Question: In a recovery control system, the probability that the system recovers from the one fault is 0.64 and the probability that the system recovers from two faults is 0.51. What is the probability that the system recovers from the second fault given that it covered from the first fault successfully?

A. 0.797  B. 0.741  C. 0.45  D. 0.54
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\[ P(A \text{ AND } B) \]

\[ P(A \mid B) = \frac{P(A \text{ AND } B)}{P(B)} \]

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$$P(A \mid B) = \frac{P(A \text{ AND } B)}{P(B)} = \frac{0.51}{0.64} = 0.797$$
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**Question:** In a hospital, 35% of those with high blood pressure have had strokes and 20% of those without high blood pressure have had strokes. If 40% of the patients have high blood pressure, what percent of the patients have had strokes?

A. 0.13  
B. 0.26  
C. 0.33  
D. Not Enough Information is given

Time: 3 minutes, Difficulty Level: Average
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- **With high blood pressure**
  - 40% of 35% = 0.4 x 0.35

- **Without high blood pressure**
  - 60% of 20% = 0.6 x 0.20

Total percent of patients who have had strokes = 0.4 x 0.35 + 0.6 x 0.20 = 0.27 + 0.12 = 0.39 or 39%
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\[
P(\text{Patient had Stroke}) = 0.4 \times 0.35 + 0.6 \times 0.2 = 0.26
\]
What we need to know for this session

- Sum of all the probabilities for every random experiment:
  - Expected Value:
  - Standard Deviation:
- Integral:
What we need to know from past for this session

- Sum of all the probabilities for every random experiment:

- Expected Value:

- Standard Deviation:

- Integral:
What we need to know from past for this session

- Sum of all the probabilities for every random experiment:
  \[ p_1 + p_2 + p_3 + p_4 + p_5 = 1 \]

- Expected Value:

- Standard Deviation:

- Integral:
Example: We roll Two Dice, and we sum up the shown numbers.

For instance: \[ 5 + 1 = 6 \]

\[ P(1,5) = \frac{1}{36} \]

What is the probability that sum of two numbers is bigger than 4 and smaller than 8?
P(4 \leq x \leq 8) =
P(4 <= x <= 8) =
\[ P(4 \leq x \leq 8) = \frac{3}{36} + \frac{4}{36} + \frac{5}{36} + \frac{6}{36} + \frac{5}{36} = \frac{23}{36} \]
Expected Value:

Binomial Expected Value, the outcome is between two options, e.g., True or False.

Example: We toss a coin 10 times. How many Heads you could expect?

\[ E(x) = P(x) \times X \]

Probability of Head

Number of Trials

\[ \frac{1}{2} \times 10 = 5 \]
Challenge: Shall we play or .... not?

The expected value gives us the expected long term average of measurements.

This game costs you £1 per game.

You will not receive your money back no matter you win or lose.

Shall we play?
Challenge: Shall we play or .... not?

<table>
<thead>
<tr>
<th>OUTCOME</th>
<th>£0</th>
<th>£3</th>
<th>£0</th>
<th>£10</th>
<th>£1</th>
<th>-£1</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROBABILITY</td>
<td>1/4</td>
<td>1/4</td>
<td>1/4</td>
<td>1/8</td>
<td>1/8</td>
<td>1</td>
</tr>
</tbody>
</table>

Your expectation is:

\[ E = -1 \cdot £1(1) + 0(1/2) + 1(1/8) + 2(1/4) + 10(1/8) \]

\[ E = £7/8 \]

You can expect to win £0.875 ON AVERAGE per game.
For instance: 100 games, you win £87.5.
Standard Deviation (SD)

Matlab syntax: \text{std}(A)

\[
\sigma^2 = ((-224)^2 + (-94)^2 + 36^2 + 76^2 + 206^2) / 5 = 21704 \text{ mm}
\]

\[
\sigma = 147 \text{ mm}
\]
Example

<table>
<thead>
<tr>
<th>X</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>P(X)</td>
<td>0.01</td>
<td>0.25</td>
<td>0.4</td>
<td>0.3</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Find the Standard Deviation of X:

\[ \sigma = \sqrt{\sum_{i=1}^{n} p_i (x_i - E[x])^2} \]

\[ E(x) = [(2 \times 0.01) + (3 \times 0.25) + (4 \times 0.4) + (5 \times 0.3) + (6 \times 0.04)] = 4.11 \]

\[ \sigma = \sqrt{(2 - 4.11)^2(0.01) + (3 - 4.11)^2(0.25) + (4 - 4.11)^2(0.4) + (5 - 4.11)^2(0.3) + (6 - 4.11)^2(0.04)} \]

\[ \sigma = \sqrt{0.74} = 0.86 \]
Continuous Random Variables

Many practical random variables are modelled as Continuous:

1- Speed of a car
2- Measurement Error
3- Electricity Consumption
Many practical random variables are modelled as **Continuous**:

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\[ f(x) \] 

**Probability Density Function**

(PDF)

**Experiment**

**Probability**
Continuous Random Variables

Total Area is equal to 1

\[ f(x) \] : Probability Density Function
Continuous Random Variables

Rule 1: Probability Density function (PDE):

$$\int_{-\infty}^{\infty} f(x) \, dx = 1$$

$f(x)$ : Probability Density Function

Total Area is equal to 1
Continuous Random Variables

Rule 1: Probability Density function (PDE):
\[ \int_{-\infty}^{\infty} f(x) \, dx = 1 \]

Rule 2: Expected Value:
\[ \mu = E[x] = \int_{-\infty}^{+\infty} x \, f(x) \, dx \]

\( f(x) \) : Probability Density Function
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Continuous Random Variables

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\[
\sigma = \sqrt{E(x^2) - E(x)^2}
\]

\( f(x) \): Probability Density Function

Total Area is equal to 1
Let's take some integrals

\[ \int x^a \, dx \]
Lets take some integrals

\[ \int x^a \, dx = \frac{x^{a+1}}{a + 1} \]
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\[ \int \sqrt[3]{2} x^5 \, dx \]
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Let's take some integrals

\[ \int x^a \, dx = \frac{x^{a+1}}{a+1} \]

\[ \int 3\sqrt{2}x^5 \, dx = 3\sqrt{2} \frac{x^{5+1}}{5+1} = 3\sqrt{2} \frac{x^6}{6} \]
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\[ \int_1^4 3\sqrt{2}x^5 \, dx \]
Let's take some integrals

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\int x^a \, dx = \frac{x^{a+1}}{a + 1}
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\[
\int_{1}^{4} \sqrt[3]{2}x^5 \, dx = \left[ \sqrt[3]{2} \frac{x^6}{6} \right]_{1}^{4}
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\[
\int_1^4 \sqrt[3]{2} x^5 \, dx = \left[ \sqrt[3]{2} \frac{x^6}{6} \right]_1^4 = \frac{\sqrt[3]{2}}{6} (4^6 - 1^6)
\]
Lets take some integrals

\[ \int x^a \, dx = \frac{x^{a+1}}{a+1} \]

\[ \int \frac{12}{\sqrt[3]{x^2}} \, dx \]
Lets take some integrals

\[
\int x^a \, dx = \frac{x^{a+1}}{a + 1}
\]

\[
\int \frac{12}{3\sqrt[3]{x^2}} \, dx = \int \frac{12}{x^{\frac{2}{3}}} \, dx
\]
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\[ \int x^a \, dx = \frac{x^{a+1}}{a+1} \]

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\[ = 12 \frac{x^{-\frac{2}{3}} + 1}{-\frac{2}{3} + 1} \]
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\[ = 12 \frac{x^{-\frac{2}{3} + 1}}{-\frac{2}{3} + 1} = 12 \frac{x^{\frac{1}{3}}}{\frac{1}{3}} = 36x^{\frac{1}{3}} \]
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\[ \int e^{ax} \, dx \]
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\[ \int e^{ax} \, dx = \frac{e^{ax}}{a} \]
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$$\int e^{ax} \, dx = \frac{e^{ax}}{a}$$

$$\int_{1}^{4} e^{2x} \, dx$$
Let's take some integrals

\[ \int e^{ax} \, dx = \frac{e^{ax}}{a} \]

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\int e^{ax} \, dx = \frac{e^{ax}}{a}
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\[
\int_{1}^{4} e^{\sqrt{2}x} \, dx = \left[ \frac{e^{\sqrt{2}x}}{\sqrt{2}} \right]_{1}^{4} = \frac{1}{\sqrt{2}} \left( e^{\sqrt{2} \times 4} - e^{\sqrt{2} \times 1} \right)
\]
The lifetime of an electronic component (in thousands of hours) is a continuous random variable with the probability density function given by:

\[ f(x) = Ae^{-\frac{x}{2}} \quad \text{for} \quad x \geq 0 \]

and zero otherwise:

Calculate the A:
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\[ \int_{0}^{\infty} Ae^{-\frac{x}{2}} \, dx = 1 \implies \left[ A \cdot \frac{1}{-\frac{1}{2}} e^{-\frac{x}{2}} \right]_{0}^{\infty} = 1 \]
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\[ \left[ -2Ae^{-\frac{x}{2}} \right]_{0}^{\infty} \]
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\[ \int_{-\infty}^{\infty} f(x) \, dx = 1 \]

\[ \int_{0}^{\infty} Ae^{-\frac{x}{2}} \, dx = 1 \Rightarrow \left[ A \left( \frac{1}{-1} e^{-\frac{x}{2}} \right) \right]_{0}^{\infty} = 1 \]

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\[ A = \frac{1}{2} \]
Question

The lifetime of an electronic component (in thousands of hours) is a continuous random variable with the probability density function given by:

\[ f(x) = \frac{1}{2}e^{-\frac{x}{2}} \quad \text{for} \quad x \geq 0 \]

and zero otherwise:

What portion of the components last longer than 4000 hours?
The lifetime of an electronic component \textit{(in thousands of hours)} is a continuous random variable with the probability density function given by:

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Calculate \( P \geq 4 \)
Question

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Question

Calculate \((P \geq 4)\)

\[
\int_{4}^{\infty} \frac{1}{2} e^{-0.5x}
\]
Question

Calculate \( P \geq 4 \)

\[
\int_{4}^{\infty} \frac{1}{2} e^{-0.5x} = \left[-e^{-0.5x}\right]_{4}^{\infty}
\]
Calculate \( P \geq 4 \)

\[
\int_{4}^{\infty} \frac{1}{2} e^{-0.5x} = \left[ -e^{-0.5x} \right]_{4}^{\infty} = \frac{1}{2} e^{-2} = 0.067
\]
Example:

A charity group raises funds by collecting waste paper. The collected materials will contain an amount, \( X \), of other materials such as plastic bags and rubber bands. \( X \) may be regarded as a random variable with probability density function:

\[
f(x) = \begin{cases} 
  k(x - 1)(4 - x) & 1 < x < 4 \\
  0 & \text{Otherwise} 
\end{cases}
\]

(i) Show that \( K = 2/9 \)

(ii) Find the Expected Value and Standard Deviation of \( X \).

(iii) Find the Probability of \( X \) that exceeds 3.5
Example:

\[ f(x) = \begin{cases} 
  f(x) = k(x - 1)(4 - x) & 1 < x < 4 \\
  0 & Otherwise
\end{cases} \]
Example:

\[ f(x) = \begin{cases} f(x) = k(x - 1)(4 - x) & 1 < x < 4 \\ 0 & \text{Otherwise} \end{cases} \]

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(i) Show that K=2/9

\[
\int_{-\infty}^{\infty} f(x) \, dx = 1
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Example:

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f(x) = \begin{cases} f(x) = k(x - 1)(4 - x) & 1 < x < 4 \\ 0 & \text{Otherwise} \end{cases}
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(i) Show that \( K = \frac{2}{9} \)

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\[
\int_{1}^{4} k(x - 1)(4 - x) \, dx = 1
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Example:

\[ f(x) = \begin{cases} f(x) = k(x - 1)(4 - x) & 1 < x < 4 \\ 0 & Otherwise \end{cases} \]

(i) Show that \( K = \frac{2}{9} \)

\[ \int_{-\infty}^{\infty} f(x) \, dx = 1 \]

\[ 1 < x < 4 \]

\[ \int_{1}^{4} k(x - 1)(4 - x) \, dx = 1 \]

\[ k \int_{1}^{4} (x - 1)(4 - x) \, dx = 1 \]
Example:

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\]

\[
k \int_{1}^{4} (x - 1)(4 - x) \, dx = 1
\]

\[
k \left[ \frac{-x^3}{3} + \frac{-5x^2}{2} - 4x \right]_{1}^{4} = 1
\]
Example:

\[ f(x) = \begin{cases} f(x) = k(x - 1)(4 - x) & \text{if } 1 < x < 4 \\ 0 & \text{otherwise} \end{cases} \]

(i) Show that \( K = \frac{2}{9} \)

\[
\int_{-\infty}^{\infty} f(x) \, dx = 1
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\[
1 < x < 4
\]

\[
\int_{1}^{4} k (x - 1)(4 - x) \, dx = 1
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\[
k \int_{1}^{4} (x - 1)(4 - x) \, dx = 1
\]

\[
k \left[ \frac{-x^3}{3} + \frac{-5x^2}{2} - 4x \right]_{1}^{4} = 1
\]

\[
k \left[ \frac{8}{3} - \left( -\frac{11}{6} \right) \right] = 1
\]
Example:

\[ f(x) = \begin{cases}  \ f(x) = k(x - 1)(4 - x) & \text{for } 1 < x < 4 \\ 0 & \text{otherwise} \end{cases} \]

(i) Show that \( k = \frac{2}{9} \)

\[ \int_{-\infty}^{\infty} f(x) \, dx = 1 \]

\[ \int_{1}^{4} k(x - 1)(4 - x) \, dx = 1 \]
\[ k \int_{1}^{4} (x - 1)(4 - x) \, dx = 1 \]
\[ k \left[ \frac{-x^3}{3} + \frac{-5x^2}{2} - 4x \right]_{1}^{4} = 1 \]
\[ k \left[ \frac{8}{3} - \left( -\frac{11}{6} \right) \right] = 1 \]
\[ 4.5k = 1 \]
\[ k = \frac{2}{9} \]
Example:

\[ f(x) = \begin{cases} 
  f(x) = k(x - 1)(4 - x) & \text{if } 1 < x < 4 \\
  0 & \text{otherwise}
\end{cases} \]

(ii) Find the Expected Value and Standard Deviation of \( X \).
Example:

\[ f(x) = \begin{cases} 
  f(x) = k(x - 1)(4 - x) & 1 < x < 4 \\
  0 & Otherwise 
\end{cases} \]

(ii) Find the Expected Value and Standard Deviation of X.

\[ \mu = E[x] = \int_{-\infty}^{+\infty} x f(x) \, dx \]
Example:

\[
f(x) = \begin{cases} 
  f(x) = k(x - 1)(4 - x) & \text{for } 1 < x < 4 \\
  0 & \text{Otherwise}
\end{cases}
\]

(ii) Find the Expected Value and Standard Deviation of \( X \).

\[
E[x] = \int_{1}^{4} \frac{2}{9} x (x - 1) (4 - x) \, dx
\]

\[
\mu = E[x] = \int_{-\infty}^{+\infty} x f(x) \, dx
\]
Example:

\[ f(x) = \begin{cases} f(x) = k(x - 1)(4 - x) & 1 < x < 4 \\ 0 & \text{Otherwise} \end{cases} \]

(ii) Find the Expected Value and Standard Deviation of X.

\[
E[x] = \int_1^4 \frac{2}{9} x(x - 1)(4 - x) \, dx
\]

\[
= \frac{2}{9} \left( \int_1^4 x(x - 1)(4 - x) \, dx \right)
\]

\[
\mu = E[x] = \int_{-\infty}^{+\infty} x f(x) \, dx
\]
Example:

\[ f(x) = \begin{cases} 
  f(x) = k(x - 1)(4 - x) & 1 < x < 4 \\
  0 & \text{Otherwise}
\end{cases} \]

(ii) Find the Expected Value and Standard Deviation of \( X \).

\[ E[x] = \int_{1}^{4} \frac{2}{9} x (x - 1)(4 - x) \, dx \]
\[ = \frac{2}{9} \left( \int_{1}^{4} x (x - 1)(4 - x) \, dx \right) \]
\[ = \frac{2}{9} \left[ \frac{-x^4}{4} + \frac{5x^3}{3} - \frac{4x^2}{2} \right]_{1}^{4} \]

\[ \mu = E[x] = \int_{-\infty}^{+\infty} x f(x) \, dx \]
Example:

\[ f(x) = \begin{cases} 
  f(x) = k(x - 1)(4 - x) & 1 < x < 4 \\
  0 & \text{Otherwise}
\end{cases} \]

(ii) Find the Expected Value and Standard Deviation of \( X \).

\[
\mu = E[x] = \int_{-\infty}^{+\infty} x f(x) \, dx
\]

\[
E[x] = \int_1^4 \frac{2}{9} x(x - 1)(4 - x) \, dx
\]

\[
= \frac{2}{9} \left( \int_1^4 x(x - 1)(4 - x) \, dx \right)
\]

\[
= \frac{2}{9} \left[ \frac{-x^4}{4} + \frac{5x^3}{3} - \frac{4x^2}{2} \right]_1^4
\]

\[
= \frac{2}{9} \left( \frac{32}{3} - \left( -\frac{7}{12} \right) \right)
\]

\[
\mu = E[x] = \int_{-\infty}^{+\infty} x f(x) \, dx
\]
Example:

\[ f(x) = \begin{cases} 
  f(x) = k(x - 1)(4 - x) & 1 < x < 4 \\
  0 & \text{Otherwise} 
\end{cases} \]

(ii) Find the Expected Value and Standard Deviation of \( X \).

\[ \mu = E[x] = \int_{-\infty}^{+\infty} x f(x) \, dx \]

\[ E[x] = \int_1^4 \frac{2}{9} x (x - 1)(4 - x) \, dx \]

\[ = \frac{2}{9} \left( \int_1^4 x (x - 1)(4 - x) \, dx \right) \]

\[ = \frac{2}{9} \left[ \frac{-x^4}{4} + \frac{5x^3}{3} - \frac{4x^2}{2} \right]_1^4 \]

\[ = \frac{2}{9} \left( \frac{32}{3} - \left( -\frac{7}{12} \right) \right) \]

\[ = 2.5 \]
Example:

\[ f(x) = \begin{cases} 
  f(x) = k(x - 1)(4 - x) & 1 < x < 4 \\
  0 & Otherwise 
\end{cases} \]

(ii) Find the Expected Value and Standard Deviation of X.
Example:

\[ f(x) = \begin{cases} 
  f(x) = k(x - 1)(4 - x) & 1 < x < 4 \\
  0 & Otherwise 
\end{cases} \]

(ii) Find the Expected Value and Standard Deviation of X.

\[
\sigma = \sqrt{E(x^2) - E(x)^2}
\]
Example:

\[ f(x) = \begin{cases} 
  f(x) = k(x - 1)(4 - x) & \text{if } 1 < x < 4 \\
  0 & \text{otherwise} 
\end{cases} \]

(ii) Find the Expected Value and Standard Deviation of \( X \).

\[ E(x^2) = \int_1^4 \frac{2}{9} x^2 (x - 1)(4 - x) \, dx \]

\[ \sigma = \sqrt{E(x^2) - E(x)^2} \]
Example:

\[ f(x) = \begin{cases} f(x) = k(x - 1)(4 - x) & 1 < x < 4 \\ 0 & \text{Otherwise} \end{cases} \]

(ii) Find the Expected Value and Standard Deviation of X.

\[ E(x^2) = \int_{1}^{4} \frac{2}{9} x^2 (x - 1)(4 - x) \, dx \]

\[ = \frac{2}{9} \left[ -\frac{x^5}{5} + \frac{5x^4}{4} - \frac{4x^3}{x} \right]_{1}^{4} \]

\[ \sigma = \sqrt{E(x^2) - E(x)^2} \]
Example:

\[ f(x) = \begin{cases} 
  f(x) = k(x - 1)(4 - x) & 1 < x < 4 \\
  0 & \text{Otherwise}
\end{cases} \]

(ii) Find the Expected Value and Standard Deviation of \( X \).

\[
E(x^2) = \int_{1}^{4} \frac{2}{9} x^2 (x - 1)(4 - x) \, dx
\]

\[
= \frac{2}{9} \left[ -\frac{x^5}{5} + \frac{5x^4}{4} - \frac{4x^3}{x} \right]_1^4
\]

\[
= \frac{2}{9} \left( \frac{448}{15} - \left( -\frac{17}{60} \right) \right) = 6.7
\]

\[
\sigma = \sqrt{E(x^2) - E(x)^2}
\]
Example:

\[ f(x) = \begin{cases} f(x) = k(x-1)(4-x) & 1 < x < 4 \\ 0 & \text{otherwise} \end{cases} \]

(ii) Find the Expected Value and Standard Deviation of \( X \).

\[
E(x^2) = \int_1^4 \frac{2}{9} x^2 (x-1)(4-x) \, dx \\
= \frac{2}{9} \left[ -\frac{x^5}{5} + \frac{5x^4}{4} - \frac{4x^3}{x} \right]_1^4 \\
= \frac{2}{9} \left( \frac{448}{15} - \left( -\frac{17}{60} \right) \right) \\
= 6.7
\]

\[
E(x) = 2.5
\]

\[
\sigma = \sqrt{E(x^2) - E(x)^2}
\]
Example:

\[ f(x) = \begin{cases} 
  f(x) = k(x - 1)(4 - x) & 1 < x < 4 \\
  0 & \text{Otherwise} 
\end{cases} \]

(ii) Find the Expected Value and Standard Deviation of X.

\[ E(x^2) = \int_1^4 \frac{2}{9} x^2 (x - 1) (4 - x) \, dx \]

\[ = \frac{2}{9} \left[ -\frac{x^5}{5} + \frac{5x^4}{4} - \frac{4x^3}{x} \right]_1^4 \\
\]

\[ = \frac{2}{9} \left( \frac{448}{15} - \left( -\frac{17}{60} \right) \right) \\
\]

\[ = 6.7 \]

\[ E(x) = 2.5 \]

\[ \sigma = \sqrt{E(x^2) - E(x)^2} \]
Example:

\[
f(x) = \begin{cases} 
  f(x) = k(x - 1)(4 - x) & 1 < x < 4 \\
  0 & \text{Otherwise}
\end{cases}
\]

(ii) Find the Expected Value and Standard Deviation of \(X\).

\[
E(x^2) = \int_{1}^{4} \frac{2}{9} x^2 (x - 1) (4 - x) \, dx
\]

\[
= \frac{2}{9} \left[ -\frac{x^5}{5} + \frac{5x^4}{4} - \frac{4x^3}{x} \right]^4_1
\]

\[
= \frac{2}{9} \left( \frac{448}{15} - \left( -\frac{17}{60} \right) \right)
\]

\[
= 6.7
\]

\[
E(x) = 2.5
\]

\[
\sigma = \sqrt{6.7 - 2.5^2} = 0.671
\]
Example:

\[ f(x) = \begin{cases} 
  f(x) = k(x - 1)(4 - x) & 1 < x < 4 \\
  0 & \text{Otherwise}
\end{cases} \]

(iii) Find the Probability of X that exceeds 3.5
Example:

\[ f(x) = \begin{cases} 
  f(x) = k(x - 1)(4 - x) & 1 < x < 4 \\
  0 & \text{Otherwise}
\end{cases} \]

(iii) Find the Probability of X that exceeds 3.5

\[ P(x > 3.5) = \int_{3.5}^{4} \frac{2}{9} (x - 1)(4 - x) \, dx \]
Example:

\[ f(x) = \begin{cases} 
  k(x - 1)(4 - x) & \text{if } 1 < x < 4 \\
  0 & \text{Otherwise}
\end{cases} \]

(iii) Find the Probability of X that exceeds 3.5

\[
P(x > 3.5) = \int_{3.5}^{4} \frac{2}{9} (x - 1)(4 - x) \, dx
\]

\[
= \frac{2}{9} \left[ -\frac{x^3}{3} + \frac{5x^2}{2} - 4x \right]_{3.5}^{4}
\]

\[
= \frac{2}{9} \left( \frac{8}{3} - \frac{7}{3} \right)
\]

\[
= 0.0741
\]
Normal Distribution

Example: We roll Two Dice, and we sum up the shown numbers.

For instance: 5 + 1 = 6

P(1,5) = 1/36
Normal Distribution
Characteristics of a Normal Distribution
Characteristics of a Normal Distribution

1- It’s curve looks like a bell
Characteristics of a Normal Distribution

1- It’s curve looks like a bell

2- Symmetric
Characteristics of a Normal Distribution

1- It’s curve looks like a bell

2- Symmetric

3- Total Area is equal to ONE (=1)
Characteristics of a Normal Distribution

1- It’s curve looks like a bell

2- Symmetric

3- Total Area is equal to ONE (=1)
Characteristics of a Normal Distribution

1- It’s curve looks like a bell
2- Symmetric
3- Total Area is equal to ONE (=1)
Normal Distribution

Characteristics of a Normal Distribution

1- It’s curve looks like a bell

2- Symmetric

3- Total Area is equal to ONE (=1)
Characteristics of a Normal Distribution

1. It’s curve looks like a bell
2. Symmetric
3. Total Area is equal to ONE (\(=1\))

Example:

IQ Level

- Expected Value
  - 0.5
  - 0.5
Question: Suppose scores on an IQ test are normally distributed as shown.

What is the probability that a person who takes the test will score below 100?
Question: Suppose scores on an IQ test are normally distributed as shown.

What is the probability that a person who takes the test will score below 100?
**Normal Distribution**

**Question:** Suppose scores on an IQ test are normally distributed as shown.

What is the probability that a person who takes the test will score below 100?

The answer is 50%.
Question: Suppose scores on an IQ test are normally distributed as shown.

What is the probability that a person who takes the test will score above 115 and below 130?
Question: Suppose scores on an IQ test are normally distributed as shown.

What is the probability that a person who takes the test will score above 115 and below 130?
Normal Distribution

**Question:** Suppose scores on an IQ test are normally distributed as shown.

What is the probability that a person who takes the test will score **above 115 and below 130**?

It is easier to use STANDARD NORMAL DISTRIBUTION
Standard Normal Distribution has:

1- It’s curve looks like a bell

2- Symmetric

3- Total Area is equal to ONE (=1)
“Standard” Normal Distribution

Standard Normal Distribution has:

1. It’s curve looks like a bell
2. Symmetric
3. Total Area is equal to ONE (=1)
4. Mean \((\mu) = 0\)
"Standard" Normal Distribution has:

1- It’s curve looks like a bell

2- Symmetric

3- Total Area is equal to ONE (=1)

4- Mean (\(\mu\)) = 0

5- Standard Deviation (\(\sigma\)) is 1

\[
\mu = 0 \\
\sigma = 1
\]
“Standard” Normal Distribution

Standard Normal Distribution has:

1- It’s curve looks like a bell

2- Symmetric

3- Total Area is equal to ONE (=1)

4- Mean ($\mu$) = 0

5- Standard Deviation ($\sigma$) is 1
Standard Normal Distribution

Normal Distribution

Standard Normal Distribution

\[ Z = \frac{X - \mu}{\sigma} \]
“Standard” Normal Distribution

Converting Normal Distribution to Standard Normal Distribution

\[ \mu = 100 \]
\[ \sigma = 15 \]
“Standard” Normal Distribution

Converting Normal Distribution to Standard Normal Distribution

\[ Z = \frac{X - \mu}{\sigma} \]

\[ \mu = 100 \]
\[ \sigma = 15 \]
"Standard" Normal Distribution

Converting Normal Distribution to Standard Normal Distribution

\[ Z = \frac{X - \mu}{\sigma} \]

\[ \frac{100 - 100}{15} = 0 \]
“Standard” Normal Distribution

Converting Normal Distribution to Standard Normal Distribution

\[ Z = \frac{X - \mu}{\sigma} \]

\[ \frac{115 - 100}{15} = 1 \]
\[ \frac{100 - 100}{15} = 0 \]
“Standard” Normal Distribution

Converting Normal Distribution to Standard Normal Distribution

\[ Z = \frac{X - \mu}{\sigma} \]

\[
\begin{align*}
\frac{115 - 100}{15} &= 1 \\
\frac{100 - 100}{15} &= 0 \\
\frac{85 - 100}{15} &= -1
\end{align*}
\]

\[ \mu = 100 \quad \sigma = 15 \]
“Standard” Normal Distribution

Converting Normal Distribution to Standard Normal Distribution

\[ Z = \frac{X - \mu}{\sigma} \]

\[ \frac{115 - 100}{15} = 1 \]
\[ \frac{100 - 100}{15} = 0 \]
\[ \frac{85 - 100}{15} = -1 \]

Subtract each value from mean

Then divide by Standard Deviation

\[ \begin{align*}
-45 & \quad -30 & \quad -15 & \quad 0 & \quad 15 & \quad 30 & \quad 45 \\
-3 & \quad -2 & \quad -1 & \quad 0 & \quad 1 & \quad 2 & \quad 3
\end{align*} \]
Standard Normal Distribution
Standard Normal Distribution

\[ \mu = 0 \]

\[ \sigma = -3, -2, -1, 0, 1, 2, 3 \]
Standard Normal Distribution

- 68.26% of the area under the curve is within one standard deviation of the mean ($\mu = 0$).
- 34.13% of the area is to the left of $\mu - \sigma$ and 34.13% to the right of $\mu + \sigma$.

Key points:
- $\sigma = -3$ to $\sigma = 3$ cover the range of one standard deviation.
- $\mu = 0$ is the center of the distribution.

Legend:
- $\mu$: Mean
- $\sigma$: Standard Deviation
Standard Normal Distribution

- 68.26% of the distribution lies within one standard deviation ($\sigma = -1$ to $\sigma = 1$) of the mean ($\mu = 0$).
- 95.44% of the distribution lies within two standard deviations ($\sigma = -2$ to $\sigma = 2$) of the mean.
- 99.74% of the distribution lies within three standard deviations ($\sigma = -3$ to $\sigma = 3$) of the mean.
**Question:** Suppose scores on an IQ test are normally distributed as shown.

What is the probability that a person who takes the test will score **BETWEEN 115**?
Standard Normal Distribution

- $\mu = 0$
- $\sigma = 1$
- $\sigma = 2$
- $\sigma = 3$

- $2.14\%$ for $\sigma = -3$
- $13.59\%$ for $\sigma = -2$
- $34.13\%$ for $\sigma = -1$ and $\sigma = 1$
- $34.13\%$ for $\sigma = 2$
- $13.59\%$ for $\sigma = 3$
**Question:** Suppose scores on an IQ test are normally distributed as shown.

What is the probability that a person who takes the test will score **BELOW** 120?
Question: Suppose scores on an IQ test are normally distributed as shown.

What is the probability that a person who takes the test will score BELOW 120?
**Question:** Suppose scores on an IQ test are normally distributed as shown.

What is the probability that a person who takes the test will score **BELOW** 120?

\[
P(IQ \leq 120) = 2.14\% + 13.59\% + 34.13\% + 34.13\% = 83.99\% = 0.8399
\]
Question: Suppose scores on an IQ test are normally distributed as shown.

What is the probability that a person who takes the test will score BELOW 120?
**Question**: Suppose scores on an IQ test are normally distributed as shown.

What is the probability that a person who takes the test will score **BELOW 120**?

*Using Z SCORE TABLE*
Question: Suppose scores on an IQ test are normally distributed as shown.

What is the probability that a person who takes the test will score **BELOW** 120?

\[ z = \frac{X - \mu}{\sigma} \]

\[ z = \frac{120 - 100}{15} = 1.33 \]

Using Z SCORE TABLE
Z Score Table: Table entry for z is the area under the standard normal curve to the left of z.
**Z Score Table**

**Z Score Table:** Table entry for $z$ is the area under the standard normal curve to the left of $z$.

$$z = \frac{120 - 100}{15} = 1.33$$

The probability is the surface under the curve.

Look at the Z Score TABLE
<table>
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<th>Z</th>
<th>.00</th>
<th>.01</th>
<th>.02</th>
<th>.03</th>
<th>.04</th>
<th>.05</th>
<th>.06</th>
<th>.07</th>
<th>.08</th>
<th>.09</th>
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**Question:** Suppose scores on an IQ test are normally distributed as shown.

What is the probability that a person who takes the test will score **BELOW** 120?

\[
z = \frac{120 - 100}{15} = 1.33
\]

\[
P(IQ \leq 120) = 0.90824
\]
**Question:** Suppose scores on an IQ test are normally distributed as shown.

What is the probability that a person who takes the test will score above 120?

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What is the probability that a person who takes the test will score above 120?

\[ z = \frac{120 - 100}{15} = 1.33 \]

\[ P(IQ \leq 120) = 0.90824 \]

\[ P(IQ \geq 120) = 1 - 0.90824 = 0.09176 \]
**Question:** Suppose scores on an IQ test are normally distributed as shown.

What is the probability that a person who takes the test will score above 120 and below 128?
**Question:** Suppose scores on an IQ test are normally distributed as shown.

What is the probability that a person who takes the test will score above 120 and below 128?

\[
    z = \frac{120 - 100}{15} = 1.33 \quad z = \frac{128 - 100}{15} = 1.86
\]
**Question:** Suppose scores on an IQ test are normally distributed as shown.

What is the probability that a person who takes the test will score above 120 and below 128?

\[ z = \frac{120 - 100}{15} = 1.33 \]
\[ z = \frac{128 - 100}{15} = 1.86 \]

\[ \mu = 0 \quad 1.33 \quad 1.86 \quad \sigma = 3 \]
**Question:** Suppose scores on an IQ test are normally distributed as shown.

What is the probability that a person who takes the test will score above 120 and below 128?

\[ P(120 \leq IQ \leq 128) = P(1.86) - P(1.33) \]
Question: Suppose scores on an IQ test are normally distributed as shown.

What is the probability that a person who takes the test will score above 120 and below 128?

\[ P(120 \leq IQ \leq 128) = P(1.86) - P(1.33) \]
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Question: Suppose scores on an IQ test are normally distributed as shown.

What is the probability that a person who takes the test will score above 120 and below 128?

\[ P(120 \leq IQ \leq 128) = P(1.86) - P(1.33) \]
**Question:** Suppose scores on an IQ test are normally distributed as shown.

What is the probability that a person who takes the test will score above 120 and below 128?

\[
P(120 \leq IQ \leq 128) = P(1.86) - P(1.33)
\]

\[P(120 \leq IQ \leq 128) = 0.96856 - 0.9082\]

\[P(120 \leq IQ \leq 128) = 0.0603\]
**Question:** Suppose scores on an IQ test are normally distributed as shown.

What is the probability that a person who takes the test will score above 120 and below 128?

\[
P(120 \leq IQ \leq 128) = 0.0603
\]
Question: The lifetime of a battery is normally distributed with a mean life of 40 hours and a standard deviation of 1.2 hours.

Find the probability that a randomly selected battery lasts longer than 42 hours.
**Question:** Suppose scores on an IQ test are normally distributed as shown.

What is the probability that a person who takes the test will score above 115 and below 130?

\[
z = \frac{115 - 100}{15} = 1 \quad z = \frac{130 - 100}{15} = 2
\]

The answer is 13.59%.
Question: The lifetime of a battery is normally distributed with a mean life of 40 hours and a standard deviation of 1.2 hours.

Find the probability that a randomly selected battery lasts longer than 42 hours.
**Question:** The lifetime of a battery is normally distributed with a mean life of 40 hours and a standard deviation of 1.2 hours.

Find the probability that a randomly selected battery lasts longer than 42 hours.

1- Convert to Z value of 42

2- $P(BL < 42)$ from Z Score Table

3- $P(BL > 42) = 1 - P(BL < 42)$
**Question:** The lifetime of a battery is normally distributed with a mean life of 40 hours and a standard deviation of 1.2 hours.

Find the probability that a randomly selected battery lasts longer than 42 hours.

1- Convert to Z value of 42

\[ Z = \frac{42 - 40}{1.2} = 1.66 \]
**Question:** The lifetime of a battery is normally distributed with a mean life of 40 hours and a standard deviation of 1.2 hours.

Find the probability that a randomly selected battery lasts longer than 42 hours.

1- Convert to Z value of 42

\[ Z = \frac{42 - 40}{1.2} = 1.66 \]

2- P(BL < 42) from Z Score Table
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Question: The lifetime of a battery is normally distributed with a mean life of 40 hours and a standard deviation of 1.2 hours.

Find the probability that a randomly selected battery lasts longer than 42 hours.

1- Convert to Z value of 42

\[ Z = \frac{42 - 40}{1.2} = 1.66 \]

2- \( P(BL < 42) \) from Z Score Table

\[ P(BL \leq 42) = 0.9515 \]
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3- \( P(BL > 42) = 1 - P(BL < 42) \)

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2. \( P(\text{BL} < 42) \) from Z Score Table

3. \( P(\text{BL} > 42) = 1 - P(\text{BL} < 42) \)

\[ P(\text{BL} \geq 42) = 1 - 0.9515 = 0.0485 \]
Question: The time taken to assemble a car in a certain plant is a random variable having a normal distribution of 20 hours and a standard deviation of 2 hours.

What is the probability that a car can be assembled at this plant in a period of time

a) less than 19.5 hours?

b) between 20 and 22 hours?
Normal Distribution for a group

**Question:** We have a pack of 10 batteries. The lifetime of each battery is normally distributed with a mean life of 40 hours and a standard deviation of 1.2 hours.

Find the probability that this pack of batteries lasts longer than 405 hours.
Question: We have a pack of 10 batteries. The lifetime of each battery is normally distributed with a mean life of 40 hours and a standard deviation of 1.2 hours.

Find the probability that this pack of batteries lasts longer than 405 hours.

\[
\mu = N \times \mu
\]

Mean value multiplied by number of batteries

\[
\sigma = \sqrt{N} \times \sigma
\]

Standard deviation multiplied \(\sqrt{N}\)
**Question:** We have a pack of 10 batteries. The lifetime of each battery is normally distributed with a mean life of 40 hours and a standard deviation of 1.2 hours.

Find the probability that this pack of batteries lasts longer than 405 hours.

\[
\mu = N \times \mu \\
\mu = 10 \times 40 = 400
\]

Mean value multiplied by number of batteries

\[
\sigma = \sqrt{N} \times \sigma \\
\sigma = \sqrt{101.2} = 3.79
\]

Standard deviation multiplied \( \sqrt{N} \)
Question: We have a pack of 10 batteries. The lifetime of each battery is normally distributed with a mean life of 40 hours and a standard deviation of 1.2 hours.

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\[ \mu = N \times \mu \]
\[ \mu = 10 \times 40 = 400 \]

\[ \sigma = \sqrt{N} \times \sigma \]
\[ \sigma = \sqrt{101.2} = 3.79 \]

\[ z = \frac{405 - 400}{3.79} = 1.32 \]
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Question: We have a pack of 10 batteries. The lifetime of each battery is normally distributed with a mean life of 40 hours and a standard deviation of 1.2 hours.

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\[
\begin{align*}
\mu &= N \times \mu \\
\mu &= 10 \times 40 = 400 \\
\sigma &= \sqrt{N} \times \sigma \\
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\end{align*}
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z = \frac{405 - 400}{3.79} = 1.32
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P(BL \leq 405) = 0.9066
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z = \frac{405 - 400}{3.79} = 1.32
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\[
P(BL \geq 405) = 1 - P(BL \leq 405)
\]

\[
P(BL \leq 405) = 0.9066
\]
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\[ z = \frac{405 - 400}{3.79} = 1.32 \]

\[ P(\text{BL} \geq 405) = 1 - P(\text{BL} \leq 405) \]

\[ P(\text{BL} \geq 405) = 1 - 0.9066 \]
\[ P(\text{BL} \geq 405) = 0.0934 \]

Battery Life = BL