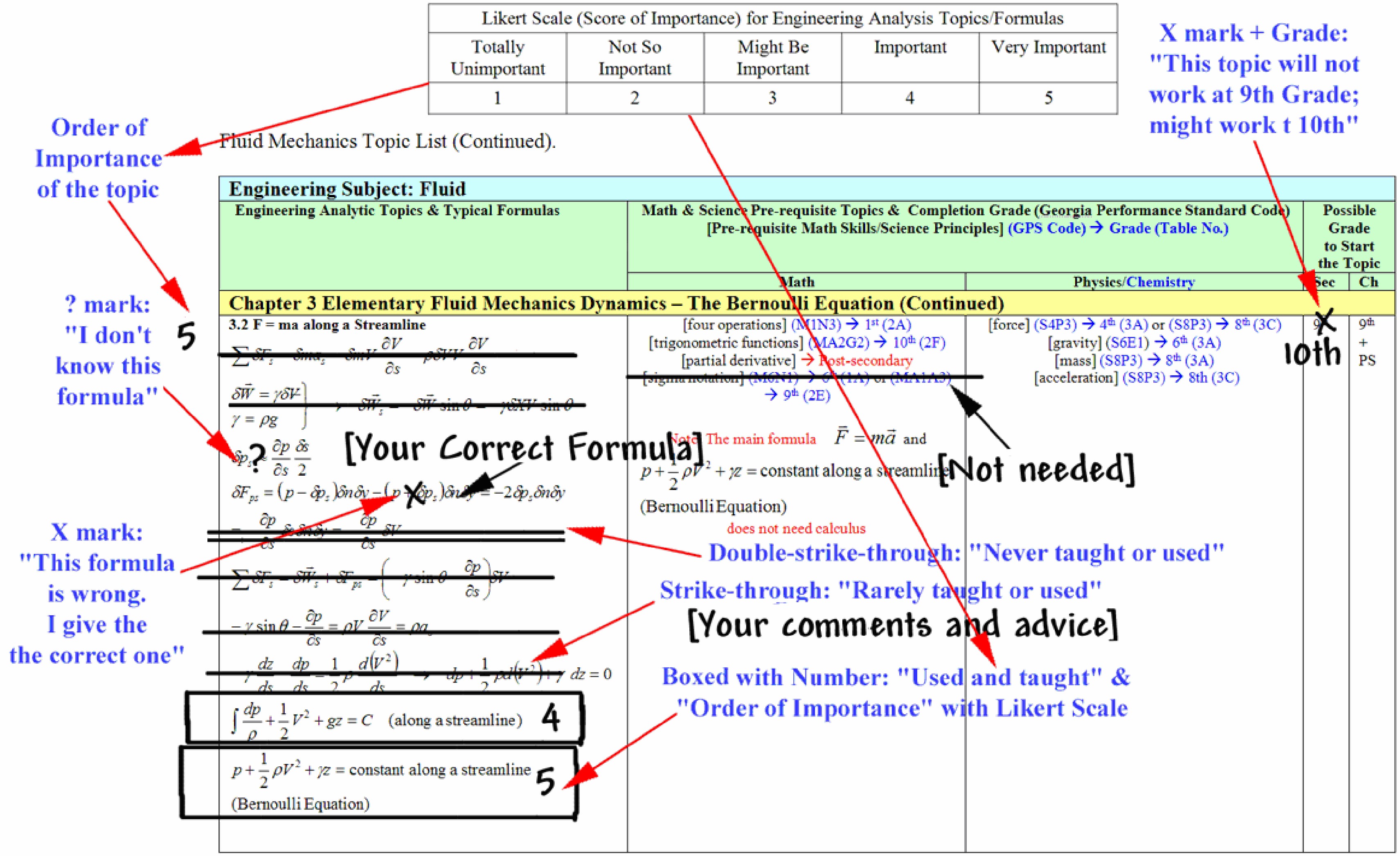

Figure 3B. Likert Scale (top) and symbols to be used for the expression of expert opinion and offer of advice.

Notes for Chapter 6 and Chapter 7

Chapter 6 (Differential Analysis of Fluid Mechanics Flow) appears to be, for all practical purposes, too deep in calculus-based mathematics for even 12th Grade students in Advanced Placement Calculus course to master.

Chapter 7 (Similitude, Dimensional Analysis, and Modeling) involve a lot of “abstract thinking” and appears to be most likely beyond the cognitive developmental maturity level of high school students.

Therefore, engineering analytic principles and skills from these two Chapters are NOT analyzed for the eventual inclusion into a potentially viable K-12 engineering curriculum. However, some generic knowledge content covered in these two Chapters could still be lightly explored by 9th or above Grade students; thus, their relative importance could still be rated at generic knowledge level. In addition, some appropriate skills in 7.1 (Dimensional Analysis) could be considered for high schools.

Notes about the Fluid Mechanics Analytic Principles and Formulas

The leftmost column in the *Fluid Mechanics Topic List (Engineering Topics Mathematics and Science Pre-requisite Completion Chart for the Subject of Fluid)* contains

1. The titles of each section under a particular chapter in the selected textbook, which in general represent particular sets of fluid mechanics related engineering analytic and predictive principles, in a qualitative and explanatory way;

2. Computational formulas, which symbolically represent the above engineering analytic and predictive principles, in a quantitative and mathematical way.

As shown in *Figure 3B*, the formulas extracted from the selected textbook might by categorized into five groups, corresponding to the five different symbols shown in *Figure 3B*, which could be used by the above-mentioned professors from the University of Georgia and other schools to indicate their expert opinions and advices about each formula:

1. Formulas that engineering professors actually teach in classroom lectures and that practicing engineers use in engineering design projects: These are the important ones to be included in a potentially viable K-12 engineering curriculum that shall be based on cohesive and systemic mastery of engineering analytic and predictive principles and skills. For any of these formulas, a box could be used together with a number representing its order of importance according to the five-point Likert Scale (1 = Totally Unimportant, 2 = Not So Important, 3 = Might Be Important, 4 = Important, or 5 = Very Important).

2. Formulas that are rarely used in either classroom lectures or in field practice, but are used by the original discoverer of a particular set of analytic principles to derive other formulas that are actually used in classroom lecture or in field practice: Some of these "intermediate" formulas might not be used often, in other words, they are "rarely taught or used." For any of these formulas, a strikethrough could be used. If a big enough percentage of participants (maybe 85% or above) place a strikethrough on a particular formula at the end of each round of the proposed four-round Delphi study, then the formula will be removed from the survey form for the next round. If the trend continues through all four rounds of the proposed Delphi survey, then that formula might be removed from the final list of high school appropriate fluid mechanics topics. Interestingly enough, in some cases, rarely used calculus-based "intermediate" formulas are used to derive a final one that is based on pre-calculus mathematics skills and is actually used in most homework assignments and design projects; in this case, if the "intermediate" formulas are removed from consideration, then the entire topic of fluid mechanics could be re-classified as appropriate for 9th Grade. For example, the main formula $\vec{F} = m\vec{a}$ and $p + \frac{1}{2}\rho V^2 + \gamma z =$ constant along a streamline (Bernoulli Equation) do not need calculus, and thus, could be taught to 9th Grade students. This type of formulas will make the list shorter and shorter as the proposed Delphi study moves to the next round of survey. Some of these formulas might not be in the selected textbook; I derived them for fun, sometimes with the help of my former engineering professor, Dr. Samuel Landsberger, at California State University Los Angeles.

3. Formulas that are particular to certain conditions and in real classroom lectures or field practice are, for all practical purposes, are close to be "never used:" For any of these formulas, a double-strikethrough could be used. If a big enough percentage of participants (maybe 75% or above) place a double-strikethrough on a particular formula at the end of each round of the proposed four-round Delphi study, then the formula will be removed from the survey form for the next round. If the trend continues through all four rounds of the proposed Delphi survey, then that formula might be removed from the final list of high school appropriate fluid mechanics topics. This type of formulas will also make the list shorter and shorter as the proposed Delphi study moves to the next round of survey.

4. Formulas that even experienced university engineering professors or practicing engineers might "not understand:" This is amazing but totally correct and yes, absolutely normal! There are formulas that even experienced professors might say "I do not understand this" or "I need to read the context in the book to figure this out." For any of these formulas, the participants should generally not seek to understand them (doing so does not serve the purpose of studying the relative importance of each computational formula); but instead, a question mark (?) could be used. If a big enough percentage of participants (maybe 65% or above) place a question mark (?) on a particular formula at the end of each round of the proposed four-round Delphi study, then the formula will be removed from the survey form for the next round. If the trend continues through all four rounds of the proposed Delphi survey, then that formula might be removed from the final list of high school appropriate fluid mechanics topics. Indeed, it makes little sense to include this type of formulas to a potentially viable K-12 engineering curriculum. This type of formulas will also make the list shorter and shorter as the proposed Delphi study moves to the next round of survey. Some of these formulas might not be in the selected textbook; I derived them for fun, sometimes with the help of my former engineering professor, Dr. Samuel Landsberger, at California State University Los Angeles.

5. Formulas that are wrong for any reasons (my typing errors, or the authors' errors, etc.): For any of these formulas, a cross (X) could be used and the correct formulas should be given if possible. The correction would be included in the survey forms for the subsequent rounds of the four-round five-point Likert Scale Delphi study.

For convenience of statistic analysis of expert opinions and advice, it is requested that all participants print each letter of their comment legibly and separately, using fonts commonly used in engineering notebooks.

Fluid Mechanics Topic List
Engineering Topics Mathematics and Science Pre-requisite Completion Chart for the Subject of Fluid Mechanics

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 1 - Introduction				
1.1 Some Characteristics of Fluid	N/A	[pressure] (SC5) → 9th (4B) → To be taught [velocity] (S8P3)→ 8th (3A) [force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [molecule] (S8P1)→ 8th (4A)	9th	9th + PS
1.2 Dimensions, Dimensional Homogeneity, and Units $p \equiv \frac{\vec{F}_n}{A_s} \rightarrow \vec{F}_n = pA_s \quad \tau = \frac{P}{A_s} \quad \tau \propto \delta\beta$	[unit conversion] (M6M1) → 6th (2C) [four operations] (M1N3) → 1st (2A) [square root] (M8N1) → 8th (2A)	N/A	9th	
1.3 Analysis of Fluid Mechanics Behavior N/A	N/A	[Newton's 1st, 2nd and 3rd Laws] (SP1) → 9th (3C) [mass] (S8P3) → 8th (3A)	9th	
1.4 Measures of Fluid Mechanics Mass and Weight	[four operations] (M1N3) → 1st (2A)	[mass] (S8P3) → 8th (3A) [gravity] (S6E1) → 6th (3A)	9th	
1.4.1 Density $\rho = \frac{m}{V} \quad v = \frac{V}{m} = \frac{1}{\rho}$	[four operations] (M1N3) → 1st (2A) [volume] (M5M4) → 5th (1B) (M6M3) → 6th (2B) (MA1G5) → 9th (2F)	[density] (S6E5) → 6th (4A) [mass] (S8P3) → 8th (3A)	9th	
1.4 2 Specific Weight $\gamma \equiv \frac{W}{V} = \frac{mg}{V} = \rho g$	[four operations] (M1N3) → 1st (2A)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [gravity] (S6E1) → 6th (3A) [density] (S6E5) → 6th (4A)	9th	
1.4.3 Specific Gravity $SG = \frac{\rho}{\rho_{H_2O} @ 4^\circ C}$	[four operations] (M1N3) → 1st (2A)	[pressure] (SC5) → 9th (4B) → To be taught	9th	
1.5 Ideal Gas Law $p = \rho RT$	[four operations] (M1N3) → 1st (2A)	[temperature] (SP3) → 9th (3B) [**absolute temperature**] (SP3) → 9th (3B) → To be taught [density] (S6E5) → 6th (4A)	9th	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 1 – Introduction (Continued)				
1.6 Viscosity $u = \frac{Uy}{b}$ $\tan\delta\beta \approx \delta\beta = \frac{\delta a}{b}$ $\delta a = U\delta t$ $\delta\beta = \frac{U\delta t}{b}$ $\dot{\gamma} = \lim_{\delta t \to 0}\frac{\delta\beta}{\delta t}$ $\dot{\gamma} = \frac{U}{b} = \frac{du}{dy}$ $\tau \propto \dot{\gamma}$ $\tau \propto \frac{du}{dy}$ $\tau = \mu\frac{du}{dy}$ $\mu = \frac{CT^{3/2}}{T+S}$ $\mu = De^{B/T}$ $\nu = \frac{\mu}{\rho}$	[four operations] (M1N3) → 1^{st} (2A) [derivative] → 12^{th} (To be taught) [trigonometric functions] (MA2G2) → 10^{th} (2F)	[density] (S6E5) → 6^{th} (4A) **[absolute temperature]** (SP3) → 9^{th} (3B) → To be taught	PS	9^{th} + PS
1.7 Compressibility of Fluids	N/A	N/A	9^{th}	
1.7.1 Bulk Modulus $E_v = \frac{dp}{d\forall/\forall}$ $E_v = \frac{dp}{d\rho/\rho}$	[four operations] (M1N3) → 1^{st} (2A) [derivative] → 12^{th} (To be taught as a special skill)	[pressure] (SC5) → 9^{th} (4B) → To be taught [density] (S6E5) → 6^{th} (4A)	9^{th}	
1.7.2 Compression and Expansion of Gases $\frac{p}{\rho} = \text{Constant}$ $\frac{p}{\rho^k} = \text{Constant}$ $E_v = p$ $E_v = kp$	[four operations] (M1N3) → 1^{st} (2A) [exponent] (M6A3) → 6^{th} (2A)	[pressure] (SC5) → 9^{th} (4B) → To be taught [density] (S6E5) → 6^{th} (4A)	9^{th}	
1.7.3 Speed of Sound $c = \sqrt{\frac{dp}{d\rho}} = \sqrt{\frac{E_v}{\rho}} \leftarrow \begin{cases} E_v = \frac{dp}{d\rho/\rho} = \frac{dp}{d\rho}\rho \\ \frac{E_v}{\rho} = \frac{dp}{d\rho} \end{cases}$ $\left.\begin{matrix} c = \sqrt{\frac{kp}{\rho}} \\ p = \rho RT \end{matrix}\right\} \rightarrow c = \sqrt{kRT}$	[four operations] (M1N3) → 1^{st} (2A) [square root] (M8N1) → 8^{th} (2A) [derivative] → 12^{th} (To be taught as a special skill)	[speed of sound] (SPS9) → 9^{th} (3B) → To be taught [velocity] (S8P3)→ 8^{th} (3A) **[absolute temperature]** (SP3) → 9^{th} (3B) → To be taught	9^{th}	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 1 – Introduction (Continued)				
1.8 Vapor Pressure	N/A	**[intermolecular cohesive force]** → To be taught [momentum] (SP3) → 9^{th} (3B) [pressure] (SC5) → 9^{th} (4B) → To be taught	9^{th}	9^{th} + PS
1.9 Surface Tension $2\pi R\sigma = \Delta p \pi R^2 \quad \Delta p = p_i - p_e = \frac{2\sigma}{R}$ $\gamma \pi R^2 h = 2\pi R\sigma\cos\theta \quad \rightarrow \quad h = \frac{2\sigma\cos\theta}{\gamma R}$	[areas of geometric shapes: circle, triangle] (M5M1) → 5^{th} (2B) (M5M1) → 5^{th} (2B) [unit conversion] (M6M1) → 6^{th} (2C) [height] (MKM1) → K (2B) [trigonometric functions] (MA2G2) → 10^{th} (2F)	[force] (S4P3) → 4^{th} (3A) or (S8P3) → 8^{th} (3C) [mass] (S8P3) → 8^{th} (3A) [pressure] (SC5) → 9^{th} (4B) → To be taught [weight] (MKM1) → K (2C) [gravity] (S6E1) → 6^{th} (3A)	9^{th}	
1.10 A Brief Look Back in History	N/A	N/A	9^{th}	
1.11 Chapter Summary and Study Guide	N/A	N/A	9^{th}	
Chapter 2 Fluid Statics (Continued)				
2.1 Pressure at a Point $\vec{F} = m\vec{a}$ $\sum F_y = p_y \delta x \delta z - p_s \delta x \delta s \sin\theta = \rho \frac{\delta x \delta y \delta z}{2} a_y$ $\sum F_z = p_z \delta x \delta y - p_s \delta x \delta s \cos\theta - \gamma \frac{\delta x \delta y \delta z}{2} = \rho \frac{\delta x \delta y \delta z}{2} a_z$ $\uparrow \frac{\delta x \delta y \delta z}{2} = V \quad m = \rho V \quad \leftarrow \quad \vec{F}_z = m\vec{a}_z$	[four operations] (M1N3) → 1^{st} (2A) [sigma notation] (M6N1) → 6^{th} (1A) or (MA1A3) → 9^{th} (2E) [coordinate system] (M4G3) → 4^{th} (2B) [limit] → Post-Secondary [volume] (M5M4) → 5^{th} (1B) (M6M3) → 6^{th} (2B) (MA1G5) → 9^{th} (2F)	[force] (S4P3) → 4^{th} (3A) or (S8P3) → 8^{th} (3C) [Newton's 1^{st}, 2^{nd} and 3^{rd} Laws] (SP1) → 9^{th} (3C)	PS	PS

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 2 Fluid Statics (Continued)				
2.1 Pressure at a Point (Continued) $\vec{F} = m\vec{a}$ $\sum F_y = p_y \delta x \delta z - p_s \delta x \delta s \sin\theta = \rho \frac{\delta x \delta y \delta z}{2} a_y$ $\sum F_z = p_z \delta x \delta y - p_s \delta x \delta s \cos\theta - \gamma \frac{\delta x \delta y \delta z}{2} = \rho \frac{\delta x \delta y \delta z}{2} a_z$ $\uparrow \quad \frac{\delta x \delta y \delta z}{2} = V \quad m = \rho V \quad \leftarrow \quad \vec{F}_z = m\vec{a}_z$	[four operations] (M1N3) → 1st (2A) [sigma notation] (M6N1) → 6th (1A) or (MA1A3) → 9th (2E) [coordinate system] (M4G3) → 4th (2B) [limit] → Post-Secondary [volume] (M5M4) → 5th (1B) (M6M3) → 6th (2B) (MA1G5) → 9th (2F)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [Newton's 1st, 2nd and 3rd Laws] (SP1) → 9th (3C)	PS	PS
2.2 Basic Equation for Pressure Field $\delta F_y = \left(p - \frac{\partial p}{\partial y}\frac{\delta y}{2}\right)\delta x \delta z - \left(p + \frac{\partial p}{\partial y}\frac{\delta y}{2}\right)\delta x \delta z \quad \rightarrow$ $\left.\begin{array}{l} \delta F_x = -\frac{\partial p}{\partial x}\delta x \delta y \delta z \\ \delta F_y = -\frac{\partial p}{\partial y}\delta x \delta y \delta z \\ \delta F_z = -\frac{\partial p}{\partial z}\delta x \delta y \delta z \end{array}\right\} \leftarrow \quad \delta y \delta x \delta z = V$	[four operations] (M1N3) → 1st (2A) [partial derivative] → Post-Secondary [gradient "del"] → Post-Secondary [volume] (M5M4) → 5th (1B) (M6M3) → 6th (2B) (MA1G5) → 9th (2F) [coordinate system] (M4G3) → 4th (2B)	[pressure] (SC5) → 9th (4B) → To be taught [acceleration] (S8P3) → 8th (3C)	PS	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 2 Fluid Statics (Continued)				
2.2 Basic Equation for Pressure Field (Continued) $\delta\vec{F}_s = \delta F_x\hat{i} + \delta F_y\hat{j} + \delta F_z\hat{k} = -\left(\frac{\partial p}{\partial x}\hat{i} + \frac{\partial p}{\partial y}\hat{j} + \frac{\partial p}{\partial z}\hat{k}\right)\delta x\delta y\delta z$ $\frac{\partial p}{\partial x}\hat{i} + \frac{\partial p}{\partial y}\hat{j} + \frac{\partial p}{\partial z}\hat{k} = \nabla p \quad \nabla(\ ) = \frac{(\ )}{\partial x}\hat{i} + \frac{(\ )}{\partial y}\hat{j} + \frac{(\ )}{\partial z}\hat{k}$ $\frac{\delta\vec{F}_s}{\delta x\delta y\delta z} = -\nabla p \quad -\delta W\hat{k} = -\gamma\delta x\delta y\delta z\hat{k} \quad \begin{cases}\sum\delta\vec{F} = \delta m\vec{a} \\ \delta m = p\delta x\delta y\delta z\end{cases}$ $\sum\delta\vec{F} = \delta\vec{F}_s - \delta W\hat{k} = \delta m\vec{a} \quad \rightarrow$ $-\nabla p\delta x\delta y\delta z\hat{k} - \gamma\delta x\delta y\delta z\hat{k}\hat{k} = \rho\delta x\delta y\delta z\hat{k}\vec{a} \quad \rightarrow$ $-\nabla p - \gamma\hat{k} = \rho\vec{a}$	[four operations] (M1N3) → 1st (2A) [partial derivative] → Post-Secondary [gradient “del”] → Post-Secondary [volume] (M5M4) → 5th (1B) (M6M3) → 6th (2B) (MA1G5) → 9th (2F) [coordinate system] (M4G3) → 4th (2B)	[pressure] (SC5) → 9th (4B) → To be taught [acceleration] (S8P3) → 8th (3C)	PS	PS
2.3 Pressure Variation in a Fluid Mechanics at Rest $\vec{a} = 0 \quad \rightarrow \quad -\nabla p - \gamma\hat{k} = 0$ $\frac{\partial p}{\partial x} = 0 \quad \frac{\partial p}{\partial y} = 0 \quad \frac{\partial p}{\partial z} = -\gamma \quad \rightarrow \quad \frac{dp}{dz} = -\gamma$	[four operations] (M1N3) → 1st (2A) [derivative] → 12th (To be taught) [partial derivative] → Post-Secondary [gradient] → Post-Secondary	[pressure] (SC5) → 9th (4B) → To be taught	PS	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 2 Fluid Statics (Continued)				
2.3.1 Incompressible Fluid $\int_{p_1}^{p_2} dp = -\gamma\int_{z_1}^{z_2} dz \rightarrow \begin{cases} p_2 - p_1 = -\gamma(z_2 - z_1) \\ p_1 - p_2 = \gamma(z_2 - z_1) \end{cases}$ $\rightarrow p_1 - p_2 = \gamma h \rightarrow \begin{cases} p_1 = \gamma h + p_2 \\ h = \frac{p_1 - p_2}{\gamma} \end{cases}$ $p = \gamma h + p_0 = \rho g h + p_0$	[four operations] (M1N3) → 1st (2A) [integration] → 12th (To be taught) Note: The main Survey Form ula $p = \gamma h + p_0 = \rho g h + p_0$ does not need calculus.	[pressure] (SC5) → 9th (4B) → To be taught	9th	9th
2.3.2 Compressible Fluid $\left.\begin{matrix} p = \rho RT \\ \rho = \frac{p}{RT} \\ \frac{dp}{dz} = -\gamma = -\rho g \end{matrix}\right\\} \frac{dp}{dz} = -\frac{gp}{RT} \rightarrow$ $(dz)\frac{dp}{dz(p)} = -\frac{gp}{RT(p)}(dz) \quad \frac{dp}{p} = -\frac{g}{RT}dz \rightarrow$ $\int_{p_1}^{p_2}\frac{dp}{p} = \int_{z_1}^{z_2} -\frac{g}{RT}dz = -\frac{g}{R}\int_{z_1}^{z_2}\frac{dz}{T} \rightarrow$ $\int_{p_1}^{p_2}\frac{dp}{p} = \ln\frac{p_2}{p_1} = -\frac{g}{R}\int_{z_1}^{z_2}\frac{dz}{T}$ $p_2 = p_1 \exp\left[-\frac{g(z_2 - z_1)}{RT_0}\right]$	[four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A) [integration] → 12th (To be taught as a special skill) [derivative] → 12th (To be taught) Note: The main formula $p_2 = p_1 \exp\left[-\frac{g(z_2 - z_1)}{RT_0}\right]$ does not need calculus	[pressure] (SC5) → 9th (4B) → To be taught **[absolute temperature]** (SP3) → 9th (3B) → To be taught **[gas/liquid]** (SPS5) → 9th (3B) → To be taught	9th	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 2 Fluid Statics (Continued)				
2.4 Standard Atmosphere $T = T_a - \beta z \quad p = p_a\left(1-\frac{\beta z}{T_a}\right)^{g/R\beta}$	[four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A)	[temperature] (SP3) → 9th (3B) [pressure] (SC5) → 9th (4B) → To be taught [density] (S6E5) → 6th (4A) [weight] (MKM1) → K (2C)	9th	9th + PS
2.5 Measurement of Pressure $p_{abs} = p_{gage} + p_{atm} \quad p_{atm} = \gamma h + p_{vapor}$	[four operations] (M1N3) → 1st (2A)	[pressure] (SC5) → 9th (4B) → To be taught	9th	
2.6 Monometry	[four operations] (M1N3) → 1st (2A) [cylinder] (M1G1) (M1G2) → 1st (2B)	[pressure] (SC5) → 9th (4B) → To be taught	9th	
2.6.1 Piezometer Tube $p = \gamma h + p_0 \quad p_A = \gamma_1 h_1$	[four operations] (M1N3) → 1st (2A) [height] (MKM1) → K (2B)	[pressure] (SC5) → 9th (4B) → To be taught	9th	
2.6.2 U-Tube Manometer $p = \gamma h + p_0 \quad p_A + \gamma_1 h_1 - \gamma_2 h_2 = 0 \quad \rightarrow$ $p_A = \gamma_2 h_2 - \gamma_1 h_1 \quad p_A = \gamma_2 h_2$ $p_A + \gamma_1 h_1 - \gamma_2 h_2 - \gamma_3 h_3 = p_B \quad \rightarrow$ $p_A - p_B = \gamma_2 h_2 + \gamma_3 h_3 - +\gamma_1 h_1$	[four operations] (M1N3) → 1st (2A)	[pressure] (SC5) → 9th (4B) → To be taught	9th	
2.6.3 Inclined-Tube Manometer $p_A + \gamma_1 h_1 - \gamma_2 \ell_2 \sin\theta - \gamma_3 h_3 = p_B$ $p_A - p_B = \gamma_2 \ell_2 \sin\theta + \gamma_3 h_3 - \gamma_1 h_1$ $p_A - p_B = \gamma_2 \ell_2 \sin\theta \quad \rightarrow \quad \ell_2 = \frac{p_A - p_B}{\gamma_2 \sin\theta}$	[four operations] (M1N3) → 1st (2A) [trigonometric functions] (MA2G2) → 10th (2F)	[pressure] (SC5) → 9th (4B) → To be taught	9th	
2.7 Mechanical and Electronic Pressure Measuring Devices	N/A	N/A		

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 2 Fluid Statics (Continued)				
2.8 Hydrostatic Force on a Plane Surface $F_R = \int_A \gamma h \, dA = \int_A \gamma y \sin\theta \, dA \quad F_R = \gamma \sin\theta \int_A y \, dA$ $\int_A y \, dA = y_c A \quad F_R = \gamma A y_c \sin\theta$ $F_R = \lambda h_c A \quad F_R y_R = \int_A y \, dF = \int_A \gamma \sin\theta \, y^2 dA$ $y_R = \frac{\int_A y^2 dA}{y_c A} = \frac{I_x}{y_c A} = \frac{I_{xc} + A y_c^2}{y_c A}$ $y_R = \frac{I_{xc}}{y_c A} + \frac{A y_c^2}{y_c A} = \frac{I_{xc}}{y_c A} + y_c \quad \leftarrow \quad I_x = I_{xc} + A y_c^2$ $F_R x_R = \int_A \gamma \, \sin\theta \, xy \, dA \quad x_R = \frac{\int_A xy \, dA}{y_c A} = \frac{I_{xy}}{y_c A}$ $x_R = \frac{I_{xyc}}{y_c A} + x_c \quad I_{xy} = I_{xyc} + A x_c y_c$	[surface] (M6M4) → 6th (2B) [four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A) [trigonometric functions] (MA2G2) → 10th (2F) [integration] → 12th (To be taught as a special skill)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [weight] (MKM1) → K (2C) [pressure] (SC5) → 9th (4B) → To be taught [1st moment of the area] → To be taught [2nd moment of the area] → To be taught	PS	9th + PS
2.9 Pressure Prism $F_R = p_{av} A = \gamma \left(\frac{h}{2}\right) A \quad F_R = volume = \frac{1}{2}(\gamma h)(bh) = \gamma \left(\frac{h}{2}\right) A$ $F_R = F_1 + F_2 \quad F_R y_A = F_1 y_1 + F_2 y_2$	[four operations] (M1N3) → 1st (2A) [prism] (M6G2) → 6th (2B)	[pressure] (SC5) → 9th (4B) → To be taught [force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C)	9th	
2.10 Hydrostatic Force on a Curves Surface $F_H = F_2 \quad F_v = F_1 + \vec{W}$ $F_R = \sqrt{(F_H)^2 + (F_v)^2}$	[four operations] (M1N3) → 1st (2A) [Pythagorean Theorem] (M8G2) → 8th (2B)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C)	9th	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 2 Fluid Statics (Continued)				
2.11 Buoyancy, Flotation, and Stability N/A **2.11.1 Archimedes' Principle** $F_B = F_2 - F_1 - \vec{W} \quad F_2 - F_1 = \gamma(h_2 - h_1)A$ $F_B = \gamma(h_2 - h_1)A - \gamma[(h_2 - h_1)A - \forall]$ $F_B = \gamma\forall \quad F_B y_c = F_2 y_1 - F_1 y_1 - \vec{W} y_2$ $\forall y_c = \forall_T y_1 - (\forall_T - \forall) y_2$ **2.11.2 Stability** N/A	[four operations] (M1N3) → 1st (2A) [volume] (M5M4) → 5th (2B) (M5M4) → 5th (1B) (M6M3) → 6th (2B) (MA1G5) → 9th (2F)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [weight] (M4M1) → 4th (2C)	9th	9th + PS
2.12 Pressure Variation in a Fluid Mechanics with Rigid-Body Motion $-\nabla p - \gamma\hat{k} = \rho\vec{a} \quad \rightarrow \quad \begin{cases} -\dfrac{\partial p}{\partial x} = \rho a_x \\ -\dfrac{\partial p}{\partial y} = \rho a_y \\ -\dfrac{\partial p}{\partial z} = \gamma + \rho a_z \end{cases}$	[four operations] (M1N3) → 1st (2A) [coordinate system] (M4G3) → 4th (2B) [partial derivative] → Post-secondary [gradient] → Post-secondary	[pressure] (SC5) → 9th (4B) → To be taught [density] (S6E5) → 6th (4A)	PS	
2.12.1 Linear Motion $\dfrac{\partial p}{\partial y} = -\rho a_y \quad \dfrac{\partial p}{\partial z} = -\rho(g + a_z) \quad dp = \dfrac{\partial p}{\partial y} dy + \dfrac{\partial p}{\partial z} dz$ $dp = -\rho a_y dy - \rho(g + a_z) dz$ $\dfrac{dz}{dy} = -\dfrac{a_y}{g + a_z} \quad \dfrac{dp}{dz} = -\rho(g + a_z)$	[four operations] (M1N3) → 1st (2A) [derivative] → 12th (To be taught) [partial derivative] → Post-secondary	[pressure] (SC5) → 9th (4B) → To be taught [density] (S6E5) → 6th (4A)	PS	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 2 Fluid Statics (Continued)				
2.12.2 Rigid-Body Rotation $\nabla p = \frac{\partial p}{\partial r}\hat{e}_r + \frac{1}{r}\frac{\partial p}{\partial \theta}\hat{e}_\theta + \frac{\partial p}{\partial z}\hat{e}_z \quad \vec{a}_r = -r\omega^2\hat{e}_r \quad \vec{a}_\theta = 0 \quad \vec{a}_z = 0$ $\frac{\partial p}{\partial r} = \rho r\omega^2 \quad \frac{\partial p}{\partial \theta} = 0 \quad \frac{\partial p}{\partial z} = -\gamma$ $dp = \frac{\partial p}{\partial r}dr + \frac{\partial p}{\partial z}dz \quad dp = \rho r\omega^2 dr - \gamma\ dz$ $dp = 0 \quad \rightarrow \quad 0 = \rho r\omega^2 dr - \gamma\ dz \quad \rightarrow$ $0 = \rho r\omega^2 dr - \rho g\ dz \quad \rightarrow \quad 0 = r\omega^2 dr - g\ dz \quad \rightarrow$ $g\ dz = r\omega^2 dr \quad \rightarrow \quad \frac{dz}{dr} = \frac{r\omega^2}{g} \quad \rightarrow$ $\int \frac{dz}{dr} = \int \frac{r\omega^2}{g} \quad \rightarrow \quad \int \frac{dz}{dr}(dr) = \int \frac{r\omega^2}{g}(dr) \quad \rightarrow$ $\int dz = \int \frac{r\omega^2}{g} dr \quad \rightarrow \quad z = \frac{r^2}{2}\frac{\omega^2}{g} \quad \rightarrow$ $z = \frac{\omega^2 r^2}{2g} + \text{constant} \quad \int dp = \rho\omega^2 \int r\ dr - \gamma \int dz$ $p = \frac{\rho\omega^2 r^2}{2} - \gamma z + \text{constant}$	[four operations] (M1N3) → 1^{st} (2A) [derivative] → 12^{th} (To be taught) [partial derivatives] → Post-secondary [gradient] → Post-secondary [integration] → 12^{th} (To be taught)	[pressure] (SC5) → 9^{th} (4B) → To be taught [gravity] (S6E1) → 6^{th} (3A) [force] (S4P3) → 4^{th} (3A) or (S8P3) → 8^{th} (3C)	PS	9^{th} + PS
2.13 Chapter Summary and Study Guide	N/A	N/A	**9^{th}**	
Chapter 3 Elementary Fluid Dynamics – The Bernoulli Equation				
3.1 Newton's Second Law $\vec{F} = m\vec{a} \quad \sum\left(\vec{F}_P + \vec{F}_g\right) = m\vec{a}$ $a_s = V\frac{\partial V}{\partial s} \quad a_n = V\frac{V^2}{\Re} \quad \leftarrow \quad V = \left\|\vec{V}\right\|$	[four operations] (M1N3) → 1^{st} (2A) [partial derivative] → Post-secondary [volume] (M5M4) → 5^{th} (1B) (M6M3) → 6^{th} (2B) (MA1G5) → 9^{th} (2F) Note: The main formula $\vec{F} = m\vec{a}$ does not need calculus	[Newton's 1^{st}, 2^{nd} and 3^{rd} Laws] (SP1) → 9^{th} (3C) → To be taught [force] (S4P3) → 4^{th} (3A) or (S8P3) → 8^{th} (3C) [speed] (S2P3) → 2^{nd} (3A)	9^{th}	9^{th} + PS

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 3 Elementary Fluid Dynamics – The Bernoulli Equation (Continued)				
3.2 F = ma along a Streamline $\sum \delta F_s = \delta m a_s = \delta m V \frac{\partial V}{\partial s} = \rho \delta \mathcal{V} V \frac{\partial V}{\partial s}$ $\left.\begin{matrix}\delta \vec{W} = \gamma \delta \mathcal{V} \\ \gamma = \rho g\end{matrix}\right\} \rightarrow \delta \vec{W}_s = -\delta \vec{W} \sin\theta = -\gamma \delta X \mathcal{V} \sin\theta$ $\delta p_s \approx \frac{\partial p}{\partial s} \frac{\delta s}{2}$ $\delta F_{ps} = (p - \delta p_s)\delta n \delta y - (p + \delta p_s)\delta n \delta y = -2\delta p_s \delta n \delta y$ $= -\frac{\partial p}{\partial s} \delta s \delta n \delta y = -\frac{\partial p}{\partial s} \delta \mathcal{V}$ $\sum \delta F_s = \delta \vec{W}_s + \delta F_{ps} = \left(-\gamma \sin\theta - \frac{\partial p}{\partial s}\right)\delta \mathcal{V}$ $-\gamma \sin\theta - \frac{\partial p}{\partial s} = \rho V \frac{\partial V}{\partial s} = \rho a_s$ $-\gamma \frac{dz}{ds} - \frac{dp}{ds} = \frac{1}{2}\rho \frac{d(V^2)}{ds} \rightarrow dp + \frac{1}{2}\rho d(V^2) + \gamma\, dz = 0$ $\int \frac{dp}{\rho} + \frac{1}{2}V^2 + gz = C$ (along a streamline) $p + \frac{1}{2}\rho V^2 + \gamma z =$ constant along a streamline (Bernoulli Equation)	[four operations] (M1N3) → 1^{st} (2A) [trigonometric functions] (MA2G2) → 10^{th} (2F) [partial derivative] → Post-secondary [sigma notation] (M6N1) → 6^{th} (1A) or (MA1A3) → 9^{th} (2E) Note: The main formulas $\vec{F} = m\vec{a}$ and $p + \frac{1}{2}\rho V^2 + \gamma z =$ constant along a streamline (Bernoulli Equation) do not need calculus	[force] (S4P3) → 4^{th} (3A) or (S8P3) → 8^{th} (3C) [gravity] (S6E1) → 6^{th} (3A) [mass] (S8P3) → 8^{th} (3A) [acceleration] (S8P3) → 8th (3C)	9^{th}	9^{th} + PS

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 3 Elementary Fluid Dynamics – The Bernoulli Equation (Continued)				
3.2 F = ma along a Streamline (Continued) Alternatively $p_N + \frac{1}{2}\rho_N \cdot {v_N}^2 + \rho_N \cdot g \cdot z_N = C_{streamline\,N}$ $\text{Pressure(along a streamline)} + \text{Kinetic Energy} + \text{Potential Energy}$ $= \text{Constant}$ $\begin{cases} p = \frac{F}{A} = \frac{F \cdot r}{A \cdot r} = \frac{W}{V} \text{ (Work per unit volume)} \\ \frac{1}{2}\rho \cdot v^2 = \frac{1}{2}\frac{m}{\cancel{V}} \cdot v^2 = \frac{\frac{1}{2} m \cdot v^2}{\cancel{V}} = \frac{KE}{\cancel{V}} \text{ (Kinetic energy per unit volume)} \\ \rho \cdot g \cdot z = \frac{m}{\cancel{V}} \cdot g \cdot z = \frac{m \cdot g \cdot z}{\cancel{V}} = \frac{PE}{\cancel{V}} \\ \text{(Potential energy per unit volume. } z\hat{k} \uparrow \equiv h;\ g \equiv -z\hat{k} \downarrow \text{)} \end{cases}$ Law of conservation of mass + Law of conservation of energy Bernouilli's Equation $p_N + \frac{1}{2}\rho_N \cdot {v_N}^2 + \rho_N \cdot g \cdot z_N = C_{streamline\ N}$ $(v_{in} \cdot \hat{n}_{Ain}) \cdot A_{in} = A_{2\ out} \cdot v_{2\ out} + A_{1\ out} \cdot v_{1\ out}$	[four operations] (M1N3) → 1st (2A) [trigonometric functions] (MA2G2) → 10th (2F) [dot product] → To be taught as a special math topic [partial derivative] → Post-secondary [sigma notation] (M6N1) → 6th (1A) or (MA1A3) → 9th (2E)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [gravity] (S6E1) → 6th (3A) [mass] (S8P3) → 8th (3A) [acceleration] (S8P3) → 8th (3C)	PS	9th + PS

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 3 Elementary Fluid Dynamics – The Bernoulli Equation (Continued)				
3.3 F = ma Normal to a Streamline $\sum \delta F_n = \frac{\delta m V^2}{\Re} = \frac{\rho \delta \mathcal{V} V^2}{\Re}$ $\delta \vec{W}_n = -\delta \vec{W} \cos\theta = -\lambda \delta \mathcal{V} \cos\theta$ $\delta F_{pn} = (p - \delta p_n)\delta s \delta y - (p + \delta p_n)\delta s \delta y = -2 p_n \delta s \delta y$ $= -\frac{\partial p}{\partial n}\delta s \delta n \delta y = -\frac{\partial p}{\partial n}\delta \mathcal{V}$ $\sum \delta F_n = \delta \vec{W}_n + \delta F_{pn} = \left(-\gamma \cos\theta - \frac{\partial p}{\partial n}\right)\delta \mathcal{V}$ $-\gamma \frac{dz}{dn} - \frac{\partial p}{\partial n} = \frac{\rho V^2}{\Re} \quad \frac{\partial p}{\partial n} = -\frac{\rho V^2}{\Re}$ $\left.\begin{matrix} \left(-\gamma \frac{dz}{dn} - \frac{\partial p}{\partial n}\right) dn = \left(\frac{\rho V^2}{\Re}\right) dn \\ \frac{\partial p}{\partial n} = \frac{dp}{dn} \quad s = \text{constant} \end{matrix}\right\} \rightarrow$ $\int \frac{dp}{\rho} + \int \frac{V^2}{\Re} dn + gz = \text{constant across the streamline}$ $\text{p} + \rho \int \frac{\text{V}^2}{\Re} dn + \gamma z = \text{constant across the streamline}$	[four operations] (M1N3) → 1st (2A) [trigonometric functions] (MA2G2) → 10th (2F) [partial derivative] → Post-secondary [radius] (M3G1) → 3rd (2B)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [gravity] (S6E1) → 6th (3A) [mass] (S8P3) → 8th (3A) [acceleration] (S8P3) → 8th (3C)	PS	9th + PS

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 3 Elementary Fluid Dynamics – The Bernoulli Equation (Continued)				
3.4 Physical Interpretation $p+\frac{1}{2}\rho V^2+\gamma z = \text{Constant along the streamline}$ $p+\rho\int\frac{V^2}{\Re}dn+\gamma z = \text{constant across the streamline}$ $\frac{p}{\gamma}+\frac{V^2}{2g}+z = \text{constant on a streamline}$	[four operations] (M1N3) → 1st (2A) [integration] → 12th (To be taught) Note: The main formula $p+\frac{1}{2}\rho V^2+\gamma z = \text{Constant along the streamline}$ $\frac{p}{\gamma}+\frac{V^2}{2g}+z = \text{constant on a streamline}$ do not need calculus	[density] (S6E5) → 6th (4A) [speed] (S2P3) → 2nd (3A) [gravity] (S6E1) → 6th (3A)	9th	9th + PS
3.5 Static, Stagnation, Dynamic, and Total Pressure $p_2 = p_1+\frac{1}{2}\rho V_1^2$ $p+\frac{1}{2}V^2+\gamma z = p_T = \text{constant along a streamline}$ $\left.\begin{matrix} p_3 = p+\frac{1}{2}\rho V^2 \\ p_4 = p_1 = p \end{matrix}\right\} \rightarrow \quad p_3-p_4=\frac{1}{2}\rho V^2$ $V=\sqrt{\frac{2(p_3-p_4)}{\rho}}$	[four operations] (M1N3) → 1st (2A) [square root] (M8N1) → 8th (2A)	[pressure] (SC5) → 9th (4B) → To be taught [density] (S6E5) → 6th (4A) [speed] (S2P3) → 2nd (3A)	9th	
3.6 Examples of Use of the Bernoulli Equation $p_1+\frac{1}{2}\rho V_1^2+\gamma z_1 = p_2+\frac{1}{2}\rho V_2^2+\gamma z_2$	[four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A)	[pressure] (SC5) → 9th (4B) → To be taught [density] (S6E5) → 6th (4A) [speed] (S2P3) → 2nd (3A)	9th	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 3 Elementary Fluid Dynamics – The Bernoulli Equation (Continued)				
3.6.1 Free Jets $\gamma h = \frac{1}{2}\rho V^2 \rightarrow \begin{cases} V = \sqrt{2\frac{\gamma h}{\rho}} = \sqrt{2gh} \\ V = \sqrt{2g(h+H)} \end{cases}$	[four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A) [square root] (M8N1) → 8th (2A)	[pressure] (SC5) → 9th (4B) → To be taught [density] (S6E5) → 6th (4A) [speed] (S2P3) → 2nd (3A)	9th	9th + PS
3.6.2 Confined Flows $\rho_1 A_1 V_1 = \rho_2 A_2 V_2 \rightarrow A_1 V_1 = A_2 V_2 \rightarrow Q_1 = Q_2$	[four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A) [areas of geometric shapes] (M5M1) → 5th (2B)	[density] (S6E5) → 6th (4A) [speed] (S2P3) → 2nd (3A)	9th	
3.6.3 Flowrate Measurement $p_1 + \frac{1}{2}\rho V_1^2 = p_2 + \frac{1}{2}\rho V_2^2 \quad Q = A_1 V_1 = A_2 V_2$ $Q = A_2\sqrt{\frac{2(p_1 - p_2)}{\rho\left[1-\left(\frac{A_2}{A_1}\right)^2\right]}}$ $p_1 + \frac{1}{2}\rho V_1^2 + \gamma z_1 = p_2 + \frac{1}{2}\rho V_2^2 + \gamma z_2 \quad Q = A_1 V_1 = bV_1 z_1 = A_2 V_2 = bV_2 z_2$ $p_1 = p_2 = 0 \rightarrow Q = z_2 b\sqrt{\frac{2g(z_1 - z_2)}{1-\left(\frac{z_2}{z_1}\right)^2}}$ $Q = C_1 Hb\sqrt{2gH} = C_1 b\sqrt{2g}H^{3/2}$ $z_1 >> z_2 \rightarrow Q = z_2 b\sqrt{2gz_1}$	[four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A) [square root] (M8N1) → 8th (2A) [areas of geometric shapes] (M5M1) → 5th (2B)	[density] (S6E5) → 6th (4A) [speed] (S2P3) → 2nd (3A) [pressure] (SC5) → 9th (4B) → To be taught [gravity] (S6E1) → 6th (3A)	9th	
3.7 The Energy Line and the Hydraulic Grade Line $\frac{p}{\gamma} + \frac{V^2}{2g} + z = \text{constant on a streamline} = H$	[four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A) [square root] (M8N1) → 8th (2A)	[density] (S6E5) → 6th (4A) [speed] (S2P3) → 2nd (3A) [gravity] (S6E1) → 6th (3A)	9th	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 3 Elementary Fluid Dynamics – The Bernoulli Equation (Continued)				
3.8 Restrictions on Use of the Bernoulli Equation **3.8.1 Compressibility Effects** $RT\int \frac{dp}{p} + \frac{1}{2}V^2 + gz = \text{constant} \qquad \rho = \frac{p}{RT}$ $\frac{V_1^2}{2g} + z_1 + \frac{RT}{g}\ln\left(\frac{p_1}{p_2}\right) = \frac{V_2^2}{2g} + z_2$ $C^{1/k}\int p^{-1/k}dp + \frac{1}{2}V^2 + gz = \text{constant}$ $C^{1/k}\int_{p_1}^{p_2} p^{-1/k}dp = C^{1/k}\left(\frac{k}{k-1}\right)\left[p_2^{(k-1)/k} - p_1^{(k-1)/k}\right]$ $= \left(\frac{k}{k-1}\right)\left(\frac{p_2}{p_1} - \frac{p_1}{p_1}\right)$ $\left(\frac{k}{k-1}\right)\frac{p_1}{p_1} + \frac{V_1^2}{2} + gz_1 = \left(\frac{k}{k-1}\right)\frac{p_2}{p_2} + \frac{V_2^2}{2} + gz_2$ $\frac{p_2 - p_1}{p_1} = \left[\left(1 + \frac{k-1}{2}Ma_1^2\right)^{k/k-1} - 1\right]$ (compressible) $\left.\begin{array}{l} \frac{p_2}{p_1} = \frac{V_1^2}{2RT_1} \\ Ma_1 = \frac{V_1}{\sqrt{kRT_1}} \end{array}\right\} \rightarrow \frac{p_2 - p_1}{p_1} = \frac{kMa_1^2}{2}$ (incompressible) $\frac{p_2 - p_1}{p_1} = \frac{kMa_1^2}{2}\left(1 + \frac{1}{4}Ma_1^2 + \frac{2-k}{24}Ma_1^4 + \ldots\right)$ (compressible)	[four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A) [logarithmic functions] (MA2A5) → 10th (2E) (To be taught as a special skill) [integration] → 12th (To be taught as a special skill) Note: The main formulas $RT\int \frac{dp}{p} + \frac{1}{2}V^2 + gz = \text{constant} \qquad \rho = \frac{p}{RT}$ And others do not need calculus	[density] (S6E5) → 6th (4A) [speed] (S2P3) → 2nd (3A) [gravity] (S6E1) → 6th (3A)	9th	9th + PS

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 3 Elementary Fluid Dynamics – The Bernoulli Equation (Continued)				
3.8.2 Unsteady Effects $\rho \frac{\partial V}{\partial t} ds + dp + \frac{1}{2}\rho d\left(V^2\right) + \gamma\ z = 0$ (along a streamline) $p_1 + \frac{1}{2}\rho V_1^2 + \gamma z_1 = \rho \int_{s_1}^{s_2} \frac{\partial V}{\partial t} ds + p_2 + \frac{1}{2}\rho V_2^2 + \gamma z_2$ (along a streamline)	[four operations] (M1N3) → 1st (2A) [derivative] → 12th (To be taught) [integration] → 12th (To be taught)	[pressure] (SC5) → 9th (4B) → To be taught [density] (S6E5) → 6th (4A) [speed] (S2P3) → 2nd (3A)	PS	9th + PS
3. 8.3 Rotational Effects $p_1 + \frac{1}{2}\rho V_1^2 + \gamma z_1 = p_2 + \frac{1}{2}\rho V_2^2 + \gamma z_2 = \text{constant} = \mathrm{C}_{12}$ $\left. \begin{array}{l} V_1 = V_2 = V_0 \\ z_1 = z_2 = 0 \\ p_1 = p_2 = p_0 \end{array} \right\} \rightarrow \mathrm{C}_{12} = \frac{1}{2}\rho V_0^2 + p_0$ $\left. \begin{array}{l} V_3 = V_4 = V_0 \\ z_3 = z_4 = h \\ \vec{F} = m\vec{a} \\ p_3 = p_1 - \gamma h \\ p_3 = p_4 \end{array} \right\} \rightarrow \mathrm{C}_{34} = \mathrm{C}_{12} \rightarrow$ $p + \frac{1}{2}\rho V^2 + \gamma z = \text{constant throughout flow}$ $p_4 = p_5 + \gamma H = \gamma H \quad H = \frac{p_4}{\gamma}$ **3.8.4 Other Restrictions** **3.9 Chapter Summary and Study Guide**	[four operations] (M1N3) → 1st (2A)	[pressure] (SC5) → 9th (4B) → To be taught [density] (S6E5) → 6th (4A) [speed] (S2P3) → 2nd (3A)	9th	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 4 Fluid Kinematics				
4.1 The Velocity Field $\vec{V} = u(x,y,z,t)\hat{i} + v(x,y,z,t)\hat{j} + w(x,y,z,t)\hat{k}$ $V = \lvert\vec{V}\rvert = (u^2 + v^2 + w^2)^{1/2}$	[four operations] (M1N3) → 1st (2A) [coordinate system] (M4G3) → 4th (2B) [functions] (MA1A1) → 9th (2E) and others → Post-secondary	[velocity] (S8P3)→ 8th (3A)	PS	PS
4.1.1 Eulerian and Lagrangian Flow Descriptions $\left.\begin{array}{l} x = x_0 \\ y = y_0 \\ z = z_0 \end{array}\right\}$ $T = T(x_0, y_0, z_0, t)$ $T = T(x, y, z, t)$	[four operations] (M1N3) → 1st (2A) [calculus] → Post-secondary [Eulerian method] → Post-secondary [Lagrangian method] → Post-secondary	[temperature] (SP3) → 9th (3B)	PS	
4.1.2 one-, Two-, and three-Dimensional Flows $\vec{V} = \vec{V}(x,t) = u\hat{i}$ $\vec{V} = \vec{V}(x,y,,t) = u\hat{i} + v\hat{j}$ $\vec{V} = \vec{V}(x,y,z,t) = u\hat{i} + v\hat{j} + w\hat{k}$	[four operations] (M1N3) → 1st (2A) [coordinate system] (M4G3) → 4th (2B)	[velocity] (S8P3)→ 8th (3A)	PS	
4.1.3 Steady and Unsteady Flows $\frac{\partial \vec{V}}{\partial t} = 0$	[four operations] (M1N3) → 1st (2A) [partial derivative] → Post-secondary		PS	
4.1.4 Streamilnes, Streaklines, and Pathlines $\frac{dy}{dx} = \frac{v}{u}$	[four operations] (M1N3) → 1st (2A) [derivative] → 12th (To be taught)	[velocity] (S8P3)→ 8th (3A)		
4.2 The Acceleration Field $\vec{a} = \vec{a}(t)$	[four operations] (M1N3) → 1st (2A) [functions] (MA1A1) → 9th (2E) and others → Post-secondary	[velocity] (S8P3)→ 8th (3A) [acceleration] (S8P3) → 8th (3C)	PS	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 4 Fluid Kinematics (Continued)				
4.2.1 The Material Derivative $\vec{V}_A = \vec{V}_A(r_A,t) = \vec{V}_A[x_A(t), y_A(t), z_A(t), t]$ $x_A = x_A(t) \quad y_A = y_A(t) \quad z_A = z_A(t)$ $\vec{a}_A(t) = \frac{d\vec{V}_A}{dt} = \frac{\partial \vec{V}_A}{\partial t} + \frac{\partial \vec{V}_A}{\partial x}\frac{dx_A}{dt} + \frac{\partial \vec{V}_A}{\partial y}\frac{dy_A}{dt} + \frac{\partial \vec{V}_A}{\partial z}\frac{dz_A}{dt}$ $\vec{a}_A = \frac{\partial \vec{V}_A}{\partial t} + u_A\frac{\partial \vec{V}_A}{\partial x} + v_A\frac{\partial \vec{V}_A}{\partial y} + w_A\frac{\partial \vec{V}_A}{\partial z}$ $\vec{a} = \frac{\partial \vec{V}}{\partial t} + u\frac{\partial \vec{V}}{\partial x} + v\frac{\partial \vec{V}}{\partial y} + w\frac{\partial \vec{V}}{\partial z}$ $\left.\begin{array}{l} a_x = \frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} \\ a_y = \frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z} \\ a_x = \frac{\partial w}{\partial t} + u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} + w\frac{\partial w}{\partial z} \end{array}\right\} \rightarrow \quad \vec{a} = \frac{D\vec{V}}{Dt} \quad \rightarrow$ $\frac{D(\;)}{Dt} \equiv \frac{\partial(\;)}{\partial t} + u\frac{\partial(\;)}{\partial x} + v\frac{\partial(\;)}{\partial y} + w\frac{\partial(\;)}{\partial z} = \frac{\partial(\;)}{\partial t} + (\vec{V}\cdot\nabla)(\;)$ (Material Derivative or Substantial Derivative) $\uparrow \left\{\begin{array}{l} \nabla(\;) = \frac{\partial(\;)}{\partial x}\hat{i} + \frac{\partial(\;)}{\partial y}\hat{j} + \frac{\partial(\;)}{\partial z}\hat{k} \\ \vec{V}\cdot\nabla(\;) = u\frac{\partial(\;)}{\partial x} + v\frac{\partial(\;)}{\partial y} + w\frac{\partial(\;)}{\partial z} \end{array}\right. \leftarrow \left\{\begin{array}{l} T = T(x,y,z,t) \\ \vec{V} = \vec{V}(x,y,z,t) \end{array}\right\}$ $\rightarrow \left\{\begin{array}{l} \frac{dT_A}{dt} = \frac{\partial T_A}{\partial t} + \frac{\partial T_A}{\partial x}\frac{dx_A}{dt} + \frac{\partial T_A}{\partial y}\frac{dy_A}{dt} + \frac{\partial T_A}{\partial z}\frac{dz_A}{dt} \\ \frac{DT}{Dt} = \frac{\partial T}{\partial t} + u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} + w\frac{\partial T}{\partial z} = \frac{\partial T}{\partial t} + \vec{V}\cdot\nabla T \end{array}\right.$	[four operations] (M1N3) → 1st (2A) [dot product] → To be taught as a special math topic [gradient: "del"] → Post-secondary [partial derivative] → Post-secondary	[velocity] (S8P3)→ 8th (3A) [acceleration] (S8P3) → 8th (3C)	PS	PS

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 4 Fluid Kinematics (Continued)				
4.2.2 Unsteady Effects $\because \left.\begin{array}{l}\frac{\partial u}{\partial x}=0\\ v=w=0\end{array}\right\} \quad \therefore \quad \vec{a}=\frac{\partial \vec{V}}{\partial t}+u\frac{\partial \vec{V}}{\partial x}+v\frac{\partial \vec{V}}{\partial y}w\frac{\partial \vec{V}}{\partial z}=\frac{\partial \vec{V}}{\partial t}=\frac{\partial V_0}{\partial t}\hat{i}$	[four operations] (M1N3) → 1st (2A) [partial derivatives] → Post-secondary	[velocity] (S8P3)→ 8th (3A)	PS	9th + PS
4.2.3 Convective Effects $\nabla(\ )=\frac{\partial(\ )}{\partial x}\hat{i}+\frac{\partial(\ )}{\partial y}\hat{j}+\frac{\partial(\ )}{\partial z}\hat{k}$ $(\vec{V}\cdot\nabla)\vec{V}$ (Convective Acceleration)	[four operations] (M1N3) → 1st (2A) [absolute value] (M7N1) → 7th (2A) [coordinate system] (M4G3) → 4th (2B) [analytic geometry] → Post-secondary [partial derivatives] → Post-secondary	[velocity] (S8P3)→ 8th (3A) [acceleration] (S8P3) → 8th (3C)	PS	
4.2.4 Streamline Coordinates $\vec{V}=V\hat{s}$ $\vec{a}=\frac{D\vec{V}}{Dt}=a_s\hat{s}+a_n\hat{n} \quad \vec{a}=\frac{D(V\hat{s})}{Dt}=\frac{DV}{Dt}\hat{s}+V\frac{D\hat{s}}{Dt}$ $\vec{a}=\left(\frac{\partial V}{\partial t}+\frac{\partial V}{\partial s}\frac{ds}{dt}+\frac{\partial V}{\partial n}\frac{dn}{dt}\right)\hat{s}+V\left(\frac{\partial \hat{s}}{\partial t}+\frac{\partial \hat{s}}{\partial s}\frac{ds}{dt}+\frac{\partial \hat{s}}{\partial n}\frac{dn}{dt}\right)$ $\vec{a}=\left(V\frac{\partial V}{\partial s}\right)\hat{s}+V\left(V\frac{\partial \hat{s}}{\partial s}\right)$	[four operations] (M1N3) → 1st (2A) [radius] (M3G1) → 3rd (2B) [absolute value] (M7N1) → 7th (2A) [analytic geometry] → Post-secondary [partial derivative] → Post-secondary [limit] → Post-secondary	[velocity] (S8P3)→ 8th (3A) [acceleration] (S8P3) → 8th (3C)	PS	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 4 Fluid Kinematics (Continued)				
4.2.4 Streamline Coordinates (Continued) $\left.\begin{array}{l} \delta s \to 0 \\ \lvert\hat{s}\rvert = 1 \\ \dfrac{\partial s}{\Re} = \dfrac{\lvert\delta\hat{s}\rvert}{\lvert\hat{s}\rvert} = \lvert\delta\hat{s}\rvert \\ \left\lvert\dfrac{\lvert\delta\hat{s}\rvert}{\lvert\delta s\rvert}\right\rvert = \dfrac{1}{\Re} \end{array}\right\} \to \dfrac{\partial\hat{s}}{\partial s} = \lim_{\delta s\to 0}\dfrac{\delta\hat{s}}{\delta s} = \dfrac{\hat{n}}{\Re}$ $\vec{a} = V\dfrac{\partial V}{\partial s}\hat{s} + \dfrac{V^2}{\Re}\hat{n} \leftarrow \begin{cases} a_s = \dfrac{\partial V}{\partial s} \\ a_n = \dfrac{V^2}{\Re} \end{cases}$	[four operations] (M1N3) → 1^{st} (2A) [radius] (M3G1) → 3^{rd} (2B) [absolute value] (M7N1) → 7^{th} (2A) [analytic geometry] → 12^{th} (To be taught) [partial derivative] → Post-secondary [limit] → Post-secondary	[velocity] (S8P3)→ 8^{th} (3A) [acceleration] (S8P3) → 8th (3C)	PS	9^{th} + PS
4.3 Control Volume and System Representations $F = \dfrac{d(mv)}{dt}$	[four operations] (M1N3) → 1^{st} (2A) [volume] (M5M4) → 5^{th} (1B) (M6M3) → 6^{th} (2B) (MA1G5) → 9^{th} (2F) [areas of geometric shapes] (M5M1) → 5^{th} (2B)	[velocity] (S8P3)→ 8^{th} (3A)	9^{th}	
4.4 The Reynolds Transport Theorem $B = mb \begin{cases} B = m \to b = 1 \\ B = \dfrac{mV^2}{2} \to b = \dfrac{V^2}{2} \\ \vec{B} = m\vec{V} \to \vec{b} = \vec{V} \end{cases}$ B : Extensive Property b : Intensive Property Infinitesimal fluid particles : $\delta \forall \to 0$	[four operations] (M1N3) → 1^{st} (2A) [integration] → 12^{th} (To be taught)	[velocity] (S8P3)→ 8^{th} (3A) [acceleration] (S8P3) → 8th (3C) [mass] (S8P3) → 8^{th} (3A) [temperature] (SP3) → 9^{th} (3B) [momentum] (SP3) → (3B)	9^{th}	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 4 Fluid Kinematics (Continued)				
4.4 The Reynolds Transport Theorem (Continued) $B_{sys} = \lim_{\delta\forall \to 0} = \sum_i b_i(\rho_i \delta\forall_i) = \int_{sys} \rho b \, d\forall$ $\uparrow \quad \delta B = b\rho \; \delta\forall$ $\frac{dB_{sys}}{dt} = \frac{d\left(\int_{sys} \rho b \, d\forall\right)}{dt} \quad \frac{dB_{cv}}{dt} = \frac{d\left(\int_{cv} \rho b \, d\forall\right)}{dt}$	[four operations] (M1N3) → 1st (2A) [integration] → 12th (To be taught)	[velocity] (S8P3)→ 8th (3A) [acceleration] (S8P3) → 8th (3C) [mass] (S8P3) → 8th (3A) [temperature] (SP3) → 9th (3B) [momentum] (SP3) → (3B)	PS	9th + PS
4.4.1 Derivation of the Reynolds Transport Theorem $\frac{DB_{system}}{Dt} = \frac{\partial B_{CV}}{\partial t} + \dot{m}_{out} \cdot b_{out} - \dot{m}_{in} \cdot b_{in}$ $\vec{F}_{system} = \frac{d[m\vec{V}]}{dt} = \frac{\partial [m\vec{V}]_{CV}}{\partial t} + \sum(\dot{m}_{out} \cdot \vec{V}_{out}) - \sum(\dot{m}_{in} \cdot \vec{V}_{in})$ $\leftarrow \begin{cases} \frac{d[m\vec{V}]}{dt} = m\frac{d[\vec{V}]}{dt} = m\vec{a} = \vec{F} \text{ (Newtons Second Law)} \\ \because \; \dot{m} \cdot \vec{V} \equiv \frac{dm}{dt}\vec{V} = m\frac{d\vec{V}}{dt} = m\vec{a} = \vec{F} \quad \& \quad \frac{d[\vec{M}]}{dt} = \frac{d[m\vec{V}]}{dt} = m\frac{d[\vec{V}]}{dt} = m\vec{a} = \vec{F} \\ \therefore \; \sum(\dot{m}_{out} \cdot \vec{V}_{out}) - \sum(\dot{m}_{in} \cdot \vec{V}_{in}) = \text{Momentum} \rightarrow \text{Force} \end{cases}$ Note: Other Formulas used to derive the Reynolds Transport Theorem are available in pages 171-177. $\frac{DB_{sys}}{Dt} = \frac{\partial}{\partial t}\int_{cv} \rho b \, d\forall + \int_{cs} \rho b \, \vec{V} \cdot \hat{n} \, dA$	[four operations] (M1N3) → 1st (2A) [areas of geometric shapes] (M5M1) → 5th (2B) [volume] (M5M4) → 5th (1B) (M6M3) → 6th (2B) (MA1G5) → 9th (2F) [dot product] → To be taught as a special math topic [analytic geometry] → 12th (To be taught) [integration] → 12th (To be taught)	[velocity] (S8P3)→ 8th (3A) [acceleration] (S8P3) → 8th (3C) [mass] (S8P3) → 8th (3A) [density] (S6E5) → 6th (4A) [temperature] (SP3) → 9th (3B) [momentum] (SP3) → (3B)	PS	
4.4.2 Physical Interpretation N/A				

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 4 Fluid Kinematics (Continued)				
4.4.3 Relationship to Material Derivative $\vec{V}\cdot\nabla(\ )=\frac{\partial(\ )}{\partial t}+u\frac{\partial(\ )}{\partial x}+v\frac{\partial(\ )}{\partial y}+w\frac{\partial(\ )}{\partial z}$ $\frac{D(\ )}{Dt}\equiv\frac{\partial(\ )}{\partial t}+u\frac{\partial(\ )}{\partial x}+v\frac{\partial(\ )}{\partial y}+w\frac{\partial(\ )}{\partial z}=\frac{\partial(\ )}{\partial t}+(\vec{V}\cdot\nabla)(\ )$ (Material Derivative or Substantial Derivative)	[four operations] (M1N3) → 1st (2A) [dot product] → To be taught as a special math topic [analytic geometry] → 12th (To be taught) [partial derivative] → Post-secondary	[velocity] (S8P3)→ 8th (3A) [acceleration] (S8P3) → 8th (3C)	PS	9th + PS
4.4.4 Steady Effects $\frac{DB_{sys}}{Dt}=\int_{sys}\rho b\vec{V}\cdot\hat{n}\ dA$	[four operations] (M1N3) → 1st (2A) [analytic geometry] → 12th (To be taught) [dot product] → To be taught as a special math topic [partial derivative] → Post-secondary	[velocity] (S8P3)→ 8th (3A) [density] (S6E5) → 6th (4A) [acceleration] (S8P3) → 8th (3C)	PS	
4.4.5 Unsteady Effects $\frac{DB_{sys}}{Dt}=\frac{\partial}{\partial t}\int_{cv}\rho b\ d\forall+\int_{cs}\rho b\ \vec{V}\cdot\hat{n}\ dA$ $\int_{cs}\rho b\ \vec{V}\cdot\hat{n}\ dA=0 \quad\rightarrow\quad \frac{DB_{sys}}{Dt}=\frac{\partial}{\partial t}\int_{cv}\rho b\ d\forall$ $\vec{V}=V_0\hat{i}\quad \Delta\rho=0\quad \vec{B}=\text{system momentum}=m\vec{V}=mV_0\hat{i}$ $\vec{b}=\frac{\vec{B}}{m}=\vec{V}=V_0\hat{i}\ \begin{cases}\vec{V}\cdot\hat{n}>0 & \text{(out flow)}\\ \vec{V}\cdot\hat{n}<0 & \text{(in flow)}\\ \vec{V}\cdot\hat{n}=0 & \text{(along the side of the CV)}\end{cases}$	[four operations] (M1N3) → 1st (2A) [analytic geometry] → 12th (To be taught) [dot product] → To be taught as a special math topic [integration] → 12th (To be taught) [partial derivative] → Post-secondary	[velocity] (S8P3)→ 8th (3A) [density] (S6E5) → 6th (4A) [acceleration] (S8P3) → 8th (3C) [momentum] (SP3) → (3B)	PS	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 4 Fluid Kinematics (Continued)				
4.4.5 Unsteady Effects (Continued) $\frac{DB_{sys}}{Dt} = \frac{\partial}{\partial t}\int_{cv}\rho b\, d\mathcal{V} + \int_{cs}\rho b\,\vec{V}\cdot\hat{n}\, dA$ $\int_{cs}\rho b\,\vec{V}\cdot\hat{n}\, dA = 0 \quad \rightarrow \quad \frac{DB_{sys}}{Dt} = \frac{\partial}{\partial t}\int_{cv}\rho b\, d\mathcal{V}$ $\vec{V} = V_0\hat{i} \quad \Delta\rho = 0 \quad \vec{B} = \text{system momentum} = m\vec{V} = mV_0\hat{i}$ $\vec{b} = \frac{\vec{B}}{m} = \vec{V} = V_0\hat{i} \quad \left\{\begin{array}{ll} \vec{V}\cdot\hat{n} > 0 & \text{(out flow)} \\ \vec{V}\cdot\hat{n} < 0 & \text{(in flow)} \\ \vec{V}\cdot\hat{n} = 0 & \text{(along the side of the CV)} \end{array}\right\}$ $\left.\begin{array}{ll} \vec{V}\cdot\hat{n} = -V_0 & \text{(one section)} \\ \vec{V}\cdot\hat{n} = V_0 & \text{(another section)} \end{array}\right\} \rightarrow$ $\int_{cs}\rho b\vec{V}\cdot\hat{n}\, dA = \int_{cs}\rho (V_0\hat{i})(\vec{V}\cdot\hat{n})dA$ $= \int_{(1)}\rho (V_0\hat{i})(-V_0)dA + \int_{(2)}\rho (V_0\hat{i})(V_0)dA$ $= -\rho V_0^2 A_1\hat{i} + \rho V_0^2 A_1\hat{i} = 0$	[four operations] (M1N3) → 1st (2A) [analytic geometry] → 12th (To be taught) [dot product] → To be taught as a special math topic → To be taught as a special math topic [integration] → 12th (To be taught) [partial derivative] → Post-secondary	[velocity] (S8P3)→ 8th (3A) [density] (S6E5) → 6th (4A) [acceleration] (S8P3) → 8th (3C) [momentum] (SP3) → (3B)	PS	9th + PS
4.4.6 Moving Control Volumes $\vec{V}_{cv} = \vec{V} - \vec{W} \quad \vec{V} = \vec{W} + \vec{V}_{cv}$ $\frac{DB_{sys}}{Dt} = \frac{\partial}{\partial t}\int_{cv}\rho b\, d\mathcal{V} + \int_{cs}\rho b\vec{W}\cdot\hat{n}\, dA$	[four operations] (M1N3) → 1st (2A) [analytic geometry] [integration] → 12th (To be taught) [partial derivative] → Post-secondary	[velocity] (S8P3)→ 8th (3A) [density] (S6E5) → 6th (4A) [acceleration] (S8P3) → 8th (3C) [momentum] (SP3) → (3B)	PS	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 4 Fluid Kinematics (Continued)				
4.4.7 Selection of a Control Volume N/A	N/A	N/A	9th	9th +
4.5 Chapter Summary and study Guide N/A	N/A	N/A	9th	PS
Chapter 5 Finite Control Volume Analysis				
5.1 Conservation of Mass – The Continuity Equation **5.1.1 Derivation of the Continuity Equation** $\frac{DM_{sys}}{Dt}=0 \quad M_{sys}=\int_{sys}\rho\, d\mathcal{V}$ $\frac{D}{Dt}\int_{sys}\rho\, D\mathcal{V}=\frac{\partial}{\partial t}\int_{cv}\rho\, d\mathcal{V}+\int_{cv}\rho\vec{V}\cdot\hat{n}\, dA \quad \frac{\partial}{\partial t}\int_{cv}\rho\, d\mathcal{V} \quad \int_{cs}\rho\vec{V}\cdot\hat{n}\, dA$ $\frac{\partial}{\partial t}\int_{cv}\rho\, d\mathcal{V}=0 \quad \int_{cs}\rho\vec{V}\cdot\hat{n}\, dA$ $\int_{cs}\rho\vec{V}\cdot\hat{n}\, dA=\sum\dot{m}_{out}-\sum\dot{m}_{in} \quad \frac{\partial}{\partial t}\int_{cv}\rho\, \mathcal{V}+\int_{cs}\rho\mathcal{V}\cdot\hat{n}\, dA=0$ $\dot{m}=\rho Q=\rho AV \quad \dot{m}=\int_{A}\rho\vec{V}\cdot\hat{n}\, dA$ $V_{average}=\bar{V}=\frac{\int_{A}\rho\vec{V}\cdot\hat{n}\, dA}{\rho A}$ $V_{average}=\bar{V}=\frac{\int_{A}\rho\vec{V}\cdot\hat{n}\, dA}{\rho A}=V$ For uniformly distributed velocity (one-dimensional flow)	[four operations] (M1N3) → 1st (2A) [analytic geometry] → 12th (To be taught) [volume] (M5M4) → 5th (1B) (M6M3) → 6th (2B) (MA1G5) → 9th (2F) [areas of geometric shapes] (M5M1) → 5th (2B) [integration] → 12th (To be taught as a special skill)	[mass] (S8P3) → 8th (3A) [density] (S6E5) → 6th (4A) [velocity] (S8P3)→ 8th (3A)	PS	9th + PS

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 5 Finite Control Volume Analysis (Continued)				
5.1.2 Fixed, Non-deforming Control Volume $\frac{\partial}{\partial t}\int_{cv}\rho\, dV\!\!\!/ \quad \sum \dot{m}_{out} - \sum \dot{m}_{in} = 0 \quad \sum Q_{out} - \sum Q_{in} = 0$ $\frac{\partial}{\partial t}\int_{cv}\rho\, dV\!\!\!/$ $\dot{m} = \rho AV$ uniformly distributed over the opening in the control surface (one-dimensional flow) $\dot{m} = \rho A\bar{V}$ uniformly distributed over the opening in the control surface $\dot{m} = \rho_1 A_1 \bar{V}_1 = \rho_2 A_2 \bar{V}_2 \quad Q = A_1\bar{V}_1 = A_2\bar{V}_2$ $\sum \dot{m}_{in} = \sum \dot{m}_{out}$	[four operations] (M1N3) → 1st (2A) [analytic geometry] → 12th (To be taught) [volume] (M5M4) → 5th (1B) (M6M3) → 6th (2B) (MA1G5) → 9th (2F) [areas of geometric shapes] (M5M1) → 5th (2B) [integration] → 12th (To be taught as a special skill) [sigma notation] (M6N1) → 6th (1A) or (MA1A3) → 9th (2E) Note: The main formula $\dot{m} = \rho_1 A_1 \bar{V}_1 = \rho_2 A_2 \bar{V}_2 \quad Q = A_1\bar{V}_1 = A_2\bar{V}_2$ $\sum \dot{m}_{in} = \sum \dot{m}_{out}$ are not based on calculus	[mass] (S8P3) → 8th (3A) [density] (S6E5) → 6th (4A) [velocity] (S8P3) → 8th (3A)	9th	9th + PS
5.1.3 Moving, Non-deforming Control Volume $\vec{V} = \vec{W} + \vec{V}_{cv} \quad \frac{DM_{sys}}{Dt} = \frac{\partial}{\partial t}\int_{cv}\rho\, dV\!\!\!/ + \int_{cs}\rho\vec{W}\cdot\hat{n}\, dA = 0$	[four operations] (M1N3) → 1st (2A) [dot product] → To be taught as a special math topic [integration] → 12th (To be taught)	[velocity] (S8P3) → 8th (3A) [density] (S6E5) → 6th (4A)	PS	
5.1.4 Deforming Control Volume $\frac{DM_{sys}}{Dt} = \frac{\partial}{\partial t}\int_{cv}\rho\, dV\!\!\!/ + \int_{cs}\rho\vec{W}\cdot\hat{n}\, dA = 0 \quad \frac{\partial}{\partial t}\int_{cv}\rho\, dV\!\!\!/ \neq 0$ $\vec{V} = \vec{W} + \vec{V}_{cs}$	[four operations] (M1N3) → 1st (2A) [analytic geometry] → 12th (To be taught) [volume] (M5M4) → 5th (1B) (M6M3) → 6th (2B) (MA1G5) → 9th (2F) [areas of geometric shapes] (M5M1) → 5th (2B) [dot product] → To be taught as a special math topic [partial derivatives] → Post-secondary	[velocity] (S8P3) → 8th (3A) [density] (S6E5) → 6th (4A)	PS	
5.2 Newton's Second Law – The Linear Momentum and Moment-of-Momentum Equation N/A	N/A	N/A	9th	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)		Possible Grade to Start the Topic	
	Math	Physics/Chemistry	Sec	Ch
Chapter 5 Finite Control Volume Analysis (Continued)				
5.2.1 Derivation of the Linear Momentum Equation $\frac{\partial}{\partial}\int_{sys}\vec{V}\rho\, d\forall = \sum \vec{F}_{sys}$ $\sum \vec{F}_{sys} = \sum \vec{F}_{\text{content of the coincident control volume}}$ $\frac{D}{Dt}\int_{sys}\vec{V}\rho\, d\forall = \frac{\partial}{\partial t}\int_{cv}\vec{V}\rho\, d\forall + \int_{cs}\vec{V}\rho\vec{V}\cdot\hat{n}\, dA$ $\frac{\partial}{\partial t}\int_{cv}\vec{V}\rho\, d\forall + \int_{cs}\vec{V}\rho\vec{V}\cdot\hat{n}\, dA = \sum \vec{F}_{\text{content of the control volume}}$	[four operations] (M1N3) → 1st (2A) [areas of geometric shapes] (M5M1) → 5th (2B) [vector] (MA3A10) → 11th (2H) → To be taught as a special math topics [volume] (M5M4) → 5th (1B) (M6M3) → 6th (2B) (MA1G5) → 9th (2F) [dot product] → To be taught as special math topic [analytic geometry] → 12th (To be taught) [integration] → 12th (To be taught as special skill) [derivative] → 12th (To be taught) [partial derivative]	[velocity] (S8P3)→ 8th (3A) [force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [density] (S6E5) → 6th (4A)	PS	9th + PS
5.2.2 Application of the Linear Momentum Equation $\frac{D}{Dt}\int_{sys}\vec{V}\rho\, d\forall = \frac{\partial}{\partial t}\int_{cv}\vec{V}\rho\, d\forall + \int_{cs}\vec{V}\rho\vec{W}\cdot\hat{n}\, dA$ $\frac{\partial}{\partial t}\int_{cv}\vec{V}\rho\, d\forall + \int_{cs}\vec{V}\rho\vec{W}\cdot\hat{n}\, dA = \sum \vec{F}_{\text{content of the control volum}}$ $\frac{\partial}{\partial t}\int_{cv}(\vec{W}+\vec{V}_{cv})\rho\, d\forall + \int_{cs}(\vec{W}+\vec{V}_{cv})\rho\vec{W}\cdot\hat{n}\, dA = \sum \vec{F}_{\text{contents of the control volume}}$ For constant control volume velocity $\frac{\partial}{\partial t}\int_{cv}(\vec{W}+\vec{V}_{cv})\rho\, d\forall \rightarrow$ For inertial, nondeforming control volume $\int_{cs}(\vec{W}+\vec{V}_{cv})\rho\vec{W}\cdot\hat{n}\, dA = \int_{cs}\vec{W}\rho\vec{W}\cdot\hat{n}\, dA + \vec{V}_{cv}\int_{cs}\rho\vec{W}\cdot\hat{n}\, dA$ For steady flow (on an instantaneous or time-average basis $\int_{cs}\rho\vec{W}\cdot\hat{n}\, dA = 0$ $\int_{cs}\vec{W}\rho\vec{W}\cdot\hat{n}\, dA = \sum \vec{F}_{\text{content of the control volume}}$	[four operations] (M1N3) → 1st (2A) [areas of geometric shapes] (M5M1) → 5th (2B) [volume] (M5M4) → 5th (1B) (M6M3) → 6th (2B) (MA1G5) → 9th (2F) [vector] (MA3A10) → 11th (2H) → To be taught as a special math topics [dot product] → To be taught as a special math topic [analytic geometry] → 12th (To be taught) [integration] → 12th (To be taught as a special skill) [derivative] → 12th (To be taught) [partial derivative] → Post-secondary	[velocity] (S8P3)→ 8th (3A) [force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [density] (S6E5) → 6th (4A)	PS	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 5 Finite Control Volume Analysis (Continued)				
5.2.3 Derivation of the Moment-of-Momentum Equation $\frac{D}{Dt}(\vec{V}\rho\delta\forall)=\delta\vec{F}_{particle}$ $\vec{r}\times\frac{D}{Dt}(\vec{V}\rho\,\delta\forall)=\vec{r}\times\delta\vec{F}_{particle}$ $\frac{D}{Dt}[(\vec{r}\times\vec{V})\rho\delta\forall]=\frac{D\vec{r}}{Dt}\times\vec{V}\rho\delta\forall+\vec{r}\times\frac{D(\vec{V}\rho\delta\forall)}{Dt}$ $\frac{D\vec{r}}{Dt}=\vec{V}$ $\vec{V}\times\vec{V}=0\rightarrow\frac{D}{Dt}[(\vec{r}\times\vec{V})\rho\delta\forall]=\vec{r}\times\delta\vec{F}_{particle}$ $\int_{sys}\frac{D}{Dt}[(\vec{r}\times\vec{V})\rho\,d\forall]=\sum(\vec{r}\times\vec{F})_{sys}$ $\sum\vec{r}\times\delta\vec{F}_{particle}=\sum(\vec{r}\times\vec{F})_{sys}$ $\frac{D}{Dt}\int_{sys}(\vec{r}\times\vec{V})\rho\,d\forall=\int_{sys}\frac{D}{Dt}[(\vec{r}\times\vec{V})\rho\,d\forall]$ $\frac{D}{Dt}\int_{sys}(\vec{r}\times\vec{V})\rho\,d\forall=\sum(\vec{r}\times\vec{F})_{sys}$ $\sum(\vec{r}\times\vec{F})_{sys}=\sum(\vec{r}\times\vec{F})_{cv}$ $\frac{D}{Dt}\int_{sys}(\vec{r}\times\vec{V})\rho\,d\forall=\frac{\partial}{\partial t}\int_{cv}(\vec{r}\times\vec{V})\rho\,d\forall+\int_{cs}(\vec{r}\times\vec{V})\rho\vec{V}\,\hat{n}\,dA$ $\frac{\partial}{\partial t}\int_{cv}(\vec{r}\times\vec{V})\rho\,d\forall+\int_{cs}(\vec{r}\times\vec{V})\rho\vec{V}\,\hat{n}\,dA=\sum(\vec{r}\times\vec{F})_{\text{contents of the control volume}}$	[four operations] (M1N3) → 1st (2A) [areas of geometric shapes] (M5M1) → 5th (2B) [volume] (M5M4) → 5th (1B) (M6M3) → 6th (2B) (MA1G5) → 9th (2F) [vector] (MA3A10) → 11th (2H) → To be taught as a special math topics [analytic geometry] → 12th (To be taught) [cross product] → To be taught as a special math topic [integration] → 12th (To be taught) [derivative] → 12th (To be taught) [partial derivative] → Post-secondary [sigma notation] (M6N1) → 6th (1A) or (MA1A3) → 9th (2E)	[velocity] (S8P3)→ 8th (3A) [force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [density] (S6E5) → 6th (4A)	PS	9th + PS

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 5 Finite Control Volume Analysis (Continued)				
5.2.4 Application of the Moment-of-Momentum Equation $\frac{\partial}{\partial t}\int_{cv}(\vec{r}\times\vec{V})\rho\, d\forall = 0 \quad \int_{cs}(\vec{r}\times\vec{V})\rho\vec{V}\cdot\hat{n}\, dA \quad \vec{V}=\vec{W}+\vec{U}$ $\int_{cs}(\vec{r}\times\vec{V})\rho\vec{V}\cdot\hat{n}\, dA \quad \left[\int_{cs}(\vec{r}\times\vec{V})\rho\vec{V}\cdot\hat{n}\, dA\right]_{axial} = (-r_2V_{\theta 2})(+\dot{m})$ $\sum\left[(\vec{r}\times\vec{F})_{\text{contents of the control volume}}\right]_{\text{axial}} = T_{\text{shaft}} \quad -r_2V_{\theta 2}\dot{m} = T_{shaft}$ $\dot{W}_{shaft} = T_{shaft}\omega = -r_2V_{\theta 2}\dot{m}\omega \quad \dot{W}_{shaft} = -U_2V_{\theta 2}\dot{m} \quad w_{shaft} = -U_2V_{\theta 2}$ $T_{shaft} = (-\dot{m}_{in})(\pm r_{in}V_{\theta in}) + \dot{m}_{out}(\pm r_{out}V_{\theta out}) \quad \dot{W}_{shaft} = T_{shaft}\omega$ $\dot{W}_{shaft} = (-\dot{m}_{in})(\pm r_{in}\omega V_{\theta in}) + \dot{m}_{out}(\pm r_{out}\omega V_{\theta out})$ $r\omega = U \quad \rightarrow \quad \dot{W}_{shaft} = (-\dot{m}_{in})(\pm U_{in}\omega V_{\theta in}) + \dot{m}_{out}(\pm U_{out}\omega V_{\theta out})$ $\dot{m} = \dot{m}_{in} = \dot{m}_{out} \quad w_{shaft} = -(\pm U_{in}V_{\theta in}) + (\pm U_{out}V_{\theta out})$	[four operations] (M1N3) → 1st (2A) [areas of geometric shapes] (M5M1) → 5th (2B) [volume] (M5M4) → 5th (1B) (M6M3) → 6th (2B) (MA1G5) → 9th (2F) [vector] (MA3A10) → 11th (2H) → To be taught as a special math topics [dot product] and [cross product] → To be taught as a special math topics [analytic geometry] → 12th (To be taught) [integration] → 12th (To be taught as a special skill) [derivative] → 12th (To be taught) [partial derivative] → Post-secondary	[velocity] (S8P3)→ 8th (3A) [force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [density] (S6E5) → 6th (4A)	PS	PS
5.3 First Law of Thermodynamics – The Energy Equation N/A **5.3.1 Derivation of the Energy Equation** $\frac{D}{Dt}\int_{sys} e\rho\, d\forall = \left(\sum\dot{Q}_{in} - \sum\dot{Q}_{out}\right)_{sys} + \left(\sum\dot{W}_{in} - \sum\dot{W}_{out}\right)_{sys}$ $\frac{D}{Dt}\int_{sys} e\rho\, d\forall = \left(\dot{Q}_{\substack{net\\in}} + \dot{W}_{\substack{net\\in}}\right)_{sys} \quad e = \check{u} + \frac{V^2}{2} + gz$ $\left(\dot{Q}_{\substack{net\\in}} + \dot{W}_{\substack{net\\in}}\right)_{sys} = \left(\dot{Q}_{\substack{net\\in}} + \dot{W}_{\substack{net\\in}}\right)_{\substack{\text{coincident}\\\text{control volume}}}$ $\frac{D}{Dt}\int_{sys} e\rho\, d\forall = \frac{\partial}{\partial t}\int_{cv} e\rho\, d\forall + \int_{cs} e\rho\vec{V}\cdot\hat{n}\, dA$	[four operations] (M1N3) → 1st (2A) [areas of geometric shapes] (M5M1) → 5th (2B) [volume] (M5M4) → 5th (1B) (M6M3) → 6th (2B) (MA1G5) → 9th (2F) [analytic geometry] → 12th (To be taught) [integration] → 12th (To be taught as a special skill) [derivative] → 12th (To be taught) [partial derivative] → Post-secondary [sigma notation] (M6N1) → 6th (1A) or (MA1A3) → 9th (2E)	[density] (S6E5) → 6th (4A) [heat] (S2P2) → 2nd (3A)	PS	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 5 Finite Control Volume Analysis (Continued)				
5.3.1 Derivation of the Energy Equation (Continued) $\frac{\partial}{\partial t}\int_{cv} e\rho\, dV + \int_{cs} e\rho\vec{V}\cdot\hat{n}\, dA = \left(\dot{Q}_{\substack{net\\in}} + \dot{W}_{\substack{net\\in}}\right)_{cv}$ $\dot{Q}_{\substack{net\\in}} = 0 \;\rightarrow\; \sum\dot{Q}_{in} - \sum\dot{Q}_{ou} = 0$ $\dot{W}_{shaft} = T_{shaft}\omega \quad \dot{W}_{\substack{\text{shaft}\\\text{net in}}} = \sum\dot{W}_{\substack{\text{shaft}\\\text{in}}} - \sum\dot{W}_{\substack{\text{shaft}\\\text{out}}}$ $\sigma = -p \quad \delta\dot{W}_{\text{normal stress}} = \delta\vec{F}_{\text{normal stress}}\cdot\vec{V}$ $\delta\dot{W}_{\text{normal stress}} = \sigma\hat{n}\,\delta A\cdot\vec{V} = -p\hat{n}\,\delta A\cdot\vec{V} = -p\vec{V}\cdot\hat{n}\,\delta A$ $\dot{W}_{\text{normal stress}} = \int_{cs}\sigma\vec{V}\cdot\hat{n}\,dA = \int_{cs} -p\vec{V}\cdot\hat{n}\,dA$ $\delta\dot{W}_{\text{tangential stress}} = \delta\vec{F}_{\text{tangential stress}}\cdot\vec{V}$ $\frac{\partial}{\partial t}\int_{cs} e\rho\, dV + \int_{cs} e\rho\vec{V}\cdot\hat{n}\, dA = \dot{Q}_{\substack{\text{net}\\\text{in}}} + \dot{W}_{\substack{\text{shaft}\\\text{net in}}} - \int_{cs} p\vec{V}\cdot\hat{n}\, dA$ Energy Equation: $\frac{\partial}{\partial t}\int_{cs} e\rho\, dV + \int_{cs}\left(\check{u} + \frac{p}{\rho} + \frac{V^2}{2} + gz\right)\rho\vec{V}\cdot\hat{n}\, dA = \dot{Q}_{\substack{\text{net}\\\text{in}}} + \dot{W}_{\substack{\text{shaft}\\\text{net in}}}$	[four operations] (M1N3) → 1^{st} (2A) [areas of geometric shapes] (M5M1) → 5^{th} (2B) [volume] (M5M4) → 5^{th} (1B) (M6M3) → 6^{th} (2B) (MA1G5) → 9^{th} (2F) [analytic geometry] → 12^{th} (To be taught) [integration] → 12^{th} (To be taught as a special skill) [derivative] → 12^{th} (To be taught) [partial derivative] → Post-secondary [sigma notation] (M6N1) → 6^{th} (1A) or (MA1A3) → 9^{th} (2E)	[density] (S6E5) → 6^{th} (4A) [heat] (S2P2) → 2^{nd} (3A)	PS	9^{th} + PS
5.3.2 Application of the Energy Equation $\int_{cs}\left(\check{u} + \frac{p}{\rho} + \frac{V^2}{2} + gz\right)\rho\vec{V}\cdot\hat{n}\, dA \neq 0 \;\leftarrow\; \vec{V}\cdot\hat{n} \neq 0$ $\int_{cs}\left(\check{u} + \frac{p}{\rho} + \frac{V^2}{2} + gz\right)\rho\vec{V}\cdot\hat{n}\, dA = \sum_{\substack{flow\\out}}\left(\check{u} + \frac{p}{\rho} + \frac{V^2}{2} + gz\right)\dot{m}$ $-\sum_{\substack{flow\\in}}\left(\check{u} + \frac{p}{\rho} + \frac{V^2}{2} + gz\right)\dot{m}$	[four operations] (M1N3) → 1^{st} (2A) [areas of geometric shapes] (M5M1) → 5^{th} (2B) [volume] (M5M4) → 5^{th} (1B) (M6M3) → 6^{th} (2B) (MA1G5) → 9^{th} (2F) [analytic geometry] → 12^{th} (To be taught) [integration] → 12^{th} (To be taught as a special skill)	[velocity] (S8P3)→ 8^{th} (3A) [gravity] (S6E1) → 6^{th} (3A) [density] (S6E5) → 6^{th} (4A) [mass] (S8P3) → 8^{th} (3A)	PS	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 5 Finite Control Volume Analysis (Continued)				
5.3.2 Application of the Energy Equation (Continued) $\int_{cs}\left(\check{u}+\frac{p}{\rho}+\frac{V^2}{2}+gz\right)\rho\vec{V}\cdot\hat{n}\,dA=\left(\check{u}+\frac{p}{\rho}+\frac{V^2}{2}+gz\right)_{out}\dot{m}_{out}$ $-\left(\check{u}+\frac{p}{\rho}+\frac{V^2}{2}+gz\right)_{in}\dot{m}_{in}$ $\dot{m}\left[\check{u}_{out}-\check{u}_{in}+\left(\frac{p}{\rho}\right)_{out}-\left(\frac{p}{\rho}\right)_{in}+\frac{V_{out}^2-V_{in}^2}{2}+g\left(z_{out}-z_{in}\right)\right]$ $=\dot{Q}_{\substack{net\\in}}+\dot{W}_{\substack{shaft\\net\ in}}$ $\check{h}=\check{u}+\frac{p}{\rho}\quad\rightarrow$ $\dot{m}\left[\check{h}_{out}-\check{h}_{in}+\frac{V_{out}^2-V_{in}^2}{2}+g\left(z_{out}-z_{in}\right)\right]=\dot{Q}_{\substack{net\\in}}+\dot{W}_{\substack{shaft\\net\ in}}$ Enthalpy for steady throughout, one-dimensional flow involving only one fluid stream $\dot{m}\left[\check{u}_{out}-\check{u}_{in}+\left(\frac{p}{\rho}\right)_{out}-\left(\frac{p}{\rho}\right)_{in}+\frac{V_{out}^2-V_{in}^2}{2}+g\left(z_{out}-z_{in}\right)\right]=\dot{Q}_{\substack{net\\in}}$ Enthalpy for compressive, one-dimensional, steady flow $\dot{m}\left[\check{h}_{out}-\check{h}_{in}+\frac{V_{out}^2-V_{in}^2}{2}+g\left(z_{out}-z_{in}\right)\right]=\dot{Q}_{\substack{net\\in}}$	[four operations] (M1N3) → 1st (2A) [areas of geometric shapes] (M5M1) → 5th (2B) [volume] (M5M4) → 5th (1B) (M6M3) → 6th (2B) (MA1G5) → 9th (2F) [analytic geometry] → 12th (To be taught) [integration] → 12th (To be taught as a special skill)	[velocity] (S8P3)→ 8th (3A) [gravity] (S6E1) → 6th (3A) [density] (S6E5) → 6th (4A) [mass] (S8P3) → 8th (3A)	PS	9th + PS

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 5 Finite Control Volume Analysis (Continued)				
5.3.3 Comparison of the Energy Equation with the Bernoulli Equation $\dot{m}\left[\check{u}_{out} - \check{u}_{in} + \frac{p_{out}}{\rho} - \frac{p_{in}}{\rho} + \frac{V_{out}^2 - V_{in}^2}{2} + g(z_{out} - z_{in})\right] = \dot{Q}_{\substack{net\\in}}$ $\frac{p_{out}}{\rho} + \frac{V_{out}^2}{2} + gz_{out} = \frac{p_{in}}{\rho} + \frac{V_{in}^2}{2} + gz_{in} - \left(\check{u}_{out} - \check{u}_{in} - q_{\substack{net\\in}}\right)$ $q_{\substack{net\\in}} = \frac{\dot{Q}_{net\ in}}{\dot{m}}$ $p_{out} + \frac{\rho V_{out}^2}{2} + \gamma z_{out} = p_{in} + \frac{\rho V_{in}^2}{2} + \gamma z_{in} \quad \gamma = \rho g \quad \rightarrow \quad \frac{\gamma}{\rho} = g$ $\frac{\left(p_{out} + \frac{\rho V_{out}^2}{2} + \gamma z_{out}\right)}{\rho} = \frac{\left(p_{in} + \frac{\rho V_{in}^2}{2} + \gamma z_{in}\right)}{\rho} \quad \rightarrow$ $\frac{p_{out}}{\rho} + \frac{V_{out}^2}{2} + gz_{out} = \frac{p_{in}}{\rho} + \frac{V_{in}^2}{2} + gz_{in}$ $\check{u}_{out} - \check{u}_{in} - q_{\substack{net\\in}} = 0$ (Frictionless steady incompressible flow) $\check{u}_{out} - \check{u}_{in} - q_{\substack{net\\in}} > 0$ (Steady incompressible flow with friction) $\check{u}_{out} - \check{u}_{in} - q_{\substack{net\\in}} = \text{loss}$	[four operations] (M1N3) → 1st (2A) [areas of geometric shapes] (M5M1) → 5th (2B) [volume] (M5M4) → 5th (1B) (M6M3) → 6th (2B) (MA1G5) → 9th (2F)	[velocity] (S8P3) → 8th (3A) [gravity] (S6E1) → 6th (3A) [density] (S6E5) → 6th (4A) [mass] (S8P3) → 8th (3A)	9th	9th + PS

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 5 Finite Control Volume Analysis (Continued)				
5.3.3 Comparison of the Energy Equation with the Bernoulli Equation $\frac{p_{out}}{\rho}+\frac{V_{out}^2}{2}+gz_{out}=\frac{p_{in}}{\rho}+\frac{V_{in}^2}{2}+gz_{in}-\text{loss}$ $\dot{m}\left[\check{u}_{out}-\check{u}_{in}+\frac{p_{out}}{\rho}-\frac{p_{in}}{\rho}+\frac{V_{out}^2-V_{in}^2}{2}+g\left(z_{out}-z_{in}\right)\right]=\dot{Q}_{\substack{net\\in}}+\dot{W}_{\substack{shaft\\net\,in}}$ $\frac{p_{out}}{\rho}+\frac{V_{out}^2}{2}+gz_{out}=\frac{p_{in}}{\rho}+\frac{V_{in}^2}{2}+gz_{in}+w_{\substack{shaft\\net\,in}}-\left(\check{u}_{out}-\check{u}_{in}-q_{\substack{net\\in}}\right)$ $\frac{p_{out}}{\rho}+\frac{V_{out}^2}{2}+gz_{out}=\frac{p_{in}}{\rho}+\frac{V_{in}^2}{2}+gz_{in}+w_{\substack{shaft\\net\,in}}-\text{loss}$ $p_{out}+\frac{\rho V_{out}^2}{2}+\gamma z_{out}=p_{in}+\frac{\rho V_{in}^2}{2}+\gamma z_{in}+\rho w_{\substack{shaft\\net\,in}}-\rho(\text{loss})$ $\frac{\left(\frac{p_{out}}{\rho}+\frac{V_{out}^2}{2}+gz_{out}=\frac{p_{in}}{\rho}+\frac{V_{in}^2}{2}+gz_{in}+w_{\substack{shaft\\net\,in}}-\text{loss}\right)}{g}\rightarrow$ $\frac{p_{out}}{\gamma}+\frac{V_{out}^2}{2g}+z_{out}=\frac{p_{in}}{\gamma}+\frac{V_{in}^2}{2g}+z_{in}+w_{\substack{shaft\\net\,in}}-h_s-h_L$ $h_s=\frac{w_{shaft\,net\,in}}{g}=\frac{\dot{W}_{\substack{shaft\\net\,in}}}{\dot{m}g}=\frac{\dot{W}_{\substack{shaft\\net\,in}}}{\gamma Q}$ $h_T=-\left(h_s+h_L\right)_T \quad h_p=\left(h_s+h_L\right)_P$	[four operations] (M1N3) → 1st (2A) [areas of geometric shapes] (M5M1) → 5th (2B) [volume] (M5M4) → 5th (1B) (M6M3) → 6th (2B) (MA1G5) → 9th (2F)	[velocity] (S8P3)→ 8th (3A) [gravity] (S6E1) → 6th (3A) [density] (S6E5) → 6th (4A) [mass] (S8P3) → 8th (3A)	9th	9th + PS

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 5 Finite Control Volume Analysis (Continued)				
5.3.4 Application of the Energy Equation to Non-uniform Flow $\int_{cs} \frac{V^2}{2}\rho \vec{V}\cdot\hat{n}\, dA = \dot{m}\left(\frac{\alpha_{out}\bar{V}_{out}^2}{2} - \frac{\alpha_{in}\bar{V}_{in}^2}{2}\right)$ $\frac{\dot{m}\alpha\bar{V}^2}{2} = \int_A \frac{V^2}{2}\rho\vec{V}\cdot\hat{n}\, dA \quad \alpha = \frac{\int_A (V^2/2)\rho\vec{V}\cdot\hat{n}\, dA}{\dot{m}\bar{V}^2/2}$ $\frac{p_{out}}{\rho} + \frac{\alpha_{out}\bar{V}_{out}^2}{2} + gz_{out} = \frac{p_{in}}{\rho} + \frac{\alpha_{in}\bar{V}_{in}^2}{2} + gz_{in} + w_{\substack{shaft\\ net\ in}} - \text{loss}$ $\left(\frac{p_{out}}{\rho} + \frac{\alpha_{out}\bar{V}_{out}^2}{2} + gz_{out} = \frac{p_{in}}{\rho} + \frac{\alpha_{in}\bar{V}_{in}^2}{2} + gz_{in} + w_{\substack{shaft\\ net\ in}} - \text{loss}\right)(\rho)$ $\rightarrow$ $p_{out} + \frac{\rho\alpha_{out}\bar{V}_{out}^2}{2} + \gamma z_{out} = p_{in} + \frac{\rho\alpha_{in}\bar{V}_{in}^2}{2} + \gamma z_{in} + \rho w_{\substack{shaft\\ net\ in}} - \rho(\text{loss})$ $\frac{\left(\frac{p_{out}}{\rho} + \frac{\alpha_{out}\bar{V}_{out}^2}{2} + gz_{out} = \frac{p_{in}}{\rho} + \frac{\alpha_{in}\bar{V}_{in}^2}{2} + gz_{in} + w_{\substack{shaft\\ net\ in}} - \text{loss}\right)}{g} \rightarrow$ $\frac{p_{out}}{\gamma} + \frac{\alpha_{out}\bar{V}_{out}^2}{2g} + z_{out} = \frac{p_{in}}{\gamma} + \frac{\alpha_{in}\bar{V}_{in}^2}{2g} + z_{in} + \frac{w_{\substack{shaft\\ net\ in}}}{g} - h_L$	[four operations] (M1N3) → 1st (2A) [areas of geometric shapes] (M5M1) → 5th (2B) [volume] (M5M4) → 5th (1B) (M6M3) → 6th (2B) (MA1G5) → 9th (2F) [integration] → 12th (To be taught as a special skill) Note: The main formulas $\frac{p_{out}}{\gamma} + \frac{\alpha_{out}\bar{V}_{out}^2}{2g} + z_{out} = \frac{p_{in}}{\gamma} + \frac{\alpha_{in}\bar{V}_{in}^2}{2g} + z_{in} + \frac{w_{\substack{shaft\\ net\ in}}}{g} - h_L$ is based on pre-calculus mathematics. Others used to derive this formula could be removed from classroom instruction.	[velocity] (S8P3) → 8th (3A) [gravity] (S6E1) → 6th (3A) [density] (S6E5) → 6th (4A) [mass] (S8P3) → 8th (3A)	9th	9th + PS
5.3.5 Combination of the Energy Equation and the Moment-of-momentum Equation $\eta = \frac{w_{\substack{shaft\\ net\ in}} - \text{loss}}{w_{\substack{shaft\\ net\ in}}}$	[four operations] (M1N3) → 1st (2A)	[heat] (S2P2) → 2nd (3A) [temperature] (SP3) → 9th (3B)	9th	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 5 Finite Control Volume Analysis (Continued)				
5.4 Second Law of Thermodynamics – Irreversible Flow $\check{u}_2 - \check{u}_1 - q_{\underset{in}{net}} \ge 0$	[four operations] (M1N3) → 1st (2A)	[heat] (S2P2) → 2nd (3A) [temperature] (SP3) → 9th (3B)	PS	9th + PS
5.4.1 Semi-infinitesimal Control Volume Statement of the Energy Equation $\dot{m}\left[d\check{u} + d\left(\frac{p}{\rho}\right) + d\left(\frac{V^2}{2}\right) + g(dz)\right] = \delta\dot{Q}_{\underset{in}{net}} \quad T\,ds = d\check{u} + p\,d\left(\frac{1}{\rho}\right)$ ↓ $\dot{m}\left[T\,ds + p\,d\left(\frac{1}{\rho}\right) + d\left(\frac{p}{\rho}\right) + d\left(\frac{V^2}{2}\right) + g(dz)\right] = \delta\dot{Q}_{\underset{in}{net}}$ $\frac{dp}{\rho} + d\left(\frac{V^2}{2}\right) + g\,dz = -\left(T\,ds - \delta q_{\underset{in}{net}}\right)$	[four operations] (M1N3) → 1st (2A) [volume] (M5M4) → 5th (1B) (M6M3) → 6th (2B) (MA1G5) → 9th (2F) [integration] → 12th (To be taught as a special skill) [derivative] → 12th (To be taught) [partial derivative] → Post secondary [sigma notation] (M6N1) → 6th (1A) or (MA1A3) → 9th (2E)	[mass] (S8P3) → 8th (3A) [velocity] (S8P3)→ 8th (3A) [heat] (S2P2) → 2nd (3A) [temperature] (SP3) → 9th (3B) [gravity] (S6E1) → 6th (3A)	PS	
5.4.2 Semi-infinitesimal Control Volume Statement of the Second Law of Thermodynamics $\frac{D}{Dt}\int_{sys} s\rho\,d\forall \ge \sum\left(\frac{\delta\dot{Q}_{\underset{in}{net}}}{T}\right)_{sys} \quad \sum\left(\frac{\delta\dot{Q}_{\underset{in}{net}}}{T}\right)_{sys} = \sum\left(\frac{\delta\dot{Q}_{\underset{in}{net}}}{T}\right)_{cv}$ $\frac{D}{Dt}\int_{sys} s\rho\,d\forall = \frac{\partial}{\partial t}\int_{cv} s\rho\,d\forall + \int_{cs} s\rho\vec{V}\cdot\hat{n}\,dA$ $\frac{\partial}{\partial t}\int_{cv} s\rho\,d\forall + \int_{cs} s\rho\vec{V}\cdot\hat{n}\,dA \ge \sum\left(\frac{\delta\dot{Q}_{\underset{in}{net}}}{T}\right)_{cv} \quad \frac{\partial}{\partial t}\int_{cv} s\rho\,d\forall = 0$ $\dot{m}(s_{out} - S_{IN}) \ge \sum\frac{\delta\dot{Q}_{\underset{in}{net}}}{T} \quad \dot{m}\,ds \ge \sum\frac{\delta\dot{Q}_{\underset{in}{net}}}{T}$ $T\,ds \ge \delta q_{\underset{in}{net}} \quad T\,ds - \delta q_{\underset{in}{net}} \ge 0$	[four operations] (M1N3) → 1st (2A) [volume] (M5M4) → 5th (1B) (M6M3) → 6th (2B) (MA1G5) → 9th (2F) [derivative] → 12th (To be taught) [partial derivative] → Post secondary [integration] → 12th (To be taught) [sigma notation] (M6N1) → 6th (1A) or (MA1A3) → 9th (2E)	[heat] (S2P2) → 2nd (3A) [velocity] (S8P3)→ 8th (3A) [density] (S6E5) → 6th (4A) [temperature] (SP3) → 9th (3B)	PS	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 5 Finite Control Volume Analysis (Continued)				
5.4.3 Combination of the Equations of the First and Second Laws of Thermodynamics $-\left[\frac{dp}{\rho}+d\left(\frac{V^2}{2}\right)+g\ dz\right]\geq 0$ $-\left[\frac{dp}{\rho}+d\left(\frac{V^2}{2}\right)+g\ dz\right]=\delta(\text{loss})=\left(T\ ds-\delta q_{\substack{net\\in}}\right)$ $\frac{dp}{\rho}+d\left(\frac{V^2}{2}\right)+g\ dz=0$ $-\left[\frac{dp}{\rho}+d\left(\frac{V^2}{2}\right)+g\ dz\right]=\delta(\text{loss})-\delta w_{\substack{shaft\\net\ in}}$ $d\check{u}+pd\left(\frac{1}{\rho}\right)-\delta q_{\substack{net\\in}}=\delta(\text{loss})$ $d\left(\frac{1}{\rho}\right)=0\ \rightarrow\ d\check{u}-\delta q_{\substack{net\\in}}=\delta(\text{loss})$ $\check{u}_{out}-\check{u}_{in}-q_{\substack{net\\in}}=\text{loss}$ $d\left(\frac{1}{\rho}\right)\neq 0\ \rightarrow\ \check{u}_{out}-\check{u}_{in}+\int_{in}^{out}pd\left(\frac{1}{\rho}\right)-q_{\substack{net\\in}}=\text{loss}$	[four operations] (M1N3) → 1st (2A) [volume] (M5M4) → 5th (1B) (M6M3) → 6th (2B) (MA1G5) → 9th (2F) [derivative] → 12th (To be taught) [partial derivative] → Post secondary [integration] → 12th (To be taught)	[heat] (S2P2) → 2nd (3A) [velocity] (S8P3)→ 8th (3A) [density] (S6E5) → 6th (4A) [temperature] (SP3) → 9th (3B)	PS	9th + PS

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 5 Finite Control Volume Analysis (Continued)				
5.4.4 Application of the Loss Form of the Energy Equation $\frac{p_2}{\rho}+\frac{V_2^2}{2}+gz_2=\frac{p_1}{\rho}+\frac{V_1^2}{2}+gz_1$ $\int_2^2\frac{dp}{\rho}+\frac{V_2^2}{2}+gz_2=\frac{V_1^2}{2}+gz_1$ $\frac{p}{\rho^k}=\text{constant}$ $\int_1^2\frac{dp}{\rho}=\frac{k}{k-1}\left(\frac{p_2}{\rho_2}-\frac{p_1}{\rho_1}\right)$ $\frac{k}{k-1}\frac{p_2}{\rho_2}+\frac{V_2^2}{2}+gz_2=\frac{k}{k-1}\frac{p_1}{\rho_1}+\frac{V_1^2}{2}+gz_1$	[four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A) [derivative] → 12th (To be taught) [partial derivative] → Post secondary [integration] → 12th (To be taught) Note: The main formula $\frac{k}{k-1}\frac{p_2}{\rho_2}+\frac{V_2^2}{2}+gz_2=\frac{k}{k-1}\frac{p_1}{\rho_1}+\frac{V_1^2}{2}+gz_1$ is not based on calculus	[velocity] (S8P3)→ 8th (3A) [density] (S6E5) → 6th (4A) [pressure] (SC5) → 9th (4B) → To be taught [gravity] (S6E1) → 6th (3A)	9th	9th + PS
5.5 Chapter Summary and Study Guide N/A	N/A	N/A	9th	
Chapter 6 Differential Analysis of Fluid Mechanics Flow (Note: This whole Chapter appears to be too deep in calculus-based mathematics. Actually, some professors in undergraduate engineering programs cut the whole Chapter off when teaching Fluid Mechanics course. Therefore, engineering analytic principles and skills from this Chapter are NOT analyzed for the eventual inclusion into a potentially viable K-12 engineering curriculum. The subheadings of Sections are still listed below for reference purposes).				

6.1 Fluid Mechanics Element Kinematics	6.3.2 Equations of Motion	6.5.3 Vortex	6.8.2 The Navier-Stokes Equations	PS
6.1.1 Velocity and Acceleration Fields Revisited	6.4 Inviscid Flow	6.5.4 Doublet	6.9 Some Simple Solutions for Viscous, Incompressible Fluids	
6.1.2 Linear Motion and Deformation	6.4.1 Euler's Equations of Motion	6.6 Superposition of Basic, Plane Potential Flows	6.9.1 Steady, Laminar Flow between Fixed Parallel Plates	
6.1.3 Angular Motion and Deformation	6.4.2 The Bernoulli Equation	6.6.1 Source in a Uniform Stream – Half-Body	6.9.2 Couette Flow	
6.2 Conservation of mass	6.4.3 Irrotational Flow	6.6.2 Rankine Ovals	6.9.3 Steady, Laminar Flow in Circular Tubes	
6.2.1 Differential Survey Form of Continuity Equation	6.4.4 The Bernoulli Equation for Irrotational Flow	6.6.3 Flow around a Circular Cylinder	6.9.4 Steady, Axial, Laminar Flow in an Annulus	
6.2.2 Cylindrical Polar Coordinates	6.4.5 The Velocity Potential	6.7 Other Aspects of Potential Flow Analysis	6.10 Other Aspects of Differential Analysis	
6.2.3 The Stream Function	6.5 Some Basic, Plane Potential Flows	6.8 Viscous Flow	6.10.1 Numerical Methods	
6.3 Conservation of Linear Momentum	6.5.1 Uniform Flow	6.8.1 Stress-Deformation Relationships	Chapter Summary and Study Guide	
6.3.1 Description of Forces Acting on the Differential Element	6.5.2 Source and Sink			

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 7 Similitude, Dimensional Analysis, and Modeling (Note: This whole Chapter appears to be mildly deep in calculus-based mathematics. However, the type of "abstract thinking" required to understand and to apply the content knowledge contained in this Chapter appears to be most likely beyond the cognitive developmental maturity level of high school students. Therefore, engineering analytic principles and skills from this Chapter are NOT analyzed for the eventual inclusion into a potentially viable K-12 engineering curriculum. The subheadings of Sections are still listed before for reference purposes). Some appropriate skills in 7.1 (Dimensional Analysis) could be considered for high schools.				
7.1 Dimensional Analysis	7.4.3 Uniqueness of Pi Terms	7.8 Modeling and Similitude	7.9.2 Flow around Immersed Bodies	PS
7.2 Buckingham Pi Theorem	7.5 Determination of Pi Terms by Inspection	7.8.1 Theory of Models	7.9.3 Flow with a Free Surface	
7.3 Determination of Pi Terms	7.6 Common Dimensionless Groups in Fluid Mechanics	7.8.2 Model Space	7.10 Similitude Based on Governing Differential Equations	
7.4 Some Additional Comments about Dimensional Analysis	7.7 Correlation of Experimental Data	7.8.3 Practical Aspects of Using Models	7.11 Chapter Summary and Study Guide	
7.4.1 Selection of Variables	7.7.1 Problems with One Pi Term	7.9 Some Typical Model Studies		
7.4.2 Determination of Reference Dimensions	7.7.2 Problems with Two or More Pi Term	7.9.1 Flow through Closed Conduits		
Chapter 8 Viscous Flow in Pipes				
8.1 General Characteristics of Pipe Flow **8.1.1 Laminar of Turbulent Flow** $\mathrm{Re} = \frac{\rho V D}{\mu}$ **8.1.2 Entrance Region and Fully Developed Flow** $\frac{\ell_e}{D} = 0.06\,\mathrm{Re}$ (for turbulent flow) $\frac{\ell_e}{D} = 4.4(\mathrm{Re})^{1/6}$ (for turbulent flow) $10^4 < \mathrm{Re} < 10^5$	[four operations] (M1N3) → 1st (2A) [coordinate system] (M4G3) → 4th (2B) [exponent] (M6A3) → 6th (2A)	[mass] (S8P3) → 8th (3A) [density] (S6E5) → 6th (4A) [force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [pressure] (SC5) → 9th (4B) → To be taught [velocity] (S8P3)→ 8th (3A) [momentum] (SP3) → (3B)	PS	9th + PS
8.1.3 Pressure and Shear Stress $\nabla p = p_1 - p_2 \quad \frac{\partial p}{\partial x} = -\frac{\Delta p}{\ell} < 0$	[four operations] (M1N3) → 1st (2A) [partial derivative] → Post-secondary	[pressure] (SC5) → 9th (4B) → To be taught	PS	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 8 Viscous Flow in Pipes (Continued)				
8.2 Fully Developed Laminar Flow **8.2.1 From F = ma Applied Directly to a Fluid Mechanics Element** $\vec{F}=m\vec{a}$ $\frac{\partial \vec{V}}{\partial t}=0$ $\vec{V}\cdot\nabla\vec{V}=u\frac{\partial u}{\partial x}\hat{i}=0$ $p_2=p_1-\Delta p$ $(p_1)\pi r^2-(p_1-\Delta p)\pi r^2-(\tau)2\pi r\ell=0$ $\frac{\Delta p}{\ell}=\frac{2\tau}{r}$ $\tau=\frac{2\tau_w r}{D}$ $\Delta p=\frac{4\ell\tau_w}{D}$ $\tau=-\mu\frac{du}{dr}$ $\frac{du}{dr}=-\left(\frac{\Delta p}{2\mu\ell}\right)r$ $\int du=-\frac{\Delta p}{2\mu\ell}\int r\,dr$ $u=-\left(\frac{\Delta p}{4\mu\ell}\right)r^2+C_1$ $u(r)=\left(\frac{\Delta pD^2}{16\mu\ell}\right)\left[1-\left(\frac{2r}{D}\right)^2\right]=V_c\left[1-\left(\frac{2r}{D}\right)^2\right]$ $u(r)=\frac{\tau_w D}{4\mu}\left[1-\left(\frac{r}{R}\right)^2\right]$ $Q=\int u\,dA=\int_{r=0}^{r=R}u(r)2\pi r\,dr=2\pi V_c\int_0^R\left[1-\left(\frac{r}{R}\right)^2\right]r\,dr$ $Q=\frac{\pi R^2V_c}{2}$ $V=\frac{Q}{A}=\frac{Q}{\pi R^2}$ $V=\frac{\pi R^2V_c}{2\pi R^2}=\frac{V_c}{2}=\frac{\Delta pD^2}{32\mu\ell}$ $Q=\frac{\pi D^4\Delta p}{128\mu\ell}$ $\frac{\Delta p-\gamma\ell\sin\theta}{\ell}=\frac{2\tau}{r}$ $V=\frac{(\Delta p-\gamma\ell\sin\theta)D^2}{32\mu\ell}$ $Q=\frac{\pi(\Delta p-\gamma\ell\sin\theta)D^4}{128\mu\ell}$	[four operations] (M1N3) → 1st (2A) [coordinate system] [trigonometric functions] (MA2G2) → 10th (2F) [dot product] → To be taught as a special math topic [integration] → 12th (To be taught) [derivative] → 12th (To be taught) [partial derivative] → Post-secondary [gradient] → Post-secondary	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [acceleration] (S8P3) → 8th (3C) [pressure] (SC5) → 9th (4B) → To be taught [velocity] (S8P3)→ 8th (3A)	PS	9th + PS

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 8 Viscous Flow in Pipes (Continued)				
8.2.2 From the Navier-Stokes Equations $\nabla\vec{V}\cdot\vec{V}=0 \quad \frac{\partial\vec{V}}{\partial t}+\vec{V}\cdot\nabla\vec{V}=-\frac{\nabla p}{\rho}+\vec{g}+\nu\nabla^2\vec{V}$ $\vec{g}=-g\hat{k} \quad \nabla\cdot\vec{V}=0 \quad \nabla p+\rho g\hat{k}=\mu\nabla^2\vec{V}$ $\frac{\partial p}{\partial x}+\rho g\sin\theta=\mu\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial u}{\partial r}\right)$	[four operations] (M1N3) → 1st (2A) [trigonometric functions] (MA2G2) → 10th (2F) [exponent] (M6A3) → 6th (2A) [dot product] → To be taught as a special math topic [vector] (MA3A10) → 11th (2H) → To be taught as a special math topics [partial derivative] → Post-secondary [gradient: "del"] → Post-secondary	[velocity] (S8P3)→ 8th (3A) [pressure] (SC5) → 9th (4B) → To be taught [density] (S6E5) → 6th (4A) [gravity] (S6E1) → 6th (3A)	PS	9th + PS
8.2.3 From Dimensional Analysis $\Delta p=F(V,\ell,D,\mu) \quad \frac{D\,\Delta p}{\mu V}=\phi\left(\frac{\ell}{D}\right) \quad \phi\left(\frac{\ell}{D}\right)=\frac{C\ell}{D} \quad C=\text{constant}$ $\frac{D\,\Delta p}{\mu V}=\frac{C\ell}{D} \quad \frac{\Delta p}{\ell}=\frac{C\mu V}{D^2} \quad Q=AV=\frac{(\pi/4C)\Delta pD^4}{\mu\ell}$ $\Delta p=\frac{32\mu\ell V}{D^2} \quad \frac{\Delta p}{\frac{1}{2}\rho V^2}=\frac{(32\mu\ell V/D^2)}{\frac{1}{2}\rho V^2}=64\left(\frac{\mu}{\rho VD}\right)\left(\frac{\ell}{D}\right)=\frac{64}{\text{Re}}\left(\frac{\ell}{D}\right)$ $\Delta p=f\frac{\ell}{D}\frac{\rho V^2}{2} \quad f=\Delta p\left(\frac{D}{\ell}\right)\left(\frac{\rho V^2}{2}\right) \quad f=\frac{64}{\text{Re}} \quad f=\frac{8\tau_w}{\rho V^2}$	[four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [velocity] (S8P3)→ 8th (3A) [pressure] (SC5) → 9th (4B) → To be taught [density] (S6E5) → 6th (4A) Note: Special topics from 7.1 (Dimensional Analysis) need to be taught	PS	
8.2.4 Energy Considerations $\frac{p_1}{\gamma}+\alpha_1\frac{V_1^2}{2g}+z_1=\frac{p_2}{\gamma}+\alpha_2\frac{V_2^2}{2g}+z_2+h_L \quad \left(\frac{p_1}{\gamma}+z_1\right)-\left(\frac{p_2}{\gamma}+z_1\right)=h_L$ $p_1=p_2+\Delta p \quad z_2-z_1=\ell\sin\theta$ $h_L=\frac{2\tau\ell}{\gamma r} \quad h_L=\frac{4\ell\tau_w}{\gamma D}$	[four operations] (M1N3) → 1st (2A) [trigonometric functions] (MA2G2) → 10th (2F)	[pressure] (SC5) → 9th (4B) → To be taught [gravity] (S6E1) → 6th (3A)	9th	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 8 Viscous Flow in Pipes (Continued)				
8.3 Fully Developed Turbulent Flow N/A **8.3.1 Transition from Laminar to Turbulent Flow** N/A **8.3.2 Turbulent Shear Stress** $\bar{u} = \frac{1}{T}\int_{t_0}^{t_0+T} u(x,y,z,t)dt \quad u=\bar{u}+u' \quad u'=u-\bar{u}$ $\bar{u}' = \frac{1}{T}\int_{t_0}^{t_0+T}(u-\bar{u})dt = \frac{1}{T}\left(\int_{t_0}^{t_0+T}u\,dt - \bar{u}\int_{t_0}^{t_0+T}dt\right) = \frac{1}{T}(T\bar{u}-T\bar{u})=0$ $\overline{(u')^2} = \frac{1}{T}\int_{t_0}^{t_0+T}(u')^2dt > 0$ Turbulence intensity $= \frac{\sqrt{\overline{(u')^2}}}{\bar{u}} = \frac{\left[\frac{1}{T}\int_{t_0}^{t_0+T}(u')^2dt\right]^{1/2}}{\bar{u}}$ $\tau=\mu\frac{du}{dy} \quad \tau\neq\mu\frac{d\bar{u}}{dy} \quad \bar{u}=\bar{u}(y) \quad \tau=\mu\frac{d\bar{u}}{dy}-\rho\overline{u'v'}=\tau_{lam}+\tau_{turb}$ $\tau_{turb}=\eta\frac{d\bar{u}}{dy} \quad \eta=\rho\ell_m^2\left\lvert\frac{d\bar{u}}{dy}\right\rvert \quad \tau_{turb}=\rho\ell_m^2\left(\frac{d\bar{u}}{dy}\right)^2$	[coordinate system] (M4G3) → 4th (2B) [analytic geometry] → 12th (To be taught) [logarithmic functions] (MA2A5) → 10th (2E) (To be taught as a special skill) [integration] → 12th (To be taught as a special skill) [derivative] → 12th (To be taught)	[velocity] (S8P3)→ 8th (3A) [density] (S6E5) → 6th (4A)	PS	9th + PS
8.3.3 Turbulent Velocity Profile $\frac{\bar{u}}{u*}=\frac{yu*}{\nu} \quad y=R-r \quad u*=\left(\frac{\tau_w}{\rho}\right)^{1/2} \quad \frac{\bar{u}}{u*}=2.5\ln\left(\frac{yu*}{\nu}\right)+5.0$ $\frac{(V_c-\bar{u})}{u*}=2.5\ln\left(\frac{R}{y}\right) \quad \frac{\bar{u}}{V_c}=\left(1-\frac{r}{R}\right)^{1/n}$ **8.3.4 Turbulent Modeling** N/A	[four operations] (M1N3) → 1st (2A) [coordinate system] (M4G3) → 4th (2B) [logarithmic functions] (MA2A5) → 10th (2E) [analytic geometry] → 12th (To be taught)	[velocity] (S8P3)→ 8th (3A)	PS	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 8 Viscous Flow in Pipes (Continued)				
8.3.5 Chaos and Turbulence N/A	N/A	N/A	PS	9th
8.4 Dimensional Analysis of Pipe Flow $h_L = h_{L\,major} + h_{L\,minor}$	[four operations] (M1N3) → 1st (2A)	Note: Special topics from 7.1 (Dimensional Analysis) need to be taught	9th	+ PS
8.4.1 Major Losses $h_L = h_{L\,major} + h_{L\,minor}$ $\Delta p = F(V, D, \ell, \varepsilon, \mu, \rho)$ $\frac{\Delta p}{\frac{1}{2}\rho V^2} = \tilde{\phi}\left(\frac{\rho V D}{\mu}, \frac{\ell}{D}, \frac{\varepsilon}{D}\right)$ $\mathrm{Re} = \frac{\rho V D}{\mu}$ $\frac{\Delta p}{\frac{1}{2}\rho V^2} = \frac{\ell}{D}\phi\left(\mathrm{Re}, \frac{\varepsilon}{D}\right)$ $f = \phi\left(\mathrm{Re}, \frac{\varepsilon}{D}\right)$ $\frac{p_1}{\gamma} + \alpha_1\frac{V_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \alpha_2\frac{V_2^2}{2g} + z_2 + h_L$ $h_{L\,major} = f\frac{\ell}{D}\frac{V^2}{2g}$ $p_1 - p_2 = \gamma(z_2 - z_1) + \gamma h_L = \gamma(z_2 - z_1) + f\frac{\ell}{D}\frac{\rho V^2}{2}$ $\frac{1}{\sqrt{f}} = -2.0\log\left(\frac{\varepsilon/D}{3.7} + \frac{2.51}{\mathrm{Re}\sqrt{f}}\right)$	[four operations] (M1N3) → 1st (2A) [areas of geometric shapes: circle, triangle] (M5M1) → 5th (2B) (M5M1) → 5th (2B) [logarithmic functions] (MA2A5) → 10th (2E) (To be taught as a special skill) [exponent] (M6A3) → 6th (2A) [square root] (M8N1) → 8th (2A) [graph] (S7CS6) → 7th (6)	[velocity] (S8P3)→ 8th (3A) [pressure] (SC5) → 9th (4B) → To be taught [force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [gravity] (S6E1) → 6th (3A) [density] (S6E5) → 6th (4A) Note: Special topics from 7.1 (Dimensional Analysis) need to be taught	9th	
8.4.2 Minor Losses $K_L = \frac{h_{L\,minor}}{V^2/2g} = \frac{\Delta p}{\frac{1}{2}\rho V^2}$ $\Delta p = K_L\frac{1}{2}\rho V^2$ $h_{L\,minor} = K_L\frac{V^2}{2g}$ $K_L = \phi(geometry, \mathrm{Re})$ $h_{L\,minor} = K_L\frac{V^2}{2g} = f\frac{\ell_{eq}}{D}\frac{V^2}{2g}$ $\ell_{eq} = \frac{K_L D}{f}$ $A_1V_1 = A_3V_3$ $p_1A_3 - p_3A_3 = \rho A_3V_3(V_3 - V_1)$ $\frac{p_1}{\gamma} + \frac{V_1^2}{2g} = \frac{p_3}{\gamma} + \frac{V_3^2}{2g} + h_L$ $K_L = \frac{h_L}{V_1^2/2g}$ $K_L = \left(1 - \frac{A_1}{A_2}\right)^2$ $C_p = (p_2 - p_1)\left(\frac{\rho V_1^2}{2}\right)$				

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 8 Viscous Flow in Pipes (Continued)				
8.4.3 Noncircular Conduits $f = \frac{C}{\mathrm{Re}_h}$ $\mathrm{Re}_h = \frac{\rho V D_h}{\mu}$ $D_h = \frac{4A}{P} = \frac{4(\pi D^2/4)}{\pi D} = D$ $h_L = f\frac{(\ell/D_h)V^2}{2g}$	[four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A) [areas of geometric shapes] (M5M1) → 5th (2B)	[velocity] (S8P3)→ 8th (3A) [gravity] (S6E1) → 6th (3A) [density] (S6E5) → 6th (4A)	9th	9th + PS
8.5 Pipe Flow Examples N/A				
8.5.1 Single Pipes N/A				
8.5.2 Multiple Pipe Systems N/A				
8.6 Pipe Flowrate Measurement **8.6.1 Pipe Flowrate Meters** $Q_{ideal} = A_2V_2 = A_2\sqrt{\frac{2(p_1-p_2)}{\rho(1-\beta^4)}}$ $Q = A_1V_1 = A_2V_2$ $\frac{p_1}{\gamma}+\frac{V_1^2}{2g} = \frac{p_2}{\gamma}+\frac{V_2^2}{2g}+h_L$ $Q = C_0Q_{ideal} = C_0A_0\sqrt{\frac{2(p_1-p_2)}{\rho(1-\beta^4)}}$ $\beta = \frac{d}{D}$ $\mathrm{Re} = \frac{\rho VD}{\mu}$ $V = \frac{Q}{A_1}$ $Q = C_nQ_{ideal} = C_nA_n\sqrt{\frac{2(p_1-p_2)}{\rho(1-\beta^4)}}$ $Q = C_vQ_{ideal} = C_vA_T\sqrt{\frac{2(p_1-p_2)}{\rho(1-\beta^4)}}$ **8.6.2 Volume Flow Meters** N/A	[four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A) [square root] (M8N1) → 8th (2A) [areas of geometric shapes] (M5M1) → 5th (2B)	[velocity] (S8P3)→ 8th (3A) [pressure] (SC5) → 9th (4B) → To be taught [gravity] (S6E1) → 6th (3A) [density] (S6E5) → 6th (4A)	9th	
8.7 Chapter Summary and Study Guide N/A	N/A	N/A	9th	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 9 Flow over Immersed Bodies				
9.1 General External Flow Characteristics **9.1.1 Lift and Drag Concepts** $\left.\begin{array}{l} dF_x = (p\ dA)\cos\theta + (\tau_w\ dA)\sin\theta \\ dF_y = -(p\ dA)\sin\theta + (\tau_w\ dA)\cos\theta \end{array}\right\} \rightarrow$ $\vec{D} = \int dF_x = \int p\ \cos\theta\, dA + \int \tau_w\ \sin\theta\, dA$ $\vec{L} = \int dF_y = -\int p\ \sin\theta\, dA + \int \tau_w\ \cos\theta\, dA$ $C_L = \frac{\vec{L}}{\frac{1}{2}\rho U^2 A} \quad C_D = \frac{\vec{D}}{\frac{1}{2}\rho U^2 A}$	[four operations] (M1N3) → 1st (2A) [areas of geometric shapes] (M5M1) → 5th (2B) [trigonometric functions] (MA2G2) → 10th (2F) [integration] → 12th (To be taught as a special skill) [derivative] → 12th (To be taught) Note: The main formulas $C_L = \frac{\vec{L}}{\frac{1}{2}\rho U^2 A} \quad C_D = \frac{\vec{D}}{\frac{1}{2}\rho U^2 A}$ are not based on calculus	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C)	9th	9th + PS
9.1.2 Characteristics of Flow Past an Object N/A	N/A	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [Reynolds Number] → To be taught as special topic	9th	
9.2 Boundary Layer Characteristics N/A **9.2.1 Boundary Layer structure and Thickness on a Flat Plate** $\delta^* bU = \int_0^\infty (U-u)b\ dy \quad \delta^* = \int_0^\infty \left(1-\frac{u}{U}\right)dy$ $\int \rho u(U-u)\ dA = \rho b\int_0^\infty u(U-u)dy \quad \rho b U^2 \Theta = \int_0^\infty u(U-u)dy$ $\Theta = \int_0^\infty \frac{u}{U}\left(1-\frac{u}{U}\right)dy$	[four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A) [areas of geometric shapes] (M5M1) → 5th (2B) [integration] → 12th (To be taught as a special skill)	[velocity] (S8P3)→ 8th (3A) [density] (S6E5) → 6th (4A)	PS	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 9 Flow over Immersed Bodies (Continued)				
9.2.2 Prandtl/Blasius Boundary Layer Solution $u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=-\frac{1}{\rho}\frac{\partial p}{\partial x}+\nu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)$ $u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}=-\frac{1}{\rho}\frac{\partial p}{\partial x}+\nu\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right)$ $\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \quad \left.\begin{matrix} v<<u \\ \frac{\partial}{\partial x}<<\frac{\partial}{\partial y}\end{matrix}\right\}\rightarrow \quad \frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0$ $u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\nu\frac{\partial^2 u}{\partial y^2} \quad u=v=0 \quad on \quad y=0$ $u\rightarrow U \quad as \quad y\rightarrow\infty \quad \frac{u}{U}=g\left(\frac{y}{\delta}\right) \quad \delta\sim\left(\frac{\nu x}{U}\right)^{1/2}$ $\eta=\left(\frac{U}{\nu x}\right)^2 \quad \Psi=(\nu x U)^{1/2} f(\eta) \quad f=f(\eta)$ $u=\frac{\partial\Psi}{\partial y} \quad v=-\frac{\partial\Psi}{\partial x} \quad u=Uf'(\eta) \quad v=\left(\frac{\nu U}{4x}\right)^{1/2}(\eta f'-f)$ $2f'''-ff''=0 \quad f=f'=0 \quad at \quad \eta=0$ $f=f'=0 \quad at \quad \eta=0 \quad and \quad f'\rightarrow 1 \quad as \quad \eta\rightarrow\infty$ $\delta=5\sqrt{\frac{\nu x}{U}} \quad \frac{\delta}{x}=\frac{5}{\sqrt{\mathrm{Re}_x}} \quad \frac{\delta^*}{x}=\frac{1.721}{\sqrt{\mathrm{Re}_x}} \quad \frac{\Theta}{x}=\frac{0.664}{\sqrt{\mathrm{Re}_x}}$ $\tau_w=0.332U^{3/2}\sqrt{\frac{\rho\mu}{x}}$	[four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A) [square root] (M8N1) → 8th (2A) [functions] (MA1A1) → 9th (2E) and others → Post-secondary [partial derivative] → Post-secondary [3rd order non-linear differential equation] → Post-secondary	[velocity] (S8P3)→ 8th (3A) [density] (S6E5) → 6th (4A) [gravity] (S6E1) → 6th (3A)	PS	9th + PS

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 9 Flow over Immersed Bodies (Continued)				
9.2.3 Momentum Integral boundary Layer Equation for a Flat Plate $\sum F_x = \rho\int_{(1)} u\vec{V}\cdot\hat{n}\ dA + \rho\int_{(2)} u\vec{V}\cdot\hat{n}\ dA$ $\sum F_x = -\vec{D} = -\int_{plate}\tau_w\ dA = -\int_{plate}\tau_w\ dx$ $-\vec{D} = \rho\int_{(1)} U(-U)\ dA + \rho\int_{(2)} u^2 dA \quad \vec{D} = \rho U^2 bh - \rho b\int_0^\delta u^2\ dy$ $Uh = \int_0^\delta u\ dy \quad \rho U^2 bh = \rho b\int_0^\delta Uu\ dy \quad \vec{D} = \rho b\int_0^\delta u(U-u)dy$ $\vec{D} = \rho bU^2\Theta \quad \frac{d\vec{D}}{dx} = \rho bU^2\frac{d\Theta}{dx} \quad \frac{d\vec{D}}{dx} = b\tau_w \quad \tau_w = \rho U^2\frac{d\Theta}{dx}$ $\vec{D} = \rho b\int_0^\delta u(U-u)dy = \rho bU^2\delta\int_0^1 g(Y)[1-g(Y)]dY$ $\vec{D} = \rho bU^2\delta C_1 \quad C_1 = \int_0^1 g(Y)[1-g(Y)]dY$ $\tau_w = \mu\frac{\partial u}{\partial y}\Big\rvert_{y=0} = \frac{\mu U}{\delta}\frac{dg}{dY}\Big\rvert_{Y=0} = \frac{\mu U}{\delta}C_2 \quad C_2 = \frac{dg}{dY}\Big\rvert_{Y=0}$ $\delta\ d\delta = \frac{\mu C_2}{\rho UC_1}dx \quad \delta = \sqrt{\frac{2vC_2 x}{UC_1}} \quad \frac{\delta}{x} = \frac{\sqrt{2C_2/C_1}}{\sqrt{Re_x}}$ $\tau_w = \sqrt{\frac{C_1C_2}{2}}U^{3/2}\sqrt{\frac{\rho\mu}{x}} \quad c_f = \frac{\tau_w}{\frac{1}{2}\rho U^2}$ $c_f = \sqrt{2C_1C_2}\sqrt{\frac{\mu}{\rho Ux}} = \frac{\sqrt{2C_1C_2}}{\sqrt{Re_x}} \quad c_f = \frac{0.664}{\sqrt{Re_x}}$	[four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A) [dot product] → To be taught as a special math topic [square root] (M8N1) → 8th (2A) [sigma notation] (M6N1) → 6th (1A) or (MA1A3) → 9th (2E) [integration] → 12th (To be taught as a special skill) [partial derivative] → Post-secondary	[velocity] (S8P3)→ 8th (3A) [density] (S6E5) → 6th (4A) [gravity] (S6E1) → 6th (3A)	PS	9th + PS

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 9 Flow over Immersed Bodies (Continued)				
9.2.3 Momentum Integral boundary Layer Equation for a Flat Plate (Continued) $C_{Df}=\frac{\vec{D}_f}{\frac{1}{2}\rho U^2 b\ell}=\frac{b\int_0^\ell \tau_w dx}{\frac{1}{2}\rho U^2 b\ell}$ $C_{Df}=\frac{1}{\ell}\int_0^\ell c_f dx$ $C_{Df}=\frac{\sqrt{8C_1C_2}}{\sqrt{\mathrm{Re}_\ell}}$ $C_{Df}=\frac{1.328}{\sqrt{\mathrm{Re}_\ell}}$	[four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A) [dot product] → To be taught as a special math topic [square root] (M8N1) → 8th (2A) [sigma notation] (M6N1) → 6th (1A) or (MA1A3) → 9th (2E) [integration] → 12th (To be taught as a special skill) [partial derivative] → Post-secondary	[velocity] (S8P3)→ 8th (3A) [density] (S6E5) → 6th (4A) [gravity] (S6E1) → 6th (3A)	PS	9th + PS
9.2.4 Transition from Laminar to Turbulent Flow N/A				
9.2.5 Turbulent Boundary Layer Flow N/A				
9.2.6 Effects of Pressure Gradient N/A				
9.2.7 Momentum Integral Boundary Layer Equation with Nonzero Pressure Gradient $\frac{dp}{dx}=-\rho U_{fs}\frac{dU_{fs}}{dx}$ $\tau_w=\rho\frac{d}{dx}\left(U_{fs}^2\Theta\right)+\rho\delta^* U_{fs}\frac{dU_{fs}}{dx}$ $U_{fs}=U=\text{constant}$	[four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A) [partial derivative] → Post-secondary	[velocity] (S8P3)→ 8th (3A) [density] (S6E5) → 6th (4A)	**PS**	
9.3 Drag $C_D=\frac{\vec{D}}{\frac{1}{2}\rho U^2 A}$ $C_D=\phi(shape,\mathrm{Re},Ma,Fr,\varepsilon/\ell)$	[four operations] (M1N3) → 1st (2A) [areas of geometric shapes] (M5M1) → 5th (2B)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [density] (S6E5) → 6th (4A)	9th	
9.3.1 Friction Drag $\vec{D}_f=\frac{1}{2}\rho U^2 b\ell C_{Df}$	[four operations] (M1N3) → 1st (2A) [areas of geometric shapes] (M5M1) → 5th (2B)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [density] (S6E5) → 6th (4A)	9th	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 9 Flow over Immersed Bodies (Continued)				
9.3.2 Pressure Drag $D_p = \int \rho \cos\theta \, dA$ $C_{Dp} = \frac{\vec{D}_p}{\frac{1}{2}\rho U^2 A} = \frac{\int \rho \cos\theta \, dA}{\frac{1}{2}\rho U^2 A} = \frac{\int C_p \cos\theta \, dA}{A}$ $\vec{D} = f(U, \ell, \mu)$ $\vec{D} = C\mu\ell U$ $C_D = \frac{\vec{D}}{\frac{1}{2}\rho U^2 \ell^2} = \frac{2C\mu\ell U}{\rho U^2 \ell^2} = \frac{2C}{\text{Re}}$	[four operations] (M1N3) → 1^{st} (2A) [areas of geometric shapes] (M5M1) → 5^{th} (2B) [integration] → 12^{th} (To be taught as a special skill)	[force] (S4P3) → 4^{th} (3A) or (S8P3) → 8^{th} (3C) [density] (S6E5) → 6^{th} (4A)	9^{th}	9^{th} + PS
9.3.3 Drag Coefficient Data and Examples				
9.4 Lift **9.4.1 Surface Pressure Distribution** $C_L = \frac{\vec{L}}{\frac{1}{2}\rho U^2 A}$ $C_L = \phi(shape, \text{Re}, Ma, Fr, \varepsilon/\ell)$	[four operations] (M1N3) → 1^{st} (2A) [areas of geometric shapes] (M5M1) → 5^{th} (2B)	[force] (S4P3) → 4^{th} (3A) or (S8P3) → 8^{th} (3C) [density] (S6E5) → 6^{th} (4A)	9^{th}	
9.4.2 Circulation N/A				
9.5 Chapter Summary and Study Guide N/A	N/A	N/A	9^{th}	
Chapter 10 Open Channel Flow				
10.1 General Characteristics of Open-Channel Flow $\text{Re} = \rho V R_h / \mu$ $Fr = V/(g\ell)^{1/2}$	[four operations] (M1N3) → 1^{st} (2A) [exponent] (M6A3) → 6^{th} (2A) [trigonometric functions] (MA2G2) → 10^{th} (2F) [ellipse] (MA2G4) → 10^{th} (2F) → To be taught	[velocity] (S8P3)→ 8^{th} (3A) [gravity] (S6E1) → 6^{th} (3A)	9^{th}	9^{th} + PS

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 10 Open Channel Flow (Continued)				
10.2 Surface Waves **10.2.1 Wave Speed** $-cyb = (-c+\delta V)(y+\delta y)b$ $c = \frac{(y+\delta y)\delta V}{\delta y}$ $\delta y << y \rightarrow c = y\frac{\delta V}{\delta y}$ } $\rightarrow$ $\frac{1}{2}\gamma y^2 b - \frac{1}{2}\gamma(y+\delta y)^2 b = \rho bcy[(c-\delta V)-c]$ $F_1 = \frac{\gamma y_{c1}A_1 = \gamma(y+\delta y)^2 b}{2}$ $F_2 = \frac{\gamma y_{c2}A_2 = \gamma(y+\delta y)^2 b}{2}$ $\frac{\delta V}{\delta y} = \frac{g}{c}$ $c = \sqrt{gy}$ $\frac{V^2}{2g} + y = \text{constant}$ $\frac{V\,\delta V}{g} + \delta y = 0$ $y\,\delta V + V\,\delta y = 0$ $\frac{\delta y}{y} << 1 \rightarrow c \approx \sqrt{gy}\left(1+\frac{\delta y}{y}\right)^{1/2}$ } $\rightarrow$	[four operations] (M1N3) → 1st (2A) [square root] (M8N1) → 8th (2A) [trigonometric functions] (MA2G2) → 10th (2F) [derivative] → 12th (To be taught)	[velocity] (S8P3) → 8th (3A) [speed] (S2P3) → 2nd (3A) [gravity] (S6E1) → 6th (3A)	9th	9th + PS

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 10 Open Channel Flow (Continued)				
10.2.1 Wave Speed (Continued) $c=\left[\frac{g\lambda}{2\pi}\tanh\left(\frac{2\pi y}{\lambda}\right)\right]^{1/2} \quad y>>\lambda \quad \rightarrow \quad c=\sqrt{\frac{g\lambda}{2\pi}}$ $\tanh\left(\frac{2\pi y}{\lambda}\right)\rightarrow 1 \quad as \quad \frac{y}{\lambda}\rightarrow\infty$ $\tanh\left(\frac{2\pi y}{\lambda}\right)\rightarrow \frac{2\pi y}{\lambda} \quad as \quad \frac{y}{\lambda}\rightarrow 0$	[four operations] (M1N3) → 1st (2A) [square root] (M8N1) → 8th (2A) [trigonometric functions] (MA2G2) → 10th (2F) [analytic geometry: hyperbolic tangent] Post-secondary → To be taught [derivative] → 12th (To be taught)	[velocity] (S8P3)→ 8th (3A) [speed] (S2P3) → 2nd (3A) [gravity] (S6E1) → 6th (3A)	9th	9th + PS
10.2.2 Froude Number Effects N/A	N/A	[velocity] (S8P3)→ 8th (3A) [speed] (S2P3) → 2nd (3A)	9th	
10.3 Energy Considerations $\left.\frac{p_1}{\gamma}+\frac{V_1^2}{2g}+z_1=\frac{p_2}{\gamma}+\frac{V_2^2}{2g}+z_2+h_L \quad \begin{array}{l} z_1-z_2=S_0\ell \\ \frac{p_1}{\gamma}=y_1 \\ \frac{p_2}{\gamma}=y_2 \end{array}\right\} \rightarrow$ $y_1+\frac{V_1^2}{2g}+S_0\ell=y_2+\frac{V_2^2}{2g}+h_L$ $S_f=\frac{h_L}{\ell} \quad \rightarrow \quad y_1-y_2=\frac{(V_2^2-V_1^2)}{2g}+(S_f-S_0)\ell$ $\left.\begin{array}{l} S_f=0 \\ S_0=0 \end{array}\right\} \rightarrow \quad y_1-y_2=\frac{(V_2^2-V_1^2)}{2g}$	[four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A)	[velocity] (S8P3)→ 8th (3A) [gravity] (S6E1) → 6th (3A) [potential energy] (SP3) → 9th (3A)	9th	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 10 Open Channel Flow (Continued)				
10.3.1 Specific Energy $E = y + \frac{V^2}{2g}$ $E_1 = E_2 + (S_f - S_0)\ell$ $E = y + \frac{q^2}{2gy^2}$ $\frac{dE}{dy} = 1 - \frac{q^2}{gy^3} = 0$ $y_c = \left(\frac{q^2}{g}\right)^{1/3}$ $E_{min} = \frac{3y_c}{2}$ $V_c = \frac{q}{y_c} = \frac{(y_c^{3/2} g^{1/2})}{y_c} = \sqrt{gy_c}$ $Fr \equiv V_c/(gy_c)^{1/2} = 1$	[four operations] (M1N3) → 1st (2A) [derivative] → 12th (To be taught)	[energy] (SP3) → 9th (3B) [gravity] (S6E1) → 6th (3A) [velocity] (S8P3)→ 8th (3A)	9th	9th + PS
10.3.2 Channel Depth Variations $H_1 = H_2 + h_L$ $\frac{dH}{dx} = S_f$ $\frac{dz}{dx} = S_0$ $\frac{dH}{dx} = \frac{d}{dx}\left(\frac{V^2}{2g} + y + z\right) = \frac{V}{g}\frac{dV}{dx} + \frac{dy}{dx} + \frac{dz}{dx}$ $\frac{dh_L}{dx} = \frac{V}{g}\frac{dV}{dx} + \frac{dy}{dx} + S_0$ $\frac{V}{g}\frac{dV}{dx} + \frac{dy}{dx} = S_f - S_0$ $\frac{dV}{dx} = -\frac{q}{y^2}\frac{dy}{dx} = -\frac{V}{y}\frac{dy}{dx}$ $\frac{V}{g}\frac{dV}{dx} = \frac{V^2}{gy}\frac{dy}{dx} = -Fr^2\frac{dy}{dx}$ $Fr = V/(gy)^{1/2}$ $\frac{dy}{dx} = \frac{(S_f - S_0)}{(1 - Fr^2)}$	[four operations] (M1N3) → 1st (2A) [derivative] → 12th (To be taught)	[velocity] (S8P3)→ 8th (3A) [gravity] (S6E1) → 6th (3A)	PS	
10.4 Uniform Depth Channel Flow **10.4.1 Uniform Flow Approximations** N/A	[areas of geometric shapes] (M5M1) → 5th (2B) [perimeter] (M3M3) (M3M4) → 3rd (2B)	[velocity] (S8P3) → 8th (3A) [stress] → To be taught	9th	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 10 Open Channel Flow (Continued)				
10.4.2 The Chezy and Manning Equations $\sum F_x = \rho Q(V_2 - V_1) = 0 \quad F_1 - F_2 - \tau_w P\ell + \vec{W}\sin\theta = 0 \quad \sum F_x = 0$ $\left.\begin{array}{l} \tau_w = \frac{\vec{W}\sin\theta}{P\ell} = \frac{WS_0}{P\ell} \\ \sin\theta \approx \tan\theta = S_0 \\ S_0 << 1 \\ \vec{W} = \gamma A\ell \\ R_h = A/P \end{array}\right\} \rightarrow \begin{array}{l} \tau_w = \frac{\gamma A\ell S_0}{P\ell} = \gamma R_h S_0 \\ \tau_w == K\rho\frac{V^2}{2} \quad K\rho\frac{V^2}{2} = \gamma R_h S_0 \quad \rightarrow \\ V = C\sqrt{R_h S_0} \\ V = \frac{R_h^{2/3} S_0^{1/2}}{n} \end{array}$ $V = \frac{\kappa}{n} A R_h^{2/3} S_0^{1/2} \quad Q = \frac{\kappa}{n} A R_h^{2/3} S_0^{1/2}$	[four operations] (M1N3) → 1^{st} (2A) [exponent] (M6A3) → 6^{th} (2A) [areas of geometric shapes] (M5M1) → 5^{th} (2B) [trigonometric functions] (MA2G2) → 10^{th} (2F)	[pressure] (SC5) → 9^{th} (4B) → To be taught [velocity] (S8P3)→ 8^{th} (3A)	**9^{th}**	9^{th} + PS
10.4.3 Uniform Depth Examples N/A				
10.5 Gradually Varied Flow N/A				
10.5.1 Classification of Surface Shapes N/A				
10.5.2 Examples of Gradually Varied Flows N/A				
10.6 Rapidly Varied Flow N/A	[four operations] (M1N3) → 1^{st} (2A) [exponent] (M6A3) → 6^{th} (2A) [square root] (M8N1) → 8^{th} (2A)	[force] (S4P3) → 4^{th} (3A) or (S8P3) → 8^{th} (3C) [velocity] (S8P3)→ 8^{th} (3A) [gravity] (S6E1) → 6^{th} (3A) [pressure] (SC5) → 9^{th} (4B) → To be taught	9^{th}	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 10 Open Channel Flow (Continued)				
10.6.1 The Hydraulic Jump $F_1 - F_2 = \rho Q(V_2 - V_1) = \rho V_1 y_1 b(V_2 - V_1)$ $\left.\begin{array}{l} F_1 = p_{c1}A_1 = \frac{\gamma y_1^2 b}{2} \quad p_{c1} = \frac{\gamma y_1}{2} \\ F_2 = p_{c2}A_2 = \frac{\gamma y_2^2 b}{2} \quad p_{c1} = \frac{\gamma y_2}{2} \end{array}\right\} \rightarrow \frac{y_1^2}{2} - \frac{y_2^2}{2} = \frac{V_1 y_1}{g}(V_2 - V_1)$ $y_1 b_1 V_1 = y_2 b_2 V_2 = Q \quad y_1 + \frac{V_1^2}{2g} = y_2 + \frac{V_2^2}{2g} + h_L$ $\frac{y_1^2}{2} - \frac{y_2^2}{2} = \frac{V_1 y_1}{g}\left(\frac{V_1 y_1}{y_2} - V_1\right) = \frac{V_1^2 y_1}{g y_2}(y_1 - y_2)$ $\left.\left(\frac{y_2}{y_1}\right)^2 + \left(\frac{y_2}{y_1}\right) - 2Fr_1^2 = 0 \quad \begin{array}{l} Fr_1 = \frac{V_1}{\sqrt{g y_1}} \\ \frac{y_2}{y_1} = \frac{1}{2}\left(-1 \pm \sqrt{1+8Fr_1^2}\right) \end{array}\right\} \rightarrow$ $\frac{y_2}{y_1} = \frac{1}{2}\left(-1+\sqrt{1+8Fr_1^2}\right) \quad \frac{h_L}{y_1} = 1 - \frac{y_2}{y_1} + \frac{Fr_1^2}{2}\left[1 - \left(\frac{y_1}{y_2}\right)^2\right]$	[four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A) [square root] (M8N1) → 8th (2A)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [velocity] (S8P3)→ 8th (3A) [gravity] (S6E1) → 6th (3A) [pressure] (SC5) → 9th (4B) → To be taught	9th	9th + PS

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 10 Open Channel Flow (Continued)				
10.6.2 Sharp-Crested Weirs $\frac{p_A}{\gamma}+\frac{V_1^2}{2g}+z_A=(H+P_w-h)+\frac{u_2^2}{2g}\quad u_2=\sqrt{2g\left(h+\frac{V_1^2}{2g}\right)}$ $Q=\int_{(2)}u_2\,dA=\int_{h=0}^{h=H}u_2\ell\,dh$ $\ell=b\;\rightarrow\;Q=\sqrt{2g}\,b\int_0^H\left(h+\frac{V_1^2}{2g}\right)^{1/2}dh$ $Q=\frac{2}{3}\sqrt{2g}\,b\left[\left(H+\frac{V_1^2}{2g}\right)^{3/2}-\left(\frac{V_1^2}{2g}\right)^{3/2}\right]\left.\begin{matrix}P_w>>H\\ \frac{V_1^2}{2g}<<H\end{matrix}\right\}\rightarrow$ $Q=\frac{2}{3}\sqrt{2g}H^{3/2}\quad Q=C_{wr}\frac{2}{3}\sqrt{2g}bH^{3/2}\quad C_{wr}=0.611+0.075\left(\frac{H}{P_w}\right)$ $\ell=2(H-h)\tan\left(\frac{\theta}{2}\right)\quad\frac{V_1^2}{2g}<<H\;\rightarrow\;Q=\frac{8}{15}\tan\left(\frac{\theta}{2}\right)\sqrt{2g}H^{5/2}$ $Q=C_{wt}\frac{8}{15}\tan\left(\frac{\theta}{2}\right)\sqrt{2g}H^{5/2}$	[four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A) [square root] (M8N1) → 8th (2A) [trigonometric functions] (MA2G2) → 10th (2F) [integration] → 12th (To be taught as a special skill) Nore: The main formulas are not based on calculus.	[velocity] (S8P3)→ 8th (3A) [gravity] (S6E1) → 6th (3A)	9th	9th + PS
10.6.3 Broad-Crested Weirs $H+P_w+\frac{V_1^2}{2g}=y_c+p_w+\frac{V_c^2}{2g}\quad H-y_c=\frac{\left(V_c^2-V_1^2\right)}{2g}=\frac{V_c^2}{2g}$ $\left.\begin{matrix}V_2=V_c=(gy_c)^{1/2}\\ V_c^2=gy_c\end{matrix}\right\}\rightarrow\;H-y_c=\frac{y_c}{2}\;\rightarrow\;y_c=\frac{2H}{3}$	[four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A) [square root] (M8N1) → 8th (2A)	[velocity] (S8P3)→ 8th (3A) [gravity] (S6E1) → 6th (3A)	9th	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 10 Open Channel Flow (Continued)				
10.6.3 Broad-Crested Weirs (Continued) $Q = by_2V_2 = by_cV_c = by_c(gy_c)^{1/2} = b\sqrt{g}\,y_c^{3/2} \rightarrow$ $Q = b\sqrt{g}\left(\frac{2}{3}\right)^{3/2} H^{3/2}$ $Q = C_{wb}b\sqrt{g}\left(\frac{2}{3}\right)^{3/2} H^{3/2}$ $C_{wb} = \frac{0.65}{(1+H/P_w)^{1/2}}$	[four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A) [square root] (M8N1) → 8th (2A)	[velocity] (S8P3)→ 8th (3A) [gravity] (S6E1) → 6th (3A)	9th	9th + PS
10.6.4 Underflow Gates $q = C_d a\sqrt{2gy_1}$	[four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A) [square root] (M8N1) → 8th (2A)	[velocity] (S8P3)→ 8th (3A) [gravity] (S6E1) → 6th (3A)	9th	
10.7 Chapter Summary and Study Guide N/A	N/A	N/A	9th	
Chapter 11 Compressible Flow				
11.1 Ideal Gas Relationships $p = \rho RT$ $R = \frac{\lambda}{M_{gas}}$ $c_v = \left(\frac{\partial \check{u}}{\partial T}\right)_v = \frac{d\check{u}}{dT}$ $d\check{u} = c_v dT$ $\check{u}_2 - \check{u}_1 = \int_{T_1}^{T_2} c_v\, dT$ $\forall = \frac{1}{\rho}$ $\check{u}_2 - \check{u}_1 = c_v(T_2 - T_1)$ $\check{h} = \check{u} + \frac{p}{\rho}$ $\check{u} = \check{u}(T)$ $\frac{p}{\rho} = RT$ $\check{h} = \check{h}(T)$ $c_p = \left(\frac{\partial \check{h}}{\partial T}\right)_p = \frac{d\check{h}}{dT}$ $d\check{h} = c_p dT$ $\check{h}_2 - \check{h}_1 = \int_{T_1}^{T_2} c_p\, dT$ $\check{h}_2 - \check{h}_1 = c_p(T_2 - T_1)$ $\check{h} = \check{u} + RT$	[four operations] (M1N3) → 1st (2A) [volume] (M5M4) → 5th (1B) (M6M3) → 6th (2B) (MA1G5) → 9th (2F) [functions] (MA1A1) → 9th (2E) and others → Post-secondary [integration] → 12th (To be taught as a special skill) [partial derivative] → Post-secondary	[**Ideal Gas Law**] → Post-secondary → to be taught [heat] (S2P2) → 2nd (3A) [temperature] (SP3) → 9th (3B) [density] (S6E5) → 6th (4A) [pressure] (SC5) → 9th (4B) → To be taught	PS	9th + PS

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 11 Compressible Flow (Continued)				
11.1 Ideal Gas Relationships (Continued) $d\check{h} = d\check{u} + R\ dT \quad \frac{d\check{h}}{dT} = \frac{d\check{u}}{dT} + R \quad c_p - c_v = R \quad k = \frac{c_p}{c_v}$ $c_p = \frac{Rk}{k-1} \quad c_v = \frac{R}{k-1} \quad T\ ds = d\check{u} + pd\left(\frac{1}{\rho}\right)$ $d\check{h} = d\check{u} + pd\left(\frac{1}{\rho}\right) + \left(\frac{1}{\rho}\right)dp \quad T\ ds = d\check{h} - \left(\frac{1}{\rho}\right)dp$ $ds = c_v \frac{dT}{T} + \frac{R}{1/\rho} d\left(\frac{1}{\rho}\right) \quad ds = c_p \frac{dT}{T} - R\frac{dp}{p}$ $s_2 - s_1 = c_v \ln\frac{T_2}{T_1} + R\ln\frac{\rho_1}{\rho_2} \quad s_2 - s_1 = c_p \ln\frac{T_2}{T_1} + R\ln\frac{p_2}{p_1}$	[four operations] (M1N3) → 1st (2A) [volume] (M5M4) → 5th (1B) (M6M3) → 6th (2B) (MA1G5) → 9th (2F) [functions] (MA1A1) → 9th (2E) and others → Post-secondary [integration] → 12th (To be taught as a special skill) [partial derivative] → Post-secondary	[**Ideal Gas Law**] → Post-secondary → to be taught [heat] (S2P2) → 2nd (3A) [temperature] (SP3) → 9th (3B) [density] (S6E5) → 6th (4A) [pressure] (SC5) → 9th (4B) → To be taught	PS	9th + PS
11.2 Mach Number and Speed of Sound $Ma = \frac{V}{c} \quad \rho Ac = (\rho + \delta\rho)(c - \delta V)$ $\rho c = \rho c - \rho\delta V + c\delta\rho - (\delta\rho)(\delta V) \quad \rho\ \delta V = c\ \delta\rho$ $-c\rho cA + (c - \delta V)(\rho + \delta\rho)(c - \delta V)A = pA - (p + \delta p)A$ $-c\rho cA + (c - \delta V)\rho Ac = -\delta pA \quad \rho\delta V = \frac{\delta p}{c} \quad c^2 = \frac{\delta p}{\delta\rho} \quad c = \sqrt{\frac{\delta p}{\delta\rho}}$ $\frac{\delta p}{\rho} + \delta\left(\frac{V^2}{2}\right) + g\ \delta z = \delta(\text{loss}) \quad \frac{\delta p}{\rho} + \frac{(c - \delta V)^2}{2} - \frac{c^2}{2} = 0$ $\rho\ \delta V = \frac{\delta p}{c}$	[four operations] (M1N3) → 1st (2A) [areas of geometric shapes] (M5M1) → 5th (2B) [exponent] (M6A3) → 6th (2A) [square root] (M8N1) → 8th (2A) [partial derivative] → Post-secondary	[speed of sound] (SPS9) → 9th (3B) [pressure] (SC5) → 9th (4B) → To be taught [density] (S6E5) → 6th (4A) [velocity] (S8P3)→ 8th (3A)	PS	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 11 Compressible Flow (Continued)				
11.2 Mach Number and Speed of Sound (Continued) $\left.\begin{matrix} c=\sqrt{\frac{\delta p}{\delta\rho}} \\ \delta p\to\partial p\to 0\end{matrix}\right\} \to c=\sqrt{\left(\frac{\partial p}{\partial\rho}\right)_s} \quad p=(\text{constant})(\rho^k)$ $\left(\frac{\partial p}{\partial\rho}\right)_s=(\text{constant})k\rho^{k-1}=\frac{p}{\rho^k}k\rho^{k-1}=\frac{p}{\rho}k=RTk \quad c=\sqrt{RTk}$ $E_v=\frac{dp}{d\rho/\rho}=\rho\left(\frac{\partial p}{\partial\rho}\right)_s \quad c=\sqrt{\frac{E_v}{\rho}}$	[four operations] (M1N3) → 1^{st} (2A) [volume] (M5M4) → 5^{th} (1B) (M6M3) → 6^{th} (2B) (MA1G5) → 9^{th} (2F) [functions] (MA1A1) → 9^{th} (2E) and others → Post-secondary [integration] → 12^{th} (To be taught as a special skill) [partial derivative] → Post-secondary	[**Ideal Gas Law**] → Post-secondary → to be taught [heat] (S2P2) → 2^{nd} (3A) [temperature] (SP3) → 9^{th} (3B) [density] (S6E5) → 6^{th} (4A) [pressure] (SC5) → 9^{th} (4B) → To be taught	PS	9^{th} + PS
11.3 Categories of Compressible Flow $r=(t-t_{wave})c \quad \sin\alpha=\frac{c}{V}=\frac{1}{Ma}$	[four operations] (M1N3) → 1^{st} (2A) [trigonometric functions] (MA2G2) → 10^{th} (2F)	[velocity] (S8P3)→ 8^{th} (3A) [speed of sound] (SPS9) → 9^{th} (3B)	9^{th}	
11.4 Isentropic Flow of an Ideal Gas **11.4.1 Effect of Variations in Flow Cross-Sectional Areas** $\dot{m}=\rho AV=\text{constant} \quad dp+\frac{1}{2}\rho\, d(V^2)+\gamma\, dz=0 \quad \frac{dp}{\rho V^2}=-\frac{dV}{V}$ $\ln\rho+\ln A+\ln V=\text{constant} \quad \frac{d\rho}{\rho}+\frac{dA}{A}+\frac{dV}{V}=0 \quad \to$ $\left.\begin{matrix} -\frac{dV}{V}=\frac{d\rho}{\rho}+\frac{dA}{A} \\ \frac{dp}{\rho V^2}=-\frac{dV}{V}\end{matrix}\right\} \to \frac{dp}{\rho V^2}\left(1-\frac{V^2}{dp/d\rho}\right)=\frac{dA}{A}$	[four operations] (M1N3) → 1^{st} (2A) [areas of geometric shapes] (M5M1) → 5^{th} (2B) [exponent] (M6A3) → 6^{th} (2A) [partial derivatives] → Post-secondary	[pressure] (SC5) → 9^{th} (4B) → To be taught [velocity] (S8P3) → 8^{th} (3A) [density] (S6E5) → 6^{th} (4A)	PS	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 11 Compressible Flow (Continued)				
11.4.1 Effect of Variations in Flow Cross-Sectional Areas (Continued) $\left.\begin{array}{l} c=\sqrt{\left(\frac{\partial p}{\partial \rho}\right)_s} \\ Ma=\frac{V}{c} \\ \frac{dp}{\rho V^2}\left(1-\frac{V^2}{dp/d\rho}\right)=\frac{dA}{A}\end{array}\right\} \rightarrow \frac{dp}{\rho V^2}\left(1-Ma^2\right)=\frac{dA}{A}$ $\left.\begin{array}{l} \frac{dp}{\rho V^2}=-\frac{dV}{V} \\ \frac{dp}{\rho V^2}\left(1-Ma^2\right)=\frac{dA}{A}\end{array}\right\} \rightarrow \frac{dV}{V}=-\frac{dA}{A}\frac{1}{\left(1-Ma^2\right)}$ $\frac{d\rho}{\rho}=\frac{dA}{A}\frac{Ma^2}{\left(1-Ma^2\right)} \quad \frac{dA}{dV}=-\frac{A}{V}\left(1-Ma^2\right)$	[four operations] (M1N3) → 1st (2A) [areas of geometric shapes] (M5M1) → 5th (2B) [exponent] (M6A3) → 6th (2A) [partial derivatives] → Post-secondary	[pressure] (SC5) → 9th (4B) → To be taught [velocity] (S8P3) → 8th (3A) [density] (S6E5) → 6th (4A)	PS	9th + PS
11.4.2 Converging-Diverging Duct Flow $\frac{p}{p^k}=\text{constant}=\frac{p_0}{p_0^k} \quad \frac{dp}{\rho}+d\left(\frac{V^2}{2}\right)=0 \quad \frac{p_0^{1/k}}{\rho_0}\frac{dp}{(p)^{1/k}}+d\left(\frac{V^2}{2}\right)=0$ $\frac{k}{k-1}\left(\frac{p_0}{\rho_0}-\frac{p}{\rho}\right)-\frac{V^2}{2}=0 \quad \frac{kR}{k-1}\left(T_0-T\right)-\frac{V^2}{2}=0$ $\left.\begin{array}{l} c_p\left(T_0-T\right)-\frac{V^2}{2}=0 \\ \check{h}_2-\check{h}_1=c_p\left(T_2-T_1\right)\end{array}\right\} \rightarrow \check{h}_0-\left(\check{h}+\frac{V^2}{2}\right)=0$	[four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A) [square root] (M8N1) → 8th (2A)	[pressure] (SC5) → 9th (4B) → To be taught [density] (S6E5) → 6th (4A) [velocity] (S8P3) → 8th (3A) [**Ideal Gas Law**] → Post-secondary → to be taught	9th	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 11 Compressible Flow (Continued)				
11.4.2 Converging-Diverging Duct Flow (Continued) $\frac{T}{T_0}=\frac{1}{1+[(k-1)/2]Ma^2}$ $\left(\frac{p}{p_0}\right)\left(\frac{\rho_0}{\rho}\right)=\frac{T}{T_0}$ $\left(\frac{p}{p_0}\right)=\left(\frac{T}{T_0}\right)^{k/(k-1)}$ $\left.\begin{matrix}\frac{T}{T_0}=\frac{1}{1+[(k-1)/2]Ma^2}\\ \left(\frac{p}{p_0}\right)=\left(\frac{T}{T_0}\right)^{k/(k-1)}\end{matrix}\right\} \rightarrow \frac{p}{p_0}=\left\{\frac{1}{1+[(k-1)/2]Ma^2}\right\}^{k/(k-1)}$ $\left.\begin{matrix}\frac{T}{T_0}=\frac{1}{1+[(k-1)/2]Ma^2}\\ \left(\frac{p}{p_0}\right)\left(\frac{\rho_0}{\rho}\right)=\frac{T}{T_0}\\ \frac{p}{p_0}=\left\{\frac{1}{1+[(k-1)/2]Ma^2}\right\}^{k/(k-1)}\end{matrix}\right\} \rightarrow$ $\frac{\rho_0}{\rho}=\left\{\frac{1}{1+[(k-1)/2]Ma^2}\right\}^{k/(k-1)}$ $\frac{p^*}{p_0}=\left(\frac{2}{k+1}\right)^{k/(k-1)}$ $\left(\frac{p^*}{p_0}\right)_{k=1.4}=0.528$ $p^*_{k=1.4}=0.528p_{atm}$ $\frac{T^*}{T_0}=\frac{2}{k+1}$ $\left(\frac{T^*}{T_0}\right)_{k=1.4}=0.833$ $T^*_{k=1.4}=0.833T_{atm}$	[four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A) [square root] (M8N1) → 8th (2A)	[pressure] (SC5) → 9th (4B) → To be taught [density] (S6E5) → 6th (4A) [velocity] (S8P3) → 8th (3A) [**Ideal Gas Law**] → Post-secondary → to be taught	9th	9th + PS

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 11 Compressible Flow (Continued)				
11.4.2 Converging-Diverging Duct Flow (Continued) $\left.\begin{array}{l} Ma=1 \\ p=\rho RT \\ \frac{p^*}{p_0}=\left(\frac{2}{k+1}\right)^{k/(k-1)} \\ \frac{T^*}{T_0}=\frac{2}{k+1} \end{array}\right\} \rightarrow$ $\frac{\rho^*}{\rho_0}=\left(\frac{p^*}{T^*}\right)\left(\frac{T_0}{p_0}\right)=\left(\frac{2}{k+1}\right)^{k/(k-1)}\left(\frac{k+1}{2}\right)=\left(\frac{2}{k+1}\right)^{k/(k-1)}$ $\left(\frac{\rho^*}{\rho_0}\right)_{k=1.4}=0.634$ $\rho AV=\rho^* A^* V^* \quad \frac{A}{A^*}=\left(\frac{\rho^*}{\rho}\right)\left(\frac{V^*}{V}\right) \quad V^*=\sqrt{RT^*k}$ $V=Ma\sqrt{RTk}$ $\frac{A}{A^*}=\frac{1}{Ma}\left(\frac{\rho^*}{\rho_0}\right)\left(\frac{\rho_0}{\rho}\right)\sqrt{\frac{(T^*/T_0)}{T/T_0}}$	[four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A) [square root] (M8N1) → 8th (2A)	[pressure] (SC5) → 9th (4B) → To be taught [density] (S6E5) → 6th (4A) [velocity] (S8P3) → 8th (3A) [**Ideal Gas Law**] → Post-secondary → to be taught	9th	9th + PS

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 11 Compressible Flow (Continued)				
11.4.2 Converging-Diverging Duct Flow (Continued) $\frac{T}{T_0}=\frac{1}{1+[(k-1)/2]Ma^2}$ $\frac{p}{p_0}=\left\{\frac{1}{1+[(k-1)/2]Ma^2}\right\}^{k/(k-1)}$ $\frac{T^*}{T_0}=\frac{2}{k+1}$ $\frac{\rho^*}{\rho_0}=\left(\frac{\rho^*}{T^*}\right)\left(\frac{T_0}{p_0}\right)=\left(\frac{2}{k+1}\right)^{k/(k-1)}\left(\frac{k+1}{2}\right)=\left(\frac{2}{k+1}\right)^{k/(k-1)}$ $\frac{A}{A^*}=\frac{1}{Ma}\left(\frac{\rho^*}{\rho_0}\right)\left(\frac{\rho_0}{\rho}\right)\sqrt{\frac{(T^*/T_0)}{T/T_0}}$ → $\frac{A}{A^*}=\frac{1}{Ma}\left\{\frac{1+[(k-1)/2]Ma^2}{1+[(k-1)/2]}\right\}^{(k+1)/[2(k-1)]}$	[four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A) [square root] (M8N1) → 8th (2A)	[pressure] (SC5) → 9th (4B) → To be taught [density] (S6E5) → 6th (4A) [velocity] (S8P3) → 8th (3A) [**Ideal Gas Law**] → Post-secondary → to be taught	**9th**	9th + PS
11.4.3 Constant Area Duct Flow N/A	N/A	[density] (S6E5) → 6th (4A) [velocity] (S8P3)→ 8th (3A) [pressure] (SC5) → 9th (4B) [friction] (S8P3) → 8th (3A) → To be taught [acceleration] (S8P3) → 8th (3C)	**9th**	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 11 Compressible Flow (Continued)				
11.5 Nonisentropic Flow of an Ideal Gas **11.5.1 Adiabatic Constant Area Duct Flow with Friction (Fanno Flow)** $\dot{m}\left[\check{h}_2-\check{h}_1+\frac{V_2^2-V_1^2}{2}+g(z_2-z_1)\right]=\dot{Q}_{\underset{in}{net}}+\dot{W}_{\underset{net\ in}{shaft}}$ $\left.\begin{matrix}\check{h}+\frac{V^2}{2}=\check{h}_0=\text{constant}\\ \check{h}-\check{h}_0=c_p(T-T_0)\end{matrix}\right\}\rightarrow\left\{\begin{matrix}T+\frac{V^2}{2c_p}=T_0=\text{constant}\\ T+\frac{(\rho V)^2}{2c_p\rho^2}=T_0=\text{constant}\end{matrix}\right.$ $T+\frac{(\rho V)^2T^2}{2c_p(p^2/R^2)}=T_0=\text{constant}\quad\leftarrow\quad p=\rho RT\quad\uparrow$ $s-s_1=c_p\ln\frac{T}{T_1}-R\ln\frac{p}{p_1}$ $T\,ds=d\check{h}-\frac{dp}{\rho}\quad\left.\begin{matrix}d\check{h}=c_pdT\\ p=\rho RT\end{matrix}\right\}\rightarrow\frac{dp}{p}=\frac{d\rho}{\rho}+\frac{dT}{T}$ $T\,ds=c_pdT-RT\left(\frac{d\rho}{\rho}+\frac{dT}{T}\right)\quad\rho V=\text{constant}\quad\frac{d\rho}{\rho}=-\frac{dV}{V}\rightarrow$ $T\,ds=c_pdT-RT\left(-\frac{dV}{V}+\frac{dT}{T}\right)\quad\frac{ds}{dT}=\frac{c_p}{T}-R\left(-\frac{1}{V}\frac{dV}{dT}+\frac{1}{T}\right)$ $\frac{dV}{dT}=-\frac{c_p}{V}\quad\frac{ds}{dT}=\frac{c_p}{T}-R\left(\frac{c_p}{V^2}+\frac{1}{T}\right)\quad V_a=\sqrt{RT_ak}$	[four operations] (M1N3) → 1st (2A) [areas of geometric shapes] (M5M1) → 5th (2B) [exponent] (M6A3) → 6th (2A) [logarithmic functions] (MA2A5) → 10th (2E) (To be taught as a special skill) [square root] (M8N1) → 8th (2A) [integration] → 12th (To be taught) [derivative] → Post-secondary	[velocity] (S8P3)→ 8th (3A) [density] (S6E5) → 6th (4A) [**Ideal Gas Law**] → Post-secondary → to be taught [temperature] (SP3) → 9th (3B) [entropy] → Post-secondary → To be taught [pressure] (SC5) → 9th (4B) → To be taught [momentum] (SP3) → 9th (3B) [pressure] (SC5) → 9th (4B) [friction] (S8P3) → 8th (3A) → To be taught [wave] (S8P4) → 8th (3A)	PS	9th + PS

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 11 Compressible Flow (Continued)				
11.5.1 Adiabatic Constant Area Duct Flow with Friction (Fanno Flow) $p_1A_1 - p_2A_2 - R_x = \dot{m}(V_2 - V_1)$ $p_1 - p_2 - \frac{R_x}{A} = \rho V(V_2 - V_1)$ $-dp - \frac{\tau_w \pi D\, d_x}{A} = \rho V\, dV$ $f = \frac{8\tau_w}{\rho V^2}$ $\uparrow\ A = \frac{\pi D^2}{4} \rightarrow -dp - f\rho\frac{V^2}{2}\frac{dx}{D} = \rho V\, dV$ $dp + \frac{f}{p}\frac{\rho V^2}{2}\frac{dx}{D} + \frac{\rho}{p}\frac{d(V^2)}{2} = 0$ $\frac{dp}{p} + \frac{fk}{2}Ma^2\frac{dx}{D} + k\frac{Ma^2}{2}\frac{d(V^2)}{V^2} = 0$ $V^2 = Ma^2RTk$ $\frac{d(V^2)}{V^2} = \frac{d(Ma^2)}{Ma^2} + \frac{dT}{T}$ $\frac{dT}{T} + \frac{d(V^2)}{2c_pT} = 0$ $\frac{dT}{T} + \frac{k-1}{2}Ma^2\frac{d(V^2)}{V^2} = 0$ $\frac{d(V^2)}{V^2} = \frac{d(Ma^2)/Ma^2}{1+[(k-1)/2]Ma^2}$ $\frac{dp}{p} = \frac{1}{2}\frac{d(V^2)}{V^2} - \frac{d(Ma^2)}{Ma^2}$ $\frac{1}{2}(1+kMa^2)\frac{d(V^2)}{V^2} - \frac{d(Ma^2)}{Ma^2} + \frac{f}{k}Ma^2\frac{dx}{D} = 0$	[four operations] (M1N3) → 1st (2A) [areas of geometric shapes] (M5M1) → 5th (2B) [exponent] (M6A3) → 6th (2A) [logarithmic functions] (MA2A5) → 10th (2E) (To be taught as a special skill) [square root] (M8N1) → 8th (2A) [integration] → 12th (To be taught) [derivative] → Post-secondary	[velocity] (S8P3)→ 8th (3A) [density] (S6E5) → 6th (4A) [**Ideal Gas Law**] → Post-secondary → to be taught [temperature] (SP3) → 9th (3B) [entropy] → Post-secondary → To be taught [pressure] (SC5) → 9th (4B) → To be taught [momentum] (SP3) → 9th (3B) [pressure] (SC5) → 9th (4B) [friction] (S8P3) → 8th (3A) → To be taught [wave] (S8P4) → 8th (3A)	PS	9th + PS

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 11 Compressible Flow (Continued)				
11.5.1 Adiabatic Constant Area Duct Flow with Friction (Fanno Flow) (Continued) $\frac{(1-Ma^2)d(Ma^2)}{\{1+[(k-1)/2]Ma^2\}kMa^4} = f\frac{dx}{D}$ $\int_{Ma}^{Ma^*=1} \frac{(1-Ma^2)d(Ma^2)}{\{1+[(k-1)/2]Ma^2\}kMa^4} = \int_{\ell}^{\ell^*} f\frac{dx}{D}$ $\frac{1}{k}\frac{(1-Ma^2)}{Ma^2} + \frac{k+1}{2k}\ln\left\{\frac{[(k+1)/2]Ma^2}{1+[(k-1)/2]Ma^2}\right\} = \frac{f(\ell^*-\ell)}{D}$ $\frac{f(\ell^*-\ell_2)}{D} - \frac{f(\ell^*-\ell_1)}{D} = \frac{f}{D}(\ell_1-\ell_2)$ $\frac{dT}{T} = -\frac{(k-1)}{2\{1+[(k-1)/2]Ma^2\}}d(Ma^2)$ $\frac{T}{T^*} = \frac{(k+1)/2}{1+[(k-1)/2]Ma^2}$ $\frac{V}{V^*} = \frac{Ma\sqrt{RTk}}{\sqrt{RT^*k}} = Ma\sqrt{\frac{T}{T^*}}$ $\frac{V}{V^*} = \left\{\frac{[(k+1)/2]Ma^2}{1+[(k-1)/2]Ma^2}\right\}^{1/2}$ $\frac{\rho}{\rho^*} = \frac{V^*}{V}$ $\frac{\rho}{\rho^*} = \left\{\frac{1+[(k-1)/2]Ma^2}{[(k+1)/2]Ma^2}\right\}^{1/2}$ $\frac{p}{p^*} = \frac{\rho}{\rho^*}\frac{T}{T^*}$ $\frac{p}{p^*} = \frac{1}{Ma}\left\{\frac{(k+1)/2}{1+[(k-1)/2]Ma^2}\right\}^{1/2}$ $\frac{p_0}{p^*_0} = \left(\frac{p_0}{p}\right)\left(\frac{p}{p^*}\right)\left(\frac{p^*}{p^*_0}\right)$ $\frac{p_0}{p^*_0} = \frac{1}{Ma}\left[\left(\frac{2}{k+1}\right)\left(1+\frac{k-1}{2}Ma^2\right)\right]^{(k+1)/2(k-1)}$	[four operations] (M1N3) → 1st (2A) [areas of geometric shapes] (M5M1) → 5th (2B) [exponent] (M6A3) → 6th (2A) [logarithmic functions] (MA2A5) → 10th (2E) (To be taught as a special skill) [square root] (M8N1) → 8th (2A) [integration] → 12th (To be taught) [derivative] → Post-secondary	[velocity] (S8P3)→ 8th (3A) [density] (S6E5) → 6th (4A) [**Ideal Gas Law**] → Post-secondary → to be taught [temperature] (SP3) → 9th (3B) [entropy] → Post-secondary → To be taught [pressure] (SC5) → 9th (4B) → To be taught [momentum] (SP3) → 9th (3B) [pressure] (SC5) → 9th (4B) [friction] (S8P3) → 8th (3A) → To be taught [wave] (S8P4) → 8th (3A)	PS	9th + PS

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 11 Compressible Flow (Continued)				
11.5.2 Frictionless Constant Area Duct Flow with Heat Transfer (Rayleigh Flow) $p_1A_1+\dot{m}V_1=p_2A_2+\dot{m}V_2+R_x \quad p+\frac{(\rho V)^2}{\rho}=\text{constant}$ $p+\frac{(\rho V)^2 RT}{\rho}=\text{constant} \quad \rho V=\text{constant}$ $dp=-\rho V\,dV \quad \frac{dp}{\rho}=-V\,dV \quad T\,ds=d\check{h}+V\,dV$ $T\,ds=c_p\,dT+V\,dV \quad \frac{ds}{dT}=\frac{c_p}{T}+\frac{V}{T}\frac{dV}{dT}$ $\frac{ds}{dT}=\frac{c_p}{T}+\frac{V}{T}\frac{1}{[(T/V)-(V/R)]} \quad V_a=\sqrt{RT_ak} \quad Ma_a=1$ $\frac{dT}{ds}=\frac{1}{ds/dT}=\frac{1}{(c_p/T)+(V/T)[(T/V)-(V/R)]^{-1}}$ $\frac{dT}{ds}=0 \rightarrow Ma_b=\sqrt{\frac{1}{k}}$ $d\check{h}+V\,dV=\delta q \quad \frac{dV}{V}=\frac{\delta q}{c_pT}\left[\frac{V}{T}\frac{dT}{dV}+\frac{V^2(k-1)}{kRT}\right]^{-1}$ $\frac{dV}{V}=\frac{\delta q}{c_pT}\frac{1}{(1-Ma^2)} \quad p+\rho V^2=p_a+\rho_aV_a^2 \quad \frac{p}{p_a}+\frac{\rho V^2}{p_a}=1+\frac{\rho_a}{p_a}V_a^2$ $\frac{p}{p_a}=\frac{1+k}{1+kMa^2} \quad \frac{T}{T_a}=\frac{p}{p_a}\frac{\rho_a}{\rho} \quad \frac{\rho_a}{\rho}=\frac{V}{V_a}$	[four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A) [derivative] → 12th + [square root] (M8N1) → 8th (2A)	[velocity] (S8P3)→ 8th (3A) [density] (S6E5) → 6th (4A) [temperature] (SP3) → 9th (3B) [pressure] (SC5) → 9th (4B) → To be taught	PS	9th + PS

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 11 Compressible Flow (Continued)				
11.5.2 Frictionless Constant Area Duct Flow with Heat Transfer (Rayleigh Flow) (Continued) $\frac{\rho_a}{\rho} = Ma\sqrt{\frac{T}{T_a}}$ $\frac{T}{T_a} = \left(\frac{p}{p_a}Ma\right)^2$ $\frac{T}{T_a} = \left[\frac{(1+k)Ma}{1+kMa^2}\right]^2$ $\frac{\rho_a}{\rho} = \frac{V}{V_a} = Ma\left[\frac{(1+k)Ma}{1+kMa^2}\right]$ $\frac{T}{T_{0,a}} = \left(\frac{T_0}{T}\right)\left(\frac{T}{T_a}\right)\left(\frac{T_a}{T_{0,a}}\right)$ $\frac{T}{T_{0,a}} = \frac{2(k+1)Ma^2\left(1+\frac{k-1}{2}Ma^2\right)}{(1+kMa^2)^2}$ $\frac{p_0}{p_{0,a}} = \left(\frac{p_0}{p}\right)\left(\frac{p}{p_a}\right)\left(\frac{p_a}{p_{0,a}}\right)$ $\frac{p_0}{p_{0,a}} = \frac{(1+k)}{(1+kMa^2)}\left[\left(\frac{2}{k+1}\right)\left(1+\frac{k-1}{2}\right)Ma^2\right]^{k/(k-1)}$	[four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A) [derivative] → 12th + [square root] (M8N1) → 8th (2A)	[velocity] (S8P3)→ 8th (3A) [density] (S6E5) → 6th (4A) [temperature] (SP3) → 9th (3B) [pressure] (SC5) → 9th (4B) → To be taught	PS	9th + PS
11.5.3 Normal Shock Waves $\rho V = \text{constant}$ $p+\rho V^2 = \text{constant}$ $p + \frac{(\rho V)^2 RT}{p} = \text{constant}$ $\check{h} + \frac{V^2}{2} = \check{h}_0 = \text{constant}$ $\check{h} - \check{h}_0 = c_p(T-T_0)$ $p = \rho RT$ $T + \frac{(\rho V)^2 T^2}{2c_p(p^2/R^2)} = T_0 = \text{constant}$ $\frac{p_y}{p_x} = \left(\frac{p_y}{p_a}\right)\left(\frac{p_a}{p_x}\right)$ $\frac{p_y}{p_a} = \frac{1+k}{1+kMa_y^2}$ $\frac{p_x}{p_a} = \frac{1+k}{1+kMa_x^2}$	[four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A)	[**Ideal Gas Law**] → Post-secondary → to be taught [temperature] (S3P1) → 3rd (3A) [density] (S6E5) → 6th (4A) [pressure] (SC5) → 9th (4B) → To be taught [speed] (S2P3) → 2nd (3A) [velocity] (S8P3)→ 8th (3A) [graph] (S7CS6) → 7th (6)	9th	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 11 Compressible Flow (Continued)				
11.5.3 Normal Shock Waves (Continued) $\frac{p_y}{p_x}=\frac{1+k\mathrm{Ma}_x^2}{1+k\mathrm{Ma}_y^2}$ $\frac{p_y}{p_x}=\left(\frac{p_y}{p^*}\right)\left(\frac{p^*}{p_x}\right)$ $\frac{p}{p^*}=\frac{1}{Ma}\left\{\frac{(k+1)/2}{1+[(K-1)/2]Ma^2}\right\}^{1/2}$ $p_x+\rho_x V_x^2=p_y+\rho_y V_Y^2$ $\frac{\rho V^2}{p}=\frac{V^2}{RT}=\frac{kV^2}{RTk}=k\mathrm{Ma}^2$ $\frac{T_y}{T_x}=\left(\frac{T_y}{T^*}\right)\left(\frac{T^*}{T_x}\right)$ $\left.\begin{matrix}\frac{T_y}{T^*}=\frac{(k+1)/2}{1+[(k-1)/2]\mathrm{Ma}_y^2}\\ \frac{T_x}{T^*}=\frac{(k+1)/2}{1+[(k-1)/2]\mathrm{Ma}_x^2}\end{matrix}\right\}\rightarrow$ $\frac{T_y}{T_x}=\frac{1+[(k-1)/2]\mathrm{Ma}_x^2}{1+[(k-1)/2]\mathrm{Ma}_y^2}$ $\frac{p_y}{p_x}=\left(\frac{T_y}{T_x}\right)\left(\frac{\rho_y}{\rho_x}\right)$ $\rho_x V_x=\rho_y V_y$ $\frac{p_y}{p_x}=\left(\frac{T_y}{T_x}\right)\left(\frac{V_x}{V_y}\right)$ $\frac{p_y}{p_x}=\left(\frac{T_y}{T_x}\right)^{1/2}\left(\frac{\mathrm{Ma}_x}{\mathrm{Ma}_y}\right)$ $\frac{p_y}{p_x}=\left\{\frac{1+[(k-1)/2]\mathrm{M}a_x^2}{1+[(k-1)/2]\mathrm{M}a_y^2}\right\}^{1/2}\frac{\mathrm{M}a_x}{\mathrm{M}a_y}$ $\mathrm{M}a_y^2=\frac{\mathrm{M}a_x^2+[2/(k-1)]}{[2k/(k-1)]\mathrm{Ma}_x^2-1}$ $\frac{p_y}{p_x}=\frac{2k}{k+1}\mathrm{Ma}_x^2-\frac{k-1}{k+1}$ $\frac{T_y}{T_x}=\frac{\{1+[(k-1)/2]\mathrm{Ma}_x^2\}\{2k/(k-1)\}\mathrm{Ma}_x^2-1}{\{(k+1)^2/2(k-1)\}\mathrm{Ma}_x^2}$	[four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A)	[**Ideal Gas Law**] → Post-secondary → to be taught [temperature] (S3P1) → 3rd (3A) [density] (S6E5) → 6th (4A) [pressure] (SC5) → 9th (4B) → To be taught [speed] (S2P3) → 2nd (3A) [velocity] (S8P3)→ 8th (3A) [graph] (S7CS6) → 7th (6)	9th	9th + PS

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 11 Compressible Flow (Continued)				
11.5.3 Normal Shock Waves (Continued) $\frac{\rho_y}{\rho_x}=\frac{V_x}{V_y}$ $\frac{\rho_y}{\rho_x}=\left(\frac{p_y}{p_x}\right)\left(\frac{T_x}{T_y}\right)$ $\frac{\rho_y}{\rho_x}=\frac{V_x}{V_y}=\frac{(k+1)\mathrm{Ma}_x^2}{(k-1)\mathrm{Ma}_x^2+2}$ $\frac{p_{0,y}}{p_{0,x}}=\left(\frac{p_{0,y}}{p_y}\right)\left(\frac{p_y}{p_x}\right)\left(\frac{p_x}{p_{0,x}}\right)$ $\frac{p_{0,y}}{p_{0,x}}=\frac{\left(\frac{k+1}{2}\mathrm{Ma}_x^2\right)^{k/(k-1)}\left(1+\frac{k-1}{2}\mathrm{Ma}_x^2\right)^{k/(1-k)}}{\left(\frac{2k}{k+1}\mathrm{Ma}_x^2-\frac{k-1}{k+1}\right)^{1/(k-1)}}$	[four operations] (M1N3) → 1st (2A) [exponent] (M6A3) → 6th (2A)	[**Ideal Gas Law**] → Post-secondary → to be taught [temperature] (S3P1) → 3rd (3A) [density] (S6E5) → 6th (4A) [pressure] (SC5) → 9th (4B) → To be taught [speed] (S2P3) → 2nd (3A) [velocity] (S8P3)→ 8th (3A) [graph] (S7CS6) → 7th (6)	9th	9th + PS
11.6 Analogy between Compressible and Open-Channel Flows $Ma=\frac{V}{c}$ $Fr=\frac{V_{oc}}{\sqrt{gy}}$ $c_{oc}=\sqrt{gy}$ $Fr=\frac{V_{oc}}{c_{oc}}$ $\rho AV=\text{constant}$ $ybV_{oc}=\text{constant}$ $\mathrm{c}=\sqrt{(\text{constant})k\rho^{k-1}}$	[four operations] (M1N3) → 1st (2A) [square root] (M8N1) → 8th (2A) [areas of geometric shapes] (M5M1) → 5th (2B)	[density] (S6E5) → 6th (4A) [velocity] (S8P3)→ 8th (3A) [gravity] (S6E1) → 6th (3A) [mass] (S8P3) → 8th (3A)	9th	
11.7 Two-Dimensional Compressible Flow $V_{t1}=V_{t2}$	[four operations] (M1N3) → 1st (2A) [triangle] (M5M1) → 5th (2B)	[velocity] (S8P3)→ 8th (3A)	9th	
11.8 Chapter Summary and Study Guide N/A	N/A	N/A	9th	
Chapter 12 Turbomachines				
12.1 Introduction N/A	N/A	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [work] (S8P3) → 8th (3A) [energy] (SP3) → 9th (3B) [power] (SP3) → 9th (3B)	9th	9th

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 12 Turbomachines (Continued)				
12.2 Basic Energy Considerations $\vec{V}=\vec{W}+\vec{U}$ $U=\omega r$	[four operations] (M1N3) → 1st (2A) [radius] (M3G1) → 3rd (2B)	[velocity] (S8P3)→ 8th (3A)	9th	9th
12.3 Basic Angular Momentum Considerations $\sum(\vec{r}\times\vec{F})=\int_{cs}(\vec{r}\times\vec{V})\rho\vec{V}\cdot\hat{n}\,dA$ $T_{shaft}=-\dot{m}_1(r_1V_{\theta 1})+-\dot{m}_2(r_1V_{\theta 2})$ $m=\rho Q$ $\dot{W}_{shaft}=T_{shaft}\omega$ $\dot{W}_{shaft}=-\dot{m}_1(U_1V_{\theta 1})+-\dot{m}_2(U_1V_{\theta 2})$ $w_{shaft}=\frac{\dot{W}_{shaft}}{\dot{m}}$ $w_{shaft}=-U_1V_{\theta 1}+U_1V_{\theta 2}$ $V^2=V_\theta^2+V_x^2$ $V_x^2+(V_\theta-U)^2=W^2$ $V_\theta U=\frac{V^2+U^2-W^2}{2}$ $w_{shaft}=\frac{V_2^2-V_1^2+U_2^2-U_1^2-(W_2^2-W_1^2)}{2}$	[sigma notation] (M6N1) → 6th (1A) or (MA1A3) → 9th (2E) [integration] → 12th (To be taught as a special skill) [special math: cross product] → To be taught as a special math topic [analytic geometry] → 12th (To be taught) [areas of geometric shapes] (M5M1) → 5th (2B)	[density] (S6E5) → 6th (4A) [torque] → Post-secondary → To be taught [momentum] (SP3) → 9th (3B)	9th	
12.4 The Centrifugal Pump N/A	N/A	N/A	9th	
12.4.1 Theoretical Considerations $\vec{V}_1=\vec{W}_1+\vec{U}_1$ $U_1=r_1\omega$ $\dot{m}_1=\dot{m}_2=\dot{m}$ $\vec{V}_2=\vec{W}_2+\vec{U}_2$ $U_2=r_2\omega$ $T_{shaft}=\dot{m}(r_2V_{\theta 2}-r_1V_{\theta 1})$ $T_{shaft}=\rho Q(r_2V_{\theta 2}-r_1V_{\theta 1})$ $\dot{W}_{shaft}=T_{shaft}\omega$ $\dot{W}_{shaft}=\rho Q\omega(r_2V_{\theta 2}-r_1V_{\theta 1})$ $\dot{W}_{shaft}=\rho Q(U_2V_{\theta 2}-U_1V_{\theta 1})$ $w_{shaft}=\frac{\dot{W}_{shaft}}{\rho Q}=U_2V_{\theta 2}-U_1V_{\theta 1}$ $\dot{W}_{shaft}=\rho gQh_i$ $h_i=\frac{1}{g}(U_2V_{\theta 2}-U_1V_{\theta 1})$	[four operations] (M1N3) → 1st (2A) [triangle] (M5M1) → 5th (2B) [trigonometric functions] (MA2G2) → 10th (2F) [areas of geometric shapes] (M5M1) → 5th (2B)	[velocity] (S8P3)→ 8th (3A) [density] (S6E5) → 6th (4A) [gravity] (S6E1) → 6th (3A)	9th	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 12 Turbomachines (Continued)				
12.4.1 Theoretical Considerations (Continued) $h_i = \frac{1}{2g}\left[\left(V_2^2 - V_1^2\right) + \left(U_2^2 - U_1^2\right) + \left(W_2^2 - W_1^2\right)\right]$ $h_i = \frac{U_2 V_{\theta 2}}{g}$ $\cot\beta_2 = \frac{U_2 - V_{\theta 2}}{V_{r2}}$ $h_i = \frac{U_2^2}{g} - \frac{U_2 V_{r2}\cot\beta_2}{g}$ $Q = 2\pi r_2 b_2 V_{r2}$ $h_i = \frac{U_2^2}{g} - \frac{U_2 \cot\beta_2}{2\pi r_2 b_2 g}Q$	[four operations] (M1N3) → 1st (2A) [triangle] (M5M1) → 5th (2B) [trigonometric functions] (MA2G2) → 10th (2F) [areas of geometric shapes] (M5M1) → 5th (2B)	[velocity] (S8P3)→ 8th (3A) [density] (S6E5) → 6th (4A) [gravity] (S6E1) → 6th (3A)	9th	9th
12.4.2 Pump Performance Characteristics $h_a = \frac{p_2 - p_1}{\gamma} + z_2 - z_1 + \frac{V_2^2 - V_1^2}{2g}$ $h_a = h_p = h_s - h_L$ $h_a \approx \frac{p_2 - p_1}{\gamma}$ $\wp_f = \gamma Q h_a$ $\wp_f = \text{water horsepower} = \frac{\gamma Q h_a}{550}$ $\eta = \frac{\text{power gained by thev fluid}}{\text{shaft power driving the pump}} = \frac{\wp_f}{\dot{W}_{shaft}}$ $\eta = \frac{\gamma Q h_a / 550}{bhp}$ $\eta = \eta_h \eta_m \eta_v$	[four operations] (M1N3) → 1st (2A) [areas of geometric shapes] (M5M1) → 5th (2B) [unit conversion] (M6M1) → 6th (2C)	[pressure] (SC5) → 9th (4B) → To be taught [velocity] (S8P3)→ 8th (3A) [gravity] (S6E1) → 6th (3A)	9th	
12.4.3 Net Positive Suction Head (NPSH) $NPSH = \frac{p_s}{\gamma} + \frac{V_s^2}{2g} - \frac{p_v}{\gamma}$ $\frac{p_{atm}}{\gamma} - z_1 = \frac{p_s}{\gamma} + \frac{V_s^2}{2g} = \sum h_L$ $\rightarrow$ $\frac{p_s}{\gamma} + \frac{V_s^2}{2g} = \frac{p_{atm}}{\gamma} - z_1 - \sum h_L$ $\rightarrow$ $NPSH = \frac{p_{atm}}{\gamma} - z_1 - \sum h_L - \frac{p_v}{\gamma}$	[four operations] (M1N3) → 1st (2A) [sigma notation] (M6N1) → 6th (1A) or (MA1A3) → 9th (2E)	[pressure] (SC5) → 9th (4B) → To be taught [velocity] (S8P3)→ 8th (3A) [gravity] (S6E1) → 6th (3A) [density] (S6E5) → 6th (4A)	9th	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 12 Turbomachines (Continued)				
12.4 4 System Characteristics and Pump Selection $h_p = z_2 - z_1 + \sum h_L \quad h_p = z_2 - z_1 + KQ^2$	[four operations] (M1N3) → 1st (2A) [sigma notation] (M6N1) → 6th (1A) or (MA1A3) → 9th (2E)	[velocity] (S8P3)→ 8th (3A) [density] (S6E5) → 6th (4A)	9th	9th
12.5 Dimensionless Parameters and Similarity Laws $\text{dependent variable} = f(D, \ell_i, \varepsilon, Q, \omega, \mu, \rho)$ $\text{dependent pi term} = \phi\left(\frac{\ell_i}{D}, \frac{\varepsilon}{D}, \frac{Q}{\omega D^3}, \frac{\rho \omega D^2}{\mu}\right)$ $C_H = \frac{g h_a}{\omega^2 D^2} = \phi_1\left(\frac{\ell_i}{D}, \frac{\varepsilon}{D}, \frac{Q}{\omega D^3}, \frac{\rho \omega D^2}{\mu}\right)$ $C_{\wp} = \frac{\dot{W}_{shaft}}{\rho \omega^3 D^5} = \phi_2\left(\frac{\ell_i}{D}, \frac{\varepsilon}{D}, \frac{Q}{\omega D^3}, \frac{\rho \omega D^2}{\mu}\right)$ $\eta = \frac{\rho g Q h_a}{\dot{W}_{shaft}} = \phi_3\left(\frac{\ell_i}{D}, \frac{\varepsilon}{D}, \frac{Q}{\omega D^3}, \frac{\rho \omega D^2}{\mu}\right)$ $\frac{g h_a}{\omega^2 D^2} = \phi_1\left(\frac{Q}{\omega D^3}\right) \quad \frac{\dot{W}_{shaft}}{\rho \omega^3 D^5} = \phi_2\left(\frac{Q}{\omega D^3}\right) \quad \eta = \phi_3\left(\frac{Q}{\omega D^3}\right)$ $\left(\frac{Q}{\omega D^3}\right)_1 = \left(\frac{Q}{\omega D^3}\right)_2 \quad \left(\frac{g h_a}{\omega^2 D^2}\right)_1 = \left(\frac{g h_a}{\omega^2 D^2}\right)_2$ $\left(\frac{\dot{W}_{shaft}}{\rho \omega^3 D^5}\right)_1 = \left(\frac{\dot{W}_{shaft}}{\rho \omega^3 D^5}\right)_2 \quad \eta = \eta_2$	[four operations] (M1N3) → 1st (2A) [ratio] (M6A1) → 6th (2A)	[gravity] (S6E1) → 6th (3A) [density] (S6E5) → 6th (4A) [energy] (SP3) → 9th (3B) [velocity] (S8P3)→ 8th (3A)	9th	
12.5.1 Special Pump Scaling Laws $\frac{Q_1}{Q_2} = \frac{\omega_1}{\omega_2} \quad \frac{h_{a1}}{h_{a2}} = \frac{\omega_1^2}{\omega_2^2} \quad \frac{\dot{W}_{shaft1}}{\dot{W}_{shaft2}} = \frac{\omega_1^3}{\omega_2^3} \quad \frac{Q_1}{Q_2} = \frac{D_1^3}{D_2^3} \quad \frac{h_{a1}}{h_{a2}} = \frac{D_1^2}{D_2^2}$ $\frac{\dot{W}_{shaft1}}{\dot{W}_{shaft2}} = \frac{D_1^5}{D_2^5} \quad \frac{1-\eta_2}{1-\eta_1} \approx \left(\frac{D_1}{D_2}\right)^{1/5}$	[four operations] (M1N3) → 1st (2A) [areas of geometric shapes: circle, triangle] (M5M1) → 5th (2B) (M5M1) → 5th (2B) [exponent] (M6A3) → 6th (2A) [ratio] (M6A1) → 6th (2A)	[velocity] (S8P3)→ 8th (3A) [power] (SP3) → 9th (3B) [energy] (SP3) → 9th (3B)	9th	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 12 Turbomachines (Continued)				
12.5.2 Specific Speed $\frac{(Q/\omega D^3)^{1/2}}{(gh_a/\omega^2 D^2)^{3/4}} = \frac{\omega\sqrt{Q}}{(gh_a)^{3/4}} = N_s \quad N_{sd} = \frac{\omega(rpm)\sqrt{Q(gpm)}}{[h_a(ft)]^{3/4}}$	[four operations] (M1N3) → 1st (2A) [ratio] (M6A1) → 6th (2A)	[speed] (S2P3) → 2nd (3A)	9th	9th
12.5.3 Suction Specific Speed $S_s = \frac{\omega\sqrt{Q}}{[g(NPSH_R)]^{3/4}} \quad S_{sd} = \frac{\omega(rpm)\sqrt{Q(gpm)}}{[NPSH_R(ft)]^{3/4}}$	[four operations] (M1N3) → 1st (2A) [ratio] (M6A1) → 6th (2A)	[speed] (S2P3) → 2nd (3A)	9th	
12.6 Axial-Flow and Mixed-Flow Pump N/A	[graph] (S7CS6) → 7th (6)	[speed] (S2P3) → 2nd (3A)	9th	
12.7 Fans $\left(\frac{p_a}{\rho\omega^2 D^2}\right)_1 = \left(\frac{p_a}{\rho\omega^2 D^2}\right)_2$	[four operations] (M1N3) → 1st (2A) [areas of geometric shapes: circle, triangle] (M5M1) → 5th (2B) (M5M1) → 5th (2B) [ratio] (M6A1) → 6th (2A)	[speed] (S2P3) → 2nd (3A) [pressure] (SC5) → 9th (4B) → To be taught [density] (S6E5) → 6th (4A)	9th	
12.8 Turbines **12.8.1 Impulse Turbines** $V_{\theta 1} = V_1 = W_1 + U \quad V_{\theta 2} = W_2 \cos\beta + U$ $V_{\theta 2} - V_{\theta 1} = (U - V_1)(1-\cos\beta) \quad T_{shaft} = \dot{m}r_m(U - V_1)(1-\cos\beta)$ $\dot{W}_{shaft} = T_{shaft}\omega = \dot{m}U(U - V_1)(1-\cos\beta) \quad U\|_{\substack{max\\power}} = \frac{V^2}{2}$	[four operations] (M1N3) → 1st (2A) [trigonometric functions] (MA2G2) → 10th (2F) [derivative] → 12th (To be taught)	[power] (SP3) → 9th (3B) [speed] (S2P3) → 2nd (3A) [force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C)	9th	

Fluid Mechanics Topic List (Continued).

Engineering Subject: Fluid				
Engineering Analytic Topics & Typical Formulas	**Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code)** **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**		**Possible Grade to Start the Topic**	
	Math	**Physics/Chemistry**	**Sec**	**Ch**
Chapter 12 Turbomachines (Continued)				
12.8.2 Reaction Turbines $C_Q = \frac{Q}{\omega D^3}$ $C_H = \frac{gh_T}{\omega^2 D^2}$ $C_\wp = \frac{\dot{W}_{shaft}}{\rho\omega^3 D^5}$ $\eta = \frac{\dot{W}_{shaft}}{\rho g Q h_T}$ $C_H = \phi_1(C_Q)$ $C_\wp = \phi_2(C_Q)$ $\eta = \phi_3(C_Q)$ $\eta = \frac{C_\wp}{C_H C_Q}$ $N'_s = \frac{\omega\sqrt{\dot{W}_{shaft}/\rho}}{(gh_T)^{5/4}}$ $N'_{sd} = \frac{\omega(rpm)\sqrt{\dot{W}_{shaft}(bhp)}}{[h_T(ft)]^{5/4}}$	[four operations] (M1N3) → 1st (2A) [square root] (M8N1) → 8th (2A) [exponent] (M6A3) → 6th (2A)	[power] (SP3) → 9th (3B) [speed] (S2P3) → 2nd (3A) [force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [density] (S6E5) → 6th (4A) [gravity] (S6E1) → 6th (3A)	9th	9th
12.9 Compressible Flow Turbomachines **12.9.1 Compressors** $\left(\frac{R\dot{m}\sqrt{kRT_{01}}}{D^2 p_{01}}\right)_{test} = \left(\frac{R\dot{m}\sqrt{kRT_{01}}}{D^2 p_{01}}\right)_{std}$ $\dot{m}_{std} = \frac{\dot{m}_{std}\sqrt{T_{01\ test}/T_{0\ std}}}{p`_{01\ test}/p_{0\ std}}$ $\frac{ND}{\sqrt{kRT_{01}}}$ $N_{std} = \frac{N}{\sqrt{T_{01}/T_{std}}}$	[four operations] (M1N3) → 1st (2A) [square root] (M8N1) → 8th (2A) [graph] (S7CS6) → 7th (6)	[mass] (S8P3) → 8th (3A) [pressure] (SC5) → 9th (4B) [friction] (S8P3) → 8th (3A) → To be taught [velocity] (S8P3)→ 8th (3A) [temperature] (S3P1) → 3rd (3A)	9th	
12.9.2 Compressible Flow Turbines N/A	N/A	[mass] (S8P3) → 8th (3A) [pressure] (SC5) → 9th (4B) → To be taught [friction] (S8P3) → 8th (3A) → To be taught [velocity] (S8P3)→ 8th (3A) [temperature] (S3P1) → 3rd (3A)	9th	
12.10 Chapter Summary and Study Guide N/A	N/A	N/A	9th	
THE END				

Part Two
1st Round of Delphi –
Five-Point Likert Scale Survey Forms

Proposed Procedures for Survey Response

To facilitate survey response to the initial selection of fluid mechanics topics that could be possibly taught to students at 9th or above Grade, as listed in the *Fluid Mechanics Survey Form A* and *Survey Form B*, the following procedures are hereby proposed:

1. Rate the importance of each Section as a topic in a potentially viable 9th or above Grade fluid mechanics subject, and write a number representing its "importance" value (*Figure 4A*), using the five-point Likert Scale (*Figure 4B*);

2. Check the formulas listed under the **Engineering Analytic Topics & Typical Formulas** column, and use symbols shown in *Figure 4B* to indicate your expert opinion and advice about each formula;

3. Add your general comments and advice in the empty space.

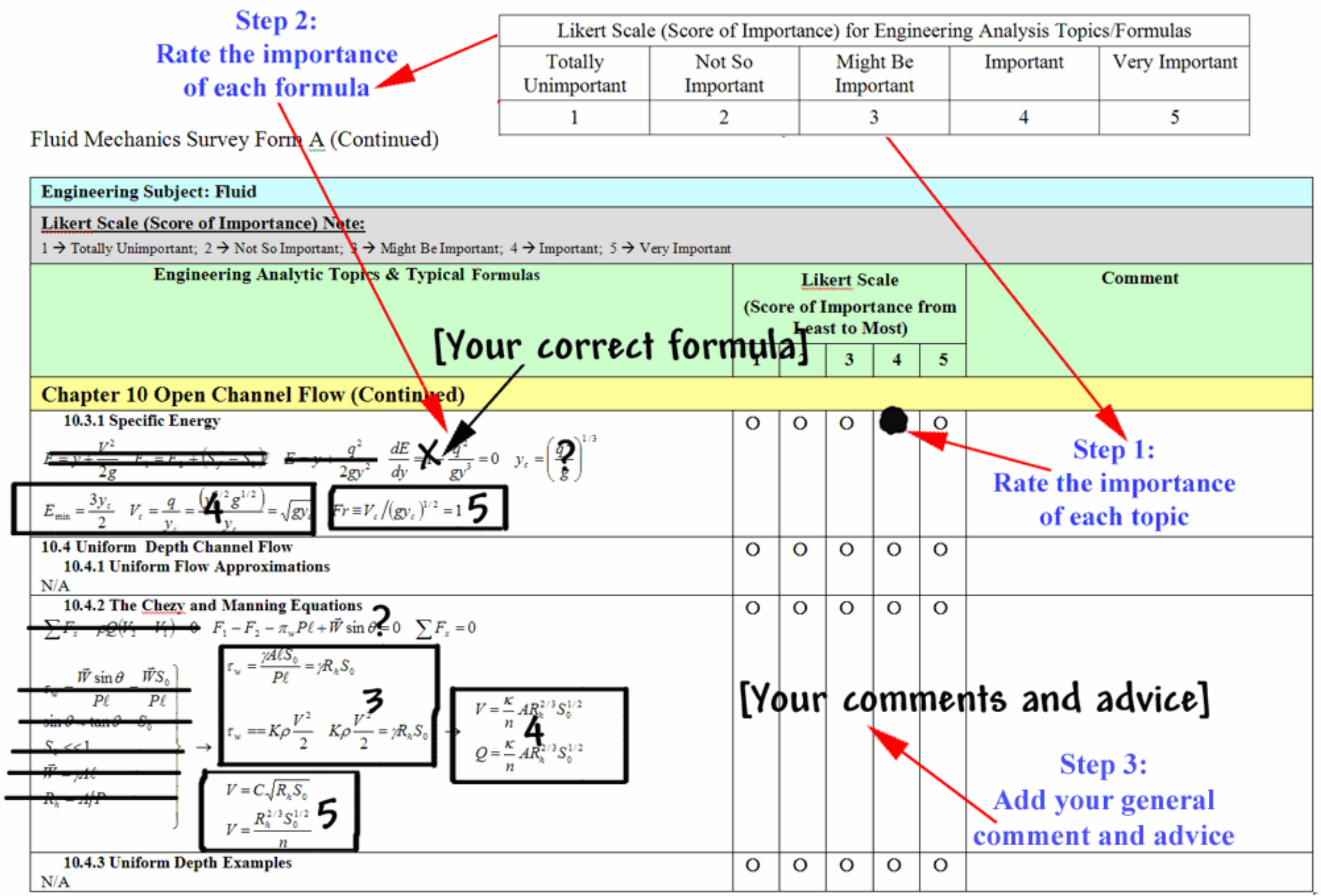

Figure 4A. *Step-by-step procedures proposed for the review and validation of data.*

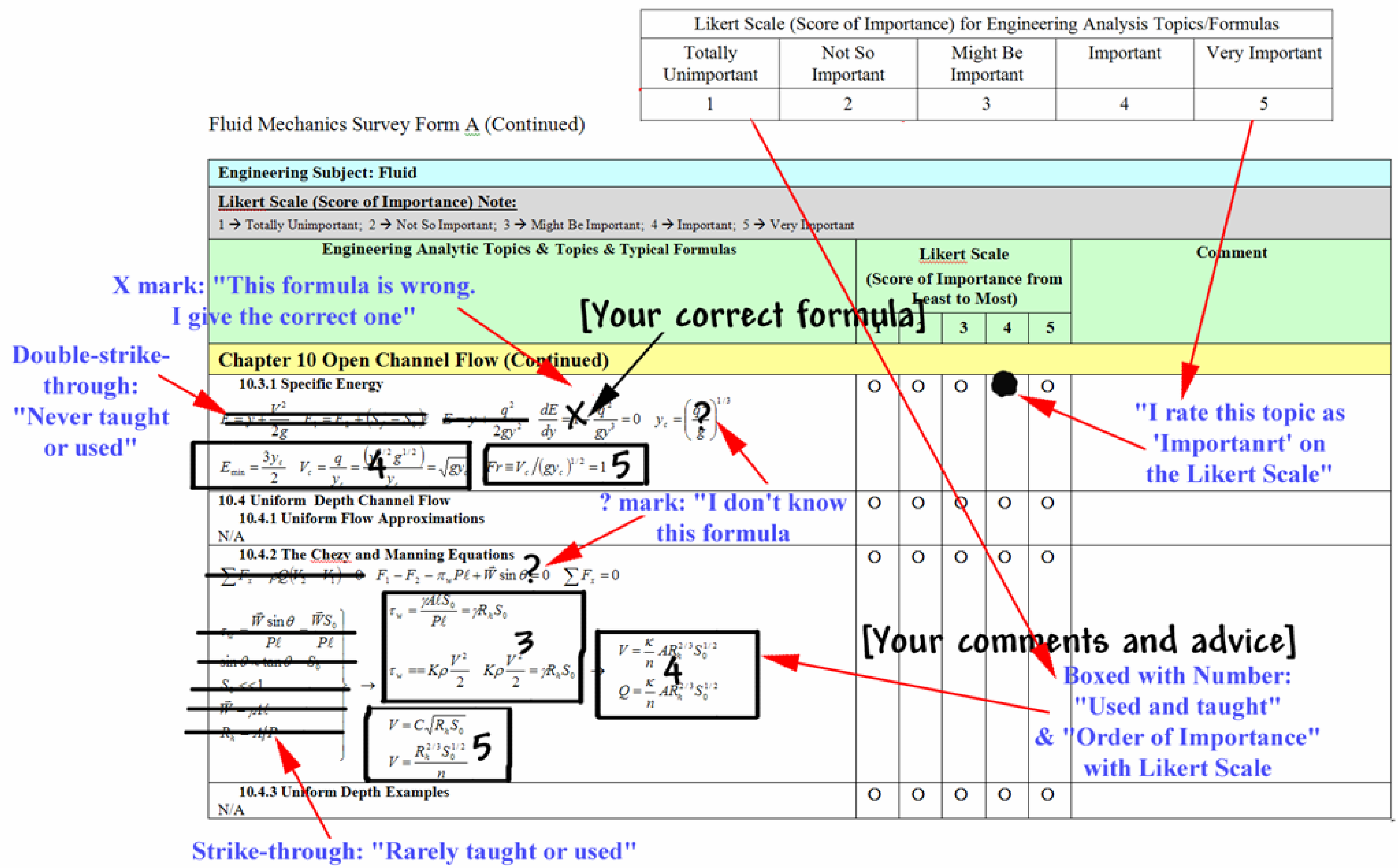

Figure 4B. Likert Scale (top) and symbols to be used for the expression of expert opinion and offer of advice.

Notes for Chapter 6 and Chapter 7

Chapter 6 (Differential Analysis of Fluid Mechanics Flow) appears to be, for all practical purposes, too deep in calculus-based mathematics for even 12th Grade students in Advanced Placement Calculus course to master.

Chapter 7 (Similitude, Dimensional Analysis, and Modeling) involve a lot of “abstract thinking” and appears to be most likely beyond the cognitive developmental maturity level of high school students.

Therefore, engineering analytic principles and skills from these two Chapters are NOT analyzed for the eventual inclusion into a potentially viable K-12 engineering curriculum. However, some generic knowledge content covered in these two Chapters could still be lightly explored by 9th or above Grade students; thus, their relative importance could still be rated at generic knowledge level.

Notes about the Fluid Mechanics Analytic Principles and Formulas

The leftmost column in the *Fluid Mechanics Survey Form A* and *Survey Form B* contain

1. The titles of each section under a particular chapter in the selected textbook, which in general represent particular sets of fluid mechanics related engineering analytic and predictive principles, in a qualitative and explanatory way;

2. Computational formulas, which symbolically represent the above engineering analytic and predictive principles, in a quantitative and mathematical way.

As shown in *Figure 4B*, the formulas extracted from the selected textbook might by categorized into five groups, corresponding to the five different symbols shown in *Figure 4B*, which could be used by the above-mentioned five Groups of Participants:

1. Formulas that engineering professors actually teach in classroom lectures and that practicing engineers use in engineering design projects: These are the important ones to be included in a potentially viable K-12 engineering curriculum that shall be based on cohesive and systemic mastery of engineering analytic and predictive principles and skills. For any of these formulas, a box could be used together with a number representing its order of importance according to the five-point Likert Scale (1 = Totally Unimportant, 2 = Not So Important, 3 = Might Be Important, 4 = Important, or 5 = Very Important).

2. Formulas that are rarely used in either classroom lectures or in field practice, but are used by the original discoverer of a particular set of analytic principles to derive other formulas that are actually used in classroom lecture or in field practice: Some of these "intermediate" formulas might not be used often, in other words, they are "rarely taught or used." For any of these formulas, a strikethrough could be used. If a big enough percentage of participants (maybe 85% or above) place a strikethrough on a particular formula at the end of each round of the proposed four-round Delphi study, then the formula will be removed from the survey form for the next round. If the trend continues through all four rounds of the proposed Delphi survey, then that formula might be removed from the final list of high school appropriate fluid mechanics topics. Interestingly enough, in some cases, rarely used calculus-based "intermediate" formulas are used to derive a final one that is based on pre-calculus mathematics skills and is actually used in most homework assignments and design projects; in this case, if the "intermediate" formulas are removed from consideration, then the entire topic of fluid mechanics could be re-classified as appropriate for 9th Grade. For example, the main formula $\vec{F} = m\vec{a}$ and $p + \frac{1}{2}\rho V^2 + \gamma z = \text{constant along a streamline}$ (Bernoulli Equation) do not need calculus, and thus, could be taught to 9th Grade students. This type of formulas will make the list shorter and shorter as the proposed Delphi study moves to the next round of survey. Some of these formulas might not be in the selected textbook; I derived them for fun, sometimes with the help of my former engineering professor, Dr. Samuel Landsberger, at California State University Los Angeles.

3. Formulas that are particular to certain conditions and in real classroom lectures or field practice are, for all practical purposes, close to be "never used:" For any of these formulas, a double-strikethrough could be used. If a big enough percentage of participants (maybe 75% or above) place a double-strikethrough on a particular formula at the end of each round of the proposed four-round Delphi study, then the formula will be removed from the survey form for the next round. If the trend continues through all four rounds of the proposed Delphi survey, then that formula might be removed from the final list of high school appropriate fluid mechanics topics. This type of formulas will also make the list shorter and shorter as the proposed Delphi study moves to the next round of survey.

4. Formulas that even experienced university engineering professors or practicing engineers might "not understand:" This is amazing but totally correct and yes, absolutely normal! There are formulas that even experienced professors might say "I do not understand this" or "I need to read the context in the book to figure this out." For any of these formulas, the participants should generally not seek to understand them (doing so does not serve the purpose of studying the relative importance of each computational formula); but instead, a question mark (?) could be used. If a big enough percentage of participants (maybe 65% or above) place a question mark (?) on a particular formula at the end of each round of the proposed four-round Delphi study, then the formula will be removed from the survey form for the next round. If the trend continues through all four rounds of the proposed Delphi survey, then that formula might be removed from the final list of high school appropriate fluid mechanics topics. Indeed, it makes little sense to include this type of formulas to a potentially viable K-12 engineering curriculum. This type of formulas will also make the list shorter and shorter as the proposed Delphi study moves to the next round of survey. Some of these formulas might not be in the selected textbook; I derived them for fun, sometimes with the help of my former engineering professor, Dr. Samuel Landsberger, at California State University Los Angeles.

6. Formulas that are wrong for any reasons (my typing errors, or the authors' errors, etc.): For any of these formulas, a cross (X) could be used and the correct formulas should be given if possible. The correction would be included in the survey forms for the subsequent rounds of the four-round five-point Likert Scale Delphi study.

For convenience of statistic analysis of expert opinions and advice, it is requested that all participants print each letter of their comment legibly and separately, using fonts commonly used in engineering notebooks.

Fluid Mechanics Survey Form A
1st Round of Delphi - Likert Scale Questionnaire on the Importance of Various Fluid Mechanics Topics Selected for High School Engineering Curriculum (For the Pre-calculus Portion)

Engineering Subject: Fluid						
Likert Scale (Score of Importance) Note: 1 → Totally Unimportant; 2 → Not So Important; 3 → Might Be Important; 4 → Important; 5 → Very Important						
Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 1 - Introduction						
1.1 Some Characteristics of Fluid	○	○	○	○	○	
1.2 Dimensions, Dimensional Homogeneity, and Units $p \equiv \frac{\vec{F}_n}{A_s} \rightarrow \vec{F}_n = pA_s \quad \tau = \frac{P}{A_s} \quad \tau \propto \delta\beta$	○	○	○	○	○	
1.3 Analysis of Fluid Mechanics Mechanics Behavior N/A	○	○	○	○	○	
1.4 Measures of Fluid Mechanics Mechanics Mass and Weight	○	○	○	○	○	
1.4.1 Density $\rho = \frac{m}{V} \quad v = \frac{V}{m} = \frac{1}{\rho}$	○	○	○	○	○	
1.4 2 Specific Weight $\gamma \equiv \frac{W}{V} = \frac{mg}{V} = \rho g$	○	○	○	○	○	
1.4.3 Specific Gravity $SG = \frac{\rho}{\rho_{H_2O} @ 4^\circ C}$	○	○	○	○	○	

Fluid Mechanics Survey Form A (Continued)

Engineering Subject: Fluid						
Likert Scale (Score of Importance) Note: 1 → Totally Unimportant; 2 → Not So Important; 3 → Might Be Important; 4 → Important; 5 → Very Important						
Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 1 – Introduction (Continued)						
1.5 Ideal Gas Law $p = \rho RT$	○	○	○	○	○	
1.7 Compressibility of Fluids	○	○	○	○	○	
1.7.1 Bulk Modulus $E_v = \frac{dp}{d\forall/\forall}$ $E_v = \frac{dp}{d\rho/\rho}$	○	○	○	○	○	
1.7.2 Compression and Expansion of Gases $\frac{p}{\rho} = \text{Constant}$ $\frac{p}{\rho^k} = \text{Constant}$ $E_v = p$ $E_v = kp$	○	○	○	○	○	
1.7.3 Speed of Sound $c = \sqrt{\frac{dp}{d\rho}} = \sqrt{\frac{E_v}{\rho}} \leftarrow \left\{ \begin{array}{l} E_v = \frac{dp}{d\rho/\rho} = \frac{dp}{d\rho}\rho \\ \frac{E_v}{\rho} = \frac{dp}{d\rho} \end{array} \right. \quad \left. \begin{array}{l} c = \sqrt{\frac{kp}{\rho}} \\ p = \rho RT \end{array} \right\} \rightarrow c = \sqrt{kRT}$	○	○	○	○	○	
1.8 Vapor Pressure	○	○	○	○	○	

Fluid Mechanics Survey Form A (Continued)

Engineering Subject: Fluid						
<u>Likert Scale (Score of Importance) Note:</u> 1 → Totally Unimportant; 2 → Not So Important; 3 → Might Be Important; 4 → Important; 5 → Very Important						
Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 1 – Introduction (Continued)						
1.9 Surface Tension $2\pi R\sigma = \Delta p \pi R^2 \quad \Delta p = p_i - p_e = \frac{2\sigma}{R}$ $\gamma\pi R^2 h = 2\pi R\sigma\cos\theta \quad \rightarrow \quad h = \frac{2\sigma\cos\theta}{\gamma R}$	○	○	○	○	○	
1.10 A Brief Look Back in History	○	○	○	○	○	
1.11 Chapter Summary and Study Guide	○	○	○	○	○	
Chapter 2 Fluid Statics						
2.3.1 Incompressible Fluid $\int_{p_1}^{p_2} dp = -\gamma\int_{z_1}^{z_2} dz \rightarrow \begin{cases} p_2 - p_1 = -\gamma(z_2 - z_1) \\ p_1 - p_2 = \gamma(z_2 - z_1) \end{cases}$ $\rightarrow p_1 - p_2 = \gamma h \rightarrow \begin{cases} p_1 = \gamma h + p_2 \\ h = \frac{p_1 - p_2}{\gamma} \end{cases} \quad p = \gamma h + p_0 = \rho g h + p_0$ Note: The main formulas $p = \gamma h + p_0 = \rho g h + p_0$ does not need calculus.	○	○	○	○	○	

Fluid Mechanics Survey Form A (Continued)

Engineering Subject: Fluid						
Likert Scale (Score of Importance) Note: 1 → Totally Unimportant; 2 → Not So Important; 3 → Might Be Important; 4 → Important; 5 → Very Important						
Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 2 Fluid Statics (Continued)						
2.3.2 Compressible Fluid $\left.\begin{aligned} p &= \rho RT \\ \rho &= \frac{p}{RT} \\ \frac{dp}{dz} &= -\gamma = -\rho g \end{aligned}\right\} \frac{dp}{dz} = -\frac{gp}{RT} \rightarrow$ $(dz)\frac{dp}{dz(p)} = -\frac{gp}{RT(p)}(dz) \quad \frac{dp}{p} = -\frac{g}{RT}dz \rightarrow$ $\int_{p_1}^{p_2}\frac{dp}{p} = \int_{z_1}^{z_2}-\frac{g}{RT}dz = -\frac{g}{R}\int_{z_1}^{z_2}\frac{dz}{T} \rightarrow$ $\int_{p_1}^{p_2}\frac{dp}{p} = \ln\frac{p_2}{p_1} = -\frac{g}{R}\int_{z_1}^{z_2}\frac{dz}{T}$ $p_2 = p_1 \exp\left[-\frac{g(z_2 - z_1)}{RT_0}\right]$ Note: The main formula $p_2 = p_1 \exp\left[-\frac{g(z_2 - z_1)}{RT_0}\right]$ does not need calculus	○	○	○	○	○	
2.4 Standard Atmosphere $T = T_a - \beta z \quad p = p_a\left(1 - \frac{\beta z}{T_a}\right)^{g/R\beta}$	○	○	○	○	○	
2.5 Measurement of Pressure $p_{abs} = p_{gage} + p_{atm} \quad p_{atm} = \gamma h + p_{vapor}$	○	○	○	○	○	

Fluid Mechanics Survey Form A (Continued)

Engineering Subject: Fluid						
Likert Scale (Score of Importance) Note: 1 → Totally Unimportant; 2 → Not So Important; 3 → Might Be Important; 4 → Important; 5 → Very Important						
Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 2 Fluid Statics (Continued)						
2.6 Monometry	○	○	○	○	○	
2.6.1 Piezometer Tube $p = \gamma h + p_0 \quad p_A = \gamma_1 h_1$	○	○	○	○	○	
2.6.2 U-Tube Manometer $p = \gamma h + p_0 \quad p_A + \gamma_1 h_1 - \gamma_2 h_2 = 0 \quad \rightarrow$ $p_A = \gamma_2 h_2 - \gamma_1 h_1 \quad p_A = \gamma_2 h_2$ $p_A + \gamma_1 h_1 - \gamma_2 h_2 - \gamma_3 h_3 = p_B \quad \rightarrow$ $p_A - p_B = \gamma_2 h_2 + \gamma_3 h_3 - + \gamma_1 h_1$	○	○	○	○	○	
2.6.3 Inclined-Tube Manometer $p_A + \gamma_1 h_1 - \gamma_2 \ell_2 \sin\theta - \gamma_3 h_3 = p_B$ $p_A - p_B = \gamma_2 \ell_2 \sin\theta + \gamma_3 h_3 - \gamma_1 h_1$ $p_A - p_B = \gamma_2 \ell_2 \sin\theta \quad \rightarrow \quad \ell_2 = \frac{p_A - p_B}{\gamma_2 \sin\theta}$	○	○	○	○	○	
2.7 Mechanical and Electronic Pressure Measuring Devices	○	○	○	○	○	
2.9 Pressure Prism $F_R = p_{av} A = \gamma \left(\frac{h}{2}\right) A \quad F_R = volume = \frac{1}{2}(\gamma k)(bh) = \gamma \left(\frac{h}{2}\right) A$ $F_R = F_1 + F_2 \quad F_R y_A = F_1 y_1 + F_2 y_2$	○	○	○	○	○	

Fluid Mechanics Survey Form A (Continued)

Engineering Subject: Fluid						
Likert Scale (Score of Importance) Note: 1 → Totally Unimportant; 2 → Not So Important; 3 → Might Be Important; 4 → Important; 5 → Very Important						
Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 2 Fluid Statics (Continued)						
2.10 Hydrostatic Force on a Curves Surface $F_H = F_2 \quad F_v = F_1 + \vec{W}$ $F_R = \sqrt{(F_H)^2 + (F_v)^2}$	○	○	○	○	○	
2.11 Buoyancy, Flotation, and Stability N/A **2.11.1 Archimedes' Principle** $F_B = F_2 - F_1 - \vec{W} \quad F_2 - F_1 = \gamma(h_2 - h_1)A$ $F_B = \gamma(h_2 - h_1)A - \gamma[(h_2 - h_1)A - \mathcal{V}]$ $F_B = \gamma\mathcal{V} \quad F_B y_c = F_2 y_1 - F_1 y_1 - \vec{W} y_2$ $\mathcal{V} y_c = \mathcal{V}_T y_1 - (\mathcal{V}_T - \mathcal{V}) y_2$ **2.11.2 Stability** N/A	○	○	○	○	○	
Chapter 3 Elementary Fluid Dynamics – The Bernoulli Equation						
3.1 Newton's Second Law $\vec{F} = m\vec{a} \quad \sum(\vec{F}_p + \vec{F}_g) = m\vec{a}$ $a_s = V\frac{\partial V}{\partial s} \quad a_n = V\frac{V^2}{\Re} \quad \leftarrow \quad V = \lvert\vec{V}\rvert$ Note: The main formula $\vec{F} = m\vec{a}$ does not need calculus	○	○	○	○	○	

Fluid Mechanics Survey Form A (Continued)

<table>
<tr><td colspan="7">Engineering Subject: Fluid</td></tr>
<tr><td colspan="7"><u>Likert Scale (Score of Importance) Note:</u>
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<tr><td rowspan="2">Engineering Analytic Topics & Typical Formulas</td><td colspan="5">Likert Scale (Score of Importance from Least to Most)</td><td rowspan="2">Comment</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td colspan="7">Chapter 3 Elementary Fluid Dynamics – The Bernoulli Equation (Continued)</td></tr>
<tr><td>3.2 F = ma along a Streamline
$\sum \delta F_s = \delta m a_s = \delta m V \frac{\partial V}{\partial s} = \rho \delta \forall V \frac{\partial V}{\partial s} \quad \left.\begin{matrix} \delta \vec{W} = \gamma \delta \forall \\ \gamma = \rho g \end{matrix}\right\} \rightarrow \delta \vec{W}_s = -\delta \vec{W} \sin\theta = -\gamma \delta X \forall \sin\theta$
$\delta p_s \approx \frac{\partial p}{\partial s}\frac{\delta s}{2} \quad y\delta F_{ps} = (p - \delta p_s)\delta n \delta y - (p + \delta p_s)\delta n \delta y = -2\delta p_s \delta n \delta y = -\frac{\partial p}{\partial s}\delta s \delta n \delta y = -\frac{\partial p}{\partial s}\delta \forall$
$\sum \delta F_s = \delta \vec{W}_s + \delta F_{ps} = \left(-\gamma \sin\theta - \frac{\partial p}{\partial s}\right)\delta \forall \quad -\gamma \sin\theta - \frac{\partial p}{\partial s} = \rho V \frac{\partial V}{\partial s} = \rho a_s$
$-\gamma \frac{dz}{ds} - \frac{dp}{ds} = \frac{1}{2}\rho \frac{d(V^2)}{ds} \rightarrow dp + \frac{1}{2}\rho d(V^2) + \gamma \, dz = 0$
$\int \frac{dp}{\rho} + \frac{1}{2}V^2 + gz = C$ (along a streamline)
$p + \frac{1}{2}\rho V^2 + \gamma z =$ constant along a streamline (Bernoulli Equation)
Note: The main formulas $\vec{F} = m\vec{a}$ and $p + \frac{1}{2}\rho V^2 + \gamma z =$ constant along a streamline (Bernoulli Equation) does not need calculus</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td><td></td></tr>
</table>

Fluid Mechanics Survey Form A (Continued)

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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 3 Elementary Fluid Dynamics – The Bernoulli Equation (Continued)						
3.4 Physical Interpretation $p+\frac{1}{2}\rho V^2+\gamma z=\text{Constant along the streamline}$ $p+\rho\int\frac{V^2}{\Re}dn+\gamma z=\text{constant across the streamline}$ $\frac{p}{\gamma}+\frac{V^2}{2g}+z=\text{constant on a streamline}$ Note: The main formulas $p+\frac{1}{2}\rho V^2+\gamma z=\text{Constant along the streamline}$ do not need calculus $\frac{p}{\gamma}+\frac{V^2}{2g}+z=\text{constant on a streamline}$	○	○	○	○	○	
3.5 Static, Stagnation, Dynamic, and Total Pressure $p_2=p_1+\frac{1}{2}\rho V_1^2$ $p+\frac{1}{2}V^2+\gamma z=p_T=\text{constant along a streamline}$ $\left.\begin{matrix}p_3=p+\frac{1}{2}\rho V^2\\ p_4=p_1=p\end{matrix}\right\}\rightarrow p_3-p_4=\frac{1}{2}\rho V^2$ $V=\sqrt{\frac{2(p_3-p_4)}{\rho}}$	○	○	○	○	○	
3.6 Examples of Use of the Bernoulli Equation $p_1+\frac{1}{2}\rho V_1^2+\gamma z_1=p_2+\frac{1}{2}\rho V_2^2+\gamma z_2$	○	○	○	○	○	

Fluid Mechanics Survey Form A (Continued)

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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
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Chapter 3 Elementary Fluid Dynamics – The Bernoulli Equation (Continued)						
3.6.1 Free Jets $\gamma h = \frac{1}{2}\rho V^2 \rightarrow \begin{cases} V = \sqrt{2\frac{\gamma h}{\rho}} = \sqrt{2gh} \\ V = \sqrt{2g(h+H)} \end{cases}$	○	○	○	○	○	
3.6.2 Confined Flows $\rho_1 A_1 V_1 = \rho_2 A_2 V_2 \rightarrow A_1 V_1 = A_2 V_2 \rightarrow Q_1 = Q_2$	○	○	○	○	○	
3.6.3 Flowrate Measurement $p_1 + \frac{1}{2}\rho V_1^2 = p_2 + \frac{1}{2}\rho V_2^2 \quad Q = A_1 V_1 = A_2 V_2$ $Q = A_2 \sqrt{\frac{2(p_1 - p_2)}{\rho\left[1 - \left(\frac{A_2}{A_1}\right)^2\right]}} \quad p_1 + \frac{1}{2}\rho V_1^2 + \gamma z_1 = p_2 + \frac{1}{2}\rho V_2^2 + \gamma z_2 \quad Q = A_1 V_1 = b V_1 z_1 = A_2 V_2 = b V_2 z_2$ $p_1 = p_2 = 0 \rightarrow Q = z_2 b \sqrt{\frac{2g(z_1 - z_2)}{1 - \left(\frac{z_2}{z_1}\right)^2}} \quad Q = C_1 H b \sqrt{2gH} = C_1 b \sqrt{2g} H^{3/2} \quad z_1 >> z_2 \rightarrow Q = z_2 b \sqrt{2g z_1}$	○	○	○	○	○	
3.7 The Energy Line and the Hydraulic Grade Line $\frac{\rho}{\gamma} + \frac{V^2}{2g} + z = \text{constant on a streamline} = H$	○	○	○	○	○	

Fluid Mechanics Survey Form A (Continued)

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	1	**2**	**3**	**4**	**5**	
Chapter 3 Elementary Fluid Dynamics – The Bernoulli Equation (Continued)						
3.8 Restrictions on Use of the Bernoulli Equation **3.8.1 Compressibility Effects** $RT\int \frac{dp}{p}+\frac{1}{2}V^2+gz=\text{constant} \quad \rho=\frac{p}{RT} \quad \frac{V_1^2}{2g}+z_1+\frac{RT}{g}\ln\left(\frac{p_1}{p_2}\right)=\frac{V_2^2}{2g}+z_2$ $C^{1/k}\int p^{-1/k}dp+\frac{1}{2}V^2+gz=\text{constant}$ $C^{1/k}\int_{p_1}^{p_2} p^{-1/k}dp=C^{1/k}\left(\frac{k}{k-1}\right)\left[p_2^{(k-1)/k}-p_1^{(k-1)/k}\right]=\left(\frac{k}{k-1}\right)\left(\frac{p_2}{p_1}-\frac{p_1}{p_1}\right)$ $\left(\frac{k}{k-1}\right)\frac{p_1}{p_1}+\frac{V_1^2}{2}+gz_1=\left(\frac{k}{k-1}\right)\frac{p_2}{p_2}+\frac{V_2^2}{2}+gz_2$ $\frac{p_2-p_1}{p_1}=\left[\left(1+\frac{k-1}{2}Ma_1^2\right)^{k/k-1}-1\right]$ (compressible) $\left.\begin{array}{l}\frac{p_2}{p_1}=\frac{V_1^2}{2RT_1}\\ Ma_1=\frac{V_1}{\sqrt{kRT_1}}\end{array}\right\} \rightarrow \frac{p_2-p_1}{p_1}=\frac{kMa_1^2}{2}$ (incompressible) $\frac{p_2-p_1}{p_1}=\frac{kMa_1^2}{2}\left(1+\frac{1}{4}Ma_1^2+\frac{2-k}{24}Ma_1^4+\ldots\right)$ (compressible)	○	○	○	○	○	

Fluid Mechanics Survey Form A (Continued)

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Engineering Analytic Topics & Typical Formulas	Likert Scale (Score of Importance from Least to Most)					Comment
	1	2	3	4	5	
Chapter 3 Elementary Fluid Dynamics – The Bernoulli Equation (Continued)						
3.8.1 Compressibility Effects (Continued) $\left.\begin{array}{l}\frac{p_2}{p_1}=\frac{V_1^2}{2RT_1}\\ Ma_1=\frac{V_1}{\sqrt{kRT_1}}\end{array}\right\} \rightarrow \frac{p_2-p_1}{p_1}=\frac{kMa_1^2}{2}$ (incompressible) $\frac{p_2-p_1}{p_1}=\frac{kMa_1^2}{2}\left(1+\frac{1}{4}Ma_1^2+\frac{2-k}{24}Ma_1^4+...\right)$ (compressible) Note: The main formulas $RT\int\frac{dp}{p}+\frac{1}{2}V^2+gz=\text{constant}$ $\rho=\frac{p}{RT}$ and others do not need calculus	○	○	○	○	○	
3.8.3 Rotational Effects $p_1+\frac{1}{2}\rho V_1^2+\gamma z_1=p_2+\frac{1}{2}\rho V_2^2+\gamma z_2=\text{constant}=C_{12}$ $\left.\begin{array}{l}V_1=V_2=V_0\\ z_1=z_2=0\\ p_1=p_2=p_0\end{array}\right\} \rightarrow C_{12}=\frac{1}{2}\rho V_0^2+p_0$ $\left.\begin{array}{l}V_3=V_4=V_0\\ z_3=z_4=h\\ \vec{F}=m\vec{a}\\ p_3=p_1-\gamma h\\ p_3=p_4\end{array}\right\} \rightarrow C_{34}=C_{12} \rightarrow$ $p+\frac{1}{2}\rho V^2+\gamma z=\text{constant throughout flow}$ $p_4=p_5+\gamma H=\gamma H$ $H=\frac{p_4}{\gamma}$ **3.8.4 Other Restrictions** **3.9 Chapter Summary and Study Guide**	○	○	○	○	○	

Fluid Mechanics Survey Form A (Continued)

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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 4 Fluid Kinematics						
4.3 Control Volume and System Representations $F = \frac{d(mv)}{dt}$	O	O	O	O	O	
4.4 The Reynolds Transport Theorem $B = mb \quad \begin{cases} B = m \rightarrow b = 1 \\ B = \frac{mV^2}{2} \rightarrow b = \frac{V^2}{2} \\ \vec{B} = m\vec{V} \rightarrow \vec{b} = \vec{V} \end{cases}$ $\text{B : Extensive Property} \quad \text{b : Intensive Property}$ $\text{Infinitesimal fluid particles}: \quad \delta\forall \rightarrow 0$	O	O	O	O	O	
4.4.7 Selection of a Control Volume N/A	O	O	O	O	O	
4.5 Chapter Summary and study Guide N/A	O	O	O	O	O	

Fluid Mechanics Survey Form A (Continued)

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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 5 Finite Control Volume Analysis						
5.1.2 Fixed, Non-deforming Control Volume $\frac{\partial}{\partial t}\int_{cv}\rho\, d\forall$ $\sum \dot{m}_{out} - \sum \dot{m}_{in} = 0$ $\sum Q_{out} - \sum Q_{in} = 0$ $\frac{\partial}{\partial t}\int_{cv}\rho\, d\forall$ $\dot{m} = \rho AV$ uniformly distributed over the opening in the control surface (one-dimensional flow) $\dot{m} = \rho A\overline{V}$ uniformly distributed over the opening in the control surface $\dot{m} = \rho_1 A_1\overline{V}_1 = \rho_2 A_2\overline{V}_2$ $Q = A_1\overline{V}_1 = A_2\overline{V}_2$ $\sum \dot{m}_{in} = \sum \dot{m}_{out}$ Note: The main formulas $\dot{m} = \rho_1 A_1\overline{V}_1 = \rho_2 A_2\overline{V}_2$ $Q = A_1\overline{V}_1 = A_2\overline{V}_2$ $\sum \dot{m}_{in} = \sum \dot{m}_{out}$ re not based on calculus	○	○	○	○	○	

Fluid Mechanics Survey Form A (Continued)

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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 5 Finite Control Volume Analysis (Continued)						
5.3.3 Comparison of the Energy Equation with the Bernoulli Equation $\dot{m}\left[\check{u}_{out} - \check{u}_{in} + \frac{p_{out}}{\rho} - \frac{p_{in}}{\rho} + \frac{V_{out}^2 - V_{in}^2}{2} + g(z_{out} - z_{in})\right] = \dot{Q}_{\underset{in}{net}}$ $\frac{p_{out}}{\rho} + \frac{V_{out}^2}{2} + gz_{out} = \frac{p_{in}}{\rho} + \frac{V_{in}^2}{2} + gz_{in} - \left(\check{u}_{out} - \check{u}_{in} - q_{\underset{in}{net}}\right) \quad q_{\underset{in}{net}} = \frac{\dot{Q}_{net\ in}}{\dot{m}}$ $p_{out} + \frac{\rho V_{out}^2}{2} + \gamma z_{out} = p_{in} + \frac{\rho V_{in}^2}{2} + \gamma z_{in} \quad \gamma = \rho g \quad \rightarrow \quad \frac{\gamma}{\rho} = g$ $\frac{\left(p_{out} + \frac{\rho V_{out}^2}{2} + \gamma z_{out}\right)}{\rho} = \frac{\left(p_{in} + \frac{\rho V_{in}^2}{2} + \gamma z_{in}\right)}{\rho} \quad \rightarrow \quad \frac{p_{out}}{\rho} + \frac{V_{out}^2}{2} + gz_{out} = \frac{p_{in}}{\rho} + \frac{V_{in}^2}{2} + gz_{in}$ $\check{u}_{out} - \check{u}_{in} - q_{\underset{in}{net}} = 0$ (Frictionless steady incompressible flow) $\check{u}_{out} - \check{u}_{in} - q_{\underset{in}{net}} > 0$ (Steady incompressible flow with friction) $\check{u}_{out} - \check{u}_{in} - q_{\underset{in}{net}} = \text{loss}$	○	○	○	○	○	

Fluid Mechanics Survey Form A (Continued)

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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 5 Finite Control Volume Analysis (Continued)						
5.3.3 Comparison of the Energy Equation with the Bernoulli Equation (Continued) $\frac{p_{out}}{\rho}+\frac{V_{out}^2}{2}+gz_{out}=\frac{p_{in}}{\rho}+\frac{V_{in}^2}{2}+gz_{in}-\text{loss}$ $\dot{m}\left[\check{u}_{out}-\check{u}_{in}+\frac{p_{out}}{\rho}-\frac{p_{in}}{\rho}+\frac{V_{out}^2-V_{in}^2}{2}+g(z_{out}-z_{in})\right]=\dot{Q}_{\substack{net\\in}}+\dot{W}_{\substack{shaft\\net\ in}}$ $\frac{p_{out}}{\rho}+\frac{V_{out}^2}{2}+gz_{out}=\frac{p_{in}}{\rho}+\frac{V_{in}^2}{2}+gz_{in}+w_{\substack{shaft\\net\ in}}-\left(\check{u}_{out}-\check{u}_{in}-q_{\substack{net\\in}}\right)$ $\frac{p_{out}}{\rho}+\frac{V_{out}^2}{2}+gz_{out}=\frac{p_{in}}{\rho}+\frac{V_{in}^2}{2}+gz_{in}+w_{\substack{shaft\\net\ in}}-\text{loss}$ $p_{out}+\frac{\rho V_{out}^2}{2}+\gamma z_{out}=p_{in}+\frac{\rho V_{in}^2}{2}+\gamma z_{in}+\rho w_{\substack{shaft\\net\ in}}-\rho(\text{loss})$ $\frac{\left(\frac{p_{out}}{\rho}+\frac{V_{out}^2}{2}+gz_{out}=\frac{p_{in}}{\rho}+\frac{V_{in}^2}{2}+gz_{in}+w_{\substack{shaft\\net\ in}}-\text{loss}\right)}{g}\rightarrow$ $\frac{p_{out}}{\gamma}+\frac{V_{out}^2}{2g}+z_{out}=\frac{p_{in}}{\gamma}+\frac{V_{in}^2}{2g}+z_{in}+w_{\substack{shaft\\net\ in}}-h_s-h_L$ $h_s=\frac{w_{shaft\ net\ in}}{g}=\frac{\dot{W}_{\substack{shaft\\net\ in}}}{\dot{m}g}=\frac{\dot{W}_{\substack{shaft\\net\ in}}}{\gamma Q}\quad h_T=-(h_s+h_L)_T\quad h_p=(h_s+h_L)_P$	○	○	○	○	○	

Fluid Mechanics Survey Form A (Continued)

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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 5 Finite Control Volume Analysis (Continued)						
5.3.4 Application of the Energy Equation to Non-uniform Flow $\int_{cs} \frac{V^2}{2}\rho\vec{V}\cdot\hat{n}\, dA = \dot{m}\left(\frac{\alpha_{out}\bar{V}_{out}^2}{2} - \frac{\alpha_{in}\bar{V}_{in}^2}{2}\right)$ $\frac{\dot{m}\alpha\bar{V}^2}{2} = \int_A \frac{\bar{V}^2}{2}\rho\vec{V}\cdot\hat{n}\, dA \quad \alpha = \frac{\int_A (V^2/2)\rho\vec{V}\cdot\hat{n}\, dA}{\dot{m}\alpha\bar{V}^2/2}$ $\frac{p_{out}}{\rho} + \frac{\alpha_{out}\bar{V}_{out}^2}{2} + gz_{out} = \frac{p_{in}}{\rho} + \frac{\alpha_{in}\bar{V}_{in}^2}{2} + gz_{in} + w_{\substack{shaft\\net\ in}} - \text{loss}$ $\left(\frac{p_{out}}{\rho} + \frac{\alpha_{out}\bar{V}_{out}^2}{2} + gz_{out} = \frac{p_{in}}{\rho} + \frac{\alpha_{in}\bar{V}_{in}^2}{2} + gz_{in} + w_{\substack{shaft\\net\ in}} - \text{loss}\right)(\rho)$ $\rightarrow$ $p_{out} + \frac{\rho\alpha_{out}\bar{V}_{out}^2}{2} + \gamma z_{out} = p_{in} + \frac{\rho\alpha_{in}\bar{V}_{in}^2}{2} + \gamma z_{in} + \rho w_{\substack{shaft\\net\ in}} - \rho(\text{loss})$ $\frac{\left(\frac{p_{out}}{\rho} + \frac{\alpha_{out}\bar{V}_{out}^2}{2} + gz_{out} = \frac{p_{in}}{\rho} + \frac{\alpha_{in}\bar{V}_{in}^2}{2} + gz_{in} + w_{\substack{shaft\\net\ in}} - \text{loss}\right)}{g} \rightarrow$ $\frac{p_{out}}{\gamma} + \frac{\alpha_{out}\bar{V}_{out}^2}{2g} + z_{out} = \frac{p_{in}}{\gamma} + \frac{\alpha_{in}\bar{V}_{in}^2}{2g} + z_{in} + \frac{w_{\substack{shaft\\net\ in}}}{g} - h_L$	○	○	○	○	○	

Fluid Mechanics Survey Form A (Continued)

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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 5 Finite Control Volume Analysis (Continued)						
5.3.5 Combination of the Energy Equation and the Moment-of-momentum Equation $\eta = \frac{w_{\substack{shaft \\ net\ in}} - \text{loss}}{w_{\substack{shaft \\ net\ in}}}$	○	○	○	○	○	
5.4.4 Application of the Loss Form of the Energy Equation $\frac{p_2}{\rho} + \frac{V_2^2}{2} + gz_2 = \frac{p_1}{\rho} + \frac{V_1^2}{2} + gz_1$ $\int_2^2 \frac{dp}{\rho} + \frac{V_2^2}{2} + gz_2 = \frac{V_1^2}{2} + gz_1$ $\frac{p}{\rho^k} = \text{constant}$ $\int_1^2 \frac{dp}{\rho} = \frac{k}{k-1}\left(\frac{p_2}{\rho_2} - \frac{p_1}{\rho_1}\right)$ $\frac{k}{k-1}\frac{p_2}{\rho_2} + \frac{V_2^2}{2} + gz_2 = \frac{k}{k-1}\frac{p_1}{\rho_1} + \frac{V_1^2}{2} + gz_1$	○	○	○	○	○	
5.5 Chapter Summary and Study Guide N/A	○	○	○	○	○	
8.2.4 Energy Considerations $\frac{p_1}{\gamma} + \alpha_1\frac{V_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \alpha_2\frac{V_2^2}{2g} + z_2 + h_L$ $\left(\frac{p_1}{\gamma} + z_1\right) - \left(\frac{p_2}{\gamma} + z_1\right) = h_L$ $p_1 = p_2 + \Delta p$ $z_2 - z_1 = \ell \sin\theta$ $h_L = \frac{2\tau\ell}{\gamma r}$ $h_L = \frac{4\ell\tau_w}{\gamma D}$	○	○	○	○	○	

Fluid Mechanics Survey Form A (Continued)

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Chapter 8 Viscous Flow in Pipes						
8.4 Dimensional Analysis of Pipe Flow $h_L = h_{\text{L major}} + h_{\text{L minor}}$	○	○	○	○	○	
8.4.1 Major Losses $h_L = h_{\text{L major}} + h_{\text{L minor}}$ $\Delta p = F(V, D, \ell, \varepsilon, \mu, \rho)$ $\frac{\Delta p}{\frac{1}{2}\rho V^2} = \tilde{\phi}\left(\frac{\rho VD}{\mu}, \frac{\ell}{D}, \frac{\varepsilon}{D}\right)$ $\text{Re} = \frac{\rho VD}{\mu}$ $\frac{\Delta p}{\frac{1}{2}\rho V^2} = \frac{\ell}{D}\phi\left(\text{Re}, \frac{\varepsilon}{D}\right)$ $f = \phi\left(\text{Re}, \frac{\varepsilon}{D}\right)$ $\frac{p_1}{\gamma} + \alpha_1\frac{V_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \alpha_2\frac{V_2^2}{2g} + z_2 + h_L$ $h_{\text{L major}} = f\frac{\ell}{D}\frac{V^2}{2g}$ $p_1 - p_2 = \gamma(z_2 - z_1) + \gamma h_L = \gamma(z_2 - z_1) + f\frac{\ell}{D}\frac{\rho V^2}{2}$ $\frac{1}{\sqrt{f}} = -2.0\log\left(\frac{\varepsilon/D}{3.7} + \frac{2.51}{\text{Re}\sqrt{f}}\right)$	○	○	○	○	○	
8.4.2 Minor Losses $K_L = \frac{h_{\text{L minor}}}{V^2/2g} = \frac{\Delta p}{\frac{1}{2}\rho V^2}$ $\Delta p = K_L\frac{1}{2}\rho V^2$ $h_{\text{L minor}} = K_L\frac{V^2}{2g}$ $K_L = \phi(geometry, \text{Re})$ $h_{\text{L minor}} = K_L\frac{V^2}{2g} = f\frac{\ell_{eq}}{D}\frac{V^2}{2g}$ $\ell_{eq} = \frac{K_L D}{f}$ $A_1V_1 = A_3V_3$ $p_1A_3 - p_3A_3 = \rho A_3V_3(V_3 - V_1)$ $\frac{p_1}{\gamma} + \frac{V_1^2}{2g} = \frac{p_3}{\gamma} + \frac{V_3^2}{2g} + h_L$ $K_L = \frac{h_L}{V_1^2/2g}$ $K_L = \left(1 - \frac{A_1}{A_2}\right)^2$ $C_p = (p_2 - p_1)\left(\frac{\rho V_1^2}{2}\right)$	○	○	○	○	○	
8.4.3 Noncircular Conduits $f = \frac{C}{\text{Re}_h}$ $\text{Re}_h = \frac{\rho VD_h}{\mu}$ $D_h = \frac{4A}{P} = \frac{4(\pi D^2/4)}{\pi D} = D$ $h_L = f\frac{(\ell/D_h)V^2}{2g}$	○	○	○	○	○	

Fluid Mechanics Survey Form A (Continued)

Engineering Subject: Fluid						
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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 8 Viscous Flow in Pipes (Continued)						
8.5 Pipe Flow Examples N/A	○	○	○	○	○	
8.5.1 Single Pipes N/A	○	○	○	○	○	
8.5.2 Multiple Pipe Systems N/A	○	○	○	○	○	
8.6 Pipe Flowrate Measurement **8.6.1 Pipe Flowrate Meters** $Q_{ideal} = A_2V_2 = A_2\sqrt{\frac{2(p_1 - p_2)}{\rho(1-\beta^4)}}$ $Q = A_1V_1 = A_2V_2$ $\frac{p_1}{\gamma} + \frac{V_1^2}{2g} = \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + h_L$ $Q = C_0 Q_{ideal} = C_0 A_0\sqrt{\frac{2(p_1 - p_2)}{\rho(1-\beta^4)}}$ $\beta = \frac{d}{D}$ $\mathrm{Re} = \frac{\rho V D}{\mu}$ $V = \frac{Q}{A_1}$ $Q = C_n Q_{ideal} = C_n A_n\sqrt{\frac{2(p_1 - p_2)}{\rho(1-\beta^4)}}$ $Q = C_v Q_{ideal} = C_v A_T\sqrt{\frac{2(p_1 - p_2)}{\rho(1-\beta^4)}}$ **8.6.2 Volume Flow Meters** N/A	○	○	○	○	○	
8.7 Chapter Summary and Study Guide N/A	○	○	○	○	○	

Fluid Mechanics Survey Form A (Continued)

Engineering Subject: Fluid						
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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 9 Flow over Immersed Bodies (Continued)						
9.1 General External Flow Characteristics **9.1.1 Lift and Drag Concepts** $\left.\begin{aligned} dF_x &= (p\ dA)\cos\theta + (\tau_w\ dA)\sin\theta \\ dF_y &= -(p\ dA)\sin\theta + (\tau_w\ dA)\cos\theta \end{aligned}\right\} \rightarrow \begin{aligned} \vec{D} &= \int dF_x = \int p\ \cos\theta\ dA + \int \tau_w\ \sin\theta\ dA \\ \vec{L} &= \int dF_y = -\int p\ \sin\theta\ dA + \int \tau_w\ \cos\theta\ dA \end{aligned}$ $C_L = \frac{\vec{L}}{\frac{1}{2}\rho U^2 A} \quad C_D = \frac{\vec{D}}{\frac{1}{2}\rho U^2 A}$	○	○	○	○	○	
9.1.2 Characteristics of Flow Past an Object N/A	○	○	○	○	○	
9.3 Drag $C_D = \frac{\vec{D}}{\frac{1}{2}\rho U^2 A} \quad C_D = \phi(shape, \mathrm{Re}, Ma, Fr, \varepsilon/\ell)$	○	○	○	○	○	
9.3.1 Friction Drag $\vec{D}_f = \frac{1}{2}\rho U^2 b\ell C_{Df}$	○	○	○	○	○	

Fluid Mechanics Survey Form A (Continued)

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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 9 Flow over Immersed Bodies						
9.3.2 Pressure Drag $D_p = \int \rho \cos\theta \, dA \quad C_{Dp} = \frac{\vec{D}_p}{\frac{1}{2}\rho U^2 A} = \frac{\int \rho \cos\theta \, dA}{\frac{1}{2}\rho U^2 A} = \frac{\int C_p \cos\theta \, dA}{A} \quad D_p = \int \rho \cos\theta \, dA$ $C_{Dp} = \frac{\vec{D}_p}{\frac{1}{2}\rho U^2 A} = \frac{\int \rho \cos\theta \, dA}{\frac{1}{2}\rho U^2 A} = \frac{\int C_p \cos\theta \, dA}{A} \quad \vec{D} = f(U, \ell, \mu) \quad \vec{D} = C\mu\ell U$ $C_D = \frac{\vec{D}}{\frac{1}{2}\rho U^2 \ell^2} = \frac{2C\mu\ell U}{\rho U^2 \ell^2} = \frac{2C}{\mathrm{Re}} \quad \vec{D} = f(U, \ell, \mu) \quad \vec{D} = C\mu\ell U \quad C_D = \frac{\vec{D}}{\frac{1}{2}\rho U^2 \ell^2} = \frac{2C\mu\ell U}{\rho U^2 \ell^2} = \frac{2C}{\mathrm{Re}}$	○	○	○	○	○	
9.3.3 Drag Coefficient Data and Examples	○	○	○	○	○	
9.4 Lift **9.4.1 Surface Pressure Distribution** $C_L = \frac{\vec{L}}{\frac{1}{2}\rho U^2 A} \quad C_L = \phi(shape, \mathrm{Re}, Ma, Fr, \varepsilon/\ell)$	○	○	○	○	○	
9.4.2 Circulation N/A	○	○	○	○	○	
9.5 Chapter Summary and Study Guide N/A	○	○	○	○	○	

Fluid Mechanics Survey Form A (Continued)

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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 10 Open Channel Flow						
10.1 General Characteristics of Open-Channel Flow $\text{Re} = \rho V R_h / \mu \quad Fr = V / (g\ell)^{1/2}$	○	○	○	○	○	
10.2 Surface Waves **10.2.1 Wave Speed** $c = \left[\frac{g\lambda}{2\pi}\tanh\left(\frac{2\pi y}{\lambda}\right)\right]^{1/2} \quad y >> \lambda \rightarrow c = \sqrt{\frac{g\lambda}{2\pi}}$ $\tanh\left(\frac{2\pi y}{\lambda}\right) \rightarrow 1 \quad as \quad \frac{y}{\lambda} \rightarrow \infty$ $\tanh\left(\frac{2\pi y}{\lambda}\right) \rightarrow \frac{2\pi y}{\lambda} \quad as \quad \frac{y}{\lambda} \rightarrow 0$	○	○	○	○	○	
10.2.2 Froude Number Effects N/A	○	○	○	○	○	
10.3 Energy Considerations $\frac{p_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_L \quad \left.\begin{matrix} z_1 - z_2 = S_0\ell \\ \frac{p_1}{\gamma} = y_1 \\ \frac{p_2}{\gamma} = y_2 \end{matrix}\right\} \rightarrow y_1 + \frac{V_1^2}{2g} + S_0\ell = y_2 + \frac{V_2^2}{2g} + h_L$ $S_f = \frac{h_L}{\ell} \rightarrow y_1 - y_2 = \frac{(V_2^2 - V_1^2)}{2g} + (S_f - S_0)\ell \quad \left.\begin{matrix} S_f = 0 \\ S_0 = 0 \end{matrix}\right\} \rightarrow y_1 - y_2 = \frac{(V_2^2 - V_1^2)}{2g}$	○	○	○	○	○	

Fluid Mechanics Survey Form A (Continued)

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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 10 Open Channel Flow (Continued)						
10.3.1 Specific Energy $E = y + \frac{V^2}{2g}$ $E_1 = E_2 + (S_f - S_0)\ell$ $E = y + \frac{q^2}{2gy^2}$ $\frac{dE}{dy} = 1 - \frac{q^2}{gy^3} = 0$ $y_c = \left(\frac{q^2}{g}\right)^{1/3}$ $E_{\min} = \frac{3y_c}{2}$ $V_c = \frac{q}{y_c} = \frac{(y_c^{3/2} g^{1/2})}{y_c} = \sqrt{gy_c}$ $Fr \equiv V_c / (gy_c)^{1/2} = 1$	○	○	○	○	○	
10.4 Uniform Depth Channel Flow **10.4.1 Uniform Flow Approximations** N/A	○	○	○	○	○	
10.4.2 The Chezy and Manning Equations $\sum F_x = \rho Q(V_2 - V_1) = 0$ $F_1 - F_2 - \tau_w P\ell + \vec{W}\sin\theta = 0$ $\sum F_x = 0$ $\left.\begin{array}{l} \tau_w = \frac{\vec{W}\sin\theta}{P\ell} = \frac{\vec{W}S_0}{P\ell} \\ \sin\theta \approx \tan\theta = S_0 \\ S_0 << 1 \\ \vec{W} = \gamma A\ell \\ R_h = A/P \end{array}\right\} \rightarrow$ $\tau_w = \frac{\gamma A\ell S_0}{P\ell} = \gamma R_h S_0$ $\tau_w == K\rho\frac{V^2}{2}$ $K\rho\frac{V^2}{2} = \gamma R_h S_0$ $\rightarrow$ $V = \frac{\kappa}{n} A R_h^{2/3} S_0^{1/2}$ $Q = \frac{\kappa}{n} A R_h^{2/3} S_0^{1/2}$ $V = C\sqrt{R_h S_0}$ $V = \frac{R_h^{2/3} S_0^{1/2}}{n}$	○	○	○	○	○	
10.4.3 Uniform Depth Examples N/A	○	○	○	○	○	

Fluid Mechanics Survey Form A (Continued)

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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 10 Open Channel Flow (Continued)						
10.5 Gradually Varied Flow N/A	○	○	○	○	○	
10.5.1 Classification of Surface Shapes N/A	○	○	○	○	○	
10.5.2 Examples of Gradually Varied Flows N/A	○	○	○	○	○	
10.6 Rapidly Varied Flow N/A	○	○	○	○	○	
10.6.1 The Hydraulic Jump $F_1 - F_2 = \rho Q(V_2 - V_1) = \rho V_1 y_1 b(V_2 - V_1)$ $\left.\begin{array}{l} F_1 = p_{c1}A_1 = \frac{\gamma y_1^2 b}{2} \quad p_{c1} = \frac{\gamma y_1}{2} \\ F_2 = p_{c2}A_2 = \frac{\gamma y_2^2 b}{2} \quad p_{c1} = \frac{\gamma y_2}{2} \end{array}\right\} \rightarrow \frac{y_1^2}{2} - \frac{y_2^2}{2} = \frac{V_1 y_1}{g}(V_2 - V_1)$ $y_1 b_1 V_1 = y_2 b_2 V_2 = Q \quad y_1 + \frac{V_1^2}{2g} = y_2 + \frac{V_2^2}{2g} + h_L \quad \frac{y_1^2}{2} - \frac{y_2^2}{2} = \frac{V_1 y_1}{g}\left(\frac{V_1 y_1}{y_2} - V_1\right) = \frac{V_1^2 y_1}{g y_2}(y_1 - y_2)$ $\left.\begin{array}{l} \left(\frac{y_2}{y_1}\right)^2 + \left(\frac{y_2}{y_1}\right) - 2Fr_1^2 = 0 \quad Fr_1 = \frac{V_1}{\sqrt{g y_1}} \\ \frac{y_2}{y_1} = \frac{1}{2}\left(-1 \pm \sqrt{1 + 8Fr_1^2}\right) \end{array}\right\} \rightarrow \begin{array}{l} \frac{y_2}{y_1} = \frac{1}{2}\left(-1 + \sqrt{1 + 8Fr_1^2}\right) \\ \frac{h_L}{y_1} = 1 - \frac{y_2}{y_1} + \frac{Fr_1^2}{2}\left[1 - \left(\frac{y_1}{y_2}\right)^2\right] \end{array}$	○	○	○	○	○	

Fluid Mechanics Survey Form A (Continued)

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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 10 Open Channel Flow (Continued)						
10.6.2 Sharp-Crested Weirs $\frac{p_A}{\gamma}+\frac{V_1^2}{2g}+z_A=(H+P_w-h)+\frac{u_2^2}{2g}$ $u_2=\sqrt{2g\left(h+\frac{V_1^2}{2g}\right)}$ $Q=\int_{(2)}u_2\,dA=\int_{h=0}^{h=H}u_2\ell\,dh$ $\ell=b \rightarrow Q=\sqrt{2g}b\int_0^H\left(h+\frac{V_1^2}{2g}\right)^{1/2}dh$ $Q=\frac{2}{3}\sqrt{2g}b\left[\left(H+\frac{V_1^2}{2g}\right)^{3/2}-\left(\frac{V_1^2}{2g}\right)^{3/2}\right]$ $\left.\begin{matrix}P_w>>H\\ \frac{V_1^2}{2g}<<H\end{matrix}\right\}\rightarrow$ $Q=\frac{2}{3}\sqrt{2g}H^{3/2}$ $Q=C_{wr}\frac{2}{3}\sqrt{2g}bH^{3/2}$ $C_{wr}=0.611+0.075\left(\frac{H}{P_w}\right)$ $\ell=2(H-h)\tan\left(\frac{\theta}{2}\right)$ $\frac{V_1^2}{2g}<<H \rightarrow Q=\frac{8}{15}\tan\left(\frac{\theta}{2}\right)\sqrt{2g}H^{5/2}$ $Q=C_{wt}\frac{8}{15}\tan\left(\frac{\theta}{2}\right)\sqrt{2g}H^{5/2}$	○	○	○	○	○	
10.6.3 Broad-Crested Weirs $H+P_w+\frac{V_1^2}{2g}=y_c+p_w+\frac{V_c^2}{2g}$ $H-y_c=\frac{(V_c^2-V_1^2)}{2g}=\frac{V_c^2}{2g}$ $\left.\begin{matrix}V_2=V_c=(gy_c)^{1/2}\\ V_c^2=gy_c\end{matrix}\right\}\rightarrow H-y_c=\frac{y_c}{2}\rightarrow y_c=\frac{2H}{3}$	○	○	○	○	○	
10.6.3 Broad-Crested Weirs (Continued) $Q=by_2V_2=by_cV_c=by_c(gy_c)^{1/2}=b\sqrt{g}\,y_c^{3/2} \rightarrow Q=b\sqrt{g}\left(\frac{2}{3}\right)^{3/2}H^{3/2}$ $Q=C_{wb}b\sqrt{g}\left(\frac{2}{3}\right)^{3/2}H^{3/2}$ $C_{wb}=\frac{0.65}{(1+H/P_w)^{1/2}}$	○	○	○	○	○	

Fluid Mechanics Survey Form A (Continued)

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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 10 Open Channel Flow (Continued)						
10.6.4 Underflow Gates $q = C_d a\sqrt{2gy_1}$	○	○	○	○	○	
10.7 Chapter Summary and Study Guide N/A	○	○	○	○	○	
Chapter 11 Compressible Flow						
11.3 Categories of Compressible Flow $r = (t - t_{wave})c \quad \sin\alpha = \frac{c}{V} = \frac{1}{Ma}$	○	○	○	○	○	
11.4.2 Converging-Diverging Duct Flow $\frac{p}{p^k} = \text{constant} = \frac{p_0}{p_0^k} \quad \frac{dp}{\rho} + d\left(\frac{V^2}{2}\right) = 0 \quad \frac{p_0^{1/k}}{\rho_0}\frac{dp}{(p)^{1/k}} + d\left(\frac{V^2}{2}\right) = 0 \quad \frac{k}{k-1}\left(\frac{p_0}{\rho_0} - \frac{p}{\rho}\right) - \frac{V^2}{2} = 0$ $\frac{kR}{k-1}(T_0 - T) - \frac{V^2}{2} = 0 \quad \left. c_p \begin{matrix} (T_0 - T) - \frac{V^2}{2} = 0 \\ \check{h}_2 - \check{h}_1 = c_p(T_2 - T_1) \end{matrix} \right\} \rightarrow \check{h}_0 - \left(\check{h} + \frac{V^2}{2}\right) = 0$	○	○	○	○	○	

Fluid Mechanics Survey Form A (Continued)

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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 11 Compressible Flow (Continued)						
11.4.2 Converging-Diverging Duct Flow (Continued) $\frac{T}{T_0}=\frac{1}{1+[(k-1)/2]Ma^2}$ $\left(\frac{p}{p_0}\right)\left(\frac{\rho_0}{\rho}\right)=\frac{T}{T_0}$ $\left(\frac{p}{p_0}\right)=\left(\frac{T}{T_0}\right)^{k/(k-1)}$ $\left.\begin{array}{l}\frac{T}{T_0}=\frac{1}{1+[(k-1)/2]Ma^2}\\ \left(\frac{p}{p_0}\right)=\left(\frac{T}{T_0}\right)^{k/(k-1)}\end{array}\right\}\rightarrow\frac{p}{p_0}=\left\{\frac{1}{1+[(k-1)/2]Ma^2}\right\}^{k/(k-1)}$ $\left.\begin{array}{l}\frac{T}{T_0}=\frac{1}{1+[(k-1)/2]Ma^2}\\ \left(\frac{p}{p_0}\right)\left(\frac{\rho_0}{\rho}\right)=\frac{T}{T_0}\\ \frac{p}{p_0}=\left\{\frac{1}{1+[(k-1)/2]Ma^2}\right\}^{k/(k-1)}\end{array}\right\}\rightarrow$ $\frac{\rho_0}{\rho}=\left\{\frac{1}{1+[(k-1)/2]Ma^2}\right\}^{k/(k-1)}$ $\frac{p^*}{p_0}=\left(\frac{2}{k+1}\right)^{k/(k-1)}$ $\left(\frac{p^*}{p_0}\right)_{k=1.4}=0.528$ $p^*_{k=1.4}=0.528p_{atm}$ $\frac{T^*}{T_0}=\frac{2}{k+1}$ $\left(\frac{T^*}{T_0}\right)_{k=1.4}=0.833$ $T^*_{k=1.4}=0.833T_{atm}$	○	○	○	○	○	

Fluid Mechanics Survey Form A (Continued)

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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 11 Compressible Flow (Continued)						
11.4.2 Converging-Diverging Duct Flow (Continued) $\left.\begin{array}{l} Ma=1 \\ p=\rho RT \\ \frac{p^*}{p_0}=\left(\frac{2}{k+1}\right)^{k/(k-1)} \\ \frac{T^*}{T_0}=\frac{2}{k+1}\end{array}\right\} \rightarrow \begin{array}{l} \frac{\rho^*}{\rho_0}=\left(\frac{\rho^*}{T^*}\right)\left(\frac{T_0}{p_0}\right)=\left(\frac{2}{k+1}\right)^{k/(k-1)}\left(\frac{k+1}{2}\right)=\left(\frac{2}{k+1}\right)^{k/(k-1)} \\ \left(\frac{\rho^*}{\rho_0}\right)_{k=1.4}=0.634 \quad \rho AV=\rho^* A^* V^* \\ \frac{A}{A^*}=\left(\frac{\rho^*}{\rho}\right)\left(\frac{V^*}{V}\right) \quad \begin{array}{l} V^*=\sqrt{RT^*k} \\ V=Ma\sqrt{RTk}\end{array} \\ \frac{A}{A^*}=\frac{1}{Ma}\left(\frac{\rho^*}{\rho_0}\right)\left(\frac{\rho_0}{\rho}\right)\sqrt{\frac{(T^*/T_0)}{T/T_0}}\end{array}$	○	○	○	○	○	

Fluid Mechanics Survey Form A (Continued)

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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 11 Compressible Flow (Continued)						
11.4.2 Converging-Diverging Duct Flow (Continued) $\frac{T}{T_0}=\frac{1}{1+[(k-1)/2]Ma^2}$ $\frac{p}{p_0}=\left\{\frac{1}{1+[(k-1)/2]Ma^2}\right\}^{k/(k-1)}$ $\frac{T^*}{T_0}=\frac{2}{k+1}$ $\frac{\rho^*}{\rho_0}=\left(\frac{\rho^*}{T^*}\right)\left(\frac{T_0}{p_0}\right)=\left(\frac{2}{k+1}\right)^{k/(k-1)}\left(\frac{k+1}{2}\right)=\left(\frac{2}{k+1}\right)^{k/(k-1)}$ $\frac{A}{A^*}=\frac{1}{Ma}\left(\frac{\rho^*}{\rho_0}\right)\left(\frac{\rho_0}{\rho}\right)\sqrt{\frac{(T^*/T_0)}{T/T_0}}$ $\frac{A}{A^*}=\frac{1}{Ma}\left\{\frac{1+[(k-1)/2]Ma^2}{1+[(k-1)/2]}\right\}^{(k+1)/[2(k-1)]}$	○	○	○	○	○	
11.4.3 Constant Area Duct Flow N/A	○	○	○	○	○	
11.5.3 Normal Shock Waves $\rho V=\text{constant}$ $p+\rho V^2=\text{constant}$ $p+\frac{(\rho V)^2 RT}{p}=\text{constant}$ $\check{h}+\frac{V^2}{2}=\check{h}_0=\text{constant}$ $\check{h}-\check{h}_0=c_p(T-T_0)$ $p=\rho RT$ $T+\frac{(\rho V)^2 T^2}{2c_p(p^2/R^2)}=T_0=\text{constant}$ $\frac{p_y}{p_x}=\left(\frac{p_y}{p_a}\right)\left(\frac{p_a}{p_x}\right)$ $\frac{p_y}{p_a}=\frac{1+k}{1+k\text{Ma}_y^2}$ $\frac{p_x}{p_a}=\frac{1+k}{1+k\text{Ma}_x^2}$						

Fluid Mechanics Survey Form A (Continued)

Engineering Subject: Fluid						
Likert Scale (Score of Importance) Note: 1 → Totally Unimportant; 2 → Not So Important; 3 → Might Be Important; 4 → Important; 5 → Very Important						
Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 11 Compressible Flow (Continued)						
11.5.3 Normal Shock Waves (Continued) $\frac{p_y}{p_x}=\frac{1+k\mathrm{Ma}_x^2}{1+k\mathrm{Ma}_y^2}$ $\frac{p_y}{p_x}=\left(\frac{p_y}{p^*}\right)\left(\frac{p^*}{p_x}\right)$ $\frac{p}{p^*}=\frac{1}{\mathrm{Ma}}\left\{\frac{(k+1)/2}{1+[(K-1)/2]\mathrm{Ma}^2}\right\}^{1/2}$ $p_x+\rho_x V_x^2=p_y+\rho_y V_Y^2$ $\frac{\rho V^2}{p}=\frac{V^2}{RT}=\frac{kV^2}{RTk}=k\mathrm{Ma}^2$ $\frac{T_y}{T_x}=\frac{1+[(k-1)/2]\mathrm{Ma}_x^2}{1+[(k-1)/2]\mathrm{Ma}_y^2}$ $\frac{p_y}{p_x}=\left(\frac{T_y}{T_x}\right)\left(\frac{\rho_y}{\rho_x}\right)$ $\frac{T_y}{T_x}=\left(\frac{T_y}{T^*}\right)\left(\frac{T^*}{T_x}\right)$ $\left.\begin{array}{l}\frac{T_y}{T^*}=\frac{(k+1)/2}{1+[(k-1)/2]\mathrm{Ma}_y^2}\\ \frac{T_x}{T^*}=\frac{(k+1)/2}{1+[(k-1)/2]\mathrm{Ma}_x^2}\end{array}\right\}\rightarrow$ $\rho_x V_x=\rho_y V_y$ $\frac{p_y}{p_x}=\left(\frac{T_y}{T_x}\right)\left(\frac{V_x}{V_y}\right)$ $\frac{p_y}{p_x}=\left(\frac{T_y}{T_x}\right)^{1/2}\left(\frac{\mathrm{Ma}_x}{\mathrm{Ma}_y}\right)$ $\frac{p_y}{p_x}=\left\{\frac{1+[(k-1)/2]\mathrm{Ma}_x^2}{1+[(k-1)/2]\mathrm{Ma}_y^2}\right\}^{1/2}\frac{\mathrm{Ma}_x}{\mathrm{Ma}_y}$ $\mathrm{Ma}_y^2=\frac{\mathrm{Ma}_x^2+[2/(k-1)]}{[2k/(k-1)]\mathrm{Ma}_x^2-1}$ $\frac{p_y}{p_x}=\frac{2k}{k+1}\mathrm{Ma}_x^2-\frac{k-1}{k+1}$ $\frac{T_y}{T_x}=\frac{\{1+[(k-1)/2]\mathrm{Ma}_x^2\}\{2k/(k-1)\}\mathrm{Ma}_x^2-1}{\{(k+1)^2/2(k-1)\}\mathrm{Ma}_x^2}$	○	○	○	○	○	

Fluid Mechanics Survey Form A (Continued)

Engineering Subject: Fluid						
<u>Likert Scale (Score of Importance) Note:</u> 1 → Totally Unimportant; 2 → Not So Important; 3 → Might Be Important; 4 → Important; 5 → Very Important						
Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 11 Compressible Flow (Continued)						
11.5.3 Normal Shock Waves (Continued) $\frac{\rho_y}{\rho_x}=\frac{V_x}{V_y}$ $\frac{\rho_y}{\rho_x}=\left(\frac{p_y}{p_x}\right)\left(\frac{T_x}{T_y}\right)$ $\frac{\rho_y}{\rho_x}=\frac{V_x}{V_y}=\frac{(k+1)\mathrm{Ma}_x^2}{(k-1)\mathrm{Ma}_x^2+2}$ $\frac{p_{0,y}}{p_{0,x}}=\left(\frac{p_{0,y}}{p_y}\right)\left(\frac{p_y}{p_x}\right)\left(\frac{p_x}{p_{0,x}}\right)$ $\frac{p_{0,y}}{p_{0,x}}=\frac{\left(\frac{k+1}{2}\mathrm{Ma}_x^2\right)^{k/(k-1)}\left(1+\frac{k-1}{2}\mathrm{Ma}_x^2\right)^{k/(1-k)}}{\left(\frac{2k}{k+1}\mathrm{Ma}_x^2-\frac{k-1}{k+1}\right)^{1/(k-1)}}$	○	○	○	○	○	
11.6 Analogy between Compressible and Open-Channel Flows $Ma=\frac{V}{c}$ $Fr=\frac{V_{oc}}{\sqrt{gy}}$ $c_{oc}=\sqrt{gy}$ $Fr=\frac{V_{oc}}{c_{oc}}$ $\rho AV=\text{constant}$ $ybV_{oc}=\text{constant}$ $\mathrm{c}=\sqrt{(\text{constant})k\rho^{k-1}}$	○	○	○	○	○	
11.7 Two-Dimensional Compressible Flow $V_{t1}=V_{t2}$	○	○	○	○	○	
11.8 Chapter Summary and Study Guide N/A	○	○	○	○	○	
Chapter 12 Turbomachines						
12.1 Introduction N/A	○	○	○	○	○	
12.2 Basic Energy Considerations $\vec{V}=\vec{W}+\vec{U}$ $U=\omega r$	○	○	○	○	○	

Fluid Mechanics Survey Form A (Continued)

Engineering Subject: Fluid						
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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 12 Turbomachines (Continued)						
12.3 Basic Angular Momentum Considerations $\sum(\vec{r}\times\vec{F})=\int_{cs}(\vec{r}\times\vec{V})\rho\vec{V}\cdot\hat{n}\ dA$ $T_{shaft}=-\dot{m}_1(r_1V_{\theta 1})+-\dot{m}_2(r_1V_{\theta 2})$ $m=\rho Q$ $\dot{W}_{shaft}=T_{shaft}\omega$ $\dot{W}_{shaft}=-\dot{m}_1(U_1V_{\theta 1})+-\dot{m}_2(U_1V_{\theta 2})$ $w_{shaft}=\frac{\dot{W}_{shaft}}{\dot{m}}$ $w_{shaft}=-U_1V_{\theta 1}+U_1V_{\theta 2}$ $V^2=V_\theta^2+V_x^2$ $V_x^2+(V_\theta-U)^2=W^2$ $V_\theta U=\frac{V^2+U^2-W^2}{2}$ $w_{shaft}=\frac{V_2^2-V_1^2+U_2^2-U_1^2-(W_2^2-W_1^2)}{2}$	○	○	○	○	○	
12.4 The Centrifugal Pump N/A	○	○	○	○	○	
12.4.1 Theoretical Considerations $\vec{V}_1=\vec{W}_1+\vec{U}_1$ $U_1=r_1\omega$ $\vec{V}_2=\vec{W}_2+\vec{U}_2$ $U_2=r_2\omega$ $\dot{m}_1=\dot{m}_2=\dot{m}$ $T_{shaft}=\dot{m}(r_2V_{\theta 2}-r_1V_{\theta 1})$ $T_{shaft}=\rho Q(r_2V_{\theta 2}-r_1V_{\theta 1})$ $\dot{W}_{shaft}=T_{shaft}\omega$ $\dot{W}_{shaft}=\rho Q\omega(r_2V_{\theta 2}-r_1V_{\theta 1})$ $\dot{W}_{shaft}=\rho Q(U_2V_{\theta 2}-U_1V_{\theta 1})$ $w_{shaft}=\frac{\dot{W}_{shaft}}{\rho Q}=U_2V_{\theta 2}-U_1V_{\theta 1}$ $\dot{W}_{shaft}=\rho gQh_i$ $h_i=\frac{1}{g}(U_2V_{\theta 2}-U_1V_{\theta 1})$	○	○	○	○	○	
12.4.1 Theoretical Considerations (Continued) $h_i=\frac{1}{2g}\left[(V_2^2-V_1^2)+(U_2^2-U_1^2)+(W_2^2-W_1^2)\right]$ $h_i=\frac{U_2V_{\theta 2}}{g}$ $\cot\beta_2=\frac{U_2-V_{\theta 2}}{V_{r2}}$ $h_i=\frac{U_2^2}{g}-\frac{U_2V_{r2}\cot\beta_2}{g}$ $Q=2\pi r_2b_2V_{r2}$ $h_i=\frac{U_2^2}{g}-\frac{U_2\cot\beta_2}{2\pi r_2b_2g}Q$	○	○	○	○	○	

Fluid Mechanics Survey Form A (Continued)

Engineering Subject: Fluid						
Likert Scale (Score of Importance) Note: 1 → Totally Unimportant; 2 → Not So Important; 3 → Might Be Important; 4 → Important; 5 → Very Important						
Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 12 Turbomachines (Continued)						
12.4.2 Pump Performance Characteristics $h_a = \frac{p_2 - p_1}{\gamma} + z_2 - z_1 + \frac{V_2^2 - V_1^2}{2g}$ $h_a = h_p = h_s - h_L$ $h_a \approx \frac{p_2 - p_1}{\gamma}$ $\wp_f = \gamma Q h_a$ $\wp_f = \text{water horsepower} = \frac{\gamma Q h_a}{550}$ $\eta = \frac{\text{power gained by thev fluid}}{\text{shaft power driving the pump}} = \frac{\wp_f}{\dot{W}_{shaft}}$ $\eta = \frac{\gamma Q h_a / 550}{bhp}$ $\eta = \eta_h \eta_m \eta_v$	○	○	○	○	○	
12.4.3 Net Positive Suction Head (NPSH) $NPSH = \frac{p_s}{\gamma} + \frac{V_s^2}{2g} - \frac{p_v}{\gamma}$ $\frac{p_{atm}}{\gamma} - z_1 = \frac{p_s}{\gamma} + \frac{V_s^2}{2g} = \sum h_L \rightarrow$ $\frac{p_s}{\gamma} + \frac{V_s^2}{2g} = \frac{p_{atm}}{\gamma} - z_1 - \sum h_L \rightarrow NPSH = \frac{p_{atm}}{\gamma} - z_1 - \sum h_L - \frac{p_v}{\gamma}$	○	○	○	○	○	
12.4 4 System Characteristics and Pump Selection $h_p = z_2 - z_1 + \sum h_L$ $h_p = z_2 - z_1 + KQ^2$	○	○	○	○	○	

Fluid Mechanics Survey Form A (Continued)

Engineering Subject: Fluid						
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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 12 Turbomachines (Continued)						
12.5 Dimensionless Parameters and Similarity Laws $\text{dependent variable} = f(D, \ell_i, \varepsilon, Q, \omega, \mu, \rho)$ $\text{dependent pi term} = \phi\left(\frac{\ell_i}{D}, \frac{\varepsilon}{D}, \frac{Q}{\omega D^3}, \frac{\rho\omega D^2}{\mu}\right)$ $C_H = \frac{gh_a}{\omega^2 D^2} = \phi_1\left(\frac{\ell_i}{D}, \frac{\varepsilon}{D}, \frac{Q}{\omega D^3}, \frac{\rho\omega D^2}{\mu}\right)$ $C_\wp = \frac{\dot{W}_{shaft}}{\rho\omega^3 D^5} = \phi_2\left(\frac{\ell_i}{D}, \frac{\varepsilon}{D}, \frac{Q}{\omega D^3}, \frac{\rho\omega D^2}{\mu}\right)$ $\eta = \frac{\rho g Q h_a}{\dot{W}_{shaft}} = \phi_3\left(\frac{\ell_i}{D}, \frac{\varepsilon}{D}, \frac{Q}{\omega D^3}, \frac{\rho\omega D^2}{\mu}\right)$ $\frac{gh_a}{\omega^2 D^2} = \phi_1\left(\frac{Q}{\omega D^3}\right)$ $\frac{\dot{W}_{shaft}}{\rho\omega^3 D^5} = \phi_2\left(\frac{Q}{\omega D^3}\right)$ $\eta = \phi_3\left(\frac{Q}{\omega D^3}\right)$ $\left(\frac{Q}{\omega D^3}\right)_1 = \left(\frac{Q}{\omega D^3}\right)_2$ $\left(\frac{gh_a}{\omega^2 D^2}\right)_1 = \left(\frac{gh_a}{\omega^2 D^2}\right)_2$ $\left(\frac{\dot{W}_{shaft}}{\rho\omega^3 D^5}\right)_1 = \left(\frac{\dot{W}_{shaft}}{\rho\omega^3 D^5}\right)_2$ $\eta = \eta_2$	○	○	○	○	○	
12.5.1 Special Pump Scaling Laws $\frac{Q_1}{Q_2} = \frac{\omega_1}{\omega_2}$ $\frac{h_{a1}}{h_{a2}} = \frac{\omega_1^2}{\omega_2^2}$ $\frac{\dot{W}_{shaft1}}{\dot{W}_{shaft2}} = \frac{\omega_1^3}{\omega_2^3}$ $\frac{Q_1}{Q_2} = \frac{D_1^3}{D_2^3}$ $\frac{h_{a1}}{h_{a2}} = \frac{D_1^2}{D_2^2}$ $\frac{\dot{W}_{shaft1}}{\dot{W}_{shaft2}} = \frac{D_1^5}{D_2^5}$ $\frac{1-\eta_2}{1-\eta_1} \approx \left(\frac{D_1}{D_2}\right)^{1/5}$	○	○	○	○	○	
12.5.2 Specific Speed $\frac{(Q/\omega D^3)^{1/2}}{(gh_a/\omega^2 D^2)^{3/4}} = \frac{\omega\sqrt{Q}}{(gh_a)^{3/4}} = N_s$ $N_{sd} = \frac{\omega(rpm)\sqrt{Q(gpm)}}{[h_a(ft)]^{3/4}}$	○	○	○	○	○	
12.5.3 Suction Specific Speed $S_s = \frac{\omega\sqrt{Q}}{[g(NPSH_R)]^{3/4}}$ $S_{sd} = \frac{\omega(rpm)\sqrt{Q(gpm)}}{[NPSH_R(ft)]^{3/4}}$	○	○	○	○	○	
12.6 Axial-Flow and Mixed-Flow Pump N/A	○	○	○	○	○	

Fluid Mechanics Survey Form A (Continued)

Engineering Subject: Fluid						
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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 12 Turbomachines						
12.7 Fans $\left(\frac{p_a}{\rho\omega^2 D^2}\right)_1 = \left(\frac{p_a}{\rho\omega^2 D^2}\right)_2$	○	○	○	○	○	
12.8 Turbines **12.8.1 Impulse Turbines** $V_{\theta 1}=V_1=W_1+U \quad V_{\theta 2}=W_2\cos\beta+U \quad V_{\theta 2}-V_{\theta 1}=(U-V_1)(1-\cos\beta)$ $T_{shaft}=\dot{m}r_m(U-V_1)(1-\cos\beta) \quad \dot{W}_{shaft}=T_{shaft}\omega=\dot{m}U(U-V_1)(1-\cos\beta) \quad U\big\vert_{\substack{max\\ power}}=\frac{V^2}{2}$	○	○	○	○	○	
12.8.2 Reaction Turbines $C_Q=\frac{Q}{\omega D^3} \quad C_H=\frac{gh_T}{\omega^2 D^2} \quad C_\wp=\frac{\dot{W}_{shaft}}{\rho\omega^3 D^5} \quad \eta=\frac{\dot{W}_{shaft}}{\rho g Q h_T} \quad C_H=\phi_1(C_Q) \quad C_\wp=\phi_2(C_Q)$ $\eta=\phi_3(C_Q) \quad \eta=\frac{C_\wp}{C_H C_Q} \quad N'_s=\frac{\omega\sqrt{\dot{W}_{shaft}/\rho}}{(gh_T)^{5/4}} \quad N'_{sd}=\frac{\omega(rpm)\sqrt{\dot{W}_{shaft}(bhp)}}{[h_T(ft)]^{5/4}}$	○	○	○	○	○	
12.9 Compressible Flow Turbomachines	○	○	○	○	○	
12.9.1 Compressors $\left(\frac{R\dot{m}\sqrt{kRT_{01}}}{D^2 p_{01}}\right)_{test}=\left(\frac{R\dot{m}\sqrt{kRT_{01}}}{D^2 p_{01}}\right)_{std} \quad \dot{m}_{std}=\frac{\dot{m}_{std}\sqrt{T_{01\ test}/T_{0\ std}}}{p`_{01\ test}/p_{0\ std}} \quad \frac{ND}{\sqrt{kRT_{01}}} \quad N_{std}=\frac{N}{\sqrt{T_{01}/T_{std}}}$	○	○	○	○	○	
12.9.2 Compressible Flow Turbines N/A	○	○	○	○	○	
12.10 Chapter Summary and Study Guide N/A	○	○	○	○	○	
THE END						

Fluid Mechanics Survey Form B
1st Round of Delphi - Likert Scale Questionnaire on the Importance of Various Fluid Mechanics Topics Selected for High School Engineering Curriculum (For the Calculus Portion)

Engineering Subject: Fluid						
Likert Scale (Score of Importance) Note: 1 → Totally Unimportant; 2 → Not So Important; 3 → Might Be Important; 4 → Important; 5 → Very Important						
Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 1 – Introduction						
1.6 Viscosity $u = \frac{Uy}{b}$ $\tan\delta\beta \approx \delta\beta = \frac{\delta a}{b}$ $\delta a = U\delta t$ $\delta\beta = \frac{U\delta t}{b}$ $\dot{\gamma} = \lim_{\delta t \to 0}\frac{\delta\beta}{\delta t}$ $\dot{\gamma} = \frac{U}{b} = \frac{du}{dy}$ $\tau \propto \dot{\gamma}$ $\tau \propto \frac{du}{dy}$ $\tau = \mu\frac{du}{dy}$ $\mu = \frac{CT^{3/2}}{T+S}$ $\mu = De^{B/T}$ $\nu = \frac{\mu}{\rho}$	○	○	○	○	○	
Chapter 2 Fluid Statics						
2.1 Pressure at a Point $\vec{F} = m\vec{a}$ $\sum F_y = p_y\delta x\delta z - p_s\delta x\delta s\sin\theta = \rho\frac{\delta x\delta y\delta z}{2}a_y$ $\sum F_z = p_z\delta x\delta y - p_s\delta x\delta s\cos\theta - \gamma\frac{\delta x\delta y\delta z}{2} = \rho\frac{\delta x\delta y\delta z}{2}a_z$ $\uparrow$ $\frac{\delta x\delta y\delta z}{2} = V$ $m = \rho V$ $\leftarrow$ $\vec{F}_z = m\vec{a}_z$ $\uparrow$ $\delta y = \delta s\cos\theta$ $\delta z = \delta s\sin\theta$	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

Engineering Subject: Fluid						
Likert Scale (Score of Importance) Note: 1 → Totally Unimportant; 2 → Not So Important; 3 → Might Be Important; 4 → Important; 5 → Very Important						
Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 2 Fluid Statics (Continued)						
2.1 Pressure at a Point $\left.\begin{matrix} p_y - p_s = \rho a_y \frac{\delta y}{2} \quad as \quad \frac{\delta y}{2} \to 0 \\ p_z - p_s = (\rho a_z - \gamma)\frac{\delta z}{2} \quad as \quad \frac{\delta z}{2} \to 0 \end{matrix}\right\} \to \begin{cases} p_y = p_s \\ p_z = p_s \end{cases}$	○	○	○	○	○	
2.2 Basic Equation for Pressure Field $\delta F_y = \left(p - \frac{\partial p}{\partial y}\frac{\delta y}{2}\right)\delta x \delta z - \left(p + \frac{\partial p}{\partial y}\frac{\delta y}{2}\right)\delta x \delta z \to \left.\begin{matrix} \delta F_x = -\frac{\partial p}{\partial x}\delta x \delta y \delta z \\ \delta F_y = -\frac{\partial p}{\partial y}\delta x \delta y \delta z \\ \delta F_z = -\frac{\partial p}{\partial z}\delta x \delta y \delta z \end{matrix}\right\} \leftarrow \delta y \delta x \delta z = V$ $\delta \vec{F}_s = \delta F_x \hat{i} + \delta F_y \hat{j} + \delta F_z \hat{k} = -\left(\frac{\partial p}{\partial x}\hat{i} + \frac{\partial p}{\partial y}\hat{j} + \frac{\partial p}{\partial z}\hat{k}\right)\delta x \delta y \delta z \quad \frac{\partial p}{\partial x}\hat{i} + \frac{\partial p}{\partial y}\hat{j} + \frac{\partial p}{\partial z}\hat{k} = \nabla p$ $\nabla(\ ) = \frac{(\ )}{\partial x}\hat{i} + \frac{(\ )}{\partial y}\hat{j} + \frac{(\ )}{\partial z}\hat{k} \quad \frac{\delta \vec{F}_s}{\delta x \delta y \delta z} = -\nabla p \quad -\delta W\hat{k} = -\gamma \delta x \delta y \delta z \hat{k} \quad \begin{cases} \sum \delta \vec{F} = \delta m \vec{a} \\ \delta m = \rho \delta x \delta y \delta \end{cases} z$ $\sum \delta \vec{F} = \delta \vec{F}_s - \delta W\hat{k} = \delta m \vec{a} \to -\nabla p \delta x \delta y \delta z \hat{k} - \gamma \delta x \delta y \delta z \hat{k}\hat{k} = \rho \delta x \delta y \delta z \hat{k} \vec{a} \to$ $-\nabla p - \gamma \hat{k} = \rho \vec{a}$	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

Engineering Subject: Fluid						
Likert Scale (Score of Importance) Note: 1 → Totally Unimportant; 2 → Not So Important; 3 → Might Be Important; 4 → Important; 5 → Very Important						
Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 2 Fluid Statics (Continued)						
2.3 Pressure Variation in a Fluid Mechanics Mechanics at Rest $\vec{a}=0 \quad \rightarrow \quad -\nabla p-\gamma\hat{k}=0 \quad \frac{\partial p}{\partial x}=0 \quad \frac{\partial p}{\partial y}=0 \quad \frac{\partial p}{\partial z}=-\gamma \quad \rightarrow \quad \frac{dp}{dz}=-\gamma$	○	○	○	○	○	
2.8 Hydrostatic Force on a Plane Surface $F_R=\int_A \gamma h\ dA=\int_A \gamma y\sin\theta\ dA \quad F_R=\gamma\sin\theta\int_A y\ dA \quad \int_A y\ dA=y_c A \quad F_R=\gamma A y_c\sin\theta$ $F_R=\lambda h_c A \quad F_R y_R=\int_A y\ dF=\int_A \gamma\sin\theta\ y^2 dA \quad y_R=\frac{\int_A y^2 dA}{y_c A}=\frac{I_x}{y_c A}=\frac{I_{xc}+Ay_c^2}{y_c A}$ $y_R=\frac{I_{xc}}{y_c A}+\frac{Ay_c^2}{y_c A}=\frac{I_{xc}}{y_c A}+y_c \quad \leftarrow \quad I_x=I_{xc}+Ay_c^2 \quad F_R x_R=\int_A \gamma\ \sin\theta\ xy\ dA \quad x_R=\frac{\int_A xy\ dA}{y_c A}=\frac{I_{xy}}{y_c A}$ $x_R=\frac{I_{xyc}}{y_c A}+x_c \quad I_{xy}=I_{xyc}+Ax_c y_c$	○	○	○	○	○	
2.12 Pressure Variation in a Fluid Mechanics Mechanics with Rigid-Body Motion $-\nabla p-\gamma\hat{k}=\rho\vec{a} \quad \rightarrow \quad \begin{cases} -\frac{\partial p}{\partial x}=\rho a_x \\ -\frac{\partial p}{\partial y}=\rho a_y \\ -\frac{\partial p}{\partial z}=\gamma+\rho a_z \end{cases}$	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

Engineering Subject: Fluid						
Likert Scale (Score of Importance) Note: 1 → Totally Unimportant; 2 → Not So Important; 3 → Might Be Important; 4 → Important; 5 → Very Important						
Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 2 Fluid Statics (Continued)						
2.12.1 Linear Motion $\frac{\partial p}{\partial y} = -\rho a_y \quad \frac{\partial p}{\partial z} = -\rho(g + a_z) \quad dp = \frac{\partial p}{\partial y}dy + \frac{\partial p}{\partial z}dz \quad dp = -\rho a_y dy - \rho(g + a_z)dz$ $\frac{dz}{dy} = -\frac{a_y}{g + a_z} \quad \frac{dp}{dz} = -\rho(g + a_z)$	○	○	○	○	○	
2.12.2 Rigid-Body Rotation $\nabla p = \frac{\partial p}{\partial r}\hat{e}_r + \frac{1}{r}\frac{\partial p}{\partial \theta}\hat{e}_\theta + \frac{\partial p}{\partial z}\hat{e}_z \quad \vec{a}_r = -r\omega^2\hat{e}_r \quad \vec{a}_\theta = 0 \quad \vec{a}_z = 0 \quad \frac{\partial p}{\partial r} = \rho r\omega^2 \quad \frac{\partial p}{\partial \theta} = 0 \quad \frac{\partial p}{\partial z} = -\gamma$ $dp = \frac{\partial p}{\partial r}dr + \frac{\partial p}{\partial z}dz \quad dp = \rho r\omega^2 dr - \gamma\ dz \quad dp = 0 \rightarrow 0 = \rho r\omega^2 dr - \gamma\ dz \rightarrow 0 = \rho r\omega^2 dr - \rho g\ dz \rightarrow$ $0 = r\omega^2 dr - g\ dz \rightarrow g\ dz = r\omega^2 dr \rightarrow \frac{dz}{dr} = \frac{r\omega^2}{g} \rightarrow$ $\int \frac{dz}{dr} = \int \frac{r\omega^2}{g} \rightarrow \int \frac{dz}{dr}(dr) = \int \frac{r\omega^2}{g}(dr) \rightarrow \int dz = \int \frac{r\omega^2}{g}dr \rightarrow z = \frac{r^2}{2}\frac{\omega^2}{g} \rightarrow$ $z = \frac{\omega^2 r^2}{2g} + \text{constant} \quad \int dp = \rho\omega^2 \int r\,dr - \gamma \int dz \quad p = \frac{\rho\omega^2 r^2}{2} - \gamma z + \text{constan}$	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

Engineering Subject: Fluid						
Likert Scale (Score of Importance) Note: 1 → Totally Unimportant; 2 → Not So Important; 3 → Might Be Important; 4 → Important; 5 → Very Important						
Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 3 Elementary Fluid Dynamics – The Bernoulli Equation						
3.2 F = ma along a Streamline (Continued) Alternatively $p_N + \frac{1}{2}\rho_N \cdot v_N{}^2 + \rho_N \cdot g \cdot z_N = C_{streamline\,N}$ Pressure(along a streamline) + Kinetic Energy + Potential Energy = Constant $\begin{cases} p = \frac{F}{A} = \frac{F \cdot r}{A \cdot r} = \frac{W}{V} \text{ (Work per unit volume)} \\ \frac{1}{2}\rho \cdot v^2 = \frac{1}{2}\frac{m}{V} \cdot v^2 = \frac{\frac{1}{2}m \cdot v^2}{V} = \frac{KE}{V} \text{ (Kinetic energy per unit volume)} \\ \rho \cdot g \cdot z = \frac{m}{V} \cdot g \cdot z = \frac{m \cdot g \cdot z}{V} = \frac{PE}{V} \\ \text{(Potential energy per unit volume. } z\hat{k}\uparrow \equiv h;\ g \equiv -z\hat{k}\downarrow) \end{cases}$ Law of conservation of mass + Law of conservation of energy Bernouilli's Equation $p_N + \frac{1}{2}\rho_N \cdot v_N{}^2 + \rho_N \cdot g \cdot z_N = C_{streamline\,N}$ $(v_{in} \cdot \hat{n}_{Ain}) \cdot A_{in} = A_{2\,out} \cdot v_{2\,out} + A_{1\,out} \cdot v_{1\,out}$	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

Engineering Subject: Fluid						
Likert Scale (Score of Importance) Note: 1 → Totally Unimportant; 2 → Not So Important; 3 → Might Be Important; 4 → Important; 5 → Very Important						
Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 3 Elementary Fluid Dynamics – The Bernoulli Equation (Continued)						
3.3 F = ma Normal to a Streamline $\sum \delta F_n = \frac{\delta m V^2}{\Re} = \frac{\rho \delta \forall V^2}{\Re}$ $\quad \delta \vec{W}_n = -\delta \vec{W} \cos\theta = -\lambda \delta \forall \cos\theta$ $\delta F_{pn} = (p - \delta p_n)\delta s \delta y - (p + \delta p_n)\delta s \delta y = -2 p_n \delta s \delta y = -\frac{\partial p}{\partial n}\delta s \delta n \delta y = -\frac{\partial p}{\partial n}\delta \forall$ $\sum \delta F_n = \delta \vec{W}_n + \delta F_{pn} = \left(-\gamma \cos\theta - \frac{\partial p}{\partial n}\right)\delta \forall \quad -\gamma \frac{dz}{dn} - \frac{\partial p}{\partial n} = \frac{\rho V^2}{\Re} \quad \frac{\partial p}{\partial n} = -\frac{\rho V^2}{\Re}$ $\left.\begin{array}{l} \left(-\gamma \frac{dz}{dn} - \frac{\partial p}{\partial n}\right)dn = \left(\frac{\rho V^2}{\Re}\right)dn \\ \frac{\partial p}{\partial n} = \frac{dp}{dn} \quad s = \text{constant} \end{array}\right\} \rightarrow \begin{array}{l} \int \frac{dp}{\rho} + \int \frac{V^2}{\Re} dn + gz = \text{constant across the streamline} \\ \mathrm{p} + \rho \int \frac{\mathrm{V}^2}{\Re} dn + \gamma z = \text{constant across the streamline} \end{array}$	○	○	○	○	○	
3.8.2 Unsteady Effects $\rho \frac{\partial V}{\partial t} ds + dp + \frac{1}{2}\rho d\left(V^2\right) + \gamma\ z = 0$ (along a streamline) $p_1 + \frac{1}{2}\rho V_1^2 + \gamma z_1 = \rho \int_{s_1}^{s_2} \frac{\partial V}{\partial t} ds + p_2 + \frac{1}{2}\rho V_2^2 + \gamma z_2$ (along a streamline)	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

Engineering Subject: Fluid						
Likert Scale (Score of Importance) Note: 1 → Totally Unimportant; 2 → Not So Important; 3 → Might Be Important; 4 → Important; 5 → Very Important						
Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 4 Fluid Kinematics						
4.1 The Velocity Field $\vec{V} = u(x,y,z,t)\hat{i} + v(x,y,z,t)\hat{j} + w(x,y,z,t)\hat{k} \quad V = \lvert\vec{V}\rvert = (u^2 + v^2 + w^2)^{1/2}$	○	○	○	○	○	
4.1.1 Eulerian and Lagrangian Flow Descriptions $\left.\begin{array}{l} x = x_0 \\ y = y_0 \\ z = z_0 \end{array}\right\} \quad \begin{array}{l} T = T(x_0, y_0, z_0, t) \\ T = T(x, y, z, t) \end{array}$	○	○	○	○	○	
4.1.2 one-, Two-, and three-Dimensional Flows $\vec{V} = \vec{V}(x,t) = u\hat{i} \quad \vec{V} = \vec{V}(x,y,,t) = u\hat{i} + v\hat{j} \quad \vec{V} = \vec{V}(x,y,z,t) = u\hat{i} + v\hat{j} + w\hat{k}$	○	○	○	○	○	
4.1.3 Steady and Unsteady Flows $\frac{\partial \vec{V}}{\partial t} = 0$	○	○	○	○	○	
4.1.4 Streamilnes, Streaklines, and Pathlines $\frac{dy}{dx} = \frac{v}{u}$	○	○	○	○	○	
4.2 The Acceleration Field $\vec{a} = \vec{a}(t)$	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

Engineering Subject: Fluid						
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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 4 Fluid Kinematics (Continued)						
4.2.1 The Material Derivative $\vec{V}_A = \vec{V}_A(r_A, t) = \vec{V}_A[x_A(t), y_A(t), z_A(t), t] \quad x_A = x_A(t) \quad y_A = y_A(t) \quad z_A = z_A(t)$ $\vec{a}_A(t) = \frac{d\vec{V}_A}{dt} = \frac{\partial \vec{V}_A}{\partial t} + \frac{\partial \vec{V}_A}{\partial x}\frac{dx_A}{dt} + \frac{\partial \vec{V}_A}{\partial y}\frac{dy_A}{dt} + \frac{\partial \vec{V}_A}{\partial z}\frac{dz_A}{dt} \quad \vec{a}_A = \frac{\partial \vec{V}_A}{\partial t} + u_A\frac{\partial \vec{V}_A}{\partial x} + v_A\frac{\partial \vec{V}_A}{\partial y} + w_A\frac{\partial \vec{V}_A}{\partial z}$ $\vec{a} = \frac{\partial \vec{V}}{\partial t} + u\frac{\partial \vec{V}}{\partial x} + v\frac{\partial \vec{V}}{\partial y} + w\frac{\partial \vec{V}}{\partial z}$ $\left.\begin{array}{l} a_x = \frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} \\ a_y = \frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z} \\ a_x = \frac{\partial w}{\partial t} + u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} + w\frac{\partial w}{\partial z} \end{array}\right\} \rightarrow \vec{a} = \frac{D\vec{V}}{Dt} \rightarrow \frac{D(\ )}{Dt} \equiv \frac{\partial(\ )}{\partial t} + u\frac{\partial(\ )}{\partial x} + v\frac{\partial(\ )}{\partial y} + w\frac{\partial(\ )}{\partial z} = \frac{\partial(\ )}{\partial t} + (\vec{V}\cdot\nabla)(\ )$ (Material Derivative or Substantial Derivative) $\uparrow \left\{\begin{array}{l} \nabla(\ ) = \frac{\partial(\ )}{\partial x}\hat{i} + \frac{\partial(\ )}{\partial y}\hat{j} + \frac{\partial(\ )}{\partial z}\hat{k} \\ \vec{V}\cdot\nabla(\ ) = u\frac{\partial(\ )}{\partial x} + v\frac{\partial(\ )}{\partial y} + w\frac{\partial(\ )}{\partial z} \end{array}\right. \leftarrow \left\{\begin{array}{l} T = T(x, y, z, t) \\ \vec{V} = \vec{V}(x, y, z, t) \end{array}\right\}$ $\rightarrow \left\{\begin{array}{l} \frac{dT_A}{dt} = \frac{\partial T_A}{\partial t} + \frac{\partial T_A}{\partial x}\frac{dx_A}{dt} + \frac{\partial T_A}{\partial y}\frac{dy_A}{dt} + \frac{\partial T_A}{\partial z}\frac{dz_A}{dt} \\ \frac{DT}{Dt} = \frac{\partial T}{\partial t} + u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} + w\frac{\partial T}{\partial z} = \frac{\partial T}{\partial t} + \vec{V}\cdot\nabla T \end{array}\right.$	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

Engineering Subject: Fluid						
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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 4 Fluid Kinematics (Continued)						
4.2.2 Unsteady Effects $\because \left.\begin{matrix}\frac{\partial u}{\partial x}=0\\ v=w=0\end{matrix}\right\} \quad \therefore \quad \vec{a}=\frac{\partial \vec{V}}{\partial t}+u\frac{\partial \vec{V}}{\partial x}+v\frac{\partial \vec{V}}{\partial y}w\frac{\partial \vec{V}}{\partial z}=\frac{\partial \vec{V}}{\partial t}=\frac{\partial V_0}{\partial t}\hat{i}$	○	○	○	○	○	
4.2.3 Convective Effects $\nabla(\ )=\frac{\partial(\ )}{\partial x}\hat{i}+\frac{\partial(\ )}{\partial y}\hat{j}+\frac{\partial(\ )}{\partial z}\hat{k} \quad (\vec{V}\cdot\nabla)\vec{V}$ (Convective Acceleration)	○	○	○	○	○	
4.2.4 Streamline Coordinates $\vec{V}=V\hat{s} \quad \vec{a}=\frac{D\vec{V}}{Dt}=a_s\hat{s}+a_n\hat{n} \quad \vec{a}=\frac{D(V\hat{s})}{Dt}=\frac{DV}{Dt}\hat{s}+V\frac{D\hat{s}}{Dt}$ $\vec{a}=\left(\frac{\partial V}{\partial t}+\frac{\partial V}{\partial s}\frac{ds}{dt}+\frac{\partial V}{\partial n}\frac{dn}{dt}\right)\hat{s}+V\left(\frac{\partial \hat{s}}{\partial t}+\frac{\partial \hat{s}}{\partial s}\frac{ds}{dt}+\frac{\partial \hat{s}}{\partial n}\frac{dn}{dt}\right) \quad \vec{a}=\left(V\frac{\partial V}{\partial s}\right)\hat{s}+V\left(V\frac{\partial \hat{s}}{\partial s}\right)$	○	○	○	○	○	
4.2.4 Streamline Coordinates (Continued) $\left.\begin{matrix}\delta s\to 0\\ \lvert\hat{s}\rvert=1\\ \frac{\partial s}{\Re}=\frac{\lvert\delta\hat{s}\rvert}{\lvert\hat{s}\rvert}=\lvert\delta\hat{s}\rvert\\ \left\lvert\frac{\lvert\delta\hat{s}\rvert}{\lvert\delta s\rvert}=\frac{1}{\Re}\right\rvert\end{matrix}\right\} \rightarrow \frac{\partial \hat{s}}{\partial s}=\lim_{\delta s\to 0}\frac{\delta\hat{s}}{\delta s}=\frac{\hat{n}}{\Re} \quad \vec{a}=V\frac{\partial V}{\partial s}\hat{s}+\frac{V^2}{\Re}\hat{n} \leftarrow \left\{\begin{matrix}a_s=\frac{\partial V}{\partial s}\\ a_n=\frac{V^2}{\Re}\end{matrix}\right.$	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

Engineering Subject: Fluid						
Likert Scale (Score of Importance) Note: 1 → Totally Unimportant; 2 → Not So Important; 3 → Might Be Important; 4 → Important; 5 → Very Important						
Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 4 Fluid Kinematics (Continued)						
4.4 The Reynolds Transport Theorem (Continued) $B_{sys} = \lim_{\delta V \to 0} = \sum_i b_i(\rho_i \delta V_i) = \int_{sys} \rho b \, dV \quad \leftarrow \quad \delta B = b\rho \; \delta V$ $\frac{dB_{sys}}{dt} = \frac{d\left(\int_{sys} \rho b \, dV\right)}{dt} \quad \frac{dB_{cv}}{dt} = \frac{d\left(\int_{cv} \rho b \, dV\right)}{dt}$	○	○	○	○	○	
4.4.1 Derivation of the Reynolds Transport Theorem $\frac{DB_{system}}{Dt} = \frac{\partial B_{CV}}{\partial t} + \dot{m}_{out} \cdot b_{out} - \dot{m}_{in} \cdot b_{in} \quad \vec{F}_{system} = \frac{d[m\vec{V}]}{dt} = \frac{\partial [m\vec{V}]_{CV}}{\partial t} + \sum(\dot{m}_{out} \cdot \vec{V}_{out}) - \sum(\dot{m}_{in} \cdot \vec{V}_{in})$ $\leftarrow \begin{cases} \frac{d[m\vec{V}]}{dt} = m\frac{d[\vec{V}]}{dt} = m\vec{a} = \vec{F} \text{ (Newtons Second Law)} \\ \because \; \dot{m} \cdot \vec{V} \equiv \frac{dm}{dt}\vec{V} = m\frac{d\vec{V}}{dt} = m\vec{a} = \vec{F} \quad \& \quad \frac{d[\vec{M}]}{dt} = \frac{d[m\vec{V}]}{dt} = m\frac{d[\vec{V}]}{dt} = m\vec{a} = \vec{F} \\ \therefore \; \sum(\dot{m}_{out} \cdot \vec{V}_{out}) - \sum(\dot{m}_{in} \cdot \vec{V}_{in}) = \text{Momentum} \to \text{Force} \end{cases}$ Note: Other Formulas used to derive the Reynolds Transport Theorem are available in pages 171-177. $\frac{DB_{sys}}{Dt} = \frac{\partial}{\partial t}\int_{cv} \rho b \, dV + \int_{cs} \rho b \, \vec{V} \cdot \hat{n} \, dA$	○	○	○	○	○	
4.4.2 Physical Interpretation N/A	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 4 Fluid Kinematics (Continued)						
4.4.3 Relationship to Material Derivative $\vec{V}\cdot\nabla(\ )=\frac{\partial(\ )}{\partial t}+u\frac{\partial(\ )}{\partial x}+v\frac{\partial(\ )}{\partial y}+w\frac{\partial(\ )}{\partial z}$ $\frac{D(\ )}{Dt}\equiv\frac{\partial(\ )}{\partial t}+u\frac{\partial(\ )}{\partial x}+v\frac{\partial(\ )}{\partial y}+w\frac{\partial(\ )}{\partial z}=\frac{\partial(\ )}{\partial t}+(\vec{V}\cdot\nabla)(\ )$ (Material Derivative or Substantial Derivative)	○	○	○	○	○	
4.4.4 Steady Effects $\frac{DB_{sys}}{Dt}=\int_{sys}\rho b\vec{V}\cdot\hat{n}\ dA$	○	○	○	○	○	
4.4.5 Unsteady Effects $\frac{DB_{sys}}{Dt}=\frac{\partial}{\partial t}\int_{cv}\rho b\ d\mathcal{V}+\int_{cs}\rho b\ \vec{V}\cdot\hat{n}\ dA \quad \int_{cs}\rho b\ \vec{V}\cdot\hat{n}\ dA=0 \ \rightarrow\ \frac{DB_{sys}}{Dt}=\frac{\partial}{\partial t}\int_{cv}\rho b\ d\mathcal{V}$ $\vec{V}=V_0\hat{i}\quad \Delta\rho=0\quad \vec{B}=\text{system momentum}=m\vec{V}=mV_0\hat{i}$ $\vec{b}=\frac{\vec{B}}{m}=\vec{V}=V_0\hat{i}\quad \left\{\begin{array}{ll}\vec{V}\cdot\hat{n}>0 & \text{(out flow)}\\ \vec{V}\cdot\hat{n}<0 & \text{(in flow)}\\ \vec{V}\cdot\hat{n}=0 & \text{(along the side of the CV)}\end{array}\right\}$	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

Engineering Subject: Fluid						
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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 4 Fluid Kinematics (Continued)						
4.4.5 Unsteady Effects (Continued) $\frac{DB_{sys}}{Dt}=\frac{\partial}{\partial t}\int_{cv}\rho b\ d\forall+\int_{cs}\rho b\ \vec{V}\cdot\hat{n}\ dA \quad \int_{cs}\rho b\ \vec{V}\cdot\hat{n}\ dA=0 \ \rightarrow\ \frac{DB_{sys}}{Dt}=\frac{\partial}{\partial t}\int_{cv}\rho b\ d\forall$ $\vec{V}=V_0\hat{i} \quad \Delta\rho=0 \quad \vec{B}=\text{system momentum}=m\vec{V}=mV_0\hat{i}$ $\vec{b}=\frac{\vec{B}}{m}=\vec{V}=V_0\hat{i} \quad \left\{\begin{array}{ll}\vec{V}\cdot\hat{n}>0 & \text{(out flow)}\\ \vec{V}\cdot\hat{n}<0 & \text{(in flow)}\\ \vec{V}\cdot\hat{n}=0 & \text{(along the side of the CV)}\end{array}\right\}$ $\left.\begin{array}{ll}\vec{V}\cdot\hat{n}=-V_0 & \text{(one section)}\\ \vec{V}\cdot\hat{n}=V_0 & \text{(another section)}\end{array}\right\} \rightarrow \begin{array}{l}\int_{cs}\rho b\vec{V}\cdot\hat{n}\ dA=\int_{cs}\rho\left(V_0\hat{i}\right)\left(\vec{V}\cdot\hat{n}\right)dA\\ =\int_{(1)}\rho\left(V_0\hat{i}\right)\left(-V_0\right)dA+\int_{(2)}\rho\left(V_0\hat{i}\right)\left(V_0\right)dA\\ =-\rho V_0^2A_1\hat{i}+\rho V_0^2A_1\hat{i}=0\end{array}$	○	○	○	○	○	
4.4.6 Moving Control Volumes $\vec{V}_{cv}=\vec{V}-\vec{W} \quad \vec{V}=\vec{W}+\vec{V}_{cv} \quad \frac{DB_{sys}}{Dt}=\frac{\partial}{\partial t}\int_{cv}\rho b\ d\forall+\int_{cs}\rho b\vec{W}\cdot\hat{n}\ dA$	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

Engineering Subject: Fluid						
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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 5 Finite Control Volume Analysis						
5.1 Conservation of Mass – The Continuity Equation **5.1.1 Derivation of the Continuity Equation** $\frac{DM_{sys}}{Dt}=0 \quad M_{sys}=\int_{sys}\rho\, d\forall \quad \frac{D}{Dt}\int_{sys}\rho\, D\forall=\frac{\partial}{\partial t}\int_{cv}\rho\, d\forall+\int_{cv}\rho\vec{V}\cdot\hat{n}\, dA \quad \frac{\partial}{\partial t}\int_{cv}\rho\, d\forall \quad \int_{cs}\rho\vec{V}\cdot\hat{n}\, dA$ $\frac{\partial}{\partial t}\int_{cv}\rho\, d\forall=0 \quad \int_{cs}\rho\vec{V}\cdot\hat{n}\, dA \quad \int_{cs}\rho\vec{V}\cdot\hat{n}\, dA=\sum\dot{m}_{out}-\sum\dot{m}_{in} \quad \frac{\partial}{\partial t}\int_{cv}\rho\, \forall+\int_{cs}\rho\forall\cdot\hat{n}\, dA=0$ $\dot{m}=\rho Q=\rho AV \quad \dot{m}=\int_{A}\rho\vec{V}\cdot\hat{n}\, dA \quad V_{average}=\bar{V}=\frac{\int_A\rho\vec{V}\cdot\hat{n}\, dA}{\rho A}$ $V_{average}=\bar{V}=\frac{\int_A\rho\vec{V}\cdot\hat{n}\, dA}{\rho A}=V$ For uniformly distributed velocity (one-dimensional flow)	○	○	○	○	○	
5.1.3 Moving, Non-deforming Control Volume $\vec{V}=\vec{W}+\vec{V}_{cv} \quad \frac{DM_{sys}}{Dt}=\frac{\partial}{\partial t}\int_{cv}\rho\, d\forall+\int_{cs}\rho\vec{W}\cdot\hat{n}\, dA=0$	○	○	○	○	○	
5.1.4 Deforming Control Volume $\frac{DM_{sys}}{Dt}=\frac{\partial}{\partial t}\int_{cv}\rho\, d\forall+\int_{cs}\rho\vec{W}\cdot\hat{n}\, dA=0 \quad \frac{\partial}{\partial t}\int_{cv}\rho\, d\forall\neq 0 \quad \vec{V}=\vec{W}+\vec{V}_{cs}$	○	○	○	○	○	
5.2 Newton's Second Law – The Linear Momentum and Moment-of-Momentum Equation **5.2.1 Derivation of the Linear Momentum Equation** $\frac{\partial}{\partial}\int_{sys}\vec{V}\rho\, d\forall=\sum\vec{F}_{sys} \quad \sum\vec{F}_{sys}=\sum\vec{F}_{\text{content of the coincident control volume}}$ $\frac{D}{Dt}\int_{sys}\vec{V}\rho\, d\forall=\frac{\partial}{\partial t}\int_{cv}\vec{V}\rho\, d\forall+\int_{cs}\vec{V}\rho\vec{V}\cdot\hat{n}\, dA \quad \frac{\partial}{\partial t}\int_{cv}\vec{V}\rho\, d\forall+\int_{cs}\vec{V}\rho\vec{V}\cdot\hat{n}\, dA=\sum\vec{F}_{\text{content of the control volume}}$	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

Engineering Subject: Fluid						
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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 5 Finite Control Volume Analysis (Continued)						
5.2.2 Application of the Linear Momentum Equation $\frac{D}{Dt}\int_{sys}\vec{V}\rho\, d\forall = \frac{\partial}{\partial t}\int_{cv}\vec{V}\rho\, d\forall + \int_{cs}\vec{V}\rho\vec{W}\cdot\hat{n}\, dA \quad \frac{\partial}{\partial t}\int_{cv}\vec{V}\rho\, d\forall + \int_{cs}\vec{V}\rho\vec{W}\cdot\hat{n}\, dA = \sum\vec{F}_{\text{content of the control volum}}$ $\frac{\partial}{\partial t}\int_{cv}\left(\vec{W}+\vec{V}_{cv}\right)\rho\, d\forall + \int_{cs}\left(\vec{W}+\vec{V}_{cv}\right)\rho\vec{W}\cdot\hat{n}\, dA = \sum\vec{F}_{\text{contents of the control volume}}$ For constant control volume velocity $\frac{\partial}{\partial t}\int_{cv}\left(\vec{W}+\vec{V}_{cv}\right)\rho\, d\forall \quad \rightarrow$ For inertial, nondeforming control volume $\int_{cs}\left(\vec{W}+\vec{V}_{cv}\right)\rho\vec{W}\cdot\hat{n}\, dA = \int_{cs}\vec{W}\rho\vec{W}\cdot\hat{n}\, dA + \vec{V}_{cv}\int_{cs}\rho\vec{W}\cdot\hat{n}\, dA$ For steady flow (on an instantaneous or time - average basis $\int_{cs}\rho\vec{W}\cdot\hat{n}\, dA = 0 \quad \int_{cs}\vec{W}\rho\vec{W}\cdot\hat{n}\, dA = \sum\vec{F}_{\text{content of the control volume}}$	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

Engineering Subject: Fluid						
Likert Scale (Score of Importance) Note: 1 → Totally Unimportant; 2 → Not So Important; 3 → Might Be Important; 4 → Important; 5 → Very Important						
Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 5 Finite Control Volume Analysis (Continued)						
5.2.3 Derivation of the Moment-of-Momentum Equation $\frac{D}{Dt}(\vec{V}\rho\delta V\!\!\!\!-)=\delta\vec{F}_{\text{particle}}$ $\vec{r}\times\frac{D}{Dt}(\vec{V}\rho\ \delta V\!\!\!\!-)=\vec{r}\times\delta\vec{F}_{\text{particle}}$ $\frac{D}{Dt}[(\vec{r}\times\vec{V})\rho\delta V\!\!\!\!-]=\frac{D\vec{r}}{Dt}\times\vec{V}\rho\delta V\!\!\!\!-+\vec{r}\times\frac{D(\vec{V}\rho\delta V\!\!\!\!-)}{Dt}$ $\frac{D\vec{r}}{Dt}=\vec{V}$ $\vec{V}\times\vec{V}=0$ $\rightarrow$ $\frac{D}{Dt}[(\vec{r}\times\vec{V})\rho\delta V\!\!\!\!-]=\vec{r}\times\delta\vec{F}_{\text{particle}}$ $\int_{sys}\frac{D}{Dt}[(\vec{r}\times\vec{V})\rho\ dV\!\!\!\!-]=\sum(\vec{r}\times\vec{F})_{sys}$ $\sum\vec{r}\times\delta\vec{F}_{\text{particle}}=\sum(\vec{r}\times\vec{F})_{sys}$ $\frac{D}{Dt}\int_{sys}(\vec{r}\times\vec{V})\rho\ dV\!\!\!\!-=\int_{sys}\frac{D}{Dt}[(\vec{r}\times\vec{V})\rho\ dV\!\!\!\!-]$ $\frac{D}{Dt}\int_{sys}(\vec{r}\times\vec{V})\rho\ dV\!\!\!\!-=\sum(\vec{r}\times\vec{F})_{sys}$ $\sum(\vec{r}\times\vec{F})_{sys}=\sum(\vec{r}\times\vec{F})_{cv}$ $\frac{D}{Dt}\int_{sys}(\vec{r}\times\vec{V})\rho\ dV\!\!\!\!-=\frac{\partial}{\partial t}\int_{cv}(\vec{r}\times\vec{V})\rho\ dV\!\!\!\!-+\int_{cs}(\vec{r}\times\vec{V})\rho\vec{V}\ \hat{n}\ dA$ $\frac{\partial}{\partial t}\int_{cv}(\vec{r}\times\vec{V})\rho\ dV\!\!\!\!-+\int_{cs}(\vec{r}\times\vec{V})\rho\vec{V}\ \hat{n}\ dA=\sum(\vec{r}\times\vec{F})_{\text{contents of the control volume}}$	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

Engineering Subject: Fluid						
Likert Scale (Score of Importance) Note: 1 → Totally Unimportant; 2 → Not So Important; 3 → Might Be Important; 4 → Important; 5 → Very Important						
Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 5 Finite Control Volume Analysis (Continued)						
5.2.4 Application of the Moment-of-Momentum Equation $\frac{\partial}{\partial t}\int_{cv}(\vec{r}\times\vec{V})\rho\, d\forall = 0 \quad \int_{cs}(\vec{r}\times\vec{V})\rho\vec{V}\cdot\hat{n}\, dA \quad \vec{V}=\vec{W}+\vec{U} \quad \int_{cs}(\vec{r}\times\vec{V})\rho\vec{V}\cdot\hat{n}\, dA$ $\left[\int_{cs}(\vec{r}\times\vec{V})\rho\vec{V}\cdot\hat{n}\, dA\right]_{axial} = (-r_2V_{\theta 2})(+\dot{m}) \quad \sum\left[(\vec{r}\times\vec{F})_{\text{contents of the control volume}}\right]_{axial} = T_{\text{shaft}} \quad -r_2V_{\theta 2}\dot{m} = T_{shaft}$ $\dot{W}_{shaft} = T_{shaft}\omega = -r_2V_{\theta 2}\dot{m}\omega \quad \dot{W}_{shaft} = -U_2V_{\theta 2}\dot{m} \quad w_{shaft} = -U_2V_{\theta 2}$ $T_{shaft} = (-\dot{m}_{in})(\pm r_{in}V_{\theta in}) + \dot{m}_{out}(\pm r_{out}V_{\theta out}) \quad \dot{W}_{shaft} = T_{shaft}\omega$ $\dot{W}_{shaft} = (-\dot{m}_{in})(\pm r_{in}\omega V_{\theta in}) + \dot{m}_{out}(\pm r_{out}\omega V_{\theta out})$ $r\omega = U \quad \rightarrow \quad \dot{W}_{shaft} = (-\dot{m}_{in})(\pm U_{in}\omega V_{\theta in}) + \dot{m}_{out}(\pm U_{out}\omega V_{\theta out})$ $\dot{m} = \dot{m}_{in} = \dot{m}_{out} \quad w_{shaft} = -(\pm U_{in}V_{\theta in}) + (\pm U_{out}V_{\theta out})$	○	○	○	○	○	
5.3 First Law of Thermodynamics – The Energy Equation N/A **5.3.1 Derivation of the Energy Equation** $\frac{D}{Dt}\int_{sys} e\rho\, d\forall = \left(\sum\dot{Q}_{in} - \sum\dot{Q}_{out}\right)_{sys} + \left(\sum\dot{W}_{in} - \sum\dot{W}_{out}\right)_{sys}$ $\frac{D}{Dt}\int_{sys} e\rho\, d\forall = \left(\dot{Q}_{\substack{net\\in}} + \dot{W}_{\substack{net\\in}}\right)_{sys} \quad e = \check{u} + \frac{V^2}{2} + gz$ $\left(\dot{Q}_{\substack{net\\in}} + \dot{W}_{\substack{net\\in}}\right)_{sys} = \left(\dot{Q}_{\substack{net\\in}} + \dot{W}_{\substack{net\\in}}\right)_{\text{coincident control volume}} \quad \frac{D}{Dt}\int_{sys} e\rho\, d\forall = \frac{\partial}{\partial t}\int_{cv} e\rho\, d\forall + \int_{cs} e\rho\vec{V}\cdot\hat{n}\, dA$	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

Engineering Subject: Fluid						
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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 5 Finite Control Volume Analysis (Continued)						
5.3.1 Derivation of the Energy Equation (Continued) $\frac{\partial}{\partial t}\int_{cv} e\rho\, dV\!\!\!/ + \int_{cs} e\rho\vec{V}\cdot\hat{n}\, dA = \left(\dot{Q}_{\underset{in}{net}} + \dot{W}_{\underset{in}{net}}\right)_{cv}$ $\dot{Q}_{\underset{in}{net}} = 0 \rightarrow \sum\dot{Q}_{in} - \sum\dot{Q}_{ou} = 0$ $\dot{W}_{shaft} = T_{shaft}\omega$ $\dot{W}_{\underset{\text{net in}}{\text{shaft}}} = \sum\dot{W}_{\underset{\text{in}}{\text{shaft}}} - \sum\dot{W}_{\underset{\text{out}}{\text{shaft}}}$ $\sigma = -p$ $\delta\dot{W}_{\text{normal stress}} = \delta\vec{F}_{\text{normal stress}}\cdot\vec{V}$ $\delta\dot{W}_{\text{normal stress}} = \sigma\hat{n}\,\delta A\cdot\vec{V} = -p\hat{n}\,\delta A\cdot\vec{V} = -p\vec{V}\cdot\hat{n}\,\delta A$ $\dot{W}_{\text{normal stress}} = \int_{cs}\sigma\vec{V}\cdot\hat{n}\, dA = \int_{cs} -p\vec{V}\cdot\hat{n}\, dA$ $\delta\dot{W}_{\text{tangential stress}} = \delta\vec{F}_{\text{tangential stress}}\cdot\vec{V}$ $\frac{\partial}{\partial t}\int_{cs} e\rho\, dV\!\!\!/ + \int_{cs} e\rho\vec{V}\cdot\hat{n}\, dA = \dot{Q}_{\underset{\text{in}}{\text{net}}} + \dot{W}_{\underset{\text{net in}}{\text{shaft}}} - \int_{cs} p\vec{V}\cdot\hat{n}\, dA$ Energy Equation: $\frac{\partial}{\partial t}\int_{cs} e\rho\, dV\!\!\!/ + \int_{cs}\left(\check{u} + \frac{p}{\rho} + \frac{V^2}{2} + gz\right)\rho\vec{V}\cdot\hat{n}\, dA = \dot{Q}_{\underset{\text{in}}{\text{net}}} + \dot{W}_{\underset{\text{net in}}{\text{shaft}}}$	○	○	○	○	○	
5.3.2 Application of the Energy Equation $\int_{cs}\left(\check{u} + \frac{p}{\rho} + \frac{V^2}{2} + gz\right)\rho\vec{V}\cdot\hat{n}\, dA \neq 0 \leftarrow \vec{V}\cdot\hat{n} \neq 0$ $\int_{cs}\left(\check{u} + \frac{p}{\rho} + \frac{V^2}{2} + gz\right)\rho\vec{V}\cdot\hat{n}\, dA = \sum_{\underset{out}{flow}}\left(\check{u} + \frac{p}{\rho} + \frac{V^2}{2} + gz\right)\dot{m} - \sum_{\underset{in}{flow}}\left(\check{u} + \frac{p}{\rho} + \frac{V^2}{2} + gz\right)\dot{m}$	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

Engineering Subject: Fluid						
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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 5 Finite Control Volume Analysis (Continued)						
5.3.2 Application of the Energy Equation (Continued) $\int_{cs}\left(\check{u}+\frac{p}{\rho}+\frac{V^2}{2}+gz\right)\rho\vec{V}\cdot\hat{n}\,dA=\left(\check{u}+\frac{p}{\rho}+\frac{V^2}{2}+gz\right)_{out}\dot{m}_{out}-\left(\check{u}+\frac{p}{\rho}+\frac{V^2}{2}+gz\right)_{in}\dot{m}_{in}$ $\dot{m}\left[\check{u}_{out}-\check{u}_{in}+\left(\frac{p}{\rho}\right)_{out}-\left(\frac{p}{\rho}\right)_{in}+\frac{V_{out}^2-V_{in}^2}{2}+g(z_{out}-z_{in})\right]=\dot{Q}_{net\,in}+\dot{W}_{shaft\,net\,in}$ $\check{h}=\check{u}+\frac{p}{\rho}\ \rightarrow\ \dot{m}\left[\check{h}_{out}-\check{h}_{in}+\frac{V_{out}^2-V_{in}^2}{2}+g(z_{out}-z_{in})\right]=\dot{Q}_{net\,in}+\dot{W}_{shaft\,net\,in}$ Enthalpy for steady throughout, one - dimensional flow involving only one fluid stream $\dot{m}\left[\check{u}_{out}-\check{u}_{in}+\left(\frac{p}{\rho}\right)_{out}-\left(\frac{p}{\rho}\right)_{in}+\frac{V_{out}^2-V_{in}^2}{2}+g(z_{out}-z_{in})\right]=\dot{Q}_{net\,in}$ Enthalpy for compressive, one - dimensional, steady flow $\dot{m}\left[\check{h}_{out}-\check{h}_{in}+\frac{V_{out}^2-V_{in}^2}{2}+g(z_{out}-z_{in})\right]=\dot{Q}_{net\,in}$	○	○	○	○	○	
5.4 Second Law of Thermodynamics – Irreversible Flow $\check{u}_2-\check{u}_1-q_{net\,in}\geq 0$	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

Engineering Subject: Fluid						
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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 5 Finite Control Volume Analysis (Continued)						
5.4.1 Semi-infinitesimal Control Volume Statement of the Energy Equation $\underbrace{\dot{m}\left[d\check{u}+d\left(\frac{p}{\rho}\right)+d\left(\frac{V^2}{2}\right)+g(dz)\right]=\delta\dot{Q}_{\underset{in}{net}} \quad T\,ds=d\check{u}+pd\left(\frac{1}{\rho}\right)}$ $\dot{m}\left[T\,ds+pd\left(\frac{1}{\rho}\right)+d\left(\frac{p}{\rho}\right)+d\left(\frac{V^2}{2}\right)+g(dz)\right]=\delta\dot{Q}_{\underset{in}{net}} \quad \frac{dp}{\rho}+d\left(\frac{V^2}{2}\right)+g\ dz=-\left(T\,ds-\delta q_{\underset{in}{net}}\right)$	○	○	○	○	○	
5.4.2 Semi-infinitesimal Control Volume Statement of the Second Law of Thermodynamics $\frac{D}{Dt}\int_{sys}s\rho\,d\forall\geq\sum\left(\frac{\delta\dot{Q}_{\underset{in}{net}}}{T}\right)_{sys} \quad \sum\left(\frac{\delta\dot{Q}_{\underset{in}{net}}}{T}\right)_{sys}=\sum\left(\frac{\delta\dot{Q}_{\underset{in}{net}}}{T}\right)_{cv}$ $\frac{D}{Dt}\int_{sys}s\rho\,d\forall=\frac{\partial}{\partial t}\int_{cv}s\rho\,d\forall+\int_{cs}s\rho\vec{V}\cdot\hat{n}\,dA \quad \frac{\partial}{\partial t}\int_{cv}s\rho\,d\forall+\int_{cs}s\rho\vec{V}\cdot\hat{n}\,dA\geq\sum\left(\frac{\delta\dot{Q}_{\underset{in}{net}}}{T}\right)_{cv} \quad \frac{\partial}{\partial t}\int_{cv}s\rho\,d\forall=0$ $\dot{m}(s_{out}-S_{IN})\geq\sum\frac{\delta\dot{Q}_{\underset{in}{net}}}{T} \quad \dot{m}\,ds\geq\sum\frac{\delta\dot{Q}_{\underset{in}{net}}}{T} \quad T\,ds\geq\delta q_{\underset{in}{net}} \quad T\,ds-\delta q_{\underset{in}{net}}\geq 0$	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 5 Finite Control Volume Analysis (Continued)						
5.4.3 Combination of the Equations of the First and Second Laws of Thermodynamics $-\left[\frac{dp}{\rho}+d\left(\frac{V^2}{2}\right)+g\ dz\right]\geq 0$ $-\left[\frac{dp}{\rho}+d\left(\frac{V^2}{2}\right)+g\ dz\right]=\delta(\text{loss})=\left(T\ ds-\delta q_{\substack{net\\in}}\right)$ $\frac{dp}{\rho}+d\left(\frac{V^2}{2}\right)+g\ dz=0$ $-\left[\frac{dp}{\rho}+d\left(\frac{V^2}{2}\right)+g\ dz\right]=\delta(\text{loss})-\delta w_{\substack{shaft\\net\ in}}$ $d\check{u}+pd\left(\frac{1}{\rho}\right)-\delta q_{\substack{net\\in}}=\delta(\text{loss})$ $d\left(\frac{1}{\rho}\right)=0\ \rightarrow$ $d\check{u}-\delta q_{\substack{net\\in}}=\delta(\text{loss})$ $\check{u}_{out}-\check{u}_{in}-q_{\substack{net\\in}}=\text{loss}$ $d\left(\frac{1}{\rho}\right)\neq 0\ \rightarrow$ $\check{u}_{out}-\check{u}_{in}+\int_{in}^{out}pd\left(\frac{1}{\rho}\right)-q_{\substack{net\\in}}=\text{loss}$	○	○	○	○	○	
Chapter 6 Differential Analysis of Fluid Flow						
6.1 Fluid Mechanics Element Kinematics	○	○	○	○	○	
6.1.1 Velocity and Acceleration Fields Revisited	○	○	○	○	○	
6.1.2 Linear Motion and Deformation	○	○	○	○	○	
6.1.3 Angular Motion and Deformation	○	○	○	○	○	
6.2 Conservation of mass	○	○	○	○	○	
6.2.1 Differential Survey Form of Continuity Equation	○	○	○	○	○	
6.2.2 Cylindrical Polar Coordinates	○	○	○	○	○	
6.2.3 The Stream Function	○	○	○	○	○	
6.3 Conservation of Linear Momentum	○	○	○	○	○	
6.3.1 Description of Forces Acting on the Differential Element	○	○	○	○	○	
6.3.2 Equations of Motion	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

Engineering Subject: Fluid						
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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 6 Differential Analysis of Fluid Flow (Continued)						
6.4 Inviscid Flow	○	○	○	○	○	
6.4.1 Euler's Equations of Motion	○	○	○	○	○	
6.4.2 The Bernoulli Equation	○	○	○	○	○	
6.4.3 Irrotational Flow	○	○	○	○	○	
6.4.4 The Bernoulli Equation for Irrotational Flow	○	○	○	○	○	
6.4.5 The Velocity Potential	○	○	○	○	○	
6.5 Some Basic, Plane Potential Flows	○	○	○	○	○	
6.5.1 UniSurvey Form Flow	○	○	○	○	○	
6.5.2 Source and Sink	○	○	○	○	○	
6.5.3 Vortex	○	○	○	○	○	
6.5.4 Doublet	○	○	○	○	○	
6.6 Superposition of Basic, Plane Potential Flows	○	○	○	○	○	
6.6.1 Source in a UniSurvey Form Stream – Half-Body	○	○	○	○	○	
6.6.2 Rankine Ovals	○	○	○	○	○	
6.6.3 Flow around a Circular Cylinder	○	○	○	○	○	
6.7 Other Aspects of Potential Flow Analysis	○	○	○	○	○	
6.8 Viscous Flow	○	○	○	○	○	
6.8.1 Stress-DeSurvey Form ation Relationships	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 6 Differential Analysis of Fluid Flow (Continued)						
6.8.2 The Navier-Stokes Equations	○	○	○	○	○	
6.9 Some Simple Solutions for Viscous, Incompressible Fluids	○	○	○	○	○	
6.9.1 Steady, Laminar Flow between Fixed Parallel Plates	○	○	○	○	○	
6.9.2 Couette Flow	○	○	○	○	○	
6.9.3 Steady, Laminar Flow in Circular Tubes	○	○	○	○	○	
6.9.4 Steady, Axial, Laminar Flow in an Annulus	○	○	○	○	○	
6.10 Other Aspects of Differential Analysis	○	○	○	○	○	
6.10.1 Numerical Methods	○	○	○	○	○	
Chapter Summary and Study Guide	○	○	○	○	○	
Chapter 7 Similitude, Dimensional Analysis, and Modeling						
7.1 Dimensional Analysis	○	○	○	○	○	
7.2 Buckingham Pi Theorem	○	○	○	○	○	
7.3 Determination of Pi Terms	○	○	○	○	○	
7.4 Some Additional Comments about Dimensional Analysis	○	○	○	○	○	
7.4.1 Selection of Variables	○	○	○	○	○	
7.4.2 Determination of Reference Dimensions	○	○	○	○	○	
7.4.3 Uniqueness of Pi Terms	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 7 Similitude, Dimensional Analysis, and Modeling (Continued)						
7.5 Determination of Pi Terms by Inspection	○	○	○	○	○	
7.6 Common Dimensionless Groups in Fluid Mechanics	○	○	○	○	○	
7.7 Correlation of Experimental Data	○	○	○	○	○	
7.7.1 Problems with One Pi Term	○	○	○	○	○	
7.7.2 Problems with Two or More Pi Term	○	○	○	○	○	
7.8 Modeling and Similitude	○	○	○	○	○	
7.8.1 Theory of Models	○	○	○	○	○	
7.8.2 Model Space	○	○	○	○	○	
7.8.3 Practical Aspects of Using Models	○	○	○	○	○	
7.9 Some Typical Model Studies	○	○	○	○	○	
7.9.1 Flow through Closed Conduits	○	○	○	○	○	
7.9.2 Flow around Immersed Bodies	○	○	○	○	○	
7.9.3 Flow with a Free Surface	○	○	○	○	○	
7.10 Similitude Based on Governing Differential Equations	○	○	○	○	○	
7.11 Chapter Summary and Study Guide	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

Engineering Subject: Fluid						
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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 8 Viscous Flow in Pipes						
8.1 General Characteristics of Pipe Flow **8.1.1 Laminar of Turbulent Flow** $\mathrm{Re} = \frac{\rho V D}{\mu}$ **8.1.2 Entrance Region and Fully Developed Flow** $\frac{\ell_e}{D} = 0.06\,\mathrm{Re}\ (\text{for turbulent flow})$ $\frac{\ell_e}{D} = 4.4(\mathrm{Re})^{1/6}\ (\text{for turbulent flow})$ $10^4 < \mathrm{Re} < 10$	○	○	○	○	○	
8.1.3 Pressure and Shear Stress $\nabla p = p_1 - p_2$ $\frac{\partial p}{\partial x} = -\frac{\Delta p}{\ell} < 0$	○	○	○	○	○	
8.2 Fully Developed Laminar Flow **8.2.1 From F = ma Applied Directly to a Fluid Mechanics Element** $\vec{F} = m\vec{a}$ $\frac{\partial \vec{V}}{\partial t} = 0$ $\vec{V} \cdot \nabla \vec{V} = u \frac{\partial u}{\partial x} \hat{i} = 0$ $p_2 = p_1 - \Delta p$ $(p_1)\pi r^2 - (p_1 - \Delta p)\pi r^2 - (\tau) 2\pi r \ell = 0$ $\frac{\Delta p}{\ell} = \frac{2\tau}{r}$ $\tau = \frac{2\tau_w r}{D}$ $\Delta p = \frac{4\ell \tau_w}{D}$ $\tau = -\mu \frac{du}{dr}$ $\frac{du}{dr} = -\left(\frac{\Delta p}{2\mu\ell}\right) r$ $\int du = -\frac{\Delta p}{2\mu\ell} \int r\,dr$ $u = -\left(\frac{\Delta p}{4\mu\ell}\right) r^2 + C_1$ $u(r) = \left(\frac{\Delta p D^2}{16\mu\ell}\right)\left[1 - \left(\frac{2r}{D}\right)^2\right] = V_c\left[1 - \left(\frac{2r}{D}\right)^2\right]$ $u(r) = \frac{\tau_w D}{4\mu}\left[1 - \left(\frac{r}{R}\right)^2\right]$ $Q = \int u\,dA = \int_{r=0}^{r=R} u(r) 2\pi r\,dr = 2\pi\,V_c \int_0^R \left[1 - \left(\frac{r}{R}\right)^2\right] r\,dr$ $Q = \frac{\pi R^2 V_c}{2}$ $V = \frac{Q}{A} = \frac{Q}{\pi R^2}$	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

Engineering Subject: Fluid						
Likert Scale (Score of Importance) Note: 1 → Totally Unimportant; 2 → Not So Important; 3 → Might Be Important; 4 → Important; 5 → Very Important						
Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 8 Viscous Flow in Pipes (Continued)						
8.2.1 From F = ma Applied Directly to a Fluid Mechanics Element Continued) $\vec{F} = m\vec{a}$ $\frac{\partial \vec{V}}{\partial t} = 0$ $\vec{V} \cdot \nabla \vec{V} = u \frac{\partial u}{\partial x} \hat{i} = 0$ $p_2 = p_1 - \Delta p$ $(p_1)\pi r^2 - (p_1 - \Delta p)\pi r^2 - (\tau)2\pi r \ell = 0$ $\frac{\Delta p}{\ell} = \frac{2\tau}{r}$ $\tau = \frac{2\tau_w r}{D}$ $\Delta p = \frac{4\ell \tau_w}{D}$ $\tau = -\mu \frac{du}{dr}$ $\frac{du}{dr} = -\left(\frac{\Delta p}{2\mu\ell}\right) r$ $\int du = -\frac{\Delta p}{2\mu\ell} \int r\, dr$ $u = -\left(\frac{\Delta p}{4\mu\ell}\right) r^2 + C_1$ $u(r) = \left(\frac{\Delta p D^2}{16\mu\ell}\right)\left[1 - \left(\frac{2r}{D}\right)^2\right] = V_c\left[1 - \left(\frac{2r}{D}\right)^2\right]$ $u(r) = \frac{\tau_w D}{4\mu}\left[1 - \left(\frac{r}{R}\right)^2\right]$ $Q = \int u\, dA = \int_{r=0}^{r=R} u(r) 2\pi r\, dr = 2\pi V_c \int_0^R \left[1 - \left(\frac{r}{R}\right)^2\right] r\, dr$ $Q = \frac{\pi R^2 V_c}{2}$ $V = \frac{Q}{A} = \frac{Q}{\pi R^2}$ $V = \frac{\pi R^2 V_c}{2\pi R^2} = \frac{V_c}{2} = \frac{\Delta p D^2}{32\mu\ell}$ $Q = \frac{\pi D^4 \Delta p}{128\mu\ell}$ $\frac{\Delta p - \gamma\ell \sin\theta}{\ell} = \frac{2\tau}{r}$ $V = \frac{(\Delta p - \gamma\ell\sin\theta)D^2}{32\mu\ell}$ $Q = \frac{\pi(\Delta p - \gamma\ell\sin\theta)D^4}{128\mu\ell}$	○	○	○	○	○	
8.3 Fully Developed Turbulent Flow N/A	○	○	○	○	○	
8.3.1 Transition from Laminar to Turbulent Flow N/A	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

Engineering Subject: Fluid

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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 8 Viscous Flow in Pipes (Continued)						
8.3.2 Turbulent Shear Stress $\bar{u} = \frac{1}{T}\int_{t_0}^{t_0+T} u(x,y,z,t)dt \quad u = \bar{u} + u' \quad u' = u - \bar{u}$ $\bar{u}' = \frac{1}{T}\int_{t_0}^{t_0+T}(u-\bar{u})dt = \frac{1}{T}\left(\int_{t_0}^{t_0+T} u\,dt - \bar{u}\int_{t_0}^{t_0+T} dt\right) = \frac{1}{T}(T\bar{u} - T\bar{u}) = 0 \quad \overline{(u')^2} = \frac{1}{T}\int_{t_0}^{t_0+T}(u')^2 dt > 0$ $\text{Turbulence intensity} = \frac{\sqrt{\overline{(u')^2}}}{\bar{u}} = \frac{\left[\frac{1}{T}\int_{t_0}^{t_0+T}(u')^2 dt\right]^{1/2}}{\bar{u}} \quad \tau = \mu\frac{du}{dy} \quad \tau \neq \mu\frac{d\bar{u}}{dy} \quad \bar{u} = \bar{u}(y)$ $\tau = \mu\frac{d\bar{u}}{dy} - \rho\overline{u'v'} = \tau_{lam} + \tau_{turb} \quad \tau_{turb} = \eta\frac{d\bar{u}}{dy} \quad \eta = \rho\ell_m^2\left\lvert\frac{d\bar{u}}{dy}\right\rvert \quad \tau_{turb} = \rho\ell_m^2\left(\frac{d\bar{u}}{dy}\right)^2$	○	○	○	○	○	
8.3.3 Turbulent Velocity Profile $\frac{\bar{u}}{u^*} = \frac{yu^*}{v} \quad y = R - r \quad u^* = \left(\frac{\tau_w}{\rho}\right)^{1/2} \quad \frac{\bar{u}}{u^*} = 2.5\ln\left(\frac{yu^*}{v}\right) + 5.0$ $\frac{(V_c - \bar{u})}{u^*} = 2.5\ln\left(\frac{R}{y}\right) \quad \frac{\bar{u}}{V_c} = \left(1 - \frac{r}{R}\right)^{1/n}$	○	○	○	○	○	
8.3.4 Turbulent Modeling N/A	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 9 Flow over Immersed Bodies						
9.2 Boundary Layer Characteristics N/A **9.2.1 Boundary Layer structure and Thickness on a Flat Plate** $\delta^* bU = \int_0^\infty (U-u)b\ dy$ $\delta^* = \int_0^\infty \left(1-\frac{u}{U}\right)dy$ $\int \rho u(U-u)\ dA = \rho b\int_0^\infty u(U-u)dy$ $\rho bU^2\Theta = \int_0^\infty u(U-u)dy$ $\Theta = \int_0^\infty \frac{u}{U}\left(1-\frac{u}{U}\right)dy$	○	○	○	○	○	
9.2.2 Prandtl/Blasius Boundary Layer Solution $u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y} = -\frac{1}{\rho}\frac{\partial p}{\partial x}+\nu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)$ $u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y} = -\frac{1}{\rho}\frac{\partial p}{\partial x}+\nu\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right)$ $\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0$ $\left.\begin{matrix} v \ll u \\ \frac{\partial}{\partial x} \ll \frac{\partial}{\partial y}\end{matrix}\right\} \rightarrow$ $\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0$ $u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\nu\frac{\partial^2 u}{\partial y^2}$ $u=v=0\ \ on\ \ y=0$ $u\rightarrow U\ \ as\ \ y\rightarrow\infty$ $\frac{u}{U}=g\left(\frac{y}{\delta}\right)$ $\delta \sim \left(\frac{\nu x}{U}\right)^{1/2}$ $\eta = \left(\frac{U}{\nu x}\right)^2$ $\Psi = (VxU)^{1/2} f(\eta)$ $f = f(\eta)$ $u=\frac{\partial \Psi}{\partial y}$ $v=-\frac{\partial \Psi}{\partial x}$ $u=Uf'(\eta)$ $v=\left(\frac{\nu U}{4x}\right)^{1/2}(\eta f'-f)$ $2f'''-ff''=0$ $f=f'=0\ \ at\ \ \eta=0$ $f=f'=0\ \ at\ \ \eta=0\ \ and\ \ f'\rightarrow 1\ \ as\ \ \eta\rightarrow\infty$ $\delta = 5\sqrt{\frac{\nu x}{U}}$ $\frac{\delta}{x}=\frac{5}{\sqrt{\mathrm{Re}_x}}$ $\frac{\delta^*}{x}=\frac{1.721}{\sqrt{\mathrm{Re}_x}}$ $\frac{\Theta}{x}=\frac{0.664}{\sqrt{\mathrm{Re}_x}}$ $\tau_w = 0.332U^{3/2}\sqrt{\frac{\rho\mu}{x}}$	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

Engineering Subject: Fluid						
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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 9 Flow over Immersed Bodies (Continued)						
9.2.3 Momentum Integral boundary Layer Equation for a Flat Plate $\sum F_x = \rho\int_{(1)} u\vec{V}\cdot\hat{n}\ dA + \rho\int_{(2)} u\vec{V}\cdot\hat{n}\ dA \quad \sum F_x = -\vec{D} = -\int_{plate}\tau_w\ dA = -\int_{plate}\tau_w\ dx$ $-\vec{D} = \rho\int_{(1)} U(-U)\ dA + \rho\int_{(2)} u^2 dA \quad \vec{D} = \rho U^2 bh - \rho b\int_0^\delta u^2\ dy \quad Uh = \int_0^\delta u\ dy \quad \rho U^2 bh = \rho b\int_0^\delta Uu\ dy$ $\vec{D} = \rho b\int_0^\delta u(U-u)dy \quad \vec{D} = \rho bU^2\Theta \quad \frac{d\vec{D}}{dx} = \rho bU^2\frac{d\Theta}{dx} \quad \frac{d\vec{D}}{dx} = b\tau_w \quad \tau_w = \rho U^2\frac{d\Theta}{dx}$ $\vec{D} = \rho b\int_0^\delta u(U-u)dy = \rho bU^2\delta\int_0^1 g(Y)[1-g(Y)]dY \quad \vec{D} = \rho bU^2\delta C_1 \quad C_1 = \int_0^1 g(Y)[1-g(Y)]dY$ $\tau_w = \mu\left.\frac{\partial u}{\partial y}\right\|_{y=0} = \frac{\mu U}{\delta}\left.\frac{dg}{dY}\right\|_{Y=0} = \frac{\mu U}{\delta}C_2 \quad C_2 = \left.\frac{dg}{dY}\right\|_{Y=0} \quad \delta\ d\delta = \frac{\mu C_2}{\rho UC_1}dx \quad \delta = \sqrt{\frac{2\nu C_2 x}{UC_1}} \quad \frac{\delta}{x} = \frac{\sqrt{2C_2/C_1}}{\sqrt{\mathrm{Re}_x}}$ $\tau_w = \sqrt{\frac{C_1C_2}{2}}U^{3/2}\sqrt{\frac{\rho\mu}{x}} \quad c_f = \frac{\tau_w}{\frac{1}{2}\rho U^2} \quad c_f = \sqrt{2C_1C_2}\sqrt{\frac{\mu}{\rho Ux}} = \frac{\sqrt{2C_1C_2}}{\sqrt{\mathrm{Re}_x}} \quad c_f = \frac{0.664}{\sqrt{\mathrm{Re}_x}}$	○	○	○	○	○	
9.2.3 Momentum Integral boundary Layer Equation for a Flat Plate (Continued) $C_{Df} = \frac{\vec{D}_f}{\frac{1}{2}\rho U^2 b\ell} = \frac{b\int_0^\ell \tau_w dx}{\frac{1}{2}\rho U^2 b\ell} \quad C_{Df} = \frac{1}{\ell}\int_0^\ell c_f dx \quad C_{Df} = \frac{\sqrt{8C_1C_2}}{\sqrt{\mathrm{Re}_\ell}} \quad C_{Df} = \frac{1.328}{\sqrt{\mathrm{Re}_\ell}}$	○	○	○	○	○	
9.2.4 Transition from Laminar to Turbulent Flow N/A	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 9 Flow over Immersed Bodies (Continued)						
9.2.5 Turbulent Boundary Layer Flow N/A	○	○	○	○	○	
9.2.6 Effects of Pressure Gradient N/A						
9.2.7 Momentum Integral Boundary Layer Equation with Nonzero Pressure Gradient $\frac{dp}{dx} = -\rho U_{fs} \frac{dU_{fs}}{dx} \quad \tau_w = \rho \frac{d}{dx}\left(U_{fs}^2 \Theta\right) + \rho \delta^* U_{fs} \frac{dU_{fs}}{dx}$ $U_{fs} = U = \text{constant}$						
Chapter 10 Open Channel Flow						
10.2 Surface Waves **10.2.1 Wave Speed** $\left.\begin{array}{l} -cyb = (-c+\delta V)(y+\delta y)b \\ c = \frac{(y+\delta y)\delta V}{\delta y} \\ \delta y << y \quad \rightarrow \quad c = y\frac{\delta V}{\delta y} \end{array}\right\} \rightarrow \frac{1}{2}\gamma y^2 b - \frac{1}{2}\gamma (y+\delta y)^2 b = \rho bcy[(c-\delta V)-c]$ $F_1 = \frac{\gamma y_{c1} A_1 = \gamma (y+\delta y)^2 b}{2} \quad F_2 = \frac{\gamma y_{c2} A_2 = \gamma (y+\delta y)^2 b}{2} \quad \frac{\delta V}{\delta y} = \frac{g}{c} \quad c = \sqrt{gy}$ $\frac{V^2}{2g} + y = \text{constant} \quad \frac{V\ \delta V}{g} + \delta y = 0 \quad y\ \delta V + V\ \delta y = 0 \quad \frac{\delta y}{y} << 1 \ \rightarrow \ c \approx \sqrt{gy}\left(1+\frac{\delta y}{y}\right)^{1/2}$	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 10 Open Channel Flow (Continued)						
10.3.2 Channel Depth Variations $H_1 = H_2 + h_L \quad \frac{dH}{dx} = S_f \quad \frac{dz}{dx} = S_0 \quad \frac{dH}{dx} = \frac{d}{dx}\left(\frac{V^2}{2g} + y + z\right) = \frac{V}{g}\frac{dV}{dx} + \frac{dy}{dx} + \frac{dz}{dx}$ $\frac{dh_L}{dx} = \frac{V}{g}\frac{dV}{dx} + \frac{dy}{dx} + S_0 \quad \frac{V}{g}\frac{dV}{dx} + \frac{dy}{dx} = S_f - S_0 \quad \frac{dV}{dx} = -\frac{q}{y^2}\frac{dy}{dx} = -\frac{V}{y}\frac{dy}{dx} \quad \frac{V}{g}\frac{dV}{dx} = \frac{V^2}{gy}\frac{dy}{dx} = -Fr^2\frac{dy}{dx}$ $Fr = V/(gy)^{1/2} \quad \frac{dy}{dx} = \frac{(S_f - S_0)}{(1 - Fr^2)}$	○	○	○	○	○	
Chapter 11 Compressible Flow						
11.1 Ideal Gas Relationships $p = \rho RT \quad R = \frac{\lambda}{M_{gas}} \quad c_v = \left(\frac{\partial \check{u}}{\partial T}\right)_v = \frac{d\check{u}}{dT} \quad d\check{u} = c_v dT$ $\check{u}_2 - \check{u}_1 = \int_{T_1}^{T_2} c_v \, dT \quad \forall = \frac{1}{\rho} \quad \check{u}_2 - \check{u}_1 = c_v(T_2 - T_1)$ $\check{h} = \check{u} + \frac{p}{\rho} \quad \check{u} = \check{u}(T) \quad \frac{p}{\rho} = RT \quad \check{h} = \check{h}(T) \quad c_p = \left(\frac{\partial \check{h}}{\partial T}\right)_p = \frac{d\check{h}}{dT}$ $d\check{h} = c_p dT \quad \check{h}_2 - \check{h}_1 = \int_{T_1}^{T_2} c_p \, dT \quad \check{h}_2 - \check{h}_1 = c_p(T_2 - T_1) \quad \check{h} = \check{u} + RT$	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

Engineering Subject: Fluid						
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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 11 Compressible Flow (Continued)						
11.1 Ideal Gas Relationships $d\check{h} = d\check{u} + R\,dT$ $\frac{d\check{h}}{dT} = \frac{d\check{u}}{dT} + R$ $c_p - c_v = R$ $k = \frac{c_p}{c_v}$ $c_p = \frac{Rk}{k-1}$ $c_v = \frac{R}{k-1}$ $T\,ds = d\check{u} + pd\left(\frac{1}{\rho}\right)$ $d\check{h} = d\check{u} + pd\left(\frac{1}{\rho}\right) + \left(\frac{1}{\rho}\right)dp$ $T\,ds = d\check{h} - \left(\frac{1}{\rho}\right)dp$ $ds = c_v\frac{dT}{T} + \frac{R}{1/\rho}d\left(\frac{1}{\rho}\right)$ $ds = c_p\frac{dT}{T} - R\frac{dp}{p}$ $s_2 - s_1 = c_v\ln\frac{T_2}{T_1} + R\ln\frac{\rho_1}{\rho_2}$ $s_2 - s_1 = c_p\ln\frac{T_2}{T_1} + R\ln\frac{p_2}{p_1}$	○	○	○	○	○	
11.2 Mach Number and Speed of Sound $Ma = \frac{V}{c}$ $\rho Ac = (\rho + \delta\rho)(c - \delta V)$ $\rho c = \rho c - \rho\delta V + c\delta\rho - (\delta\rho)(\delta V)$ $\rho\ \delta V = c\ \delta\rho$ $-c\rho cA + (c - \delta V)(\rho + \delta\rho)(c - \delta V)A = pA - (p + \delta p)A$ $-c\rho cA + (c - \delta V)\rho Ac = -\delta pA$ $\rho\delta V = \frac{\delta p}{c}$ $c^2 = \frac{\delta p}{\delta\rho}$ $c = \sqrt{\frac{\delta p}{\delta\rho}}$ $\frac{\delta p}{\rho} + \delta\left(\frac{V^2}{2}\right) + g\ \delta z = \delta(\text{loss})$ $\frac{\delta p}{\rho} + \frac{(c - \delta V)^2}{2} - \frac{c^2}{2} = 0$ $\rho\ \delta V = \frac{\delta p}{c}$	○	○	○	○	○	
11.2 Mach Number and Speed of Sound (Continued) $\left.\begin{array}{l} c = \sqrt{\frac{\delta p}{\delta\rho}} \\ \delta p \to \partial p \to 0 \end{array}\right\} \to c = \sqrt{\left(\frac{\partial p}{\partial\rho}\right)_s}$ $p = (\text{constant})(\rho^k)$ $\left(\frac{\partial p}{\partial\rho}\right)_s = (\text{constant})k\rho^{k-1} = \frac{p}{\rho^k}k\rho^{k-1} = \frac{p}{\rho}k = RTk$ $c = \sqrt{RTk}$ $E_v = \frac{dp}{d\rho/\rho} = \rho\left(\frac{\partial p}{\partial\rho}\right)_s$ $c = \sqrt{\frac{E_v}{\rho}}$	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 11 Compressible Flow (Continued)						
11.4 Isentropic Flow of an Ideal Gas	○	○	○	○	○	
11.4.1 Effect of Variations in Flow Cross-Sectional Areas $\dot{m}=\rho AV=\text{constant}\quad dp+\frac{1}{2}\rho\, d(V^2)+\gamma\, dz=0\quad \frac{dp}{\rho V^2}=-\frac{dV}{V}\quad \ln\rho+\ln A+\ln V=\text{constant}\ \rightarrow$ $\frac{d\rho}{\rho}+\frac{dA}{A}+\frac{dV}{V}=0\ \rightarrow \left.\begin{matrix}-\frac{dV}{V}=\frac{d\rho}{\rho}+\frac{dA}{A}\\ \frac{dp}{\rho V^2}=-\frac{dV}{V}\end{matrix}\right\}\rightarrow \frac{dp}{\rho V^2}\left(1-\frac{V^2}{dp/d\rho}\right)=\frac{dA}{A}$	○	○	○	○	○	
11.4.1 Effect of Variations in Flow Cross-Sectional Areas (Continued) $\left.\begin{matrix}c=\sqrt{\left(\frac{\partial p}{\partial\rho}\right)_s}\\ Ma=\frac{V}{c}\\ \frac{dp}{\rho V^2}\left(1-\frac{V^2}{dp/d\rho}\right)=\frac{dA}{A}\end{matrix}\right\}\rightarrow \frac{dp}{\rho V^2}(1-Ma^2)=\frac{dA}{A}\quad \left.\begin{matrix}\frac{dp}{\rho V^2}=-\frac{dV}{V}\\ \frac{dp}{\rho V^2}(1-Ma^2)=\frac{dA}{A}\end{matrix}\right\}\rightarrow$ $\frac{dV}{V}=-\frac{dA}{A}\frac{1}{(1-Ma^2)}\quad \frac{d\rho}{\rho}=\frac{dA}{A}\frac{Ma^2}{(1-Ma^2)}\quad \frac{dA}{dV}=-\frac{A}{V}(1-Ma^2)$	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 11 Compressible Flow (Continued)						
11.5 Nonisentropic Flow of an Ideal Gas **11.5.1 Adiabatic Constant Area Duct Flow with Friction (Fanno Flow)** $\dot{m}\left[\check{h}_2-\check{h}_1+\frac{V_2^2-V_1^2}{2}+g(z_2-z_1)\right]=\dot{Q}_{\substack{net\\in}}+\dot{W}_{\substack{shaft\\net\ in}}$ $\left.\begin{matrix}\check{h}+\frac{V^2}{2}=\check{h}_0=\text{constant}\\ \check{h}-\check{h}_0=c_p(T-T_0)\end{matrix}\right\\} \rightarrow \left\\{\begin{matrix}T+\frac{V^2}{2c_p}=T_0=\text{constant}\\ T+\frac{(\rho V)^2}{2c_p\rho^2}=T_0=\text{constant}\end{matrix}\right.$ $T+\frac{(\rho V)^2T^2}{2c_p(p^2/R^2)}=T_0=\text{constant} \leftarrow \quad p=\rho RT \quad \uparrow \quad s-s_1=c_p\ln\frac{T}{T_1}-R\ln\frac{p}{p_1}$ $T\ ds=d\check{h}-\frac{dp}{\rho}\quad \left.\begin{matrix}d\check{h}=c_pdT\\ p=\rho RT\end{matrix}\right\\} \rightarrow \frac{dp}{p}=\frac{d\rho}{\rho}+\frac{dT}{T}$ $T\ ds=c_pdT-RT\left(\frac{d\rho}{\rho}+\frac{dT}{T}\right)\quad \rho V=\text{constant}\quad \frac{d\rho}{\rho}=-\frac{dV}{V} \rightarrow T\ ds=c_pdT-RT\left(-\frac{dV}{V}+\frac{dT}{T}\right)$ $\frac{ds}{dT}=\frac{c_p}{T}-R\left(-\frac{1}{V}\frac{dV}{dT}+\frac{1}{T}\right)\quad \frac{dV}{dT}=-\frac{c_p}{V}\quad \frac{ds}{dT}=\frac{c_p}{T}-R\left(\frac{c_p}{V^2}+\frac{1}{T}\right)\quad V_a=\sqrt{RT_ak}$	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

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Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 11 Compressible Flow (Continued)						
11.5.1 Adiabatic Constant Area Duct Flow with Friction (Fanno Flow) $p_1A_1 - p_2A_2 - R_x = \dot{m}(V_2 - V_1)$ $p_1 - p_2 - \frac{R_x}{A} = \rho V(V_2 - V_1)$ $-dp - \frac{\tau_w \pi D\ d_x}{A} = \rho V\ dV$ $f = \frac{8\tau_w}{\rho V^2}$ $\leftarrow$ $A = \frac{\pi D^2}{4}$ $\rightarrow$ $-dp - f\rho\frac{V^2}{2}\frac{dx}{D} = \rho V\ dV$ $dp + \frac{f}{p}\frac{\rho V^2}{2}\frac{dx}{D} + \frac{\rho}{p}\frac{d(V^2)}{2} = 0$ $\frac{dp}{p} + \frac{fk}{2}Ma^2\frac{dx}{D} + k\frac{Ma^2}{2}\frac{d(V^2)}{V^2} = 0$ $V^2 = Ma^2RTk$ $\frac{d(V^2)}{V^2} = \frac{d(Ma^2)}{Ma^2} + \frac{dT}{T}$ $\frac{dT}{T} + \frac{d(V^2)}{2c_pT} = 0$ $\frac{dT}{T} + \frac{k-1}{2}Ma^2\frac{d(V^2)}{V^2} = 0$ $\frac{d(V^2)}{V^2} = \frac{d(Ma^2)/Ma^2}{1 + [(k-1)/2]Ma^2}$ $\frac{dp}{p} = \frac{1}{2}\frac{d(V^2)}{V^2} - \frac{d(Ma^2)}{Ma^2}$ $\frac{1}{2}(1 + kMa^2)\frac{d(V^2)}{V^2} - \frac{d(Ma^2)}{Ma^2} + \frac{f}{k}Ma^2\frac{dx}{D} = 0$	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

Engineering Subject: Fluid						
Likert Scale (Score of Importance) Note: 1 → Totally Unimportant; 2 → Not So Important; 3 → Might Be Important; 4 → Important; 5 → Very Important						
Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 11 Compressible Flow (Continued)						
11.5.1 Adiabatic Constant Area Duct Flow with Friction (Fanno Flow) (Continued) $\frac{(1-Ma^2)d(Ma^2)}{\{1+[(k-1)/2]Ma^2\}kMa^4} = f\frac{dx}{D}$ $\int_{Ma}^{Ma^*=1}\frac{(1-Ma^2)d(Ma^2)}{\{1+[(k-1)/2]Ma^2\}kMa^4} = \int_{\ell}^{\ell^*} f\frac{dx}{D}$ $\frac{1}{k}\frac{(1-Ma^2)}{Ma^2}+\frac{k+1}{2k}\ln\left\{\frac{[(k+1)/2]Ma^2}{1+[(k-1)/2]Ma^2}\right\} = \frac{f(\ell^*-\ell)}{D}$ $\frac{f(\ell^*-\ell_2)}{D}-\frac{f(\ell^*-\ell_1)}{D} = \frac{f}{D}(\ell_1-\ell_2)$ $\frac{dT}{T} = -\frac{(k-1)}{2\{1+[(k-1)/2]Ma^2\}}d(Ma^2)$ $\frac{T}{T^*} = \frac{(k+1)/2}{1+[(k-1)/2]Ma^2}$ $\frac{V}{V^*} = \frac{Ma\sqrt{RTk}}{\sqrt{RT^*k}} = Ma\sqrt{\frac{T}{T^*}}$ $\frac{V}{V^*} = \left\{\frac{[(k+1)/2]Ma^2}{1+[(k-1)/2]Ma^2}\right\}^{1/2}$ $\frac{\rho}{\rho^*} = \frac{V^*}{V}$ $\frac{\rho}{\rho^*} = \left\{\frac{1+[(k-1)/2]Ma^2}{[(k+1)/2]Ma^2}\right\}^{1/2}$ $\frac{p}{p^*} = \frac{\rho}{\rho^*}\frac{T}{T^*}$ $\frac{p}{p^*} = \frac{1}{Ma}\left\{\frac{(k+1)/2}{1+[(k-1)/2]Ma^2}\right\}^{1/2}$ $\frac{p_0}{p^*_0} = \left(\frac{p_0}{p}\right)\left(\frac{p}{p^*}\right)\left(\frac{p^*}{p^*_0}\right)$ $\frac{p_0}{p^*_0} = \frac{1}{Ma}\left[\left(\frac{2}{k+1}\right)\left(1+\frac{k-1}{2}Ma^2\right)\right]^{(k+1)/2(k-1)}$	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

Engineering Subject: Fluid						
Likert Scale (Score of Importance) Note: 1 → Totally Unimportant; 2 → Not So Important; 3 → Might Be Important; 4 → Important; 5 → Very Important						
Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 11 Compressible Flow (Continued)						
11.5.2 Frictionless Constant Area Duct Flow with Heat Transfer (Rayleigh Flow) $p_1 A_1 + \dot{m} V_1 = p_2 A_2 + \dot{m} V_2 + R_x \quad p + \frac{(\rho V)^2}{\rho} = \text{constant} \quad p + \frac{(\rho V)^2 RT}{\rho} = \text{constant} \quad \rho V = \text{constant}$ $dp = -\rho V\ dV \quad \frac{dp}{\rho} = -V\ dV \quad T\ ds = d\check{h} + V\ dV \quad T\ ds = c_p\ dT + V\ dV \quad \frac{ds}{dT} = \frac{c_p}{T} + \frac{V}{T}\frac{dV}{dT}$ $\frac{ds}{dT} = \frac{c_p}{T} + \frac{V}{T}\frac{1}{[(T/V) - (V/R)]} \quad V_a = \sqrt{RT_a k} \quad Ma_a = 1$ $\frac{dT}{ds} = \frac{1}{ds/dT} = \frac{1}{(c_p/T) + (V/T)[(T/V) - (V/R)]^{-1}} \quad \frac{dT}{ds} = 0 \quad \rightarrow \quad Ma_b = \sqrt{\frac{1}{k}}$ $d\check{h} + V\ dV = \delta q \quad \frac{dV}{V} = \frac{\delta q}{c_p T}\left[\frac{V}{T}\frac{dT}{dV} + \frac{V^2(k-1)}{kRT}\right]^{-1} \quad \frac{dV}{V} = \frac{\delta q}{c_p T}\frac{1}{(1 - Ma^2)} \quad p + \rho V^2 = p_a + \rho_a V_a^2$ $\frac{p}{p_a} + \frac{\rho V^2}{p_a} = 1 + \frac{\rho_a}{p_a} V_a^2 \quad \frac{p}{p_a} = \frac{1+k}{1+kMa^2} \quad \frac{T}{T_a} = \frac{p}{p_a}\frac{\rho_a}{\rho} \quad \frac{\rho_a}{\rho} = \frac{V}{V_a}$	○	○	○	○	○	

Fluid Mechanics Survey Form B (Continued)

Engineering Subject: Fluid						
Likert Scale (Score of Importance) Note: 1 → Totally Unimportant; 2 → Not So Important; 3 → Might Be Important; 4 → Important; 5 → Very Important						
Engineering Analytic Topics & Typical Formulas	**Likert Scale (Score of Importance from Least to Most)**					**Comment**
	1	**2**	**3**	**4**	**5**	
Chapter 11 Compressible Flow (Continued)						
11.5.2 Frictionless Constant Area Duct Flow with Heat Transfer (Rayleigh Flow) (Continued) $\frac{\rho_a}{\rho} = Ma\sqrt{\frac{T}{T_a}}$ $\frac{T}{T_a} = \left(\frac{p}{p_a} Ma\right)^2$ $\frac{T}{T_a} = \left[\frac{(1+k)Ma}{1+kMa^2}\right]^2$ $\frac{\rho_a}{\rho} = \frac{V}{V_a} = Ma\left[\frac{(1+k)Ma}{1+kMa^2}\right]$ $\frac{T}{T_{0,a}} = \left(\frac{T_0}{T}\right)\left(\frac{T}{T_a}\right)\left(\frac{T_a}{T_{0,a}}\right)$ $\frac{T}{T_{0,a}} = \frac{2(k+1)Ma^2\left(1+\frac{k-1}{2}Ma^2\right)}{(1+kMa^2)^2}$ $\frac{p_0}{p_{0,a}} = \left(\frac{p_0}{p}\right)\left(\frac{p}{p_a}\right)\left(\frac{p_a}{p_{0,a}}\right)$ $\frac{p_0}{p_{0,a}} = \frac{(1+k)}{(1+kMa^2)}\left[\left(\frac{2}{k+1}\right)\left(1+\frac{k-1}{2}\right)Ma^2\right]^{k/(k-1)}$	○	○	○	○	○	
THE END						

Part Three
Findings from the Research Project

List 1A. Pre-Calculus Based Fluid Mechanics Topics That Possibly Could Be Taught at 9th Grade

Chapter/Section	Page Numbers	Number of Pages
Chapter 1 – Introduction (pp. 1-30 → 30 pages sub-total. 10 sections out of 11)		
1.1 Some Characteristics of Fluid	1-13	13
1.2 Dimensions, Dimensional Homogeneity, and Units		
1.3 Analysis of Fluid Mechanics Behavior		
1.4 Measures of Fluid Mechanics Mass and Weight		
1.4.1 Density		
1.4 2 Specific Weight		
1.4.3 Specific Gravity		
1.5 Ideal Gas Law		
1.7 Compressibility of Fluids	20-30	11
1.7.1 Bulk Modulus		
1.7.2 Compression and Expansion of Gases		
1.7.3 Speed of Sound		
1.8 Vapor Pressure		
1.9 Surface Tension		
1.10 A Brief Look Back in History		
1.11 Chapter Summary and Study Guide		
Chapter 2 Fluid Statics (pp. 38-79 → 42 pages sub-total. 9 sections out of 13)		
2.3 Pressure Variation in a Fluid at Rest (Concept only)*		
2.3.1 Incompressible Fluid	42-56	15
2.3.2 Compressible Fluid		
2.4 Standard Atmosphere		
2.5 Measurement of Pressure		
2.6 Monometry		
2.6.1 Piezometer Tube		
2.6.2 U-Tube Manometer		
2.6.3 Inclined-Tube Manometer		
2.7 Mechanical and Electronic Pressure Measuring Devices		
2.9 Pressure Prism	63-72	10
2.10 Hydrostatic Force on a Curves Surface		
2.11 Buoyancy, Flotation, and Stability		
2.11.1 Archimedes' Principle		
2.11.2 Stability		
2.13 Chapter Summary and Study Guide	78-79	2

* Basic principles covered under this section heading could be explored; but the formulas used are calculus-based.

List 1A. (Continued)

Chapter/Section	Page Numbers	Number of Pages
Chapter 3 Elementary Fluid Dynamics – The Bernoulli Equation (pp. 95-135 → 41 pages sub-total. 8 sections out of 9)		
3.1 Newton's Second Law	95-101	7
3.2 F = ma along a Streamline		
3.4 Physical Interpretation	104-135	32
3.5 Static, Stagnation, Dynamic, and Total Pressure		
3.6 Examples of Use of the Bernoulli Equation		
3.6.1 Free Jets		
3.6.2 Confined Flows		
3.6.3 Flowrate Measurement		
3.7 The Energy Line and the Hydraulic Grade Line		
3.8 Restrictions on Use of the Bernoulli Equation		
3.8.1 Compressibility Effects		
3.8.3 Rotational Effects		
3.8.4 Other Restrictions		
3.9 Chapter Summary and Study Guide		
Chapter 4 Fluid Kinematics (pp. 150-184 → 35 pages sub-total. 3 sections out of 5)		
4.3 Control Volume and System Representations	168-169	2
4.4 The Reynolds Transport Theorem	170-171	2
4.4.7 Selection of a Control Volume	182-182	3
4.5 Chapter Summary and study Guide		
Chapter 5 Finite Control Volume Analysis (pp. 192-252 → 61 pages sub-total 2 sections out of 5)		
5.1 Conservation of Mass – The Continuity Equation (Concept only)*		
5.1.2 Fixed, Non-deforming Control Volume	195-200	6
5.3.3 Comparison of the Energy Equation with the Bernoulli Equation	236-246	11
5.3.4 Application of the Energy Equation to Non-uniform Flow		
5.3.5 Combination of the Energy Equation and the Moment-of-momentum Equation		
5.4.4 Application of the Loss Form of the Energy Equation	249-252	4
5.5 Chapter Summary and Study Guide		
Chapter 6 Differential Analysis of Fluid Flow (pp. 272-334 → 63 pages sub-total. 0 sections out of 11)		
Chapter 7 Similitude, Dimensional Analysis, and Modeling (pp. 346-391 → 46 pages sub-total. 0 sections out of 11)		

* Basic principles covered under this section heading could be explored; but the formulas used are calculus-based.

List 1A. (Continued)

Chapter/Section	Page Numbers	Number of Pages
Chapter 8 Viscous Flow in Pipes (pp. 401-472 → 72 pages sub-total. 5 sections out of 7)		
8.2 Fully Developed Laminar Flow (Concept only)*		
8.2.4 Energy Considerations	416-417	2
8.4 Dimensional Analysis of Pipe Flow	430-472	43
8.4.1 Major Losses		
8.4.2 Minor Losses		
8.4.3 Noncircular Conduits		
8.5 Pipe Flow Examples		
8.5.1 Single Pipes		
8.5.2 Multiple Pipe Systems		
8.6 Pipe Flowrate Measurement		
8.6.1 Pipe Flowrate Meters		
8.6.2 Volume Flow Meters		
8.7 Chapter Summary and Study Guide		
Chapter 9 Flow over Immersed Bodies (pp. 483-550 → 68 pages sub-total. 4 sections out of 5)		
9.1 General External Flow Characteristics	484-493	10
9.1.1 Lift and Drag Concepts		
9.1.2 Characteristics of Flow Past an Object		
9.3 Drag	518-550	33
9.3.1 Friction Drag		
9.3.2 Pressure Drag		
9.3.3 Drag Coefficient Data and Examples		
9.4 Lift		
9.4.1 Surface Pressure Distribution		
9.4.2 Circulation		
9.5 Chapter Summary and Study Guide		
Chapter 10 Open Channel Flow (Whole Chapter; pp. 561-605 → 45 pages sub-total. 7 sections out of 7)		
10.1 General Characteristics of Open-Channel Flow	561-573	13
10.2 Surface Waves		
10.2.1 Wave Speed		
10.2.2 Froude Number Effects		
10.3 Energy Considerations		
10.3.1 Specific Energy		

* Basic principles covered under this section heading could be explored; but the formulas used are calculus-based.

List 1A. (Continued)

List 1A. (Continued)

Chapter/Section	Page Numbers	Number of Pages
12.5 Dimensionless Parameters and Similarity Laws	↑	↑
12.5.1 Special Pump Scaling Laws		
12.5.2 Specific Speed		
12.5.3 Suction Specific Speed		
12.6 Axial-Flow and Mixed-Flow Pump		
12.7 Fans		
12.8 Turbines		
12.8.1 Impulse Turbines		
12.8.2 Reaction Turbines		
12.9 Compressible Flow Turbomachines		
12.9.1 Compressors		
12.9.2 Compressible Flow Turbines		
12.10 Chapter Summary and Study Guide		

Statistical Summary

Total Number of Pages Covered by Text (Excluding "Problems" Section)	621
Total Numbers of Sections Covered Under All Chapters	64 out of 102

Percentage of Pre-Calculus Sections

$$\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Sections}}{\text{Total Number of Sections}}\right)(100\%) = \left(\frac{64}{102}\right)(100\%) = 62.7\%$$

Total Numbers of Chapters Covered	10 out of 12

Percentage of Chapters with Pre-Calculus Sections

$$\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Chapters with Pre-Calculus Sections}}{\text{Total Number of Chapters}}\right)(100\%) = \left(\frac{10}{12}\right)(100\%) = 83.3\%$$

Total Number of Pages Covered by Pre-Calculus Portion	317

Percentage of Pre-Calculus Volume

$$\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Pages}}{\text{Total Number of Pages}}\right)(100\%) = \left(\frac{317}{621}\right)(100\%) = 51.0\%$$

List 1B. Pre-Requisite Mathematics and Science Topics to Be Reviewed Before Teaching the Pre-Calculus Portion of Fluid Mechanics Topics to 9^{th} Grade Students

Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) **[Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)**	
Math	**Physics/Chemistry**
1. [analytic geometry] → 12^{th} (To be taught as a special skill)	1. **[absolute temperature]** (SP3) → 9^{th} (3B) → To be taught
2. [analytic geometry: hyperbolic tangent] Post-secondary → To be taught	2. [acceleration] (S8P3) → 8th (3C)
3. [areas of geometric shapes: circle, triangle, etc.] (M5M1) → 5^{th} (2B)	3. [Dimensional Analysis] → Special topics from 7.1 to be taught
4. [cylinder] (M1G1) (M1G2) → 1^{st} (2B)	4. [density] (S6E5) → 6^{th} (4A)
5. [derivative] → 12^{th} (To be taught as a special skill)	5. [energy] (SP3) → 9^{th} (3B)
6. cross product] → To be taught as a special math topic	6. [force] (S4P3) → 4^{th} (3A) or (S8P3) → 8^{th} (3C)
7. [ellipse] (MA2G4) → 10^{th} (2F) → To be taught	7. [friction] (S8P3) → 8^{th} (3A) → To be taught
8. [exponent] (M6A3) → 6^{th} (2A)	8. **[gas/liquid]** (SPS5) → 9^{th} (3B) → To be taught
9. [four operations] (M1N3) → 1^{st} (2A)	9. [graph] (S7CS6) → 7^{th} (6)
10. [graph] (S7CS6) → 7^{th} (6)	10. [gravity] (S6E1) → 6^{th} (3A)
11. [height] (MKM1) → K (2B)	11. [heat] (S2P2) → 2^{nd} (3A)
12. [integration] → 12^{th} (To be taught as a special skill)	12. **[Ideal Gas Law]** → Post-secondary → to be taught
13. [logarithmic functions] (MA2A5) → 10^{th} (2E) (To be taught as a special skill)	13. **[intermolecular cohesive force]** → To be taught
14. [perimeter] (M3M3) (M3M4) → 3^{rd} (2B)	14. [mass] (S8P3) → 8^{th} (3A)
15. [Pythagorean Theorem] (M8G2) → 8^{th} (2B)	15. [molecule] (S8P1)→ 8^{th} (4A)
16. [prism] (M6G2) → 6^{th} (2B)	16. [momentum] (SP3) → 9^{th} (3B)
17. [radius] (M3G1) → 3^{rd} (2B)	17. [Newton's 1^{st}, 2^{nd} and 3^{rd} Laws] (SP1) → 9^{th} (3C) → To be taught
18. [ratio] (M6A1) → 6th (2A)	18. [potential energy] (SP3) → 9^{th} (3A)
19. [sigma notation] (M6N1) → 6^{th} (1A) or (MA1A3) → 9^{th} (2E)	19. [power] (SP3) → 9^{th} (3B)
20. [square root] (M8N1) → 8^{th} (2A)	20. [pressure] (SC5) → 9^{th} (4B) → To be taught
21. [triangle] (M5M1) → 5^{th} (2B)	21. [Reynolds Number] → To be taught as special topic
22. [trigonometric functions] (MA2G2) → 10^{th} (2F)	22. [speed] (S2P3) → 2^{nd} (3A)
23. [unit conversion] (M6M1) → 6^{th} (2C)	23. [speed of sound] (SPS9) → 9^{th} (3B) → To be taught
24. [volume] (M5M4) → 5^{th} (1B) (M6M3) → 6^{th} (2B) (MA1G5) → 9^{th} (2F)	24. [stress] → To be taught
	25. [temperature] (S3P1) → 3^{rd} (3A) and (SP3) → 9^{th} (3B)
	26. [torque] → Post-secondary → To be taught
	27. [velocity] (S8P3)→ 8^{th} (3A)
	28. [weight] (MKM1) → K (2C)
	29. [work] (S8P3) → 8^{th} (3A)

List 2A. Calculus Based Fluid Mechanics Topics for Post-Secondary Engineering Education

Chapter/Section	Page Nos.
Chapter 1 – Introduction	
1.6 Viscosity	13-20
Chapter 2 Fluid Statics	
2.1 Pressure at a Point	38-42
2.2 Basic Equation for Pressure Field	
2.3 Pressure Variation in a Fluid Mechanics at Rest	
2.8 Hydrostatic Force on a Plane Surface	57-63
2.12 Pressure Variation in a Fluid Mechanics with Rigid-Body Motion	73-78
2.12.1 Linear Motion	
2.12.2 Rigid-Body Rotation	
Chapter 3 Elementary Fluid Dynamics – The Bernoulli Equation	
3.2 F = ma along a Streamline (Continued)	97-104
3.3 F = ma Normal to a Streamline	
3.8.2 Unsteady Effects	131-132
Chapter 5 Finite Control Volume Analysis	
5.1 Conservation of Mass – The Continuity Equation	193-195
5.1.1 Derivation of the Continuity Equation	
5.1.3 Moving, Non-deforming Control Volume	200-205
5.1.4 Deforming Control Volume	
5.2.1 Derivation of the Linear Momentum Equation	205-236
5.2.2 Application of the Linear Momentum Equation	
5.2.3 Derivation of the Moment-of-Momentum Equation	
5.2.4 Application of the Moment-of-Momentum Equation	
5.3 First Law of Thermodynamics – The Energy Equation	
5.3.1 Derivation of the Energy Equation	
5.3.2 Application of the Energy Equation	
5.4 Second Law of Thermodynamics – Irreversible Flow	246-249
5.4.1 Semi-infinitesimal Control Volume Statement of the Energy Equation	
5.4.2 Semi-infinitesimal Control Volume Statement of the Second Law of Thermodynamics	
5.4.3 Combination of the Equations of the First and Second Laws of Thermodynamics	

Chapter/Section	Page Nos.
Chapter 4 Fluid Kinematics	
4.1 The Velocity Field	150-168
4.1.1 Eulerian and Lagrangian Flow Descriptions	
4.1.2 one-, Two-, and three-Dimensional Flows	
4.1.3 Steady and Unsteady Flows	
4.1.4 Streamilnes, Streaklines, and Pathlines	
4.2 The Acceleration Field	
4.2.1 The Material Derivative	
4.2.2 Unsteady Effects	
4.2.3 Convective Effects	
4.2.4 Streamline Coordinates	
4.4 The Reynolds Transport Theorem	170-182
4.4.1 Derivation of the Reynolds Transport Theorem	
4.4.2 Physical Interpretation	
4.4.3 Relationship to Material Derivative	
4.4.4 Steady Effects	
4.4.5 Unsteady Effects	
4.4.6 Moving Control Volumes	
Chapter 6 Differential Analysis of Fluid Flow	
6.1 Fluid Mechanics Element Kinematics	272-334
6.1.1 Velocity and Acceleration Fields Revisited	
6.1.2 Linear Motion and Deformation	
6.1.3 Angular Motion and Deformation	
6.2 Conservation of mass	
6.2.1 Differential Survey Form of Continuity Equation	
6.2.2 Cylindrical Polar Coordinates	
6.2.3 The Stream Function	
6.3 Conservation of Linear Momentum	
6.3.1 Description of Forces Acting on the Differential Element	
6.3.2 Equations of Motion	
6.4 Inviscid Flow	
6.4.1 Euler's Equations of Motion	
6.4.2 The Bernoulli Equation	
6.4.3 Irrotational Flow	

List 2A. (Continued)

List 2A. (Continued)

Chapter/Section	Page Nos.	Chapter/Section	Page Nos.
Chapter 9 Flow over Immersed Bodies		**Chapter 10 Open Channel Flow**	
9.2 Boundary Layer Characteristics	493-518	10.3 Energy Considerations 10.3.2 Channel Depth Variations	573-574
9.2.1 Boundary Layer structure and Thickness on a Flat Plate			
9.2.2 Prandtl/Blasius Boundary Layer Solution			
9.2.3 Momentum Integral boundary Layer Equation for a Flat Plate			
9.2.4 Transition from Laminar to Turbulent Flow			
9.2.5 Turbulent Boundary Layer Flow			
9.2.6 Effects of Pressure Gradient			
9.2.7 Momentum Integral Boundary Layer Equation with Nonzero Pressure Gradient			
Chapter 11 Compressible Flow			
11.1 Ideal Gas Relationships	614-623		
11.2 Mach Number and Speed of Sound			
11.4 Isentropic Flow of an Ideal Gas	628-631		
11.4.1 Effect of Variations in Flow Cross-Sectional Areas			
11.5 Nonisentropic Flow of an Ideal Gas	647-664		
11.5.1 Adiabatic Constant Area Duct Flow with Friction (Fanno Flow)			
11.5.2 Frictionless Constant Area Duct Flow with Heat Transfer (Rayleigh Flow)			

List 2B. Pre-Requisite Math and Science Topics to Be Reviewed Before Teaching the Calculus Portion of Fluid Mechanics Topics

Math & Science Pre-requisite Topics & Completion Grade (Georgia Performance Standard Code) [Pre-requisite Math Skills/Science Principles] (GPS Code) → Grade (Table No.)	
Math	**Physics/Chemistry**
1. [absolute value] (M7N1) → 7th (2A) 2. [analytic geometry] → Post-secondary 3. [analytic geometry: hyperbolic tangent] Post-secondary → To be taught 4. [areas of geometric shapes: circle, triangle, etc.] (M5M1) → 5th (2B) 5. [coordinate system] (M4G3) → 4th (2B) 6. [cross product] → To be taught as a special math topic 7. [cylinder] (M1G1) (M1G2) → 1st (2B) 8. [derivative] → 12th and [partial derivative] → Post-Secondary 9. [dot product] → To be taught as a special math topic 10. [ellipse] (MA2G4) → 10th (2F) → To be taught 11. [Eulerian method] → Post-secondary 12. [exponent] (M6A3) → 6th (2A) 13. [four operations] (M1N3) → 1st (2A) 14. [functions] (MA1A1) → 9th (2E) and others → Post-secondary 15. [gradient "del"] → Post-Secondary 16. [graph] (S7CS6) → 7th (6) 17. [height] (MKM1) → K (2B) 18. [integration] → 12th (To be taught as a special skill) 19. [Lagrangian method] → Post-secondary 20. [limit] → Post-secondary 21. [logarithmic functions] (MA2A5) → 10th (2E) 22. [perimeter] (M3M3) (M3M4) → 3rd (2B) 23. [Pythagorean Theorem] (M8G2) → 8th (2B) 24. [prism] (M6G2) → 6th (2B) 25. [radius] (M3G1) → 3rd (2B) 26. [ratio] (M6A1) → 6th (2A) 27. [sigma notation] (M6N1) → 6th (1A) or (MA1A3) → 9th (2E) 28. [square root] (M8N1) → 8th (2A) 29. [surface] (M6M4) → 6th (2B) 30. [3rd order non-linear differential equation] → Post-secondary 31. [triangle] (M5M1) → 5th (2B) and [trigonometric functions] (MA2G2) → 10th (2F) 32. [unit conversion] (M6M1) → 6th (2C) 33. [vector] (MA3A10) → 11th (2H) → To be taught as a special math topics 34. [volume] (M5M4) → 5th (1B) (M6M3) → 6th (2B) (MA1G5) → 9th (2F)	1. **[absolute temperature]** (SP3) → 9th (3B) → To be taught 2. [acceleration] (S8P3) → 8th (3C) 3. [Dimensional Analysis] → Special topics from 7.1 to be taught 4. [density] (S6E5) → 6th (4A) 5. [energy] (SP3) → 9th (3B) 6. [entropy] → Post-secondary → To be taught 7. [1st moment of the area] → To be taught 8. [force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) 9. [friction] (S8P3) → 8th (3A) → To be taught 10. **[gas/liquid]** (SPS5) → 9th (3B) → To be taught 11. [graph] (S7CS6) → 7th (6) 12. [gravity] (S6E1) → 6th (3A) 13. [heat] (S2P2) → 2nd (3A) 14. **[Ideal Gas Law]** → Post-secondary → to be taught 15. **[intermolecular cohesive force]** → To be taught 16. [mass] (S8P3) → 8th (3A) 17. [molecule] (S8P1)→ 8th (4A) 18. [momentum] (SP3) → 9th (3B) 19. [Newton's 1st, 2nd and 3rd Laws] (SP1) → 9th (3C) → To be taught 20. [potential energy] (SP3) → 9th (3A) 21. [power] (SP3) → 9th (3B) 22. [pressure] (SC5) → 9th (4B) → To be taught 23. [Reynolds Number] → To be taught as special topic 24. [2nd moment of the area] → To be taught 25. [speed] (S2P3) → 2nd (3A) 26. [speed of sound] (SPS9) → 9th (3B) → To be taught 27. [stress] → To be taught 28. [temperature] (S3P1) → 3rd (3A) and (SP3) → 9th (3B) 29. [torque] → Post-secondary → To be taught 30. [velocity] (S8P3)→ 8th (3A) 31. [wave] (S8P4) → 8th (3A) 32. [weight] (MKM1) → K (2C) 33. [work] (S8P3) → 8th (3A)