INTERNATONAL CERTIFIED ENERGY MANAGER
COURSE OUTLINE & STUDY GUIDE
(SI UNITS)

The following is a list of subjects for the SI CEM exam. The primary reference is Guide to Energy Management 5th International Edition by Barney L. Capehart, Wayne C. Turner and William J. Kennedy.

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
- Industrial Systems
- Building Envelope
- Thermal Energy Storage Systems
- Boiler and Steam Systems
- HVAC Systems
- Maintenance
- Motors and Drives
- Combined Heat & Power Systems
- Building Automation Systems
- Lighting Systems Maintenance
- Control Systems
- Commissioning, Measurement & Verification

I. ENERGY ACCOUNTING AND ECONOMICS

- 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
- Life Cycle Cost Method
- Energy Unit Conversions
- Interest Formulas and Tables
- Project Life
- Annual Cost Method
- Economic Performance Measures
- Impact of Fuel Escalation Rates
- GJ and kWh Reporting
- Efficiency Measures

REF: Capehart, Turner and Kennedy, Guide to Energy Management, International Edition, Chapter 4

II. ENERGY AUDITS AND INSTRUMENTATION

- Role of Audits
- Energy Management Measures
- Combustion Analysis
- Power Factor Correction
- Very Basic Thermodynamics
- Audit Equipment
- Load Factors
- Combustion Analyzers
- Electric Metering Equipment
- Temperature Measurement

Air Velocity Measurement
Light Level Measurement
Infrared Equipment
Fuel Choices
Energy Use Index
Level 1 Audit
Level 3 Audit
ASHRAE 90.1
ASHREA 135
IEC
Mini Data Loggers
Pressure Measurement
Humidity Measurement
Energy and Power Measurement
HHV and LHV
Energy Cost Index
Level 2 Audit
ISO 50001
ASHRAE 62.1
Energy Star Portfolio Manager
IECC
ASHRAE 55

REF: Capehart, Turner and Kennedy, Guide to Energy Management, International Edition, Chapter 2

III. ELECTRICAL SYSTEMS

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

REF: Capehart, Turner and Kennedy, Guide to Energy Management, International Edition, Chapter 3

IV. HVAC SYSTEMS

Heating, Ventilating, and Air Conditioning (HVAC)
Affinity Laws
Psychrometric Chart
HVAC Equipment Types
Degree Days
Heat Transfer
Vapor Compression Cycle
Cooling Towers
ASHRAE Ventilation Standard
ASHRAE Thermal Confort Standard
Performance Rating (COP, EER)
HVAC Economizers
Air Distribution Systems (Reheat, Multizone, VAV)
Chillers
Energy Consumption Estimates
Absorption Cycle
Air and Water Based Heat Flow
Demand Control Ventilation
Reading Psychrometric Charts

REF: Capehart, Turner and Kennedy, Guide to Energy Management, International Edition, Chapter 6

V. MOTORS AND DRIVES

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

REF: Capehart, Turner and Kennedy, Guide to Energy Management, International Edition, Chapter 12

VI. INDUSTRIAL SYSTEMS

- 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
- Pumps
- Air Compressors
- Air Leaks

REF: Capehart, Turner and Kennedy, Guide to Energy Management, International Edition, Chapter 7, 11

VII. BUILDING ENVELOPE

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

REF: Capehart, Turner and Kennedy, Guide to Energy Management, International Edition, Chapter 6, 11

VIII. BUILDING AUTOMATION SYSTEMS

- Energy Management Strategies
- Distributed Control
- Optimization Controls
- Building Control Strategies
- Expert Systems
- Self-Tuning Control Loops
- TCP/IP
- BAS Systems
- Artificial Intelligence
- Energy Information Systems
- Internet, Intranets and WWW
- Web Based Systems

REF: Capehart, Turner and Kennedy, Guide to Energy Management, International Edition, Chapter 6, 9

IX. CONTROL SYSTEMS

- Basic Controls
- BACnet & LON
- Power Line Carriers
- Terminology
- Signal Carriers
- Electric Controls
- PID Controls
- Direct Digital Control
- Central Control
- Reset Controls
- Communication Protocols
- Pneumatic Controls
- Basic Control Definitions

REF: Capehart, Turner and Kennedy, Guide to Energy Management, International Edition, Chapter 9

X. COMBINED HEAT AND POWER SYSTEMS; RENEWABLE ENERGY

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

REF: Capehart, Turner and Kennedy, Guide to Energy Management, International Edition, Chapter 13, 14

XI. LIGHTING SYSTEMS

- Light Sources
- Lamp Life
- Lighting Retrofits
- Zonal Cavity Design Method
- LED Lighting
- Coefficient of Utilization
- Lamp Lumen Depreciation
- Dimming
- Color Temperature
- Visual Comfort Factor
- Ballasts
- Efficiency and Efficacy
- Strike and Restrike
- Lux
- Inverse Square Law
- Room Cavity Ratios
- Light Loss Factors
- Lighting Controls
- Color Rendering Index
- Reflectors
- Ballast Factor
- IES Lighting Standards

REF: Capehart, Turner and Kennedy, Guide to Energy Management, International Edition, Chapter 5

XII. MAINTENANCE

- Combustion Control
- Steam Leaks
- Insulation
- Group Relamping
- Preventive Maintenance
- Boiler Scale
- Compressed Air Leaks
- Steam Traps
- Outside Air Ventilation
- Scheduled Maintenance
- Proactive Maintenance
- Water Treatment

REF: Capehart, Turner and Kennedy, Guide to Energy Management, International Edition, Chapter 10, 11

XIII. BOILER AND STEAM SYSTEMS

- Combustion Efficiency
- Excess Air
- Steam Traps
- Condensate Return
- Waste Heat Recovery
- Scaling and Fouling
- Condensing Boilers
- Air to Fuel Ratio
- Boiler Economizers
- Steam Leaks
- Boiler Blowdown
- Flash Steam
- Turbulators

REF: Capehart, Turner and Kennedy, Guide to Energy Management, International Edition, Chapter 7, 8

XIV. THERMAL ENERGY STORAGE SYSTEMS

Design Strategies	Operating Strategies
Storage Media	Advantages and Limitations
Chilled Water Storage	Ice Storage
Sizing	Volume Requirements
Full Storage Systems	Partial Storage Systems

XV. COMMISSIONING

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

XV. MEASUREMENT AND VERIFICATION (M&V)

Baseline Energy Use	Goals of M&V
Post Retrofit Energy Use	Calibrated Simulation Modeling
Utility Bill Comparison	IPMVP/EVO
Measurement & Verification Protocols	M&V Baseline for Savings
ASHREA M&V Protocol	Continuous Measurement
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. 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) 1.9 5 %
(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

16. (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√PD = 0.01√100 = 0.1 L/s
39. (C)
40. (B) False