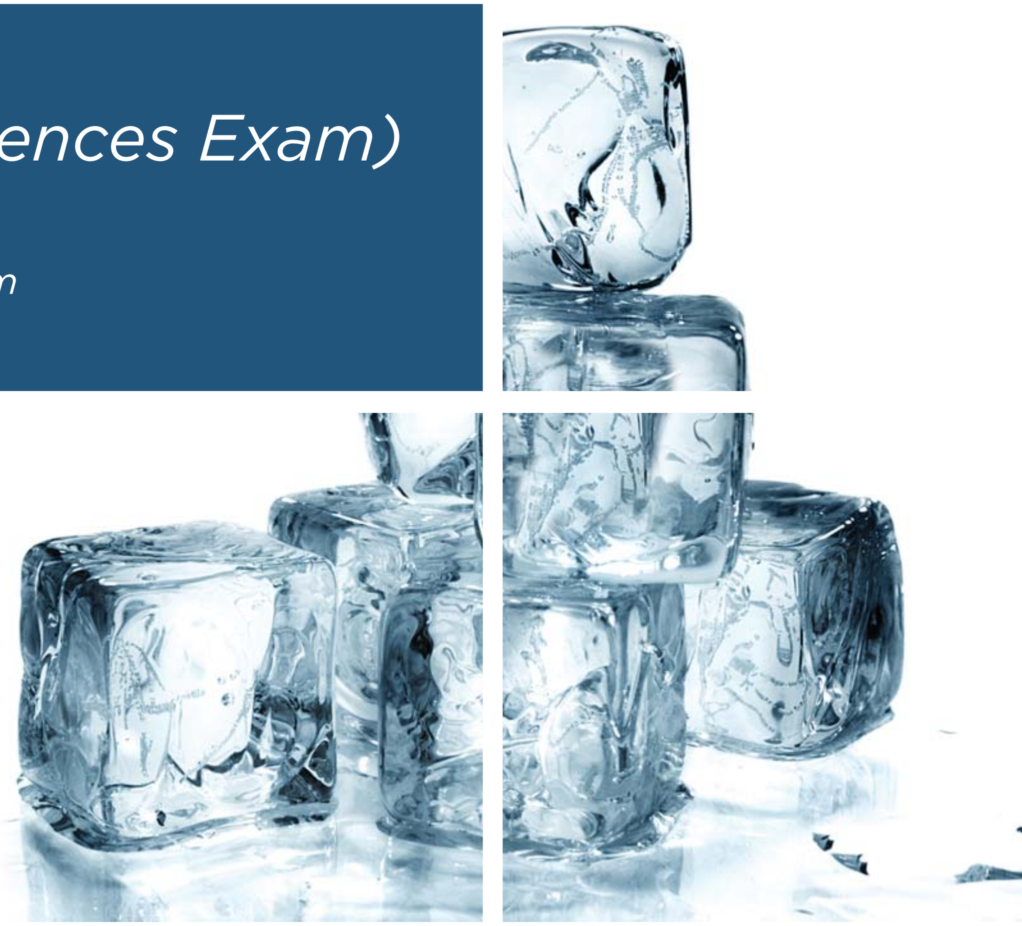
HVAC & Refrigeration

Mechanical PE

Exam 3 *(References Exam)*

2022 Exam Edition

Updated for Latest CBT Exam



Test your understanding of the key concepts and skills

Engineering Pro Guides

by **Justin Kauwale, P.E.**

Mechanical PE: HVAC & Refrigeration Exam 3 (References Exam)

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Mechanical PE: HVAC & Refrigeration Exam 3
(References Exam)

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HVAC & REFRIGERATION PE EXAM 3
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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 this sample exam and technical study guides.

This sample exam is intended to be a sample test on ONLY your knowledge of the experience based questions and prompt you to be familiar with the contents of the *NCEES PE Mechanical Reference Handbook* and additional contents of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Handbooks. Although the only reference you will have during the test is the NCEES Handbook, you should still review the key concepts within the ASHRAE Handbooks. A good deal of the content in the NCEES Handbook was taken from the ASHRAE Handbooks. The ASHRAE Handbooks are one of the main resources that HVAC Engineers use in the field. Understanding the key sections and its content will help you to get a leg up on the experience type questions.

1.1 Key Concepts and Skills

The key concepts and skills tested in this sample 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 the PM exam (4 hours). Within the Mechanical Engineering field, there are three specialties to choose from for the exam: HVAC & Refrigeration, Thermal & Fluids and Mechanical Systems & Materials.

This sample exam focuses on the HVAC and Refrigeration topic. NCEES indicates on their website that the HVAC and Refrigeration exam will focus on the following topics:

(http://ncees.org/engineering/pe/):

- Topic 1.0 - Introduction (0 of 80 problems)
- Topic 2.0 - Basic Engineering Practice (4-6 of 80 problems)
- Topic 3.0 - Thermodynamics (4-6 of 80 problems)
- Topic 4.0 - Psychrometrics (7-11 of 80 problems)
- Topic 5.0 - Heat Transfer (6-9 of 80 problems)
- Topic 6.0 - Fluid Mechanics (3-5 of 80 problems)
- Topic 7.0 - Energy/Mass Balance (4-6 of 80 problems)
- Topic 8.0 - Heating/Cooling Loads (7-11 of 80 problems)
- Topic 9.0 - Equipment & Components (16-24 of 80 problems)
- Topic 10.0 - Systems & Components (16-24 of 80 problems)

- Topic 11.0 - Supportive Knowledge (3-5 of 80 problems)

Each of these topics were investigated and filtered by Engineering Pro Guides for concepts and skills that meet the following criteria:

(1) First, the concept and skill must be commonly used in the HVAC & Refrigeration field of Mechanical Engineering. For example, pump sizing, fan sizing, determining friction losses and calculating net positive suction head are regular occurrences in the HVAC & Refrigeration field. The breakdown of question topics is shown in the list above.

(2) Second, the skill and concept must be testable in roughly 6 minutes per problem. There are (40) questions on the afternoon exam and you will be provided with 4 hours to complete the test. 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, pressure drop calculations are common in the HVAC & Refrigeration field, but the calculation is often very lengthy because of the number of steps involved, especially if a unique fluid and flow condition is used. Thus, common fluids like water/air and common pipe/duct materials are used.

(3) Third, the key concepts and skills must be used or be known by practicing HVAC & Refrigeration Mechanical Engineers. 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 HVAC & Refrigeration, Thermal & Fluids and Mechanical Systems & 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.

(4) The P.E. Exam must test the principle or application of the skill and concept and not the derivations or 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 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 theory of evaporation in a cooling tower and more with the performance and selection of a cooling tower.

In summary, this book is intended to provide a sample of the necessary skills and concepts to develop a minimally competent, practicing professional engineer in the Mechanical Engineering field, with a focus on reference or experience type questions. This book does this through the following means:

(1) Providing sample problems that can be completed in roughly 6 minutes per problem.

(2) Providing solutions to these problems that teach skills and concepts used by practicing Mechanical Engineers.

(3) Providing sample problems that require reference lookup and/or is based on practical experience.

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).

1.3 Computer Based Test (CBT)

As of April 2020, the exam will be converted from the paper-pencil/scantron testing method to a computer based platform. This allows the test to be offered year round instead of twice per year. This also means you will not have the same set of the questions as the next person. The style of the testing interface will be very similar to the fundamentals of engineering (FE) exam that is also administered by NCEES. If you have gone through the computer based version of the FE exam, you should be familiar with the format. The main difference is the number and difficulty of questions and the length of the exam. It is important to review the NCEES Examinee Guide to understand the testing rules and format. Below is a summary of the major content.

(1) Year Round: The exam may be taken any time throughout the year, as long as the testing facility is open. However, you are only allowed to take the exam once per quarter (Jan – March, April – June, July – Sept, Oct – Dec) and at most 3 times per 12 months. The turnaround time from your exam application to test date will be much faster and the results should be received within 7-10 days. The only thing holding you up may be your state approval.

(2) Day of Timeline: The overall time at the testing facility will be 9 hours, with 1 hour allotted for prep time and breaks and 8 hours of actual exam time. You will have a maximum of 4 hours to complete the first half of the exam. Once you submit the first section you cannot return to those questions. You will then have a maximum of 50 minutes of break time, where you are allowed to leave the facility. Finally, you will have a maximum of 4 hours to complete the second half of the exam.

(3) Question Types: One of the main changes in the actual content of the computer-based test is the ability to incorporate different question types. Majority of the questions will be multiple choice with one answer out of four options, but additional question types include (1) multiple answers, (2) selecting a point, (3) drag and drop for matching, sorting, labeling, etc, and (4) fill in the blank. The exam questions are written in a way that can be confusing or meant to trick the examinee, so you can imagine how this can really add to the difficulty of the problem.

(4) NCEES Reference Handbook: Perhaps the greatest consequence of shifting to the computer based conversion is that examinees are no longer able to bring in outside resources. Your only aid during the test is the *NCEES PE Mechanical Reference Handbook*, see the following section for a write-up on the handbook. There are pros and cons to this, aside from no longer needing to lug a suitcase full of books to the test site.

The benefit is that everything is contained and focused towards one resource and that resource is now searchable, see the computer interface section below. The search function is probably one of the biggest benefits of the computer based format, reducing the time spent flipping through resources and giving you the opportunity to search for various topics that may provide hints into solving problems that you may otherwise not know how to begin. You also will not have to worry about having the right table or graphs in your possession, as this will all be provided to you.

The cons are you are no longer able to bring in cheat sheets and unit conversion books to help you with speed or notes that help you to understand concepts that you may struggle with. Instead, you will have to be completely reliant on the handbook and fully understand how to use the variables in the provided equations. Another major concern is that not all topics may be covered in the handbook, especially the experience type questions that you could normally find in ASHRAE. Therefore, it is still important to read other resources and review other content outside of the NCEES Handbook to get a better foundation.

(5) Computer Interface: All exam content and references will be on the computer with a 24" monitor. You'll have a split screen with one section for the questions and the other for the *NCEES PE Mechanical Reference Handbook*. The handbook is bookmarked by chapter and has a searchable function to easily find content and equations. There is a calculator on the screen, but it is recommended that you bring your own NCEES approved calculator that you are familiar with. A countdown timer will be located on the upper right corner of the screen. You'll also have the ability to flag and return to problems, as long as you have not exited the section (i.e. morning or afternoon session). The interface only allows you to input answers; your work will be done separately on reusable dry erase sheets. This makes it a little more cumbersome to check your answers, instead of being able to work the problem out right under the question, so you'll just have to be neat about it. For a demo of the computer interface, see the following link http://pearsonvue.com/demo/.

1.4 NCEES PE Mechanical Reference Handbook

The *NCEES PE Mechanical Reference Handbook* is the only resource allowed during the exam. As mentioned in the previous section, it will be provided electronically on the same computer screen as the actual test. You may download a free copy of this pdf on your MyNCEES account. It is recommended that you practice doing problems with the electronic version of this resource, so that you may become familiar with its contents and how to navigate through the search and bookmark functions. You should understand the variables and the default units used in the equations and be quick with locating of all major charts and tables.

The same handbook is used for all mechanical exam disciplines: HVAC, Machine Design, and Thermal & Fluids. There will be sections that are not applicable to the HVAC exam, so don't waste your time trying to understand sections that are obviously irrelevant. Review the NCEES HVAC exam specification alongside the handbook to realize what may be pertinent to the test. For example, most of the Machine Design & Materials chapter does not apply to the HVAC test, except perhaps the basic spring deflection equation and thermal deformation equation, which could be used for equipment vibration isolation and thermal expansion of pipes. The more basic fluids equations would be used for the HVAC exam, while the more involved sections, such as impulse momentum and Mach numbers would be used for the Thermal & Fluids exam. The engine and turbine cycles, Brayton and Rankine are also not applicable to the HVAC exam, only the refrigeration cycle.

Even though your studying will be focused around this handbook for references and equations, you should spend a good amount of time reading other resources to become familiar with background concepts and applications that can be tested, but would not be covered in the handbook. The handbook is more of one large cheat sheet resource and is not intended to provide any explanations.

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 Sample Exam

This exam 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 with a focus on reference materials, and are limited to fit a full exam length and therefore is not comprehensive of all concepts.

Reference Lookup: As much as possible, limit your lookup to only the *NCEES PE Mechanical Reference Handbook*, since this is the only resource you will have during the exam. There are however, some questions that require you to use the ASHRAE Handbooks. The intent is to prompt you to read and understand concepts that are not covered by the NCEES reference material. With all questions, make sure you review the background information and the role that various equipment play in HVAC systems. Also, be sure to use a pdf version of the NCEES Handbook to get used to the search function and navigating the resource with a computer interface.

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 or two sittings and timed for four hours per section 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 *NCEES PE Mechanical Reference Handbook*. 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 in Testing Room:

1. Religious head coverings
2. Approved calculator
3. Eyeglasses without case
4. Magnifying glass without case
5. Light jacket without hood
6. Pearson VUE provided items (earplugs, tissues).
7. Pearson VUE approved comfort items (medical items, unwrapped cough drops, unpackaged pills, etc). See the complete list linked in the NCEES Examinee Guide.

Prohibited:

1. Cell phones
2. Watches
3. Food/Beverages – *You may access food and beverages during unscheduled breaks during the exam.*
4. Hats and hoods
5. Slide charts, wheel charts, drafting compasses
6. Weapons
7. Tobacco
8. Personal Chairs
9. Eyeglass/Magnifying glass cases
10. Scratch Paper (all writing items will be provided by the test center)

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. Reference Handbook: Use the search function or go through pertinent sections of the NCEES Reference Handbook. During times of uncertainty, this will likely lead you to your answers. Determine the key words/concept that is being asked in the question and do a search. The answer can hopefully be extracted from the handbook.

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 the 75% range 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 is number is also just a range; there is no finite 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. Review the resources outside of your NCEES Handbook to gain more background information around these topics. 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. You will not be able to use these references during the exam, but with review, you will gain background knowledge and experience with the listed topics. This will help you to answer any experience type or qualitative type question that may appear on the exam, but are not covered in the *NCEES PE Mechanical Reference Handbook*.

When reviewing these references, make sure you understand the content and follow through the example problems when they exist. These references do not go into depth on explaining the equations or derivations but are simply references. If you require additional background information, then you may need to research the information on the internet. Secondly, you should try to relate the information you gather from these references to the *NCEES PE Mechanical Reference Handbook*. This will allow you to have associate the concepts learned with the resource you will use in the exam.

Complete List of References for the HVAC & Refrigeration 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 HVAC & Refrigeration PE Exam. If you have any suggestions to this list, please email me Justin at contact@engproguides.com			
Topic 2.0	**Basic Engineering Practice**	**4 of 80 problems**	
	Electrical Concepts (power consumption, motor ratings, heat output, amperage)	ASHRAE Systems 2016	Ch 45 Motors, Motor Controls and Variable Frequency Drives
Topic 3.0	**Thermodynamics**	**4 of 80 problems**	
	Cycles	ASHRAE Fundamentals 2017	Ch 2 Thermodynamics
	Properties	ASHRAE Fundamentals 2017	Ch 2 Thermodynamics
	Compression Process	ASHRAE Fundamentals 2017	Ch 2 Thermoddynamics
Topic 4.0	**Psychrometrics**	**10 of 80 problems**	
	Heating/Cooling Processes	ASHRAE Fundamentals 2017	Ch 1 Psychrometrics
	Humidification/Dehumidification Processes	ASHRAE Fundamentals 2017	Ch 1 Psychrometrics
Topic 5.0	**Heat Transfer**	**4 of 80 problems**	
	Conduction	ASHRAE Fundamentals 2017	Ch 4 Heat Transfer
	Convection	ASHRAE Fundamentals 2017	Ch 4 Heat Transfer
	Radiation	ASHRAE Fundamentals 2017	Ch 4 Heat Transfer
Topic 6.0	**Fluid Mechanics**	**4 of 80 problems**	

http://www.johnsoncontrols.com/~/media/jci/be/united-states/airside-systems/air-handling-units/files/be_appguide_energyrecoverywheel_ahu.pdf?la=en

- Vibration Isolation

https://www.novibes.com/images/Technical%20Section.pdf

5.0 PAST EXAM SURVEYS

After every PE exam, I conduct an online survey with as many PE exam test takers that I can find. I primarily use my website, www.engproguides.com and www.engineerboards.com to find test takers to take the survey. The survey provides insight into an estimated passing score, how well test takers do based on experience and number of hours studied, and which areas of the exam are difficult or easy. The raw results of the survey and analysis of the results are provided in the link below. This link shows a summary of the results with and without pivot chart analysis.

HVAC PE Survey Results:

https://www.engproguides.com/hvac-pe-exam-survey.html

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1 – AM Exam Problems

HVAC & REFRIGERATION PE EXAM 3

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PROBLEM 1 – HVAC SYSTEMS & COMPONENTS

There is a 105 foot long, 6” schedule 40 steel pipe carrying 100-psig steam, run aboveground, horizontally, suspended from the ceiling. There are no valves or other ancillary equipment on this section of pipe. According to MSS Standard SP-69, how many support hangers should be provided on this section of pipe? Assume there are already supports at the beginning and end of the section.

Hint: See ASHRAE Fundamentals, Chapter 22 Pipe Design

(A) 4

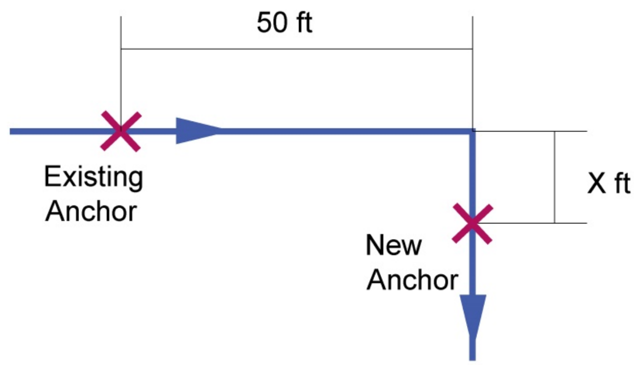
(B) 6

(C) 8

(D) 10

PROBLEM 2 - HVAC SYSTEMS & COMPONENTS

A schedule 80 XS, steel, 8” OD pipe is being checked for expansion and contraction. Assume A53B steel. The pipe carries chilled water at 45°F, but when not in use, this pipe can reach a temperature of 120 °F. The pipe has an anchor located 50 feet before a 90 degree turn. What is the minimum length of pipe from the 90 degree turn to the next anchor, in order to accommodate thermal expansion of the 50 foot long section of pipe?



(A) 8 inches

(B) 10 inches

(C) 2 feet

(D) 10 feet

PROBLEM 29 - HVAC SYSTEMS & COMPONENTS

2,000 lb/h steam at 12 psig is flowing through a 4” schedule 40 steel pipe. What is the pressure drop after 1,000 feet of pipe?

(A) 2.2 psi

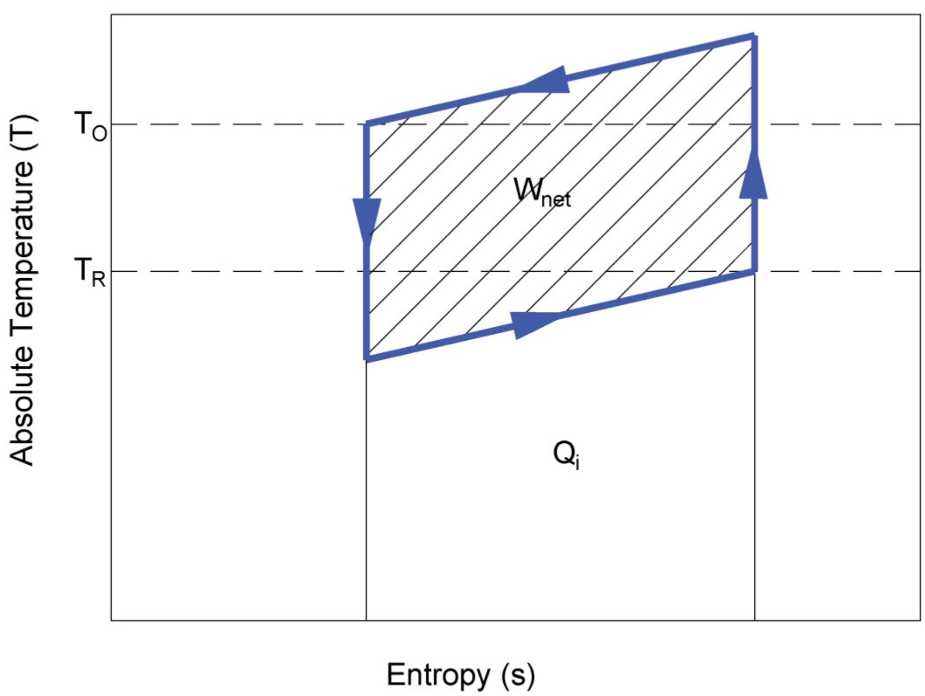
(B) 3.6 psi

(C) 17.1 psi

(D) 26.6 psi

PROBLEM 30 - THERMODYNAMICS

The following temperature-entropy graph has the characteristics of what type of refrigeration cycle?



(A) Carnot Cycle

(B) Lorenz Cycle

(C) Zeotropic Cycle

(D) Vapor Compression Cycle

PROBLEM 59 – SUPPORTIVE KNOWLEDGE

Which of the following will NOT decrease aerodynamically generated sound?

Hint: See ASAHRAE Fundamentals, Chapter 8 Sound and Vibration and ASHRAE HVAC Applications, Chapter 48 Noise and Vibration Control.

(a) Reducing air velocity

(b) Increasing straight duct length before/after transitions

(c) Location of the volume dampers

(d) Providing vanes in elbows

PROBLEM 60 – SUPPORTIVE KNOWLEDGE

An air handling unit with vibration isolators is currently running at 2000 RPM and is producing 2,300 CFM. The air enters supply ductwork and it is found that the ductwork is making a significant amount of noise. It is also found that one of the main reasons is that the system is operating at its resonance frequency. Which of the following will NOT decrease the sound due to operating at the resonance frequency?

Hint: See ASHRAE Fundamentals, Chapter 8 Sound and Vibration and NCEES Mechanical PE

(a) Decrease fan speed

(b) Increase mass of ductwork

(c) Decrease spring coefficient of vibration isolators

(d) Add vanes to the ductwork

3 – AM Exam Solutions

HVAC & REFRIGERATION PE EXAM 3

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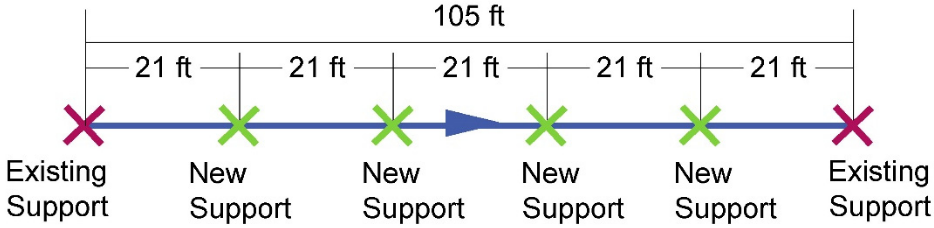
Solution 1 - HVAC Systems & Components

There is a 105 foot long, 6” schedule 40 steel pipe carrying 100-psig steam, run aboveground, horizontally, suspended from the ceiling. There are no valves or other ancillary equipment on this section of pipe. According to MSS Standard SP-69, how many support hangers should be provided on this section of pipe? Assume there are already supports at the beginning and end of the section.

Hint: See ASHRAE Fundamentals, Chapter 22 Pipe Design

According to **ASHRAE Fundamentals 2017, Chapter 22 Pipe Design**, Table 11 or **ASHRAE Systems 2016, Chapter 46 Pipes, Tubes and Fittings**, Table 6, a 6” standard steel pipe carrying steam should have hangers spaced at every 21 feet. Thus for this situation, 4 new supports are required.



Although this table was not carried over into the *NCEES Mechanical PE Reference Handbook* you should be familiar with the contents of ASHRAE Fundamentals Pipe Design and ASHRAE Systems Pipes, Tubes, and Fittings chapter and should generally understand the piping support concepts. Pipe supports are installed to prevent the pipe from exceeding its allowable stress, which are determined by the pipe material, pipe/accessory weight, fluid weight, thermal expansion, etc. It is very unlikely that you will be required to perform stress calculations, as this generally goes beyond the NCEES HVAC specifications, but understand that these criteria are how the pipe support tables are derived. The piping support table and other tables not provided in the NCEES handbook will have to be given to you in the question.

It is a good idea to compare what is provided in the NCEES Handbook from the ASHRAE Handbooks to understand how to use the tables and equations provided.

The correct answer is most nearly, (A) 4.

(A) 4

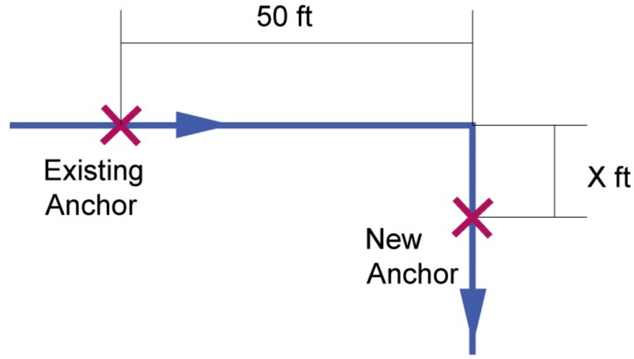
(B) 6

(C) 8

(D) 10

Solution 2 - HVAC Systems & Components

A schedule 80 XS, steel, 8” OD pipe is being checked for expansion and contraction. Assume A53B steel. The pipe carries chilled water at 45°F, but when not in use, this pipe can reach a temperature of 120 °F. The pipe has an anchor located 50 feet before a 90 degree turn. What is the minimum length of pipe from the 90 degree turn to the next anchor, in order to accommodate thermal expansion of the 50 foot long section of pipe?



This problem requires you to jump around the NCEES Handbook to find various equations and tables. Thermal expansion and contraction design is very important for designing pipe systems with large temperature variations and long straight runs. It is important to give the pipe room to move and to ensure that the pipe will not fail from stress with the use of guides and anchors. This problem focuses on an L-Bend design but you should also be familiar with the U-Bend design and Z-Bend design.

Pipe Expansion References:

NCEES Handbook Section 9.5 Pipe Expansion & Contraction
ASHRAE 2017 Fundamentals Chapter 22 Pipe Design
ASHRAE Systems 2016 Chapter 46 Pipes, Tubes and Fittings.

Navigate to the **NCEES Handbook, Section 9.5 Pipe Expansion & Contraction** (ASHRAE Fundamentals Chapter 22 Pipe Design) for the necessary equation pipe expansion equations.

First find the amount of thermal expansion in the pipe with the general thermal deformation equation. This can be found in the NCEES Handbook, Chapter 2 Machine Design and Material.

$$\Delta = \alpha L(T_f - T_i)$$

Find the coefficient of expansion in the **NCEES Handbook Chapter 1 Basic Engineering Practice** or **ASHRAE 2017 Fundamentals, Chapter 22 Pipe Design** Table 18 Properties of Pipe Materials. This table will give you the necessary properties of steel or A53B steel.

Based on A53B steel, E = 27.5 x 10^6 psi and the coefficient of expansion is 6.31 in/10^6 in °F.

Find the total expansion from the cold to hot temperature of the 50 foot long section of pipe.

SOLUTION 29 – HVAC SYSTEMS & COMPONENTS

2,000 lb/h steam at 12 psig is flowing through a 4" schedule 40 steel pipe. What is the pressure drop after 1,000 feet of pipe?

The section 6.2 Flow Rate of Steam in Schedule 40 Pipe of the NCEES Mechanical PE Reference Handbook has pressure drop tables for steam piping. Navigate to the steam table that shows flow rate and velocity of steam in schedule 40 pipe at staturation pressure of 12 psig. You will need to interpolate to the 2,000 lb/hr value.

1,690 lb/h: 0.25 psi per 100 ft | 2,400 lb/h: 0.5 psi per 100 ft

$$\frac{0.5 - 0.25\, psi\ per\ 100\ ft}{2{,}400 - 1{,}690\ lb/h} * (2{,}000 - 1690)\frac{lb}{h} = (X - 0.25)$$

$$X = 0.359\ psi\ per\ 100\ ft$$

The value is 0.36 psi/100 ft. Multiply by 1,000 ft and the result is 3.6 psi pressure drop.

The correct answer is most nearly, (B) 3.6 psi.

(A) 2.2 psi

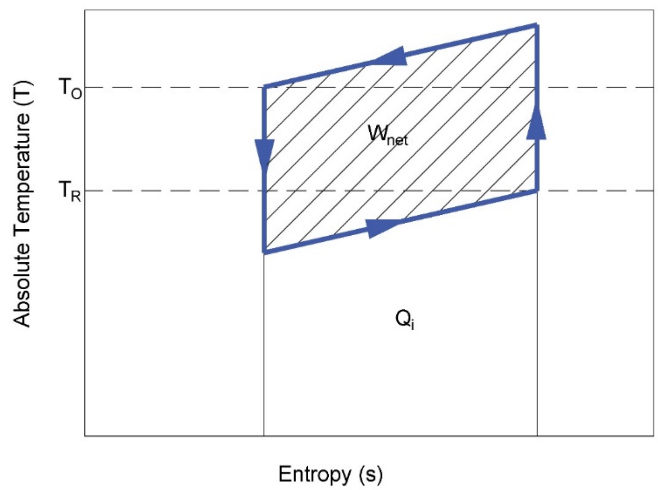
(B) 3.6 psi

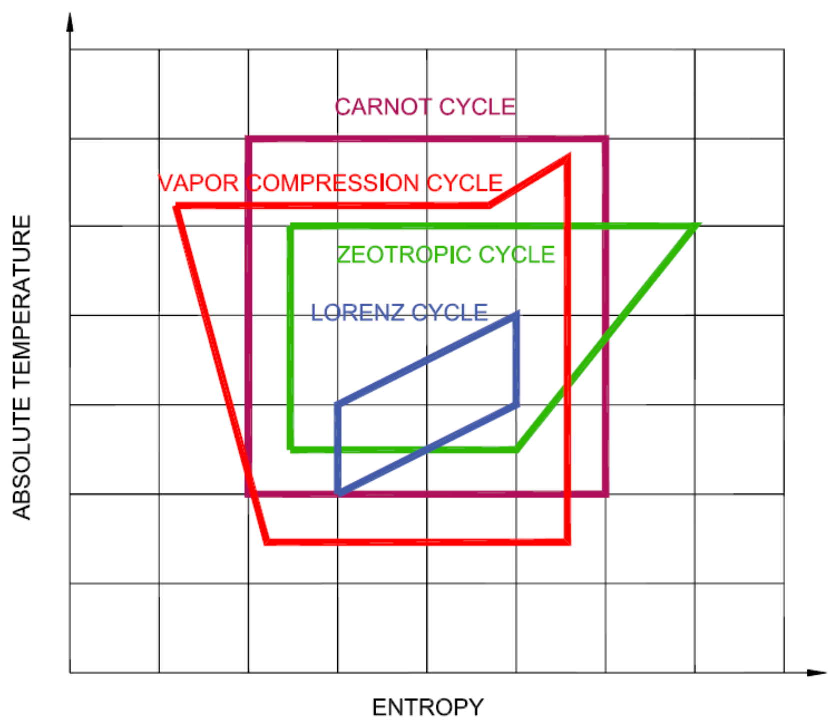
(C) 17.1 psi

(D) 26.6 psi

SOLUTION 30 - THERMODYNAMICS

The following temperature-entropy graph has the characteristics of what type of refrigeration cycle?





For more information on this topic you can refer to **ASHRAE Fundamentals 2017, Chapter 2 Thermodynamics and Refrigeration Cycles**.

The correct answer is (B), the graph is representative of a Lorenz Refrigeration Cycle.

(A) Carnot Cycle

(B) Lorenz Cycle

(C) Zeotropic Cycle

(D) Vapor Compression Cycle

Hint: See ASAHRAE Fundamentals, Chapter 8 Sound and Vibration and ASHRAE HVAC Applications, Chapter 48 Noise and Vibration Control.

Airborne Sound: Sound can be transmitted through air, both indoors and outdoors. Airborne sound transmission can be via a direct line of sight or the sound can be reflected off walls, floors, ceilings, furnishing, etc.

Aerodynamic Sound: Aerodynamic sound is created when airflow turbulence occurs. Aerodynamic sound should be monitored during design at duct fittings, dampers, and air terminal units. The aerodynamic sound magnitude is heavily dependent on the air velocity.

Ductborne Sound: Ducts provide a sound transmission path for sound from fans to the spaces. Transfer ducts between spaces can also transmit sound from one space to another. The sound is contained within the duct and sound can be transmitted upstream and downstream.

The correct answer is most nearly, (a) aerodynamic sound.

(a) Aerodynamic sound

(b) Ductborne sound

(c) Airborne direct sound

(d) Airborne reflected sound

Solution 59 – Supportive Knowledge

Which of the following will NOT decrease aerodynamically generated sound?

Hint: See ASAHRAE Fundamentals, Chapter 8 Sound and Vibration and ASHRAE HVAC Applications, Chapter 48 Noise and Vibration Control.

Reducing the air velocity will lower the turbulence, which will lower the sound created. The increase in straight lengths and addition of vanes will reduce turbulence, which will reduce sound generated. The only thing that will not reduce the sound generated will be the location of the volume dampers. The volume dampers will generate sound in any location. In practice, volume dampers are located away from occupied areas so the sound generated does not enter into the occupied areas.

The correct answer is most nearly, (c) location of volume dampers.

(a) Reducing air velocity

(b) Increasing straight duct length before/after transitions

(c) Location of the volume dampers

(d) Providing vanes in elbows

SOLUTION 60 – SUPPORTIVE KNOWLEDGE

An air handling unit with vibration isolators is currently running at 2000 RPM and is producing 2,300 CFM. The air enters supply ductwork and it is found that the ductwork is making a significant amount of noise. It is also found that one of the main reasons is that the system is operating at its resonance frequency. Which of the following will NOT decrease the sound due to operating at the resonance frequency?

Hint: See ASHRAE Fundamentals, Chapter 8 Sound and Vibration and NCEES Mechanical PE Reference Handbook, 2.15 Vibration/Dynamic Analysis.

The natural frequency must be changed so the disturbing frequency and the natural frequency are not equal to each other. Normally, the natural frequency is decreased. The mass can be increased or the spring coefficient (k) can be reduced.

$$w_n = \sqrt{\frac{k}{m}} = \sqrt{\frac{g}{\delta_{deflection}}}$$

Another option is to change the disturbing frequency. This can be done by changing the fan speed.

The correct answer is most nearly, (d) Add vanes to the ductwork.

(a) Decrease fan speed

(b) Increase mass of ductwork

(c) Decrease spring coefficient of vibration isolators

(d) Add vanes to the ductwork

SOLUTION 61 – SUPPORTIVE KNOWLEDGE

A cooling tower is located outdoors. The cooling tower has a sound rating of 80 dB at a distance of 3 feet from the cooling tower. What is the sound rating at a distance of 48 feet from the cooling tower?

Hint: See HVAC Applications, Chapter 48, Noise and Vibration Control

The sound level will be reduced by -6 dB every time the distance is doubled.

3 ft	80 dB
6 ft	74 dB

5 – Conclusion

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5.0 Conclusion

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