



STUDY GUIDE FOR THE CERTIFIED CONTROLS ENGINEER CERTIFICATION EXAM



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EXAM OVERVIEW

The Certified Controls Engineer (CCE) is a multi-subject exam emphasizing automation and control system applicable to a broad swath of industrial applications. Successful graduates of ATMAE accredited four-year programs emphasizing electricity, electronics, and/or computer technologies are expected to be adequately prepared for this exam. Specifically, the CCE exam includes questions from the following content areas:

Automated Systems	Energy Management/Alternative Energy	Mechanical Advantage
Controls (Open Loop/Closed Loop Systems)	Financial Justification	Networking Fundamentals
Electrical Power Systems	Fluidics/Fluid Power	Programming Fundamentals
Electrical Safety Systems	Industrial Maintenance	Robotic Systems
Electronics Fundamentals	Instrumentation	

Certified Controls Engineer (CCE) is the initial certification status awarded to eligible applicants. CCE status is ongoing upon annual dues payments. Reporting of continuing education activity is not required to maintain CCE status; CCE holders may report continuing education activity to qualify for Certified Senior Controls Engineer (CSCE) status.

Certified Senior Controls Engineer (CSCE) is the higher-level "senior" status. Eligible CCE applicants with three years of post-graduate professional experience who have completed 30 PDUs of continuing education activity before their initial application for CSCE certification can apply.

Continuing education is required for CSCE status renewal every three years. Thirty (30) PDUs of continuing education activity within each 3-year CSCE period to be eligible for re-certification for another 3 years. CSCE holders who do not report 30 PDUs at the end of the 3-year certification lose their CSCE status.

The CCE examination can be used for individual certification and program assessment. The exam is an open-book*, 120-question, multiple-choice examination with questions on *Automated Systems, Controls (Open Loop/Closed Loop Systems), Electrical Power Systems, Electrical Safety Systems, Electronics Fundamentals, Energy Management/Alternative Energy, Financial Justification, Fluidics/Fluid Power, Industrial Maintenance, Instrumentation, Mechanical Advantage, Networking Fundamentals, Programming Fundamentals, and Robotic Systems.* (*Examinees are allowed to use printed reference materials (e.g., reference texts) during the exam. However, internet or software-based references are not allowed to be used during the exam. Oversight of this is the responsibility of the exam proctor.) Passage of the exam is determined by a cumulative score on the examination of 60% or higher.

EXAM CONTENT

The Certified Controls Engineer (CCE) exam is comprised of 14 primary content areas. Example problems and study references for each content section are included in the following pages of this study guide. The intent of these is to aid in preparing for the examination.

For further details regarding the exam eligibility, fees, and policies, please refer to www.atmae.org/page/CertificationHome.

Content Sections	Number of Questions
1. Automated Systems	15
2. Electronics Fundamentals	15
3. Controls (Open-Loop/Closed-Loop Systems)	15
4. Instrumentation	15
5. Programming Fundamentals	7
6. Robotic Systems	7
7. Electrical Power Systems	7
8. Safety Systems	7
9. Networking Fundamentals	7
10. Fluidics/Fluid Power	5
11. Financial Justification	5
12. Industrial Maintenance	5
13. Mechanical Advantage	5
14. Energy Management/Alternative Energy	5

NOTE: Individual content section mastery data of examinees can be provided to programs using this exam for assessment purposes.

SECTION 1 AUTOMATED SYSTEMS

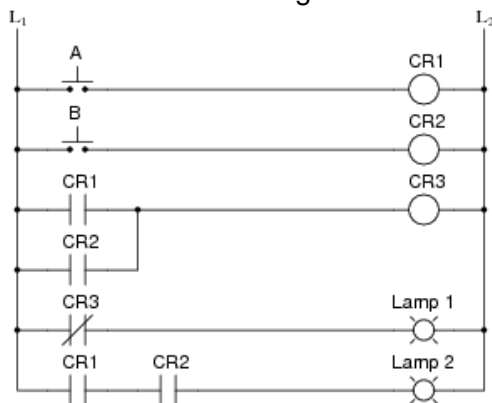
Body of Knowledge

Automated Systems are those that require limited-to-no human intervention to operate. Often these systems include computer software and electronic hardware components that automatically control the operation of electromechanical hardware (i.e., actuators, relays, and sensors) to perform functions and processes.

Sample Questions

These are sample questions that do not appear on the exam; however, they will help you familiarize yourself with the exam. An answer key is located on page 19 of this study guide.

- As a general rule in control system design, to turn an output OFF, you _____ a _____ contact or switch.
 - Close :: Normally Open
 - Open :: Normally Open
 - Close :: Normally Closed
 - Open :: Normally Closed
- Which of the following control device is most appropriate for controlling a collar heater via PWM?
 - NEMA 00 starter
 - Electromechanical relay
 - Solid State Relay
 - Solenoid
- When will "CR3" be energized?
 - when "A" or "B" are closed
 - when "A" and "B" are closed
 - when "A" or "B" is open
 - when "A" and "B" are open
- In an industrial control systems, which device is used to provide analog control of a hydraulic actuator via an electronic control signal?
 - Current to Pressure Transducer
 - Electromechanical relay
 - Solid State Relay
 - Solenoid
- Which of the following would NOT be considered an output field device to a PLC system?
 - Solenoid valve
 - Pressure sensor
 - Pilot light
 - Auxiliary contact



References

- Kuphaldt, T. R. (2007b). *Vol. IV - Digital—Electronics Textbook* (4th ed.). Retrieved from <https://www.allaboutcircuits.com/textbook/digital/>
- Ballee, S. A., & Shearer, G. R. (2018). *Industrial Maintenance and Mechatronics*. GOODHEART WILLCOX Company.

SECTION 2 ELECTRONICS FUNDAMENTALS

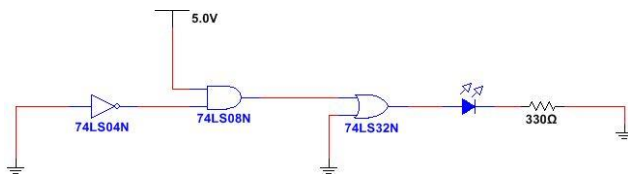
Body of Knowledge

Electronic Fundamentals include basic electrical theory, analysis, and application of direct current (DC), alternating current (AC), digital, and analog circuits, components, and designs. Particular emphasis is placed on the relationships between current, voltage, resistance, inductance, capacitance, reactance (both inductive and capacitive), impedance, power (true, apparent, and reactive), electromagnetism, semiconductors, and logic in series, parallel, and combination series-parallel circuits.

Sample Questions

These are sample questions that do not appear on the exam; however, they will help you familiarize yourself with the exam. An answer key is located on page 19 of this study guide.

- The most common waveform for commercial alternating current is the _____ wave.
 - Sawtooth
 - Square
 - Sine
 - Sequential
- According to Ohm's law, assuming a body path resistance of $100\ \Omega$, what amount of current would flow if a person came in contact with $120\ \text{V}$?
 - $1.20\ \text{A}$
 - $0.83\ \text{A}$
 - $12.00\ \text{mA}$
 - $833.33\ \text{mA}$
- Based on the connections of the digital circuit given below, evaluate the status of the output LED:
 - It will switch on and off alternately
 - It will be on
 - It will be off
 - None of the above
- A color-coded resistor brown, black, red has a value of:
 - $10\ \Omega$
 - $100\ \Omega$
 - $1\ \text{k}\Omega$
 - $10\ \text{k}\Omega$
- Which of the following electrical formulas is NOT correct?
 - $P = I^2R$
 - $I = P/V$
 - $P = V^2/R$
 - $R = P^2/V$



References

- Fowler, R. (2012). *Electricity: Principles and Applications: Eighth Edition*. McGraw-Hill Higher Education.
- Floyd, T. L., & Buchla, D. M. (2010). *Electronics Fundamentals: Circuits, Devices, and Applications*. Pearson.
- Kuphaldt, T. R. (2006). Vol. I - Direct Current (DC)—Electronics Textbook (5th ed.). Retrieved from <https://www.allaboutcircuits.com/textbook/direct-current/>

SECTION 3 CONTROLS (OPEN-LOOP/CLOSED-LOOP SYSTEMS)

Body of Knowledge

Open-Loop and Closed-Loop Controls Systems include both static (open-loop) and dynamic (closed-loop) continuous control of actuator signals based on sensor feedback and/or setpoint comparison. These systems are often controlled by a supervisory electronic control system that determines output signals based on input feedback (closed-loop) or predetermined set point (open-loop) values.

Sample Questions

These are sample questions that do not appear on the exam; however, they will help you familiarize yourself with the exam. An answer key is located on page 19 of this study guide.

1. A servo robot is a(n) ____ system because it allows for feedback signals.
 - a. servo
 - b. open-loop
 - c. closed-loop
 - d. direct-drive
2. Derivative control is a control strategy that uses the ____ of error between the setpoint and the process variable.
 - a. magnitude
 - b. maximum value
 - c. sum
 - d. slope
3. Controller gain is ____ of action taken by the controller in response to a process variable not being equal to a setpoint.
 - a. duration
 - b. polarity
 - c. strength
 - d. latency
4. Which control mode considers the slope of the process variable over time?
 - a. Proportional mode (P)
 - b. Proportional-Integral mode (PI)
 - c. Proportional-Derivative mode (PD)
 - d. Proportional-Integral-Derivative mode (PID)
5. A feedback signal is compared against a setpoint, resulting in a(n) _____ that is proportional to the difference between the feedback and the set point?
 - a. deadband
 - b. error signal
 - c. load disturbance
 - d. process variable

References

- Ballee, S. A., & Shearer, G. R. (2018). *Industrial Maintenance and Mechatronics*. GOODHEART WILLCOX Company.

SECTION 4 INSTRUMENTATION

Body of Knowledge

Instrumentation involves selecting, installing, calibrating, troubleshooting, and using equipment to measure the physical properties level, pressure, weight, temperature, humidity, flow, pH, conductivity, force, speed, etc. Both non-electronic and electronic instruments are included, with electronic instruments acting as feedback to a supervisory control system(s), via digital or analog signal type, to control a system's process variable(s).

Sample Questions

These are sample questions that do not appear on the exam; however, they will help you familiarize yourself with the exam. An answer key is located on page 19 of this study guide.

1. This PLC scaling instruction utilizes $y = m(x) + b$
 - a. Scale to Parameters
 - b. Scale to Limits
 - c. Both a & b
 - d. 32,768
2. A cold junction compensation is used with a thermocouple to compensate:
 - a. For the cold junction of the thermocouple not being at 0°F
 - b. For the cold junction of the thermocouple not being at 0°C
 - c. For the cold junction of the thermocouple not being at 100°F
 - d. For the cold junction of the thermocouple not being at 100°C
3. What is a capacitance probe primarily used for in-process control systems?
 - a. Flow
 - b. Pressure
 - c. Level
 - d. Temperature
4. If you use a 4-20mA pressure transmitter to read the level of a 30 ft water tank, what is the pressure on the transmitter when it is reading 10.4 mA?
 - a. 5.2 PSI
 - b. 15.6 PSI
 - c. 6.8 PSI
 - d. Cannot be determined
5. A gauge reads 50 PSIG, what is the absolute pressure?
 - a. 64.7 PSIA
 - b. 35.3 PSIA
 - c. 50 PSIA
 - d. Cannot be determined

References

- Ballee, S. A., & Shearer, G. R. (2018). *Industrial Maintenance and Mechatronics*. GOODHEART WILLCOX Company.

SECTION 5 PROGRAMMING FUNDAMENTALS

Body of Knowledge

Programming Fundamentals includes the basic concepts of syntax, data types, flow control, conditionals, comparisons, arithmetic operators, functions, communications, etc. Visual and textual programming languages are included, with an emphasis on execution sequence and machine processing.

Sample Questions

These are sample questions that do not appear on the exam; however, they will help you familiarize yourself with the exam. An answer key is located on page 19 of this study guide.

1. In C++, what must the value of "var" be so that the second case subroutine runs?

```
switch (var)
{
  case 4:
    // first case code
    break;
  case 8:
    // second case code
    break;
  case 12:
    // third case code
    break;
  case 19:
    //fourth case code
    break;
  default:
    // if nothing else matches, do the
  default
}
```

- a. 4
- b. 8
- c. 12
- d. 19

2. In C++, an **Else IF()** statement...?
- a. tests whether a certain condition is true or false regardless of the preceding **IF()** statement's test result
 - b. never tests whether a certain condition is true or false after the preceding **IF()** statement is false

- c. only tests whether a certain condition is true or false after the preceding **IF()** statement is false
- d. tests whether a certain condition is true or false separate from the preceding **IF()** statement's test result

3. In C++, which of the following is NOT the correct way to add 1 to variable x?

- a. `x = + 1`
- b. `x += 1`
- c. `x++`
- d. `x = x + 1`

4. Custom functions are sections of code that...?

- a. are rarely used in a program
- b. add library code to a program
- c. comment out lines of code in a program
- d. perform repetitive tasks and reduce clutter in a program

5. Which variable type should be used to store the value of pi (3.1415)?

- a. int
- b. float
- c. char
- d. void

References

- Kirch-Prinz, U., & Prinz, P. (2002). A complete guide to programming in C++. Sudbury, MA: Jones and Bartlett Publishers.

SECTION 6 ROBOTIC SYSTEMS

Body of Knowledge

Robotic Systems include those that are comprised of mechanical actuators (i.e., motor, cylinder, etc.), electronic sensors (i.e., vision, pressure, etc.), and processing controllers (i.e., micro-controller, embedded controller, etc.) and perform intelligent automated functions based on environmental, process, and control feedback. Both fixed (i.e., industrial) and mobile (i.e., humanoid) systems are included.

Sample Questions

These are sample questions that do not appear on the exam; however, they will help you familiarize yourself with the exam. An answer key is located on page 19 of this study guide.

1. This is the range of motion over which a robot arm can move. In practice, it is the set of points in space that the robot can reach.
 - a. The Traverse Region
 - b. The Manipulation Area
 - c. The Articulation Zone
 - d. The Work Envelope
2. Term for the actual arrangement of links and joints in the robot, which determines the robot's possible range of motions.
 - a. Dynatetics
 - b. Mechatronics
 - c. Compliance
 - d. Kinematics
3. Artificial intelligence is the ability of a computer program to make decisions based on ___.
 - a. previous experience
 - b. a human operator's input
 - c. software capabilities
 - d. known information
4. The ____ configuration consists of two orthogonal slides placed at a 90-degree angle and mounted on a rotary axis.
 - a. Cylindrical
 - b. Cartesian
 - c. revolute
 - d. spherical
5. A given industrial robot can move its tooling anywhere within a 3-dimensional volume. Moreover, it can control the rotation of its tooling. How many degrees of freedom are required for this robot?
 - a. 4
 - b. 3
 - c. 5
 - d. 6

References

- Fuller, J. L. (1999). *Robotics: Introduction, Programming, and Projects* (2nd ed.). Upper Saddle River, NJ: Prentice Hall.

SECTION 7 ELECTRICAL POWER SYSTEMS

Body of Knowledge

Electrical Power Systems involve components, circuits, and equipment used to generate, transmit, transform, measure/monitor, and control electrical energy to perform work. Designing, selecting, installing, calibrating, troubleshooting, and using electrical energy generation technologies, transmission lines, transformers and power supplies, power and phase instrumentation, and smart grid control for polyphase alternating current (AC) and direct current (DC) systems.

Sample Questions

These are sample questions that do not appear on the exam; however, they will help you familiarize yourself with the exam. An answer key is located on page 19 of this study guide.

- In a 3-phase system, the voltage in each phase is _____ degrees separated from each other.
 - 90
 - 120
 - 180
 - 360
- A 3-phase balanced resistive load is supplied by 450 V (line-to-line). The load draws 10.6 A (line-to-line). What is the per-phase power consumption?
 - 2.75 kW
 - 8.25 kW
 - 4.77 kW
 - 1.59 kW
- A 3-phase balanced resistive load is supplied by 240 V (line-to-line). The load draws 8 A (line-to-line). What is the 3-phase power consumption?
 - 9.98 kW
 - 1.92 kW
 - 3.33 kW
 - 2.25 kW
- What is the power factor of a circuit with the following parameter values?
Line voltage: 125.7 V
True power: 1.101 kW
Apparent power: 1.698 kVA
 - 1.15
 - 0.65
 - 0.55
 - 0.70
- What is the line current of a 3-phase motor with the following parameter values?
Line voltage: 237 V
True power: 0.972 kW
Apparent power: 1.621 kVA
 - 1.15 A
 - 1.67 A
 - 3.9 A
 - 11.7 A

References

- Kuphaldt, T. R. (2007a). *Vol. II - Alternating Current (AC)—Electronics Textbook* (6th ed.). Retrieved from <https://www.allaboutcircuits.com/textbook/alternating-current/>
- Floyd, T. L., & Buchla, D. M. (2010). *Electronics Fundamentals: Circuits, Devices, and Applications*. Pearson.
- Fowler, R. (2012). *Electricity: Principles and Applications: Eighth Edition*. McGraw-Hill Higher Education.

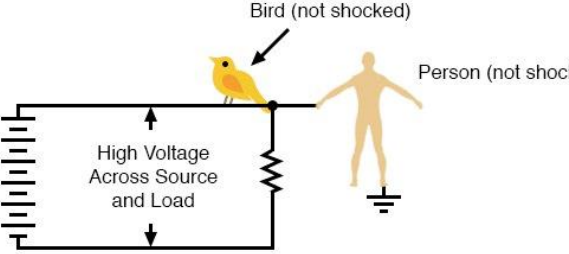
SECTION 8 SAFETY SYSTEMS

Body of Knowledge

Safety Systems include the design, selection, installation, and use of circuits, equipment, labels, and procedures to ensure the safety of humans and equipment. Special attention is given to mitigating human shock hazards, protecting against overcurrent and overload scenarios, designing for hazardous environments, and following applicable Occupational Safety and Health Administration, National Fire Protection Agency, and National Electric Code regulations.

Sample Questions

These are sample questions that do not appear on the exam; however, they will help you familiarize yourself with the exam. An answer key is located on page 19 of this study guide.

- Which circuit device is designed to stop current flow to a motor when there is near zero resistance in the circuit?
 - Motor Overload
 - Motor Controller
 - Disconnect
 - Short-Circuit Protection Device
- Which code specifically defines requirements for certified industrial control panels?
 - National Fire Protection Agency (NFPA) 70
 - Institute of Electrical and Electronics Engineers (IEEE) 802.11
 - Underwriters Laboratories (UL) 508A
 - National Electrical Manufacturers Association (NEMA) 12
- How fast (in seconds) will it take a typical Class 10 motor overload to trip, if over 500% full load current is flowing through it?
 - 5 s
 - 10 s
 - 15 s
 - 20 s
- When considering Safety Integrity Level (SIL) rated equipment, which level rating provides a $10^3 - 10^4$ risk reduction?
 - SIL 1
 - SIL 2
 - SIL 3
 - SIL 4
- In the picture below, why is the person not shocked?
 - The source is not grounded with the person.
 - The persons' skin resistance is too high.
 - The circuit current is too low.
 - The person is connected to the positive source voltage.

References

- Kuphaldt, T. R. (2006). *Vol. I - Direct Current (DC)—Electronics Textbook* (5th ed.). Retrieved from <https://www.allaboutcircuits.com/textbook/direct-current/>
- Fowler, R. (2012). *Electricity: Principles and Applications: Eighth Edition*. McGraw-Hill Higher Education.
- Ballee, S. A., & Shearer, G. R. (2018). *Industrial Maintenance and Mechatronics*. GOODHEART WILLCOX Company.

SECTION 9 NETWORKING FUNDAMENTALS

Body of Knowledge

Networking Fundamentals includes network hardware and configurations including personal area networks, local area networks, and wide area networks; network software including protocol layers, connection—oriented vs. connectionless service, and service primitives; as well as OSI and TCP/IP reference models. Special focus is given to designing, selecting, installing, troubleshooting, and using computer networks.

Sample Questions

These are sample questions that do not appear on the exam; however, they will help you familiarize yourself with the exam. An answer key is located on page 19 of this study guide.

1. The protocol for sending emails across the Internet is used the following port number:
 - a. 21
 - b. 22
 - c. 23
 - d. 25
2. Which of the following reasons BEST describes the reason a network technician would replace a hub with a switch?
 - a. All the ports on the hub are in use
 - b. One of the ports on the hub is defective
 - c. Reduce the number of collisions occurring in the LAN
 - d. Hubs do not support Power Over Ethernet (PoE)
3. A computer system on a LAN is unable to connect to an external website. A network technician would like to view the route, or the number of hops, taken by packets between this system and the remote server. She should use the following command:
 - a. ping
 - b. tracert
 - c. netstat
 - d. nslookup
4. A Windows computer system on a network has an IP address of 169.254.1.1. This MOST LIKELY means that:
 - a. the DHCP server on the LAN is unavailable.
 - b. this system is acting as a proxy server.
 - c. the loopback address has been assigned manually.
 - d. IPv6 addressing is being used on this network.
5. The network administrator would like to increase network security across the organization in order to prevent human-in-the-middle incidents. Which Internet protocol should be implemented to ensure this:
 - a. Telnet
 - b. HTTPS
 - c. SNMP
 - d. SMTP

References

- Lammler, T. (2018). *CompTIA Network+ Deluxe Study Guide: Exam N10-007 (4 edition)*. Sybex.
- Meyers, M, & Weissman, J. (n.d.). *Mike Meyers' CompTIA Network+ Certification Passport (Exam N10-007) (6th ed.)*. New York: McGraw-Hill Education.
- Meyers, Mike. (2018). *CompTIA Network+ Certification All-in-One Exam Guide, Seventh Edition (7 edition)*. New York: McGraw-Hill Education.

SECTION 10 FLUIDICS/FLUID POWER

Body of Knowledge

Fluidics/Fluid Power systems use pressurized hydraulic or pneumatic fluids to generate, transmit, and control power to perform work. Designing, selecting, installing, calibrating, troubleshooting, and using pumps, motors, compressors, valves, actuators, and piping. Special emphasis is placed on fluid properties, principles of mechanics, and fluid laws.

Sample Questions

These are sample questions that do not appear on the exam; however, they will help you familiarize yourself with the exam. An answer key is located on page 19 of this study guide.

1. To increase cylinder force in a hydraulic system, adjust the _____.
 - a. flow control valve
 - b. the pressure relief valve
 - c. hose diameter
 - d. pump output
2. To increase cylinder speed in a hydraulic system, adjust the _____.
 - a. flow control valve
 - b. the pressure relief valve
 - c. hose diameter
 - d. pump output
3. What is the most common use for a non-positive displacement pump?
 - a. Pressurizing systems
 - b. Moving fluid from one system to another
 - c. High-pressure situations
 - d. Moving heavy loads
4. The statement "Fluid in a container exerts equal pressure, at right angles, to the container wall," is _____.
 - a. Boyle's Law
 - b. Pascal's Law
 - c. Charles' Law
 - d. Boolean's Theory
5. A(n) _____ drive system uses fluid and consists of a pump connected to a reservoir tank, control valves, and an actuator.
 - a. Hydraulic
 - b. pneumatic
 - c. direct
 - d. electric

References

- Ballee, S. A., & Shearer, G. R. (2018). *Industrial Maintenance and Mechatronics*. GOODHEART WILLCOX Company.
- Esposito, A. (2013). *Fluid Power with Applications*. Pearson Education Limited.
- Eaton. (2015). *Industrial Hydraulics Manual: Your Comprehensive Guide to Industrial Hydraulics*. Eaton Hydraulics.

SECTION 11 FINANCIAL JUSTIFICATION

Body of Knowledge

Financial Justification involves determining the payback period, total cost, and return-on-investment for the purchase of automated equipment that may be recommended. Use of discounted cash flow, net present worth, process capability, and future value of money concepts to refine financial recommendations.

Sample Questions

These are sample questions that do not appear on the exam; however, they will help you familiarize yourself with the exam. An answer key is located on page 19 of this study guide.

1. _____ = $PV * (1 + r)^n$
 - a. Payback period
 - b. ROI
 - c. Net Present Worth
 - d. FV
 2. If the total cost of an automated solution, including its implementation and all annual cost for the life of the equipment (20,000 hrs) equals \$300,000. What is the projected total savings for the solution given the annual saving equals \$100,000? Assume the company utilizes the equipment 2000 hrs/yr.
 - a. \$700,000
 - b. \$580,000
 - c. \$1.2 Million
 - d. \$3.4 Million
 3. Determine the Payback Period for the following scenario:
 - Total cost to build a solution including installation (25% safety margin already included) = \$100,000
 - One worker is displaced by the solution (Salary = \$30,000/yr.)
 - Annual Productivity Savings = \$10,000/yr
 4. If a company borrows \$100,000 to implement an automated solution at a rate of 10% paid back over a five-year term, how much will the solution cost the company?
 - a. 1.15 years
 - b. 1.92 years
 - c. 4.5 years
 - d. 35.3 years
 5. _____ = $\frac{C}{W + I + D - (M+S)}$
 - a. Payback period
 - b. ROI
 - c. Net Present Worth
 - d. FV
- Robot Depreciation Allowance = \$20,000 (based on 20%)
 - Maintenance Costs = \$3,000/yr.
 - New Staffing Costs = \$5,000/yr.
 - Life Expectancy = 12 years

References

- Fuller, J. L. (1999). *Robotics: Introduction, Programming, and Projects* (2nd ed.). Upper Saddle River, NJ: Prentice Hall.
- Al-Odeh, M. (2019). *Economics and Cost Analysis for Operations and Project Managers*. Linus Publications.

SECTION 12 INDUSTRIAL MAINTENANCE

Body of Knowledge

Industrial Maintenance involves reactive, proactive, and predictive maintenance to ensure the proper, efficient, and effective operation of electromechanical equipment. Reactive maintenance includes actions taken to repair equipment only once failures occur. Proactive maintenance involves calendar-based (i.e., monthly, quarterly, yearly) scheduled maintenance procedures based on failure rates. Predictive maintenance monitors equipment health (i.e., heat, vibration, etc.) to dynamically predict when maintenance activities are required.

Sample Questions

These are sample questions that do not appear on the exam; however, they will help you familiarize yourself with the exam. An answer key is located on page 19 of this study guide.

1. Which of the following is a measure of a material's ability to deform without breaking under a load?
 - a. Ductility
 - b. Hardness
 - c. Strength
 - d. Brittleness
2. The measure of how well a system reproduces an established outcome under uniform conditions is _____ ?
 - a. resolution
 - b. repeatability
 - c. accuracy
 - d. the bathtub curve
3. A technician notices localized cavities on the surface of a metal plate. This is evidence of which type of corrosion?
 - a. Galvanic corrosion
 - b. Fretting corrosion
 - c. Pitting corrosion
 - d. Abrasive corrosion
4. What is the natural frequency of a machine?
 - a. A measure of how much an object vibrates without damping.
 - b. Vibration occurs when an input force is applied.
 - c. An imbalance caused by vibration.
 - d. Noise in machinery as compared to the initial installation.
5. Lubrication changes, checking and adjusting system pressures, and replacing filters are considered _____ tasks.
 - a. troubleshooting
 - b. planned maintenance
 - c. installation
 - d. preventive maintenance

References

- Ballee, S. A., & Shearer, G. R. (2018). Industrial Maintenance and Mechatronics. GOODHEART WILLCOX Company.
- Brumbach, M. E. (2012). Industrial Maintenance. Cengage Learning.
- Green, D., & Gosse, J. F. (2010). Industrial Maintenance. American Technical Publishers Incorporated.

SECTION 13 MECHANICAL ADVANTAGE

Body of Knowledge

Mechanical Advantage involves the analysis of linear and rotational force transmission, conversion, and amplification through the use of mechanical means. Special emphasis is placed on the practical applications of levels, gears, pulleys, rollers, shafts, chains, and belts in simple and compound machines.

Sample Questions

These are sample questions that do not appear on the exam; however, they will help you familiarize yourself with the exam. An answer key is located on page 19 of this study guide.

1. What force is needed to accelerate a 2,550 kg car at 18 m/s^2 ?
 - a. 22.950 kN
 - b. 45.900 kN
 - c. 413.100 kN
 - d. 449.820 kN
2. What is the turning force applied to an object being rotated on a fixed axis?
 - a. Energy
 - b. Force
 - c. Pressure
 - d. Torque
3. How much work completed if a force of 125 lb is applied to move a 12 lb wagon across a 25 ft distance?
 - a. 5 ft-lb
 - b. 1500 ft-lb
 - c. 3,125 ft-lb
 - d. 37,500 ft-lb
4. Which action would produce a decrease in power output?
 - a. Decreasing distance as force and time is held constant.
 - b. Decreasing time as force and distance are held constant.
 - c. Increasing force as distance and time is held constant.
 - d. Increasing distance as force and time is held constant.
5. Calculate the mechanical advantage of a 2 ft radius wheel and a 4 in radius axis.
 - a. 0.5
 - b. 1
 - c. 2
 - d. 6

References

- Ballee, S. A., & Shearer, G. R. (2018). Industrial Maintenance and Mechatronics. GOODHEART WILLCOX Company.
- Esposito, A. (2013). Fluid Power with Applications. Pearson Education Limited.

SECTION 14 ENERGY MANAGEMENT/ALTERNATIVE ENERGY

Body of Knowledge

Energy Management/Alternative Energy involves the planned transmission, conversion, and usage of energy and its generation by non-fossil fuel sources. Special emphasis is placed on reducing cost and consumption through increased system monitoring, controlling, conserving, and efficiency, as well as reducing environmental impacts by using solar, wind, hydro, thermal, and chemical energy generation technologies.

Sample Questions

These are sample questions that do not appear on the exam; however, they will help you familiarize yourself with the exam. An answer key is located on page 19 of this study guide.

1. Lift is produced on the wind turbine blade?
 - a. When the blade is set to the furled condition
 - b. Anytime the wind blows, regardless of the direction from which it blows against the turbine
 - c. When the wind blows across the blade from the leading edge to trailing edge
 - d. When the wind blows across the blade from the trailing edge to leading-edge
2. A ___ battery is a battery that uses a combination of plate designs to maximize the desirable characteristics.
 - a. secondary
 - b. stationary
 - c. nickel-cadmium
 - d. hybrid
3. Solar ___ is the intensity of solar power.
 - a. irradiance
 - b. strength
 - c. insolation
 - d. irradiation
4. Which answer choice list all five of the kinetic energy types?
 - a. Motion, electrical, sound, nuclear, thermal
 - b. Mechanical, sound, heat, radiant, gas
 - c. Motion, electrical, sound, radiant, thermal
 - d. Gravitational, light, sound, radiant, chemical
5. If the wind speeds doubles, the energy output of a wind turbine output will be?
 - a. 8 times higher
 - b. 4 times higher
 - c. 2 times higher
 - d. 6 times higher

References

- Buchla, D. M., Kissell, T. E., & Floyd, T. L. (2015). Renewable Energy Systems. Pearson Education, Incorporated.
- Kissell, T. E. (2011). Introduction to Wind Principles. Prentice Hall.

ANSWERS TO SAMPLE QUESTIONS

Section 1 Automated Systems

1. b
2. c
3. a
4. a
5. d

Section 2 Electronics Fundamentals

1. c
2. a
3. b
4. c
5. d

Section 3 Controls (Open-Loop/Closed-Loop Systems)

1. c
2. d
3. c
4. d
5. b

Section 4 Instrumentation

1. c
2. b
3. c
4. a
5. a

Section 5 Programming Fundamentals

1. b
2. c
3. a
4. d
5. b

Section 6 Robotic Systems

1. d
2. d
3. d
4. a
5. a

Section 7 Electrical Power Systems

1. b
2. a
3. c
4. b
5. c

Section 8 Safety Systems

1. d
2. c
3. b
4. c
5. a

Section 9 Networking Fundamentals

1. d
2. c
3. b
4. a
5. b

Section 10 Fluidics/Fluid Power

1. b
2. a
3. b
4. b
5. a

Section 11 Financial Justification

1. d
2. a
3. b
4. a
5. a

Section 12 Industrial Maintenance

1. a
2. b
3. c
4. a
5. d

Section 13 Mechanical Advantage

1. b
2. d
3. c
4. a
5. d

Section 14 Energy Management/Alternative Energy

1. c
2. d
3. a
4. c
5. a

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