**Problem 1.** According to the Anxiety and Depression Association of America, Anxiety Disorders and Depression are very common in the US population. The most common mental illness in the US are anxiety disorders, which affect 18.1% of the population. Of those who have an anxiety disorder, 36.9% receive treatment. One anxiety disorder, Generalized Anxiety Disorder affects 3.1% of the US population, with women twice as likely to be affected than men. Major Depressive Disorder affects approximately 6.7% of the US population. About 50% of individuals with Major Depressive Disorder are also diagnosed with an anxiety disorder.

a. Are anxiety disorders and Major Depressive Disorders mutually exclusive? Are they independent?

b. Is Generalized Anxiety Disorder independent of gender?

c. We know that 36.9% of those who have an anxiety disorder are receiving treatment. How would we write this using mathematical notation?

d. We know that 50% of individuals with Major Depressive Disorder are also diagnosed with an anxiety disorder. How would we write this using mathematical notation. What is the probability that someone has both Major Depressive Disorder and an anxiety disorder?

---

**a. not mutually exclusive - people fall in both groups at the same time**

- \[ P(A) = P(A|B) - \text{NO, not independent} \]
- \[ P(\text{anxiety disorder}) = 0.181 \]
- \[ P(\text{anxiety disorder} | \text{MDD}) = 0.50 \]

**b. NO, NOT independent, women are more likely to be affected -> relationship between gender and GAD**

**c. P(rec. treatment | anxiety disorder) = 0.369**

**d. P(anxiety disorder | MDD) = 0.50**

- \[ P(\text{anxiety} \cap \text{MDD}) = P(\text{anxiety} | \text{MDD}) P(\text{MDD}) = (0.50)(0.067) = 0.0335 \]

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Five Guys Burgers</td>
<td>5</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>In-N-Out Burger</td>
<td>162</td>
<td>181</td>
<td>343</td>
</tr>
<tr>
<td>Fat Burger</td>
<td>10</td>
<td>12</td>
<td>22</td>
</tr>
<tr>
<td>Tommy’s Hamburgers</td>
<td>27</td>
<td>27</td>
<td>54</td>
</tr>
<tr>
<td>Umami Burger</td>
<td>5</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Other</td>
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<td>20</td>
<td>46</td>
</tr>
<tr>
<td>Not Sure</td>
<td>13</td>
<td>5</td>
<td>18</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>248</td>
<td>252</td>
<td>500</td>
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</table>

a. Are being female and liking In-N-Out Burger best mutually exclusive?
b. What is the probability that a randomly selected males likes In-N-Out the best?
c. What is the probability that a randomly selected female likes In-N-Out the best?
d. What is the probability that a man and a woman who are dating both like In-N-Out the best?
   Note any assumptions you make and evaluated whether you think they are reasonable.
e. What is the probability that a randomly selected person like In-N-Out best or that person is female?

\[ a. \text{No, 181 females who picked In-N-Out} \]
\[ b. P(\text{INO} | \text{male}) = \frac{P(\text{INO} \cap \text{male})}{P(\text{male})} \]
\[ = \frac{162}{248} = 0.65 \]
\[ c. P(\text{INO} | \text{female}) = \frac{P(\text{INO} \cap \text{female})}{P(\text{female})} \]
\[ = \frac{181}{252} = 0.72 \]

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   Note any assumptions you make and evaluated whether you think they are reasonable.
e. What is the probability that a randomly selected person like In-N-Out best or that person is female?

\[
\text{d. } P(\text{male INO } \cap \text{ female INO}) = P(\text{male INO}) \times P(\text{female INO}) = (0.65)(0.72) = 0.468 \\
\]

Assume two people were independent

Most likely - valid assumption

\[
\text{e. } P(\text{INO OR F}) = P(\text{INO}) + P(\text{F}) - P(\text{INO AND F}) = \frac{343 + 252 - 181}{500} = \frac{414}{500} = 0.828 \\
\]
Problem 3. A genetic test is used to determine if people have a predisposition for thrombosis, which is the formation of a blood clot inside a blood vessel that obstructs the flow of blood through the circulatory system. It is believed that 3% of people actually have this predisposition. The genetic test is 99% accurate if a person actually has the predisposition, meaning that the probability of a positive test result when a person actually has the predisposition is 0.99. The test is 98% accurate if a person does not have the predisposition. What is the probability that a randomly selected person who tests positive for the predisposition actually has the predisposition?

\[
P(D^+ | T^+) = \frac{P(D^+ \cap T^+)}{P(T^+)} = \frac{0.0297}{0.0297 + 0.0194} = \frac{0.0297}{0.0491} = 0.6049
\]
Problem 4. An airline charges the following baggage fees: $25 for the first bag and $35 for the second bag. They do not allow individuals to bring more than two bags. Suppose 54% of passengers have no checked luggage, 34% have one piece of checked luggage, and 12% have two pieces.

a. Draw the probability model for the amount of money spent by passengers on luggage.

<table>
<thead>
<tr>
<th>Event</th>
<th>$x$</th>
<th>$P(X=x)$</th>
<th>$xP(X=x)$</th>
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</thead>
<tbody>
<tr>
<td>No Bags</td>
<td>$0$</td>
<td>0.54</td>
<td>0</td>
</tr>
<tr>
<td>1 Bag</td>
<td>$25$</td>
<td>0.34</td>
<td>8.50</td>
</tr>
<tr>
<td>2 Bags</td>
<td>$60$</td>
<td>0.12</td>
<td>7.20</td>
</tr>
</tbody>
</table>

b. What is the expected value?

\[ E(X) = 0 + 8.50 + 7.20 = \$15.70 \]

Problem 5. Suppose weights of the checked baggage of airline passengers follow a nearly normal distribution with a mean of 45 pounds and a standard deviation of 3.2 pounds. Most airlines charge a fee for baggage that weights in excess of 50 pounds. What percent of airline passengers incur this fee?

\[ X \sim \mathcal{N}(\mu = 45, \sigma = 3.2) \]

1. Picture

2. \[ z\text{-score} = \frac{\text{obs} - \text{mean}}{\text{std dev}} = \frac{50 - 45}{3.2} = \frac{5}{3.2} = 1.56 \]

3. \[ CP = P(X < 50) = P(z < 1.56) = 0.9406 \]

4. \[ P(X > 50) = P(z > 1.56) = 1 - P(z < 1.56) = 1 - 0.9406 = 0.0594 \]
Problem 6. Heights of 10 year olds, regardless of gender, closely follow a normal distribution with a mean of 55 inches and a standard deviation of 6 inches. Calculate the following using the Empirical Rule:

a. Draw the appropriate Empirical Rule diagram for this scenario.
b. What is the probability that a randomly selected 10 year old is 55 inches or taller?
c. What is the probability that a randomly selected 10 year old is 49 inches or taller?
d. What is the probability that a randomly selected 10 year old is 43 inches or shorter?
e. What is the probability that a randomly selected 10 year old is between 43 and 61 inches tall?
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d. What is the probability that a randomly selected 10 year old is 43 inches or shorter?
e. What is the probability that a randomly selected 10 year old is between 43 and 61 inches tall?

\[ P(X > 55) = 0.34 + 0.13\sigma + 0.023\sigma + 0.001\sigma \]
\[ = 0.50 \]

\[ P(X > 49) = 0.34 + 0.34 + 0.13\sigma + 0.023\sigma + 0.001\sigma \]
\[ = 0.84 \]

\[ P(X < 43) = 0.001\sigma + 0.023\sigma \]
\[ = 0.025 \]

\[ P(43 < X < 61) = 0.13\sigma + 0.34 + 0.34 \]
\[ = 0.815 \]
Problem 7. Let’s continue looking at the scenario presented in question 6. Heights of 10 year olds, regardless of gender, closely follow a normal distribution with a mean of 55 inches and a standard deviation of 6 inches. Calculate the following using the z-score method:

a. What is the probability that a randomly selected 10 year old is shorter than 48 inches?

b. What is the probability that a randomly selected 10 year old is taller than 58 inches?

c. What is the probability that a randomly selected 10 year old is between 60 and 65 inches tall?

d. If the tallest 10% of the class is considered "very tall," what is the height cutoff for being very tall?

e. The height requirement for Batman the Ride at Six Flags Magic Mountain is 54 inches. What percent of 10 year olds cannot go on this ride?

f. Suppose there are four 10 year olds. What is the chance that at least two of them will be able to ride Batman the Ride?

\[ Z = \frac{\text{obs} - \text{mean}}{\text{stddev}} \]

\[ Z = \frac{48 - 55}{6} = -1.17 \]

\[ P(X < 48) = P(Z < -1.17) = 0.1210 \]
Problem 7. Let’s continue looking at the scenario presented in question 6. Heights of 10 year olds, regardless of gender, closely follow a normal distribution with a mean of 55 inches and a standard deviation of 6 inches. Calculate the following using the z-score method:

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\[ b. \ P(x > 58) \]

\[ z = \frac{\text{obs} - \text{mean}}{\text{std dev}} \]

\[ = \frac{58 - 55}{6} \]

\[ = \frac{3}{6} = 0.50 \]

**CP:** \( P(x < 58) = P(z < 0.50) = 0.6915 \)

**WTK:** \( P(x > 58) = P(z > 0.50) = 1 - P(z < 0.50) \)

\[ = 1 - 0.6915 = 0.3085 \]
Problem 7. Let’s continue looking at the scenario presented in question 6. Heights of 10 year olds, regardless of gender, closely follow a normal distribution with a mean of 55 inches and a standard deviation of 6 inches. Calculate the following using the z-score method:

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f. Suppose there are four 10 year olds. What is the chance that at least two of them will be able to ride *Batman the Ride*?

\[ Z_A = \frac{60 - 55}{6} = \frac{5}{6} = 0.83 \]

CP: \( P(X < 60) = P(Z < 0.83) = 0.7967 \)

\[ Z_B = \frac{65 - 55}{6} = \frac{10}{6} = 1.67 \]

CP: \( P(X < 65) = P(Z < 1.67) = 0.9525 \)

WTK: \[ P(60 < X < 65) = P(0.83 < Z < 1.67) \\
= P(Z < 1.67) - P(Z < 0.83) \\
= 0.9525 - 0.7967 \\
= 0.1558 \]
Problem 7. Let’s continue looking at the scenario presented in question 6. Heights of 10 year olds, regardless of gender, closely follow a normal distribution with a mean of 55 inches and a standard deviation of 6 inches. Calculate the following using the z-score method:

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f. Suppose there are four 10 year olds. What is the chance that at least two of them will be able to ride *Batman the Ride*?

\[
p(X < 54)
\]

\[
z = \frac{\text{obs} - \text{mean}}{\text{std dev}} = \frac{54 - 55}{6} = -\frac{1}{6} = -0.17
\]

\[
\text{CP: } p(X < 54) = p(z < -0.17) = 0.4325
\]

43.25% of 10 year olds are too short.
Problem 7. Let’s continue looking at the scenario presented in question 6. Heights of 10 year olds, regardless of gender, closely follow a normal distribution with a mean of 55 inches and a standard deviation of 6 inches. Calculate the following using the z-score method:

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f. Suppose there are four 10 year olds. What is the chance that at least two of them will be able to ride *Batman the Ride*?

\[
p(\text{can\ 't\ ride}) = 0.4325 \\
p(\text{can\ ride}) = 1 - 0.4325 = 0.5675
\]

\[
P(\text{at\ least\ 2\ can\ ride}) = P(X \geq 2) \\
P(X \geq 2) = P(X = 2) + P(X = 3) + P(X = 4)
\]

\[
P(X = k) = \binom{n}{k} p^k (1-p)^{n-k}
\]

\[
P(X = 2) = \binom{4}{2} (0.5675)^2 (0.4325)^2
\]

\[
= 0.3615
\]
Problem 7. Let’s continue looking at the scenario presented in question 6. Heights of 10 year olds, regardless of gender, closely follow a normal distribution with a mean of 55 inches and a standard deviation of 6 inches. Calculate the following using the z-score method:

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\[
\begin{align*}
\text{f. cont.} \\
P(X = 3) &= \binom{4}{3} (0.5675)^3 (0.4325)^1 \\
&= 0.3162 \\
P(X = 4) &= \binom{4}{4} (0.5675)^4 (0.4325)^0 \\
&= 0.1037 \\
P(X = 2) &= 0.3615 + 0.3162 + 0.1037 \\
&= 0.7814
\end{align*}
\]
Problem 8. The National Vaccine Information Center estimates that 90% of Americans have had chickenpox by the time they reach adulthood.

a. Suppose we take a random sample of 100 American adults. Is the use of the binomial distribution appropriate for calculating the probability that exactly 97 out of 100 randomly sampled American adults had chickenpox during childhood? Explain.

b. Calculate the probability that exactly 97 out of 100 randomly sampled American adults had chickenpox during childhood.

c. What is the probability that exactly 3 out of a new sample of 100 American adults have not had chickenpox in their childhood?

d. What is the probability that at least 1 out of 10 randomly sampled American adults have had chickenpox?

e. What is the probability that at most 3 out of 10 randomly sampled American adults have not had chickenpox?

\[
P(X=k) = \binom{n}{k} p^k (1-p)^{n-k}
\]

\[
X = \# \text{ who had chickenpox}
\]

\[
P(X=97) = \binom{100}{97} (0.90)^{97} (1-0.90)^{100-97}
\]

\[
= \binom{100}{97} (0.90)^{97} (0.10)^3
\]

\[
= (161,700) (0.0000364) (0.001)
\]

\[
= 0.00589
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Problem 8. The National Vaccine Information Center estimates that 90% of Americans have had chickenpox by the time they reach adulthood.

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d. What is the probability that at least 1 out of 10 randomly sampled American adults have had chickenpox?

e. What is the probability that at most 3 out of 10 randomly sampled American adults have not had chickenpox?

\[ P(X = 3) \]

Define \( X = \# \text{ who didn't have chickenpox} \)

\[ P(3 \text{ didn't have chickenpox}) = P(97 \text{ had chickenpox}) = 0.00589 \]

\[ d. P(X \geq 1) = P(X = 1) + P(X = 2) + \ldots + P(X = 10) \]

\[ X = \text{had chickenpox} \]

\[ P(X \geq 1) = 1 - P(X = 0) \]

\[ P(X = 0) = \binom{10}{0}(0.90)^0(0.10)^0 \approx \emptyset \]

\[ \approx 0 \]

\[ P(X \geq 1) = 1 - P(X = 0) \approx 1 \]
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b. Calculate the probability that exactly 97 out of 100 randomly sampled American adults had chickenpox during childhood.

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d. What is the probability that at least 1 out of 10 randomly sampled American adults have had chickenpox?

e. What is the probability that at most 3 out of 10 randomly sampled American adults have not had chickenpox?

\[
P(X \leq 3) = P(X=0) + P(X=1) + P(X=2) + P(X=3)
\]

\[
P(X=0) = \binom{10}{0} (0.10)^0 (0.90)^{10} = 0.3487
\]

\[
P(X=1) = \binom{10}{1} (0.10)^1 (0.90)^9 = 0.3874
\]

\[
P(X=2) = \binom{10}{2} (0.10)^2 (0.90)^8 = 0.1937
\]

\[
P(X=3) = \binom{10}{3} (0.10)^3 (0.90)^7 = 0.0574
\]

\[
P(X \leq 3) = 0.3487 + 0.3874 + 0.1937 + 0.0574 = 0.9872
\]

a. How many people in this sample would you expect to have had chickenpox in their childhood? What would you expect the standard deviation to be?

b. Would you be surprised if there were 105 people in the sample who have had chickenpox in their childhood?

c. What is the probability that 105 or fewer people in this sample have had chickenpox in their childhood? How does this probability relate to your answer to part b?

\[ n = 120 \quad p = 0.90 \]

a. \[ \mu = np = (120)(0.90) = 108 \]
\[ \sigma = \sqrt{np(1-p)} = \sqrt{(120)(0.90)(0.10)} = 3.29 \]

b. \[ Z = \frac{\text{obs} - \text{mean}}{\text{stdev}} = \frac{105 - 108}{3.29} = -3 \]

\( \hat{\text{Unusual obs: more than 2 standard deviations away from mean}} \)
\( \hat{\text{105 is not more than 2 standard deviations away from the mean, not really surprising}} \)

a. How many people in this sample would you expect to have had chickenpox in their childhood? What would you expect the standard deviation to be?

b. Would you be surprised if there were 105 people in the sample who have had chickenpox in their childhood?

c. What is the probability that 105 or fewer people in this sample have had chickenpox in their childhood? How does this probability relate to your answer to part b?

\[
P(X \leq 105) = P(X=0) + P(X=1) + P(X=2) + \cdots + P(X=105)
\]

Binomial Distn \( \sim N \)

when: \( np \geq 10 \) AND \( n(1-p) \geq 10 \)

\[
np = (120)(0.90) = 108 \geq 10 \checkmark
\]

\[
n(1-p) = (120)(0.10) = 12 \geq 10 \checkmark
\]

\[
X \sim N(\mu=108, \sigma=3.29)
\]

a. How many people in this sample would you expect to have had chickenpox in their childhood? What would you expect the standard deviation to be?

b. Would you be surprised if there were 105 people in the sample who have had chickenpox in their childhood?

c. What is the probability that 105 or fewer people in this sample have had chickenpox in their childhood? How does this probability relate to your answer to part b?

\[
z = \frac{105 - 108}{3.29} = \frac{-3}{3.29} = -0.91
\]

\[P(X < 105) = P(z < -0.91) = 0.1814\]

\[\text{prob} = 0.1814 \text{ is not super small}\]
Problem 10. Sickle cell anemia is a genetic blood disorder where red blood cells lose their flexibility and assume an abnormal, rigid, "sickle" shape, which results in a risk of various complications. If both parents are carriers of the disease, then a child has a 25% chance of having the disease, a 50% chance of being a carrier, and a 25% chance of neither having the disease nor being a carrier. Consider two parents who are carriers of the disease having three children.

a. What is the expected number of children who will have the disease?
b. What is the expected number of children who will be carriers for the disease?
c. What is the probability that exactly two will have the disease?
d. What is the probability that none will have the disease?
e. What is the probability that none will be a carrier?
f. What is the probability that at least one will neither have the disease nor be a carrier?

\[ a. \ n=3, \ p=0.25, \ \mu=np=(3)(0.25) = 0.75 \]

\[ b. \ n=3, \ p=0.50, \ \mu=np=(3)(0.50) = 1.50 \]

\[ c. \ n=3, \ p=0.25, \ \Pr(X=2) \]

\[ \Pr(X=2) = \binom{3}{2}(0.25)^2(0.75)^1 = 0.1406 \]
Problem 10. Sickle cell anemia is a genetic blood disorder where red blood cells lose their flexibility and assume an abnormal, rigid, "sickle" shape, which results in a risk of various complications. If both parents are carriers of the disease, then a child has a 25% chance of having the disease, a 50% chance of being a carrier, and a 25% chance of neither having the disease nor being a carrier. Consider two parents who are carriers of the disease having three children.

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c. What is the probability that exactly two will have the disease?
d. What is the probability that none will have the disease?
e. What is the probability that none will be a carrier?
f. What is the probability that at least one will neither have the disease nor be a carrier?

\[ d. \; n = 3, \; p = 0.25, \; P(X = \emptyset) = \binom{3}{0} (0.25)^0 (0.75)^3 = 0.4219 \]

\[ e. \; n = 3, \; p = 0.50, \; P(X = \emptyset) = \binom{3}{0} (0.50)^0 (0.50)^3 = 0.125 \]
Problem 10. Sickle cell anemia is a genetic blood disorder where red blood cells lose their flexibility and assume an abnormal, rigid, "sickle" shape, which results in a risk of various complications. If both parents are carriers of the disease, then a child has a 25% chance of having the disease, a 50% chance of being a carrier, and a 25% chance of neither having the disease nor being a carrier. Consider two parents who are carriers of the disease having three children.

a. What is the expected number of children who will have the disease?

b. What is the expected number of children who will be carriers for the disease?

c. What is the probability that exactly two will have the disease?

d. What is the probability that none will have the disease?

e. What is the probability that none will be a carrier?

f. What is the probability that at least one will neither have the disease nor be a carrier?

f. $n = 3 \quad p = 0.25 \quad P(X = 1)$

$P(X = 1) = 1 - P(X = \emptyset)$

$P(X = \emptyset) = \binom{3}{0}(0.25)^0(0.75)^3$

$= 0.4219$

$P(X = 1) = 1 - 0.4219$

$= 0.5781$