INTERNATIONAL VERSION

The Association of Energy Engineers

CERTIFIED ENERGY MANAGER ® TRAINING PROGRAM

Outline & Study Guide (SI Units)

CEM ® Certified Energy Manager

The following is a list of subjects for the SI CEM exam. 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 have a good chance of passing the exam.

The exam will be open book and will last four hours. All questions are 8 points each. The maximum exam score is 1040 points and passing score is 704. All candidates must answer Sections I and II: Energy Accounting and Economics, and Energy Audits and Instrumentation. The candidate should choose 9 of the remaining 13 sections. If more than 9 additional sections are marked, only the first 9 will be scored. After the first two mandatory sections, the thirteen sections remaining are as follows:

Electrical Systems
Motor and Drive Systems
Building Envelope
Building Automation Systems
Control Systems
Lighting Systems
Maintenance and Commissioning
Heating, Ventilating and Air Conditioning Systems
Industrial Systems
Combined Heat & Power Systems and Renewable Energy Systems
Thermal Energy Storage Systems
Boiler and Steam Systems
Financing, Performance Contracts, Measurement & Verification

I. ENERGY ACCOUNTING AND ECONOMICS

Life-cycle Cost Analysis
Simple Payback Period
Time Value of Money
Present Worth
Net Present Value
Present Worth Method
Internal Rate of Return
Energy Accounting
Point of Use Costs
Discounted Cash Flows
Energy Unit Conversions
Interest Formulas and Tables
Project Life
Annual Worth Method
Economic Performance Measures
Minimum Annual Rate of Return
Energy Use Index
Efficiency Measures

II. ENERGY AUDITS AND INSTRUMENTATION

Role of Audits
Energy Management Measures
Combustion Analysis
Power Factor Correction
Basic Thermodynamics
Air Velocity Measurement
Light Level Measurement
Infrared Equipment
Audit Equipment
Load Factors
Combustion Analyzers
Electric Metering Equipment
Temperature Measurement
Pressure Measurement
Humidity Measurement
Data Loggers

Energy Rate Tariffs
Energy and Power Measurement
Fuel Choices
Energy Use Index
Level 1 Audit
Level 3 Audit
ASHRAE Standard 90.1
ASHRAE Standard 135
IEC
Understanding Utility Bills
Energy Conversion Factors
HHV and LHV
Energy Cost Index
Level 2 Audit
ISO 50001
ASHRAE Standard 62.1
ASHRAE Standard 55
IECC

III. ELECTRICAL SYSTEMS

Demand and Energy
Real Power
Power Factor
Power Factor Correction
Rate Structure and Analysis
Variable Speed Drives
Voltage Imbalance
Harmonics
Load Factors
Reactive Power
Single- and Three-phase Systems
Peak Demand Reduction
Motors and Motor Drives
Affinity Laws (Pump and Fan Laws)
Power Quality
IEEE Power Quality Standard 519

IV. HEATING, VENTILATING, AND AIR CONDITIONING SYSTEMS

Heating Systems
Air Conditioning Systems
HVAC Equipment Types
Cooling Towers
Vapor Compression Cycle
Affinity Laws
Psychrometric Charts
Heat Transfer
Air- and Water-based Heat Flow
Demand Control Ventilation
Ventilation Heat Recovery
Ventilating Systems
Economizers
Chillers
Heaters
Absorption Cycle
Performance Ratings (COP, HSPF, EER, kW/ton, and more)
Heating and Cooling Degree Days
Air Distribution Systems (Reheat, Multizone, VAV)
Energy Consumption Estimates
ASHRAE Ventilation Standard 62.1
ASHRAE Thermal Comfort Standard 55

V. MOTOR AND DRIVE SYSTEMS

AC Induction Motors
DC Motors
Load Factor and Slip
Motor Speed Control
Fan and Pump Laws
Motor Selection Criteria
Motor Management Software
AC Synchronous Motors
High Efficiency Motors
Power Factor and Efficiency
Variable Frequency Drives
Variable Flow Systems
New vs Rewound Motors
Power Factor Correction

VI. INDUSTRIAL SYSTEMS

Waste Heat Recovery
Industrial Energy Management
Fuel Choices
Steam Systems
Heat Exchangers
Turbines
Affinity Laws
Compressed Air Systems
Air Compressor Controls
Boilers and Thermal Systems
Pipe Insulation
Fuel Selection
Steam Tables
Steam Traps
Pumps
Compressors
Air Compressors
Compressed Air Leaks

VII. BUILDING ENVELOPE

Thermal Resistance	Heat Transfer Coefficients
Heating and Cooling Degree Days	Infiltration and Exfiltration
Insulation	Vapor Barriers
Solar Heat Gain	Solar Shading
Thermally Light Facilities	Thermally Heavy Facilities
Conduction Heat Transfer	Psychrometric Chart Calculations
Air Heat Transfer	Water Heat Transfer

VIII. COMBINED HEAT AND POWER SYSTEMS AND RENEWABLE ENERGY SYSTEMS

Power Cycles	Fuel Selection
Combined Cycles	Operating Strategies
Topping Cycles	Bottoming Cycles
Prime Movers	Distributed Generation
Load Calculations	Efficiencies (Power, Thermal, and System)
Combined Heat and Power	Solar, Wind, Biomass, Hydropower and Other RE Systems
Net Metering	Solar Thermal and Solar Photovoltaic Systems
Regulations	Renewable Energy Resources

IX. BUILDING AUTOMATION SYSTEMS

Energy Management Strategies	Interactive Control Strategies
Distributed Control	Building Automation Systems
Optimization Controls	Artificial Intelligence
Building Control Strategies	Energy Information Systems
Expert Systems	Internet, Intranets and WWW
Self-Tuning Control Loops	Web Based Systems
Communication Protocols	ASHRAE Standard 135

X. CONTROL SYSTEMS

Basic Controls	Direct Digital Control
BACnet & LON	Central Control
Open- and Closed-loop Controls	Control Signals
Power Line Carriers	Reset Controls
Terminology	Communication Protocols
Signal Carriers	Pneumatic Controls
Electric Controls	Basic Control Definitions
PID Controls	Cut-in, Cut-out, Differentials, and Dead Bands

XI. THERMAL ENERGY STORAGE SYSTEMS

Design Strategies	Operating Strategies
Storage Media	Advantages and Limitations
Thermal Calculations	Interaction with Utility Rate Tarrifs
Chilled Water Storage	Ice Storage
Equipment Sizing	Volume Requirements
Full Storage Systems	Partial Storage Systems

XII. LIGHTING SYSTEMS

Light Sources	Efficiency and Efficacy
Lamp Life	Strike and Restrike
Lighting Retrofits	Lux
Zonal Cavity Design Method	Inverse Square Law

LED Lighting
Coefficient of Utilization
Lamp Lumen Depreciation
Dimming
Color Temperature
Visual Comfort Factor
Ballasts

Room Cavity Ratios
Light Loss Factors
Lighting Controls
Color Rendering Index
Lighting Quality Factors
Ballast Factor
Group Relamping

XIII. BOILER AND STEAM SYSTEMS

Combustion Efficiency
Excess Air
Steam Tables
Steam Traps
Condensate Return
Waste Heat Recovery
Scaling and Fouling
Condensing Boilers

Air to Fuel Ratio
Combustion Control
Boiler Economizers
Steam Leaks
Boiler Blowdown
Flash Steam
Turbulators
Heat Transfer

XIV. MAINTENANCE AND BUILDING COMMISSIONING

Combustion Control
Steam Leaks
Insulation
Group Relamping
Preventive Maintenance
Boiler Scale
Purpose of Commissioning
Need for Commissioning
Measurement & Verification
Phases of Commissioning
Commissioning Documentation
Benefits of Commissioning

Compressed Air Leaks
Steam Traps
Outside Air Ventilation
Scheduled Maintenance
Proactive Maintenance
Water Treatment
Commissioning New Buildings
Real Time and Continuous Commissioning
Commissioning Agent
Facility Design Intent
Re-commissioning
Monitoring-based Commissioning

XV. FINANCING, PERFORMANCE CONTRACTS, & MEASUREMENT AND VERIFICATION (M&V)

Sources of Capital
Leasing
Performance Contracts
Shared Savings
Risk Management
Baseline Energy Use
Goals of M&V
Utility Bill Comparison
Measurement & Verification Protocols
EVO IPMVP
Continuous Measurement

Project Finance Options
Capital Lease
Energy Service Companies
Utility Financing
Contract Adjustments
Post Retrofit Energy Use
M&V Baseline for Savings
Calibrated Simulation Modeling
ASHRAE Guideline 14
IPMVP M&V Options
Spot Measurement

EXAM REVIEW QUESTIONS

1. One of the most basic goals of an energy audit is to determine the cost of energy that a facility uses.
(A) True (B) False

2. What would be used to find the quantity of electric current in an electrical circuit?
(A) Ohmmeter (B) Ammeter
(C) Wattmeter (D) None of the above

3. If electricity costs $0.06 per kilowatt-hour and is used for electric heating with an efficiency of 100%, what is the equivalent price of natural gas per gigajoule if it can be burned with an efficiency of 80% ?
(A) $8.00/GJ (B) $13.30/GJ
(C) $15.10/GJ (D) $21.20/GJ
(E) $24.30/GJ

4. In operating a boiler with dual fuel capability, which is the lowest cost of fuel given the following?
Natural gas $4.00/GJ efficiency = 92%,
Fuel oil $123/ton efficiency = 88% (42,000 *kJ/kg)*
(A) Natural gas (B) Fuel oil

5. A 1000 square metre building consumes the following amounts of energy per year. What is the Energy Use Index in MJ per square metre per year?
Natural Gas 500 GJ/year Electricity 60,000 kwh/year
(A) 716 MJ/ m^2 /yr (B) 883 MJ/m^2 /yr
(C) 8150 MJ/m^2 /yr (D) 17,500 MJ/m^2 /yr
(E) 70,000 MJ/m^2 /yr

6. 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%?
(A) $112,180 (B) $53,590
(C) $76,451 (D) $178,420

7. An energy saving device costs $34,500 and will save $9,000 per year for its full life of 8 years. What is the approximate internal rate of return?
(A) 10% (B) 12%
(C) 15% (D) 20%
(E) 25%

8. A new device costs $40,000 installed. The device will last 10 years at which time it will have to be replaced. How much will it have to save each year to obtain a 15% internal rate of return before taxes?
(A) $4,600 (B) $6,450
(C) $7,970 (D) $9,460

9. An audit for one facility showed that the cos ϕ is almost always 70% and that the demand is 1000 kW. What capacitor size is needed to correct cos ϕ to 90%?
(A) 266 kvar (B) 536 kvar
(C) 1,000 kvar (D) 618 kvar
(E) 1,214 kvar

10. The amount of reactive power that must be supplied by capacitors to correct a cos ϕ of 84% to 95% in a 300 kW motor at 75% load and 98% efficiency is:
(A) 72.8 kvar (B) 82.5 kvar
(C) 92.4 kvar (D) 90.0 kvar
(E) 123.4 kvar

11. Power factor (Cos ϕ) correcting capacitors may be located:
(A) At the inductive load
(B) At load control centres

(C) At the primary transformer (customer side)
(D) All of the above
(E) A & B only

12. One disadvantage of metal halide lamps is a pronounced tendency to shift colours as the lamp ages.
(A) True (B) False

13. A lighting survey of a 400 square metre office building identified the following fixtures:
30 - 4 tube fixtures @ 192 watts/fixture
10 - 100 watt incandescent floodlights
20 - 75 watt task lamps
What is the lighting density in W/m^2 of this facility?
(A) 82.7 (B) 46.7
(C) 56.4 (D) 20.7
(E) 10.1

14. A building currently has the following lighting system:
Present: 196 mercury vapour light fixtures
Size: 250 watt/lamp, 285 watt/fixture, including ballast

You have chosen to replace the existing system with the following:
Proposed: 140 high pressure sodium fixtures
Size: 150 watt/lamp, 185 watt/fixture, including ballast

The facility operates 24 hours/day. Approximate the heating effect if the heating system efficiency is 80%, fuel costs $5.00/GJ and there are 200 heating days in a year.
(A) $4,446/yr (B) $2,490/yr
(C) $6,900/yr (D) $5,290/yr
(E) $3,240/yr

15. You find that you can replace a 50 kW motor with a 5 kW motor by cutting the total air flow requirements. Calculate the total dollar savings, given the information below:
Runtime: 8,760 hours/year
Motor Efficiency: 90% (both motors)
Electrical Rate: $9.00/kW-month & $0.05/kWh
Fuel Cost Adjustment: $0.005/kWh
(A) $29,490 (B) $20,400
(C) $22,090 (D) $14,010
(E) $6,460

16. In a facility audit you find one large air handling unit delivering 200 m^3/min conditioned air. The air is delivered to two manufacturing areas. One has been discontinued, so you find you can close some dampers and cut air flow to 150 m^3/min. What will be the size required for the new motor if the old one was 20 kW?
(A) 45.12 kW (B) 13.67 kW
(C) 8.44 kW (D) 5.82 kW
(E) 2.0 kW

17. A 75 kW rotary screw air compressor (and motor) generates approximately how much heat as it compresses the air?
Assume the air compressor only produces 10% of its input in the form of useful work with compressed air.
(A) 1000 kJ/hr (B) 10,000 kJ/hr
(C) 100,000 kJ/hr (D) 250,000 kJ/hr
(E) 500,000 kJ/h

18. In calculating heat flows, metal generally provides little resistance to heat flow compared to insulation or even air films.
(A) True (B) False

19. Air at 20.6 °C dry bulb and 50% relative humidity flows at 3,185 L/s and is heated to 32.2°C dry bulb. How many kW is required in this heating process?
(A) 4.67 kW (B) 26.56 kW
(C) 44.33 kW (D) 69.33 kW
(E) 75 kW

20. Estimate the seasonal energy consumption for a building if its design heating load has been determined to be 105 kW for a design temperature difference of 30°C if the heating season has 1,800 degree days. The heating unit efficiency is 80%.
(A) 700.0 GJ/yr (B) 350.1 GJ/yr
(C) 462.2 GJ/yr (D) 720.6 GJ/yr
(E) 680.4 GJ/yr

21. An absorption chiller system with a COP of 0.8 is powered by hot water that enters at 90°C and leaves at 80° C at a rate of 2 L/s. The chilled water operates on a 5°C temperature difference and the condenser water on a 10°C temperature difference. Calculate the water flow.
(A) 0.8 L/s (B) 1.6 L/s
(C) 3.2 L/s (D) 3.6 L/s
(E) 2.4 L/s

22. A wall has a total thermal resistance of 2.64 $m^{2\cdot}$ °C/W. Determine the annual cost of the heat loss per square metre in a climate having 2,500 heating degree days. The heating unit efficiency is 70% and the fuel cost is $5.00/GJ.
(A) $0.41/m^2$ (B) $0.33/m^2$
(C) $0.58/m^2$ (D) $0.20/m^2$
(E) $0.06/m^2$

23. The k value for a particular piece of insulation changes with temperature.
(A) True (B) False

24. When a large insurance call center has an unmanned server room, it produces 340,000 kJ per hour of heat from equipment and lights. How many kW of air conditioning is needed just to remove this heat from the equipment and lights?
(A) 17.13 kW (B) 44.70 kW
(C) 94.44 kW (D) 134.37 kW
(E) 189.29 kW

25. 5000 L/s of air leaves an air handler at 10°C. It is delivered to a room at 18°C. How many kW of air conditioning capacity was lost in the ductwork?
(A) 48 kW (B) 20 kW
(C) 36 kW (D) 60 kW
(E) 3 kW

26. The refrigerant in a vapour compression air conditioner is always in the vapour state.
(A) True (B) False

27. Given the parameters below, estimate the percent outside air in this simple single zone heating system.
Outside Air Temperature = 5 °C
Return Air Temperature = 22 °C
Mixed Air Temperature= 18.3 °C
(A) 27.2 % (B) 21.8 %
(C) 36.5 % (D) 5.0%
(E) 86.5 %

28. A large commercial building will be retrofitted with a closed loop air heat pump system. Individual meters will measure costs at each department. Demand billing a small part of the total electrical cost. Would you recommend a TES?
(A) Yes (B) No

29. With a load levelling TES strategy, a building manager will:
(A) Not operate the chiller during peak hours
(B) Essentially base load the chiller (i.e., operate at a high load most of the time)
(C) Operate only during the peaking times
(D) Operate in the "off" season

30. What is the percentage fuel savings in a natural gas fired boiler if the installation of turbulators reduces the stack temperature from 250°C to 200°C? Assume the boiler is operating with 20% excess air.
(A)1.10 % (B) 1.95 %
(C) 2.65% (D) 3.65%

31. Which of the following methods could be used to detect failed steam traps?
(A) Ultrasonic equipment to listen to the steam trap operation
(B) Infrared camera to detect the change in temperature
(C) Real time MMS using conductance probes
(D) All the above

32. Given the same amount of excess air and the same flue gas temperature, which fuel provides the highest combustion efficiency?
(A) Natural Gas (B) No.2 Fuel Oil
(C) No.6 Fuel Oil (D) Coal
(E) Propane

33. A boiler is rated at 300 kW (output) and 80% efficient. What is the input rating?
(A) 325,000 J/s (B) 375,000 J/s
(C) 10,000 J/s (D) 1,050,000 J/s
(E) 5,068,000 J/s

34. Which of the following is not a positive displacement air compressor?
(A) Helical compressor
(B) Reciprocating compressor
(C) Sliding vane compressor
(D) Axial compressor
(E) none of the above

35. Which of the following heat exchanger types is most likely to allow cross contamination between heat exchange fluids?
A) Shell & tube B) Heat pipe
C) Heat wheel D) Recuperator

36. How does steam injection into a gas turbine affect the operation?
(A) Increases thermal efficiency
(B) Reduces NOx
(C) Increases NOx
(D) A and B
(E) A and C

37. How much will an air leak cost a facility annually in energy if it has a leak hole that is 6.35 mm in diameter at a pressure of 690 kPa and it goes unrepaired for three months? (based upon 7 cents per kWh)
(A) $935.00
(B) $2390.00
(C) $1620.00
(D) $5390.00

38. What is the flow rate of 16°C water through a control valve with a flow coefficient of 0.01 and a pressure difference across the valve of 100 kPa?

(A) 0.1 L/s (B) 0.2 L/s
(C) 0.3 L/s (D) 0.4 L/s

39. 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:
(A) Throttling range (B) Offset
(C) Differential (D) Control Point

40. Devices using 4-20 mA current loops are using digital data transmission.
(A) True (B) False

EXAM REVIEW SOLUTIONS

1. (A) True
2. (B)
3. (B) (\$0.06/kWh) x (277. 8 kWh/GJ) = (\$16.67/GJ)
   = (\$ X/GJ) x (1/0.8)
   X = \$13.30/GJ.
4. (B) For natural gas
   (\$4.00/GJ)(1.0/0.92) = \$4.35/GJ
   For fuel oil
   (\$123/ton)(1 ton/1000 kg)(1 kg/42,000 kJ)(1/0.8)
   (1,000,000 kJ/GJ) = \$3.33/GJ
   Choose fuel oil
5. (A) Gas (500 GJ/yr)(1000 MJ/GJ) = 500,000 MJ/yr
   Elect (60,000 kWh/yr)(3.6 MJ/kWh) = 216,000 MJ/yr
   EUI = (716,000 MJ/yr)/1000 m^2 = 716 MJ/ m2 yr
6. (A) P = A x [P/A, I, N]
   P = 25,000 x [P/A, 15%, 8]
   = 25,000 x [4.4873] = \$112,182 (round off)
   or \$112,175 (depending on tables)

7. (D) P = A x [P/A ,IRR,8))
   34,500 = 9000 x [P/A, IRR, 8]

[P/A, IRR, 8} = 34500/9000 = 3.833
From the Interest Tables – Look for P/A and 8 years
For I = 20% table; P/A = 3.83 so IRR = 20%

8. (C) P = A x [P/A, I, N] 40,000 = A x [P/A, 15%, 10]
   A = 40,000/[5.0188] = \$7970
9. (B) kVAR = 1,000 kW x [tan ($\cos^{-1}$ 0.7) – tan ($\cos^{-1}$ 0.9)]
   kVAR = 1,000 kW x [0.3172 (from table)] = 536 kvar
10. (A) kW = (300 kW) x 0.75/0.98 = 229.6 kW
    kvar = 229.6 kW x [tan (cos–1 0.84) – tan(cos-1 0.95)] = 72.8 kvar
11. (D)
12. (A) True
13. (D) W = [(30 x 192) + (10 x 10) + (20 x 75)]
    = 8260 watts
    W/m^2 = 8260 W/400 m^2 = 20.67 W/m^2
14. (E) kW saved = 196 fix x (0.285 kW/fix)
    - 140 fix x (0.185 kW/fix) = 30 kW
    Heating effect
    (30 kW) x (24 h/day) x (1/0.8) x (200 days/yr) x (3.6MJ/kWh) = 648,000 MJ/yr = 648 GJ/yr
    Added cost = (648 GJ/yr)(\$5/GJ) = \$3,240/yr
15. (A) kW saved = (45) x 1/0.9 = 50 kW
    kWh saved = 50 kW x 8,760 hours/yr
    = 438,000 kWh
    \$ saved = 50 kW x \$ 9/kW/mo x 12 mo/yr
    + 438,000 kWh x \$0.055/kWh
    = \$29,490/yr
16. (C) kWn = 20 x $(150/200)^3$ = 8.44 kW
17. (D) kJ/h = (75 kW)(3600 kJ/h/kW)(0.9) = 243,000 kJ/h
18. (A) True
19. (C) q = LPS x 1.2 x DT = (3185)(1.2)(32.2-20.6) = 44.3 kW
20. (E) q = UA DT;
    UA = 105 kW/30 C = 3.5 kW/C
    Also,
    Q = UA x 24 x DD
    = (3,500) W/C x 24 h/day x 1,800 C-day/yr x 1/0.8
    = 189,000 kWh/yr = 680.4 GJ/yr

21. (C) q = LPS x 4.2 x DT
q in = (2)(4.2)(90-80) = 84 kW
q out = COP x q in = 0.8 x q in = 67.2 kW
67.2 = (LPS)(4.2)(5)
LPS out = 3.2 LPS

22. (C) Q = UA x 24 x DD
= (1/2.64) W/m^2.C x 24 h/day x 2,500 C-day/yr
x 1/0.7 x 0.0036 MJ/Wh x \$0.005/MJ = \$0.584/m^2 yr

23. (A) True

24. (C) kW = (340,000 kJ/h)/(3600 kJ/kWh)
= 94.44 kW

25. (A) q = LPS x 1.2 x DT
= 5000 x 1.2 x 10 = 48,000 W = 48 kW

26. (B) False

27. (B) % = (RAT – MAT)/(RAT – OAT)
= (22 – 18.3)/(22 – 5) = 21.8%

28. (B) No

29. (B)

30. (C) From combustion chart
Eff_{OLD} = 80.5% Eff_{NEW} = 82.7%
% savings = (Eff_{NEW} – Eff_{OLD})/Eff_{NEW}
= (82.7 – 80.5)/82.7 = 2.65%

31. (D)

32. (D)

33. (B) Input = 300 kW x (1/0.8) = 375 kW = 375,000 J/s

34. (D)

35. (C)

36. (D)

37. (C)

38. (A) L/s = Cv$\sqrt{PD}$ = 0.01$\sqrt{100}$ = 0.1 L/s

39. (C)

40. (B) False