Engineering Analytic Principles and Predictive Computational Skills for K-12 Students:

Statistics on High School Age-Possible Statics Topics for Engineering and Technology Educators and Curriculum Developers

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Introduction

In the most recent decade, middle and high schools across the United States have tried to incorporate engineering design into traditional technology curriculum, with various degrees of success; however, "the fragmented focus and lack of a clear curriculum framework" had been "detrimental to the potential of the field and have hindered efforts aimed at achieving the stated goals of technological literacy for all students" (Smith and Wicklein, 2007, pp. 2-3). A report issued on September 8, 2009, by the Committee on K-12 Engineering Education established by the National Academy of Engineering and the National Research Council, titled *Engineering in K-12 Education: Understanding the Status and Improving the Prospects* (2009), confirmed the existence of similar problems, such as the "absence of a clear description of which engineering knowledge, skills, and habits of mind are most important, how they relate to and build on one another, and how and when (i.e., at what age) they should be introduced to students" (pp. 7-8; p. 151). K-12 engineering curriculum in the United States remains skeletal so far; its main focus is on generic design process using a "trial-and-error" approach; and the coverage of analytic and predictive knowledge contents is generally in an "ad hoc" fashion and not sequentially structured. In response to the above problems, many scholars have voiced their points of view. Hacker (2011) pointed out that "trial-and-error problem solving takes substantial classroom time, and often does not allow teachers and students to focus on the most important learning goals." Lewis (2007, pp. 846-848) discussed the need to: (a). establish a "codified body of knowledge that can be ordered and articulated across the grades" instead of short term efforts focused on a particular topic or unit, and (b). make engineering education a coherent system with the creation of content standards for the subject area, in line with science and technology education.

High School Age-possible Engineering Topics (Statics)

Research Questions and Practical Conceptual Framework

The above evaluation of the current status of K-12 engineering education in the United States could lead to these questions: (1). "How could we determine what engineering analytic principles and predictive skills from what subject should be taught to students at what Grade in the K-12 curriculum, in a rational and scientific way?" (2). "How could we make sure that what students learned from high school engineering curriculum could be transferred to university programs?" Based on the way engineering curriculum has been historically developed, I have constructed a practical conceptual framework to answer the above two questions. If we read any typical information sheet for university level undergraduate engineering program, we will see that the courses are organized in a sequence based on the fulfillment of pre-requisites in mathematics, physics, chemistry, technology and previous engineering courses; and these pre-requisites are usually listed in course descriptions. Therefore, we could hypothesize that the same principles used historically in the development of curricular structure in university undergraduate engineering programs could apply to the selection of K-12 age-possible engineering analytic principles and predictive skills for any particular Grade, and for any particular subject of engineering. In addition, based on the fact that university undergraduate engineering textbooks, especially those used in foundation courses (such as statics, dynamics, strength of materials, engineering economics, etc.), all contain portions that are based on pre-calculus mathematics and scientific principles which are usually covered in K-12 mathematics and science courses, we could also hypothesize that these pre-calculus portions of engineering topics could possibly be taught at various Grade levels, provided that the pre-requisite pre-calculus mathematics and science principles have been covered in previous Grade levels (or in some cases, taught as special topics); and the coverage of such pre-requisites are usually mandated by the performance standards in mathematics and science established by any particular state. This conceptual framework has been used as a practical tool for the initial determination of 9th grade age-possible statics and fluid mechanics topics. The step-by-step procedure or the "ideal" procedure (Locke, 2009a, pp. 26-27) includes the following (*Figure 1*): (1) selection of data source (selection of popular university undergraduate engineering textbooks and other instructional and learning materials); (2) analysis of data source (careful reading of every paragraph in the body text as well as relevant computational formulas to find and record the pre-requisite mathematics skills and scientific principles needed for each topic; (3) comparison (between the recorded mathematics and science pre-requisites, and my interpretation of the mandates of the Performance Standards for Mathematics and Sciences of the Department of Education of a selected state, in this case, the State of Georgia, to determine the Grade level for the age-possible inclusion of the topics). I selected the State of Georgia's Standards as a reference for the research because (1) the University of Georgia, my alma mater, gave me the opportunity to study the subject of K-12 engineering education and (2) many professors at the College of Education and the College of Agricultural and Environmental Sciences (Department of Biological and Agricultural Engineering) offered me valuable advice and criticism. Due to the fact that the variations among the K-12 mathematics and science performance standards of the 50 states are not substantial, the outcomes of the research should apply to other states with some reasonable adaptations.

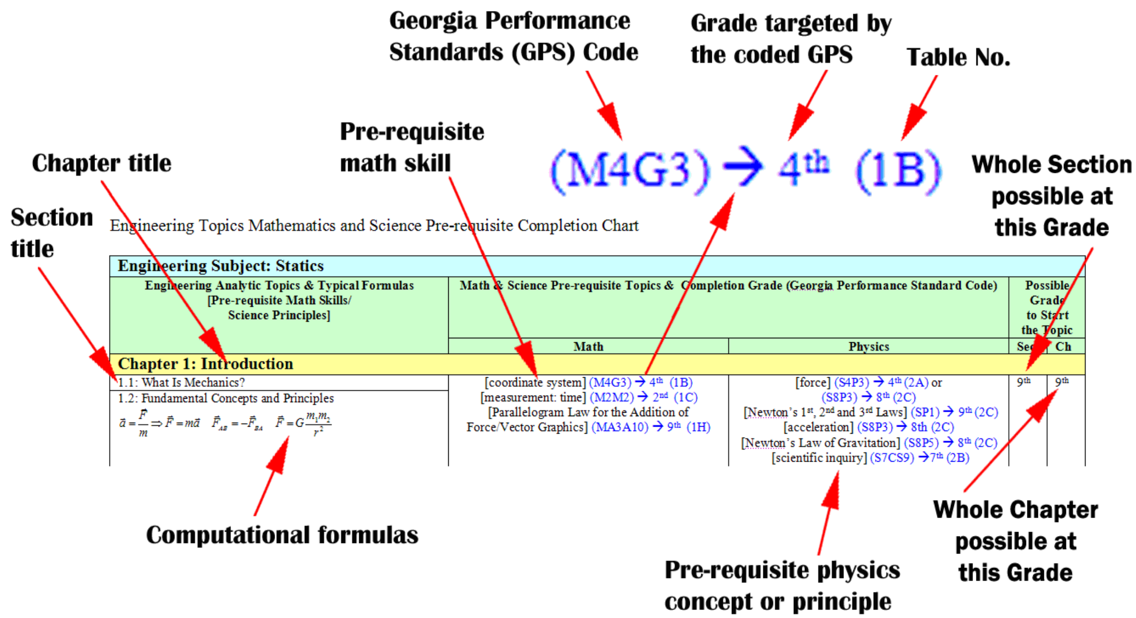

Figure 1. The original research data table used to initially determine high school 9th Grade age-possible statics topics.

After completing all lower-division undergraduate mechanical engineering courses plus two upper-division ones, and conducting a careful and fairly thorough examination of many other college-level engineering textbooks, I have made the conclusion that all engineering textbooks include the following major elements:

(1) **<u>Descriptive and informational:</u>** Paragraphs, data tables, charts, graphs, illustrations and photos that explain natural phenomena, scientific principles, properties of materials, behaviors of structures and systems, in "plain English," without going into the details of analytic and predictive computations using formulas based on mathematics skills.

(2) **<u>Analytic and predictive:</u>** Mathematics-based formulas, including those used in pre-requisite physics and chemistry concepts, principles and analysis, and those used in engineering analysis and design, and step-by-step procedures, including sample problems with solutions, for analyzing problems, predicting outcomes, or designing systems or products; and these mathematics

skills could be at either pre-calculus level, i.e., arithmetic, trigonometry, geometry, algebra, or at calculus level, i.e., integration and differentiation.

In terms of the relative amount of each of the above major elements in the overall composition of the content of the textbooks, all sets of college-level engineering textbooks used in any particular course or subject could be classified into three major categories; i.e., (1) Mixture of Pre-calculus and Calculus, (2) Heavily Pre-calculus, and (3) Heavily Descriptive and Informational. It takes different amounts of time and efforts to examine different sets of textbooks under different categories in order to tentatively determine and select K12 age-possible engineering content knowledge and skills, including descriptive and informational materials, analytic and predictive computational formulas and step-by-step problem solving procedures; and the procedure of this examination include (a) interpretation of the mandates of the Performance Standards for Mathematics and Sciences of the Department of Education of a selected state, in this case, the State of Georgia, to create a coded list of items of mathematics, physics and chemistry concepts and skills, such as *M4G3→4th Grade (1B)* shown in *Figure 1*, from the original online government document, to be used for comparison with the mathematics, physics and chemistry concepts and skills found from the relevant textbooks; (b) paragraph-by-paragraph or page-by-page examination of the selected textbooks for the extraction and documentation of the mathematics, physics and chemistry concepts and skills needed to understand the content and to solve homework problems; and (c) comparison between the interpreted, itemized and coded lists of Performance Standards and the items extracted from the textbooks, to tentatively determine and select sections and chapters in the textbooks that could be K12 age-possible. In the United States, we have a very decentralized management structure for the publication and adaptation of textbooks; and this is especially true for textbooks used in the institutions of higher education where professors usually select textbooks out of their own choices free from government intervention; for any college courses or subject, we can find several excellent and popular textbooks, all of them cover a majority of similar topics plus a small number of different ones; therefore, to be holistic and comprehensive, at least two of the most popular textbooks will be used, one as the “primary source of data” and the rest as “secondary source of data” and “additional sources of data.” The nature of composition of the above-mentioned three major categories of textbooks and the average amount of time it takes for their examination are as follows:

1. **Mixture of Pre-calculus and Calculus:** Textbooks under this category include, for the undergraduate mechanical engineering major, those used in the courses of statics, dynamics, strength of materials, electric machines, mechanical design, aerodynamics, fluid mechanics, electrical circuits, heat transfer, thermodynamics, and others. For these textbooks, calculus and pre-calculus skills are used intermittently throughout substantial portions of most of the chapters. These textbooks are usually voluminous and the numbers of pages range from 600 to 900. Therefore, a thorough investigation of all paragraphs, formulas, and even sample problems in the textbooks, and a very detailed record of all pertinent information in tabular forms is needed to determine and to select K-12 age-possible engineering topics for different grade levels. My research projects on the subjects of statics and fluid mechanics have been completed this way. This procedure is very thorough and time-consuming and for one subject, it takes

between 3 to 5 weeks for one textbook (the "primary source of data"), and additional 1 to 2 weeks for another textbook (the "secondary source of data" used to pick up additional K12 age-possible topics); these amounts of time cover careful reading of all chapters, sections, and even appendices and glossaries throughout the entire textbooks, analysis and recording of mathematics, physics and chemistry concepts and skills involved, typing of titles of chapters, sections, formulas, names of pre-requisite items, write-ups of conclusions, as well as a section-by-section review. Typing of titles of chapters, sections, and formulas could take up to one third of the above amounts of time needed for the research. It is the exact or "ideal" procedure advocated in my published Vision Paper.

2. **Heavily Pre-calculus:** Textbooks under this category include those used in the courses of engineering economics, probability and statistics, and others. For these textbooks, the mathematics skills involved in the majority or even the overwhelming majority of chapters and sections are at pre-calculus level; the calculus skills involved in a few sections or chapters are the very beginning ones such as [first integral] and [first derivative]; and the principles and skills related to physics and chemistry are also the very basic ones; therefore, a less time-consuming approach is used to determine and select K12 age-possible engineering topics, by carefully examine each page in the textbooks to record (1) the pre-calculus level mathematics skills as well as physics and chemistry concepts, principles and skills found in all pages; (2) the calculus-level mathematics skills found in some pages, the page numbers where these calculus skills are found, the numbers and names as well as the pages ranges of the sections involving the calculus skills; and (3) result of comparison between the pre-calculus skills as well as physics and chemistry concepts and skills found throughout the textbooks, and the mandates of the Performance Standards for Mathematics and Sciences of the Department of Education of a selected state, in this case, the State of Georgia, to determine the earliest Grade level for the age-possible inclusion of the topics. My research projects on the subjects of engineering economics, probability and statistics, and engineering materials have been completed this way. This procedure is fairly thorough but much less time-consuming because no record of mathematics-based formulas or typing of the names of chapters and sections of the textbooks that involve only pre-calculus mathematics skills is needed, and for one subject, it takes between 5 to 7 days for one textbook (the "primary source of data") and additional 2 to 4 days for another textbook (the "secondary source of data"). These amounts of time cover careful reading of all chapters, sections, and even appendices and glossaries throughout the entire textbooks, analysis and recording of mathematics, physics and chemistry concepts and skills involved as pre-requisites, typing of page numbers and titles of chapters and sections involving calculus stills as well as numbers of the individual pages involved, write-ups of conclusions, as well as a section-by-section review. It is a convenient and "ad hoc" revision of the "ideal" procedure advocated in my published Vision Paper.

3. **Heavily Descriptive and Informational:** Textbooks under this category include those used in the courses of introduction to science, engineering and technology, ethics and professionalism in engineering, and others. These textbooks involve little or no

mathematics skills; their primary goal is to expose students to broad knowledge about engineering, science, technology, as well as their relationship with "other stuff" such as society, ecology, legal system, philosophy, and others. Similar method as the one used for the "Heavily Pre-calculus" textbooks is used here but the amounts of time spent is substantially reduced because, for the "Heavily Descriptive and Informational" textbook, mathematics, physics and chemistry pre-requisites are rarely involved. For one subject, it takes between 1 to 3 days for one textbook (the "primary source of data") and additional 1 to 2 days for another textbook (the "secondary source of data"). These amounts of time cover careful reading of all chapters, sections, and even appendices and glossaries throughout the entire textbooks, analysis and recording of a few mathematics, physics and chemistry concepts and skills involved as pre-requisites, write-ups of conclusions, as well as a section-by-section review. It is a convenient, "ad hoc" and more drastic revision of the "ideal" procedure advocated in my published Vision Paper.

Sources of Data

Table 1 lists (1) the college-level Textbook 1 (the "primary source of data") used for the extraction of analytic and predictive principles and computational formulas related to the subject of statics, and (2) the instructor's or student's solution manuals used to double-check for the mathematics computational skills needed for the study of various topics of statics contained in the selected.

Table 1. Data Source (Statics Textbook)

	Main Textbook	**Instructor's Solution Manuals**	
Title	Vector Mechanics for Engineers Statics, 7th Edition	Instructor's and Solutions Manual to Accompany Vector Mechanics for Engineers – Statics, 7th Edition, Volume 1	Instructor's and Solutions Manual to Accompany Vector Mechanics for Engineers – Statics, 7th Edition, Volume 2
Authors	Ferdinand P. Beer & E. Russell Johnston & Elliot R. Eisenberg	Ferdinand P. Beer & E. Russell Johnston & Elliot R. Eisenberg	Ferdinand P. Beer & E. Russell Johnston & Elliot R. Eisenberg
Publisher	McGraw-Hill Higher Education	McGraw-Hill Higher Education	McGraw-Hill Higher Education
Year	2004	2004	2004
ISBN	0-07-230493-6	10: 0072536055	10: 0072962623

Original Research Data

Table 2 (Statics Topic List - Engineering Topics Mathematics and Science Pre-requisite Completion Chart for the Subject of Statics) constitute the original research data; the way data is recorded and analyzed is shown in *Figure 1*. The leftmost column in the Table 1 (Statics Topic List - Engineering Topics Mathematics and Science Pre-requisite Completion Chart for the Subject of Statics) contains

1. The titles of each section under a particular chapter in the selected textbook, which in general represent particular sets of statics 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.

The middle column (divided into two sub-columns, i.e., Math, and Physics/Chemistry, is reserved for recording mathematics and science (physics and chemistry) pre-requisites for understanding the knowledge content and using the formulas contained in the particular chapters or sections, as well as the grade levels these pre-requisites are expected to be fulfilled according to Georgia Performance Standards.

The right column records the prediction on the possible grade a particular chapter or section could be taught to K12 students.

Findings from the Research Project

Table 3A (Pre-Calculus Based Statics Topics That Possibly Could Be Taught at 9th Grade), Table 3B (Pre-Requisite Mathematics and Science Topics to Be Reviewed Before Teaching the Pre-Calculus Portion of Statics Topics to 9th Grade Students), Table 4A (Calculus Based Statics Topics for Post-Secondary Engineering Education), and Table 4B (Pre-Requisite Math and Science Topics to Be Reviewed Before Teaching the Calculus Portion of Statics Topics) constitute the outcomes of the research, which is presented here to the public as “public domain” knowledge, to be used as sources of reference by K12 engineering and technology education practitioners and curriculum developers, nationally and internationally, including myself, of course!

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

Engineering Subject: Statics				
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**	**Sec**	**Ch**
Chapter 1: Introduction				
1.1: What Is Mechanics? **1.2: Fundamental Concepts and Principles** $\vec{a}=\frac{\vec{F}}{m}\Rightarrow\vec{F}=m\vec{a}$ $\vec{F}_{AB}=-\vec{F}_{BA}$ $\vec{F}=G\frac{m_1m_2}{r^2}$	[coordinate system] (M4G3) → 4th (2B) [measurement: time] (M2M2) → 2nd (2C) [Parallelogram Law for the Addition of Force/Vector Graphics] (MA3A10) → 11th (2H) → To be taught as a special math topic	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [Newton's 1st, 2nd and 3rd Laws] (SP1) → 9th (3C) [acceleration] (S8P3) → 8th (3C) [Newton's Law of Gravitation] (S8P5) → 8th (3C) [scientific inquiry] (S7CS9) →7th (3B)	9th	9th
1.3: Systems of Units **1.4: Conversion from One System of Units to Another**	[unit conversion] (M6M1) → 6th (2C)	N/A	6th	
1.5: Method of Problem Solution	[problem-solving] (M3N5) → 3rd (2A)	N/A	3rd	
1.6: Numerical Accuracy	[percent] (M5N5) → 5th (2A)	N/A	5th	
Chapter 2: Statics of Particles				
2.1: Introduction **<u>Forces in a Plane</u>** **2.2: Force on a Particle. Resultant of Two Forces**	[four operations] (M1N3) → 1st (2A) + (M2N3) → 2nd (1A), or (M7N1) → 7th (2A) [coordinate system] (M4G3) → 4th (2B)	[force] (S4P3) → 4th (3A)	4th	9th
2.3: Vectors **2.4: Addition of Vectors** **2.5: Resultant of Several Concurrent Forces**	[vector graphics] (MA3A10) → 9th (2H) → To be taught as a special math topic	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C)	9th	
2.6: Resolution of a Force into Components **2.7: Rectangular Components of a Force. Unit Vectors**	[vector graphics] (MA3A10) → 9th (2H) [trigonometric functions] (MA2G2) → 9th (2F)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C)	9th	
2.8: Addition of Forces by Summing *x* and *y* Components $\vec{F}=F_x\hat{i}+F_y\hat{j}$ $F_x=F\cos\theta$ $F_y=F\sin\theta$ $\tan\theta=\frac{F_y}{F_x}$ $F=\sqrt{F_x^2+F_y^2}$	[four operations] (M1N3) → 1st (2A) + (M2N3) → 2nd (2A), or (M7N1) → 7th (2A) [square root] (M8N1) → 8th (2A) [trigonometric functions] (MA2G2) → 10th (2F) → To be taught as a special math topic [coordinate system] (M4G3) → 4th (2B)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C)	8th	
2.9: Equilibrium of a Particle $R=\sum F=F_1+F_2+...=0 \Rightarrow R_x=\sum F_x=0$ $R_y=\sum F_y=0$ $R_z=\sum F_z=0$	[sigma notation] (M6N1) → 6th (1A) or (MA1A3) → 9th (2E) → To be taught as a special math topic [four operations] (M1N3) → 1st (2A) + (M2N3) → 2nd (1A), or (M7N1) → 7th (2A)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (2C)	9th	

Table 2. Statics Topics List (Continued).

Engineering Subject: Statics				
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**	**Sec**	**Ch**
Chapter 2: Statics of Particles (Continued)				
2.10: Newton's First Law of Motion **2.11: Problems Involving the Equilibrium of a Particle. Free-Body Diagrams**	[four operations] (M1N3) → 1st (2A) + (M2N3) → 2nd (1A), or (M7N1) → 7th (2A)	[Newton's 1st, 2nd and 3rd Laws] (SP1) → 9th (3C) [acceleration] (S8P3) → 8th (3C)	9th	9th
<u>Forces in Space</u> **2.12: Rectangular Components of a Force in Space** $F_y = F\cos\theta_y \quad F_h = F\sin\theta_y$ $F_x = F_h\cos\phi = F\sin\theta_y\cos\phi \quad F_z = F_h\sin\phi = F\sin\theta_y\sin\phi$ $F^2 = F_y + F_h = F_y + F_x + F_z \quad \rightarrow \quad F = \sqrt{F_x + F_y + F_z}$ $F_x = F\cos\theta_x \quad F_y = F\cos\theta_y \quad F_z = F\cos\theta_z \quad (0^\circ < \theta_{x,y,z} < 180^\circ)$ $\vec{F} = F_x\hat{i} + F_y\hat{j} + F_z\hat{k}$ $\vec{F} = F\left(\cos\theta_x\hat{i} + \cos\theta_y\hat{j} + \cos\theta_z\hat{k}\right)$ $\cos\theta_x = \frac{F_x}{F} = \frac{d_x}{d} = \frac{R_x}{R} \quad \cos\theta_y = \frac{F_y}{F} = \frac{d_y}{d} = \frac{R_y}{R} \quad \cos\theta_z = \frac{F_z}{F} = \frac{d_z}{d} = \frac{R_z}{R}$ $\theta_{x(y,z)} = \cos^{-1}\frac{F_{x(y,z)}}{F} = \cos^{-1}\frac{d_{x(y,z)}}{d} \quad F = \sqrt{F_x^2 + F_y^2 + F_z^2}$ $\hat{\lambda} = \cos\theta_x\hat{i} + \cos\theta_y\hat{j} + \cos\theta_z\hat{k} \quad \hat{\lambda} = \frac{\vec{F}}{F} \quad \hat{i} = \frac{d_x}{d} \quad \hat{j} = \frac{d_y}{d} \quad \hat{k} = \frac{d_z}{d}$ $\cos^2\theta_x + \cos^2\theta_y + \cos^2\theta_z = 1 \quad \rightarrow \quad \hat{\lambda}_x^2 + \hat{\lambda}_y^2 + \hat{\lambda}_z^2 = 1$	[four operations] (M1N3) → 1st (2A) + (M2N3) → 2nd (1A), or (M7N1) → 7th (2A) [square root] (M8N1) → 8th (2A) [trigonometric functions] (MA2G2) → 10th (2F) → To be taught as a special math topic [coordinate system] (M4G3) → 4th (2B)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C)	9th	

Table 2. Statics Topics List (Continued).

Engineering Subject: Statics				
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**	**Sec**	**Ch**
Chapter 2: Statics of Particles (Continued)				
2.13: Force Defined by Its Magnitude and Two Points on Its Line of Action $\overrightarrow{MN} = d_x\hat{i} + d_y\hat{j} + d_z\hat{k}$ $\hat{\lambda} = \frac{\overrightarrow{MN}}{MN} = \frac{1}{d}\left(d_x\hat{i} + d_y\hat{j} + d_z\hat{k}\right)$ $d_{x(y,z)} = x(y,z)_2 - x(y,z)_1 \quad d = \sqrt{d_x^2 + d_y^2 + d_z^2}$ $\vec{F} = F\hat{\lambda} = \frac{F}{d}\left(d_x^2\hat{i} + d_y^2\hat{j} + d_z^2\hat{k}\right)$ $F_x = \frac{Fd_x}{d} \quad F_y = \frac{Fd_y}{d} \quad F_z = \frac{Fd_z}{d}$	[four operations] (M1N3) → 1st (2A) + (M2N3) → 2nd (1A), or (M7N1) → 7th (2A) [square root] (M8N1) → 8th (1A) [trigonometric functions] (MA2G2) → 10th (2F) → To be taught as a special math topic [coordinate system] (M4G3) → 4th (2B)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [Newton's 1st, 2nd and 3rd Laws] (SP1) → 9th (3C)	9th	9th
2.14: Addition of Concurrent Forces in Space $\vec{R} = \sum\vec{F} \quad R = \sqrt{R_x^2 + R_y^2 + R_z^2}$ $R_x\hat{i} + R_y\hat{j} + R_z\hat{k} = \left(\sum F_x\right)\hat{i} + \left(\sum F_y\right)\hat{j} + \left(\sum F_z\right)\hat{k}$	[four operations] (M1N3) → 1st (2A) + (M2N3) → 2nd (1A), or (M7N1) → 7th (2A) [square root] (M8N1) → 8th (2A) [trigonometric functions] (MA2G2) → 10th (2F) → To be taught as a special math topic [coordinate system] (M4G3) → 4th (2B)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [Newton's 1st, 2nd and 3rd Laws] (SP1) → 9th (3C)	9th	
2.15: Equilibrium of a Particle in Space $R = \sum F = F_1 + F_2 + ... = 0 \quad \rightarrow \quad R_x = \sum F_x = 0 \quad R_y = \sum F_y = 0 \quad R_z = \sum F_z = 0$ $\begin{bmatrix} a & b & c \\ d & e & f \\ g & h & i \end{bmatrix} \times \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} ax+by+cz \\ dx+ey+fz \\ gx+hy+iz \end{bmatrix} \quad \begin{bmatrix} a & b & c \\ d & e & f \\ g & h & i \end{bmatrix} \times \begin{bmatrix} F_1 \\ F_2 \\ F_3 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$ $\begin{matrix} R_x = \sum F_x = 0 & aF_1 + bF_2 + cF_3 = 0 \\ R_y = \sum F_y = 0 & dF_1 + eF_2 + fF_3 = 0 \\ R_z = \sum F_z = 0 & gF_1 + hF_2 + iF_3 = 0 \end{matrix} \quad \begin{bmatrix} a & b & c \\ d & e & f \\ g & h & i \end{bmatrix} \times \begin{bmatrix} F_1 \\ F_2 \\ F_3 \end{bmatrix} = \begin{bmatrix} aF_1 + bF_2 + cF_3 \\ dF_1 + eF_2 + fF_3 \\ gF_1 + hF_2 + iF_3 \end{bmatrix}$	[coordinate system] (M4G3) → 4th (2B) [four operations] (M1N3) → 1st (2A) + (M2N3) → 2nd (1A), or (M7N1) → 7th (2A) [linear algebra](MA2A6) (MA2A7) (MA2A8) (MA2A9) → 10th (2G) → To be taught as a special math topic	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [Newton's 1st, 2nd and 3rd Laws] (SP1) → 9th (3C)	9th	

Table 2. Statics Topics List (Continued).

Engineering Subject: Statics				
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**	**Sec**	**Ch**
Chapter 3: Rigid Bodies - Equivalent Systems of Forces				
3.1: Introduction **3.2: External and Internal Forces** **3.3: Principle of Transmissibility. Equivalent Forces**	[four operations] (M1N3) → 1st (2A) + (M2N3) → 2nd (2A) [geometry: point, axis/line, 3D body] (M6G1) (M6G2) (M6M3) → 6th (2B)	[force] (S4P3) → 4th (3A) [motion] (SKP2) → K (3A)	6th	9th
3.4: Vector Product of Two Vectors $\vec{V}=\vec{P}\times\vec{Q}$ $V=PQ\sin\theta$ $\vec{V}\perp\vec{P}$ $\vec{V}\perp\vec{Q}$ $\vec{V}\perp Plane_{\vec{P},\vec{Q}}$ $\vec{P}\times(\vec{Q}_1+\vec{Q}_2)=\vec{P}\times\vec{Q}_1+\vec{P}\times Q_2$ $(\vec{P}\times\vec{Q})\times\vec{S}\neq\vec{P}\times(\vec{Q}\times\vec{S})$ $\vec{V}=\vec{Q}\times\vec{P}=-(\vec{P}\times\vec{Q})$ $\vec{Q}\times\vec{P}\neq\vec{P}\times\vec{Q}$ $\vec{P}\times\vec{Q}=-\vec{V}$ $\vec{P}\times(\vec{Q}_1+Q_2)=\vec{P}\times\vec{Q}_1+\vec{P}\times Q_2$ $\vec{Q}\times\vec{P}\neq\vec{P}\times\vec{Q}$ $\vec{V}=\vec{Q}\times\vec{P}=-(\vec{P}\times\vec{Q})$ $\vec{P}\times\vec{Q}=-\vec{V}$ $\vec{V}=\vec{P}\times\vec{Q}$ $(\vec{P}\times\vec{Q})\times\vec{S}\neq\vec{P}\times(\vec{Q}\times\vec{S})$	[trigonometric functions] (MA2G2) → 10th (2F) → To be taught as a special math topic [cross product] → To be taught as a special math topic	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [motion] (SKP2) → K (3A)	9th	
3.5: Vector Products Expressed in Terms of Rectangular Components $\hat{i}\times\hat{i}=\hat{j}\times\hat{j}=\hat{k}\times\hat{k}=0$ $\hat{i}\times\hat{j}=\hat{k}$ $\hat{j}\times\hat{k}=\hat{i}$ $\hat{k}\times\hat{i}=\hat{j}$ $\hat{i}\times\hat{k}=-\hat{j}$ $\hat{j}\times\hat{i}=-\hat{k}$ $\hat{k}\times\hat{j}=-\hat{i}$ $\vec{P}=P_x\hat{i}+P_y\hat{j}+P_z\hat{k}$ $\vec{Q}=Q_x\hat{i}+Q_y\hat{j}+Q_z\hat{k}$ $\vec{V}=\vec{P}\times\vec{Q}=\begin{vmatrix}\hat{i} & \hat{j} & \hat{k}\\ P_x & P_y & P_z\\ Q_x & Q_y & Q_z\end{vmatrix}=V_x\hat{i}+V_y\hat{j}+V_z\hat{k}$ $V_x=P_yQ_z-P_zQ_y$ $V_y=-(P_xQ_z-P_zQ_x)=P_zQ_x-P_xQ_z$ $V_z=P_xQ_y-P_yQ_x$	[trigonometric functions] (MA2G2) → 10th (2F) [cross product] → To be taught as a special math topic [dot product] → To be taught as a special math topic	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C)	9th	

Table 2. Statics Topics List (Continued).

Engineering Subject: Statics				
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**	**Sec**	**Ch**
Chapter 3: Rigid Bodies - Equivalent Systems of Forces (Continued)				
3.6: Moment of a Force about a Point $\vec{M}_0 = \vec{r} \times \vec{F} \quad M_0 = rF\sin\theta = Fd$ $\vec{r} = \vec{v}_{position}^{O \to A} \quad \theta = \angle_{\vec{r} \to \vec{F}} \quad d \perp \vec{F}$ $\vec{M}_0 = \vec{r} \times \vec{F} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ x & y & z \\ F_x & F_y & F_z \end{vmatrix} = M_x\hat{i} + M_y\hat{j} + M_z\hat{k}$ $M_x = yF_z - zF_y \quad M_y = -(xF_z - zF_x) = zF_x - xF_z \quad M_z = xF_y - yF_x$	[four operations] (M1N3) → 1st (1A) + (M2N3) → 2nd (2A) [geometry: point, axis/line, 3D body] (M6G1) (M6G2) (M6M3) → 6th (2B) [\cross product] → To be taught as a special math topic [dot product] → To be taught as a special math topic [linear algebra](MA2A6) (MA2A7) (MA2A8) (MA2A9) → 10th (2G) → To be taught as a special math topic	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C)	9th	9th
3.7: Varignon's Theorem $\vec{r} \times (\vec{F}_1 + \vec{F}_2 + ...) = \vec{r} \times \vec{F}_1 + \vec{r} \times \vec{F}_2 + ...$	[four operations] (M1N3) → 1st (1A) + (M2N3) → 2nd (2A) [cross product] → To be taught as a special math topic [dot product] → To be taught as a special math topic	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C)	9th	
3.8: Rectangular Components of the Moment of a Force $\vec{M}_B = \vec{r}_{A/B} \times \vec{F} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ x_{A/B} & y_{A/B} & z_{A/B} \\ F_x & F_y & F_z \end{vmatrix}$ $\vec{r}_{A/B} = x_{A/B}\hat{i} + y_{A/B}\hat{j} + z_{A/B}\hat{k}$ $x_{A/B} = x_A - x_B \quad y_{A/B} = y_A - y_B \quad z_{A/B} = z_A - z_B$	[four operations] (M1N3) → 1st (1A) + (M2N3) → 2nd (2A) [cross product] → To be taught as a special math topic	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C)	9th	

Table 2. Statics Topics List (Continued).

Engineering Subject: Statics				
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**	**Sec**	**Ch**
Chapter 3: Rigid Bodies - Equivalent Systems of Forces (Continued)				
3.9: Scalar Product of Two Vectors $\vec{P}\bullet\vec{Q}=PQ\cos\theta=P_xQ_x+P_yQ_y+P_zQ_z \quad \theta=\angle_{\vec{P}\to\vec{Q}}$ $\vec{P}\bullet\vec{Q}=\vec{Q}\bullet\vec{P} \quad \vec{P}\bullet(\vec{Q}_1+\vec{Q}_2)=\vec{P}\bullet\vec{Q}_1+\vec{P}\bullet\vec{Q}_2$ $P_{OL}=\vec{P}\bullet\hat{\lambda}=P_x\cos\theta_x+P_y\cos\theta_y+P_z\cos\theta_z$ (More formulas on p. pp. 94-95)	[four operations] (M1N3) → 1st (1A) + (M2N3) → 2nd (2A) [dot product] → To be taught as a special math topic	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C)	9th	9th
3.10: Mixed Triple Product of Three Vectors $\vec{S}\bullet(\vec{P}\times\vec{Q})=\begin{vmatrix}S_x & S_y & S_z\\ P_x & P_y & P_z\\ Q_x & Q_y & Q_z\end{vmatrix}$	[four operations] (M1N3) → 1st (1A) + (M2N3) → 2nd (2A) [cross product] → To be taught as a special math topic	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C)	9th	
3.11: Moment of a Force about a Given Axis $M_{OL}=\hat{\lambda}\bullet\vec{M}_O=\hat{\lambda}\bullet(\vec{r}\times\vec{F})=\begin{vmatrix}\lambda_x & \lambda_y & \lambda_z\\ x & y & z\\ F_x & F_y & F_z\end{vmatrix}$ (More formulas on p. pp. 98)	[four operations] (M1N3) → 1st (1A) + (M2N3) → 2nd (2A) [dot product] → To be taught as a special math topic	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C)	9th	
3.12: Moment of a Couple $\vec{M}=\vec{r}\times\vec{F} \quad M=rF\sin\theta=Fd$	[four operations] (M1N3) → 1st (1A) + (M2N3) → 2nd (2A) [trigonometric functions] (MA2G2) → 10th (2F) → To be taught as a special math topic [cross product] → To be taught as a special math topic	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [motion] (SKP2) → K (3A) [lever] (S4P3) → 4th (3A)	9th	
3.13: Equivalent Couples $F_1d_1=F_2d_2$	[four operations] (M1N3) → 1st (1A) + (M2N3) → 2nd (2A) [geometry: point, axis/line, 3D body] (M6G1) (M6G2) (M6M3) → 6th (2B)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [motion] (SKP2) → K (3A) [lever] (S4P3) → 4th (3A)	6th	

Table 2. Statics Topics List (Continued).

Engineering Subject: Statics				
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**	**Sec**	**Ch**
Chapter 3: Rigid Bodies - Equivalent Systems of Forces (Continued)				
3.14: Addition of Couples $\vec{M} = \vec{r} \times \vec{R} = \vec{r} \times (\vec{F}_1 + \vec{F}_2) = \vec{r} \times \vec{F}_1 + \vec{r} \times \vec{F}_2 \quad \vec{M} = \vec{M}_1 + \vec{M}_2$	[four operations] (M1N3) → 1st (1A) + (M2N3) → 2nd (2A) [cross product] → To be taught as a special math topic	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C)	9th	9th
3.15: Couples Can Be Represented by Vectors	[vector graphics] (MA3A10) → 11th (2H) → To be taught as a special math topic	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C)	9th	
3.16: Resolution of a Given Force Into a Force at *O* and a Couple $\vec{M}_{O'} = \vec{r}' \times \vec{F} = (\vec{r} + \vec{s}) \times \vec{F} = \vec{r} \times \vec{F} + \vec{s} \times \vec{F} \quad \vec{M}_{O'} = \vec{M}_O + \vec{s} \times \vec{F}$	[four operations] (M1N3) → 1st (1A) + (M2N3) → 2nd (2A) [cross product] → To be taught as a special math topic	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C)	9th	
3.17: Reduction of a System of Forces to One Force and One Couple $\vec{R} = \sum \vec{F} \quad \vec{M}_O^R = \sum \vec{M}_O = \sum (\vec{r} \times \vec{F})$ $\vec{M}_{O'}^R = \vec{M}_O + \vec{s} \times \vec{R} \quad \vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$ $\vec{F} = F_x\hat{i} + F_y\hat{j} + F_z\hat{k} \quad \vec{R} = R_x\hat{i} + R_y\hat{j} + R_z\hat{k}$ $\vec{M}_O^R = M_x^R\hat{i} + M_y^R\hat{j} + M_z^R\hat{k}$	[four operations] (M1N3) → 1st (1A) + (M2N3) → 2nd (2A) [cross product] → To be taught as a special math topic	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C)	9th	
3.18: Equivalent Systems of Forces $\sum \vec{F} = \sum \vec{F}' \quad \& \quad \sum \vec{M}_0 = \sum \vec{M}'_0$ $\sum \vec{F} = \sum \vec{F}' \quad and \quad \sum \vec{M}_O = \vec{M}_O'$ $\sum F_x = \sum F'_x \quad \sum F_y = \sum F'_y \quad \sum F_z = \sum F'_z$ $\sum M_x = \sum M'_x \quad \sum M_y = \sum M'_y \quad \sum M_z = \sum M'_z$	[four operations] (M1N3) → 1st (1A) + (M2N3) → 2nd (2A) [coordinate system] (M4G3) → 4th (2B)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C)	8th	
3.19: Equipollent Systems of Vectors	[vector graphics] (MA3A10) → 11th (2H) → To be taught as a special math topic	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C)	9th	
3.20: Further Reduction of a System of Forces	[coordinate system] (M4G3) → 4th (2B)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C)	8th	

Table 2. Statics Topics List (Continued).

Engineering Subject: Statics				
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**	**Sec**	**Ch**
Chapter 3: Rigid Bodies - Equivalent Systems of Forces (Continued)				
3.21: Reduction of a System of Forces to a Wrench $p=\frac{M_1}{R}\quad M_1=\frac{\vec{R}\bullet\vec{M}_O^R}{R}\quad p=\frac{M_1}{R}=\frac{\vec{R}\bullet\vec{M}_O^R}{R^2}$ $\vec{M}_1=p\vec{R}\ \rightarrow\ \vec{M}_1+\vec{r}\times\vec{R}=\vec{M}_O^R$ $p\vec{R}+\vec{r}\times\vec{R}=\vec{M}_O^R$	[four operations] (M1N3) → 1st (1A) + (M2N3) → 2nd (2A) [geometry: point, axis/line, 3D body] (M6G1) (M6G2) (M6M3) → 6th (2B) [trigonometric functions] (MA2G2) → 10th (2F) → To be taught as a special math topic [dot product] → To be taught as a special math topic [cross product] → To be taught as a special math topic	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [motion] (SKP2) → K (2A) [lever] (S4P3) → 4th (2A)	9th	9th
Chapter 4: Equilibrium of Rigid Bodies				
4.1: Introduction $\sum\vec{F}=0\quad\sum F_x=0\quad\sum F_y=0\quad\sum F_z=0$ $\sum\vec{M}_O=\sum(\vec{r}\times\vec{F})=0\quad\sum M_x=0\quad\sum M_y=0\quad\sum M_z=0$	[sigma notation] (M6N1) → 6th (1A) or (MA1A3) → 9th (2E) → To be taught as a special math topic [coordinate system] (M4G3) → 4th (2B)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [Newton's 3rd Law: Action and Reaction] (SP1) → 9th (3C)	9th	9th
4.2: Free-Body Diagram				
Equilibrium in Two Dimensions **4.3: Reactions at Supports and Connections for a Two-Dimensional Structure**				
4.4: Equilibrium of a Rigid Body in Two Dimensions $F_z=0\quad M_x=M_y=0\quad M_z=M_O$ $\sum F_x=0\quad\sum F_y=0\quad\sum M_O=0$ $\sum M_A=0\quad\sum M_B=0\quad\sum M_C=0$				
4.5: Statically Indeterminate Reactions. Partial Constraints				
4.6: Equilibrium of a Two-Force Body				
4.7: Equilibrium of a Three-Force Body				

Table 2. Statics Topics List (Continued).

Engineering Subject: Statics				
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**	**Sec**	**Ch**
Chapter 4: Equilibrium of Rigid Bodies (Continued)				
<u>Equilibrium in Three Dimensions</u> **4.8: Equilibrium of a Rigid Body in Three Dimensions** $\sum \vec{F}=0 \quad \sum \vec{M}_O=\sum(\vec{r}\times\vec{F})=0$ $\sum F_x=0 \quad \sum F_y=0 \quad \sum F_z=0$ $\sum M_x=0 \quad \sum M_y=0 \quad \sum M_z=0$ **4.9: Reactions at Supports and Connections for a Three-Dimensional Structure**	[sigma notation] (M6N1) → 6th (1A) or (MA1A3) → 9th (2E) → To be taught as a special math topic [coordinate system] (M4G3) → 4th (2B)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [Newton's 3rd Law: Action and Reaction] (SP1) → 9th (3C)	9th	9th
Chapter 5: Distributed Forces: Centroids and Centers of Gravity				
5.1: Introduction **<u>Areas and Lines</u>** **5.2: Center of Gravity of a Two-Dimensional Body** $Plate: \ \sum F_z: \ W=\Delta W_1+\Delta W_2+...+\Delta W_n$ $\sum M_y: \ \bar{x}W=x_1\Delta W+x_2\Delta W+...+x_n\Delta W$ $\sum M_x: \ \bar{y}W=y_1\Delta W+y_2\Delta W+...+y_n\Delta W$ $W=\int dW \quad \bar{x}W=\int xdW \quad \bar{y}W=\int ydW$ $Wire: \ \sum M_y: \ \bar{x}W=\sum x\Delta W \quad \sum M_x: \ \bar{y}W=\sum y\Delta W$	[coordinate system] (M4G3) → 4th (2B) [sigma notation] (M6N1) → 6th (1A) or (MA1A3) → 9th (2E) → To be taught as a special math topic [integration] → 12th (To be taught)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [Newton's Law of Gravitation] (S8P5) → 8th (3C)	PS	PS
5.3: Centroids of Areas and Lines $Plate: \ \Delta W=\gamma t\Delta A \quad W=\gamma tA \quad \bar{x}A=\int xdA \quad \bar{y}A=\int ydA$ $Line: \ \Delta W=\gamma a\Delta L \quad \bar{x}L=\int xdL \quad \bar{y}L=\int ydL$	[measurement: area, weight, thickness] (M6M1) (M6M2) → 6th (2C) [integration] → 12th (To be taught)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [Newton's Law of Gravitation] (S8P5) → 8th (3C)	PS	

Table 2. Statics Topics List (Continued).

Engineering Subject: Statics				
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**	**Sec**	**Ch**
Chapter 5: Distributed Forces: Centroids and Centers of Gravity (Continued)				
5.4: First Moments of Areas and Lines $\bar{x}A = Q_y = \int x dA \quad \bar{y}A = Q_x = \int y dA$	[integration] → 12th (To be taught) [coordinate system] (M4G3) → 4th (2B) [two-dimensional figures: circle, arc, triangle, ellipse, parabolic] (M1G1) (M1G2) → 1st (1B) + (MA2G4) → 10th (2F) → To be taught as a special math topic [special two-dimensional figures: parabolic spandrel, general spandrel] → To be taught as a special math topic	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [Newton's Law of Gravitation] (S8P5) → 8th (3C)	PS	PS
5.5: Composite Plates and Wires $\bar{X}\sum W = \sum \bar{x}W \quad \bar{Y}\sum W = \sum \bar{y}W$ $Q_y = \bar{X}\sum A = \sum \bar{x}A \quad Q_x = \bar{Y}\sum A = \sum \bar{y}A$	[coordinate system] (M4G3) → 4th (2B) [sigma notation] (M6N1) → 6th (1A) or (MA1A3) → 9th (2E) → To be taught as a special math topic [measurement: area, weight, thickness] (M6M1) (M6M2) → 6th (2C)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [Newton's Law of Gravitation] (S8P5) → 8th (3C)	PS	
5.6: Determination of Centroids by Integration $Q_y = \bar{x}A = \int \bar{x}_{el} dA \quad Q_x = \bar{y}A = \int \bar{y}_{el} dA$	[integration] → 12th (To be taught) [coordinate system] (M4G3) → 4th (2B) [areas of geometric shapes: circle, triangle, etc.] (M5M1) → 5th and (2B) (M6M2) → 6th (2C)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [Newton's Law of Gravitation] (S8P5) → 8th (3C)	PS	
5.7: Theorems of Pappus-Guldinus $A = 2\pi\bar{y}L \quad V = 2\pi\bar{y}A$	[integration: area of surface of revolution, curve, volume of body of revolution] → 12th (To be taught)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [Newton's Law of Gravitation] (S8P5) → 8th (3C)	PS	
5.8: Distributed Loads on Beams $W = \int_O^L w dx \quad W = \int dA = A \quad (OP)W = \int x dW \quad (OP)A = \int_O^L x dA$	[coordinate system] (M4G3) → 4th (2B) [integration] → 12th (To be taught) [areas of geometric shapes: circle, triangle, etc.] (M5M1) → 5th and (2B) (M6M2) → 6th (2C)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [Newton's Law of Gravitation] (S8P5) → 8th (3C)	PS	
5.9: Forces on Submerged Surfaces $w = bp = b\gamma h$	[areas of geometric shapes: circle, triangle, etc.] (M5M1) → 5th and (2B) (M6M2) → 6th (2C)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C)	8th → PS	

Table 2. Statics Topics List (Continued).

Engineering Subject: Statics				
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**	**Sec**	**Ch**
Chapter 5: Distributed Forces: Centroids and Centers of Gravity (Continued)				
Volumes **5.10: Center of Gravity of a Three- Dimensional Body. Centroid of a Volume** $\bar{x}W = \int x dW \quad \bar{y}W = \int y dW \quad \bar{z}W = \int z dW$ $\bar{x}V = \int x dV \quad \bar{y}V = \int y dV \quad \bar{z}V = \int z dV$	[coordinate system] (M4G3) → 4^{th} (2B) [volume: sphere, cone, pyramid] (M5M4) → 5^{th} (1B) (M6M3) → 6^{th} (2B) (MA1G5) → 9^{th} (2F) [volume: ellipsoid, paraboloid] → To be taught as a special math topic [integration] → 12^{th} (To be taught) [integration: area of surface of revolution, curve, volume of body of revolution] → 12^{th} (To be taught)	[force] (S4P3) → 4^{th} (3A) or (S8P3) → 8^{th} (3C) [Newton's Law of Gravitation] (S8P5) → 8^{th} (3C)	PS	PS
5.11: Composite Bodies $\bar{X}\sum W = \sum \bar{x}W \quad \bar{Y}\sum W = \sum \bar{y}W \quad \bar{Z}\sum W = \sum \bar{z}W$ $\bar{X}\sum V = \sum \bar{x}V \quad \bar{Y}\sum V = \sum \bar{y}V \quad \bar{Z}\sum V = \sum \bar{z}V$				
5.12: Determination of Centroids of Volumes by Integration $\bar{x}V = \int \bar{x}_{el} dV \quad \bar{y}V = \int \bar{y}_{el} dV \quad \bar{z}V = \int \bar{z}_{el} dV \quad \bar{x}V = \int \bar{x}_{el} dV$				
Chapter 6: Analysis of Structures				
6.1: Introduction	[sigma notation] (M6N1) → 6^{th} (1A) or (MA1A3) → 9^{th} (2E) → To be taught as a special math topic [four operations] (M1N3) → 1^{st} (1A) + (M2N3) → 2^{nd} (1A), or (M7N1) → 7^{th} (2A) [coordinate system] (M4G3) → 4^{th} (2B)	[force] (S4P3) → 4^{th} (3A) or (S8P3) → 8^{th} (3C) [Newton's 3^{rd} Law: Action and Reaction] (SP1) → 9^{th} (3C)	9^{th}	9^{th}
Trusses **6.2: Definition of a Truss**				
6.3: Simple Trusses				
6.4: Analysis of Trusses by the Method of Joints				
6.5: Joints under Special Loading Conditions				
6.6: Space Trusses				
6.7: Analysis of Trusses by the Method of Sections				
6.8: Trusses Made of Several Simple Trusses				
Frames and Machines **6.9: Structures Containing Multiforce Members**	[trigonometric functions] (MA2G2) → 10^{th} (2F) [coordinate system] (M4G3) → 4^{th} (2B) [sigma notation] (M6N1) → 6^{th} (1A) or (MA1A3) → 9^{th} (2E) → To be taught as a special math topic [four operations] (M1N3) → 1^{st} (2A) + (M2N3) → 2^{nd} (1A), or (M7N1) → 7^{th} (2A)	[force] (S4P3) → 4^{th} (3A) or (S8P3) → 8^{th} (3C) [Newton's 3^{rd} Law: Action and Reaction] (SP1) → 9^{th} (3C)	9^{th}	
6.10: Analysis of a Frame				
6.11: Frames Which Cease to Be Rigid When Detached from Their Supports				

Table 2. Statics Topics List (Continued).

Engineering Subject: Statics				
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**	**Sec**	**Ch**
Chapter 6: Analysis of Structures (Continued)				
6.12: Machines	[sigma notation] (M6N1) → 6th (1A) or (MA1A3) → 9th (2E) → To be taught as a special math topic [four operations] (M1N3) → 1st (2A) + (M2N3) → 2nd (1A), or (M7N1) → 7th (2A) [trigonometric functions] (MA2G2) → 10th (2F) → To be taught as a special math topic [coordinate system] (M4G3) → 4th (2B)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [Newton's 3rd Law: Action and Reaction] (SP1) → 9th (3C)	9th	9th
Chapter 7: Forces in Beams and Cables				
7.1: Introduction **7.2: Internal Forces in Members** **<u>Beams</u>** **7.3: Various Types of Loading and Support** **7.4: Shear and Bending Moment in a Beam** **7.5: Shear and Bending-Moment Diagrams**	[sigma notation] (M6N1) → 6th (1A) or (MA1A3) → 9th (2E) → To be taught as a special math topic [four operations] (M1N3) → 1st (2A) + (M2N3) → 2nd (2A), or (M7N1) → 7th (2A) [integration] → 12th (To be taught)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C)	PS	PS
7.6: Relations among Load, Shear, and Bending Moment $\frac{dV}{dx} = -w$ $V_D - V_C = -\int_{x_C}^{x_D} w dx = -wx = =$ -(Area under load curve between C an D) $\frac{dM}{dx} = V$ $M_D - M_C = \int_{x_C}^{x_D} V dx = -$(Area under shear curve between C an D)	[sigma notation] (M6N1) → 6th (1A) or (MA1A3) → 9th (2E) → To be taught as a special math topic [four operations] (M1N3) → 1st (1A) + (M2N3) → 2nd (1A), or (M7N1) → 7th (2A) [integration] → 12th (to be taught) [differentiation] → 12th (to be taught)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C)	PS	

Table 2. Statics Topics List (Continued).

Engineering Subject: Statics				
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**	**Sec**	**Ch**
Chapter 7: Forces in Beams and Cables (Continued)				
Cables **7.7: Cables with Concentrated Loads** **7.8: Cables with Distributed Loads** $T\cos\theta = T_O \quad T\sin\theta = W \quad T = \sqrt{T_O^2 + W^2} \quad \tan\theta = \frac{W}{T_O}$ **7.9: Parabolic Cable** $y = \frac{wx^2}{2T_O}$	[sigma notation] (M6N1) → 6th (1A) or (MA1A3) → 9th (2E) → To be taught as a special math topic [trigonometric functions] (MA2G2) → 10th (2F) → To be taught as a special math topic [four operations] (M1N3) → 1st (2A) + (M2N3) → 2nd (2A), or (M7N1) → 7th (2A) [square root] (M8N1) → 8th (2A)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C)	8th	PS
7.10: Catenary $T = \sqrt{T_O^2 + w^2s^2} \quad c = \frac{T_O}{w} \quad T_O = wc \quad W = ws \quad T = w\sqrt{c^2 + s^2}$ $dx = ds\cos\theta = \frac{T_O}{T}ds = \frac{wcds}{w\sqrt{c^2+s^2}}$ $x = \int_O^S \frac{ds}{\sqrt{1+\frac{s^2}{c^2}}} = c\left[\sinh^{-1}\frac{s}{c}\right]_O^S = c\sinh^{-1}\frac{s}{c}$ $s = c\sinh\frac{x}{c} \quad y = c\cosh\frac{x}{c} \quad y^2 - s^2 = c^2 \quad T_O = wc \quad W = ws$ $T = wy \quad h = y_A = c$	[sigma notation] (M6N1) → 6th (1A) or (MA1A3) → 9th (2E) → To be taught as a special math topic [trigonometric functions] (MA2G2) → 9th (2F) [four operations] (M1N3) → 1st (2A) + (M2N3) → 2nd (2A), or (M7N1) → 7th (2A) [square root] (M8N1) → 8th (2A) [integration] → 12th (to be taught) [differentiation] → 12th (to be taught)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C)	PS	

Table 2. Statics Topics List (Continued).

Engineering Subject: Statics				
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**	**Sec**	**Ch**
Chapter 8: Friction				
8.1: Introduction	[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 [surface] (M6M4) → 6th (2B)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C)	9th	PS
8.2: The Laws of Dry Friction. Coefficients of Friction $F_m = \mu_s N \quad F_k = \mu_k N$				
8.3: Angles of Friction $\tan\phi_s = \frac{F_m}{N} = \frac{\mu_s N}{N} \rightarrow \tan\phi_s = \mu_s$ $\tan\phi_k = \frac{F_k}{N} = \frac{\mu_k N}{N} \rightarrow \tan\phi_k = \mu_k$				
8.4: Problems Involving Dry Friction				
8.5: Wedges				
8.6: Square-Threaded Screws $Q = P\frac{a}{r} \quad L = nP$				
8.7: Journal Bearings. Axle Friction $M = Rr\sin\phi_k \approx Rr\mu_k \quad r_f = r\sin\phi_k \approx r\mu_k$				
8.8: Thrust Bearings. Disk Friction $\Delta M = r\Delta F = \frac{r\mu_k P\Delta A}{\pi\left(R_2^2 - R_1^2\right)}$ $M = \frac{\mu_k P}{\pi\left(R_2^2 - R_1^2\right)}\int_0^{2\pi}\int_{R_1}^{R_2} r^2 dr d\theta = \frac{\mu_k P}{\pi\left(R_2^2 - R_1^2\right)}\int_0^{2\pi}\left[\frac{r^{2+1}}{2+1}\right]_{R_1}^{R_2} d\theta$ $= \frac{\mu_k P}{\pi\left(R_2^2 - R_1^2\right)}\int_0^{2\pi}\frac{1}{3}\left(R_2^3 - R_1^3\right)d\theta$ Ring area : $M = \frac{2}{3}\mu_k P\frac{R_2^3 - R_1^3}{R_2^2 - R_1^2}$ Full circle : $M = \frac{2}{3}\mu_k PR$	[four operations] (M1N3) → 1st (2A) + (M2N3) → 2nd (2A), or (M7N1) → 7th (2A) [integration] → 12th (to be taught)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C)	PS	
8.9: Wheel Friction. Rolling Resistance $\Pr = Wb$	[four operations] (M1N3) → 1st (2A) + (M2N3) → 2nd (2A), or (M7N1) → 7th (2A)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C)	8th	

Table 2. Statics Topics List (Continued).

Engineering Subject: Statics				
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**	**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)	[sigma notation] (M6N1) → 6th (1A) or (MA1A3) → 9th (2E) → To be taught as a special math topic [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

Table 2. Statics Topics List (Continued).

Engineering Subject: Statics				
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**	**Sec**	**Ch**
Chapter 9: Distributed Forces: Moments of Inertia				
9.1: Introduction **Moments of Inertia of Areas** **9.2: Second Moment, or Moment of Inertia, of an Area** $R=\int kydA=k\int ydA \quad M=\int ky^2dA=k\int y^2dA$ $R=\int \gamma ydA=\gamma\int ydA \quad M_x=\int y^2dA=\gamma\int y^2dA$ **9.3: Determination of the Moment of Inertia of an Area by Integration** $I_x=\int y^2dA \quad I_y=\int x^2dA \quad dA=b\,dy \quad dI_x=y^2b\,dy$ $I_x=\int_O^h by^2dy=\frac{1}{3}BH^3 \quad dI_x=\frac{1}{3}y^3dx \quad dI_y=x^2dA=x^2ydx$ **9.4: Polar Moment of Inertia** $J_O=\int r^2\,dA=\int\left(x^2+y^2\right)dA=\int y^2dA+\int x^2dA$ $J_O==I_x+I_y$ **9.5: Radius of Gyration of an Area** $I_x=k_x^2A \rightarrow k_x=\sqrt{\frac{I_x}{A}} \quad I_y=k_y^2A \rightarrow k_y=\sqrt{\frac{I_y}{A}}$ $J_O=k_O^2A \rightarrow k_O=\sqrt{\frac{J_O}{A}}$ **9.6: Parallel-Axis Theorem** $I=\int y^2dA$ $I=\int y^2dA=\int\left(y'+d\right)^2dA=\int y'^2\,dA+2d\int y'dA+d^2\int dA$ $I=\bar{I}+Ad^2 \quad k^2=\bar{k}^2+d^2 \quad J_O=\bar{J}_O+Ad^2 \quad or \quad k_O^2=\bar{k}_O^2+d^2$	[integration] → 12th (to be taught) [differentiation] → 12th (to be taught) [four operations] (M1N3) → 1st (2A) + (M2N3) → 2nd (2A), or (M7N1) → 7th (2A) [area] (M3M3) (M3M4) → 3rd (2B) [square root] (M8N1) → 8th (2A) [coordinate system] (M4G3) → 4th (2B) [areas of geometric shapes: circle, triangle] (M5M1) → 5th (2B) [geometric shapes: ellipse] (MA2G4) → 10th (2F) → To be taught as a special math topic [three-dimensional bodies: thin rectangular plate, rectangular prism] (M5M4) → 5th (2B) [three-dimensional bodies: slender rod, circular cylinder, cone] (M6M3) → 6th (2B) [three-dimensional bodies: circular cone, sphere] (M2G2) → 2nd (2B) [trigonometric functions] (MA2G2) → 10th (2F) → To be taught as a special math topic [cross product] → To be taught as a special math topic [partial differentiation] → 12th (to be taught) [gradient: "del"] → 12th (to be taught) [linear algebra] (MA2A6) (MA2A7) (MA2A8) (MA2A9) → 10th (2G)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [power] (SP3) → 9th (3C)	PS	PS

Table 2. Statics Topics List (Continued).

Engineering Subject: Statics				
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**	**Sec**	**Ch**
Chapter 9: Distributed Forces: Moments of Inertia (Continued)				
9.7: Moments of Inertia of Composite Areas (Formulas for moments of inertia of common geometric shapes can be found on page 485) **9.8: Product of Inertia** $I_{xy} = \int xy \; dA = \int (x'+\bar{x})(y'+\bar{y})dA$ $= \int x'y'dA + \bar{y}\int x'dA + \bar{x}\int y'dA + \bar{x}\bar{y}\int dA$ $I_{xy} == \bar{I}_{x'y'} + \bar{x}\bar{y}A$ **9.9: Principal Axes and Principal Moments of Inertia** (Formulas for principle axis and principle moments of inertia can be found on pages 498-500) **9.10: Mohr's Circle for Moments and Products of Inertia** **<u>Moments of Inertia of Masses</u>** **9.11: Moment of Inertia of a Mass** $I = \int r^2 dm \quad I = k^2 m \quad or \quad k = \sqrt{\frac{I}{m}}$ $I_x = \int (y^2 + z^2)dm \quad I_y = \int (z^2 + x^2)dm$ $I_z = \int (x^2 + y^2)dm$ Note: This Chapter involves substantial amount of calculus-based computations; and is most likely beyond high school students' mathematics skill level.	[integration] → 12th (to be taught) [differentiation] → 12th (to be taught) [four operations] (M1N3) → 1st (2A) + (M2N3) → 2nd (2A), or (M7N1) → 7th (2A) [area] (M3M3) (M3M4) → 3rd (2B) [square root] (M8N1) → 8th (2A) [coordinate system] (M4G3) → 4th (2B) [areas of geometric shapes: circle, triangle] (M5M1) → 5th (2B) [geometric shapes: ellipse] (MA2G4) → 10th (2F) → To be taught as a special math topic [three-dimensional bodies: thin rectangular plate, rectangular prism] (M5M4) → 5th (2B) [three-dimensional bodies: slender rod, circular cylinder, cone] (M6M3) → 6th (2B) [three-dimensional bodies: circular cone, sphere] (M2G2) → 2nd (2B) [trigonometric functions] (MA2G2) → 10th (2F) → To be taught as a special math topic [cross product] → To be taught as a special math topic [partial differentiation] → 12th (to be taught) [gradient: "del"] → 12th (to be taught) [linear algebra] (MA2A6) (MA2A7) (MA2A8) (MA2A9) → 10th (2G) → To be taught as a special math topic	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [power] (SP3) → 9th (3C)	PS	PS

Table 2. Statics Topics List (Continued).

Engineering Subject: Statics				
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**	**Sec**	**Ch**
Chapter 9: Distributed Forces: Moments of Inertia (Continued)				
9.12: Parallel-Axis Theorem $x = x' + \bar{x} \quad y = y' + \bar{y} \quad z = z' + \bar{z}$ $I_x = \int (y^2 + z^2) dm$ $I_x = \bar{I}_{x'} + m(\bar{y}^2 + \bar{z}^2) = \int [(y'+\bar{y})^2 + (z'+\bar{z})^2] dm$ $= \int (y'^2 + z'^2) dm + 2\bar{y}\int y'\, dm + 2\bar{z}\int z'\, dm + (\bar{y}^2+\bar{z}^2)\int dm$ $I_y = \bar{I}_{y'} + m(\bar{z}^2+\bar{x}^2) \quad I_z = \bar{I}_{z'} + m(\bar{x}^2+\bar{y}^2)$ $I = \bar{I} + md^2 \quad k^2 = \bar{k}^2 + d^2$	[integration] → 12th (to be taught) [differentiation] → 12th (to be taught) [four operations] (M1N3) → 1st (2A) + (M2N3) → 2nd (2A), or (M7N1) → 7th (2A) [area] (M3M3) (M3M4) → 3rd (2B) [square root] (M8N1) → 8th (2A) [coordinate system] (M4G3) → 4th (2B) [areas of geometric shapes: circle, triangle] (M5M1) → 5th (2B) [geometric shapes: ellipse] (MA2G4) → 10th (2F) → To be taught as a special math topic [three-dimensional bodies: thin rectangular plate, rectangular prism] (M5M4) → 5th (2B) [three-dimensional bodies: slender rod, circular cylinder, cone] (M6M3) → 6th (2B) [three-dimensional bodies: circular cone, sphere] (M2G2) → 2nd (2B) [trigonometric functions] (MA2G2) → 10th (2F) → To be taught as a special math topic [cross product] → To be taught as a special math topic [partial differentiation] → 12th (to be taught) [gradient: "del"] → 12th (to be taught) [linear algebra] (MA2A6) (MA2A7) (MA2A8) (MA2A9) → 10th (2G) → To be taught as a special math topic	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [power] (SP3) → 9th (3C)	PS	PS
9.13: Moments of Inertia of Thin Plates $\left.\begin{array}{l} I_{AA',mass} = \int r^2 dm \\ dm = \rho t\, dA \end{array}\right\} I_{AA',mass} = \rho t \int r^2 dA$ $I_{AA',mass} = \rho t I_{AA',area} \quad I_{BB',mass} = \rho t I_{BB',area}$ $I_{CC',mass} = \rho t J_{C,area} \quad I_{CC'} = I_{AA'} + I_{BB'}$ Rectangular Plate $I_{AA',mass} = \rho t I_{AA',area} = \rho t\left(\frac{1}{12}a^3 b\right) \quad I_{BB',mass} = \rho t I_{BB',area} = \rho t\left(\frac{1}{12}ab^3\right)$ $I_{AA'} = \frac{1}{12}ma^2 \quad I_{BB'} = \frac{1}{12}mb^2 \quad I_{CC'} = I_{AA'} + I_{BB'} = \frac{1}{12}m(a^2+b^2)$ Circular Plate $I_{AA',mass} = \rho t I_{AA',area} = \rho t\left(\frac{1}{4}\pi r^4\right) \quad I_{AA'} = I_{BB'} = \frac{1}{4}mr^2$ $I_{CC'} = I_{AA'} + I_{BB'} = \frac{1}{12}mr^2$				

Table 2. Statics Topics List (Continued).

Engineering Subject: Statics				
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**	**Sec**	**Ch**
Chapter 9: Distributed Forces: Moments of Inertia (Continued)				
9.14: Determination of the Moment of Inertia of a Three-Dimensional Body by Integration (Formulas for mass moments of inertia of common geometric shapes can be found on page 517).	[integration] → 12th (to be taught) [differentiation] → 12th (to be taught) [four operations] (M1N3) → 1st (2A) + (M2N3) → 2nd (2A), or (M7N1) → 7th (2A) [area] (M3M3) (M3M4) → 3rd (2B) [square root] (M8N1) → 8th (2A) [coordinate system] (M4G3) → 4th (2B) [areas of geometric shapes: circle, triangle] (M5M1) → 5th (2B) [geometric shapes: ellipse] (MA2G4) → 10th (2F) → To be taught as a special math topic [three-dimensional bodies: thin rectangular plate, rectangular prism] (M5M4) → 5th (2B) [three-dimensional bodies: slender rod, circular cylinder, cone] (M6M3) → 6th (2B) [three-dimensional bodies: circular cone, sphere] (M2G2) → 2nd (1B) [trigonometric functions] (MA2G2) → 9th (2F) [cross product] → To be taught as a special math topic [partial differentiation] → 12th (to be taught) [gradient: "del"] → 12th (to be taught) [linear algebra] (MA2A6) (MA2A7) (MA2A8) (MA2A9) → 10th (2G) → To be taught as a special math topic	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [power] (SP3) → 9th (3C)	PS	PS
9.15: Moments of Inertia of Composite Bodies				
9.16: Moment of Inertia of a Body with Respect to an Arbitrary Axis through *O*. Mass Products of Inertia $I_{OL} = \int p^2 dm = \int \left\lvert \vec{\lambda} \times \vec{r} \right\rvert^2 dm$ $= \int \left[(\lambda_x y - \lambda_y x)^2 + (\lambda_y z - \lambda_z y)^2 + (\lambda_z x - \lambda_x z)^2 \right]$ $= \lambda_x^2 \int (y^2 + z^2) dm + \lambda_y^2 \int (z^2 + x^2) dm + \lambda_z^2 \int (x^2 + y^2) dm -$ $2\lambda_x \lambda_y \int xy\ dm - 2\lambda_y \lambda_z \int yz\ dm - 2\lambda_z \lambda_x \int zx\ dm$ $I_{xy} = \int xy\ dm \quad I_{yz} = \int yz\ dm \quad I_{zx} = \int zx\ dm$ $I_{OL} = I_x \lambda_x^2 + I_y \lambda_y^2 + I_z \lambda_z^2 - 2I_{xy} \lambda_x \lambda_y - 2I_{yz} \lambda_y \lambda_{yz} - 2I_{zx} \lambda_z \lambda_x$ $I_{xy} = \bar{I}_{x'y'} + m\bar{x}\bar{y} \quad I_{yz} = \bar{I}_{y'z'} + m\bar{y}\bar{z} \quad I_{zx} = \bar{I}_{z'x'} + m\bar{z}\bar{x}$				
9.17: Ellipsoid of Inertia. Principal Axes of Inertia $(OQ)\lambda_x = x \quad (OQ)\lambda_y = y \quad (OQ)\lambda_z = z$ $I_x x^2 + I_y y^2 + I_z z^2 - 2I_{xy} xy - 2I_{yz} yz - 2I_{zx} zx = 1$ $I_{x'} x'^2 + I_{y'} y'^2 + I_{z'} z'^2 = 1$ $I_{OL} = I_{x'} \lambda_{x'}^2 + I_{y'} \lambda_{y'}^2 + I_{z'} \lambda_{z'}^2$				

Table 2. Statics Topics List (Continued).

Engineering Subject: Statics				
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**	**Sec**	**Ch**
Chapter 9: Distributed Forces: Moments of Inertia (Continued)				
9.18: Determination of the Principal Axes and Principal Moments of Inertia of a Body of Arbitrary Shape $\left.\begin{array}{l}\nabla f = (2K)\vec{r} \\ K = \text{constant} \\ \vec{r} = x\hat{i} + y\hat{j} + z\hat{k}\end{array}\right\} \rightarrow \nabla f = \frac{\partial f}{\partial x}\hat{i} + \frac{\partial f}{\partial y}\hat{j} + \frac{\partial f}{\partial z}\hat{k}$ $f(x,y,z) = I_x x^2 + I_y y^2 + I_z z^2 - 2I_{xy}xy - 2I_{yz}yz - 2I_{zx}zx - 1$ ... $\begin{vmatrix} I_x - K & -I_{xy} & -I_{zx} \\ -I_{xy} & I_y - K & -I_{yz} \\ -I_{zx} & -I_{yz} & I_z - K \end{vmatrix} = 0$ (More calculus- and linear algebra- based formulas can be found n pages 534-535)	[integration] → 12th (to be taught) [differentiation] → 12th (to be taught) [four operations] (M1N3) → 1st (2A) + (M2N3) → 2nd (2A), or (M7N1) → 7th (2A) [area] (M3M3) (M3M4) → 3rd (2B) [square root] (M8N1) → 8th (1A) [coordinate system] (M4G3) → 4th (2B) [areas of geometric shapes: circle, triangle] (M5M1) → 5th (2B) [geometric shapes: ellipse] (MA2G4) → 10th (2F) → To be taught as a special math topic [three-dimensional bodies: thin rectangular plate, rectangular prism] (M5M4) → 5th (2B) [three-dimensional bodies: slender rod, circular cylinder, cone] (M6M3) → 6th (2B) [three-dimensional bodies: circular cone, sphere] (M2G2) → 2nd (2B) [trigonometric functions] (MA2G2) → 10th (2F) → To be taught as a special math topic [cross product] → To be taught as a special math topic [partial differentiation] → 12th (to be taught) [gradient: "del"] → 12th to be taught) [linear algebra] (MA2A6) (MA2A7) (MA2A8) (MA2A9) → 10th (2G) → To be taught as a special math topic	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [power] (SP3) → 9th (3C)	PS	PS

Table 2. Statics Topics List (Continued).

Engineering Subject: Statics				
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**	**Sec**	**Ch**
Chapter 10: Method of Virtual Work				
10.1: Introduction	[integration] → 12^{th} (to be taught) [differentiation] → 12^{th} (to be taught) [trigonometric functions] (MA2G2) → 10^{th} (2F) → To be taught as a special math topic [dot product] → To be taught as a special math topic [coordinate system] (M4G3) → 4^{th} (2B) [partial differentiation] → 12^{th} (to be taught)	[force] (S4P3) → 4^{th} (3A) or (S8P3) → 8^{th} (3C) [work] (S8P3) → 8^{th} (3C) [potential energy] (SP3) → 9^{th} (3C)	PS	PS
10.2: Work of a Force $dU = \vec{F} \bullet d\vec{x} \quad dU = F\, ds \cos\alpha \quad dU = M\ d\theta$				
10.3: Principle of Virtual Work $\delta U = \vec{F}_1 \bullet \delta\vec{r} + \vec{F}_2 \bullet \delta\vec{r} + ... + \vec{F}_n \bullet \delta\vec{r}$ $= \left(\vec{F}_1 + \vec{F}_2 + ... + \vec{F}_n\right) \bullet \delta\vec{r} \quad \rightarrow \quad \delta U = \vec{R} \bullet \delta\vec{r}$				
10.4: Applications of the Principle of Virtual Work $x_B = 2\ell \sin\theta \quad y_C = \ell \cos\theta$ $\delta x_B = 2\ell \cos\theta \delta\theta \quad \delta y_C = -\ell \sin\theta \delta\theta$ $\delta U = \delta U_Q + \delta U_P = -Q\delta x_B - P\delta y_C$ $= -2Q\ell \cos\theta\ \delta\theta + P\ell \sin\theta\ \delta\theta$ $\delta U = 0 \quad \rightarrow$ $2Q\ell \cos\theta\ \delta\theta = P\ell \sin\theta\ \delta\theta \quad \rightarrow \quad Q = \frac{1}{2} P \tan\theta$ $B_x = -\frac{1}{2} P \tan\theta$				
10.5: Real Machines. Mechanical Efficiency $\delta U = -Q\delta x_B - P\delta y_C - F\delta x_B$ $= -2Q\ell \cos\theta\ \delta\theta + P\ell \sin\theta\ \delta\theta - \mu P\ell \cos\theta\ \delta\theta$ $\delta U = 0 \quad \rightarrow \quad 2Q\ell \cos\theta\ \delta\theta = P\ell \sin\theta\ \delta\theta - \mu P\ell \cos\theta\ \delta\theta \quad \rightarrow$ $\eta = \frac{\text{output work}}{\text{input work}} = \frac{2Q\ell \cos\theta\ \delta\theta}{P\ell \sin\theta\ \delta\theta}$ $\eta = \frac{2\left(\frac{1}{2} P(\tan\theta - \mu)\right)\ell \cos\theta\ \delta\theta}{P\ell \sin\theta\ \delta\theta} = \frac{P(\tan\theta - \mu)\ell \cos\theta\ \delta\theta}{P\ell \sin\theta\ \delta\theta} = 1 - \mu \cot\theta$				

Table 2. Statics Topics List (Continued).

Engineering Subject: Statics				
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**	**Sec**	**Ch**
Chapter 10: Method of Virtual Work (Continued)				
10.6: Work of a Force during a Finite Displacement $dU = \vec{F} \bullet d\vec{r} \quad \rightarrow \quad U_{1\rightarrow 2} = \int_{A_1}^{A_2} \vec{F} \bullet d\vec{r}$ $dU = F\,ds\cos\alpha \quad \rightarrow \quad U_{1\rightarrow 2} = \int_{S_1}^{S_2} (F\cos\alpha)ds$ $dU = Md\theta \quad \rightarrow \quad U_{1\rightarrow 2} = \int_{\theta_1}^{\theta_2} M\,d\theta \quad U_{1\rightarrow 2} = M(\theta_2 - \theta_1)$ Work of a weight $dU = -W\,dy \quad \rightarrow \quad U_{1\rightarrow 2} = -\int_{y_1}^{y_2} W\,dy \quad U_{1\rightarrow 2} = -W(y_2 - y_1) = -W\,\Delta y$ Work of the force exerted by a spring $F = kx \quad \rightarrow \quad dU = -F\,dx = -kx\,dx$ $U_{1\rightarrow 2} = -\int_{x_1}^{x_2} kx\,dx = \frac{1}{2}kx_1^2 - \frac{1}{2}kx_2^2 \quad U_{1\rightarrow 2} = -\frac{1}{2}(F_1 + F_2)\Delta x$	[integration] → 12th (to be taught) [differentiation] → 12th (to be taught) [trigonometric functions] (MA2G2) → 10th (2F) → To be taught as a special math topic [dot product] → To be taught as a special math topic [coordinate system] (M4G3) → 4th (2B) [partial differentiation] → 12th (to be taught)	[force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) [work] (S8P3) → 8th (3C) [potential energy] (SP3) → 9th (3C)	PS	PS
10.7: Potential Energy $U_{1\rightarrow 2} = (V_g)_1 - (V_g)_2 \quad \leftarrow \quad V_g = Wy$ $U_{1\rightarrow 2} = (V_e)_1 - (V_e)_2 \quad \leftarrow \quad V_e = \frac{1}{2}kx^2$ $dU = -dV \quad U_{1\rightarrow 2} = V_1 - V_2$				

Table 2. Statics Topics List (Continued).

Engineering Subject: Statics				
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**	**Sec**	**Ch**
Chapter 10: Method of Virtual Work (Continued)				
10.8: Potential Energy and Equilibrium $\frac{dV}{d\theta}=0 \quad V_e=\frac{1}{2}kx_B^2 \quad V_g=Wy_C \quad x_B=2\ell\sin\theta \quad y_C=\ell\cos\theta$ $V_e=\frac{1}{2}k(2\ell\sin\theta)^2 \quad V_g=W(\ell\cos\theta)$ $V=V_e+V_g=2k\ell^2\sin^2\theta+W\ell\cos\theta$ $\frac{dV}{d\theta}=4k\ell^2\sin\theta\cos\theta-W\ell\sin\theta=0$ $\frac{dV}{d\theta}=\ell\sin\theta(4k\ell\cos\theta-W)=0$	[integration] → 12th (to be taught) [differentiation] → 12th (to be taught) [trigonometric functions] (MA2G2) → 10th (2F) → To be taught as a special math topic [dot product] → To be taught as a special math topic [coordinate system] (M4G3) → 4th (2B) [partial differentiation] → 12th (to be taught)	[force] (S4P3) → 4th (2A) or (S8P3) → 8th (3C) [work] (S8P3) → 8th (3C) [potential energy] (SP3) → 9th (3C)	PS	PS
10.9: Stability of Equilibrium $\frac{dV}{d\theta}=0 \quad \frac{d^2V}{d\theta^2}>0:\text{stable equilibrium}$ $\frac{dV}{d\theta}=0 \quad \frac{d^2V}{d\theta^2}<0:\text{unstable equilibrium}$ $\frac{\partial V}{\partial\theta_1}=\frac{\partial V}{\partial\theta_2}=0 \quad \left(\frac{\partial^2V}{\partial\theta_1\partial\theta_2}\right)^2-\frac{\partial^2V}{\partial\theta_1^2}\frac{\partial^2V}{\partial\theta_2^2}<0$ $\frac{\partial^2V}{\partial\theta_1^2}>0 \quad \text{or} \quad \frac{\partial^2V}{\partial\theta_2^2}>0$				
TE END				

Table 3A. Pre-Calculus Based Statics Topics That Possibly Could Be Taught at 9th Grade

Chapter/Section	Page Numbers	Number of Pages
Chapter 1: Introduction (pp. 1-13 → 13 pages sub-total. 6 sections out of 6)		
1.1: What Is Mechanics?	1-13	13
1.2: Fundamental Concepts and Principles		
1.3: Systems of Units		
1.4: Conversion from One System of Units to Another		
1.5: Method of Problem Solution		
1.6: Numerical Accuracy		
Chapter 2: Statics of Particles (pp. 15-63 → 49 pages sub-total. 15 sections out of 15)		
2.1: Introduction	15-63	49
2.2: Force on a Particle. Resultant of Two Forces		
2.3: Vectors		
2.4: Addition of Vectors		
2.5: Resultant of Several Concurrent Forces		
2.6: Resolution of a Force into Components		
2.7: Rectangular Components of a Force. Unit Vector		
2.8: Addition of Forces by Summing *x* and *y* Components		
2.9: Equilibrium of a Particle		
2.10: Newton's First Law of Motion		
2.11: Problems Involving the Equilibrium of a Particle. Free-Body Diagrams		
2.12: Rectangular Components of a Force in Space		
2.13: Force Defined by Its Magnitude and Two Points on Its Line of Action		
2.14: Addition of Concurrent Forces in Space		
2.15: Equilibrium of a Particle in Space		
Chapter 3: Rigid Bodies - Equivalent Systems of Forces (pp. 74-145 → 72 pages sub-total. 21 sections out of 21)		
3.1: Introduction	74-145	72
3.2: External and Internal Forces		
3.3: Principle of Transmissibility. Equivalent Forces		
3.4: Vector Product of Two Vectors		
3.5: Vector Products Expressed in Terms of Rectangular Components		
3.6: Moment of a Force about a Point		
3.7: Varignon's Theorem		
3.8: Rectangular Components of the Moment of a Force		
3.9: Scalar Product of Two Vectors		
3.10: Mixed Triple Product of Three Vectors		

Table 3A. Pre-Calculus Based Statics Topics That Possibly Could Be Taught at 9th Grade (Continued)

Chapter/Section	Page Numbers	Number of Pages
Chapter 3: Rigid Bodies - Equivalent Systems of Forces (Continued)		
3.11: Moment of a Force about a Given Axis	↑	↑
3.12: Moment of a Couple		
3.13: Equivalent Couples		
3.14: Addition of Couples		
3.15: Couples Can Be Represented by Vectors		
3.16: Resolution of a Given Force Into a Force at *O* and a Couple		
3.17: Reduction of a System of Forces to One Force and One Couple		
3.18: Equivalent Systems of Forces		
3.19: Equipollent Systems of Vectors		
3.20: Further Reduction of a System of Forces		
3.21: Reduction of a System of Forces to a Wrench		
Chapter 4: Equilibrium of Rigid Bodies (pp. 158-210 → 53 pages sub-total. 9 sections out of 9)		
4.1: Introduction	158-210	53
4.2: Free-Body Diagram		
4.3: Reactions at Supports and Connections for a Two-Dimensional Structure		
4.4: Equilibrium of a Rigid Body in Two Dimensions		
4.5: Statically Indeterminate Reactions. Partial Constraints		
4.6: Equilibrium of a Two-Force Body		
4.7: Equilibrium of a Three-Force Body		
4.8: Equilibrium of a Rigid Body in Three Dimensions		
4.9: Reactions at Supports and Connections for a Three-Dimensional Structure		
Chapter 5: Distributed Forces: Centroids & Centers of Gravity (pp. 219-273 → 55 pages sub-total. 0 sections out of 11)		
Chapter 6: Analysis of Structures (pp. 284-342 → 59 pages sub-total. 12 sections out of 12)		
6.1: Introduction	284-342	59
6.2: Definition of a Truss		
6.3: Simple Trusses		
6.4: Analysis of Trusses by the Method of Joints		
6.5: Joints under Special Loading Conditions		
6.6: Space Trusses		
6.7: Analysis of Trusses by the Method of Sections		
6.8: Trusses Made of Several Simple Trusses		
6.9: Structures Containing Multiforce Members		

Table 3A. Pre-Calculus Based Statics Topics That Possibly Could Be Taught at 9th Grade (Continued)

Chapter/Section	Page Numbers	Number of Pages
Chapter 6: Analysis of Structures (Continued)		
6.10: Analysis of a Frame	↑	↑
6.11: Frames Which Cease to Be Rigid When Detached from Their Supports		
6.12: Machines		
Chapter 7: Forces in Beams and Cables (pp. 353-401 → 49 pages sub-total. 0 sections out of 10)		
Chapter 8: Friction (pp. 411-460 → 50 pages sub-total. 8 sections out of 10)		
8.1: Introduction	411-441	31
8.2: The Laws of Dry Friction. Coefficients of Friction		
8.3: Angles of Friction		
8.4: Problems Involving Dry Friction		
8.5: Wedges		
8.6: Square-Threaded Screws		
8.7: Journal Bearings. Axle Friction		
8.9: Wheel Friction. Rolling Resistance	443-450	8
Chapter 9: Distributed Forces: Moments of Inertia (pp. 471-544 → 74 pages sub-total. 0 sections out of 18)		
Chapter 10: Method of Virtual Work (pp. 557-591→ 35 pages sub-total. 0 sections out of 9)		

Table 3A. Pre-Calculus Based Statics Topics That Possibly Could Be Taught at 9th Grade (Continued)

Summary	
Total Number of Pages Covered by Text (Excluding “Review and Summary for Chapters,” “Review Problems” and “Computer Problems Sections)	509
Total Numbers of Sections Covered Under All Chapters	71 out of 121
Percentage of Pre-Calculus Sections $\%_{\text{Pre-Calculus}} = \left(\dfrac{\text{Number of Pre-Calculus Sections}}{\text{Total Number of Sections}}\right)(100\%) = \left(\dfrac{71}{121}\right)(100\%) = 58.7\%$	
Total Numbers of Chapters Covered	6 out of 10
Percentage of Chapters with Pre-Calculus Sections $\%_{\text{Pre-Calculus}} = \left(\dfrac{\text{Number of Chapters with Pre-Calculus Sections}}{\text{Total Number of Chapters}}\right)(100\%) = \left(\dfrac{6}{10}\right)(100\%) = 60.0\%$	
Total Number of Pages Covered by Pre-Calculus Portion	285
Percentage of Pre-Calculus Volume $\%_{\text{Pre-Calculus}} = \left(\dfrac{\text{Number of Pre-Calculus Pages}}{\text{Total Number of Pages}}\right)(100\%) = \left(\dfrac{285}{509}\right)(100\%) = 56.0\%$	

Table 3B. Pre-Requisite Mathematics and Science Topics to Be Reviewed Before Teaching the Pre-Calculus Portion of Statics Topics to 9th 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**
1. [areas of geometric shapes: circle, triangle, etc.] (M5M1) → 5th and (2B) (M6M2) → 6th (2C) 2. [coordinate system] (M4G3) → 4th (2B) 3. [cross product] → To be taught as a special math topic 4. [dot product] → To be taught as a special math topic 5. [four operations] (M1N3) → 1st (2A) + (M2N3) → 2nd (1A), or (M7N1) → 7th (2A) 6. [geometry: point, axis/line, 3D body] (M6G1) (M6G2) (M6M3) → 6th (2B) 7. [linear algebra](MA2A6) (MA2A7) (MA2A8) (MA2A9) → 10th (2G) → To be taught as a special math topic 8. [measurement: time] (M2M2) → 2nd (2C) 9. [Parallelogram Law for the Addition of Force/Vector Graphics] (MA3A10) → 11th (2H) → To be taught as a special math topic 10. [percent] (M5N5) → 5th (2A) 11. [problem-solving] (M3N5) → 3rd (2A) 12. [sigma notation] (M6N1) → 6th (1A) or (MA1A3) → 9th (2E) → To be taught as a special math topic 13. [square root] (M8N1) → 8th (2A) 14. [surface] (M6M4) → 6th (2B) **15.** [trigonometric functions] (MA2G2) → 10th (2F) → To be taught as a special math topic [unit conversion] (M6M1) → 6th (2C) 16. [vector graphics] (MA3A10) → 9th (2H) → To be taught as a special math topic	1. [acceleration] (S8P3) → 8th (3C) 2. [force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) 3. [lever] (S4P3) → 4th (3A) 4. [motion] (SKP2) → K (3A) 5. [Newton's 1st, 2nd and 3rd Laws] (SP1) → 9th (3C) 6. [Newton's Law of Gravitation] (S8P5) → 8th (3C) 7. [scientific inquiry] (S7CS9) →7th (3B)

Table 4A. Calculus Based Statics Topics for Post-Secondary Engineering Education

Chapter/Section	Page Nos.	Chapter/Section	Page Nos.
Chapter 5: Distributed Forces: Centroids & Centers of Gravity		**Chapter 7: Forces in Beams and Cables**	
5.1: Introduction	219-273	7.1: Introduction	354-401
5.2: Center of Gravity of a Two-Dimensional Body		7.2: Internal Forces in Members	
5.3: Centroids of Areas and Lines		7.3: Various Types of Loading and Support	
5.4: First Moments of Areas and Lines		7.4: Shear and Bending Moment in a Beam	
5.5: Composite Plates and Wires		7.5: Shear and Bending-Moment Diagrams	
5.6: Determination of Centroids by Integration		7.6: Relations among Load, Shear, and Bending Moment	
5.7: Theorems of Pappus-Guldinus		7.7: Cables with Concentrated Loads	
5.8: Distributed Loads on Beams		7.8: Cables with Distributed Loads	
5.9: Forces on Submerged Surfaces		7.9: Parabolic Cable	
5.10: Center of Gravity of a Three- Dimensional Body. Centroid of a Volume		7.10: Catenary	
		Chapter 8: Friction	
5.11: Composite Bodies		8.8: Thrust Bearings. Disk Friction	442-443
5.12: Determination of Centroids of Volumes by Integration		8.10: Belt Friction	450-460
Chapter 9: Distributed Forces: Moments of Inertia			
9.1: Introduction	472-544	9.10: Mohr's Circle for Moments and Products of Inertia	←
9.2: Second Moment, or Moment of Inertia, of an Area		9.11: Moment of Inertia of a Mass	
9.3: Determination of the Moment of Inertia of an Area by Integration		9.12: Parallel-Axis Theorem	
9.4: Polar Moment of Inertia		9.13: Moments of Inertia of Thin Plates	
9.5: Radius of Gyration of an Area		9.14: Determination of the Moment of Inertia of a Three-Dimensional Body by Integration	
9.6: Parallel-Axis Theorem		9.15: Moments of Inertia of Composite Bodies	
9.7: Moments of Inertia of Composite Areas		9.16: Moment of Inertia of a Body with Respect to an Arbitrary Axis through *O*. Mass Products of Inertia	
9.8: Product of Inertia		9.17: Ellipsoid of Inertia. Principal Axes of Inertia	
9.9: Principal Axes and Principal Moments of Inertia		9.18: Determination of the Principal Axes and Principal Moments of Inertia of a Body of Arbitrary Shape	
Chapter 10: Method of Virtual Work			
10.1: Introduction	557-591	10.6: Work of a Force during a Finite Displacement	←
10.2: Work of a Force		10.7: Potential Energy	
10.3: Principle of Virtual Work		10.8: Potential Energy and Equilibrium	
10.4: Applications of the Principle of Virtual Work		10.9: Stability of Equilibrium	
10.5: Real Machines. Mechanical Efficiency			

Table 4B. Pre-Requisite Math and Science Topics to Be Reviewed Before Teaching the Calculus Portion of Statics 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. [areas of geometric shapes: circle, triangle, etc.] (M3M3) (M3M4) → 3rd (2B), (M5M1) → 5th and (2B) (M6M2) → 6th (2C) 2. [coordinate system] (M4G3) → 4th (2B) 3. [cross product] → To be taught as a special math topic 4. [differentiation] → 12th (to be taught) 5. [dot product] → To be taught as a special math topic 6. [four operations] (M1N3) → 1st (2A) + (M2N3) → 2nd (1A), or (M7N1) → 7th (2A) 7. [geometry: point, axis/line, 3D body] (M6G1) (M6G2) (M6M3) → 6th (2B) 8. [geometric shapes: ellipse] (MA2G4) → 10th (2F) → To be taught as a special math topic 9. [gradient: “del”] → 12th (to be taught) 10. [integration] → 12th (To be taught) 11. [integration: area of surface of revolution, curve, volume of body of revolution] → 12th (To be taught) 12. [linear algebra](MA2A6) (MA2A7) (MA2A8) (MA2A9) → 10th (2G) → To be taught as a special math topic 13. [logarithmic functions] (MA2A4) → 10th (2E) → To be taught as a special math topic 14. [measurement: area, weight, thickness] (M6M1) (M6M2) → 6th (2C) 15. [measurement: time] (M2M2) → 2nd (2C) 16. [Parallelogram Law for the Addition of Force/Vector Graphics] (MA3A10) → 11th (2H) → To be taught as special topic 17. [partial differentiation] → 12th (to be taught) 18. [percent] (M5N5) → 5th (2A) 19. [problem-solving] (M3N5) → 3rd (2A) 20. [sigma notation] (M6N1) → 6th (1A) or (MA1A3) → 9th (2E) → To be taught as a special math topic 21. [special two-dimensional figures: parabolic spandrel, general spandrel] → To be taught as a special math topic 22. [square root] (M8N1) → 8th (2A) 23. [surface] (M6M4) → 6th (2B) 24. [three-dimensional bodies: circular cone, sphere] (M2G2) → 2nd (2B) 25. [three-dimensional bodies: slender rod, circular cylinder, cone] (M6M3) → 6th (2B) 26. [three-dimensional bodies: thin rectangular plate, rectangular prism] (M5M4) → 5th (2B) 27. [trigonometric functions] (MA2G2) → 10th (2F) → To be taught as a special math topic 28. [two-dimensional figures: circle, arc, triangle, ellipse, parabolic] (M1G1) (M1G2) → 1st (1B) + (MA2G4) → 10th (2F) → To be taught as a special math topic **29.** [unit conversion] (M6M1) → 6th (2C) 30. [vector graphics] (MA3A10) → 9th (2H) → To be taught as a special math topic 31. [volume: sphere, cone, pyramid] (M5M4) → 5th (1B) (M6M3) → 6th (2B) 32. (MA1G5) → 9th (2F) 33. [volume: ellipsoid, paraboloid] → To be taught as a special math topic	1. [acceleration] (S8P3) → 8th (3C) 2. [force] (S4P3) → 4th (3A) or (S8P3) → 8th (3C) 3. [lever] (S4P3) → 4th (3A) 4. [motion] (SKP2) → K (3A) 5. [Newton’s 1st, 2nd and 3rd Laws] (SP1) → 9th (3C) 6. [Newton’s Law of Gravitation] (S8P5) → 8th (3C) 7. [potential energy] (SP3) → 9th (3C) 8. [power] (SP3) → 9th (3C) 9. [scientific inquiry] (S7CS9) → 7th (3B) 10. [work] (S8P3) → 8th (3C)

Conclusions and Recommendations

This report has presented (1) information about one popular college-level statics textbook (the first textbook or the "primary source of data) selected for the initial determination and selection of high school age-possible topics (Table 1), and (2) the outcomes of the research on the inclusion of mathematics, physics and chemistry concepts and skills needed for reading and homework assignments (Tables 2 through 4B). The following are recommended: (1) **Pilot study**: High schools could conduct pilot pedagogic experiments to determine the actual age-feasibility and age-appropriateness of all pre-calculus level statics-related analytic knowledge content identified in Table 3A (Pre-Calculus Based Statics Topics That Possibly Could Be Taught at 9th Grade), Table 3B (Pre-Requisite Mathematics and Science Topics to Be Reviewed Before Teaching the Pre-Calculus Portion of Statics Topics to 9th Grade Students), using the selected textbook; and K-12 mathematics and science teachers could use the same Tables as references to incorporate statics topics into respective curriculum; and (2) **Curriculum development**: Existing K-12 engineering and technology curriculum developers could use the same Tables as references for the development of new K-12 engineering instructional materials or for the incorporation of statics-related knowledge and skills into their previously developed instructional materials.

References

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