Solutionbank S2
Edexcel AS and A Level Modular Mathematics

Exercise A, Question 1

Question:

The discrete random variable X takes integer values and is to be approximated by a normal distribution. Apply a continuity correction to the following probabilities.

a $P(X \leq 7)$

b $P(X < 10)$

c $P(X > 5)$

d $P(X \geq 3)$

e $P(17 \leq X \leq 20)$

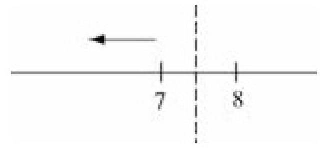
f $P(18 < X < 30)$

g $P(28 < X \leq 40)$

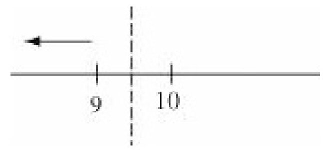
h $P(23 \leq X < 35)$

Solution:

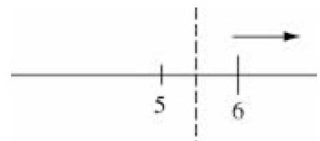
a $P(X \le 7) = P(X \le 7.5)$



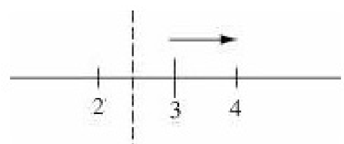
b $P(X < 10) = P(X \le 9.5)$



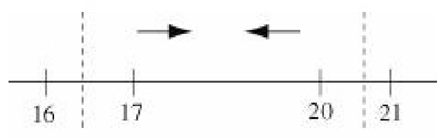
c $P(X > 5) = P(X \ge 5.5)$



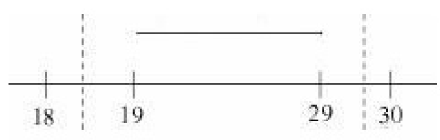
d $P(X \ge 3) = P(X \ge 2.5)$



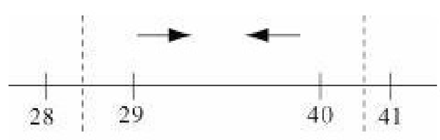
e $P(17 \le X \le 20) = P(16.5 \le X < 20.5)$



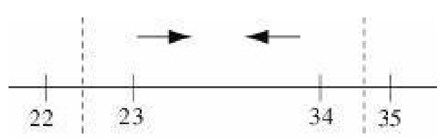
f $P(18 < X < 30) = P(18.5 \le X < 29.5)$



g $P(28 < X \le 40) = P(28.5 \le X < 40.5)$



h $P(23 \le X < 35) = P(22.5 \le X < 34.5)$



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Edexcel AS and A Level Modular Mathematics

Exercise B, Question 1

Question:

The random variable $X \sim \mathrm{B}(150, \frac{1}{3})$. Use a suitable approximation to estimate

a $\mathrm{P}(X \le 40)$,

b $\mathrm{P}(X > 60)$,

c $\mathrm{P}(45 \le X \le 60)$.

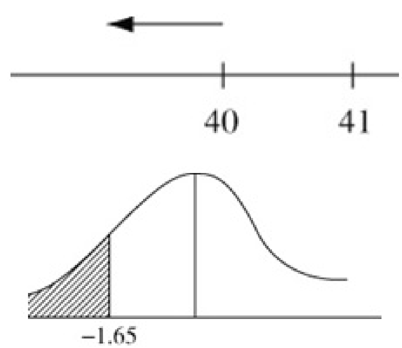
Solution:

$X \sim \mathrm{B}(150, \frac{1}{3})$

$Y \sim \mathrm{N}(50, \sqrt{\frac{100}{3}}^2)$ $\qquad X \approx Y$

a

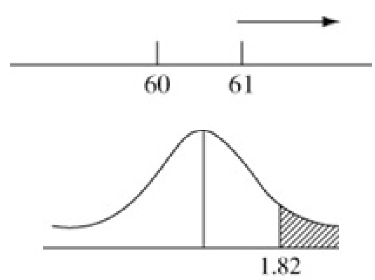
$$\begin{aligned}\mathrm{P}(X \le 40) &\approx \mathrm{P}(Y < 40.5)\\ &= \mathrm{P}\left(Z < \frac{40.5-50}{\sqrt{\frac{100}{3}}}\right)\\ &= \mathrm{P}(Z < -1.645\ldots)\\ &= 1-0.9505\\ &= 0.0495\end{aligned}$$



$(\text{calc} = 0.0499\ldots)$

b

$$\begin{aligned}\mathrm{P}(X > 60) &\approx \mathrm{P}(Y > 60.5)\\ &= \mathrm{P}(Z > 1.818\ldots)\\ &= 1-0.9656\\ &= 0.0344\end{aligned}$$



$(\text{calc} = 0.03448\ldots)$

So accept awrt 0.0340 (3 s.f.)

c

$$\begin{aligned}\mathrm{P}(45 \le X \le 60) &\approx \mathrm{P}(44.5 \le Y < 60.5)\\ &= \mathrm{P}(-0.95 \le Z < 1.82)\\ &= 0.9656-(1-0.8289)\\ &= 0.7945\end{aligned}$$

$(\text{calc} = 0.79512\ldots)$

accept awrt 0.795

Solutionbank S2

Edexcel AS and A Level Modular Mathematics

Exercise B, Question 2

Question:

The random variable $X \sim \mathrm{B}(200, 0.2)$. Use a suitable approximation to estimate

a $\mathrm{P}(X < 45)$,

b $\mathrm{P}(25 \le X < 35)$,

c $\mathrm{P}(X = 42)$.

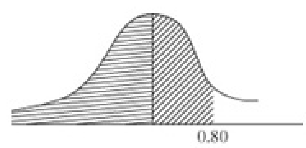
Solution:

$X \sim \mathrm{B}(200, 0.2)$

$Y \sim \mathrm{N}(40, \sqrt{32}^2)$ $\qquad X \approx Y$

a

$$\begin{aligned} \mathrm{P}(X < 45) &\approx \mathrm{P}(Y \le 44.5) \\ &= \mathrm{P}\left(Z < \frac{44.5 - 40}{\sqrt{32}}\right) \\ &= \mathrm{P}(Z < 0.7954\ldots) \\ &= 0.7881 \end{aligned}$$

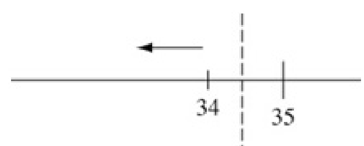


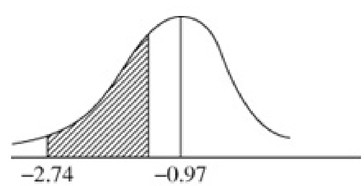
$(\text{calc} = 0.7868\ldots)$

So accept awrt $0.788 \sim 0.787$

b

$$\begin{aligned} \mathrm{P}(25 \le X < 35) &= \mathrm{P}(24.5 \le Y < 34.5) \\ &= \mathrm{P}(-2.74 \le Z < -0.97\ldots) \\ &= [1 - 0.8340] - [1 - 0.9970] \\ &= 0.163 \end{aligned}$$



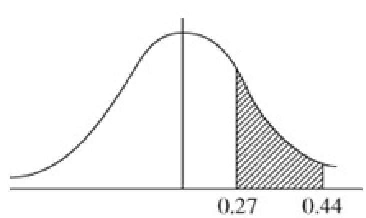


$(\text{calc} = 0.162386\ldots)$

so accept awrt $0.162 \sim 0.163$

c

$$\begin{aligned} \mathrm{P}(X = 42) &= \mathrm{P}(41.5 \le Y < 42.5) \\ &= \mathrm{P}(0.265\ldots \le Z < 0.4419\ldots) \\ &= 0.6700 - 0.6064 \\ &= 0.0636 \end{aligned}$$



$(\text{calc} = 0.066175\ldots)$

so accept awrt $0.0640 \sim 0.0660$

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Edexcel AS and A Level Modular Mathematics

Exercise B, Question 3

Question:

The random variable $X \sim B(100, 0.65)$. Use a suitable approximation to estimate

a $P(X > 58)$,

b $P(60 < X \leq 72)$,

c $P(X = 70)$.

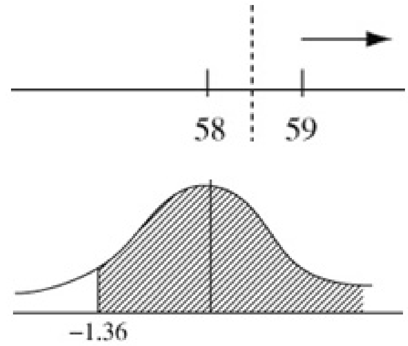
Solution:

$X \sim B(100, 0.65)$

$Y \sim N(65, \sqrt{22.75}^2)$ $\qquad X \approx Y$

a

$$
\begin{aligned}
P(X > 58) &\approx P(Y > 58.5) \\
&= P(Z > -1.36\ldots) \\
&= 0.9131
\end{aligned}
$$

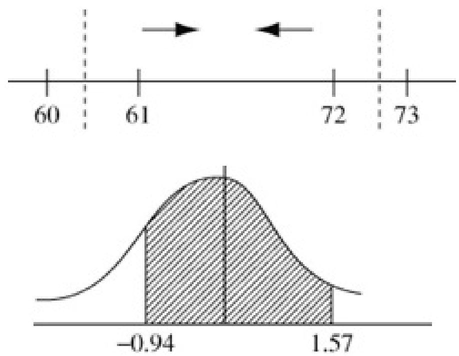


(calc $= 0.9135\ldots$)

So accept awrt $0.913 \sim 0.914$

b

$$
\begin{aligned}
P(60 < X \leq 72) &\approx P(60.5 \leq Y < 72.5) \\
&= P(-0.94 \leq Z < 1.57\ldots) \\
&= 0.9418 - (1 - 0.8264) \\
&= 0.7682
\end{aligned}
$$

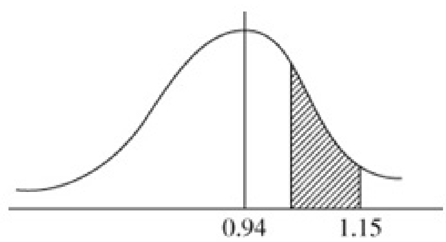


(calc $= 0.76935\ldots$)

So accept awrt $0.768 \sim 0.769$

c

$$
\begin{aligned}
P(X = 70) &\approx P(69.5 \leq Y < 70.5) \\
&= P(0.943 \leq Z < 1.153\ldots) \\
&= 0.8749 - 0.8264 \\
&= 0.0485
\end{aligned}
$$



(calc $= 0.04829\ldots$)

So accept awrt $0.0483 \sim 0.0485$

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Edexcel AS and A Level Modular Mathematics

Exercise B, Question 4

Question:

Sarah rolls a fair die 90 times. Use a suitable approximation to estimate the probability that the number of sixes she obtains is over 20.

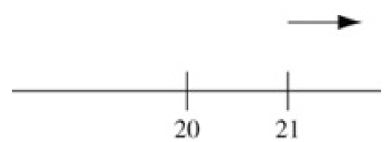
Solution:

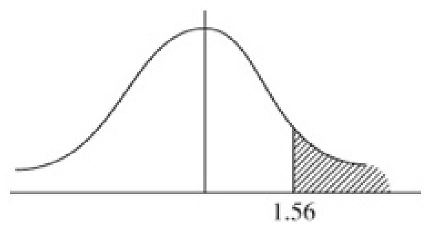
$X =$ number of sixes in 90 rolls

$X \sim \mathrm{B}(90, \frac{1}{6})$

$Y \sim \mathrm{N}(15, \sqrt{12.5}^2)$ $X \approx Y$

$$\begin{aligned} \mathrm{P}(X > 20) &\approx \mathrm{P}(Y \geq 20.5) \\ &= \mathrm{P}\left(Z \geq \frac{20.5-15}{\sqrt{12.5}}\right) \\ &= \mathrm{P}(Z \geq 1.555\ldots) \\ &= 1-0.9406 \\ &= 0.0594 \end{aligned}$$





$(\text{calc} = 0.059897\ldots)$

So accept awrt $0.059 \sim 0.060$

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Exercise B, Question 5

Question:

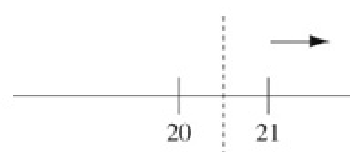
In a multiple choice test there are 4 possible answers to each question. Given that there are 60 questions on the paper, use a suitable approximation to estimate the probability of getting more than 20 questions correct if the answer to each question is chosen at random from the 4 available choices for each question.

Solution:

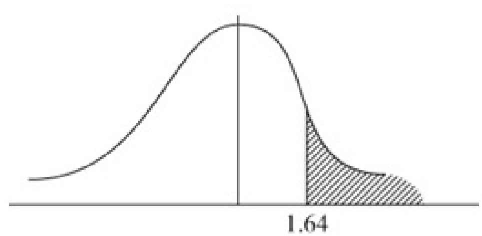
$X =$ number of correct answers

$X \sim \mathrm{B}(60, \frac{1}{4})$

$Y \sim \mathrm{N}(15, \sqrt{11.25}^2)$ $\quad X \approx Y$



$$\begin{aligned} \mathrm{P}(X > 20) &\approx \mathrm{P}(Y \geq 20.5) \\ &= \mathrm{P}\left(Z \geq \frac{20.5-15}{\sqrt{11.25}}\right) \\ &= \mathrm{P}(Z \geq 1.639\ldots) \\ &= 1 - 0.9495 \\ &= 0.0505 \end{aligned}$$



(calc gives 0.050525…)
So accept awrt 0.0505

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Exercise B, Question 6

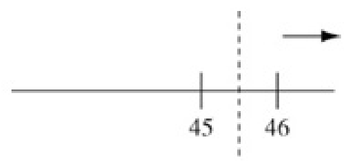
Question:

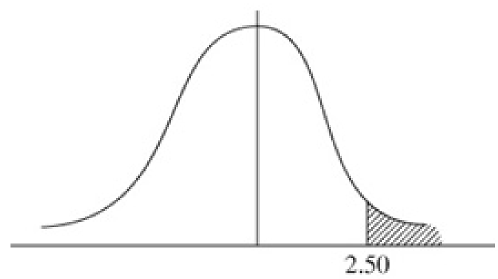
A fair coin is tossed 70 times. Use a suitable approximation to estimate the probability of obtaining more than 45 heads.

Solution:

$X =$ number of heads in 70 tosses of a fair coin
$X \sim \mathrm{B}(70, 0.5)$
$Y \sim \mathrm{N}(35, \sqrt{17.5}^2)$ $\quad X \approx Y$

$$\begin{aligned} \mathrm{P}(X > 45) &= \mathrm{P}(Y \geq 45.5) \\ &= \mathrm{P}\left(Z > \frac{45.5 - 35}{\sqrt{17.5}}\right) \\ &= \mathrm{P}(Z > 2.5099\ldots) \\ &= 1 - 0.9940 \\ &= 0.0060 \end{aligned}$$





(calc gives 0.006036...)
So accept awrt 0.006

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Edexcel AS and A Level Modular Mathematics

Exercise C, Question 1

Question:

The random variable $X \sim \text{Po}(30)$. Use a suitable approximation to estimate

a $\text{P}(X \leq 20)$,

b $\text{P}(X > 43)$,

c $\text{P}(25 \leq X \leq 35)$.

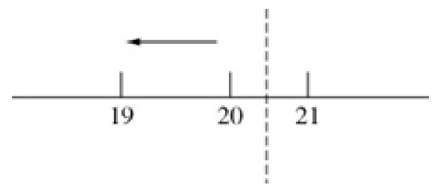
Solution:

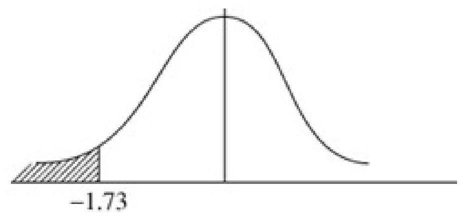
$X \sim \text{Po}(30)$

$Y \sim \text{N}(30, \sqrt{30})$ $X \approx Y$

a

$$\begin{aligned} \text{P}(X \le 20) &\approx \text{P}(Y \le 20.5) \\ &= \text{P}\left(Z < \frac{20.5-30}{\sqrt{30}}\right) \\ &= \text{P}(Z < -1.7344\ldots) \\ &= 1-0.9582 \\ &= 0.0418 \end{aligned}$$

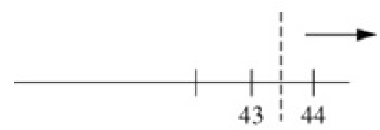


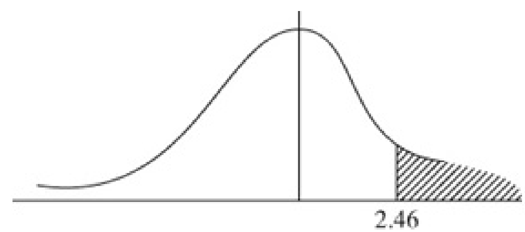


(calc gives 0.041418...)
So accept awrt 0.0410 ~ 0.0420

b

$$\begin{aligned} \text{P}(X > 43) &\approx \text{P}(Y > 43.5) \\ &= \text{P}\left(Z > \frac{43.5-30}{\sqrt{30}}\right) \\ &= \text{P}(Z > 2.46\ldots) \\ &= 1-0.9931 \\ &= 0.0069 \end{aligned}$$

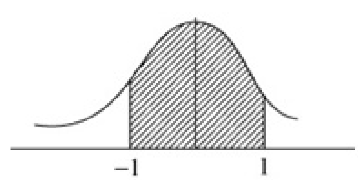




(calc gives 0.006855...)
accept awrt 0.0069

c

$$\begin{aligned} \text{P}(25 \le X \le 35) &\approx \text{P}(24.5 \le Y < 35.5) \\ &= \text{P}(-1.00 < Z < 1.00\ldots) \\ &= 2 \times 0.3413 \\ &= 0.6826 \end{aligned}$$



(calc gives 0.68469...)
accept awrt 0.683 ~ 0.685

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Edexcel AS and A Level Modular Mathematics

Exercise C, Question 2

Question:

The random variable $X \sim \text{Po}(45)$. Use a suitable approximation to estimate

a $\text{P}(X < 40)$,

b $\text{P}(X \geq 50)$,

c $\text{P}(43 < X \leq 52)$.

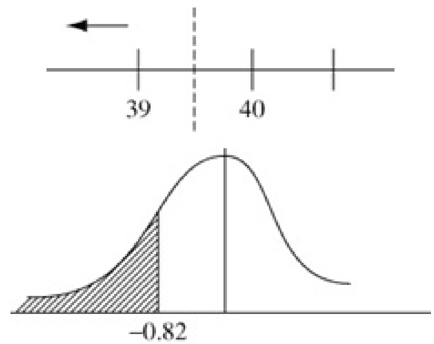
Solution:

$X \sim \text{Po}(45)$

$Y \sim \text{N}(45, \sqrt{45})$ $X \approx Y$

a

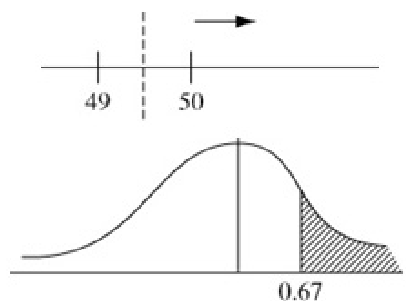
$$\begin{aligned} \text{P}(X < 40) &\approx \text{P}(Y \leq 39.5) \\ &= \text{P}\left(Z < \frac{39.5 - 45}{\sqrt{45}}\right) \\ &= \text{P}(Z < -0.819\ldots) \\ &= 1 - 0.7939 \\ &= 0.2061 \end{aligned}$$



(calc gives 0.20613…)
So accept awrt 0.206

b

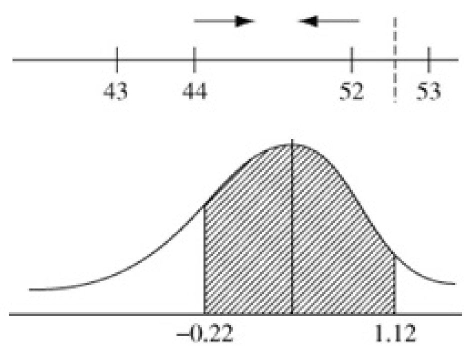
$$\begin{aligned} \text{P}(X \geq 50) &\approx \text{P}(Y \geq 49.5) \\ &= \text{P}(Z \geq 0.6708\ldots) \\ &= 1 - 0.7486 \\ &= 0.2514 \end{aligned}$$



(calc gives 0.25116…)
So accept awrt 0.251

c

$$\begin{aligned} \text{P}(43 < X \leq 52) &\approx \text{P}(43.5 \leq Y < 52.5) \\ &= \text{P}(-0.22\ldots \leq Z < 1.12\ldots) \\ &= 0.8686 - (1 - 0.5871) \\ &= 0.4557 \end{aligned}$$



(calc gives 0.45669…)
So accept awrt 0.456 ~ 0.457

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Edexcel AS and A Level Modular Mathematics

Exercise C, Question 3

Question:

The random variable $X \sim \text{Po}(60)$. Use a suitable approximation to estimate

a $\text{P}(X \leq 62)$,

b $\text{P}(X = 63)$,

c $\text{P}(55 \leq X < 65)$.

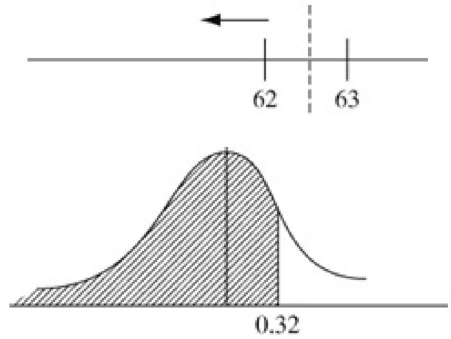
Solution:

$X \sim \text{Po}(60)$ $\quad X \approx Y$

$Y \sim \text{N}(60, \sqrt{60}^2)$

a

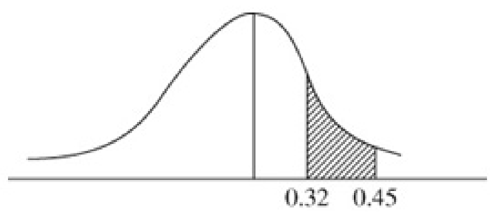
$$
\begin{aligned}
\text{P}(X \le 62) &\approx \text{P}(Y < 62.5) \\
&= \text{P}\left(Z < \frac{62.5 - 60}{\sqrt{60}}\right) \\
&= \text{P}(Z < 0.3227\ldots) \\
&= 0.6255
\end{aligned}
$$



(calc gives 0.62655…)
So accept awrt 0.626 ~ 0.627

b

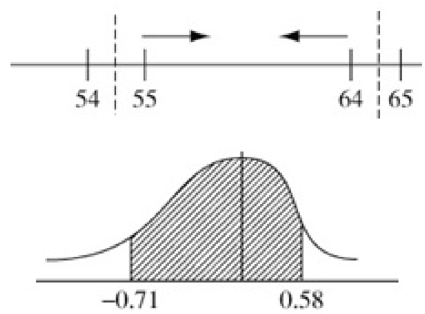
$$
\begin{aligned}
\text{P}(X = 63) &\approx \text{P}(62.5 \le Y < 63.5) \\
&= \text{P}(0.32\ldots \le Z < 0.45\ldots) \\
&= 0.6736 - 0.6255 \\
&= 0.0481
\end{aligned}
$$



(calc gives 0.04775…)
So accept awrt 0.0480

c

$$
\begin{aligned}
\text{P}(55 \le X < 65) &= \text{P}(54.5 \le Y < 64.5) \\
&= \text{P}(-0.71\ldots \le Z < 0.58\ldots) \\
&= 0.7190 - (1 - 0.7611) \\
&= 0.4801
\end{aligned}
$$



(Calc gives 0.48052…)
So accept awrt 0.480 ~ 0.481

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Edexcel AS and A Level Modular Mathematics

Exercise C, Question 4

Question:

The disintegration of a radioactive specimen is known to be at the rate of 14 counts per second. Using a normal approximation for a Poisson distribution, determine the probability that in any given second the counts will be

a 20, 21 or 22,

b greater than 10,

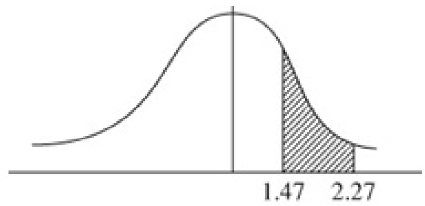
c above 12 but less than 16.

Solution:

$X =$ number of counts in one second
$X \sim \text{Po}(14)$
$Y \sim \text{N}(14, \sqrt{14}^2)$ $\quad X \approx Y$

a

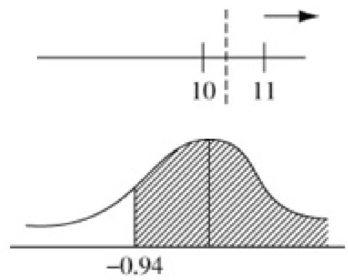
$$\begin{aligned} \text{P}(20 \leq X \leq 22) &\approx \text{P}(19.5 \leq Y < 22.5) \\ &= \text{P}(1.47 \leq Z < 2.27\ldots) \\ &= 0.9884 - 0.9292 \\ &= 0.0592 \end{aligned}$$



(calc gives 0.059237…)
So accept awrt 0.0590 ~ 0.0600

b

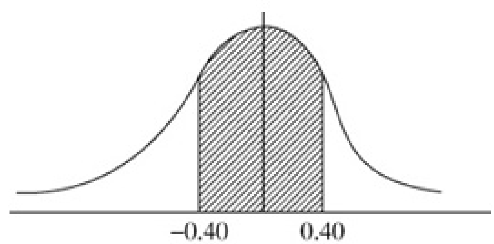
$$\begin{aligned} \text{P}(X > 10) &\approx \text{P}(Y \geq 10.5) \\ &= \text{P}(Z \geq -0.935\ldots) \\ &= 0.8264 \end{aligned}$$



(calc gives 0.8252…)
So accept awrt 0.825 ~ 0.826

c

$$\begin{aligned} \text{P}(12 < X < 16) &\approx \text{P}(12.5 \leq Y \leq 15.5) \\ &= \text{P}(-0.40\ldots \leq Z < 0.40\ldots) \\ &= 2 \times 0.1554 \\ &= 0.3108 \end{aligned}$$



(calc gives 0.311500…)
So accept awrt 0.311 ~ 0.312

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Exercise C, Question 5

Question:

A marina hires out boats on a daily basis. The mean number of boats hired per day is 15. Using the normal approximation for a Poisson distribution, find, for a period of 100 days

a how often 5 or fewer boats are hired,

b how often exactly 10 boats are hired,

c on how many days they will have to turn customers away if the marina owns 20 boats.

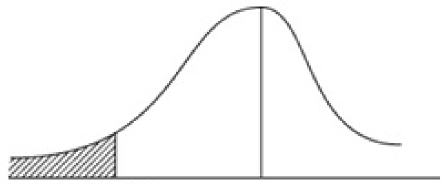
Solution:

$X =$ number of boats hired per day
$X \sim \text{Po}(15)$

$Y \sim \text{N}(15, \sqrt{15}^2)$ $X \approx Y$

a

$$\begin{aligned} \text{P}(X \le 5) &\approx \text{P}(Y < 5.5) \\ &= \text{P}(Z < -2.452\ldots) \\ &= 1 - 0.9929 \\ &= 0.0071 \end{aligned}$$

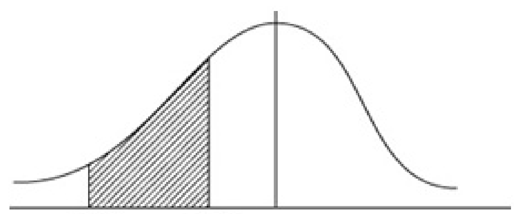


(calc gives 0.00708…)
So accept awrt 0.0070 to 0.0071

i.e. in 100 days $\approx$ 0.7 times
i.e. 1 day

b

$$\begin{aligned} \text{P}(X = 10) &\approx \text{P}(9.5 \le Y < 10.5) \\ &= \text{P}(-1.42 \le Z < -1.16) \\ &= [1 - 0.8770] - [1 - 0.9222] \\ &= 0.0452 \end{aligned}$$

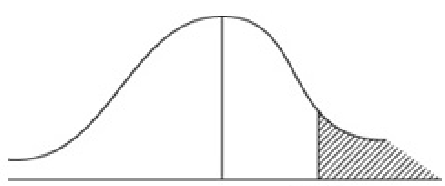


(calc gives 0.04484…)
So accept awrt 0.045

i.e. in 100 days $\approx$ 4.5 days
i.e. 4 or 5 days

c

$$\begin{aligned} \text{P}(X > 20) &\approx \text{P}(Y > 20.5) \\ &= \text{P}(Z > 1.42\ldots) \\ &= 1 - 0.9222 \\ &= 0.0778 \end{aligned}$$



(calc gives 0.07779…)
So accept 0.078

i.e. in 100 days $\approx$ 7.8 days
i.e. 8 days

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Exercise D, Question 1

Question:

A fair die is rolled and the number of sixes obtained is recorded.
Using suitable approximations, find the probability of

a no more than 10 sixes in 48 rolls of the die,

b at least 25 sixes in 120 rolls of the die.

Solution:

a $X =$ number of sixes in 48 rolls of a die

$X \sim \mathrm{B}(48, \frac{1}{6})$

$Y \sim \mathrm{Po}(8)$ $\qquad \mu = 8$

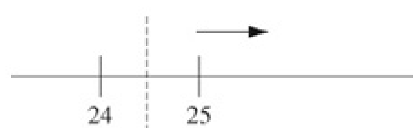
$$\mathrm{P}(X \le 10) \approx \mathrm{P}(Y \le 10)$$
$$= 0.8159 \qquad \text{(Poisson tables)}$$

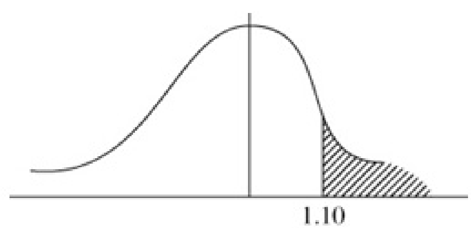
b $X =$ number of sixes in 120 rolls of a die

$X \sim \mathrm{B}(120, \frac{1}{6})$

$Y \sim \mathrm{N}(20, \sqrt{\frac{100}{6}}^2)$ or $Y \sim \mathrm{N}(20, \sqrt{\frac{50}{3}}^2)$ $\qquad \mu = 20$

$$\mathrm{P}(X \ge 25) \approx \mathrm{P}(Y \ge 24.5)$$
$$= \mathrm{P}(Z \ge 1.10\ldots)$$
$$= 1 - 0.8643$$
$$= 0.1357$$





(calc gives $0.135172\ldots$)
So accept awrt $0.135 \sim 0.136$

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Exercise D, Question 2

Question:

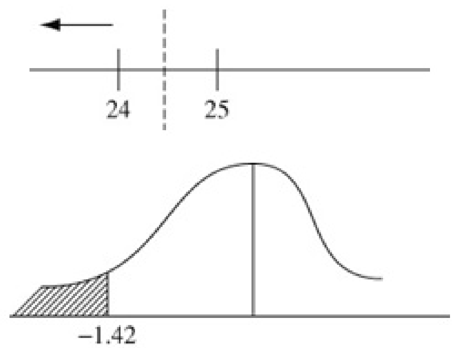
A fair coin is spun 60 times.
Use a suitable approximation to estimate the probability of obtaining fewer than 25 heads.

Solution:

$X =$ number of heads in 60 spins of a coin
$X \sim \mathrm{B}(60, 0.5)$
$Y \sim \mathrm{N}(30, \sqrt{15}^2)$

$X \approx Y$

$$\begin{aligned} \mathrm{P}(X < 25) &\approx \mathrm{P}(Y < 24.5) \\ &= \mathrm{P}(Z < -1.42\ldots) \\ &= 1 - 0.9222 \\ &= 0.0778 \end{aligned}$$



(calc gives 0.07779022…)
So accept awrt 0.0778

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Exercise D, Question 3

Question:

The owner of a local corner shop calculates that the probability of a customer buying a newspaper is 0.40 but the proportion of customers who spend over £10 is 0.04.
A random sample of 100 customer's shopping is recorded. Use suitable approximations to estimate the probability that in this sample

a at least half of the customers bought a newspaper,

b more than 5 of them spent over £10.

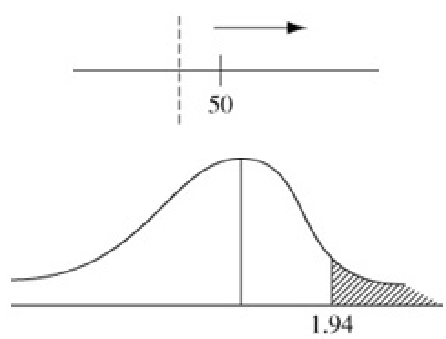
Solution:

a X = number of customers who bought a newspaper

$X \sim \mathrm{B}(100, 0.40)$

$Y \sim \mathrm{N}(40, \sqrt{24}^2)$ $\qquad X \approx Y$

$$\mathrm{P}(X \geq 50) \approx \mathrm{P}(Y \geq 49.5)$$
$$= \mathrm{P}\left(Z \geq \frac{49.5 - 40}{\sqrt{24}}\right)$$
$$= \mathrm{P}(Z \geq 1.939\ldots)$$
$$= 1 - 0.9738$$
$$= 0.0262$$



calc gives 0.026239…
So accept awrt 0.0262

b T = number of customers who spent over £10

$T \sim \mathrm{B}(100, 0.04)$ $\qquad \mu = 4$

$S \approx \mathrm{Po}(4)$

$T \approx S$

$$\mathrm{P}(T > 5) \approx \mathrm{P}(S \geq 6) \quad \text{(No continuity correction)}$$
$$= 1 - \mathrm{P}(S \leq 5)$$
$$= 1 - 0.7851 \quad \text{(Poisson tables)}$$
$$= 0.2149$$

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Exercise D, Question 4

Question:

Street light failures in a town occur at a rate of one every two days. Assuming that X, the number of street light failures per week, has a Poisson distribution, find the probabilities that the number of street lights that will fail in a given week is

a exactly 2,

b less than 6.

Using a suitable approximation estimate the probability that

c there will be fewer than 45 street light failures in a 10-week period.

Solution:

$X \sim \text{Po}(3.5)$ ← $\lambda = 7 \times \frac{1}{2}$

a

$$\begin{aligned} \text{P}(X=2) &= \text{P}(X \le 2) - \text{P}(X \le 1) \\ &= 0.3208 - 0.1359 \\ &= 0.1849 \end{aligned}$$

b

$$\begin{aligned} \text{P}(X<6) &= \text{P}(X \le 5) \\ &= 0.8576 \end{aligned}$$

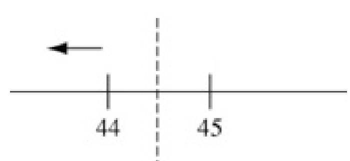
Let $Y =$ number of failures in 10-week period

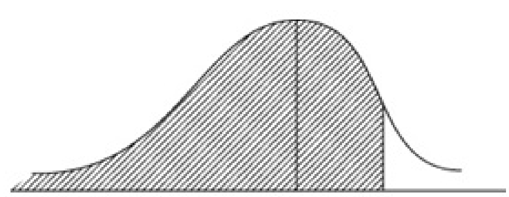
$Y \sim \text{Po}(35)$

$W \sim \text{N}(35, \sqrt{35}^2)$

c

$$\begin{aligned} \text{P}(Y<45) &\approx \text{P}(W \le 44.5) \\ &= \text{P}\left(Z \le \frac{44.5-35}{\sqrt{35}}\right) \\ &= \text{P}(Z \le 1.605\ldots) \\ &= 0.9463 \end{aligned}$$





calc gives 0.945840…

So accept awrt 0.946

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Exercise D, Question 5

Question:

Past records from a supermarket show that 20% of people who buy chocolate bars buy the family size bar. A random sample of 80 people is taken from those who had bought chocolate bars.

a Use a suitable approximation to estimate the probability that more than 20 of these 80 bought family size bars.

The probability of a customer buying a gigantic chocolate bar is 0.02.

b Using a suitable approximation estimate the probability that fewer than 5 customers in a sample of 150 buy a gigantic chocolate bar.

Solution:

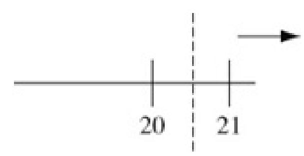
$X =$ number of people out of 80 who buy family size chocolate bars

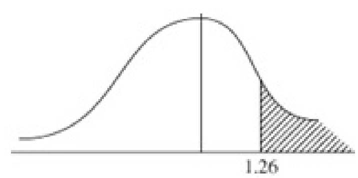
$X \sim \text{B}(80, 0.20)$

$Y \sim \text{N}(16, \sqrt{12.8}^2)$

a

$$\begin{aligned} \text{P}(X > 20) &\approx \text{P}(Y \geq 20.5) \\ &= \text{P}\left(Z \geq \frac{20.5-16}{\sqrt{12.8}}\right) \\ &= \text{P}(Z \geq 1.2577\ldots) \\ &= 1 - 0.8962 \\ &= 0.1038 \end{aligned}$$





calc gives 0.104234…

So accept awrt 0.104

b $G =$ number who buy a gigantic bar of chocolate

$G \sim \text{B}(150, 0.02)$ ← $\mu = 150 \times 0.02 = 3$

$H \sim \text{Po}(3)$ $G \approx H$

$$\begin{aligned} \text{P}(G < 5) &\approx \text{P}(H < 5) && \text{(No continuity correction)} \\ &= \text{P}(H \leq 4) \\ &= 0.8153 && \text{(Poisson tables)} \end{aligned}$$