Engineering Fundamentals Exam

Study Guide
For
Industrial Engineering Exam

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1. Objectives

The aim of this manual is to provide guidelines for the examinees about the exam structure, timing, percentage of question coverage and distribution among various topic areas. In essence, the manual represents the bridge between the developed Industrial Engineering Standards and the actual phrased questions, which constitute the tests to be administered. It is designed to familiarize the examinees with the test questions formats and contents.

2. Contents

This study guide contains essential information for the examinees. Specifically, the following topics are presented in this manual:

- Exam structure, exam schedule and organization, exam type, eligibility for exam, and exam rules
- Organization of the exam framework
- Table of Specifications which includes an overview of the table, its structure and contents
- Sample of questions and solutions for the Industrial Engineering discipline

3. Exam Structure

The exam is conducted in two sessions and the duration of each session is 3 hours.

3.1 General Engineering Exam

The first session covers the General Engineering topics. These include the following fourteen topics:

1. Mathematics
2. Probability and Statistics
3. Computer Literacy
4. Statics and Dynamics
5. Chemistry
6. Thermodynamics

7. Fluid Mechanics
8. Materials Science and Engineering
9. Electricity and Magnetism
10. Engineering Drawing
11. Engineering Economics
12. Project Management
13. Ethics
14. General Skills
    a. Use analytical thinking (logical deductions, statements and assumptions, cause and effect, verbal reasoning, analyzing arguments, statements and conclusions, break a complex problem into smaller problems and solve them)
    b. Use effective communication in writing, orally, and graphically
    c. Work cooperatively with other team members to deliver the required outcomes
    d. Set goals and ways for personal development
    e. Strive for ways to resolve conflicts while being sensitive to others opinions
    f. Be able to use time and available resources in an efficient way
    g. Recognize and interpret environmental, social, cultural, political and safety considerations in engineering solutions.
    h. Recognize decision making process
    i. Recognize major engineering concepts outside the discipline.
    j. Interpret uncertainties in measurements and calculations
    k. Analyze and interpret data
    l. Apply evaluation criteria and contemporary knowledge to select the optimum design from alternative solutions

3.2 Engineering Discipline Exam

The second session covers the Engineering Standards and is based on topics associated with one of the following engineering disciplines:

Code	***Discipline***
CE	Civil Engineering
CHE	Chemical Engineering
EE	Electrical Engineering
IE	Industrial Engineering
ME	Mechanical Engineering
SE	Structural Engineering

4. Exam Implementation

The exam consists of two sessions:

- The first session consists of General Engineering Exam. The total duration of this session is 3 hours with a total number of 90 questions.
- The second session consists of Engineering Discipline Exam. This session consists of 50 questions with a total time of 3 hours.

5. Exam Type

The exam is initially paper-based and will become computer based in a later stage. The exam, in both sessions, is of a multiple choice type where each question has four choices for the answer. There is no negative marking for wrong answers.

6. Eligibility for the Exam

Bachelor degree holders in an Engineering discipline i.e., Chemical Engineering, Civil Engineering, Electrical Engineering, Industrial Engineering, Mechanical Engineering, and Structural Engineering.

7. Exam Rules

- Books, lecture notes, or any type of materials are not allowed in the exam. Necessary reference sheets, monographs, equations, relevant data from codes will be provided in the exam.
- Calculators approved by Exam authorities are allowed.
- Admission in the examination center will be only through authorized admission card
- Examinees are subjected to all the rules and procedures applied by National Center for Assessment in Higher Education (Qiyas)

8. Organization of the Exam Framework

The core topics constitute the basis of this Engineering Exam. Indicators are used to describe the knowledge to be tested in each topic. Each of these indicators is further subdivided into three major levels following the recent Bloom's taxonomy of learning levels (Remembering and Understanding; Applying and Analyzing; and Evaluating and Creating).

Example

Topic:	**T2:** Probability and Statistics
Indicator:	**IE-T2-05:** Apply rules of regression analysis (linear and multiple)
Learning Level:	Applying and Analyzing (AA)

9. Table of Specifications

9.1 Overview

The Table of Specifications is a map which facilitates the transformation of the Engineering Standards for each Topic Area into balanced and coherent question sheets to be used in the proposed Exam The Table of Specifications is essentially a tableau structure which distributes, vertically, the exam Questions among various Topic Areas in accordance with the applicable Engineering Standards and, horizontally, over various Learning Levels (Remembering and Understanding, Applying and Analyzing, Evaluating and Creating).

9.2 Structure and Contents

The table below constitutes the Table of Specifications for the Industrial Engineering Discipline. The Table of Specifications contains the following columns:

9.2.1 Topic Area

These are the widely recognized Topic areas, which are covered in the Industrial Engineering Discipline, namely:

1. Engineering Economics
2. Probability and Statistics
3. Modeling and Computation
4. Industrial Management
5. Manufacturing and Production Systems
6. Facilities and Logistics
7. Human Factors, Productivity, Ergonomics, and Work Design
8. Quality Engineering

9.2.2 % of Test

This column summarizes the total percentage (of the total test) allocated for each Topic Area.

9.2.3 Suggested Number of Questions

This column indicates the number of questions to be allocated for each Engineering Standard. The total number of questions per test conforms to the general guidelines which govern the total duration of the test. In the present case, 50 questions are included in each Discipline.

9.2.4 Engineering Standards

This column lists the Engineering Standards to be addressed under each Topic Area.

Standards are coded **IE-TJ** (where **IE** denotes the Industrial Engineering Discipline, **TJ** denotes the **T**opic Number **J**), whereas the Indicators are coded **IE-TJ-K** (where **K** denotes the Indicator number).

For example, the code **IE-T2-05** is used to denote a question in Industrial Engineering (IE) that represents Topic 2 (Probability and Statistics) and Indicator 5.

9.2.5 Assigned Allocations among Learning Levels

The three sub-columns (Remembering and Understanding, Applying and Analyzing, and Evaluating and Creating) under this main column specify the question distribution for the Topic among the three Learning Levels. For example, for the Industrial Engineering Principles (IE-T2), there are two questions assigned to Learning Level **RU**, five questions for **AA** and no questions for **EC.**

It is to be noted that the Learning Levels used in the Table of Specifications represent the so-called cognitive levels/processes (levels of thinking) in the revised Bloom's taxonomy. Every two consecutive Learning Levels in Bloom's are combined as one level here.

It is also important to note that the distribution of questions among various Topic Areas follows a careful and rigorous question allocation process, which ensures that appropriate relative levels of coverage are maintained for the various Learning Levels. In the Industrial Engineering Discipline, the distribution of questions (for all Topic Areas) among the three Learning Levels is 13 questions (26%) for Remembering and Understanding, 25 questions (50%) for Applying and Analyzing, and 12 questions (24%) for Evaluating and Creating.

Table of Specifications for Industrial Engineering Exam

Topic Area	% of Test	# Q	Engineering Standard	Assigned Allocation of Questions Among Learning Levels		
				Remembering and Understanding	Applying and Analyzing	Evaluating and Creating
Engineering Economics	14%	7	IE-T1	2	4	1
Probability and Statistics	14%	7	IE-T2	2	5	0
Modeling and Computation	14%	7	IE-T3	1	5	1
Industrial Management	10%	5	IE-T4	2	2	1
Manufacturing and Production Systems	14%	7	IE-T5	2	3	2
Facilities and Logistics	12%	6	IE-T6	1	2	3
Human Factors, Productivity, Ergonomics, and Work Design	12%	6	IE-T7	2	2	2
Quality Engineering	10%	5	IE-T8	1	2	2
	100%	50		13 (26%)	25 (50%)	12 (24%)

10. Sample Questions

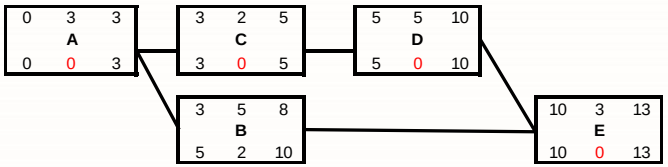
A sample of questions is shown in the following tabular format in accordance with the following instructions.

1. Learning Levels:
    - RU for Remembering and Understanding
    - AA for Applying and Analyzing
    - EC for Evaluating and Creating
2. References sheets are denoted in the last column of the Table

Table of Sample Questions

Q. No.	Topic Area	EA Code	Learning Level	Question Statement (Answer's Choices)	Answer	Expected Time (min)	Supplied Reference(s)
1	Engineering Economics	**IE-T1-05**	AA	A machine shop is considering the purchase of a new CNC machine. The new CNC machine price is $400,000 and has useful life of 10 years. The estimated value of the CNC machine at the end of its useful life is zero. Hence, the annual depreciation amounts, in $, using the straight line method is: A) 400 B) 512 C) 640 D) 800	A	3 – 4	Reference #1
2	Probability and Statistics	**IE-T2-01**	RU	For a particular binomial, the mean μ = 4 and the standard deviation $\sigma = \sqrt{3}$. Find the binomial parameter *p*. A) 0.25 B) 0.33 C) 3 D) 4	A	2 – 3	Reference #2

3	Modeling and Computation	**IE-T3-05**	AA	A technician is responsible for maintaining two machines. Mean time between failures is exponentially distributed with mean equal to 10 hours. The repair time is exponentially distributed with mean equal to 8 hours. The probability that both machines are working is: A) 0.2623 B) 0.3279 C) 0.4098 D) 0.4201	C	3 – 4	Reference #3

4	Industrial Management	**IE-T4-02**	AA	In the project network represented below,  the project activities can be crashed according to the table below: Which activity should be crashed first to cut one day from the project's duration? A) Crash A B) Crash C C) Crash D D) Crash E	C	3 – 4	Reference #4

Activity	Depend on	Normal Time, days	Normal Cost, SR	Crash Time, days	Crash Cost, SR
A	-	3	24,000	1	25,000
B	A	5	7,200	2	8,400
C	A	2	20,000	1	20,800
D	C	5	10,000	2	11,200
E	B,D	3	15,000	1	16,000

5	Manufacturing and Production Systems	**IE-T5-04**	AA	Honesty Corporation regularly imports ovens to satisfy a growing demand for ovens in Saudi Arabia. The owner, Mr. Ameen, estimates that the demand is steady at 175 oven per month. Ovens cost 694 SR each, and the fixed cost of calling his brother in New York and having the ovens flown in is 75000 SR. It takes three weeks to receive an order. Ameen's accountant, Sadek, recommends an annual cost of capital of 22%, a cost of floor space of 3% of the value of an oven, and a cost of 2% of the value of an oven for taxes and insurance. Knowing the above information, the number of ovens that Ameen should import is: A) 674 B) 1123 C) 1297 D) 2750	C	3 – 4	Reference #5
6	Facilities and Logistics	**IE-T6-04**	AA	In a local small poultry slaughterhouse an overhead conveyor belt forms a continuous closed loop. The delivery loop has a length of 100 m and the return loop is 50 m. chicken are loaded at the load station and unloaded at the unload station. Chicken are hanged by their feet in a chicken carrier where each chicken carrier on the conveyor holds only one chicken and the carriers are separated by 0.5 m. Conveyor speed is 0.2 m/s. the maximum number of chicken in the conveyor system is: A) 100 B) 150 C) 200 D) 300	D	2 – 3	Reference #6

7	Human Factors, Productivity, Ergonomics, and Work Design	**IE-T7-05**	RU	The information displayed by a speed limit sign on the side of a highway is considered  A) dynamic qualitative information B) static representational information C) dynamic alphanumeric information D) static alphanumeric information	D	1 – 2	None

<table>
<tr>
<td>8</td>
<td>Quality Engineering</td>
<td>IE-T8-04</td>
<td>AA</td>
<td>A quality engineer is using control limits chart to observe the piston diameter in a specific piston production process. The following table shows $\bar{x}$ and r values for 10 samples of two pistons each:

<table>
<tr><th></th><th>$\bar{x}$</th><th>r</th></tr>
<tr><td>1</td><td>41.5</td><td>9</td></tr>
<tr><td>2</td><td>36</td><td>4</td></tr>
<tr><td>3</td><td>38</td><td>6</td></tr>
<tr><td>4</td><td>40.5</td><td>3</td></tr>
<tr><td>5</td><td>37</td><td>8</td></tr>
<tr><td>6</td><td>45</td><td>4</td></tr>
<tr><td>7</td><td>39.5</td><td>3</td></tr>
<tr><td>8</td><td>40.5</td><td>3</td></tr>
<tr><td>9</td><td>46</td><td>8</td></tr>
<tr><td>10</td><td>38.5</td><td>1</td></tr>
</table>

The control limits for $\bar{X}$ chart are:

A) 40.25, 35.35
B) 45.15, 35.35
C) 49.46, 31.04
D) 54.95, 25.55</td>
<td>C</td>
<td>3 – 4</td>
<td>Reference #8</td>
</tr>
</table>

Reference #1

Straight line Depreciation method formula

$$d = \frac{P - SV}{N}$$

Where,

N = useful life of the machine in years

P = purchase price

d = annual depreciation deduction

SV = estimated salvage value at the end of the useful life

Reference #2

binomial distribution formulas

For a random variable *X*,

$\mu = E(X) = np$

$\sigma^2 = V(X) = np\ (1 - p)$

Where:

μ = the expected value of the random variable *X*

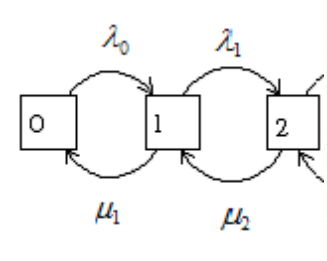
σ^2 = variance of the random variable *X*

n = number of repeated trials of the experiment

p = probability of success of the random variable *X*

Reference #3

formulas of birth-death process as a special case of continuous-time Markov process where the state transitions are of only two types.



$$p_0 + p_1 + p_2 = 1$$

$$p_1 = \frac{\lambda_0}{\mu_1} p_0$$

$$p_2 = \frac{\lambda_0 \lambda_1}{\mu_1 \mu_2} p_0$$

Where:

λ = birth rate

μ = death rate

p = probability of being at state 0, 1, or 2

Reference #4

cost slope formula (the crash cost per time period formula)

$$cost\ slope = \frac{crash\ cost - normal\ cost}{normal\ time - crash\ time}$$

Reference #5

economic order quantity formula.

$$Q^* = \sqrt{\frac{2K\lambda}{h}}$$

Where:

Q^* = economic order quantity

K = fixed order cost

λ = demand rate

h = holding cost

Reference #6

Total conveyor length (*L*) = delivery loop length (L_d) + return loop length (L_e)

Number of carriers n_c

$$n_c = \frac{L}{S_c}$$

S_c = center to center distance between carriers

Reference #8

$$UCL = \bar{\bar{x}} + A_2 \bar{r}$$

$CL = \bar{\bar{x}}$

$LCL = \bar{\bar{x}} - A_2\bar{r}$

Where:

$\bar{\bar{x}}$ = grand mean

r = sample measurement range

$\bar{r}$ = the average range

A_2 = tabulated constant for various sample sizes given in the following Table

$\bar{\bar{x}} = \frac{1}{m_i}\sum_{i=1}^{m} \bar{x}_i$

$\bar{r} = \frac{1}{m_i}\sum_{i=1}^{m} \bar{r}_i$

Table X Factors for Constructing Variables Control Charts

	Factor for Control Limits						
	$\overline{X}$ Chart			R Chart		S Chart	
n^*	A_1	A_2	d_2	D_3	D_4	c_4	n
2	3.760	1.880	1.128	0	3.267	0.7979	2
3	2.394	1.023	1.693	0	2.575	0.8862	3
4	1.880	.729	2.059	0	2.282	0.9213	4
5	1.596	.577	2.326	0	2.115	0.9400	5
6	1.410	.483	2.534	0	2.004	0.9515	6
7	1.277	.419	2.704	.076	1.924	0.9594	7
8	1.175	.373	2.847	.136	1.864	0.9650	8
9	1.094	.337	2.970	.184	1.816	0.9693	9
10	1.028	.308	3.078	.223	1.777	0.9727	10
11	.973	.285	3.173	.256	1.744	0.9754	11
12	.925	.266	3.258	.284	1.716	0.9776	12
13	.884	.249	3.336	.308	1.692	0.9794	13
14	.848	.235	3.407	.329	1.671	0.9810	14
15	.816	.223	3.472	.348	1.652	0.9823	15
16	.788	.212	3.532	.364	1.636	0.9835	16
17	.762	.203	3.588	.379	1.621	0.9845	17
18	.738	.194	3.640	.392	1.608	0.9854	18
19	.717	.187	3.689	.404	1.596	0.9862	19
20	.697	.180	3.735	.414	1.586	0.9869	20
21	.679	.173	3.778	.425	1.575	0.9876	21
22	.662	.167	3.819	.434	1.566	0.9882	22
23	.647	.162	3.858	.443	1.557	0.9887	23
24	.632	.157	3.895	.452	1.548	0.9892	24
25	.619	.153	3.931	.459	1.541	0.9896	25

*$n > 25$: $A_1 = 3/\sqrt{n}$ where n = number of observations in sample.

11. Solution of the Sample Questions

Question #1

Topic Area: **Engineering Economics**

Learning Level: Applying and Analyzing

Indicator: IE-T1-05

Utilize engineering economics analysis in decision making (budgeting, taxes, depreciation, inflation, risk and uncertainty).

Question Statement:

A machine shop is considering the purchase of a new CNC machine. The new CNC machine price is $400,000 and has useful life of 10 years. The estimated value of the CNC machine at the end of its useful life is zero. Hence, the annual depreciation amounts, using the straight line method is:

a. $400
b. $512
c. $640
d. $800

Answer:

a

Supplied Reference: Reference #1

Remarks: This question is intended to ensure that examinees are able to effectively utilize depreciation methods.

Solution:

N = 10 years

P = $4000

d = annual depreciation deduction

SV = $0

$$d = \frac{\$4000-0}{10} = \$400$$

Question #2

Topic Area: Probability and Statistics

Learning Level: Remembering and Understanding

Indicator: IE-T2-01

Recognize and utilize probability theory and probability distributions of random variables (continuous, discrete).

Question Statement:

For a particular binomial, the mean $\mu = 4$ and the standard deviation $\sigma = \sqrt{3}$. Find the binomial parameter p.

a. 0.25
b. 0.33
c. 3
d. 4

Answer:

a

Supplied reference: Reference #2

Remarks:

This question is intended to ensure that examinees are able to effectively recognize and utilize binomial distribution.

Solution:

$\mu = E(X) = np = 4$; $\sigma^2 = V(X) = np(1 - p) = 3$; $4(1 - p) = 3$

$p = 0.25$

Question #3

Topic Area: **Modeling and Computation**

Learning Level: Applying and Analyzing

Indicator: **IE-T3-05**

Utilize stochastic models (queuing, Markov, simulation).

Question Statement:

A technician is responsible for maintaining two machines. Mean time between failures is exponentially distributed with mean equal to 10 hours. The repair time is exponentially distributed with mean equal to 8 hours. The probability that both machines are working is:

a. 0.2623
b. 0.3279
c. 0.4098
d. 0.4201

Answer:

c

Supplied Reference: Reference #3

Remarks:

This question is intended to ensure that examinees are able to effectively utilize stochastic models queuing theory models.

Solution:

The probability that both machines are working is p_0 where none of them is failing or being repaired. In this problem the inverse of the time between failures represent the birth rate and inverse of the repair time represents the death rate, hence

$\lambda_0 = \lambda_1 = 0.1$

$\mu_1 = \mu_2 = 0.125$

$p_0 + p_1 + p_2 = 1$ (1)

$p_1 = \frac{0.1}{0.125} p_0$ (2)

$p_2 = \frac{0.1^2}{0.125^2} p_0$ (3)

Substituting 2 and 3 in 1

Then, p_0 = 0.4098

Question #4

Topic Area: **Industrial Management**

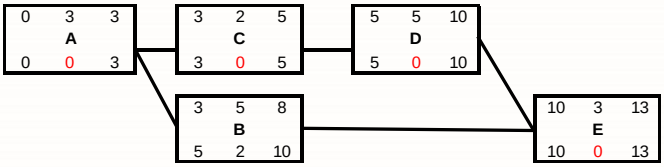
Learning Level: Applying and Analyzing

Indicator: **IE-T4-02**

Utilize project management techniques (scheduling, CPM, PERT, crashing, time control, cost control and organization).

Question Statement:

In the project network represented below,



the project activities can be crashed according to the table below:

Activity	Depend on	Normal Time, days	Normal Cost, SR	Crash Time, days	Crash Cost, SR
A	-	3	24,000	1	25,000
B	A	5	7,200	2	8,400
C	A	2	20,000	1	20,800
D	C	5	10,000	2	11,200
E	B,D	3	15,000	1	16,000

Which activity should be crashed first to cut one day from the project's duration?

a. Crash A
b. Crash C
c. Crash D
d. Crash E

Answer:

c

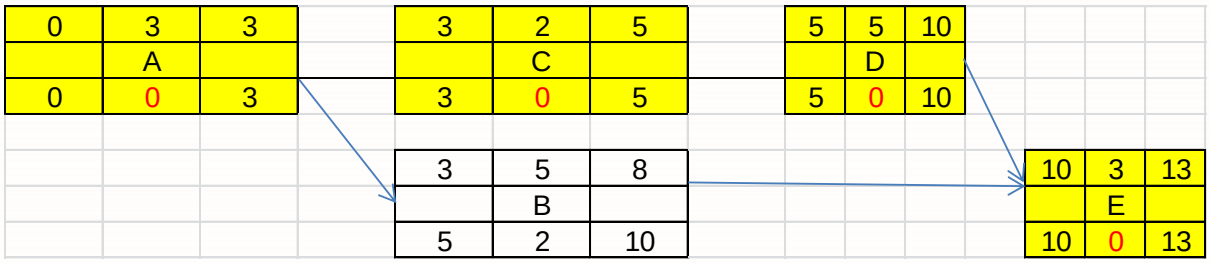
Supplied Reference: Reference #4

Remarks:

This question is intended to ensure that examinees are able to effectively crash projects' time.

Solution:

The activity to be crashed first is the one located on the critical path and has minimum cost slope. Using the above formula to calculate the cost slope for each of the five activities and drawing the project network to identify the critical path will show which activity on the critical path that has the minimum cost slope; this is the one to be crashed first. This is activity D with cost slope of $400 per day. The answer is c.



Question #5

Topic Area: **Manufacturing and Production Systems**

Learning Level: Applying and Analyzing

Indicator: IE-T5-04

Utilize production planning and control techniques (forecasting, scheduling, aggregate planning, MRP, JIT, MRPII, ERP and inventory control).

Question Statement:

Honesty Corporation regularly imports ovens to satisfy a growing demand for ovens in Saudi Arabia. The owner, Mr. Ameen, estimates that the demand is steady at 175 oven per month. Ovens cost 694 SR each, and the fixed cost of calling his brother in New York and having the ovens flown in is 75000 SR. It takes three weeks to receive an order. Ameen's accountant, Sadek, recommends an annual cost of capital of 22%, a cost of floor space of 3% of the value of an oven, and a cost of 2% of the value of an oven for taxes and insurance. Knowing the above information, the number of ovens that Ameen should import is:

a. 674
b. 1123
c. 1297
d. 2750

Answer:

c

Supplied reference: Reference #5

Remarks:

This question is intended to ensure that examinees are able to effectively calculate economic order quantity.

Solution:

Simply finding the values for the formula's components, substitute in the formula and determine the EOQ (Q^*).

K = 75000 SR

λ = 175 oven / month = 175 * 12 = 2100 oven / year

h = (22% + 3% + 2%) * 694 = 187.38 SR / oven . year

$$Q^* = \sqrt{\frac{2 \times 75000 \times 2100}{187.38}} = 1296.56 \cong 1297 \; oven \; per \; order$$

The answer is c.

Question #6

Topic Area: **Facilities and Logistics**

Learning Level: Applying and Analyzing

Indicator: **IE-T6-04** Design automated handling and storage systems.

Question Statement:

In a local small poultry slaughterhouse an overhead conveyor belt forms a continuous closed loop. The delivery loop has a length of 100 m and the return loop is 50 m. chicken are loaded at the load station and unloaded at the unload station. Chicken are hanged by their feet in a chicken carrier where each chicken carrier on the conveyor holds only one chicken and the carriers are separated by 0.5 m. Conveyor speed is 0.2 m/s. the maximum number of chicken in the conveyor system is:

a. 100
b. 150
c. 200
d. 300

Answer:

d

Supplied reference: Reference #6

Remarks:

This question is intended to ensure that examinees are able to effectively analyze continuous loop conveyors.

Solution:

$n_c = \frac{100+50}{0.5} = 300$, the answer is d.

Question #7

Topic Area: **Human Factors, Productivity, Ergonomics, and Work Design**

Learning Level: Remembering and Understanding

Indicator: IE-T7-05

Evaluate physical and mental workload and plan work/rest schedules.

Question Statement:

The information displayed by a speed limit sign on the side of a highway is considered

a. dynamic qualitative information
b. static representational information
c. dynamic alphanumeric information
d. static alphanumeric information

Answer:

d

Supplied reference: None

Remarks:

This question is intended to ensure that examinees are able to effectively distinguish different types of information display.

Question #8

Topic Area: **Quality Engineering**

Learning Level: Applying and Analyzing

Indicator: **IE-T8-04**

Apply principles of statistical quality control (control charts, process capability).

Question Statement:

A quality engineer is using control limits chart to observe the piston diameter in a specific piston production process. The following table shows $\bar{x}$ and *r* values for 10 samples of two pistons each:

	$\bar{x}$	*r*
1	41.5	9
2	36	4
3	38	6
4	40.5	3
5	37	8
6	45	4
7	39.5	3
8	40.5	3
9	46	8
10	38.5	1

The control limits for $\bar{X}$ chart are:

a. 40.25, 35.35
b. 45.15, 35.35
c. 49.46, 31.04
d. 54.95, 25.55

Answer:

d

Supplied reference: Reference #8

Remarks:

This question is intended to ensure that examinees are able to effectively determine the control limits for a process mean.

Solution:

The average of each group of measurements should be determined first, then the average of the ten groups and the standard deviation of the ten averages are to be calculated

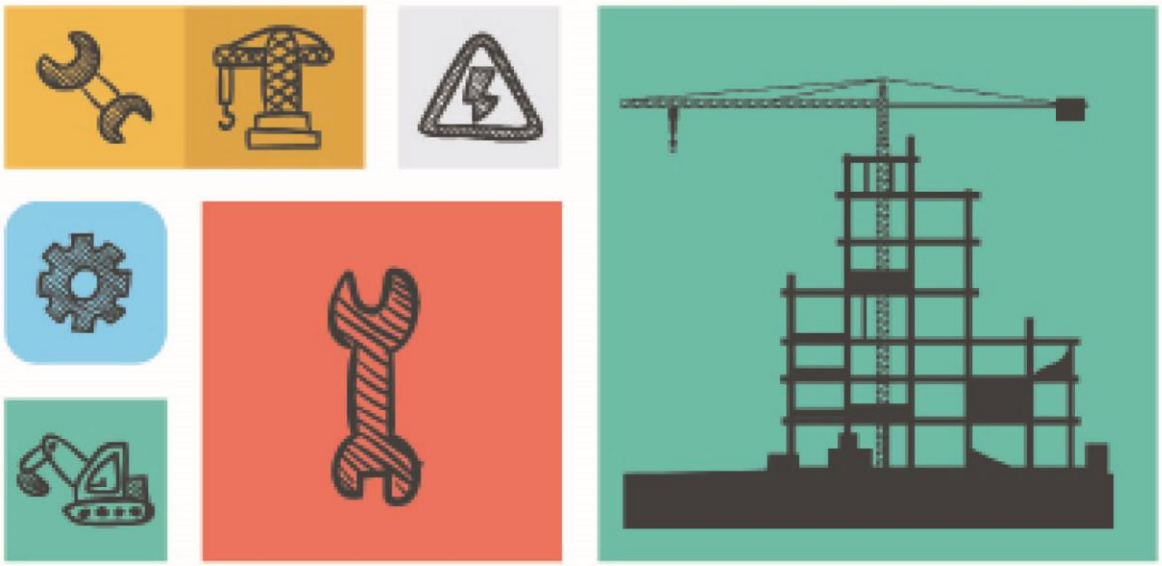
$\mu = 6.4025$

$\sigma = 0.0324$

Then

$UCL = 6.4025 + 3 * 0.0324 = 6.4998 \cong 6.50$

$LCL = 6.4025 - 3 * 0.0324 = 6.3052 \cong 6.31$



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