CEM Applicants now have access to an online version self-evaluation test of the CEM exam. There is an $80 fee to take this online test and you may access the full details at Vantage Learning:

Direct Link: http://www.vantageonlinestore.com/home.php?cat=301

This test has a “Save and Finish Later” button, allowing you to have the option to finish the test in one sitting or to resume the test at a later date. You’re given one submission attempt and the subscription period is for one year. At the end of the exam, you will receive a sections report that lets you know what sections you passed and failed. You will not be able to see the specific questions that you answered wrong/right or the answers.

The following is a list of the subjects for the CEM exam. Each subject covers a number of topics. Following the list of topics are suggested references with chapter numbers. The primary references are the Handbook of Energy Engineering, by D. Paul Mehta and Albert Thumann, the Energy Management Handbook, 8th Edition by Steve Doty and Wayne C. Turner, and Guide to Energy Management, 7th Edition by Barney L. Capehart, Wayne C. Turner and William J. Kennedy. However, some other books are also referenced as appropriate.

The study guide will not lead you to answers to all of the questions, but it will certainly lead you to a very large number of correct answers. A person with the necessary experience who reviews the study guide should not have any problem passing the exam.

The exam will: be open book, last four hours, and have 130 questions to answer. Of the 130 questions, 120 are scored and 10 randomly located questions are trial questions being prepared for possible use on future exams. The 120 questions counting toward an examinee’s score are worth 8.7 points each. The 10 trial questions do not count toward the examinee’s score. The trial questions are randomly located and are not identified. Therefore, all 130 questions should be answered. There are 17 sections listed below from which questions mainly are drawn.

## STUDY GUIDE TOPICS & REFERENCES

### I. CODES AND STANDARDS and INDOOR AIR QUALITY

#### CODES AND STANDARDS SUBJECT TOPICS

- Federal Power Act
- FERC
- National Energy Act of 1978
- Natural Gas Policy Act of 1978
- Public Utility Regulatory Policies Act of 1978
- Federal Energy Regulatory Commission Orders 436, 500, 636, 636A, 888, and 889
- Executive Order 13423 of 2007
- Energy Improvement and Extension Act of 2008
- ASHRAE/IESNA Standard 90.1-2004 and 2007

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II. ENERGY ACCOUNTING AND ECONOMICS

SUBJECT TOPICS
Simple Payback Period  Life Cycle Cost Method
Time Value of Money   Interest Formulas and Tables
Present Worth        Project Life
Net Present Value    Annual Cost Method
Present Worth Method Economic Performance Measures
After Tax Cash Flow Analysis Depreciation Methods
Internal Rate of Return Impact of Fuel Escalation Rates
Energy Accounting    Btu Reporting
Point of Use Costs  Efficiency Measures


III. ENERGY AUDITS AND INSTRUMENTATION

SUBJECT TOPICS
Role of Audits            Audit Equipment
Energy Management Measures Load Factors
Combustion Analysis      Combustion Analyzers
Power Factor Correction  Electric Metering Equipment
Very Basic Thermodynamics Temperature Measurement
Air Velocity Measurement Pressure Measurement
Light Level Measurement  Humidity Measurement
Infrared Equipment       Energy and Power Measurement
Fuel Choices             HHV and LHV
Energy Use Index         Energy Cost Index

REF: Mehta and Thumann, Handbook of Energy Engineering, Chapter 3.
## IV. ELECTRICAL SYSTEMS
### SUBJECT TOPICS
- Demand and Energy
- Load Factors
- Real Power
- Reactive Power
- Power Factor
- Three Phase Systems
- Power Factor Correction
- Peak Demand Reduction
- Rate Structure and Analysis
- Motors and Motor Drives
- Variable Speed Drives
- Affinity Laws (Pump and Fan Laws)
- Power Quality
- Harmonics
- Grounding
- IEEE PQ Standard 519


## V. HVAC SYSTEMS
### SUBJECT TOPICS
- Heating, Ventilating, and Air Conditioning (HVAC)
- Affinity Laws
- Performance Rating (COP, EER, kW/ton)
- Psychrometric Chart
- HVAC Economizers
- HVAC Equipment Types
- Air Distribution Systems (Reheat, Multizone, VAV)
- Degree Days
- Chillers
- Heat Transfer
- Energy Consumption Estimates
- Vapor Compression Cycle
- Absorption Cycle
- Cooling Towers
- Air and Water Based Heat Flow
- ASHRAE Ventilation Standard
- Demand Control Ventilation


## VI. MOTORS AND DRIVES
### SUBJECT TOPICS
- AC Induction Motors
- AC Synchronous Motors
- DC Motors
- High Efficiency Motors
- Load Factor and Slip
- Power Factor and Efficiency
- Motor Speed Control
- Variable Frequency Drives
- Fan and Pump Laws
- Variable Flow Systems
- Motor Selection Criteria
- New vs Rewound Motors
- Motor Management Software
- Power Factor Correction

VII. INDUSTRIAL SYSTEMS

SUBJECT TOPICS
- Waste Heat Recovery
- Industrial Energy Management
- Steam Systems
- Heat Exchangers
- Turbines
- Compressed Air Systems
- Air Compressor Controls
- Boilers and Thermal Systems
- Fuel Choices
- Steam Tables
- Compressors
- Air Compressors
- Pumps and Pumping Systems
- Air Leaks


VIII. BUILDING ENVELOPE

SUBJECT TOPICS
- Thermal Resistance
- Insulation
- Solar Heat Gain
- Conduction Heat Loads
- Air Heat Transfer
- Heat Transfer Coefficients
- Vapor Barriers
- Solar Shading
- Thermally Heavy Facilities
- Psychrometric Chart
- Water Heat Transfer


IX. CHP SYSTEMS and RENEWABLE ENERGY

SUBJECT TOPICS
- Topping Cycles
- Combined Cycles
- Prime Movers
- Regulations
- Combined Heat and Power
- Solar, Wind, Biomass, and Hydropower
- Solar Thermal and Solar Photovoltaic Systems
- Bottoming Cycles
- Fuel Selection
- Operating Strategies
- Codes and Standards
- Distributed Generation
- Thermal Efficiencies
- Wind Energy Systems


X. ENERGY PROCUREMENT

SUBJECT TOPICS
- Energy Policy Act of 2005
- Deregulated Natural Gas
- FERC Orders 888 and 889
- Utility Restructuring
- Marketers and Brokers
- LDC, ISO, PX, EWG
- Retail and Wholesale Wheeling
- Electric Deregulation
- Natural Gas Policy Act
- HHV and LHV
- Distributed Generation

XI. BUILDING AUTOMATION AND CONTROL SYSTEMS
SUBJECT TOPICS
- Energy Management Strategies
- Basic Controls
- BACnet & LON
- Power Line Carriers
- Distributed Control
- Optimization Controls
- Building Control Strategies
- Expert Systems
- Self-Tuning Control Loops
- TCP/IP
- BAS Systems

- Terminology
- PID Controls
- Signal Carriers
- Direct Digital Control
- Central Control
- Reset Controls
- Communication Protocols
- Artificial Intelligence
- Energy Information Systems
- Internet, Intranets and WWW
- Web Based Systems


XII. GREEN BUILDINGS, LEED, AND ENERGY STAR
SUBJECT TOPICS
- Green Buildings
- Sustainable Design
- ASHRAE 90.1 Energy Cost Budget Method
- Certified, Silver, Gold, and Platinum
- LEED CI
- Water Efficiency
- Materials and Resources
- ENERGY STAR Rating
- Energy Star Label
- ASHRAE Standard 189

- USGC
- LEED Certification
- LEED O&M
- LEED NC
- LEED CS
- Energy and Atmosphere
- Indoor Environmental Quality
- Portfolio Manager
- Green Globes
- ASHRAE Green Guide


XIII. THERMAL ENERGY STORAGE SYSTEMS
SUBJECT TOPICS
- Design Strategies
- Storage Media
- Chilled Water Storage
- Sizing
- Full Storage Systems

- Operating Strategies
- Advantages and Limitations
- Ice Storage
- Volume Requirements
- Partial Storage Systems

XIV. LIGHTING SYSTEMS
SUBJECT TOPICS
Light Sources                 Efficiency and Efficacy
Lamp Life                     Strike and Restrike
Lumens                        Footcandles
Zonal Cavity Design Method    Inverse Square Law
Coefficient of Utilization    Room Cavity Ratios
Lamp Lumen Depreciation       Light Loss Factors
Dimming                       Lighting Controls
Color Temperature             Color Rendering Index
Visual Comfort Factor         Reflectors
Ballasts                      Ballast Factor
Lighting Retrofits            IES Lighting Standards
EPACT 2005 Lighting Efficiency LED Lighting

REF: Mehta and Thumann, Handbook of Energy Engineering, Chapter 4.

XV. BOILER AND STEAM SYSTEMS
SUBJECT TOPICS
Combustion Efficiency        Air to Fuel Ratio
Excess Air                    Boiler Economizers
Steam Traps                   Steam Leaks
Condensate Return             Boiler Blowdown
Waste Heat Recovery           Flash Steam
Scaling and Fouling           Turbulators
HHV and LHV                   Condensing Boilers


XVI. MAINTENANCE AND COMMISSIONING
MAINTENANCE SUBJECT TOPICS
Combustion Control            Compressed Air Leaks
Steam Leaks                   Steam Traps
Insulation                    Outside Air Ventilation
Group Relamping               Scheduled Maintenance
Preventive Maintenance        Proactive Maintenance
Boiler Scale                  Water Treatment


COMMISSIONING SUBJECT TOPICS
Purpose of Commissioning      Benefits of Commissioning
Need for Commissioning        Commissioning New Buildings
Retro-Commissioning           Real Time and Continuous Commissioning
Measurement and Verification  Commissioning Agent
Phases of Commissioning       Facility Design Intent
Commissioning Documentation   Re-commissioning

REF: Doty and Turner, Energy Management Handbook, Chapter 26
### XVII. ALTERNATIVE FINANCING

**SUBJECT TOPICS**

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1. ASHRAE 90.1 is used as the basis for Commercial Building Codes by most states?
   i. True
   ii. False

2. Commercial building lighting requirements are specified by IESNA and are included in ASHRAE 90.1 by reference?
   i. True
   ii. False

3. If electricity is selling for $0.06 per kilowatt-hour and is used for electric heating with an efficiency of 90%, what is the equivalent price of natural gas per therm if it can be burned with an efficiency of 80%?
   i. $1.33/therm
   ii. $1.47/therm
   iii. $1.56/therm
   iv. $1.65/therm
   v. $1.780/therm

4. An energy saving device will save $25,000 per year for 8 years. How much can a company pay for this device if the interest rate (discount rate) is 15%?
   i. $10,000
   ii. $173,000
   iii. $112,000
   iv. $77,000

5. What would be used to find hot spots or phase imbalances in an AC circuit?
   i. Ohmmeter
   ii. Infrared Camera
   iii. Wattmeter
   iv. All of the above

6. An audit for one firm showed that the power factor is almost always 70% and that the demand is 1000kW. What capacitor size is needed to correct power factor to 90%?
   i. 266 kVAR
   ii. 536 kVAR
   iii. 1000 kVAR
   iv. 618 kVAR
   v. 1214 kVAR
7. The amount of reactive power that must be supplied by capacitors to correct a power factor of 84% to 95% in a 400 HP motor at 75% load and 98% efficiency is:
   i. 72.4 kVAR
   ii. 82.5 kVAR
   iii. 92.4 kVAR
   iv. 90.0 kVAR
   v. 123.5 kVAR

8. Power factor correcting capacitors may be located:
   i. At the inductive load
   ii. At load control centers
   iii. At the customer side of the service transformer
   iv. All of the above
   v. i & ii

9. You find that you can replace a 50 HP motor with a 5 HP motor by cutting the total air flow requirements. Both motors operate at full load. Calculate the total dollar savings, given the information below: {Hint: savings of 45 HP}
   - Runtime: 8,760 hours/year
   - Motor Efficiency: 90% (both motors)
   - Electrical Rate: $9.00/kW/mo
   - $0.05/kWh
   - Fuel Cost Adjustment: $0.005/kWh
   i. $22,000
   ii. $12,710
   iii. $18,798
   iv. $15,650
   v. $9,874

10. An absorption system with a COP of 0.8 is powered by hot water that enters at 200 F and exits at 180 F at a rate of 25 gpm. The chilled water operates on a 10 F temperature difference and the condenser cooling water on a 22 F temperature difference. Calculate the chilled water flow.
    i. 10 gpm
    ii. 20 gpm
    iii. 40 gpm
    iv. 45 gpm
    v. 30 gpm

11. 10,000 cfm of air leaves an air handler at 50 F; it is delivered to a room at 65 F. No air was lost in the duct. No water was added or taken away from the air in the duct. How many BTU/hr was lost in the ductwork due to conduction?
    i. 162,000 BTU/hr
    ii. 75,000 BTU/hr
    iii. 126,550 BTU/hr
    iv. 256,000 BTU/hr
    v. 10,000 BTU/hr

12. An investment tax credit of 10% for a single project at a large company:
    i. Reduces the company’s overall taxes by 10%
    ii. Increases depreciation rate by 10%
    iii. Effectively reduces first cost of the project by 10%
    iv. i & iii
13. Air at 69 F dry bulb and 50% relative humidity flows at 6750 cubic feet per minute and is heated to 90 F dry bulb. How many BTU/hr is required in this process?
   i.  50,000 BTU/hr
   ii. 75,000 BTU/hr
   iii. 152,000 BTU/hr
   iv. 10,000 BTU/hr

14. Estimate the seasonal energy consumption for a building if its design-heating load has been determined to be 350,000 BTU/hr for a design temperature difference of 70 F if the heating season has 3,500-degree days. The heating unit efficiency is 80%. Assume 1 MCF = 10^6 BTU.
   i. 625 MCF/year
   ii. 350 MCF/year
   iii. 420 MCF/year
   iv. 656 MCF/year
   v. 525 MCF/year

15. A wall has a total R-value of 15. Determine the annual cost of the heat loss per square foot in a climate having 5,000 heating degree-days. The heating unit efficiency is 70% and the fuel cost is $5.00/million BTUs.
   i. $0.057/yr/ft^2
   ii. $0.040/yr/ft^2
   iii. $0.129/yr/ft^2
   iv. $0.200/yr/ft^2
   v. $0.029/yr/ft^2

16. A 10,000 square foot building consumed the following amounts of energy last year. What is the Energy Use Index of the building in BTU per square foot per year?
   - Natural Gas 5,000 therms/year
   - Electricity 60,000 kWh/year
   i. 7,500 BTU/square foot/yr
   ii. 88,000 BTU/square foot/yr
   iii. 81,500 BTU/square foot/yr
   iv. 70,500 BTU/square foot/yr
   v. 700,000 BTU/square foot/yr

17. Assuming that adding 2 inches of fiberglass insulation drops the U-value of a building from 0.24 to 0.098, calculate the annual cooling savings per square foot from the data given below:
   - 2,000 cooling degree days; Cooling COP = 2.5; Electrical cost $0.05/kWh
   i. $0.10/ft^2-yr
   ii. $0.25/ft^2-yr
   iii. $0.04/ft^2-yr
   iv. $0.59/ft^2-yr
   v. $0.02/ft^2-yr

18. How much fuel is wasted if 100 pounds per hour of condensate at 30 psia saturated liquid is drained to the sewer and is made up with water at 60 F. Assume the boiler is 80% efficient and ignore blowdown effects.
   i. 12,090 BTU/hr
   ii. 15,200 BTU/hr
   iii. 18,000 BTU/hr
   iv. 23,850 BTU/hr
   v. 21,800 BTU/hr
19. Select the equipment best suited to efficient air-to-air heat exchange and humidity control in the HVAC system of a large office building:
   i. Heat pipe
   ii. Radiation recuperator
   iii. Rotary sensible heat wheel
   iv. Plate and frame heat exchanger
   v. Run around heat exchanger loop

20. Select the equipment best suited to extract heat from the exhaust (temperature over 2,000 deg F) of a glass melting furnace:
   i. Radiation recuperator
   ii. Heat pump
   iii. Shell and tube heat exchanger
   iv. Rotary heat wheel
   v. Heat pipe bundle

21. Chilled water reset saves energy because the energy required in refrigeration compressors is a function of the chilled water's leaving temperature.
   i. True
   ii. False

22. The difference between the setting at which the controller operates to one position and the setting at which it changes to the other is known as the:
   i. Throttling range
   ii. Offset
   iii. Differential
   iv. Control Point

23. An all-electric facility pays $100,000 annually for energy. The compressed air system has energy costs of $20,000 per year. The system air pressure can be lowered by 10 psi. Approximately how much will be saved annually?
   i. $20,000
   ii. $10,000
   iii. $5,000
   iv. $2,000
   v. $1,000

24. With a load leveling TES strategy, a building manager will
   i. Not operate the chiller during peak hours
   ii. Essentially base load the chiller (i.e., operate at high load most of the time)
   iii. Operate only during the peaking times
   iv. Operate in the “off” season

25. A large commercial building will be retrofitted with a closed-loop water to air heat pump system. Individual meters will show costs to each department. Demand billing is a small part of the total electrical cost. Would you recommend a TES?
   i. Yes
   ii. No
26. A building presently has the following lighting system:

Present System
Type: 196 mercury vapor light fixtures
Size: 250 watt/lamp (285 watt/fixture, including ballast)
Lamp Life: 20,000 hours/lamp
Lamp Cost: $44.00/lamp
Output: 10,000 lumens/lamp

You have chosen to replace the existing system with the following:

Proposed System
Type: 140 high pressure sodium fixtures
Size: 150 watt/lamp (185 watt/fixture)
Lamp Life: 24,000 hours/lamps
Lamp Cost: $54.00/lamp
Output: 15,000 lumens/lamp

The facility operates 24 hours/day. Approximate the heating effect if the heating system efficiency is 80%, fuel costs $5.00 per million BTUs and there are 200 heating days (not heating degree days) per year.

i. $4,445/year
ii. $2,548/year
iii. $6,986/year
iv. $5,289/year
v. $3,070/year

27. A program available at no-cost from a US Department of Energy website that displays cost and efficiency data on electric motors is:

i. Freeware
ii. Building Life Cycle Cost
iii. MotorMaster
iv. 3EPlus
v. QuickPEP

28. Given the same amount of excess air and the same flue gas temperature, which fuel provides the highest combustion efficiency?

i. Natural Gas
ii. No. 2 Fuel Oil
iii. No. 6 Fuel Oil

29. A boiler is rated at 30 boiler horsepower and 80% efficient. What is the input rating?

i. 1,005,000 BTU/hr
ii. 1,255,000 BTU/hr
iii. 502, 500 BTU/hr
iv. 3,628,750 BTU/hr
v. 13,400,000 BTU/hr

30. In a steam system, several things can happen to the condensate. Which of these is the best from the standpoint of energy expense?

i. Drain condensate to sewer
ii. Recover condensate in insulated system at atmospheric pressure
iii. Recover condensate in un-insulated system at boiler pressure
iv. Recover condensate in insulated system at or near boiler pressure
31. Select the item from the list below which would most likely have the shortest payback with energy savings.
   i. Replacing asbestos boiler insulation
   ii. Installing condensate return system
   iii. Repairing air leaks or steam leaks
   iv. Installing heat wheel
   v. Installing combustion air preheater

32. Estimate the waste heat available in Btu/minute from a refinery flare gas leaving a process unit at 800 deg F if it is flowing at 1,000 cfm and weighs 0.08 lb/cubic foot. Its specific heat or heat content over the temperature range is 0.3 Btu/lb·°F and you should assume the waste gas could be reduced in temperature to 250 deg F.
   i. 178,000 Btu/min
   ii. 165,000 Btu/min
   iii. 44,000 Btu/min
   iv. 19,200 Btu/min
   v. 13,200 Btu/min

33. In calculating heat flows, metal generally provides little resistance to heat flow compared to insulation or even air films.
   i. True
   ii. False

34. Water at 72 deg F is supplied to a 100 psia boiler. 1000 lb/hr of steam from the boiler is supplied to a process and the condensate is sent to the sewer drain. What fraction of the energy added in the boiler is lost with the condensate, relative to the 72 F water entering the boiler?
   i. 100%
   ii. 75%
   iii. 34%
   iv. 29%
   v. 23%

35. A 100 HP rotary screw air-compressor generates heat equivalent to about:
   i. 1000 Btu/hr
   ii. 12,000 Btu/hr
   iii. 100,000 Btu/hr
   iv. 250,000 Btu/hr

36. An optimum start is a control function that:
   i. Shuts off the outside ventilation air during start up of the building
   ii. Shuts off equipment for duty cycling purpose
   iii. Senses outdoor and indoor temperatures to determine the start time needed to heat or cool down a building to desired temperatures
   iv. Starts randomly

37. Which of the following could be used to detect failed steam traps?
   i. Ultrasonic equipment to listen to the steam trap operation
   ii. Infrared camera to detect the change in temperature
   iii. Real time MMS using conductance probes
   iv. All of the above
38. Calculate the group re-lamping interval for T12 lamp fixtures that annually operate for 4,160 hrs with rated life of 15,000 hrs (assuming replacements at 70% of rated life).

   i. 3.5 years
   ii. 4.0 years
   iii. 1.0 year
   iv. 2.5 years

### CEM Exam Review Answers

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