HVAC & Refrigeration

Mechanical

PE

Exam 1 *(formerly Full 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 1 (Full Exam)

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Mechanical PE: HVAC & Refrigeration Exam 1
(Full Exam)

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HVAC & REFRIGERATION PE EXAM 1
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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 the key concepts and skills of the HVAC & Refrigeration Mechanical P.E. Exam.

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 full 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/):

1) Principles
   a) **Basic Engineering Practice - *(4-6 questions)***
      i) Units and conversions
      ii) Economic analysis
      iii) Electrical concepts (e.g., power consumption, motor ratings, heat output, amperage)
   b) **Thermodynamics - *(4-6 questions)***
      i) *Cycles*
      ii) *Properties*
      iii) *Compression Processes*
   c) **Psychrometrics - *(7-11 questions)***
      i) *Heating/cooling cycles, humidification/dehumidification, heating/cooling loads, sea level and other elevations*
   d) **Heat Transfer - *(6-9 questions)***
   e) **Fluid Mechanics - *(3-5 questions)***
   f) **Energy/Mass Balances *(4-6 questions)***

2) Applications

   a) **Heating/Cooling Loads - *(7-11 questions)***
   b) **Equipment and Components - *(16-24 questions)***
      i) *Cooling towers and fluid coolers*
      ii) *Boilers and furnaces*
      iii) *Heat exchangers*
      iv) *Condensers/evaporators*
      v) *Pumps/compressors/fans*
      vi) *Cooling/heating coils*
      vii) *Control systems components*
      viii) *Refrigerants*
      ix) *Refrigeration components*
   c) **Systems - *(16-24 questions)***
      i) *Air distribution*
      ii) *fluid distribution*
      iii) *refrigeration*
      iv) *energy recovery*
      v) *control concepts*
   d) **Supportive Knowledge - *(3-5 questions)***
      i) *Codes and standards*
      ii) *Air quality and ventilation*
      iii) *Vibration control*
      iv) *Acoustics, economic analysis, electrical concepts*

Each of these topics were investigated and filtered by the test maker 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, capable of passing the P.E. exam. 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.

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 is familiar with the conversions table at the beginning of the *NCEES PE Mechanical Reference Handbook* 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 was 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 is 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.

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.

(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 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 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, ONLY IF you need additional assistance in a specific area. The *Engineering Pro Guides, HVAC & Refrigeration PE Textbook (Technical Study Guide)* should be sufficient for you to pass the exam. Also, 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**	
	Incompressible Flow	ASHRAE Fundamentals 2017	Ch 3 Fluid Flow
	Flow Analysis	ASHRAE Fundamentals 2017	Ch 3 Fluid Flow
Topic 7.0	**Energy/Mass Balances**	**5 of 80 problems**	
	Energy & Mass Balance	ASHRAE Fundamentals 2017	Ch 1 Psychrometrics
		ASHRAE Fundamentals 2017	Ch 2 Thermodynamics
Topic 8.0	**Heating/Cooling Loads**	**8 of 80 problems**	
	Climate Design	ASHRAE Fundamentals 2017	Ch 14 Climate Design Information
	Fenestration	ASHRAE Fundamentals 2017	Ch 15 Fenestration

Amazon Link[i] NFPA 90A, Standard for the Installation of Air Conditioning and Ventilating Systems

Amazon Link[i]: 90B, Standard for the Installation of Warm Air Heating and Air Conditioning Systems.

List of NFPA Codes and Standards

4.4 Mechanical PE: HVAC & Refrigeration Textbook

By Justin Kauwale

This book is specifically written for the Mechanical PE – HVAC and Refrigeration exam. It is a comprehensive study guide and that teaches the key concepts and skills needed for the test. It is intended to direct your learning for the need to know materials and give you a sturdy foundation in the HVAC and refrigeration principles and applications.

Link: Mechanical PE: HVAC & Refrigeration Textbook (Technical Study Guide)

Additional free material is available at www.engproguides.com

4.5 Common Property Tables and Charts

General

It is a good idea to be familiar with the following tables and charts. Some charts are provided within the question of the exam, the majority will be found in the *NCEES PE Mechanical Reference Handbook*. Review the handbook for additional HVAC related tables and charts that are not included in this list. Make sure you are comfortable with using the following:

- Basic Conversions
- Economic Interest Rates Table
- Pipe Tables: Equivalent Lengths, Friction Loss
- Density: Air, Water, Glycol/Water
- Steam Pipe Sizing
- Saturated/Superheated Water Table
- Temperature/Altitude Correction for Air
- Saturated/Superheated Refrigerant Table, R134a, R410a
- Psychrometric Chart, Air (Multiple elevations)
- Refrigerant Pipe Sizing
- Mollier Chart, Pressure-Enthalpy Diagram: Water, Refrigerant R134a, R410a
- Refrigeration of Foods
- Heating and Cooling Loads
- Building Resistances/U-Factors
- Combustion Reactions

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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[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

1 – AM Exam Problems

HVAC & REFRIGERATION PE EXAM 1 (FULL EXAM)

www.engproguides.com

PROBLEM 1 - BASIC ENGINEERING PRACTICE

Honey has a dynamic viscosity of 1000 poise, a specific heat capacity of 0.6 cal/g-°C, and a density of 0.05 oz/mL. The kinematic viscosity of honey, in ft^2/sec, is most nearly?

(A) 0.76

(B) 7.1

(C) 25

(D) 30

PROBLEM 2 - BASIC ENGINEERING PRACTICE

An 1800 RPM motor operates on 208 volts, 3 phase, 60 hertz power. The motor is providing 3 HP of mechanical power. Assume a power factor of 0.9 and a service factor of 1.15. If the motor is 85% efficient, how many amps must be supplied to the motor?

(A) 7 A

(B) 8 A

(C) 14 A

(D) 16 A

PROBLEM 12 - PSYCHROMETRICS

If you are designing an HVAC system at an elevation of 7,500 ft above sea level with outside air conditions of 60°F DB and 90% relative humidity, then what is the density and dew point of the outside air?

(A) 0.0631 lb/ft^3 and 57.1°F dp

(B) 0.0631 lb/ft^3 and 60.0°F dp

(C) 0.0574 lb/ft^3 and 57.1°F dp

(D) 0.0759 lb/ft^3 and 55.1°F dp

PROBLEM 13 - PSYCHROMETRICS

A cooling tower is used to cool 10,000 lbs/hr of condenser water from 105°F to 80°F. If the air is designed to enter at ambient air conditions of 85°F/50% relative humidty and leave at 95°F/80% relative humidity, then what is the mass flow rate of air required? Assume sea level.

(A) 1,950 lbs/hr

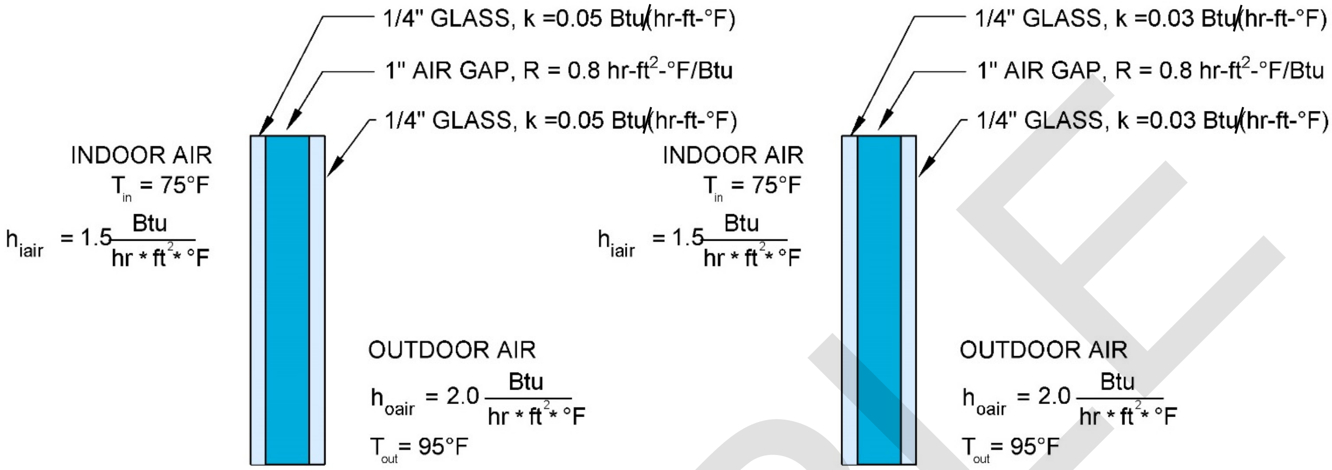
(B) 8,975 lbs/hr

(C) 10,000 lbs/hr

(D) 12,255 lbs/hr

PROBLEM 20 - HEAT TRANSFER

A client is considering replacing 1,200 ft^2 of windows with a new high efficiency window. What would be the reduction in conductive heat losses with the given below conditions?



(A) 1,500 Btu/hr

(B) 3,250 Btu/hr

(C) 8,900 Btu/hr

(D) 11,000 Btu/hr

PROBLEM 21 - HEAT TRANSFER

A chilled beam of 4" outer diameter and 100 feet in total length is located in a space with a dry bulb temperature of 75°F. If the surface temperature of the chilled beam is 50°F, then what is the radiative heat transfer to the space? Assume the emissivity of the chilled beam is 0.8.

(A) 1096 Btu/hr

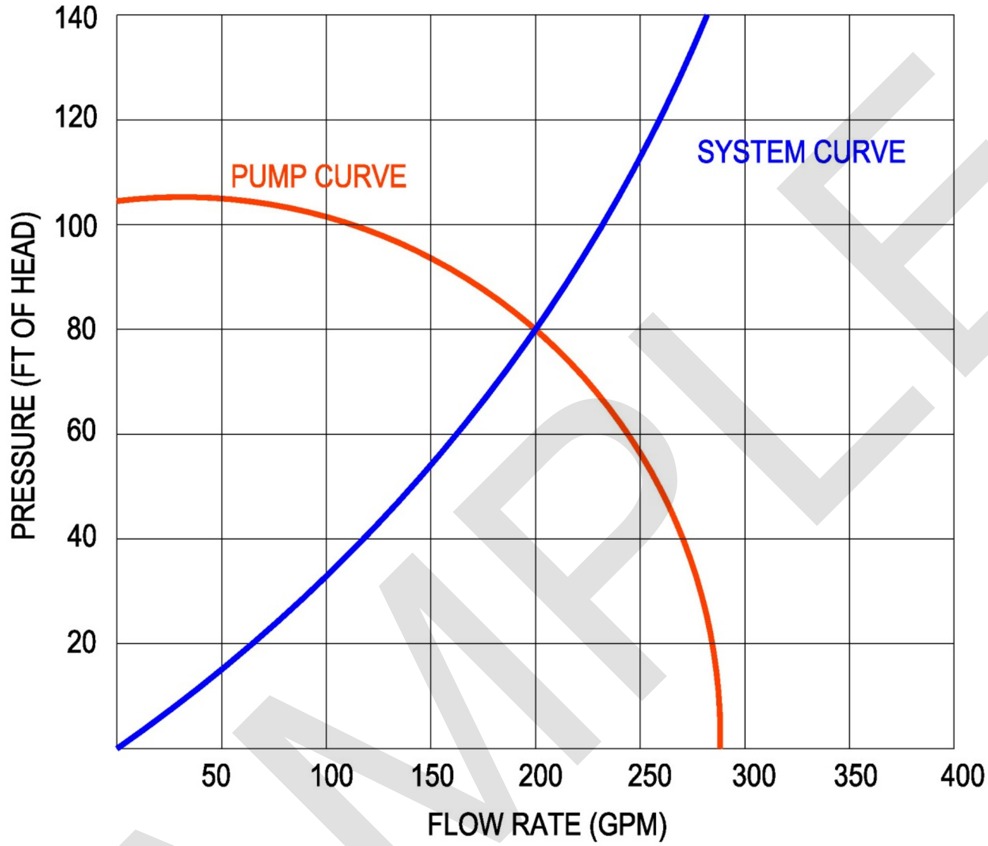
(B) 658 Btu/hr

(C) 410 Btu/hr

(D) 2,000 Btu/hr

PROBLEM 26 - FLUID MECHANICS

A new 480 Volt, 3-phase motor is provided to serve the following centrifugal pump with the design conditions shown in the below figure. If the pump's impeller diameter is increased by a factor of 1.25 and the speed of the pump remains the same, then what will be the resulting flow rate?



(A) 150 GPM

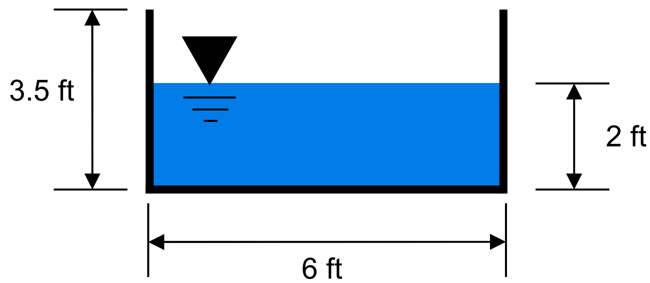
(B) 200 GPM

(C) 250 GPM

(D) 313 GPM

PROBLEM 27 - FLUID MECHANICS

Rainwater at 60°F flows down a trench at velocity of 10 ft/s. The cross section of the trench is illustrated below. What is the Reynolds number of the fluid?



(A) 2.47×10^6

(B) 3.29×10^6

(C) 3.94×10^6

(D) 4.93×10^6

PROBLEM 28 - ENERGY/MASS BALANCE

A new heat exchanger uses steam to heat water. Steam (50 lb/min) enters the heat exchanger at 20 psia, fully saturated. The condensate is not recovered. What mass flow rate of water can be expected to provide a 40 degree change in temperature?

(A) 1,000 lb/min

(B) 1,200 lb/min

(C) 1,300 lb/min

(D) 1,400 lb/min

2 – PM Exam Problems

HVAC & REFRIGERATION PE EXAM 1 (FULL EXAM)
www.engproguides.com

PROBLEM 41 - EQUIPMENT & COMPONENTS

An air handler supplies 5,000 CFM at a temperature of 55°F. The air handler was designed for 1,000 CFM of outside air at 87°F DB and 78°F WB. The remaining return air from the space is at 77°F DB and 55% relative humidity. What are the entering conditions of the air into the coil, in DB and WB?

(A) 79°F DB, 68.3 F WB

(B) 79°F DB, 59.6 F WB

(C) 85°F DB, 74.3 F WB

(D) 85°F DB, 75.7 F WB

PROBLEM 42 - EQUIPMENT & COMPONENTS

A classroom of 25 people has the following heat gains:

People: 250 Btu/h per person (Sensible); 200 Btu/h per person (Latent)

Lighting: 4,000 Btu/h; Computers: 8,000 Btu/h; Walls, Roofs, Windows: 22,000 Btu/h

Ventilation: 7,500 Btu/h (Sensible); 7,500 Btu/h (Latent)

The air handler serving the classroom has a supply air temperature of 55°F and the space is to be maintained at 75°F DB and 50% Relative humidity. What CFM is required?

(A) 2,210 CFM

(B) 2,675 CFM

(C) 2,790 CFM

(D) 3,865 CFM

PROBLEM 67 – SYSTEMS & COMPONENTS

A new cooling coil provides sensible cooling of 250,000 Btu/hr. The entering air conditions into the coil are 80°F DB. Leaving conditions from the coil at 55°F DB. If the coil is at an elevation of 5,000 FT, then what is the air flow rate in CFM? Assume negligible bypass factor and miscellaneous heat gains/losses.

Density = 0.062 lb/ft^3; Heat Capacity = 0.24 Btu/lb*°F

(A) 5,125 CFM

(B) 6,065 CFM

(C) 9,565 CFM

(D) 11,200 CFM

PROBLEM 68 – SYSTEMS & COMPONENTS

A 100% outside air handler serving a theater supplies 10,000 CFM of OAIR at 55°F DB/54°F WB to maintain space conditions at 75°F DB and 50% Relative Humidity. Outside air conditions are at 85°F DB and 80% Relative Humidity. How many tons of cooling can be saved if a total enthalpy wheel is provided with 75% effectiveness? Assume negligible bypass factor and no minor heat gains/losses.

(A) 25 tons

(B) 43 tons

(C) 56 tons

(D) 60 tons

3 – AM Exam Solutions

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SOLUTION 1 – BASIC ENGINEERING PRACTICE

Honey has a dynamic viscosity of 1000 poise, a specific heat capacity of 0.6 cal/g-°C, and a density of 0.05 oz/mL. The kinematic viscosity of honey, in ft^2/sec, is most nearly?

The equation for Kinematic Viscosity is located in the *NCEES Mechanical PE Reference Handbook* – Hydraulics, Fluids and Pipe Flow. The unit conversions necessary to complete this problem are located in the Basic Engineering Practice section and can also be deduced from the Hydraulics, Fluids and Pipe Flow section.

$$\nu = \frac{\mu}{\rho}$$

The specific heat capacity is irrelevant.

The dynamic (or absolute) viscosity is irrelevant:

$$\mu = (1000\, poise) * \frac{100 \text{ centipoise}}{1 \text{ poise}} * \frac{0.001 \text{ Pa}\cdot\text{s}}{1 \text{ centipoise}} * \frac{1\frac{\text{lbf}}{\text{in}^2}}{6895\, Pa} * \frac{144\frac{\text{lbf}}{\text{ft}^2}}{1\frac{\text{lbf}}{\text{in}^2}} = 2.09\frac{lbf \cdot s}{ft^2}$$

The density is found with the below dimensional analysis. *The NCEES Mechanical PE Reference Handbook has all of the unit conversions except for ounces to pounds.*

$$\rho = 0.05\frac{oz}{mL} * \frac{1\, lbm}{16\, oz} * \frac{1000mL}{1L} * \frac{1L}{61.02\, in^3} * \frac{1728\, in^3}{1\, ft^3} = 88.4\frac{lbm}{ft^3}$$

Therefore the kinematic viscosity is:

$$\nu = 2.09\frac{lbf \cdot s}{ft^2} * \frac{ft^3}{88.4\, lbm} * 32.2\frac{lbm * \frac{ft}{s^2}}{lbf} = 0.76\frac{ft^2}{s}$$

The correct answer is most nearly (A) 0.76

(A) 0.76

(B) 7.1

(C) 25

(D) 30

SOLUTION 2 – BASIC ENGINEERING PRACTICE

An 1800 RPM motor operates on 208 volts, 3 phase, 60 hertz power. The motor is providing 3 HP of mechanical power. Assume a power factor of 0.9 and a service factor of 1.15. If the motor is 85% efficient, how many amps must be supplied to the motor?

In order to complete this problem, you need the density factor for different elevations. This is located in the Psychrometrics section of the *NCEES Mechanical PE Reference Handbook*.

$$7{,}500\ ft \rightarrow Density\ Factor = 0.757$$

First, find the density and dew point of the air at sea level. The psychrometric chart to solve this problem is located in the Psychrometrics section of the *NCEES Mechanical PE Reference Handbook*.

$$Sea\ Level \rightarrow \rho = 0.07587 \frac{lb}{ft^3}; T_{DP} = 57.1\ °F$$

Next, adjust the density with the density factor.

$$7{,}500\ ft \rightarrow \rho = 0.07587 \frac{lb}{ft^3} * 0.757 = 0.0574 \frac{lb}{ft^3}$$

Now, you need to find the dew point. If the dry bulb temperature and relative humidity do not change, then the dew point will not change. The dew point is based on the vapor pressure of the water and that does not change with elevation. The atmospheric pressure changes, but that does not change the vapor pressure, based on the assumption that the temperature and relative humidity are the same.

$$7{,}500\ ft \rightarrow T_{DP} = 57.1\ °F$$

NCEES Mechanical PE Reference Handbook 7.3 Psychrometric Charts and 7.2 Temperature and Altitude Corrections for Air.

The correct answer is most nearly (C) 0.0574 lb/ft^3 and 57.1 F dp.

(A) 0.0631 lb/ft^3 and 57.1 F dp

(B) 0.0631 lb/ft^3 and 60.0 F dp

(C) 0.0574 lb/ft^3 and 57.1 F dp

(D) 0.0759 lb/ft^3 and 55.1 F dp

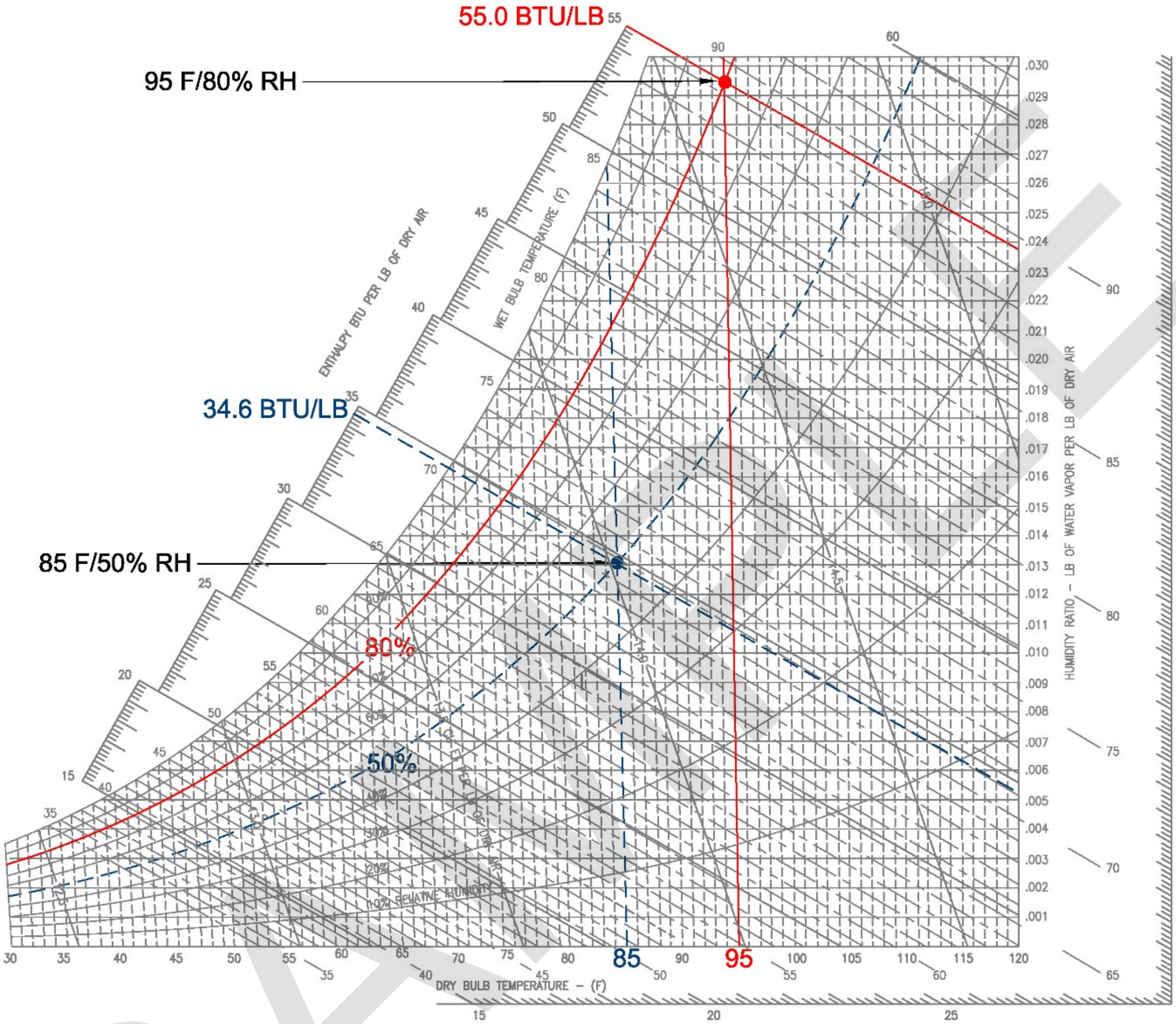
SOLUTION 13 – PSYCHROMETRICS

A cooling tower is used to cool 10,000 lbs/hr of condenser water from 105°F to 80°F. If the air is designed to enter at ambient air conditions of 85°F/50% relative humidty and leave at 95 F/80% relative humidity, then what is the mass flow rate of air required? Assume sea level.

The energy from the condenser water is transferred to the air.

$$\dot{m}_{water} * c_{p,water} * \left(T_{enter,water} - T_{leaving,water}\right) = \dot{m}_{air} * (h_{leaving,air} - h_{enter,air})$$

$$h_{leaving,air} \text{ and } h_{enter,air} \text{ are found using the psychrometric chart}$$



$$10{,}000\frac{lbs}{hr} * 1.0\frac{BTU}{lbm\ °\mathrm{F}} * (105 - 80\ F) = \dot{m}_{air} * (55.0 - 34.6\frac{BTU}{lbm})$$

$$12{,}255\frac{lbs}{hr} = \dot{m}_{air}$$

The psychrometric chart to solve this problem is located in the Psychrometrics section of the *NCEES Mechanical PE Reference Handbook*.

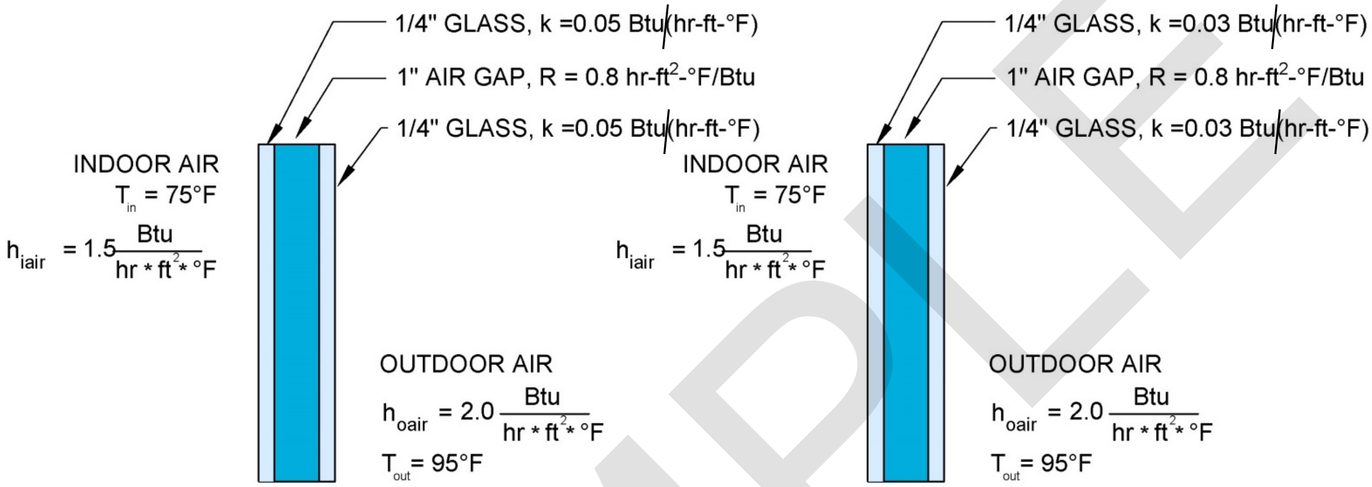
The correct answer is most nearly, (D) 12,255 lbs/hr.

(A) 1,950 lbs/hr

(D) 75 lbm/hr

SOLUTION 20 – HEAT TRANSFER

A client is considering replacing 1,200 ft^2 of windows with a new high efficiency window. What would be the reduction in conductive heat losses with the given below conditions?



You need to find the overall heat transfer coefficient, U. But it is easier to find the overall heat transfer coefficient by first converting all the heat transfer coefficients to R-values.

$$R = \frac{1}{h_{iair}(\frac{Btu}{hr-ft^2-°F})} + \frac{1}{h_{oair}(\frac{Btu}{hr-ft^2-°F})} + 2 * \frac{thickness_{glass}(ft)}{k_{glass}\left(\frac{Btu}{hr-ft-°F}\right)} + R_{air}$$

$$R_{old} = \frac{1}{1.5} + \frac{1}{2.0} + 2 * \frac{1/4"/(12"/1\,ft)}{0.05} + 0.8 = 2.8$$

$$R_{new} = \frac{1}{1.5} + \frac{1}{2.0} + 2 * \frac{1/4"/(12"/1\,ft)}{0.03} + 0.8 = 3.4$$

Next find conductive heat gains

$$Q = U * A * (T_{out} - T_{in}); where\ U = 1/R$$

$$Q_{old} = \left(\frac{1}{2.8}\right) * 1{,}200 * (95 - 75) = 8{,}571\ Btu/hr$$

$$Q_{new} = \left(\frac{1}{3.4}\right) * 1{,}200 * (95 - 75) = 7{,}152\ Btu/hr$$

NCEES Mechanical PE Reference Handbook 5.2.1 Composite Plane Wall and 5.1.3 Conduction Through a Uniform Material. You need to be able to convert between R-value, thermal conductivity and U-value.

The difference is 1,419 Btu/hr and the correct answer is most nearly, (A) 1,500 Btu/hr

(A) 1,500 Btu/hr

(B) 3,250 Btu/hr

(C) 8,900 Btu/hr

(D) 11,000 Btu/hr

SOLUTION 21 – HEAT TRANSFER

A chilled beam of 4" outer diameter and 100 feet in total length is located in a space with a dry bulb temperature of 75°F. If the surface temperature of the chilled beam is 50°F, then what is the radiative heat transfer to the space? Assume the emissivity of the chilled beam is 0.8.

The radiative heat equation is located in the Heat Transfer section of the *NCEES Mechanical PE Reference Handbook*.

In order to calculate the radiative heat gain, you should use the following equation.

$$Q = \sigma * A * \varepsilon * (T_s^4 - T_{ambient}^4 \ °R)$$

$$\sigma = Boltzmann\ constant = 1.714\ x\ 10^{-9} \frac{Btu}{hr - ft^2 - °R^4}$$

$$A = Area = \pi * D * L = \pi * 4/12 * 100 = 105\ ft^2$$

$$T_s = 50 + 460 = 510\ °R; T_{ambient} = 75 + 460 = 535\ °R;$$

$$Q = 1.714\ x\ 10^{-9} * 105 * 0.8 * (510^4 - 535^4) = 2{,}054\ Btu/hr$$

NCEES Mechanical PE Reference Handbook 5.6.6 Net Energy Exchange by Radiation Between Two Bodies.

The correct answer is most nearly, (D) 2,000 Btu/hr

(A) 1096 Btu/hr

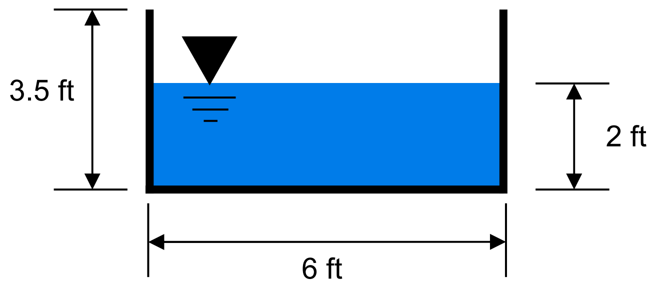
(B) 658 Btu/hr

(C) 410 Btu/hr

(D) 2,000 Btu/hr

SOLUTION 27 – FLUID MECHANICS

Rainwater at 60°F flows down a trench at velocity of 10 ft/s. The cross section of the trench is illustrated below. What is the Reynolds number of the fluid?



Reynolds number is found by the following equation. The equation is located in the Hydraulics, Fluids and Pipe Flow section of the *NCEES Mechanical PE Reference Handbook*.

$$Re = \frac{\rho v D_h}{\mu} = \frac{v D_h}{\nu}$$

where D_h is the equivalent hydraulic diameter of the trench.

For fluid partially flowing through a rectangular channel, the hydraulic diameter is:

$$D_h = \frac{4hw}{w + 2h} = \frac{4 * 2ft * 6ft}{6ft + 2 * 2ft} = 4.8ft$$

where h is the height of the fluid in the trench and w is the width of the trench.

The kinematic viscosity, ν, of water at 60°F is 1.217×10^{-5} ft²/s.

Solve for the Reynolds number.

$$Re = \frac{\left(10\frac{ft}{s}\right) * 4.8ft}{1.217 \times 10^{-5}\frac{ft^2}{s}} = 3.94 \times 10^6$$

NCEES Mechanical PE Reference Handbook: 3.4.1 Reynolds Number and 3.4.2.6 Flow in Noncircular Conduits. You also need the kinematic viscosity of water from 1.2.9 Properties of Water at Atmospheric Pressure.

The correct answer is most nearly, (C) 3.94×10^6

(A) 2.47×10^6

(B) 3.29×10^6

(C) 3.94×10^6

4 – PM Exam Solutions

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SOLUTION 41 – EQUIPMENT & COMPONENTS

An air handler supplies 5,000 CFM at a temperature of 55 °F. The air handler was designed for 1,000 CFM of outside air at 87 °F DB and 78 °F WB. The remaining return air from the space is at 77 °F DB and 55% relative humidity. What are the entering conditions of the air into the coil, in DB and WB?

This problem involves finding the mixed air condition of two airstreams. Remember that only the dry bulb temperature, humidity ratio and enthalpy are linearly related.

First, find the mixed dry bulb temperature, using the lever rule.

$$CFM_{mixed} * T_{mixed} = CFM_{rair} * T_{rair} + CFM_{oair} * T_{oair}\ [DB]$$

$$5{,}000 * T_{mixed} = 1{,}000 * 87°\text{F} + 4{,}000 * 77°\text{F}\ [DB]$$

$$T_{mixed} = 79°\text{F}\ [DB]$$

Next we are going to use the same equation, but with enthalpies.

From the psychrometric chart, $h_{rair} = 30.45 \frac{Btu}{lb}$; $h_{oair} = 41.47 \frac{Btu}{lb}$

$$CFM_{mixed} * h_{mixed} = CFM_{rair} * h_{rair} + CFM_{oair} * h_{oair}$$

$$5{,}000 * T_{mixed} = 1{,}000 * 41.47 + 4{,}000 * 30.45$$

$$h_{mixed} = 32.65 \frac{Btu}{lb}$$

The mixed air condition is $79°\text{F}\ [DB], h_{mixed} = 32.65 \frac{Btu}{lb}$

Finally, use the psychrometric chart to find the Wet Bulb condition.

NCEES Mechanical PE Reference Handbook: 9.1.7 Heat Gain Calculations Using Standard Air and Water Values and 9.2.3 Adiabatic Mixing of Two Moist Airstreams.

The correct answer is most nearly, (A) 79 F DB, 68.3 F WB.

(A) 79 F DB, 68.3 F WB

(B) 79 F DB, 59.6 F WB

(C) 85 F DB, 74.3 F WB

(D) 85 F DB, 75.7 F WB

$$Q = 1{,}000\ lbs * 110$$

$$Q = 110{,}000\ Btu$$

Calculate the total amount of cooling to bring the salmon from freezing to 10 F.

$$Q = 1{,}000\ lbs * 0.51 * (28 - 10)$$

$$Q = 9{,}180\ Btu$$

Sum up the total cooling and divide by 2 hours in order to calculate the required size of the air conditioning system.

$$Q = \frac{36{,}960 + 110{,}000 + 9{,}180\ BTU}{2\ Hr} = 78{,}070 \frac{Btu}{h}$$

NCEES Mechanical PE Reference Handbook: 8.10 Refrigeration Properties of Foods.

The correct answer is most nearly, (C) 78,070 BTUH.

(A) 18,320 BTUH

(B) 37,210 BTUH

(C) 78,070 BTUH

(D) 110,000 BTUH

SOLUTION 67 – SYSTEMS & COMPONENTS

A new cooling coil provides sensible cooling of 250,000 Btu/hr. The entering air conditions into the coil are 80 °F DB. Leaving conditions from the coil at 55 °F DB. If the coil is at an elevation of 5,000 FT, then what is the air flow rate in CFM? Assume negligible bypass factor and miscellaneous heat gains/losses.

Density = 0.062 lb/ft^3; Heat Capacity = 0.24 Btu/lb-°F

This problem is an energy balance uses the original sensible heat equation.

$$Q_{air} = Q_{coil}$$

$$Q_{air} = \dot{m} * c_p * \Delta T$$

$$250{,}000 \frac{Btu}{hr} = Q_{air} = x \frac{ft^3}{\text{min}} * \frac{60\ min}{\text{hr}} * 0.062 \frac{lb}{ft^3} * \quad 0.24 \frac{Btu}{lbm * F} (80 - 55\ F)$$

$$x = 11{,}200\ \frac{ft^3}{\text{min}}$$

5 – Conclusion

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8.0 Conclusion

If you have any questions on this book or any other Engineering Pro Guides product, then please contact me at my email below. Also if you are looking for more HVAC PE products, then please visit the website and purchase the complete set of HVAC PE products. The website also has a bunch of free information that you can use to facilitate your studying. Finally, each webpage also has a section for you to ask questions on the product and to leave comments, in addition the errata for each product is located on their respective webpages.

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6 – Diagnostics Outline

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#	Major Category	Correct?
1	Principles – Basic Engineering Practice	
2	Principles – Basic Engineering Practice	
3	Principles – Basic Engineering Practice	
4	Principles – Basic Engineering Practice	
5	Principles – Thermodynamics	
6	Principles – Thermodynamics	
7	Principles – Thermodynamics	
8	Principles – Thermodynamics	
9	Principles – Psychrometrics	
10	Principles – Psychrometrics	
11	Principles – Psychrometrics	
12	Principles – Psychrometrics	
13	Principles – Psychrometrics	
14	Principles – Psychrometrics	
15	Principles – Psychrometrics	
16	Principles – Psychrometrics	
17	Principles – Heat Transfer	
18	Principles – Heat Transfer	
19	Principles – Heat Transfer	
20	Principles – Heat Transfer	
21	Principles – Heat Transfer	
22	Principles – Heat Transfer	
23	Principles – Heat Transfer	
24	Principles – Fluid Mechanics	
25	Principles - Fluid Mechanics	
26	Principles - Fluid Mechanics	
27	Principles - Fluid Mechanics	
28	Principles – Energy/Mass Balances	
29	Principles – Energy/Mass Balances	
30	Principles – Energy/Mass Balances	
31	Principles - Energy/Mass Balances	
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33	Application – Heating/Cooling Loads	
34	Application – Heating/Cooling Loads	
35	Application – Heating/Cooling Loads	
36	Application – Heating/Cooling Loads	
37	Application – Heating/Cooling Loads	
38	Application – Heating/Cooling Loads	
39	Application – Heating/Cooling Loads	
40	Application – Heating/Cooling Loads	

#	Major Category	Correct?
41	Applications – Equipment & Components	
42	Applications – Equipment & Components	
43	Applications – Equipment & Components	
44	Applications – Equipment & Components	
45	Applications – Equipment & Components	
46	Applications – Equipment & Components	
47	Applications – Equipment & Components	
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73	Applications – Systems & Components	
74	Applications – Systems & Components	
75	Applications – Systems & Components	
76	Applications – Systems & Components	
77	Applications – Support Knowledge	
78	Applications – Support Knowledge	
79	Applications – Support Knowledge	
80	Applications – Support Knowledge	