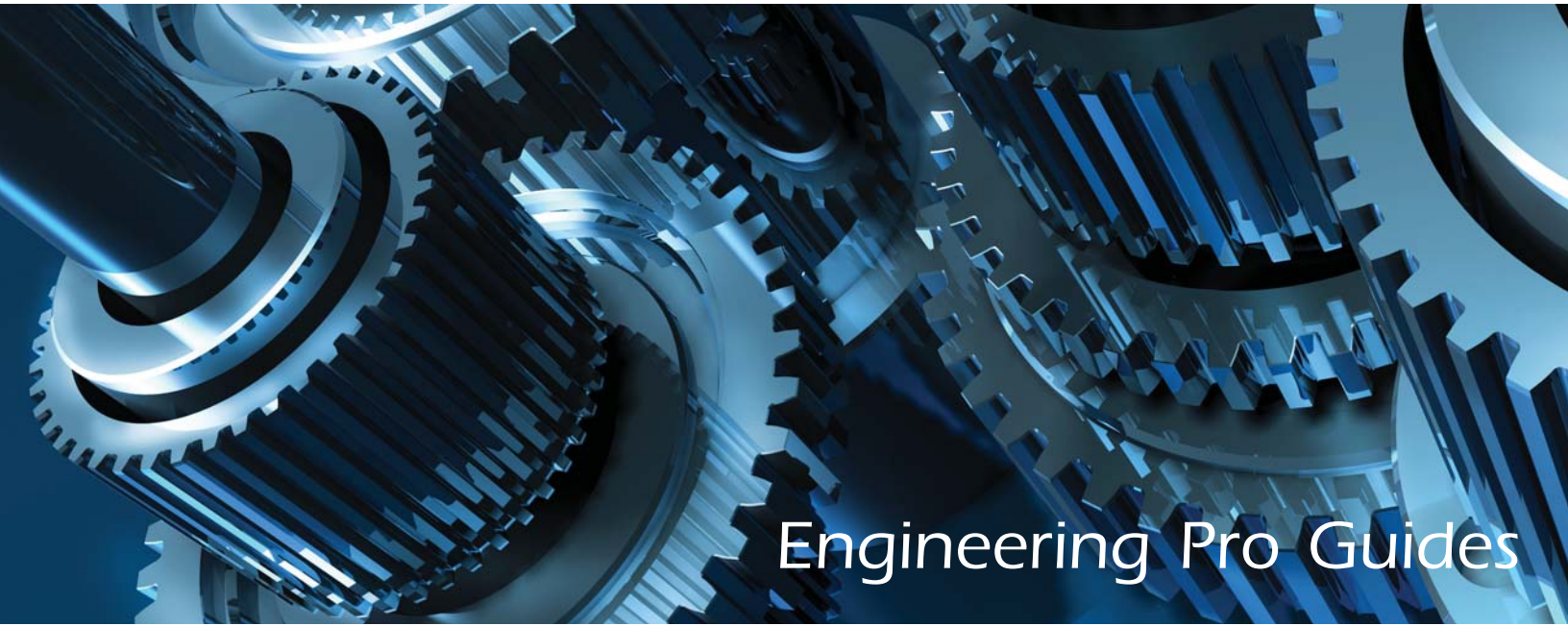# Mechanical
MDM References Exam
PE

Engineering Pro Guides

Machine Design & Materials
Supplemental Reference Lookup Practice Problems

- 40 reference specific exam problems
- Tests MDM References lookup for the MDM PE Exam
- Practice your familiarty and speed with MDM References
- Written in exam format with exam difficulty level
- Also includes detailed solutions

Justin Kauwale, P.E.

SECTION 1
INTRODUCTION

Introduction

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1.0 INTRODUCTION

One of the most important steps in an engineer's career is obtaining the professional engineering (P.E.) license. It allows an individual to legally practice engineering in the state of licensure. This credential can also help to obtain higher compensation and develop a credible reputation. In order to obtain a P.E. license, the engineer must first meet the qualifications as required by the state of licensure, including minimum experience, references and the passing of the National Council of Examiners for Engineering and Surveying (NCEES) exam. Engineering Pro Guides focuses on helping engineers pass the NCEES exam through the use of free content on the website, http://www.engproguides.com and through the creation of books like sample exams and guides that outline and teach you how to pass the PE exam.

The key to passing the PE exam is to learn the key concepts and skills that are tested on the exam. There are several issues that make this key very difficult. First, the key concepts and skills are unknown to most engineers studying for the exam. Second, the key concepts and skills are not contained in a single document. This technical guide teaches you the key concepts and skills required to pass the Machine Design & Materials Mechanical P.E. Exam.

1.1 KEY CONCEPTS AND SKILLS

How are the key concepts and skills determined?

The key concepts and skills taught and tested in the Technical Study Guide, References Exam and Full Exam were first developed through an analysis of the topics and information presented by NCEES. NCEES indicates on their website that the P.E. Exam will cover an AM exam (4 hours) followed by a PM exam (4 hours) and that the exam will be 80 questions long, 40 questions in the morning and 40 questions in the afternoon. The Machine Design & Materials Mechanical PE exam will focus on the following topics as indicated by NCEES. (http://ncees.org/engineering/pe/):

I.   Principles (40 questions)

A) Basic Engineering Practice *(9 questions)*
1   Engineering terms and symbols
2   Interpretation of technical drawings
3   Quality assurance/quality control (QA/QC)
4   Project management and economic analysis
5   Units and conversions
6   Design methodology (e.g., identifying requirements, risk assessment, verification/validation)
B) Engineering Science and Mechanics *(10 questions)*
1   Statics
2   Kinematics
3   Dynamics
C) Material Properties *(8 questions)*
1   Physical (e.g., density, melting point, optical)

    2   Chemical (e.g., corrosion, alloys, oxidation)

    3   Mechanical

        i)   Time-independent behavior (e.g., modulus, hardness, thermal expansion)

        ii) Time-dependent behavior (e.g., creep, viscoelastic, thermal conductivity)

D) Strength of Materials *(10 questions)*

    1   Stress/strain (e.g., tension, compression)

    2   Shear

    3   Bending

    4   Buckling

    5   Torsion

    6   Fatigue

    7   Failure theories (e.g., Von Mises, maximum shear stress)

E) Vibration *(3 questions)*

    1   Natural frequencies (e.g., linear, bending torsional) and acoustics

    2   Damping (e.g., frequency, damping ratio, critical damping)

    3   Forced vibrations (e.g., magnification factor, transmissibility, balancing, isolation)

II.   *Applications (40 questions)*

A. Mechanical Components (*18 questions*)

    1. Pressure vessels and piping (e.g., thick/thin wall)

    2. Bearings (e.g., types, lubrication analysis, life-load analysis)

    3. Gears (e.g., types, speed analysis, force analysis)

    4. Springs (e.g., types, force analysis, fatigue analysis)

    5. Dampers (e.g., types, selection)

    6. Belt, pulley and chain drives (e.g., types, force analysis)

    7. Clutches and brakes (e.g., types, torque/force analysis)

    8. Power screws (e.g., types, lifting and lowering torque, locking conditions)

    9. Shafts and keys (e.g., torsion, bending, static/fatigue failure, stress risers)

    10. Mechanisms (e.g., linkages, cams, slider crank, levers, force analysis, kinetic analysis)

    11. Basic mechatronics (e.g., electromechanical interfaces, sensors, basic circuits, basic controls)

    12. Hydraulic and pneumatic components (e.g., pumps, cylinders, presses)

    13. Motors and engines (e.g., energy conservation, efficiency)

B. Joints and Fasteners (*12 questions*)

    1. Welding and brazing (e.g., types, symbols, stress analysis)

    2. Bolts, screws, rivets (e.g., grade/class selection, preload, fastener group force analysis)

    3. Adhesives (e.g., types, analysis)

C. Supportive Knowledge (*10 questions*)

    1. Manufacturing processes (e.g., machining, molding, heat treatment)

    2. Fits and tolerances

    3. Codes and standards

    4. Computational methods and their limitations (e.g., FEA, CAE)

    5. Testing and instrumentation

Next, each of these broad topics were investigated and filtered for concepts and skills that met the following criteria:

(1) First, the concept and skill must be *commonly encountered* in the Machine Design & Materials field of study. For example, in the Machine Design & Materials field: Calculating stresses due to bending within a beam is a task that is regularly conducted, but the task of calculating the stress due to torsion in beams is not commonly encountered.

(2) Second, the skill and concept must be testable in roughly *6 minutes per problem*. There are (40) questions on the morning exam and you will be provided with 4 hours to complete the exam. The same is true for the afternoon portion of the exam. This results in an average of 6 minutes per problem. This criterion limits the complexity of the exam problems and the resulting solutions. For example, calculating the second moment of area in a 3-sided fillet weld is common in the Machine Design & Materials field, but the calculation is very lengthy because of the number of steps involved and is typically done on excel. Thus, you can eliminate these types of lengthy calculations and you can expect that questions that involve lengthy calculations will either give certain steps as given assumptions. The 6-minutes criterion and the low tech calculator also eliminates any complex mathematics.

(3) Third, the key concepts and skills must be used or be known by practicing Mechanical engineers in the Machine Design & Materials field. This criterion is similar to the first criterion. However, this criterion filters the concepts and skills further by limiting the field to material encountered and used by *practicing engineers*. The Machine Design & Materials fields are vast and there are many different avenues an engineer can take. Two diverging paths are those engineers involved in research and those who practice. Research engineers are pushing the boundaries of the field and are highly focused in their specific area of the field. The Professional Engineering exam does not cover emerging technologies or highly focused material. The exam focuses on material that practicing engineers may use in their day to day careers.

(4) The P.E. Exam must test the *principle or application* of the skill and concept and not the background knowledge of the topic or concept. The exam also does not cover background information on the NCEES topics. The P.E. Exam is meant to prove that the test taker is minimally competent to practice in the Mechanical Engineering – Machine Design field. The exam is less concerned with theory and more with the principle or application of the theory, skill or concept. For example, the P.E. exam is less concerned with the derivation of the beam deflection formulas and more concerned with your ability to use those formulas to determine deflection and stress.

In summary, the Technical Study Guide, Full Exam and References Exam are intended to teach and test the necessary skills and concepts required to be a minimally competent, practicing professional engineer in the Mechanical Engineering – Machine Design & Materials field.

1.2 UNITS

The primary units that are used in the P.E. Exam are United States Customary System Units (USCS). As such, this guide focuses exclusively on the USCS. However, it is recommended that the test taker have a conversion book, because certain areas of the P.E. Exam may use the International System of Units (SI).

2.0 DISCLAIMER

In no event will Engineering Pro Guides be liable for any incidental, indirect, consequential, punitive or special damages of any kind, or any other damages whatsoever, including, without limitation, those resulting from loss of profit, loss of contracts, loss of reputation, goodwill, data, information, income, anticipated savings or business relationships, whether or not Engineering Pro Guides has been advised of the possibility of such damage, arising out of or in connection with the use of this document or any referenced documents and/or websites.

This book was created on the basis of determining an independent interpretation of the minimum required knowledge and skills of a professional engineer. In no way does this document represent the National Council of Examiners for Engineers and Surveying views or the views of any other professional engineering society.

3.0 HOW TO USE THIS BOOK

First, it is recommended that the engineer in training gather the recommended references presented in the following section.

Engineering Pro Guides sample exams can be used in multiple ways, depending on where you are in your study process. If you are at the beginning or middle, it can be used to test your competency, gain an understanding and feel for the test format, and help to highlight target areas to study. If you are at the end, it can be used to determine your preparedness for the real exam. Remember that the questions are a sample of the many topics that may be tested and are limited to fit a full exam length and therefore is not comprehensive of all concepts.

Because the exam is written to be similar to the difficulty and format of the NCEES exam, it is recommended that the test be completed in one sitting and timed for (2) four hour sessions to simulate the real exam. This will give you a better indication of your status of preparation for the exam.

Review the exam day rules and replicate the environment for the real test as much as possible, including the type of calculator you may use and the acceptable references. Keep a watch or clock next to you to gauge your pace for 40 questions in 4 hours.

Based on the NCEES website, the following are general rules for exam day.

Allowed:

1. Snacks that are not disruptive to others
2. Watches and small clocks
3. Religious head coverings
4. Two straight edges: e.g. ruler, scale, protractor, triangle
5. Approved references
6. Approved calculator (2 recommended for backup)
7. Eyeglasses
8. Non electronic magnifying glass
9. (Units conversion book is also recommended)

Prohibited:

1. Cell phones
2. Hats and hoods
3. Slide charts, wheel charts, drafting compasses
4. Weapons
5. Tobacco
6. Personal Chairs
7. Eyeglass/Magnifying glass cases
8. Scratch Paper (all writing must be done in the exam booklet)

For additional references on exam day policies, exam day processes, and items to bring on your exam day, review the NCEES Examinee Guide:

http://ncees.org/exams/examinee-guide/

Similar to the NCEES exam, the tested topics are presented in a random order. For best use of your time, answer the questions that you know first and return to the questions that you are unfamiliar with later. Once all the known questions are answered, go through the test again and attempt to answer the remaining questions by level of difficulty. If time allots, review your answers.

If you are stuck on a question, seek the following avenues.

1. Study Guide: It is important to understand your study guides and indices. During times of uncertainty, these will likely lead you to your answers. Determine the key concept that is being asked in the question and refer to your indices or pre-tabbed sections. The concepts will likely be found in one of the references, listed below.

2. Process of Elimination: There are only four possible choices for each question. Ask yourself if there is an answer that does not make sense and eliminate it. Further narrow down the answer that are derived from equations or concepts that you know are not right and are instead meant to deceive the test taker. See if there are answers that are similar or separated by something like a conversion error. This may be an indication that the correct equation was used.

3. Educated Guess: Remember that there is no penalty for wrong answers. Hopefully with the process of elimination you are able to narrow down as many answers as possible and are able to create an educated guess.

4. Rules of Thumb: Rules of thumb can be used to not only speed up time, but to help lead you in the right direction.

5. If the time is almost up and there are still unanswered questions remaining, determine whether it makes sense to check for mistakes on the problems you do know how to solve, or to tackle the unanswered problems.

Typical Exam Verbiage/Design:

1. Most Nearly: Due to rounding differences, the exam answers will not match yours exactly and in fact may not closely resemble your answer. NCEES uses the term "most nearly" to test your confidence in your solution. When the question prompts you with "most nearly", choose the answer that most closely matches yours, whether it be greater than or lesser to your value.

2. Irrelevant Information: The exam is intended to test your overall understanding of concepts. At times the question will include unnecessary information that is meant to misdirect you.

3. Deceiving Answers: NCEES wants to know that you are able to determine the appropriate methods for the solutions. There are answers that were intentionally produced from wrong equations to mislead the test taker. For example, you may forget a 1/2 in the formula, $KE = (1/2)MV^2$ and there would be two answers each off by a factor of 1/2.

4. Do Not Overanalyze: The exam questions are meant to be completed in 6 minutes. Therefore, they are intended to be written as straight forward as possible. Do not be tempted to overanalyze the meaning of a question. This will only lead you down the wrong path.

Review the Solutions:

Once the sample test is completed, grade your results. Measure your aptitude in speed, concept comprehension, and overall score. If you score is above 75% then you are in good shape. This 75% score is only applicable if you have prepared completely for the exam. If you are just starting out, then please do not be worried about a low score. This number is also just a rule of thumb; there is no definite score to determine passing the test. Instead, NCEES calibrates the results against practicing professional engineers. See this page http://ncees.org/exams/scoring-process/ for a better understanding of how NCEES grades the scores.

Review the answers that you got wrong and use the solutions as a learning tool on how to address these types of problems. Compare the types of questions you are missing with the NCEES outline of topics and determine where you should focus your studying. Finally repeat as many practice problems as you can to get a better grasp of the test and to continually improve your score.

4.0 RECOMMENDED REFERENCES

The following references are recommended to be reviewed prior to the exam and/or used during the exam. When reviewing these references, make sure you first understand the content. Some of these references do not go into depth on explaining the equations or concepts but are simply references. Others provide more background information and explanation on the NCEES topics. You should also be very familiar with the indices of these references and should be able to navigate the references to find information quickly. This may require you to insert tabs into the references. Once you have completed these two tasks then you should be ready to use these references during the exam. (Tip: It is helpful to have the indices of your references printed separately to allow you to have both the index and the reference material open at the same time, making for quicker searches.)

Complete List of References for the Machine Design & Materials PE Exam		
by	Engineering Pro Guides	www.engproguides.com
Engineering Pro Guides provides a power technical study guide that teaches the key concepts and skills necessary to pass the Machine Design & Materials PE Exam. If you have any suggestions to this list, please email me, Justin Kauwale, at contact@engproguides.com or provide a comment on the Google Spreadsheet or on the webpage.		
Topic 2.0	**Basic Engineering Practice**	**9 of 80 problems**
	Engineering Terms and Symbols	Machinery's Handbook, Large Print
	Interpretation of Technical Drawings	Machinery's Handbook, Large Print
		https://app.aws.org/mwf/attachments/64/225364/AWSWeldSymbolchart.pdf
		https://app.aws.org/itrends/2009/07/it200907/it0709-14.pdfk
	Quality Assurance/Quality Control	https://www.stat.auckland.ac.nz/~wild/ChanceEnc/Ch13.pdf
		http://web.mit.edu/2.810/www/files/readings/ControlChartConstantsAndFormulae.pdf
	Project Management	http://www.math.upatras.gr/~tsantas/DownLoadFiles/hil61217_ch22.pdf

	Economic Analysis	Economics Factors
		Compound Interest Tables
	Units and Conversions	Engineering Unit Conversions
	Design Methodoloy (identifying requirements, risk assesssment, verification/validation)	Machinery's Handbook, Large Print
Topic 3.0	**Engineering Science and Mechanics**	**10 of 80 problems**
	Statics	Engineering Mechanics - Statics & Dynamics
		http://www.awc.org/pdf/codes-standards/publications/design-aids/AWC-DA6-BeamFormulas-0710.pdf
	Kinematics	Engineering Mechanics - Statics & Dynamics
	Dynamics	Engineering Mechanics - Statics & Dynamics
Topic 4.0	**Material Properties**	**8 of 80 problems**
	Physical (density, melting point, optical)	Mechanics of Materials
	Chemical (corrosion, alloys, oxidation)	Mechanics of Materials
	Mechanical (modulus, hardness, thermal expansion)	Mechanics of Materials
	Mechanical (creep, viscoelastic, thermal conductivity)	Mechanics of Materials
Topic 5.0	**Strength of Materials**	**10 of 80 problems**
	Stress/strain (tension, compression)	Mechanics of Materials
	Shear	Mechanics of Materials
	Bending	Mechanics of Materials

	Buckling	[Mechanics of Materials](#)
	Torsion	[Mechanics of Materials](#)
	Fatigue	[Shigley's Mechanical Engineering Design](#)
	Failure Theories (Von mises, maximum shear)	[Shigley's Mechanical Engineering Design](#)
Topic 6.0	**Vibration**	**3 of 80 problems**
	Natural Frequencies (linear, bending, torsional) and acoustics	[Machinery's Handbook, Large Print](#)
	Damping (frequency, damping ratio, critical damping)	http://www.novibration.com/isoselect.pdf
	Forced Vibrations (magnification factor, transmissibility, balancing, isolation)	http://www.novibration.com/isoselect.pdf
Topic 7.0	**Mechanical Components**	**18 of 80 problems**
	Pressure Vessels and Piping (thick/thin wall)	[Machinery's Handbook, Large Print](#)
	Bearings (types, lubrication, life-load analysis)	[Machinery's Handbook, Large Print](#) [Shigley's Mechanical Engineering Design](#)
	Gears (types, speed, force analysis)	[Shigley's Mechanical Engineering Design](#) [Machinery's Handbook, Large Print](#)
	Springs (types, force, fatigue analysis)	[Shigley's Mechanical Engineering Design](#)
	Dampers (types, selection)	[Machinery's Handbook, Large Print](#)
	Belt and Pulley (types, force analysis)	[Machinery's Handbook, Large Print](#) [Shigley's Mechanical Engineering Design](#)
	Chain Drives (force analysis)	[Machinery's Handbook, Large Print](#)

	Clutches and Brakes (types, torque/force analysis)	Machinery's Handbook, Large Print
	Power Screws (lifting/lowering torque, locking)	Shigley's Mechanical Engineering Design
	Shafts (torsion, bending, static/fatigue failure,)	Shigley's Mechanical Engineering Design
	Keys (stress risers)	Shigley's Mechanical Engineering Design
	Mechanisms (linkages, cams, slider crank)	Machinery's Handbook, Large Print
	Mechanisms (force, kinetic analysis)	Machinery's Handbook, Large Print
	Mechatronics (interfaces, sensors, circuits, controls)	https://web.stanford.edu/class/engr40m/reader/chapter3.pdf
	Hydraulic Components (pump, cylinder, press)	https://www.boschrexroth.com/business_units/bri/de/downloads/hyd_formelsammlung_en.pdf
		http://www.parker.com/parkerimages/mobilecylinder/cat/english/0001q.pdf
		http://www.etcs.ipfw.edu/~dupenb/MET_330/Fluid%20Power%20Notes%205%20Hydraulic%20cylinders.pdf
		http://www.gearseds.com/files/Pneumatics_Sample_Lessons.pdf
	Pneumatic Components (compressor, cylinder, press)	http://www.bimba.com/Global/Library/Catalogs/Mead-Catalog/BimbaRefHandbook-Mead.pdf
	Motors & Engines (energy, efficiency)	Machinery's Handbook, Large Print
Topic 8.0	**Joints and Fasteners**	**12 of 80 problems**
	Welding (types, symbols, stress analysis)	Shigley's Mechanical Engineering Design
	Brazing	Machinery's Handbook, Large Print

	Bolts, Screws, Rivets (grade/class selection)	Machinery's Handbook, Large Print
	Bolts, Screws, Rivets (preload)	Shigley's Mechanical Engineering Design
		Machinery's Handbook, Large Print
	Bolts, Screws, Rivets (fastener group analysis)	Shigley's Mechanical Engineering Design
	Adhesives (types)	https://multimedia.3m.com/mws/media/886363O/3m-scotch-weld-low-odor-acrylic-adh-dp8805ns-dp8810ns-tds.pdf
		https://multimedia.3m.com/mws/media/66781O/3m-scotch-weld-epoxy-adhesive-3501-b-a-gray.pdf
	Adhesives (analysis)	http://www.engr.psu.edu/lcvideos/emech210/beam_shear_stress/beam_shear/BeamShear.pdf
		http://www.assakkaf.com/Courses/ENES220/Lectures/Lecture14.pdf
		http://abe-research.illinois.edu/faculty/dickc/Engineering/shearflowa.htm
Topic 9.0	**Supportive Knowledge**	**10 of 80 problems**
	Manufacturing Processes (machining, molding)	Machinery's Handbook, Large Print
	Manufacturing Processes (heat treatment)	Machinery's Handbook, Large Print
	Fits and Tolerances	Machinery's Handbook, Large Print
	Codes and Standards	American National Standards Institute (ANSI)
		American Society for Testing and Materials (ASTM)
		American Welding Society (AWS)
		American Society of Mechanical Engineers (ASME)

		Underwriters Laboratories (UL)
		Society of Automotive Engineers (SAE)
	Computational Methods and their Limitations (FEA, CAE)	Shigley's Mechanical Engineering Design
		http://www.ametektest.com/learningzone/testtypes
	Testing and Instrumentation (hardness, strength, etc.)	Machinery's Handbook, Large Print
		http://www.ametektest.com/products

Please see the below link to the online version of this spreadsheet for any updates. You can also read below about a majority of the different references. If you have any suggestions or questions on the list, please email Justin at contact@engproguides.com or you can comment on the online version of the spreadsheet.

Link: http://www.engproguides.com/machinereferences.html

4.1A MARK'S STANDARD HANDBOOK FOR MECHANICAL ENGINEERS

By Michael Lindeburg PE

This book is referenced by the NCEES Machine Design sample exam problems. However, the next book has similar information and much more information specific to Machine Design. If you decide to purchase this book as one of your references, then as you go through the Engineering Pro Guides technical study guide or sample exam, you should tab the locations of the necessary equations and various referenced tables.

Amazon Link[i]: Mark's Standard Handbook for Mechanical Engineers, 12th Edition

Topics Covered: Section 1.0 – Basic Engineering Practice, Section 7.0 Mechanical Components, Section 8.0 Joints and Fasteners and Section 9.0 Supportive Knowledge

4.1B MACHINERY'S HANDBOOK, LARGE PRINT

By Michael Lindeburg PE

This book is similar to the Mark's Standard Handbook, but it has even more information. You should choose either Mark's Standard Handbook or the Machinery's Handbook, whichever one you feel more comfortable. As you go through the Engineering Pro Guides technical study guide or sample exam, you should tab the locations in this book for the various referenced tables and component properties. This book is very large and a lot of the information is too

detailed for the PE exam, but it is a good safety net for the random supportive knowledge type questions that may occur on the PE exam.

Amazon Link[ii]: Machinery's Handbook, Large Print

Topics Covered: Section 1.0 – Basic Engineering Practice, Section 7.0 Mechanical Components, Section 8.0 Joints and Fasteners and Section 9.0 Supportive Knowledge

4.2 ENGINEERING UNIT CONVERSIONS BOOK

By Michael Lindeburg PE

The Engineering Unit Conversions book is a recommended book to use during the exam and while studying for the exam. You should tab the most commonly used conversions that you encounter while studying and doing practice problems.

Amazon Link: Engineering Unit Conversions

Topics Covered: Section 2.0 – Basic Engineering Practice – Units & Conversions

4.3 ENGINEERING MECHANICS – STATICS & DYNAMICS

By R.C. Hibbeler

This book is a great refresher to your college engineering class on statics & dynamics. If you have your college textbooks, then those books should be sufficient for any additional information you need on this topics. However, if you don't have your college textbook then you can look at getting this book. This book covers statics, kinematics and dynamics. There are also moment of inertia tables and center of gravity tables that are also useful. This book is very expensive and thus it is only recommended if you feel like you are weak in this topic, but if you did well in college on this topic, then the material presented in the Engineering Pro Guides Technical Study Guide should be sufficient.

Amazon Link: Engineering Mechanics - Statics & Dynamics

Topics Covered: Section 3.0 – Engineering Science and Mechanics (10 questions)

4.4 MATERIALS SCIENCE AND ENGINEERING: AN INTRODUCTION 9TH EDITION

By William D. Callister, Jr. and David G. Rethwisch

Similar to the previous reference, this book is only required if you do not have your college Materials textbook and you are not comfortable with the skills and concepts presented in the Engineering Pro Guides Technical Study Guide. If you have your Materials textbook, but you are not comfortable with Section 4.0 Material Properties, then you should review your textbook. If you are not comfortable and you don't own a Materials textbook, then you should review this

recommended reference. This book covers the mechanical, physical and chemical properties presented on the NCEES Machine Design outline.

Amazon Link: Materials Science and Engineering: An Introduction 9th Edition

Topics Covered: Section 4.0 – Material Properties (8 questions)

4.5 MECHANICS OF MATERIALS

By R.C. Hibbeler

This book is only recommended if you are struggling in the principles section and do not quite understand the concepts and skills presented in Section 5.0 - Strength of Materials. This book covers in more detail concepts like stress, strain, axial loads, torsion, bending, beam deflection and column buckling. If you feel comfortable with your knowledge in these classes during college, then you should not need this book and you should be okay using the Engineering Pro Guides Technical Study Guide.

Amazon Link: Mechanics of Materials

Topics Covered: Section 5.0 – Strength of Materials (10 questions) & Section 4.0 – Material Properties (8 questions)

4.6 MACHINE ELEMENTS IN MECHANICAL DESIGN

By Robert L. Mott, P.E.

This book is only recommended if you are struggling in the Mechanical Components section or need more Mechanical Components problems. If you understand the skills and concepts in the Engineering Pro Guides book, then you should not need any more references. This book covers a brief overview and some key equations of a good portion of the Mechanical Components presented in the NCEES outline. There is a lot of good information on belt drives & chain drives, gears, spur gears, helical gears, bevel gears, worm gearing, keys, couplings, shafts, power screws, springs, mechatronics, clutches, brakes and bearings. Also included in this book are discussions on Section 8.0 Joints & Fasteners. This book does not cover pressure vessels, motors, engines, hydraulics, pneumatics and dampers,

Amazon Link: Machine Elements in Mechanical Design

Topics Covered: Section 7.0 – Mechanical Components (18 questions) and Section 8.0 – Joints & Fasteners (12 questions)

4.7 USEFUL WEBSITES

These websites help to fill in the gaps in references for Section 2.0 Basic Engineering Practice, Section 6.0 Vibration, Section 8.0 Joints and Fasteners and Section 9.0 Supportive Knowledge.

4.7.1 BEAM DESIGN FORMULAS WITH SHEAR AND MOMENT DIAGRAMS

This website provides a quick reference to various beam configurations and their shear/moment diagrams. ***Topics Covered: Section 3.0 – Engineering Science and Mechanics (10 questions).***

http://www.awc.org/pdf/codes-standards/publications/design-aids/AWC-DA6-BeamFormulas-0710.pdf

4.7.2 WELDING SYMBOL GUIDE AND CHART

This website provides a quick reference to various beam configurations and their shear/moment diagrams. ***Topics Covered: Section 2.0 – Basic Engineering Practice (9 Questions)***

https://app.aws.org/itrends/2009/07/it200907/it0709-14.pdf

https://app.aws.org/mwf/attachments/64/225364/AWSWeldSymbolchart.pdf

4.7.3 CONTROL CHARTS AND TABLES OF CONSTANTS FOR CONTROL CHARTS

These items are useful for solving quality control problems. You should have the control charts tabbed in one of your references or you can print out these tables too. ***Topics Covered: Section 2.0 – Basic Engineering Practice (9 Questions)***

https://www.stat.auckland.ac.nz/~wild/ChanceEnc/Ch13.pdf

http://web.mit.edu/2.810/www/files/readings/ControlChartConstantsAndFormulae.pdf

4.7.4 VIBRATION ISOLATION

The following website is a concise, practical guide to selecting vibration isolation. It also provides some background information on vibration topics like frequency, displacement, forcing vs. natural and transmissibility. ***Topics Covered: Section 6.0 – Vibration (3 Questions)***

http://www.novibration.com/isoselect.pdf

4.7.5 WEBSITES FOR MACHINE DESIGN STANDARDS

The following organizations produce standards that are used in the Machine Design field and you should be knowledgeable of these organizations for the Codes and Standards topic in

Section 9.0 Supportive Knowledge. **Topics Covered: Section 9.0 – Supportive Knowledge (10 Questions)**

American National Standards Institute (ANSI): https://www.ansi.org/

American Society for Testing and Materials (ASTM): https://www.astm.org/

American Welding Society (AWS): https://www.aws.org/

American Society of Mechanical Engineers (ASME): https://www.asme.org/

Underwriters Laboratories (UL): https://standardscatalog.ul.com/

Society of Automotive Engineers (SAE): http://www.sae.org/

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[i] Justin Kauwale is a participant in the Amazon Services LLC Associates Program, an affiliate advertising program designed to provide a means for sites to earn advertising fees by advertising and linking to amazon.com

[ii] Justin Kauwale is a participant in the Amazon Services LLC Associates Program, an affiliate advertising program designed to provide a means for sites to earn advertising fees by advertising and linking to amazon.com

SECTION 2
QUESTIONS

QUESTION 1

Which of the following best describes the weld in the figure below?
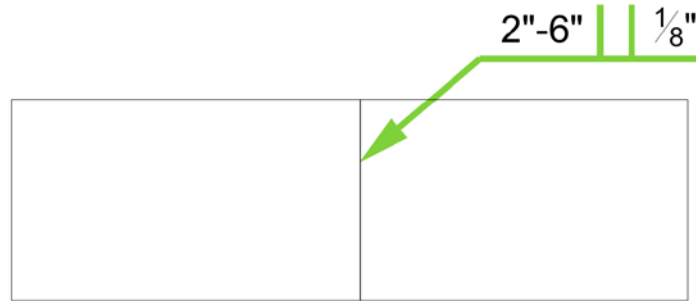
2"-6"   ⅛"

(A) A series of 2" long square weld, arranged 6" on center, 1/8" depth on arrow side.

(B) A series of 6" long square weld, arranged 2" on center, 1/8" depth on arrow side.

(C) A series of 2" long square weld, arranged 6" on center, 1/8" depth on other side.

(D) A series of 6" long square weld, arranged 2" on center, 1/8" depth on other side.

QUESTION 11

A cylindrical pressure vessel is designed to have an inner diameter of 12 inches. The pressure vessel must be able to handle gases at a pressure of 2,000 psi. The cylindrical pressure vessel shall be thick walled and shall be made of cast iron (strength = 5,000 psi). What is the minimum outer diameter size?

(A) 16-5/8 inches

(B) 18-3/8 inches

(C) 19-7/8 inches

(D) 22-1/8 inches

QUESTION 12

A 6" shaft and bearing configuration is modeled as shown in the below figure. What is the critical speed of this configuration?

25 lbs/ft

20 ft
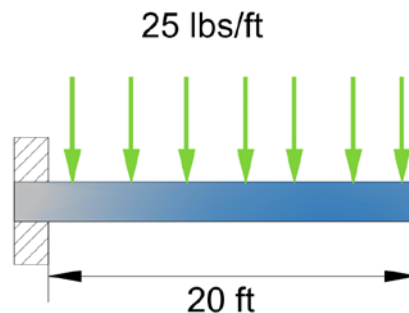
(A) 344 RPM

(B) 755 RPM

(C) 1010 RPM

(D) 1,772 RPM

QUESTION 27

The material for a pinion and gear are being selected such that both pinion and gear will have equal lifetimes. Which of the following statements is MOST true?

(A) The pinion and gear should have equal hardness.

(B) The pinion should have a greater hardness than the gear.

(C) The gear should have a greater hardness than the pinion.

(D) The hardness of the pinion and gear will not affect their lifetime.

QUESTION 28

A motor weighs 100 lbs and is supported by 4 vibration isolators. The motor has a disturbing frequency of 600 RPM. What natural frequency should be selected for the vibration isolators such that the transmissibility is limited to 10%?

(A) 3 Hz

(B) 6 Hz

(C) 10 Hz

(D) 60 Hz

QUESTION 35

Calculate the X-bar chart upper and lower control limit for the following data table.

	Sample Number							
	1	2	3	4	5	6	Mean	Range
Set 1	469	469	480	455	469	454	466.0	26
Set 2	457	454	453	453	480	480	462.8	27
Set 3	473	459	460	462	450	451	459.2	23
Set 4	480	469	456	460	465	467	466.2	24
Set 5	465	477	474	465	475	463	469.8	14
Set 6	473	476	472	454	470	466	468.5	22
Set 7	456	475	480	460	470	452	465.5	28

(A) 470 & 459

(B) 480 & 454

(C) 465 & 465

(D) 477 & 454

QUESTION 36

A 5 HP centrifugal pump provides 20 GPM at a pressure of 40 psi. The pump operates at a speed of 900 RPM. If the pump speed is reduced to 750 RPM, then what will be the pressure provided by the pump?

(A) 23 psi

(B) 28 psi

(C) 33 psi

(D) 40 psi

QUESTION 39

A flat belt has a maximum tension of 250 lbs and a coefficient of friction of 0.1. The angle of wrap is 2 radians. The motor driving the belt is 2 HP (assume 100% efficient). What is the belt speed?

(A) 1,003 FPM
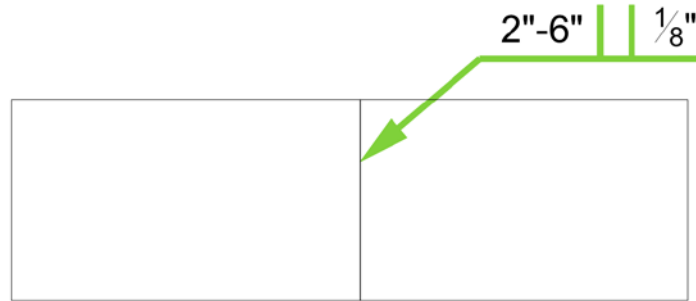
(B) 1,221 FPM

(C) 1,454 FPM

(D) 1,689 FPM

QUESTION 40

Standard roller chains are most likely manufactured to the specifications of which of the following standards?

(A) ASTM

(B) NFPA

(C) UL

(D) ANSI

SECTION 3
SOLUTIONS

SOLUTION 1

Which of the following best describes the weld in the figure below?

(A) A series of 2" long square weld, arranged 6" on center, 1/8" depth on arrow side.

(B) A series of 6" long square weld, arranged 2" on center, 1/8" depth on arrow side.

(C) A series of 2" long square weld, arranged 6" on center, 1/8" depth on other side.

(D) A series of 6" long square weld, arranged 2" on center, 1/8" depth on other side.

Machinery's Handbook Chapter Manufacturing Processes Welding Section provides all the welding symbols and descriptions of the symbols.
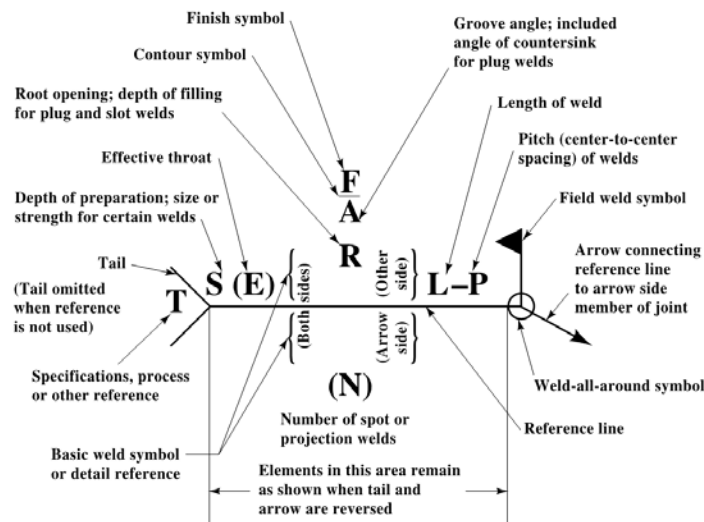
Since, the symbol is above the reference line, then the weld occurs on the "other side". Also the length of the weld is shown in between the weld symbol and the arrow as 2". The second number, 6" refers to the center to center spacing of the welds. The number between the tail and the weld symbol describes the depth of the weld. Finally, the weld symbol is a square weld.

The correct answer is most nearly, **(C) A series of 2" long square weld, arranged 6" on center, 1/8" depth on other side.**

SOLUTION 8

A friction band brake has a tension of 750 lbs (tight side) and a coefficient of friction of 0.25. The angle of wrap is 120 degrees. If the angle of wrap is changed to 150 degrees and all other properties of the brake remains the same, then what will be the difference between the old tension and the new tension (tight side) in the belt such that the same tangential force can be applied by the brake?

(A) 192 lbs

(B) 341 lbs

(C) 516 lbs

(D) 558 lbs

Machinery's Handbook Chapter Machine Elements, Friction Brakes section discusses the formulas for various friction brakes. The formula required for the friction band brake is shown below.

$$T_1 = P * \frac{1}{e^{\mu\theta} - 1}$$

Use the given properties to solve for P (tangential force).

$$750 \ lbs = P * \frac{1}{e^{0.25*2.09 \ rad} - 1}$$

$$P = 516 \ lbs$$

Now use the tangential force and the new angle of wrap to solve for tension.

$$T_1 = 516 \ lbs * \frac{1}{e^{0.25*2.62 \ rad} - 1}$$

$$T_1 = 558 \ lbs$$

The difference is 192 lbs.

The correct answer is most nearly **(A) 192 lbs.**

SOLUTION 11

A cylindrical pressure vessel is designed to have an inner diameter of 12 inches. The pressure vessel must be able to handle gases at a pressure of 2,000 psi. The cylindrical pressure vessel shall be thick walled and shall be made of cast iron (strength = 5,000 psi). What is the minimum outer diameter size?

(A) 16-5/8 inches

(B) 18-3/8 inches

(C) 19-7/8 inches

(D) 22-1/8 inches

Machinery's Handbook Chapter Mechanics and Strength of Materials, Plates Shells and Cylinders section has a table for the ratio of outside to inside radius for thick cylinders. This table shows that for a material of strength 5,000 psi and an internal pressure of 2,000 psi, the ratio of the outside to inner radius is 1.528.

$$Outer\ diameter = 12\ inches * (1.528) = 18.34\ inches$$

You can also use the thickness equation for thick walled cylinders.
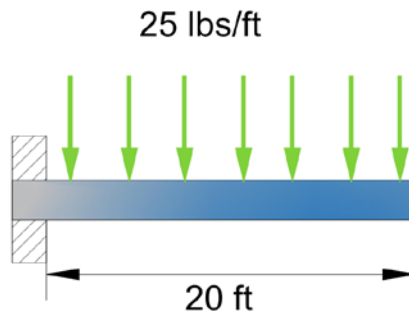
$$Thickness = r * (\frac{\sqrt{S+P}}{\sqrt{S-P}} - 1)$$

$$Thickness = 6\ inches * \left(\frac{\sqrt{5,000+2,000}}{\sqrt{5,000-2,000}} - 1\right) = 3.17\ inches$$

$$Outer\ diameter = 12\ inches + 3.17 * 2\ inches = 18.33\ inches$$

The correct answer is most nearly, **(B) 18-3/8 inches**.

SOLUTION 12

A 6" shaft and bearing configuration is modeled as shown in the below figure. What is the critical speed of this configuration?

25 lbs/ft

20 ft

(A) 344 RPM

(B) 755 RPM

(C) 1010 RPM

(D) 1,772 RPM

Machinery's Handbook Chapter Mechanics and Strength of Materials, Critical Speeds section has a table for the critical speed formulas for various configuration

The equation to find the critical spped with the above configuration is as follows.

$$N = 795,200 \frac{d^2}{l\sqrt{Wl}}$$

$$N = 795,200 \frac{6^2}{20 * 12\sqrt{(25 * 20) * 20 * 12}} = 344 \ RPM$$

The correct answer is most nearly, **(A) 344 RPM.**

SOLUTION 17

A SAE Grade 1, ¾" bolt is to be used in a machine design. What is the maximum design tensile stress for this bolt that will allow the bolt to be re-used after loosening and tightening again?

(A) 33,000 psi

(B) 36,000 psi

(C) 40,000 psi

(D) 60,000 psi

First you can either navigate to **Machinery's Handbook, Fasteners** or **Shigley's Mechanical Engineering Design, Part 3, Chapter 8 Screws, Fasteners and the Design of Nonpermanent Joints.** These references have tables for all the common bolt and screws showing their proof, tensile, yield strengths and other properties.

Proof strength	Tensile strength	Yield strength
33,000 psi	60,000 psi	36,000 psi

Proof strength is the first point at which permanent deformation will occur. Proof strength is the minimum value at which permanent deformation will occur. It is important to note that these values are the mean values and there will be some standard deviation from these values in practical application, but for the purposes of the exam these values are used. Yield strength is the point at which a certain amount of permanent deformation will occur, not when permanent deformation will first occur. Tensile strength is the point at which the bolt will break under tensile stress.

A bolt can be reused when no permanent deformation has occurred, this is because its fastening capabilities are dependent on the bolt being elastic. Thus the value that is of concern is the proof strength.

The correct answer is most nearly, **(A) 33,000 psi**.

SOLUTION 18

A pinion has 24 teeth and a gear has 56 teeth. The pinion moves at a speed of 500 RPM. The diametral pitch is ½". If the number of teeth of the pinion is increased to 30 teeth, then which of the following is true? Assume the pinion and gear are matched together to have the same diametral pitch. The diametral pitch, pinion speed and the gear dimensions do not change.

(A) The gear speed will be increase.

(B) The gear torque will be increased.

(C) The gear acceleration will be increased.

(D) The pinion pitch diameter will be decreased.

First navigate to **Machinery's Handbook, Spur Gearing or Shigley's Mechanical Engineering Design, Gears – General**. These sections provide more information on the relationship between teeth, speed, diametral pitch and gear diameters. The pinion is the smaller driving gear and the gear is the larger gear. The number of teeth and diameter pitch and pitch diameter are related by the following equation.

$$Number\ of\ Teeth = Diametral\ Pitch * Pitch\ Diameter$$

Diametral Pitch is the ratio of the number of teeth to the number of inches in the pitch diameter in the plane of rotation.

Pitch Diameter is the diameter of the pitch circle.

$$Pinion \rightarrow 24\ teeth = 1/2" * Pitch\ Diameter$$

$$Pinion \rightarrow Pitch\ Diameter = 48"$$

$$Gear \rightarrow 56\ teeth = 1/2" * Pitch\ Diameter$$

$$Gear \rightarrow Pitch\ Diameter = 112"$$

If the pinion number of teeth is increased, then the pinion pitch diameter will increase. (D) is false.

If the pinion pitch diameter is increased, then the gear ratio will decrease. This means that the torque gear will decrease and the gear speed will increase.

$$Gear\ Ratio = \frac{Pitch\ Diameter_{gear}}{Pitch\ Diameter_{pinion}} = \frac{Torque_{gear}}{Torque_{pinion}} = \frac{Speed_{pinion}}{Speed_{gear}}$$

The correct answer is most nearly, **(A) The gear speed will increase.**

SOLUTION 19

A straight bevel gear and pinion are at 90 degree angles to each other. The diametral pitch is ½", the pinion has 10 teeth and the gear has 30 teeth. The pressure angle is 20 degrees. The horsepower is 5 HP and the pinion speed is 150 RPM. What is the force acting upon the pinion shaft?

(A) 24 LBS

(B) 106 LBS

(C) 210 LBS

(D) 311 LBS

Shigley's Mechanical Engineering Design, Chapter 13 Gears has sample force analysis for spur, helical, bevel and worm gears. You should be familiar with this section, in case you encounter a gear force type problem. Gears have a pressure angle that helps to determine how the forces are distributed between the gears.

$$Pressure\ Angle\ (\phi) = Direction\ at\ which\ resultant\ forces\ act\ between\ the\ gears$$

$$Pressure\ Angle\ (\phi)\ is\ typically\ 20°\ or\ 25°$$

The pitch angle is a term specific to straight bevel gears. This term describes the relationship between the pinion and gear number of teeth. This pitch angle is in respect to the pinion, since we are calculating the force acting on the pinion. The pitch angle will be 90 degrees minus this pinion pitch angle, when calculating the force acting upon the gear.

$$Pitch\ Angle\ (\phi) \rightarrow \phi = tan^{-1}(\frac{N_P}{N_G})$$

$$\phi = tan^{-1}\left(\frac{10}{30}\right) = 18.4°$$

Next, follow the bevel gear force analysis and find the transmitted force W_T. You would use the gear torque and radius, if you wanted the forces on the gear.

$$W_T = \frac{Pinion\ Torqe}{Pinion\ Radius} = \frac{5\ HP * \frac{63,025}{150\ RPM}}{\frac{10\ teeth}{2 * 1/2"\ diametral\ pitch}} = \frac{2101}{10} = 210\ lb$$

Finally, use the following equation to find the amount of force acting upon the pinion shaft.

$$W_{pinion} = W_T * \tan(\phi) * \sin(\phi)$$

$$W_{pinion} = 210\ lbs * \tan(20°) * \sin(18.4°) = 24\ lbs$$

The correct answer is most nearly **(A) 24 lbs**.

SOLUTION 29

A master cylinder compresses the hydraulic fluid to a pressure of 80 psi. Cylinder 2 in the diagram below has a diameter of 6" and Cylinder 1 has a diameter of 1". What is the ratio of Force 2 to Force 1?
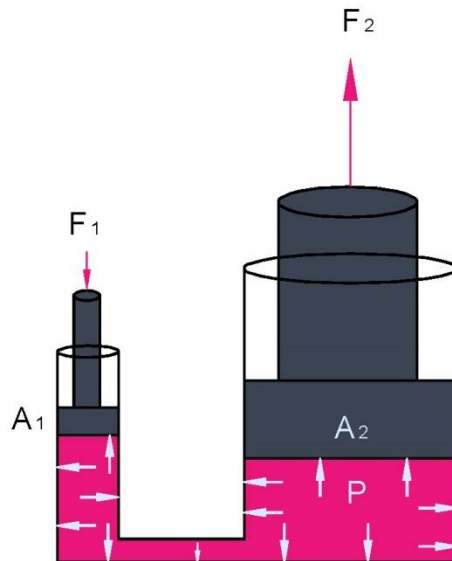
(A) 36

(B) 30

(C) 18

(D) 6

For this problem, you can refer to the following link which has a lot of information on hydraulics and even has a summary list of equations.

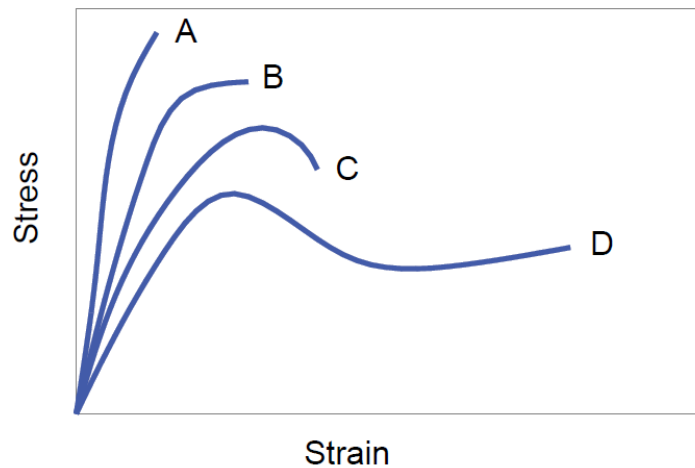A pressure of 80 psi is exerted on both area 1 and area 2, where pressure is equal to force divided by area.

$$80 \; psia = \frac{F_1}{A_1} = \frac{F_2}{A_2};$$

$$\frac{F_1}{A_1} = \frac{F_2}{A_2} \rightarrow \frac{F_2}{F_1} = \frac{A_2}{A_1}$$

$$\frac{F_2}{F_1} = \frac{\pi * \frac{D^2}{4}}{\pi * \frac{D^2}{4}}$$

SOLUTION 34

Which of the following statements is true about the graph below?

(A) Curve A representative of a ductile material.

(B) Curve B has a higher modulus of elasticity than curve A.

(C) Curve C has lower yield strength than curve B.

(D) Curve D is representative of a plastic material.

For this problem you should refer to **Materials Science and Engineering, Chapter 6 Mechanical Properties of Metals**. The slope of stress to strain is called the modulus of elasticity. The slope of A is bigger than B, so (B) is incorrect. Curve A is a plastic material nad curve D is a ductile material. The yield strength is shown when the initial straight line slope begins to change. This occurs at a lower stress level for curve C than it does for curve B.

The correct answer is most nearly **(C) Curve C has a lower yield strength than curve B**.

SOLUTION 40

Standard roller chains are most likely manufactured to the specifications of which of the following standards?

(A) ASTM

(B) NFPA

(C) UL

(D) ANSI

ASTM sets testing standards primarily for materials. NFPA stands for the National Fire Protection Association. These standards focus on fire protection related topics. UL or underwriting laboratories certifies the safety of equipment, materials and products. It does not primarily deal with the specifications of the roller chains to ensure they fit with gears. The correct answer is most nearly, (D) ANSI. ANSI provides standards of conformity for all sorts of products like roller chains. You should go through the SAE, ANSI and ASTM websites to get an idea of the standards that are on the machine design elements like shafts, bolts, gears, chains, etc.

The correct answer is most nearly, **(D) ANSI**.

SECTION 4
CONCLUSION

4.0 CONCLUSION

If you have any questions on this sample exam or any other Engineering Pro Guides product, then please contact:

Justin Kauwale at contact@engproguides.com

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