



Probability

Question1

Suppose that Box I contains 6 red balls and 9 green balls, and Box II contains 8 red balls and 12 green balls. All the balls of Box I and Box II are mixed together and a ball is chosen at random from them. Let E_1 be the event that the ball chosen belonged to Box I and let E_2 be the event that the ball chosen belonged to Box II. Let F_1 be the event that the ball chosen is red and let F_2 be the event that the ball chosen is green.

Then which of the following statements is (are) TRUE?

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Options:

A.

The events E_1 and F_1 are independent

B.

The events E_2 and F_2 are dependent

C.

The conditional probability $P(F_1|E_1)$ is equal to the conditional probability $P(F_1|E_2)$

D.

The conditional probability $P(F_1|E_1)$ is greater than the conditional probability $P(F_2|E_2)$

Answer: A

Solution:

6R
9G

Box-I
(15)

8R
12G

Box-II
(20)

14R
21G

Box (I + II)
(35)

The first step is to define the given events clearly:

$E_1 \rightarrow$ Ball from Box I $F_1 \rightarrow$ Red Ball

$E_2 \rightarrow$ Ball from Box II $F_2 \rightarrow$ Green Ball

Find total and individual probabilities.

Total number of balls in both boxes = $15 + 20 = 35$.

So, we have:

$$P(E_1) = \frac{15}{35}, \quad P(E_2) = \frac{20}{35}$$

$$P(F_1) = \frac{14}{35}, \quad P(F_2) = \frac{21}{35}$$

$$P(E_1 \cap F_1) = \frac{6}{35}, \quad P(E_1 \cap F_2) = \frac{9}{35}$$

$$P(E_2 \cap F_1) = \frac{8}{35}, \quad P(E_2 \cap F_2) = \frac{12}{35}$$

Check the given options.

Option (A):

$$P(E_1) \cdot P(F_1) = \frac{15}{35} \times \frac{14}{35} = \frac{6}{35} = P(E_1 \cap F_1)$$

This statement is true.

Option (B):

$$P(E_2) \cdot P(F_2) = \frac{20}{35} \times \frac{21}{35} = \frac{12}{35} = P(E_2 \cap F_2)$$

This statement also appears correct numerically, but let's recheck later with the next steps.

Option (C):

Find the conditional probabilities:

$$P(F_1|E_1) = \frac{\frac{6}{35}}{\frac{15}{35}} = \frac{6}{15} = \frac{2}{5},$$

$$P(F_1|E_2) = \frac{\frac{8}{35}}{\frac{20}{35}} = \frac{4}{20} = \frac{2}{5}$$

Since both are equal, $P(F_1|E_1) = P(F_1|E_2)$, this statement is true.

Option (D):

$$P(F_2|E_2) = \frac{\frac{12}{35}}{\frac{20}{35}} = \frac{3}{5} > P(F_1|E_1)$$

This means more green balls are likely from Box II than red balls from Box I.

Conclusion

The correct statements are **Options (A) and (C)**.

Question2

A bookshelf contains 6 distinct books of Mathematics and 5 distinct books of Physics. From these 11 books, 6 books are chosen at random. Let X be the absolute value of the difference between the number of Mathematics books chosen and the number of Physics books chosen. If α is the mean of the random variable X , then the value of 77α is _____.

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Answer: 100

Solution:

Let the number of Mathematics books chosen be a and the number of Physics books chosen be b .

Since a total of 6 books are selected, we have:

$$a + b = 6$$

The random variable is defined as the absolute difference between these two numbers:

$$X = |a - b|$$

Case 1: $X = 6$ This happens if all 6 books are Mathematics books and none are Physics books, or vice versa. But since only 6 Maths and 5 Physics books exist, only $a = 6, b = 0$ is possible.

$$P(X = 6) = \frac{{}^6C_6 \times {}^5C_0}{{}^{11}C_6} = \frac{1}{{}^{11}C_6}$$

Case 2: $X = 4$ This happens if $(a, b) = (5, 1)$ or $(a, b) = (1, 5)$.

$$P(X = 4) = \frac{{}^6C_5 \times {}^5C_1 + {}^6C_1 \times {}^5C_5}{{}^{11}C_6} = \frac{36}{{}^{11}C_6}$$

Case 3: $X = 2$ This happens if $(a, b) = (4, 2)$ or $(a, b) = (2, 4)$.

$$P(X = 2) = \frac{{}^6C_4 \times {}^5C_2 + {}^6C_2 \times {}^5C_4}{{}^{11}C_6} = \frac{225}{{}^{11}C_6}$$

Case 4: $X = 0$ This happens if $(a, b) = (3, 3)$.

$$P(X = 0) = \frac{{}^6C_3 \times {}^5C_3}{{}^{11}C_6} = \frac{200}{{}^{11}C_6}$$

Mean of the random variable X :

$$\alpha = \sum X \cdot P(X)$$

Substituting the values:

$$\alpha = \frac{6(1) + 4(36) + 2(225) + 0(200)}{{}^{11}C_6}$$

$$\alpha = \frac{100}{77}$$

Hence,

$$77\alpha = 100$$

Question 3

A factory has a total of three manufacturing units, M_1, M_2 , and M_3 , which produce bulbs independent of each other. The units M_1, M_2 , and M_3 produce bulbs in the proportions of $2 : 2 : 1$, respectively. It is known that 20% of the bulbs produced in the factory are defective. It is also known that, of all the bulbs produced by M_1 , 15% are defective. Suppose that, if a randomly chosen bulb produced in the factory is found to be defective, the probability that it was produced by M_2 is $\frac{2}{5}$.

If a bulb is chosen randomly from the bulbs produced by M_3 , then the probability that it is defective is _____.

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Answer: 0.30

Solution:

H_1 : The bulb is produced by unit M_1 .

H_2 : The bulb is produced by unit M_2 .

H_3 : The bulb is produced by unit M_3 .

E : The bulb is defective.

The unit production proportions and known probabilities are:

$$P(H_1) = \frac{2}{5}, P(H_2) = \frac{2}{5}, P(H_3) = \frac{1}{5}$$

$$P(E|H_1) = \frac{15}{100} = \frac{3}{20}$$

The total probability of a defective bulb is given by:

$$P(E) = P(E|H_1) \cdot P(H_1) + P(E|H_2) \cdot P(H_2) + P(E|H_3) \cdot P(H_3)$$

Given:

$$P(E) = 0.20 = \frac{3}{20} \cdot \frac{2}{5} + P(E|H_2) \cdot \frac{2}{5} + P(E|H_3) \cdot \frac{1}{5}$$

This simplifies to:

$$2P(E|H_2) + P(E|H_3) = \frac{7}{10} \quad \dots(i)$$

Additionally, the probability that a defective bulb is from M_2 is given as:

$$P(H_2|E) = \frac{2}{5} = \frac{P(E|H_2) \cdot \frac{2}{5}}{\frac{1}{5}}$$

Solving the equation above gives:

$$P(E|H_2) = \frac{1}{5} \quad \dots(ii)$$

Using the equations (i) and (ii), we substitute $P(E|H_2)$ into (i):

$$2 \cdot \frac{1}{5} + P(E|H_3) = \frac{7}{10}$$

Solving for $P(E|H_3)$:

$$\frac{2}{5} + P(E|H_3) = \frac{7}{10}$$

Converting $\frac{2}{5}$ to $\frac{4}{10}$ gives:

$$\frac{4}{10} + P(E|H_3) = \frac{7}{10}$$

$$P(E|H_3) = \frac{7}{10} - \frac{4}{10} = \frac{3}{10}$$

Therefore, the probability that a randomly chosen bulb from M_3 is defective is **0.30**.

Question 4

A bag contains N balls out of which 3 balls are white, 6 balls are green, and the remaining balls are blue. Assume that the balls are identical otherwise. Three balls are drawn randomly one after the other without replacement. For $i = 1, 2, 3$, let W_i , G_i , and B_i denote the events that the ball drawn in the i^{th} draw is a white ball, green ball, and blue ball, respectively. If the probability $P(W_1 \cap G_2 \cap B_3) = \frac{2}{5N}$ and the conditional probability $P(B_3 | W_1 \cap G_2) = \frac{2}{9}$, then N equals _____.

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Answer: 11

Solution:

3 White

6 Green

$(N - 9)$ Blue

$$\text{Given } P(W_1 \cap G_2 \cap B_3) = \frac{2}{5N}$$

$$\text{and } P(B_3 | W_1 \cap G_2) = \frac{2}{9}$$

$$\Rightarrow \frac{P(B_3 \cap W_1 \cap G_2)}{P(W_1 \cap G_2)} = \frac{2}{9}$$

$$\Rightarrow \frac{2}{5N} \times \frac{N \times (N - 1)}{3 \times 6} = \frac{2}{9}$$

$$\Rightarrow N = 11$$

Question 5

Let X be a random variable, and let $P(X = x)$ denote the probability that X takes the value x . Suppose that the points $(x, P(X = x))$, $x = 0, 1, 2, 3, 4$, lie on a fixed straight line in the xy -plane, and $P(X = x) = 0$ for all $x \in \mathbb{R} - \{0, 1, 2, 3, 4\}$. If the mean of X is $\frac{5}{2}$, and the variance of X is α , then the value of 24α is _____.

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Answer: 42

Solution:

Let equation of line is $y = mx + c$

x	0	1	2	3	4	$R - \{0, 1, 2, 3, 4\}$
P(x)	c	m + c	2m + c	3m + c	4m + c	0

$$\sum_{x=0}^4 (mx + c) = 1 \Rightarrow 10m + 5c = 1 \Rightarrow 2m + c = \frac{1}{5} \quad \dots (i)$$

$$\text{mean} = \sum x_i P_i = \sum_{i=0}^4 (mx_i + c) \cdot x_i = 30m + 10c = \frac{5}{2}$$

$$\therefore 3m + c = \frac{1}{4} \quad \dots (2)$$

$$\text{from (1) and (2) } m = \frac{1}{20}, c = \frac{1}{10}$$

$$\sum P_i x_i^2 = \sum_{i=0}^4 (mx_i + c)x_i^2$$

$$= \sum_{i=0}^4 (mx_i^3 + cx_i^2) \Rightarrow 100m + 30c \quad (\text{Now putting } m \text{ and } c)$$

$$\Rightarrow \sum P_i^2 = 5 + 3 = 8$$

$$\text{Variance} = \sum P_i x_i^2 - (\sum P_i x_i)^2 = 8 - \left(\frac{5}{2}\right)^2 = \frac{7}{4}$$

$$\therefore 24\alpha = 42$$

Question 6

Let X be the set of all five digit numbers formed using 1,2,2,2,4,4,0. For example, 22240 is in X while 02244 and 44422 are not in X . Suppose that each element of X has an equal chance of being chosen. Let p be the conditional probability that an element chosen at random is a multiple of 20 given that it is a multiple of 5. Then the value of $38p$ is equal to :

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Answer: 31

Solution:

Number of elements in X which are multiple of 5

$$\begin{array}{l}
 \underbrace{\quad\quad\quad}_1 \underbrace{\quad\quad\quad}_2 \underbrace{\quad\quad\quad}_2 \underbrace{0}_{\text{fixed}} \rightarrow \frac{\overline{4}}{\overline{3}} = 4 \\
 \underbrace{\quad\quad\quad}_1 \underbrace{\quad\quad\quad}_4 \underbrace{\quad\quad\quad}_2 \underbrace{0}_{\text{fixed}} \rightarrow \frac{\overline{4}}{\overline{2}} = 12 \\
 \underbrace{\quad\quad\quad}_4 \underbrace{\quad\quad\quad}_2 \underbrace{\quad\quad\quad}_2 \underbrace{0}_{\text{fixed}} \rightarrow \frac{\overline{4}}{\overline{3}} = 4 \\
 \underbrace{\quad\quad\quad}_2 \underbrace{\quad\quad\quad}_2 \underbrace{\quad\quad\quad}_4 \underbrace{0}_{\text{fixed}} \rightarrow \frac{\overline{4}}{\overline{2}\overline{2}} = 6 \\
 \underbrace{\quad\quad\quad}_1 \underbrace{\quad\quad\quad}_2 \underbrace{\quad\quad\quad}_4 \underbrace{0}_{\text{fixed}} \rightarrow \frac{\overline{4}}{\overline{2}} = 12
 \end{array}
 \left. \vphantom{\begin{array}{l} \frac{\overline{4}}{\overline{3}} = 4 \\ \frac{\overline{4}}{\overline{2}} = 12 \\ \frac{\overline{4}}{\overline{3}} = 4 \\ \frac{\overline{4}}{\overline{2}\overline{2}} = 6 \\ \frac{\overline{4}}{\overline{2}} = 12 \end{array}} \right\} \text{Total} = 38$$

Among these 38 elements, let us calculate when element is not divisible by 20

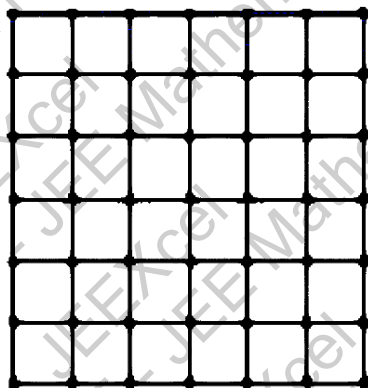
$$\begin{array}{l}
 \underbrace{\quad\quad\quad}_2 \underbrace{\quad\quad\quad}_2 \underbrace{\quad\quad\quad}_2 \underbrace{1\ 0}_{\text{fixed}} \rightarrow \frac{\overline{3}}{\overline{3}} = 1 \\
 \underbrace{\quad\quad\quad}_2 \underbrace{\quad\quad\quad}_2 \underbrace{\quad\quad\quad}_4 \underbrace{1\ 0}_{\text{fixed}} \rightarrow \frac{\overline{3}}{\overline{2}} = 3 \\
 \underbrace{\quad\quad\quad}_2 \underbrace{\quad\quad\quad}_4 \underbrace{\quad\quad\quad}_4 \underbrace{1\ 0}_{\text{fixed}} \rightarrow \frac{\overline{3}}{\overline{2}} = 3
 \end{array}
 \left. \vphantom{\begin{array}{l} \frac{\overline{3}}{\overline{3}} = 1 \\ \frac{\overline{3}}{\overline{2}} = 3 \\ \frac{\overline{3}}{\overline{2}} = 3 \end{array}} \right\} \text{Total} = 7$$

$$\therefore p = \frac{38-7}{38}$$

$$\therefore 38p = 31$$

Question 7

Consider the 6×6 square in the figure. Let $A_1, A_2, \dots, A_{49}$ be the points of intersections (dots in the picture) in some order. We say that A_i and A_j are friends if they are adjacent along a row or along a column. Assume that each point A_i has an equal chance of being chosen.

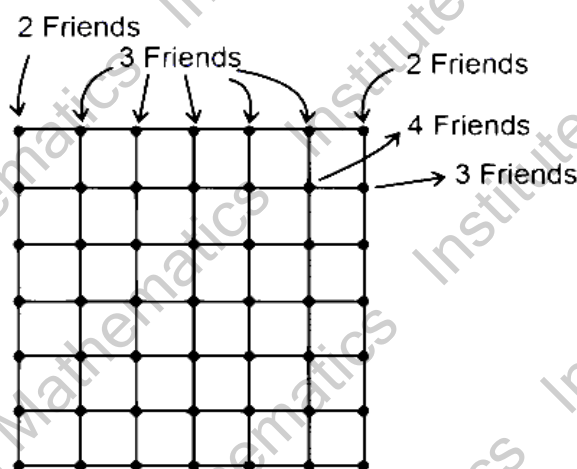


Let p_i be the probability that a randomly chosen point has i many friends, $i = 0, 1, 2, 3, 4$. Let X be a random variable such that for $i = 0, 1, 2, 3, 4$, the probability $P(X = i) = p_i$. Then the value of $7E(X)$ is :

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Answer: 24

Solution:



Number of points having 0 friend = 0

Number of points having 1 friend = 0

Number of points having 2 friends = 4

Number of points having 3 friends = $5 \times 4 = 20$

Number of points having 4 friends = $49 - 24 = 25$

P_i = Probability that randomly selected points has friends

$P_0 = 0$ (0 friends)

$P_1 = 0$ (exactly 1 friends)

$P_2 = \frac{{}^4C_1}{{}^{49}C_1} = \frac{4}{49}$ (exactly 2 friends)

$P_3 = \frac{{}^{20}C_1}{{}^{49}C_1} = \frac{20}{49}$ (exactly 3 friends)

$P_4 = \frac{{}^{25}C_1}{{}^{49}C_1} = \frac{25}{49}$ (exactly 4 friends)

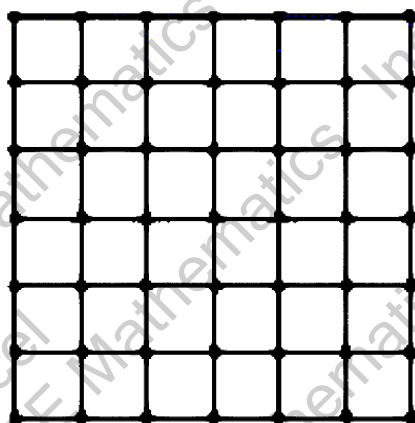
x	0	1	2	3	4
$P(x)$	0	0	$\frac{4}{49}$	$\frac{20}{49}$	$\frac{25}{49}$

$$\text{Mean} = E(x) = \sum x_i P_i = 0 + 0 + \frac{8}{49} + \frac{60}{49} + \frac{100}{49} = \frac{168}{49}$$

$$7(E(x)) = \frac{168}{49} \times 7 = 24$$

Question 8

Consider the 6×6 square in the figure. Let $A_1, A_2, \dots, A_{49}$ be the points of intersections (dots in the picture) in some order. We say that A_i and A_j are friends if they are adjacent along a row or along a column. Assume that each point A_i has an equal chance of being chosen.



Two distinct points are chosen randomly out of the points $A_1, A_2, \dots, A_{49}$. Let p be the probability that they are friends. Then the value of $7p$ is :

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Answer: 0.50

Solution:

Total number of ways of selecting 2 persons = ${}^{49}C_2$

Number of ways in which 2 friends are selected = $6 \times 7 \times 2 = 84$

$$7P = \frac{84 \times 2}{49 \times 48} \times 7 = \frac{1}{2}$$

Question9

In a study about a pandemic, data of 900 persons was collected. It was found that

190 persons had symptom of fever,

220 persons had symptom of cough,

220 persons had symptom of breathing problem,

330 persons had symptom of fever or cough or both,

350 persons had symptom of cough or breathing problem or both,

340 persons had symptom of fever or breathing problem or both,

30 persons had all three symptoms (fever, cough and breathing problem).

If a person is chosen randomly from these 900 persons, then the probability that the person has at most one symptom is _____.

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Answer: 0.80

Solution:

Let person had symptom of fever = $n(F) = 190$

Person had symptom of cough = $n(C) = 220$

Person had symptom of breathing = $n(B) = 220$

Person had symptom of fever or cough

$$= n(F \cup C) = 330$$

Person had symptom of cough or breathing

$$= n(C \cup B) = 350$$

Person had symptom of fever or breathing

$$= n(F \cup B) = 340$$

Person had symptom of fever, cough and breathing = $n(F \cap C \cup B) = 30$

$$\text{So } n(F \cap C) = n(F) + n(C) - n(F \cup C)$$

$$= 190 + 220 - 330$$

$$= 80$$

and

$$n(F \cap B) = n(F) + n(B) - n(F \cup B)$$

$$= 190 + 220 - 340$$

$$= 70$$

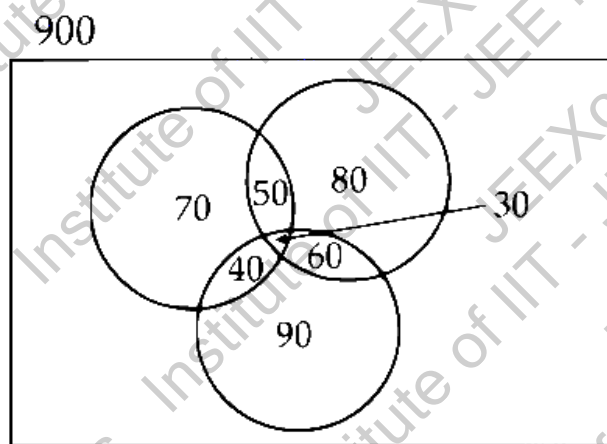
$$\text{and } n(C \cap B) = n(C) + n(B) - n(C \cup B)$$

$$= 220 + 220 - 350$$

$$= 90$$

Number of people having at most one symptom

$$= 70 + 80 + 90 + 480 = 720$$



$$\text{Required probability} = \frac{720}{900} = 0.80$$

Question 10

A number is chosen at random from the set $\{1, 2, 3, \dots, 2000\}$. Let p be the probability that the chosen number is a multiple of 3 or a multiple of 7. Then the value of $500p$ is _____.

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Answer: 214

Solution:

Given, set = $\{1, 2, 3, \dots, 2000\}$

Let E_1 = Event that it is a multiple of 3 = $\{3, 6, 9, \dots, 1998\}$

$$\therefore n(E_1) = 666$$

and E_2 = Event that it is a multiple of 7 = $\{7, 14, \dots, 1995\}$

$$\therefore n(E_2) = 285$$

$E_1 \cap E_2$ = multiple of 21 = $\{21, 42, \dots, 1995\}$

$$n(E_1 \cap E_2) = 95$$

$$\therefore P(E_1 \cup E_2) = P(E_1) + P(E_2) - P(E_1 \cap E_2)$$

$$P(E_1 \cup E_2) = \frac{666+285-95}{2000} = \frac{856}{2000} = p \text{ (given)}$$

$$\text{Hence, } 500p = 500 \times \frac{856}{2000} = \frac{856}{4} = 214$$

Question 11

Three numbers are chosen at random, one after another with replacement, from the set $S = \{1, 2, 3, \dots, 100\}$. Let p_1 be the probability that the maximum of chosen

numbers is at least 81 and p_2 be the probability that the minimum of chosen numbers is at most 40.

The value of $\frac{625}{4}p_1$ is _____.

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Answer: 76.25

Solution:

$$p_1 = 1 - p(\text{all 3 numbers are } \leq 80)$$

$$= 1 - \left(\frac{80}{100}\right)^3 = \frac{125-64}{125} = \frac{61}{125}$$

$$\text{So, } \frac{625p_1}{4} = \frac{625}{4} \times \frac{61}{125} = \frac{5}{4} \times 61 = 76.25$$

Question 12

Three numbers are chosen at random, one after another with replacement, from the set $S = \{1, 2, 3, \dots, 100\}$. Let p_1 be the probability that the maximum of chosen numbers is at least 81 and p_2 be the probability that the minimum of chosen numbers is at most 40.

The value of $\frac{125}{4}p_2$ is _____.

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Answer: 24.5

Solution:

$$p_2 = 1 - p(\text{all three numbers are } > 40)$$

$$= 1 - \left(\frac{60}{100}\right)^3 = 1 - \frac{27}{125} = \frac{98}{125}$$

$$\text{So, } \frac{125p_2}{4} = \frac{125}{4} \times \frac{98}{125} = \frac{98}{4} = 24.50$$

Question 13

The probability that a missile hits a target successfully is 0.75. In order to destroy the target completely, at least three successful hits are required. Then the minimum number of missiles that have to be fired so that the probability of completely destroying the target is NOT less than 0.95, is

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Answer: 6

Solution:

It is given that the probability, a missile hits a target successfully $p = \frac{3}{4}$, so the probability to not hit the target is $\frac{1}{4}$. And it is also given that to destroy the target completely, at least three successful hits are required.

Now, according to the question, let the minimum number of missiles required to be fired is n , so

$${}^nC_3 p^3 q^{n-3} + {}^nC_4 p^4 q^{n-4} + \dots + {}^nC_n p^n \geq 0.95$$

$$\Rightarrow 1 - \left\{ {}^nC_0 \left(\frac{1}{4}\right)^n + {}^nC_1 \left(\frac{3}{4}\right) \left(\frac{1}{4}\right)^{n-1} + {}^nC_2 \left(\frac{3}{4}\right)^2 \left(\frac{1}{4}\right)^{n-2} \right\} \geq 0.95$$

$$\Rightarrow 1 - \frac{95}{100} \geq \frac{1}{4^n} + \frac{3n}{4^n} + \frac{n(n-1)}{2} \frac{9}{4^n}$$

$$\Rightarrow \frac{4^n}{20} \geq \frac{2+6n+9n^2-9n}{2}$$

$$\Rightarrow 10(9n^2 - 3n + 2) \leq 4^n$$

Now, at $n = 3$, LHS = 720, RHS = 64

at $n = 4$, LHS = 1340, RHS = 256

at $n = 5$, $LHS = 2120$, $RHS = 1024$

at $n = 6$, $LHS = 3080$, $RHS = 4096$

Hence, $n = 6$ missiles should be fired.

Question 14

Two fair dice, each with faces numbered 1, 2, 3, 4, 5 and 6, are rolled together and the sum of the numbers on the faces is observed. This process is repeated till the sum is either a prime number or a perfect square. Suppose the sum turns out to be a perfect square before it turns out to be a prime number. If p is the probability that this perfect square is an odd number, then the value of $14p$ is

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Answer: 8

Solution:

Let an event E of sum of outputs are perfect square (i.e., 4 or 9), so

$$E = \{(1, 3), (2, 2), (3, 1), (3, 6), (4, 5), (5, 4), (6, 3)\}$$

and an event F of sum of outputs are prime numbers

(i.e., 2, 3, 5, 7, 11) so

$$F = \{(1, 1), (1, 2), (2, 1), (1, 4), (2, 3), (3, 2), (4, 1), (1, 6), (2, 5), (3, 4), (4, 3), (5, 2), (6, 1), (5, 6), (6, 5)\}$$

and event T of sum of outputs are odd numbers

(i.e., 3, 5, 7, 9, 11)

$$T = \{(1, 2), (2, 1), (1, 4), (2, 3), (3, 2), (4, 1), (1, 6), (2, 5), (3, 4), (4, 3), (5, 2), (6, 1), (3, 6), (4, 5), (5, 4), (6, 3), (5, 6), (6, 5)\}$$

Now, required probability $p = P(T/E)$

$$= \frac{P(T \cap E)}{P(E)}$$

where, $P(T \cap E)$ = probability of occurring perfect square odd number before prime

$$= \left(\frac{4}{36}\right) + \left(\frac{14}{36}\right) \left(\frac{4}{36}\right) + \left(\frac{14}{36}\right)^2 \left(\frac{4}{36}\right) + \dots \infty$$

$$= \frac{\frac{4}{36}}{1 - \frac{14}{36}} = \frac{4}{22} = \frac{2}{11}$$

and $P(E)$ = probability of occurring perfect square before prime

$$= \left(\frac{7}{36}\right) + \left(\frac{14}{36}\right) \left(\frac{7}{36}\right) + \left(\frac{14}{36}\right)^2 \left(\frac{7}{36}\right) + \dots \infty$$

$$= \frac{\frac{7}{36}}{1 - \frac{14}{36}} = \frac{7}{22}$$

$$\therefore P(T/E) = \frac{\frac{2}{11}}{\frac{7}{22}} = \frac{4}{7} = p \Rightarrow 14p = 8$$
