Q	Scheme	Marks	AOs	Pearson Progression Step and Progress Descriptor
1a	The sample mean…	**B1**	1.2	4th Be able to quote the central limit theorem
	…is (approximately) normally distributed with mean μ and variance $\frac{\sigma^2}{n}$	**B1**	1.2	
		(2)		
1b	The sample must be random	**B1**	1.2	5th Know the conditions for the use of the central limit theorem
		(1)		
				(3 marks)

Notes

1a **B1** must state *sample* mean (accept $\bar{X}$)

B1 parameters must be given. Accept standard deviation rather than variance

1b **B1** for sample is random

Q	Scheme	Marks	AOs	Pearson Progression Step and Progress Descriptor
2a	$\bar{X} \sim \mathrm{N}\left(12, \frac{9}{10}\right)$	M1	3.1a	7th Apply the central limit theorem to a range of probability distributions
	$\mathrm{P}(\bar{X} > 13) = \mathrm{P}\left(Z > \frac{13-12}{\frac{3}{\sqrt{10}}}\right)$	M1	1.1b	
	$= 0.1469$	A1	1.1b	
		(3)		
2b	No: The population is normally distributed so the sample mean is also normally distributed.	B1	2.4	5th Know the conditions for the use of the central limit theorem
		(1)		
				(4 marks)

Notes

2a **M1** for attempt to find distribution of $\bar{X}$ using given parameters, must divide by 10

M1 for attempt to find $\mathrm{P}(\bar{X} > 13)$

A1 awrt 0.147

2b **B1** for ‘No’ with correct reason

Q	Scheme	Marks	AOs	Pearson Progression Step and Progress Descriptor
3a	$\bar{X} \sim \mathrm{N}\left(21, \frac{1.1^2}{50}\right)$	M1	3.1a	7th Apply the central limit theorem to a range of probability distributions
	$\mathrm{P}(\bar{X} < 20.7) = \mathrm{P}\left(Z < \frac{20.7 - 21}{\frac{1.1}{\sqrt{50}}}\right)$	M1	1.1b	
	$= 0.0268$	A1	1.1b	
		(3)		
3b	Require $\mathrm{P}\left(Z < \frac{20.7 - 21}{\frac{1.1}{\sqrt{n}}}\right) < 0.01$	M1	3.1a	8th Recognise and apply the central limit theorem in contextualised situations
	$Z = (-)2.3263$	B1	1.1a	
	$\frac{-0.3}{\frac{1.1}{\sqrt{n}}} < -2.3263 \Rightarrow \frac{0.3\sqrt{n}}{1.1} > 2.3263$	M1	1.1b	
	$\sqrt{n} > 8.5297... \Rightarrow n > 72.7...$	M1	1.1b	
	$n = 73$	A1	3.2a	
		(5)		
				(8 marks)

Notes

3a **M1** for attempt to find distribution of $\bar{X}$ using given parameters, must divide by 50

M1 for attempt to find $\mathrm{P}(\bar{X} < 20.7)$

A1 awrt 0.027

3b **M1** for probability statement in terms of Z and using $\frac{1.1}{\sqrt{n}}$

B1 for correct Z value (from tables); accept + or – here

M1 for attempt to solve resulting equation using *their* Z (must now be –)

M1 for value for $\sqrt{n}$ leading to value for n

A1ft *their* Z value if all M marks awarded (answer must be an integer)

Q	Scheme	Marks	AOs	Pearson Progression Step and Progress Descriptor
4a	$0.1 + k + 2k + 0.3 + 0.24 = 1$	**M1**	1.1b	1st
	Hence $k = 0.12$	**A1**	1.1b	Understand how to find unknowns from a probability mass function
		(2)		
4bi	$\mathrm{E}(X) = 1 \times 0.1 + 2 \times 0.12 + 4 \times 0.24 + 5 \times 0.3 + 6 \times 0.24$	**M1**	1.1b	2nd
	$= 4.24$	**A1**	1.1b	Calculate the mean of a discrete random variable
		(2)		
4bii	$\mathrm{Var}(X) = 1^2 \times 0.1 + \ldots + 6^2 \times 0.24 - 4.24^2$	**M1**	1.1b	3rd
	$= 2.5824$	**A1**	1.1b	Calculate the variance of a discrete random variable
		(2)		
4c	CLT states that the sample mean is approximately normally distributed.	**B1**	1.2	6th Recognise when the central limit theorem is required
		(1)		
4d	$\bar{X} \approx \sim \mathrm{N}\left(4.24, \frac{2.5824}{80}\right)$	**M1**	3.1a	7th
	$\mathrm{P}(\bar{X} < 4.5) = \mathrm{P}\left(Z < \frac{4.5 - 4.24}{\sqrt{\frac{2.5824}{80}}}\right) (= \mathrm{P}(Z < 1.447))$	**M1**	1.1b	Apply the central limit theorem to a range of probability distributions
	$= 0.9265$	**A1**	1.1b	
		(3)		

4e	Estimate is fairly accurate since n is large.	**B1**	2.4	5th Know the conditions for the use of the central limit theorem
		(1)		
				(11 marks)

Notes

4a **M1** for attempt to add probabilities and equate to 1

A1 cao

4bi **M1A1ft** from *their k*

4bii **M1A1ft** from *their k*

4c **B1** for completely correct reason

4d **M1** for attempt to find distribution of $\bar{X}$ using calculated parameters, must divide by 80

M1 for attempt to find $P(\bar{X} < 4.5)$

A1ft awrt 0.927 (ft *their* **4bi** and **4bii**)

4e **B1** for correct statement including n is large

Q	Scheme	Marks	AOs	Pearson Progression Step and Progress Descriptor
5	$\bar{X} \sim \mathrm{N}\left(2.6, \frac{2.6}{50}\right)$	M1 A1	3.1a 1.1b	7th Apply the central limit theorem to a range of probability distributions
	$\mathrm{P}(\bar{X} > 2.7) = \mathrm{P}\left(Z > \frac{2.7 - 2.6}{\sqrt{\frac{2.6}{50}}}\right) (= \mathrm{P}(Z > 0.4385\ldots))$	M1	1.1b	
	$= 0.3300$	A1	1.1b	
				(4 marks)

Notes

1st **M1** for use of CLT with given Poisson parameters

1st **A1** for completely correct normal distribution

2nd **M1** for attempt to find $\mathrm{P}(\bar{X} > 2.7)$ using *their* normal distribution

2nd **A1** awrt 0.33

Q	Scheme	Marks	AOs	Pearson Progression Step and Progress Descriptor
6a	Mean: $\dfrac{1}{0.2} = 5$	**B1**	1.1b	6th Calculate the mean/variance of a geometric distribution
	Variance: $\dfrac{1-0.2}{0.2^2} = 20$	**B1**	1.1b	
		(2)		
6b	$\bar{X} \sim \mathrm{N}\left(5, \dfrac{20}{20}\right)$	**M1** **A1**	3.1a 1.1b	7th Apply the central limit theorem to a range of probability distributions
	$\mathrm{P}(\bar{X} > 6) = \mathrm{P}\left(Z > \dfrac{6-5}{\sqrt{\frac{20}{20}}}\right) (= \mathrm{P}(Z > 1))$	**M1**	1.1b	
	$= 0.1587$	**A1**	1.1b	
		(4)		
				(6 marks)

Notes

6a **B1** for correct mean

B1 for correct variance

6b 1st **M1** for use of CLT with *their* Geo parameters

1st **A1** for completely correct normal distribution

2nd **M1** for attempt to find $\mathrm{P}(\bar{X} > 6)$ using *their* normal distribution

2nd **A1** awrt 0.159

Q	Scheme	Marks	AOs	Pearson Progression Step and Progress Descriptor
7	Model is Negative B(8, 0.3)	**B1**	3.3	8th Recognise and apply the central llimit theorem in contextualised situations
	Expectation $= \frac{8}{0.3} = \frac{80}{3}$	**B1**	1.1b	
	Variance $= \frac{8(1-0.3)}{0.3^2} = \frac{560}{9}$	**B1**	1.1b	
	$\bar{X} \sim \mathrm{N}\left(\frac{80}{3}, \frac{\frac{560}{9}}{25}\right)$	**M1** **A1**	3.1a 1.1b	
	$\mathrm{P}(\bar{X} < 25) = \mathrm{P}\left(Z < \frac{25 - \frac{80}{3}}{\sqrt{\frac{\frac{560}{9}}{25}}}\right) (= \mathrm{P}(Z < -1.0564\ldots))$	**M1**	1.1b	
	$= 0.145$	**A1**	2.1	
				(7 marks)

Notes

B1 for correct model

B1 for correct expectation

B1 for correct variance

1st **M1** for use of CLT with *their* Negative B parameters

1st **A1** for completely correct normal distribution

2nd **M1** for attempt to find $\mathrm{P}(\bar{X} < 25)$ using *their* normal distribution

2nd **A1** cao

Q	Scheme	Marks	AOs	Pearson Progression Step and Progress Descriptor
8a	$P(\bar{X} < 72) = P\left(Z < \dfrac{72-75}{\frac{6}{\sqrt{24}}}\right) (= P(Z < -2.449\ldots))$	M1	3.1b	7th Apply the central limit theorem to a range of probability distributions
	$= 0.007$	A1	1.1b	
		(2)		
8b	The population is normally distributed.	B1	2.4	5th Know the conditions for the use of the central limit theorem
		(1)		
8c	Model is B(24, 0.2)	B1	3.1b	8th Recognise and apply the central llimit theorem in contextualised situations
	Mean: $24 \times 0.2 = 4.8$ Variance: $4.8 \times 0.8 = 3.84$	B1	1.1b	
	$P(\bar{X} < 4) = P\left(Z < \dfrac{4-4.8}{\sqrt{\frac{3.84}{15}}}\right) (= P(Z < -1.581\ldots))$	M1	1.1b	
	$= 0.057$	A1	2.1	
		(4)		
				(7 marks)

Notes

8a **M1** for attempt to find $P(\bar{X} < 72)$

A1 awrt 0.007

8b **B1** must state normally distributed

8c **B1** correct model

B1 mean and variance both correct

M1 for attempt to find $P(\bar{X} < 4)$ using *their* model and mean/variance

A1 cao