Mechanical Full Exam

HVAC & Refrigeration

- 80 exam difficulty level problems
- Covers Mechanical PE HVAC & Refrigeration exam topics
- Written in exam format
- Also includes detailed solutions

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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 depth 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/):

1) Principles

   a) Basic Engineering Practice - (4 questions)
      i) Units and conversions
      ii) Economic analysis
      iii) Electrical concepts (e.g., power consumption, motor ratings, heat output, amperage)
   
   b) Thermodynamics - (4 questions)
      i) Cycles
      ii) Properties
      iii) Compression Processes
   
   c) Psychrometrics - (8 questions)
      i) Heating/cooling cycles, humidification/dehumidification, heating/cooling loads, sea level and other elevations
   
   d) Heat Transfer - (7 questions)

   e) Fluid Mechanics - (4 questions)

   f) Energy/Mass Balances (5 questions)

2) Applications
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 have a conversion book, because certain areas of the P.E. Exam may use the International System of Units (SI).

2.0 DISCLAIMER
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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 sitting and timed for four hours to simulate the real exam. This will give you a better indication of your status of preparation for the exam. If you are at the ending of your studying, it is recommended to couple this exam with the AM section to simulate the full exam test day.

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 (highly recommended on test day, some test facilities do not have a clock)
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:

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 answer will hopefully be found in the Mechanical Engineering Reference Manual (MERM), the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Handbooks or one of the other 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 straightforward 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/](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.
4.4 ASHRAE HANDBOOKS (MUST HAVE)

By ASHRAE

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) is the guiding source for the HVAC engineer. The society publishes four handbooks that contain the essential topics and knowledge for practicing engineer: HVAC Systems and Equipment, HVAC Applications, Refrigeration, Fundamentals. Each of these handbooks is updated in a four year rotation. The handbooks are comprehensive and detailed. It is not necessary to know the extensive details of these books, but it is essential to understand their layout and know how to navigate them. If there is a question that you are unsure of in the test, these books will likely have the solution. But because there is so much information, it will be difficult to find the necessary references without at least having a familiarity with these resources.

Amazon Link: [2016 ASHRAE Handbook: HVAC Systems and Equipment](#)
Amazon Link: [2015 ASHRAE Handbook: HVAC Applications](#)
Amazon Link: [2014 ASHRAE Handbook: Refrigeration](#)
Amazon Link: [2013 ASHRAE Handbook: Fundamentals](#)

4.5 ASHRAE CODES & STANDARDS

By ASHRAE

ASHRAE standards are another common tool used by practicing professional HVAC engineers. The exam does not appear to be based on the latest version of the codes, since it is not referenced as a resource by NCEES. However, it is recommended at a minimum that the engineer in training be familiar with the information in each of the following codes:

Amazon Link: [ASHRAE 15, Safety Standard for Refrigeration Systems](#)
Amazon Link: [ASHRAE 55, Thermal Environmental Conditions for Human Occupancy](#)
Amazon Link: [ASHRAE 62.1, Ventilation for Acceptable Indoor Air Quality](#)
Amazon Link: [ASHRAE 90.1, Energy Standard for Building, except Low-Rise Residential Buildings](#)

4.6 NFPA CODES

By NFPA

The National Fire Protection Agency provides codes and standards related to fire protection. The only recommended NFPA codes are those relating to HVAC systems. These codes are NFPA 90A and NFPA 90B. The test may also ask the name of the code required for a certain application. Therefore, it is useful to also print the list of all the NFPA codes and standards.
4.7 MECHANICAL PE: HVAC & REFRIGERATION TECHNICAL STUDY GUIDE
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.

Additional free material is available at www.engproguides.com

4.8 COMMON PROPERTY TABLES AND CHARTS
General

Along with the compiled notes and indices that you bring to the exam, it is also a good idea to bring the following tables and figures. Some charts are provided within the question of the exam. A psychrometric chart is also provided in the test booklet, but it is useful to have these tables and figures at your fingertips, both in SI and IP units. All these tables/figures are available to print online.

- Saturated/Superheated Water Table
- Saturated/Superheated Refrigerant Table, R134a, R140a
- Psychrometric Chart, Air
- Mollier Chart, Pressure-Enthalpy Diagram: Water, Refrigerant R134a, R140a

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1 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
QUESTION 1
PRINCIPLES 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 ft²/sec, is most nearly?
(A) 0.76
(B) 7.1
(C) 25
(D) 30

QUESTION 2
PRINCIPLES – BASIC ENGINEERING PRACTICE
A 3 hp, 1800 RPM motor operates on 208 volts, 3 phase, 60 hertz 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
(B) 8
(C) 14
(D) 16
QUESTION 12

PRINCIPLES – 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/ft³ and 57.1 F dp
(B) 0.0631 lb/ft³ and 60.0 F dp
(C) 0.0574 lb/ft³ and 57.1 F dp
(D) 0.0759 lb/ft³ and 55.1 F dp

QUESTION 13

PRINCIPLES – 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 humidity and leave at 95 F/80% relative humidity, then what is the mass flow rate of air required?

(A) 1,950 lbs/hr
(B) 8,975 lbs/hr
(C) 10,000 lbs/hr
(D) 12,255 lbs/hr
**QUESTION 14**  
**PRINCIPLES – PSYCHROMETRICS**  
An evaporative cooler is used to cool an airstream of 95 F/20% relative humidity. If the air leaves the evaporative air cooler at 80 F, then what is the new relative humidity?  
(A) 29%  
(B) 48%  
(C) 57%  
(D) 69%

**QUESTION 15**  
**PRINCIPLES – PSYCHROMETRICS**  
45 F/80% relative humidity air is heated with a 8,100 Btu/hr electric heater. Then a humidifier is used to increase the relative humidity to 50%. What is the amount of energy provided, if the flow rate is 250 CFM. Assume sea level and a density of 0.075 lb/ft³.  
(A) 7,000 Btu/hr  
(B) 8,000 Btu/hr  
(C) 10,000 Btu/hr  
(D) 13,250 Btu/hr
QUESTION 20

PRINCIPLES – HEAT TRANSFER

A client is considering replacing 1,200 ft² 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
QUESTION 21
PRINCIPLES – 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

QUESTION 22
PRINCIPLES – HEAT TRANSFER
A motor is located in a mechanical room at 75 F DB. The motor operates at 10 BHP and is 95% efficient. The remaining energy is released as heat to the space. The surface temperature of the motor is 120 F. What is the overall heat transfer coefficient? The motor is approximated as a box with dimensions, 2’ X 1’ X 1’. The motor is suspended, such that all surfaces are exposed.

(A) 1.0 Btu/(hr-ft^2-°F)
(B) 2.8 Btu/(hr-ft^2-°F)
(C) 4.2 Btu/(hr-ft^2-°F)
(D) 5.6 Btu/(hr-ft^2-°F)
QUESTION 26

PRINCIPLES – FLUID MECHANICS

A new 480 Volt, 3-phase motor is provided to serve the following 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
QUESTION 27

PRINCIPLES – 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) $2.47 \times 10^6$
(B) $3.29 \times 10^6$
(C) $3.94 \times 10^6$
(D) $4.93 \times 10^6$
QUESTION 40

APPLICATION – HEATING/COOLING LOADS

Calculate the building’s heat load given the following information. The building is to be maintained at 69 F DB and the design outside air conditions are 5 F DB/75% RH. Assume no infiltration and no outside air loads.

Wall area: 20,000 SF, Roof area: 2,500 SF, Window area: 2,000 SF

Wall: R-11; Roof: R-20; Window: U-Value = 0.75

(A) 296,000 Btu/hr
(B) 220,000 Btu/hr
(C) 184,000 Btu/hr
(D) 124,000 Btu/hr
SECTION 3
PM QUESTIONS
QUESTION 41
APPLICATIONS – 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

QUESTION 42
APPLICATIONS – 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
QUESTION 43
APPLICATIONS – EQUIPMENT & COMPONENTS

A dedicated outside air unit is used to pre-cool 2,500 CFM of outside air at 88 °F DB and 85% relative humidity to 60 °F DB, 58 °F WB. What is the quantity of water removed by the coil in GPM?

(A) 0.29 GPM
(B) 0.33 GPM
(C) 2.9 GPM
(D) 2.4 GPM

QUESTION 44
APPLICATIONS – EQUIPMENT & COMPONENTS

An air handling unit cools 2,000 CFM of outside air (90 F DB/80% RH) and 6,000 CFM of return air (77 °F DB, 50% RH) to 52 °F DB, 51 °F WB. If chilled water enters the coil at 44 °F and leaves at 56 °F, what is the required GPM?

(A) 42 GPM
(B) 80 GPM
(C) 105 GPM
(D) 126 GPM
QUESTION 67
APPLICATIONS – 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
(B) 6,065
(C) 9,565
(D) 11,200

QUESTION 68
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
QUESTION 79
APPLICATIONS – SUPPORT KNOWLEDGE
The unit "clo" is used to describe the thermal insulation provided by which of the below?

(A) Wall insulation
(B) Roof insulation
(C) Garment insulation
(D) Heating equipment insulation

QUESTION 80
APPLICATIONS – SUPPORT KNOWLEDGE
Which of the following codes are least likely to be required to be checked with regards to the installation of a commercial gas furnace?

(A) NFPA 54
(B) ASHRAE 90.1
(C) NFPA 70
(D) International Fuel Gas Code
SECTION 4
AM SOLUTIONS
SOLUTION 1
PRINCIPLES 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 ft²/sec, is most nearly?

Kinematic viscosity is defined as:

\[ \nu = \frac{\mu}{\rho} \]

The specific heat capacity is irrelevant.

The dynamic (or absolute) viscosity is irrelevant:

\[ \mu = (1000 \text{ poise}) \times \frac{1 \text{ Pa} \cdot \text{s}}{10 \text{ poise}} \times \frac{0.020885 \text{ lbf} \cdot \text{ft}^{2}}{\text{Pa}} = 2.09 \frac{\text{lbf} \cdot \text{s}}{\text{ft}^{2}} \]

The density is:

\[ \rho = 0.05 \frac{\text{oz}}{\text{mL}} \times \frac{0.0625 \text{ lbm}}{1 \text{ oz}} \times \frac{28317 \text{ mL}}{1 \text{ ft}^{3}} = 88.4 \frac{\text{lbm}}{\text{ft}^{3}} \]

Therefore the kinematic viscosity is:

\[ \nu = 2.09 \frac{\text{lbf} \cdot \text{s}}{\text{ft}^{2}} \times \frac{\text{ft}^{3}}{88.4 \text{ lbm}} \times \frac{\text{lbm} \cdot \text{s}^{2}}{\text{lbf} \cdot \text{ft}^{2}} = 0.76 \frac{\text{ft}^{2}}{\text{s}} \]

The correct answer is A

(A) 0.76
SOLUTION 7
PRINCIPLES – THERMODYNAMICS

An R134a refrigeration cycle operates at pressures, 23.77 psia and 150 psia. If the refrigerant is superheated to 10 F and refrigerant is subcooled to 100 F, then what is the COP? Assume the compressor is 90% efficient.

The first step in completing this problem is to find the conditions on the R134a, pressure-enthalpy diagram.

Point D is found first as the intersection of the horizontal pressure line 150 psia and the subcooled liquid temperature of 100 F.

Point A is found by a vertical downward line from point D, which is the constant enthalpy line, and the intersection of the suction pressure 23.8 psia line.

Point B is found by the intersection of the constant pressure line 23.8 psia and the superheated temperature line 10 F.

The next step is to calculate the net refrigeration.
**SOLUTION 12**

**PRINCIPLES – 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?

In order to complete this problem, you need psychrometric charts for different elevations. For the exam you should have the necessary psychrometric charts to complete this problem. You can get Psychrometric Charts from ASHRAE at the following websites or at the following free websites.


[http://www.coolerado.com/pdfs/Psychrmtrcs/5000Psychrmtrc11x17.pdf](http://www.coolerado.com/pdfs/Psychrmtrcs/5000Psychrmtrc11x17.pdf)


Based on Psychrometric Chart 5 (elevation 7,500 ft), the dew point is 57.1 F dp and the density is 0.0574 lb/ft³. The dew point is found by navigating to 60 F dry bulb and 90% relative humidity and then drawing a horizontal line to the saturation curve (left).

**Correct answer is C.**

(A) 0.0631 lb/ft³ and 57.1 F dp  
(B) 0.0631 lb/ft³ and 60.0 F dp  
(C) 0.0574 lb/ft³ and 57.1 F dp  
(D) 0.0759 lb/ft³ and 55.1 F dp
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:

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

where $D_h$ is the equivalent hydraulic diameter of the trench.

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

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

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

The kinematic viscosity, $\nu$, of water at 60°F is $1.217 \times 10^{-5}$ ft$^2$/s.

Solve for the Reynolds number.

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

The correct answer is C.

(A) $2.47 \times 10^6$

(B) $3.29 \times 10^6$

(C) $3.94 \times 10^6$

(D) $4.93 \times 10^6$
SECTION 5
PM SOLUTIONS
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.

\[ CF_{mixed} \cdot T_{mixed} = CF_{air} \cdot T_{air} + CF_{oair} \cdot T_{oair} \ [DB] \]

\[ 5000 \cdot T_{mixed} = 1000 \cdot 87°F + 4000 \cdot 77°F \ [DB] \]

\[ T_{mixed} = 79°F [DB] \]

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

From the psychrometric chart, \( h_{air} = 30.45 \tfrac{Btu}{lb} \); \( h_{oair} = 41.47 \tfrac{Btu}{lb} \)

\[ CF_{mixed} \cdot h_{mixed} = CF_{air} \cdot h_{air} + CF_{oair} \cdot h_{oair} \]

\[ 5000 \cdot T_{mixed} = 1000 \cdot 41.47 + 4000 \cdot 30.45 \]

\[ h_{mixed} = 32.65 \tfrac{Btu}{lb} \]

The mixed air condition is 79°F [DB], \( h_{mixed} = 32.65 \tfrac{Btu}{lb} \)

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

Correct answer is A.

(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
SOLUTION 42
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?

First calculate the total loads.

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<th>Category</th>
<th>Sensible (Btu/h)</th>
<th>Total (Btu/h)</th>
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<td>Ventilation</td>
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<td>15,000</td>
</tr>
<tr>
<td>Total</td>
<td>47,750</td>
<td>60,250</td>
</tr>
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</table>

\[
Q_{sensible} = \dot{m} \cdot c_p \cdot \Delta T \\
Q_{sensible} = 1.08 \cdot \text{CFM} \cdot \Delta T \\
47,750 \text{Btu/hr} = 1.08 \cdot \text{CFM} \cdot (75 - 55\degree F) \\
\text{CFM} = 2,210
\]

Correct answer is A.

(A) 2,210 CFM
(B) 2,675 CFM
(C) 2,790 CFM
(D) 3,865 CFM
SOLUTION 57
An existing chiller is served by a chilled water pump (150 GPM, 75 TDH), 65% efficient pump, 90% efficient motor. A recent study was conducted and it was found that the pump was oversized and should be replaced with a new higher efficiency pump at 150 GPM, 50 TDH, 80% efficient pump and 95% premium efficiency motor. If the pump runs 8 hours a day, 5 days a week, 52 weeks a year, how many kWh per year will be saved by switching to the new pump?

First find the Pump horsepower, specific gravity (SG) of water is equal to 1.0.

\[
Pump\ HP_{old} = \frac{GPM \times TDH \times SG}{3956}
\]

\[
Pump\ HP_{old} = \frac{150 \times 75 \times 1.0}{3956}
\]

\[
Pump\ HP_{old} = 2.84\ HP
\]

Then find the total electricity used by dividing the Pump Horsepower by the efficiency of the pump and the motor and convert to KW.

\[
Electricity\ Use = 2.84\ HP \times \left(\frac{1}{0.65}\right) \times \left(\frac{1}{0.90}\right) \times \frac{0.746\ KW}{1\ HP} = 3.62\ KW
\]

Multiply by the number of hours the pump is used

\[
Electricity\ Usage = 3.62\ KW \times \frac{8\ hours}{day} \times \frac{5\ days}{week} \times \frac{52\ weeks}{year} = 7,530\ kWh
\]

Second find the Pump horsepower of the new Pump, specific gravity (SG) of water is equal to 1.0.

\[
Pump\ HP_{new} = \frac{GPM \times TDH \times SG}{3956}
\]

\[
Pump\ HP_{new} = \frac{150 \times 50 \times 1.0}{3956}
\]

\[
Pump\ HP_{new} = 1.90\ HP
\]

Then find the total electricity used by dividing the Pump Horsepower by the efficiency of the pump and the motor and convert to KW.

\[
Electricity\ Use = 1.90\ HP \times \left(\frac{1}{0.80}\right) \times \left(\frac{1}{0.95}\right) \times \frac{0.746\ KW}{1\ HP} = 1.87\ KW
\]

Multiply by the number of hours the pump is used

\[
Electricity\ Usage = 1.87\ KW \times \frac{8\ hours}{day} \times \frac{5\ days}{week} \times \frac{52\ weeks}{year} = 3,890\ kWh
\]
The total electricity savings is found below:

\[ 7,530 \text{ kWh} - 3,890 \text{ kWh} = 3,640 \text{ kWh} \]

Correct answer is A.

(A) 3,640 kWh

(B) 3,990 kWh

(C) 4,150 kWh

(D) 7,250 kWh
Yearly Owning Costs = $750,000 * .0640 = $48,000

The annual value is equal to the summation of the yearly savings and yearly owning costs.

\[ AV = 48,000 - 24,910 = 23,089 \]

Correct answer is A.

(A) $23,090
(B) $24,910
(C) $36,000
(D) $48,000
SOLUTION 66

A refrigeration unit is required to store 1,000 lbs of salmon (Heat Capacity Above Freezing: 0.88 Btu/lb°F, Heat Capacity Below Freezing: 0.51 Btu/lb°F, Latent heat of Fusion: 110 Btu/lb, Initial Freezing Point: 28 F). If the salmon arrives to the unit at 70 F and must be cooled to 10 F in 2 hours, then what is the required size of the air conditioning system, in Btu/hr.

It is important to note that these values of specific heat and latent heat of fusion for salmon and many other types of food can be found in ASHRAE Refrigeration.

Calculate the total amount of cooling to bring the salmon from 70 F to Freezing.

\[ Q = 1,000 \text{ lbs} \times 0.88 \times (70 - 28 \text{ °F}) \]
\[ Q = 36,960 \text{ Btu} \]

Calculate the total amount of cooling to freeze the salmon.

\[ Q = 1,000 \text{ lbs} \times 110 \]
\[ Q = 110,000 \text{ Btu} \]

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

\[ Q = 1,000 \text{ lbs} \times 0.51 \times (28 - 10) \]
\[ Q = 9,180 \text{ Btu} \]

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

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

Correct answer is C.

(A) 18,230 Btu/h

(B) 37,210 Btu/h

(C) 78,070 Btu/h

(D) 110,000 Btu/h
SOLUTION 72

A new steam boiler provides 100 lb/hr of steam at 30 PSIA, 0 degrees super heat to various hot water heaters. If the hot water heaters are designed to provide a 40 degree delta to incoming water at 80 F, then what is the total GPM of hot water that the boiler can support?

Create an energy balance equation between the steam and the hot water.

\[ Q_{\text{steam}} = \dot{m} \cdot h_f \]

Find \( h_f \) in the MERM, Steam Tables as a function of pressure, Navigate to 30 PSIA. Read the enthalpy of evaporation.

\[ Q_{\text{steam}} = 100 \frac{\text{lb}}{\text{hr}} \cdot 945.2 \frac{\text{Btu}}{\text{lb}} = 94,520 \frac{\text{Btu}}{h} \]

\[ Q_{\text{hot water}} = \dot{m} \cdot c_p \cdot \Delta T \]

\[ Q_{\text{hot water}} = 500 \ast \text{GPM} \ast \Delta T \]

\[ Q_{\text{steam}} = 94,520 \frac{\text{Btu}}{h} = Q_{\text{hot water}} = 500 \ast x \ast \text{GPM} \ast 40 \text{ F} \]

\[ x = 4.73 \text{ GPM} \]

Correct answer is A.

(A) 4.73 GPM

(B) 10.2 GPM

(C) 15.7 GPM

(D) 21.9 GPM
SOLUTION 79

The unit "clo" is used to describe the thermal insulation provided by which of the below?

This question involves knowledge of ASHRAE 55, Thermal Environmental Conditions for Human Comfort. It is used to describe the insulation provided by clothing and garments.

Walls, Roofs and Equipment insulation are typically described by R-Values, U-Factors or k-factors.

Correct answer is C.

(A) Wall insulation

(B) Roof insulation

(C) Garment insulation

(D) Heating equipment insulation
SOLUTION 80
Which of the following codes are least likely to be required to be checked with regards to the installation of a commercial gas furnace?

A commercial gas furnace installation will need to conform to the requirements of NFPA 54, the National Fuel Gas Code and the International Fuel Gas Code, depending on the jurisdiction.

ASHRAE 90.1 determines the energy efficiency requirements for commercial equipment including commercial gas furnaces, depending on the jurisdiction.

The code that is least likely to be consulted is NFPA 70, the National Electric Code. This code is primarily about the installation of electrical equipment.

Correct answer is C.

(A) NFPA 54
(B) ASHRAE 90.1
(C) NFPA 70
(D) International Fuel Gas Code
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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SECTION 7
DIAGNOSTICS
### Mechanical PE Exam – HVAC & Refrigeration

**AM Session - Sample Exam Diagnostics**

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### Mechanical PE Exam – HVAC & Refrigeration

**PM Session - Sample Exam Diagnostics**

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