This month’s article features:

- FE Exam topics for Civil Engineering
- Calculator Usage
- Probability and Statistics
- Decimal and Binary Numbers
- Mathematics
- Statics
- Dynamics
- Mechanics of Materials
- Structural Design / Wall Footings
The new Civil FE Computer-Based Test (CBT) consists of 110 multiple-choice questions (Each problem only one question) the examinee will have 6 hours to complete the test.

- Mathematics (Approx. 9 questions*)
- Probability and Statistics (5 questions)
- Computational Tools (5 questions)
- Ethics and Professional Practice (5 questions)
- Engineering Economics (5 questions)
- Statics (9 questions)
- Dynamics (5 questions)
- Mechanics of Materials (9 questions)
- Civil Engineering Materials (5 questions)
- Fluid Mechanics (5 questions)
- Hydraulics and Hydrologic Systems (10 questions)
- Structural Analysis (8 questions)
- Structural Design (8 questions)
- Geotechnical Engineering (12 questions)
- Transportation Engineering (10 questions)
- Environmental Engineering (8 questions)

* Here the number of questions are the average values taken from the NCEES Reference Handbook (Version 9.1 / Computer-Based Test)
Frequently asked two Number Systems:

1- Decimal Number System (base 10)
2- Binary Number System (base 2)

In Decimal System 10 different digits are used to create any number, but in Binary System only 0s and 1s are used to create any number.

<table>
<thead>
<tr>
<th>DECIMAL</th>
<th>BINARY</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>5</td>
<td>101</td>
</tr>
<tr>
<td>6</td>
<td>110</td>
</tr>
<tr>
<td>8</td>
<td>1000</td>
</tr>
<tr>
<td>9</td>
<td>1001</td>
</tr>
<tr>
<td>10</td>
<td>1010</td>
</tr>
<tr>
<td>12</td>
<td>1100</td>
</tr>
<tr>
<td>14</td>
<td>1110</td>
</tr>
<tr>
<td>15</td>
<td>1111</td>
</tr>
<tr>
<td>19</td>
<td>10011</td>
</tr>
<tr>
<td>25</td>
<td>11001</td>
</tr>
</tbody>
</table>
NUMBER SYSTEMS
BINARY & DECIMAL
NCEES Reference Handbook, Page: 213

Binary Number System:

In digital computers, binary number system (the base-2) is used. Conversions from BINARY to DECIMAL or from DECIMAL to BINARY can easily be done using the calculator. Binary (base-2), decimal (base-10).

Problem:

Find the binary equivalent of decimal 25? Here, decimal is base-10.

Turn on your calculator

1) Press MODE
2) Press “4”
3) Enter 25 and press “ = ”
4) Make sure to see 25 under Dec on the screen
5) Press SHIFT then “log”
6) Answer: 11001

Problem:

Find the decimal equivalent of binary 1111?

Turn on your calculator

1) Press MODE
2) Press “4”
3) Press SHIFT then press “log” key
4) Enter 1111 and then press “ = ”
5) Make sure to see 1111 under Bin on the screen
6) Press SHIFT then hit “ x^2 ” key
7) Answer: 15
BASIC RELATIONSHIPS

Mean

\[ \bar{y} = \frac{\sum y_i}{n} \]

Standard Deviation

\[ s_y = \sqrt{\frac{\sum (y_i - \bar{y})^2}{n-1}} \]

Standard Deviation

\[ s_y = \sqrt{\frac{\sum y_i^2 - (\sum y_i)^2}{n-1}} / n } \]

Variance

\[ S_y^2 = \frac{\sum (y_i - y)^2}{n-1} \]

Coefficient of Variation

\[ c.v. = \frac{s_y}{\bar{y}} \times 100 \% \]
Problem:

A data set is given as listed below:

8, 25, 7, 5, 8, 3, 10, 12, 9

(1) The mean of this set is most nearly:

(A) 7.98
(B) 8.15
(C) 9.67
(D) 12.85

(2) The standard deviation is most nearly:

(A) 6.32
(B) 7.85
(C) 8.25
(D) 9.14
**Problem:**

8, 25, 7, 5, 8, 3, 10, 12, 9

Consider the data set given above:

(a) Calculate the mean (\( \bar{y} \))

(b) Calculate the Standard Deviation (\( s_y \))

**Solution:**

The mean is the sum of scores divided by n where n is the number of scores.

1. \( \bar{y} = \frac{\sum y}{n} = \frac{(8+25+7+5+8+3+10+12+9)}{9} \)
   \[= 9.67 \]

2. the standard deviation may be calculated using the following formula:

\[
s_y = \sqrt{\frac{\sum (y_i - \bar{y})^2}{n-1}}
\]

\( \text{Deviation} = (y_i - \bar{y}) \)

In order to calculate the values in the standard deviation formula, the following table may be used:

<table>
<thead>
<tr>
<th>Score</th>
<th>Mean</th>
<th>Deviation</th>
<th>(Deviation)²</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>9.67</td>
<td>- 1.67</td>
<td>2.79</td>
</tr>
<tr>
<td>25</td>
<td>9.67</td>
<td>+15.33</td>
<td>235.01</td>
</tr>
<tr>
<td>7</td>
<td>9.67</td>
<td>- 2.67</td>
<td>7.13</td>
</tr>
<tr>
<td>5</td>
<td>9.67</td>
<td>- 4.67</td>
<td>21.81</td>
</tr>
<tr>
<td>8</td>
<td>9.67</td>
<td>- 1.67</td>
<td>2.79</td>
</tr>
<tr>
<td>3</td>
<td>9.67</td>
<td>- 6.67</td>
<td>44.49</td>
</tr>
<tr>
<td>10</td>
<td>9.67</td>
<td>+ .33</td>
<td>.11</td>
</tr>
<tr>
<td>12</td>
<td>9.67</td>
<td>+ 2.33</td>
<td>5.43</td>
</tr>
<tr>
<td>9</td>
<td>9.67</td>
<td>- .67</td>
<td>.45</td>
</tr>
</tbody>
</table>

\[\sum = 320.01\]
Standard Deviation ($S_y$)

$$S_y = \sqrt{\frac{\sum(y_i - \bar{y})^2}{n-1}} = \sqrt{\frac{320.01}{9-1}} = 6.32$$

Alternate method for calculating the Standard Deviation: (The Raw Score Method)

Consider the raw scores 8, 25, 7, 5, 8, 3, 10, 12, 9.

1. First, square each of the scores.
2. Determine $n$, which is the number of scores.
3. Compute the sum of $y_i$ and the sum of $y_i^2$.
4. Then, calculate the standard deviation as illustrated below.

<table>
<thead>
<tr>
<th>score ($y_i$)</th>
<th>$y_i^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>64</td>
</tr>
<tr>
<td>25</td>
<td>625</td>
</tr>
<tr>
<td>7</td>
<td>49</td>
</tr>
<tr>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>8</td>
<td>64</td>
</tr>
<tr>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>12</td>
<td>144</td>
</tr>
<tr>
<td>9</td>
<td>81</td>
</tr>
<tr>
<td>---</td>
<td>------</td>
</tr>
<tr>
<td>87</td>
<td>1161</td>
</tr>
</tbody>
</table>

$$s_y = \sqrt{\frac{\sum y_i^2 - (\sum y_i)^2 \over n}{n-1}} = \sqrt{\frac{(1161) - (87*87)/9}{9-1}} = \sqrt{\frac{(1161 - 7569/9)}{8}} = 6.32$$
(1) A particle will remain at rest or continue with its motion, unless acted upon by an external force.

(2) The force on an object is equal to its mass multiplied by its acceleration \((F = m.a)\).

(3) Every action has an equal and opposite reaction.

These three laws of motion are known as:

(A) Euler’s Laws
(B) Young’s Laws
(C) Poisson’s Laws
(D) Newton’s Laws
Problem:

A sprinter competing in a 100 m race accelerates uniformly for the first 40 meters in 6.0 seconds. She then runs at a constant speed for the remainder of the race. The total time (seconds) elapses when she crosses the finish line is most nearly:

(A) 10.5
(B) 11.4
(C) 12.0
(D) 13.4
The van shown moves in a straight line such that for a short time its velocity is defined by \( v = (6t^2 + 4t) \text{ ft/s} \). Knowing that \( t \) is measured in seconds, answer the following:

(1) The van’s position (ft) in \( t = 4 \) seconds is most nearly
   (A) 75
   (B) 90
   (C) 150
   (D) 160

(2) The van’s acceleration (ft/s\(^2\)) in \( t = 4 \) seconds is most nearly
   (A) 35
   (B) 42
   (C) 52
   (D) 68
DEFINITE INTEGRALS
AREAS UNDER CURVES
Using CASIO FX-115 ES PLUS

Problem:

\[ f(x) = \left(\frac{2}{3}\right)^x \]

The area under the graph shown is most nearly:

(A) 5.06
(B) 4.25
(C) 2.15
(D) 1.37
Problem:

\[ I = \int_{0}^{3} x^2 \cdot (e^{x^2}) \, dx \]

The value of the definite integral shown above is most nearly:

(A) 20
(B) 3986
(C) 1112
(D) 11432

Comments:

At first sight, this problem seems highly complex, but it is not. You can easily get the correct answer in exactly 15 seconds. Yes, in 15 seconds!
What can you do with your CASIO FX-115 ES PLUS?

Enter the equation
Into the calculator

Just hit the \(<=\) KEY
and wait 15 seconds

Answer =

11432.353
W 12 x 50

Nominal Depth (12 in.)

Weight 50 lb/ft

- $A = \text{Area} = 14.6 \text{ in}^2$
- $d = \text{Depth} = 12.2 \text{ in.}$
- $b_f = \text{Flange Width} = 8.08 \text{ in.}$
- $t_f = \text{Flange Thickness} = 0.640 \text{ in.}$
- $t_w = \text{Web Thickness} = 0.370 \text{ in.}$
- $I_x = \text{Moment of Inertia} = 391 \text{ in}^4$
- $I_y = \text{Moment of Inertia} = 56.3 \text{ in}^4$
- $S_x = \text{Section Modulus (x-x)} = 64.2 \text{ in}^3$
- $r_x = \text{Radius of Gyration} = 5.18 \text{ in}$
- Major axis or strong axis = (x-x)
- Minor axis or weak axis = (y-y)
Problem: (Deflection of Beams)

A determinate beam is loaded as shown. Knowing that the beam weight is included in the uniform load, answer the following questions:

(1) The maximum deflection (inches) is most nearly:
   (A) 0.98
   (B) 1.15
   (C) 1.39
   (D) 1.85

(2) The slope (radians) at support A is most nearly:
   (A) 0.0055
   (B) 0.0152
   (C) 0.0880
   (D) 0.1250
**Problem:** (Beam Deflections)

For the simple beam shown the beam weight is included in the uniform load. Determine the maximum deflection and the slope at A (in radians).

**Solution:** We will use NCEES-Reference Handbook, page 155 and 81.

![Beam Diagram](image)

\[ P = 12 \text{ kips} \]
\[ w = 2 \text{ kips/ft} \]
\[ W16 \times 40 \]
\[ E = 29,000 \text{ ksi} \]

\[ W = 16 \times 40 \]
\[ I = 518 \text{ in}^4 \]

For DEFLECTIONS: \( (12^3) \)

For SLOPES: \( (12^2) \)

**Finding the maximum deflection:**

The maximum deflection will be at the midpoint of the span. For quick calculations when using US unit systems, architects and engineers use conversion factors like \((12^3)\) and \((12^2)\). For DEFLECTIONS this conversion factor is \((12^3)\) and for SLOPES the conversion factor will be \((12^2)\).

\[
\delta_{\text{max}} = \frac{5}{384} \frac{wL^4}{EI} + \frac{1}{48} \frac{PL^3}{EI} = \frac{5}{384} \left(2.0\right) \left(24^4\right) \left(12^3\right) + \frac{1}{48} \left(12\right) \left(24^3\right) \left(12^2\right)
\]

\[
= 0.994 + 0.397 = 1.391 \text{ inches}
\]

**Finding the slope at support A:**

\[
\theta_A = \frac{wL^3}{24EI} + \frac{PL^2}{16EI} = \frac{1}{24} \left(2.0\right) \left(24^3\right) \left(12^2\right) + \frac{1}{16} \left(12\right) \left(24^2\right) \left(12^2\right)
\]

\[
= 0.01104 + 0.00414 = 0.01518 \text{ Radians}
\]

\[ = 0.01518 \text{ Radians} \]
Problem: (Deflections)

A composite beam is made of two W 12 x 40 welded together. The beam weight is included in the uniform load. Using the given beam dimensions and loads answer the following questions:

1. the max. moment (ft.kips) in the beam is most nearly

   (A) 126
   (B) 165
   (C) 225
   (D) 300

2. the moment of inertia (in.\(^4\)) about the horizontal centroidal axis is most nearly \(I_{cx}\)

   (A) 307
   (B) 515
   (C) 614
   (D) 720

3. the max. deflection (in.) of the beam is most nearly

   (A) 0.245
   (B) 0.363
   (C) 0.478
   (D) 0.594

4. the slope (radians) at the left support is most nearly

   (A) 0.00985
   (B) 0.00768
   (C) 0.00643
   (D) 0.02250
SHEAR AND MOMENT DIAGRAMS

5

6

7

8

MNV-15
ZEYTINCI
SPRING 2014
SHEAR AND MOMENT DIAGRAMS

9

2.0 kips/ft

A

B

15.0 ft

6.0 ft

(12.60 kips)

(12.00 kips)

x = 6.30 ft

17.40 kips

36.00 ft-kip

M_{max} = +39.69 ft-kip

(FBD)

(V)

(M)

10

2 k/ft

16 ft-kip

8 kip

A

B

8 ft

4 ft

4 ft

4 ft

(11 kip)

30.25 ft-kip

4 ft-kip

12 ft-kip

32 ft-kip

11

5 kips

2.0 kips/ft

4 kips

A

B

5.0 ft

5.0 ft

10.0 ft

21.0 kips

11.0 k

7.0 k

15.0 kips

x = 6.5 ft

M_{max} = +42.25 ft-kip

5.0 k

13.0 k

50.0 ft-kip

(FBD)

(V)

(M)

12

6 k/ft

2 k/ft

4 k

8 k

1.0 k/ft

5 kip

6 k/ft

2 k/ft

4 k

8 k

1.0 k/ft

5 kip

A

B

A = 23 kips

B = 20 kips

(15 kips)

15 kips

3 k

9 kips

5 kips

8 k

1 k

9 k

11 kips

6 ft-kip

22 ft-kip

28 ft-kip

(FBD)

(V)

(M)
A simply supported beam is loaded as shown. Using the given support conditions, the magnitude of maximum bending moment (k-ft) is most nearly:

(A) 42.50  
(B) 36.75  
(C) 34.25  
(D) 20.25  

\[ M_{\text{max}} = ? \]
FUNDAMENTALS OF ENGINEERING

Shear Force and Bending Moment Diagrams

(a) Determine the support reactions
(b) Draw the shear force diagram
(c) Draw the bending moment diagram

(FBD)

(V)

(M)

(Diagrams not drawn to scale)
A simply supported beam is loaded as shown. Using the given support conditions, the maximum bending moment (k-ft) in the beam is most nearly:

(A) 45.00  
(B) 56.25  
(C) 64.50  
(D) 72.75
FUNDAMENTALS OF ENGINEERING
Shear Force and Bending Moment Diagrams

(a) Determine the support reactions
(b) Draw the shear force diagram
(c) Draw the bending moment diagram

(Diagrams drawn not to scale)
The shear force diagram of a determinate beam is given as shown. Knowing that all lines in the diagram are straight and there are no concentrated moments (couples) anywhere in the beam, the maximum magnitude of the bending moment (ft-kips) in the beam is most nearly:

(A) 35.50
(B) 48.00
(C) 54.50
(D) 62.00

\[ M_{\text{max}} = ? \]
A R/C wall footing is loaded as shown. The material characteristics are given as listed. Using the dimensions shown, the effective soil pressure (k/ft²) is most nearly:

(A) 4.25  
(B) 3.10  
(C) 2.84  
(D) 2.25
Allowable soil pressure: $\sigma_a = 3,750 \text{ lb/ft}^2$

Using the listed data, determine:
(a) The pressure due to the weight of soil fill on top
(b) The pressure due to the weight of R/C footing
(c) The effective soil pressure

Solution:

(a) Pressure due to the weight of soil fill on top: $(q_{soil})$

$$q_{soil} = (t - h) (\gamma_{soil}) = \left( \frac{66 - 24}{12} \right) \times 100 = 3.5' \times 100 = 350 \text{ lb/ft}^2$$

(b) Pressure due to the weight of footing: $(q_{ftg})$

$$q_{ftg} = (h) (\gamma_{con}) = \left( \frac{24}{12} \right) \times 150 = 2' \times 150 = 300 \text{ lb/ft}^2$$

(c) Effective soil pressure: $(q_e)$

$$q_e = q_a - (q_{soil} + q_{ftg})$$

$$= 3,750 - (350 + 300)$$

$$= 3,100 \text{ lb/ft}^2$$

$\gamma_{soil} = 100 \text{ lb/ft}^3$

$\gamma_{con} = 150 \text{ lb/ft}^3$

$q_e = 3.10 \text{ kip/ft}^2$
A R/C wall footing is loaded as shown. The soil and concrete characteristics are given as listed. Using the dimensions shown, answer the following questions:

(1) the width \(B\) of the footing (ft) is most nearly:

(A) 9.5  
(B) 12.0  
(C) 13.0  
(D) 14.5

(2) the bearing pressure \(k/\text{ft}^2\) for strength design is most nearly:

(A) 4.92  
(B) 3.18  
(C) 2.84  
(D) 1.25
STRUCTURAL DESIGN
WALL FOOTINGS

Using the listed data, determine:
(a) The pressure due to the weight of soil fill on top
(b) The pressure due to the weight of R/C footing
(c) The effective soil pressure
(d) The width of footing (B)
(e) The bearing pressure for strength design \((q_u)\)

\[
q_{soil} = (t - h) \left( \gamma_{soil} \right) = \left( \frac{54 - 21}{12} \right) \times 115 = 2.75' \times 115 = 316 \text{ lb/ft}^2
\]

\[
q_{tg} = (h) \left( \gamma_{con} \right) = \left( \frac{21}{12} \right) \times 150 = 1.75' \times 150 = 263 \text{ lb/ft}^2
\]

(c) Effective soil pressure: \((q_e)\)

\[
q_e = q_a - (q_{soil} + q_{tg}) = 4,250 - (316 + 263) = 3,671 \text{ lb/ft}^2 = 3.67 \text{ kip/ft}^2
\]

(d) The width of the footing: \((B)\)

\[
B = \frac{DL + LL}{q_e} = \frac{20 + 25}{3.67} = 12.26 \text{ ft} \quad \rightarrow \quad B = 13.00 \text{ ft}
\]

(e) The bearing pressure for strength design: \((q_u)\)

\[
q_u = \frac{1.2 \times DL + 1.6 \times LL}{B} = \frac{1.2 \times 20 + 1.6 \times 25}{13.00} = \frac{64.00}{13.00} = 4.92 \text{ kip/ft}^2
\]

\[
q_u = 4.92 \text{ kip/ft}^2
\]