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EDEXCEL INTERNATIONAL A LEVEL MATHS: QUESTIONS BY TOPIC

The Binomial & Poisson Distributions (S2.1)

International A Level Mathematics · S2: Statistics 2 (WST02)

21 questions · 239 marks · Mark schemes included

Past papers October 2020 - June 2025 · 3 sub-topics

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HOW TO USE THIS BOOKLET

Questions are grouped by sub-topic and run from the lowest to the highest mark tariff, then oldest paper first.

Click any row below to jump straight to that sub-topic or question.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme; < QUESTION brings you back.

A gold bar in the left margin marks exactly where the question sits on the original page.

Diagrams, graphs, grids and tables are printed exactly as they appear in the original papers.

Each question is filed under its main topic; longer questions may also test skills from other topics.

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QUESTIONS

21 questions · 239 marks · 3 sub-topics

SUB-TOPIC S2.1a

THE BINOMIAL DISTRIBUTION

Sub-topic S2.1a · 1 question · 10 marks · lowest tariff first



(Total for Question 1 is 16 marks)



SUB-TOPIC S2.1b

THE POISSON DISTRIBUTION

Sub-topic S2.1b · 8 questions · 93 marks · lowest tariff first



$$W \sim \text{Po}(4) \qquad X \sim \text{B}(3, 0.8)$$

(a) Write down the value of the variance of W

(1)

(b) Determine the mode of X
Show your working clearly. **(2)**

One observation from each distribution is recorded as W_1 and X_1 respectively.

(c) Find $P(W_1 = 2 \text{ and } X_1 = 2)$

(d) Find $P(X_1 < W_1)$

(4)

Question 1 continued

Lined area for writing the answer to Question 1 continued.



Question 1 continued

Lined area for writing the answer to Question 1 continued.

(Total for Question 1 is 10 marks)



3. A sweet shop produces different coloured sweets and mixes them to sell in small, medium or large bags.

The proportion of sweets that are blue is p

Each small bag is filled with a random sample of n sweets.

The mean number of blue sweets in a small bag is 3 and the variance of the number of blue sweets in a small bag is 2.55

- (a) Find the value of n and the value of p

(3)

The proportion of sweets that are green is 0.2

Each medium bag contains a random sample of 40 sweets.

For a medium bag,

- (b) find the probability that the number of green sweets exceeds the **expected** number of green sweets.

(3)

The proportion of sweets that are yellow is 0.1

Each large bag contains a random sample of 80 sweets.

- (c) (i) Use a Poisson approximation to find the probability that a large bag of sweets contains at least 12 yellow sweets.

- (ii) Justify why a Poisson approximation is suitable in this case.

(4)



Question 3 continued

Lined area for writing the answer to Question 3 continued.



Question 3 continued

Lined area for writing the answer to Question 3 continued.



(Total for Question 5 is 16 marks)



Question 1 continued

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Question 1 continued

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Question 1 continued

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Lined area for writing the answer to Question 1.

(Total 11 marks)

Q1



1. Bhavna produces rolls of cloth. She knows that faults occur randomly in her cloth at a mean rate of 1.5 every 15 metres.

- (a) Find the probability that in 15 metres of her cloth there are

- (i) less than 3 faults,
- (ii) at least 6 faults.

(3)

Each roll contains 100 metres of Bhavna's cloth.
She selects 15 rolls at random.

- (b) Find the probability that exactly 10 of these rolls each have fewer than 13 faults.

(4)

Bhavna decides to sell her cloth in pieces.

Each piece of her cloth is 4 metres long.

The cost to make each piece is £5.00

She sells each piece of her cloth that contains no faults for £7.40

She sells each piece of her cloth that contains faults for £2.00

- (c) Find the expected profit that Bhavna will make on each piece of her cloth that she sells.

(4)



Question 1 continued



Question 1 continued

Lined area for writing the answer to Question 1 continued.



(Total for Question 1 is 11 marks)





Question 1 continued

Lined area for writing the answer to Question 1 continued.



(Total for Question 1 is 11 marks)





Question 7 continued

Handwriting practice area with horizontal lines.

(Total for Question 7 is 12 marks)

TOTAL FOR PAPER IS 75 MARKS





Question 5 continued



Question 5 continued

(Total for Question 5 is 12 marks)

1. The manager of a supermarket is investigating the number of complaints per day received from customers.

A random sample of 180 days is taken and the results are shown in the table below.

Number of complaints per day	0	1	2	3	4	5	6	≥ 7
Frequency	12	28	37	38	29	17	19	0

- (a) Calculate the mean and the variance of these data.

(3)

- (b) Explain why the results in part (a) suggest that a Poisson distribution may be a suitable model for the number of complaints per day.

(1)

The manager uses a Poisson distribution with mean 3 to model the number of complaints per day.

- (c) For a randomly selected day find, using the manager's model, the probability that there are

(i) at least 3 complaints,

(ii) more than 4 complaints but less than 8 complaints.

(4)

A week consists of 7 consecutive days.

- (d) Using the manager's model and a suitable approximation, show that the probability that there are less than 19 complaints in a randomly selected week is 0.29 to 2 decimal places.

Show your working clearly.

(Solutions relying on calculator technology are not acceptable.)

(5)

A period of 13 weeks is selected at random.

- (e) Find the probability that in this period there are exactly 5 weeks that have less than 19 complaints.

Show your working clearly.

(3)



Question 1 continued

Lined area for writing the answer to Question 1 continued.



Question 1 continued

Lined area for writing the answer to Question 1.

(Total for Question 1 is 16 marks)



SUB-TOPIC S2.1c

APPROXIMATIONS (POISSON & NORMAL)

Sub-topic S2.1c · 12 questions · 136 marks · lowest tariff first



Question 2 continued

Lined area for writing the answer to Question 2.

(Total for Question 2 is 8 marks)



Question 1 continued

Lined area for writing the answer to Question 1.

(Total for Question 1 is 8 marks)



- (2)



Question 6 continued

Lined area for writing the answer to Question 6.

(Total for Question 6 is 8 marks)



(Total for Question 4 is 9 marks)





TOTAL FOR PAPER: 75 MARKS



TOTAL FOR PAPER IS 75 MARKS

(Total for Question 1 is 11 marks)



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Question 1 continued

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Question 1 continued

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(Total 14 marks)

Q1



Question 1 continued

Lined area for writing the answer to Question 1 continued.



Question 1 continued

Lined area for writing the answer to Question 1 continued.



(Total for Question 1 is 14 marks)



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Question 5 continued

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Question 5 continued

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(Total 14 marks)

Q5





(Total for Question 5 is 14 marks)



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4. In a peat bog, Common Spotted-orchids occur at a mean rate of 4.5 per m^2

- (a) Give an assumption, not already stated, that is required for the number of Common Spotted-orchids per m^2 of the peat bog to follow a Poisson distribution.

(1)

Given that the number of Common Spotted-orchids in 1 m^2 of the peat bog can be modelled by a Poisson distribution,

- (b) find the probability that in a randomly selected 1 m^2 of the peat bog

(i) there are exactly 6 Common Spotted-orchids,

(ii) there are fewer than 10 but more than 4 Common Spotted-orchids.

(4)

Juan believes that by introducing a new management scheme the number of Common Spotted-orchids in the peat bog will increase. After three years under the new management scheme, a randomly selected 2 m^2 of the peat bog contains 11 Common Spotted-orchids.

- (c) Using a 5% significance level assess Juan's belief. State your hypotheses clearly.

(5)

Assuming that in the peat bog, Common Spotted-orchids still occur at a mean rate of 4.5 per m^2

- (d) use a normal approximation to find the probability that in a randomly selected 20 m^2 of the peat bog there are fewer than 70 Common Spotted-orchids.

(3)

Following a period of dry weather, the probability that there are fewer than 70 Common Spotted-orchids in a randomly selected 20 m^2 of the peat bog is 0.012

A random sample of 200 non-overlapping 20 m^2 areas of the peat bog is taken.

- (e) Using a suitable approximation, calculate the probability that at most 1 of these areas contains fewer than 70 Common Spotted-orchids.

(3)

Question 4 continued

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(Total 16 marks)

Q4



MARK SCHEMES

official mark schemes, in the same order as the questions



Question Number	Scheme		Marks
1 (a) (i)	$X \sim B(14, 0.2)$		
	$[P(X = 2) =]^{14}C_2 \times 0.2^2 \times 0.8^{12}$		M1
	$= 0.2501$ awrt 0.2501		A1
	$X \sim B(25, 0.2)$		
	$P(X > 3) = 1 - P(X \leq 3) = 1 - 0.2340$ or $1 - (0.0038 + 0.0236 + 0.0708 + 0.1358)$		M1
	$= 0.7660$ awrt 0.766		A1
			(4)
(b)(i)	$[np = 6 \Rightarrow] n = \frac{6}{0.2}$		M1
	$= 30$		A1
			(2)
(ii)	$Y \sim B(n, 0.2)$ we require $P(Y \geq 1) > 0.95$		
	$1 - P(Y = 0) > 0.95 \Rightarrow P(Y = 0) < 0.05$		M1
	$[{}^nC_0 \times 0.2^0] \times 0.8^n < 0.05$		M1
	$0.8^{14} = 0.04398... [< 0.05]$	$n > \frac{\ln 0.05}{\ln 0.8} \Rightarrow n > 13.425$	dM1
	$n = 14$		A1
			(4)
Notes			Total 10
(a) (i)	M1	For writing or using ${}^{14}C_2 \times 0.2^2 \times 0.8^{12}$ (Allow 91 for ${}^{14}C_2$)	
	A1	awrt 0.2501 NB 0.2501 with no working scores M1A1	
(ii)	M1	For writing or using $1 - P(X \leq 3)$	
	A1	awrt 0.766 NB awrt 0.766 with no working scores M1A1	
(b)(i)	M1	For use of $np = 6$ e.g $0.2n = 6$ (Allow $\geq$)	
	A1	Cao	
(ii)	M1	For writing or using $P(Y \geq 1) = 1 - P(Y = 0)$ (Allow $P(Y \geq 1) = 1 - P(Y \leq 0)$)	
	M1	For $0.8^n < 0.05$ oe (Allow $=$ or $\leq$)	
	dM1	Dependant on previous M1 For substitution of n (allow $0.8^{13} = 0.05497...$) or rearranging to $n > ...$ (Allow $=$ or $\geq$) If using logs allow any base e.g. $n > \log_{0.8} 0.05$	
	A1	Cao	

Question	Scheme	Marks
1. (a)	4	B1 (1)
(b)	$P(X=2) = 3 \times 0.2 \times 0.8^2 \left[= \frac{48}{125} = 0.384 \right]$ or $P(X=3) = 0.8^3 \left[= \frac{64}{125} = 0.512 \right]$ $[X =] 3$ is the mode	M1 A1 (2)
(c)	$P(W_1=2) = \frac{e^{-4} 4^2}{2} [=0.1465]$ and $P(X_1=2) = 3 \times 0.2 \times 0.8^2 [= \frac{48}{125} = 0.384]$ $P(W_1 \text{ and } X_1=2) = \frac{e^{-4} 4^2}{2} \times (3 \times 0.2 \times 0.8^2) [= 0.1465 \times 0.384]$ $= 0.05626564...$ awrt 0.0563	M1 M1 A1 (3)
(d)	$X_1=0$ and $W_1 > 0$, $X_1=1$ and $W_1 > 1$, $X_1=2$ and $W_1 > 2$, $X_1=3$ and $W_1 > 3$ $0.008 \times (1 - 0.0183) + 0.096 \times (1 - 0.0916) + 0.384 \times (1 - 0.2381) + 0.512 \times (1 - 0.4335)$ $= 0.677677...$ awrt 0.678	M1 M1M1 A1 (4)
		[10 marks]
Notes		
(a)	B1 cao	
(b)	M1 valid attempt at either probability. A1 3 (M1 must be scored) NB answer only with no method is M0A0	
(c)	1 st M1 both $P(W_1=2)$ Allow $(0.2381 - 0.0916)$ and $P(X_1=2)$ 2 nd M1 Poisson probability $\times$ binomial probability. If no working shown these probabilities must be correct A1 awrt 0.0563	
(d)	1 st M1 for listing at least 3 combinations. Implied by 2 nd M1. 2 nd M1 for sum of at least 3 correct products Condone consistent use of the tables for 3.5 or 4.5 rather than 4 3 rd M1 for a fully correct expression eg $0.008 \times (0.9817) + 0.096 \times (0.9084) + 0.384 \times (0.7619) + 0.512 \times (0.5665)$ condone 0.9816 and 0.7618 Allow figures to 3sf for method or awrt 0.00785 + awrt 0.0872 + awrt 0.293 + awrt 0.290 (allow 0.29) A1 awrt 0.678 Alternative: $W_1=1$ and $X_1=0$, $W_1=2$ and $X_1 < 2$, $W_1=3$ and $X_1 < 3$, $W_1 \geq 4$ $0.0733 \times 0.008 + 0.1465 \times 0.104 + 0.1954 \times 0.488 + (1 - 0.4335)$ awrt 0.000586 + awrt 0.0152 + awrt 0.0954 + awrt 0.567	

Question Number	Scheme		Marks
3(a)	$np = 3$ and $np(1-p) = 2.55$		M1
	$p = 0.15$ oe $n = 20$		A1 A1
			(3)
(b)	$[B(40, 0.2) \text{ so } E(X) = 8]$		B1
	$[P(X > 8) =] 1 - P(X \leq 8)$		M1
	$= 0.4069$ Calc: 0.40687 ...	awrt 0.407	A1
			(3)
(c)(i)	$[Po(np) =] Po(8)$		M1
	$[P(X \leq 12) =] 1 - P(X \leq 11)$		M1
	$= 0.1119$ Calc: 0.11192	awrt 0.112	A1
	because n is large and p is small		B1
(ii)			(4)
Notes			Total 10
(a)	M1	for both $np = 3$ and $np(1-p) = 2.55$ Allow q to imply $1-p$	
	A1	either $p = 0.15$ oe or $n = 20$	
	A1	both $p = 0.15$ oe and $n = 20$	
(b)	B1	for $E(X) = 8$ Condone $\mu/np = 8$ May be implied by $40 \times 0.2 = 8$ or $P(X > 8)$ or $1 - P(X \leq 8)$ or $P(X = 8)$	
	M1	for writing or using $1 - P(X \leq 8)$	
	A1	awrt 0.407 NB cao scores 3 out of 3	
(c)(i)	M1	for writing or using $Po(8)$ May be implied by awrt 0.112 or 0.888	
	M1	for writing or using $1 - P(X \leq 11)$	
	A1	awrt 0.112 (NB exact binomial gives awrt 0.1004 and would score M0M1A0) NB cao scores 3 out of 3	
(ii)	B1	allow $n > 50$ and $p < 0.2$ or equivalent worded statements. Allow p is close to 0. Do not allow because mean $\approx$ variance. Ignore any reference to np and $np(1-p)$	

Question Number	Scheme		Marks
1 (a)	$X = \text{faults in a week} \Rightarrow X \sim \text{Po}(6)$		
	$[P(X \geq x) = 0.1528 \Rightarrow P(X \leq x - 1)] = 0.8472$		M1
	Using tables $P(X \leq 8) = 0.8472 \Rightarrow x - 1 = 8$		M1
	$x = 9$		A1
			(3)
(b)	$Y = \text{faults in six weeks} \Rightarrow Y \sim N(36, 36)$		B1
	$P(Y < 32) = P\left(Z < \frac{31.5 - 36}{6}\right) [= P(Z < -0.75)]$		M1 M1
	$= 0.2266$	awrt 0.227	A1
			(4)
(c)	$W = \text{Number of poor weeks} \Rightarrow W \sim B(50, 0.1528)$		B1
	$[P(W > 1)] = 1 - P(W \leq 1)$		M1
	$= 1 - (0.8472^{50} + 50 \times 0.1528 \times 0.8472^{49})$		dM1
	$= 0.99748\dots$	awrt 0.997	A1
			(4)
	Notes		Total 11
1 (a)	M1	Writing or using $1 - P(X \leq x - 1)$	
	M1	For 0.8472 May be implied by $x - 1 = 8$	
	A1	$x = 9$	
(b)	B1	Writing or using $N(36, 36)$ (May be implied by a correct standardisation expression)	
	M1	Standardising with 30.5/31/31.5/32/32.5/39.5/40/40.5/41/41.5, their mean and standard deviation (Allow $\pm$)	
	M1	A fully correct standardisation. May be implied by ± 0.75	
	A1	awrt 0.227	
(c)	B1	Writing or using $B(50, 0.1528)$	
	M1	Writing or using $1 - P(W \leq 1)$ (Allow any letter)	
	dM1	Dependent on using binomial. Using $1 - [P(W = 0) + P(W = 1)]$ (implied by awrt 0.997 or 0.9975 or $1 - \text{awrt } 0.00257$) Using binomial may be implied by $(1 - p)^{50} + {}^nC_r \times p \times (1 - p)^{49}$ where p is a probability Condone ${}^nC_r$ missing	
	A1	awrt 0.997 or 0.9975	

Question Number	Scheme		Marks
1(a)(i)	$P(F < 3 F \sim \text{Po}(1.5)) =]0.8088$	awrt 0.809	B1
			(1)
(ii)	$P(F \dots 6) =]1 - P(F \dots 5) \text{ or } 1 - 0.9955$		M1
	$= 0.0045$	awrt 0.0045	A1
			(2)
(b)	$R \sim \text{Po}(10) \therefore P(R \leq 12) = 0.7916$	awrt 0.792	M1
	$X \sim B(15, "0.7916")$		M1
	$P(X = 10) =]^{15}C_{10} ("0.7916")^{10} (1 - "0.7916")^5$		M1
	$= 0.11405\dots$	awrt 0.114	A1
			(4)
(c)	$H \sim \text{Po}(0.4)$		M1
	$P(H = 0) =]e^{-0.4} [= 0.6703\dots \text{ or } P(H > 0) =]1 - e^{-0.4} [= 0.32967\dots]$		M1
	Profit = $2.4 \times "0.6703\dots" - 3 \times "0.32967\dots"$		dM1
	$= 0.6197$	awrt 0.62	A1
			(4)
Notes			Total 11
(a) (i)	B1	awrt 0.809	
(ii)	M1	Writing or using $1 - P(F \dots 5)$	
	A1	awrt 0.0045	
(b)	M1	For 0.792 or better	
	M1	For writing $B(15, " \text{their } 0.7916")$ May be implied by a fully correct method for $P(X = 10)$	
	M1	A correct method to find $P(X = 10)$ using a binomial distribution (implied by awrt 0.114)	
	A1	awrt 0.114	
(c)	M1	Writing or using $\text{Po}(0.4)$ e.g. $P(H = 1) = 0.268\dots$	
	M1	Correct method to find $P(H = 0)$ or $P(H > 0)$ May be implied by awrt 0.67 or $1 - \text{awrt } 0.67$	
	M1dep	Dependent on the previous method mark being awarded. Correct method to find the profit. Allow $7.4 \times "0.6703\dots" + 2 \times "0.32967\dots" - 5$	
	A1	awrt 0.62 Allow 62 p	

Question Number	Scheme		Marks
1(a)	$P(X = 2) = \binom{100}{2} \times 0.05^2 \times 0.95^{98} = 0.081181\dots$		M1
	awrt 0.0812		A1
			(2)
(b)	$\lambda = np = 5$		M1
	$P(X = 2) = \frac{e^{-5} \times 5^2}{2!} = 0.084224\dots$		
	awrt 0.0842		A1
			(2)
(c)	$\frac{"0.084224" - "0.0812"}{"0.0812"} \times 100 \text{ or } \left(\frac{"0.084224"}{"0.0812"} - 1 \right) \times 100$		M1
	awrt 3.7%		A1
			(2)
(d)	Eg Large values of n and small values of p		B1
			(1)
(e)	$P(Y = 6) = 0.1601 = \frac{e^{-\lambda} \times \lambda^6}{6!}$ and $P(Y = 7) = 0.1418 = \frac{e^{-\lambda} \times \lambda^7}{7!}$		M1
	$\frac{0.1418}{0.1601} = \frac{\frac{e^{-\lambda} \times \lambda^7}{7!}}{\frac{e^{-\lambda} \times \lambda^6}{6!}}$		M1
	$\lambda = 7 \times \frac{0.1418}{0.1601}$ oe e.g. $\frac{\text{awrt } 715}{\text{awrt } 115}$ or $7 \times 0.88(5696\dots) \div 0.16(08\dots)$		M1
	$\lambda = 6.19987\dots$		A1
	awrt $\lambda = 6.2$		(4)
Notes			Total 11
(a)	M1	attempt to find $P(X=2)$ using a correct binomial distribution. Either the calculation shown or can be implied by awrt 0.081. Allow ${}^{100}C_2$ or ${}^{100}C_{98}$ or $\frac{100!}{2!98!}$ for $\binom{100}{2}$	
	A1	awrt 0.0812	
(b)	M1	for mean = 5 stated or implied by working	
	A1	awrt 0.0842 or accept 0.0843 if tables used ($0.1247 - 0.0404 = 0.0843$) may be seen in (c)	
(c)	M1	correct method using their answers to (a) and (b) (can be implied by correct answer)	
	A1	awrt 3.7% or accept 3.75%. Condone awrt 3.8% if using 0.0843. Do not accept e.g. 0.037	
(d)	B1	any two suitable comments which refer to n /sample/trials being large/big and p /probability/chance being small/little, specific values not expected but allow values e.g. " $n > 50$, $p < 0.2$ " but not just " $np < 10$ ". Allow e.g. " $np < 10$ if $n > 50$ ". Ignore non-contradictory comments	
(e)	M1	Two correct simultaneous equations in terms of λ .	
	M1	for using ratio of probabilities for their two simultaneous equations (one must have been correct or implied). May be implied by awrt 6.2. Condone errors dealing with their Poisson expressions $\frac{e^{-\lambda} \times \lambda^7}{7!}$ provided they attempt to divide the two given probabilities either way round.	



	M1	for solving their linear equation in λ from two simultaneous equations (one must have been correct or implied) via a correct rearrangement. i.e. $7 \times \text{their } \frac{0.1418}{0.1601} \left(= \frac{9926}{1601} \text{ or } = \frac{89334}{14409} \right)$ Condone premature rounding/truncation of these numbers in the expression. May be implied by awrt 6.2.
	A1	awrt 6.2 following two correct simultaneous equations or a correct equation in λ . Do not allow following an invalid method seen e.g. using the equation solver on the individual equations leading to values of 6.20004 and 6.1998 which scores M1M0M0A0



Question Number	Scheme	Marks
7. (a)	$R \sim \text{Po}(8)$ $P(4 \leq R \leq 8) = P(R \leq 8) - P(R \leq 3) = 0.5925 - 0.0424$ $= 0.5501 = \text{awrt } \underline{0.550}$	B1 M1 A1 (3)
(b)	$H \sim \text{Po}(4)$ $P(H \leq 2) = 0.2381$ $Y \sim B(5, "0.2381")$ $P(Y = 2) = {}^5C_2 ("0.2381")^2 (1 - "0.2381")^3$ $= 0.25073\dots = \text{awrt } \underline{0.251}$	B1 B1 M1 M1 A1 (5)
(c)	$W = \text{number sold in first fifteen minutes}$ $X = \text{number sold in last forty five minutes}$ $P(W > X \mid R = 4) = \frac{P(W = 4)P(X = 0) + P(W = 3)P(X = 1)}{P(R = 4)}$ $= \frac{\frac{e^{-2} 2^4}{4!} \frac{e^{-6} 6^0}{0!} + \frac{e^{-2} 2^3}{3!} \frac{e^{-6} 6^1}{1!}}{\frac{e^{-8} 8^4}{4!}}$	$F = \text{number of muffins sold in first 15 minutes}$ $F \sim B(4, 0.25)$ $P(F > 2) =$ $P(F = 3) + P(F = 4)$ $= {}^4C_3 (0.25)^3 (0.75) + 0.25^4$ $= \frac{13}{256} \text{ (awrt 0.0508 or awrt 0.0509)}$ M1 M1 M1 A1 (4)
	Notes	[Total 12]
(a)	B1 writing or using Po(8) (may be implied by one correct probability from 0.5925, 0.0424 0.4530 or 0.0996) M1 writing or using $P(R \leq 8) - P(R \leq 3)$ A1 awrt 0.550 (calc: 0.55016....) correct answer scores 3 out of 3	
(b)	1 st B1 writing or using Po(4) 2 nd B1 awrt 0.238 1 st M1 choosing binomial distribution with $n = 5$ and their p 2 nd M1 ${}^5C_2 p^2 (1 - p)^3$ with $0 < p < 1$ A1 awrt 0.251	
(c)	1 st M1 attempt at either correct product $P(W = 4)P(X = 0)$ or $P(W = 3)P(X = 1)$ from $W \sim \text{Po}(2)$ and $X \sim \text{Po}(6)$ implied by awrt 0.0902×awrt 0.0025 or awrt 0.180×awrt 0.0149 or awrt 0.0029 2 nd M1 conditional probability with $P(R = 4)$ from $R \sim \text{Po}(8)$ on denominator implied by awrt 0.0573 seen in the denominator of a probability expression 3 rd M1 complete expression for the required probability implied (awrt 0.0902×awrt 0.0025+awrt 0.180×awrt 0.0149)/awrt 0.0573 for 3 rd M1 A1 allow awrt 0.0508 or awrt 0.0509 from use of tables	
ALT	1 st M1 identifying B(4, 0.25) 2 nd M1 $P(F = 3) + P(F = 4)$ from B(4, 0.25) 3 rd M1 $4p^3q + p^4$ from B(4, 0.25)	

Question	Scheme		Marks
5(a)	$D \sim B(8, 0.05)$		M1
	$P(D \dots 2) = 1 - P(D, , 1)$		M1
	$= 0.0572$ (calc 0.057244...) awrt 0.0572		A1
			(3)
(b)	$E \sim \text{Po}(50)$		M1
	$P(E = 45) = \frac{e^{-50} \times 50^{45}}{45!}$		M1
	$= 0.0458262\dots$ awrt 0.0458		A1
			(3)
(c)	$P(T > 16) = \frac{50 - 16}{50 - 10}$ or $1 - \frac{16 - 10}{50 - 10}$		M1
	$= 0.85$		A1
			(2)
(d)	$P(T < 40) = 0.75$		M1
	$F = \text{number of customers ringing in the next 40 seconds has } F \sim \text{Po}(4)$		
	$P(F = 0) [= e^{-4} = \text{awrt } 0.0183]$		M1
	$P(\text{Jia reaches the correct department and } F = 0) = 0.75 \times 0.95 \times e^{-4}$		dM1
	$= 0.013049\dots$ awrt 0.013		A1
			(4)
	Notes		Total 12
(a)	M1	for writing or using $B(8, 0.05)$	
	M1	for writing or using $1 - P(D, , 1)$	
	A1	awrt 0.0572	
(b)	M1	for writing or using $\text{Po}(50)$	
	M1	for $\frac{e^{-\lambda} \times \lambda^{45}}{45!}$ with any value of λ (may be implied by awrt 0.046)	
	A1	awrt 0.0458	
(c)	M1	for a correct method to find $P(T > 16)$	
	A1	for 0.85 oe correct answer scores 2 out of 2	
(d)	M1	for 0.75 oe	
	M1	for attempting $P(F = 0)$ from $\text{Po}(\lambda)$ allow any λ	
	dM1	dep on previous M1 "0.75" $\times$ 0.95 $\times$ "e ⁻⁴ "	
	A1	awrt 0.013	

Question Number	Scheme		Marks
1 (a)	[Mean =] 2.95		B1
	[Variance =] $\frac{2091}{180} - ("2.95")^2$		M1
	= 2.914.... ($s^2 = 2.930...$)	awrt 2.91 (2.93)	A1
			(3)
(b)	The mean is close to the variance		B1
			(1)
(c)	$W \sim \text{Po}(3)$		
(i)	$[P(W \leq 3) =] 1 - P(W \leq 2) = 0.5768$	awrt 0.577	M1 A1
(ii)	$[P(4 < W < 8) =] P(W \leq 7) - P(W \leq 4)$ or $P(W=5) + P(W=6) + P(W=7)$		M1
	= 0.1728...	awrt 0.173	A1
			(4)
(d)	$X \sim N(21, 21)$		B1
	$[P(X < 19) =] P\left(Z \leq \frac{18.5 - 21}{\sqrt{21}}\right) [= -0.5455...]$ or		M1M1A1
	$[P(X > 23) =] P\left(Z \geq \frac{23.5 - 21}{\sqrt{21}}\right) [= 0.5455...]$		
	= 0.2912 (calc 0.29268...)*		A1*cso
			(5)
(e)	$Y \sim B(13, "0.29")$		M1
	$[P(Y = 5) =] {}^{13}C_5 ("0.29")^5 (1 - "0.29")^8 = 0.170465$ (calc 0.17317...)	awrt 0.17	M1 A1
			(3)
Notes			Total 16
(a)	B1	cao allow exact equivalents	
	M1	Ft their mean. Using $\frac{\sum fx^2}{180} - (\text{their mean})^2$ or $\frac{180}{179} \left(\frac{\sum fx^2}{180} - (\text{their mean})^2 \right)$	
		Allow with a square root – may be implied by awrt 1.71	
	A1cso	awrt 2.91 (2.93)	
(b)	B1	cao – Allow equivalent wording. Allow mean = variance. If no values/non compatible values calculated, then B0. Condone the use of ‘closed’ for ‘close’	
(c)(i)	M1	for $1 - P(W \leq 2)$ or $1 - 0.4232$	
	A1	awrt 0.577	
(ii)	M1	for $P(W \leq 7) - P(W \leq 4)$ or $P(W=5) + P(W=6) + P(W=7)$	
		or 0.9881 – 0.8153 or 0.1008 + 0.0504 + 0.0216	
	A1	awrt 0.173	
(d)	B1	for writing or using $N(21, 21)$. May be seen in a standardisation expression.	
	M1	for standardisation ($\pm$) using their mean and sd. Allow 17.5, 18, 18.5, 19, 19.5, 22.5, 23, 23.5, 24, 24.5	
	M1	for using 19 ± 0.5 or 23 ± 0.5	
	A1	for a fully correct standardisation expression Implied by awrt ± 0.546	
	A1*	awrt 0.291 or 0.293 from correct working seen	
(e)	M1	for writing or using $B(13, 0.29)$ ft their 0.29 (Must be 2 sf or better) or for $(p)^5(1-p)^8$ ft their 0.29 (Must be 2 sf or better) . Condone $B(0.29, 13)$	
	M1	for ${}^{13}C_5 (p)^5 (1-p)^8$ oe with $0 < p < 1$ Allow 1287 for ${}^{13}C_5$	
	A1	awrt 0.17 (0.17168 from using 0.2912)	

Question Number	Scheme		Marks
2 (a)	$\left[P(D < 108) = \right] P\left(Z < \frac{108 - 112.4}{\sigma} \right) = 0.05$		
	$\Rightarrow \frac{108 - 112.4}{\sigma} = -1.6449$		M1 M1
	$\sigma = 2.6749... \text{ days (calc 2.67501...)}$		awrt 2.67/2.68 A1
			(3)
(b)	$J \sim B(25, 0.05)$		
	$\left[P(J \dots 4) = \right] 1 - P(J \leq 3) = 1 - 0.9659$		M1
	$= 0.0341 \text{ (calc 0.034090...)}$		awrt 0.0341 A1
			(2)
(c)	$T \sim \text{Po}[200 \times "0.0341"] = 6.82 \text{ (calc 6.8181...)}$		M1
	$\left[P(T \dots 2) = \right] 1 - P(X \leq 1) = 1 - \left(e^{-"6.82"} + e^{-"6.82"} \times "6.82" \right)$		M1
	$= 0.99146... \text{ calc (0.99144...)}$		awrt 0.991 dA1
			(3)
Notes			Total 8
(a) (i)	M1	for standardisation using 108(Condone 107.5), 112.4 and σ set equal to z where $1.5 < z < 2.5$	
	M1	for correct equation awrt -1.6449 (Allow awrt 1.6449 if compatible with their equation)	
	A1	awrt 2.67/2.68 NB M1 M0 A1 is possible	
(b)	M1	for $1 - P(J \leq 3)$ or $1 - 0.9659$	
	A1	awrt 0.0341	
(c)	M1	for writing or using correct Poisson model ft their part (b) May be implied by 0.00853(73)	
	M1	for writing or using $1 - \left(e^{-" \lambda "} + e^{-" \lambda "} \times " \lambda " \right)$ where $1 < \lambda < 200$ (may be implied by awrt 0.991) Allow $1 - P(X \leq 1)$ if Poisson distribution is stated or used	
	dA1	dep on both method marks being awarded awrt 0.991 (NB Binomial gives awrt 0.992 and if no working shown awrt 0.992 will gain M0M0A0) Allow 0.9915 if both M marks are awarded	

Question Number	Scheme		Marks
1 (a)	X = Number of items of litter found in a 2m^2 area of the beach So $X \sim \text{Po}(8)$		
	$P(X = 5) = \frac{e^{-8} \times 8^5}{5!}$ or $P(X, 5) - P(X, 4) = 0.1912 - 0.0996$		M1
	$= 0.09160\dots$ awrt 0.0916		A1
			(2)
(b)	Y = Number of face masks found in a 5m^2 area of the beach		
	$Y \sim \text{Po}(6)$ or $P(Y \dots 5) = 1 - P(Y, 4) = 1 - 0.2851$		M1
	$= 0.7149$ awrt 0.715		A1
			(2)
(c)	W = Number of items of litter that are not face masks found in a 20m^2 area of the beach		
	$W \sim N(56, 56)$		M1
	$P(W < 60) = P\left(Z < \frac{59.5 - 56}{\sqrt{56}}\right)$		M1 M1
	Tables $[= P(Z < 0.47)] = 0.6808$ calculator 0.68000... awrt 0.68		A1
			(4)
Notes			Total 8
(a)	M1	for use of $\frac{e^{-8} 8^5}{5!}$ or $P(X, 5) - P(X, 4)$	
	A1	awrt 0.0916 (correct answer scores 2 out of 2)	
(b)	M1	for writing or using Po(6) or for a correct probability statement $1 - P(Y, 4)$ or $P(Y \dots 5)$ e.g. $P(Y \dots 5) = 1 - P(Y, 5)$ is M0	
	A1	awrt 0.715 (correct answer scores 2 out of 2)	
(c)	M1	for writing or using $N(56, 56)$ may be seen in standardisation (may be implied by the standardisation $\frac{x - 56}{\sqrt{56}}$)	
	M1	standardising with 59.5/60/60.5, their mean and their standard deviation	
	M1	using a continuity correction $60 + 0.5 [=60.5]$ or $60 - 0.5 [=59.5]$	
	A1	awrt 0.68 (NB Use of exact Poisson gives 0.68617...and scores 0 out of 4)	

Question Number	Scheme		Marks
6			
(a)	$200(1-p)$		B1
			(1)
(b)	$(z =) \pm \frac{179.5 - 200}{\sqrt{200(1-p)}}$		M1M1 A1ft
	$z = (\pm)1.87$		B1
	$\frac{179.5 - 200}{\sqrt{200(1-p)}} = -1.87$ $* \sqrt{200(1-p)} = \frac{-20.5}{-1.87} = 10.962... *$		A1*cso
			(5)
(c)	$1-p = 0.600889... \text{ or } 200 - 200p = \frac{75076}{625} (=120.1216) \Rightarrow 200p = \frac{49924}{625} (=79.8784)$		M1
	$p = 0.39911...$		A1
	awrt $p = 0.40$		(2)
Notes			Total 8
(a)	B1	200(1-p) oe as variance. Must be seen in (a). isw if they subsequently square root to find sd or multiply out and make errors	
(b)	M1	attempt at continuity correction, sight of 179.5 or 180.5 may be implied by 19.5 or 20.5 imp. by a correct equation.	
	M1	standardisation using their Normal distribution N(200, (a)) (Note could use 220.5 for 179.5 and $z = 1.87$) implied by a correct equation. Condone use of 180 for this mark. Allow use of $200(1-p)$ in (b) if (a) is incorrect.	
	A1ft	for correct standardisation, ft their variance. Must have scored M1M1.	
	B1	awrt ± 1.87 calculator gives -1.8706	
	A1*	cso for achieving awrt 10.963 following a correct equation i.e. when their standardised expression is equated to ± 1.87 the signs must be compatible otherwise A0* If using a calculator to find the z-value look for awrt 10.959	
		$\frac{179.5 - 200}{\sqrt{200(1-p)}} = -1.87$ oe scores M1M1A1ftB1	
(c)	M1	for rearranging the given answer to part (b) to $1-p = \text{awrt } 0.6$ oe or $200p = \text{awrt } 80$ oe using the correct order of operations. Implied by awrt 0.4. May also rearrange to $p = \frac{10.96^2 - 200}{-200}$ or equivalent which implies this mark.	
	A1	awrt 0.40, use of 10.96 gives 0.399392	

Question Number	Scheme		Marks
4(a)	$X \sim B(20, 0.4)$		M1
	$P(5 \leq X < 8) = P(X \leq 7) - P(X \leq 4)$ or $0.4159 - 0.0510$		M1
	$= 0.3649$	awrt 0.365	A1
			(3)
(b)	$Y \sim N(56, 33.6)$		M1A1
	$\frac{n - 0.5 - "56"}{\sqrt{"33.6"}} = -1.98$		M1M1 B1
	$n = 45$		A1cao
			(6)
	Notes		Total 9
(a)	M1	Writing or using $B(20, 0.4)$	
	M1	For writing or using $P(X \leq 7) - P(X \leq 4)$ or $P(X = 5) + P(X = 6) + P(X = 7)$	
	A1	awrt 0.365	
(b)	M1	For writing or using $N(56, \dots)$ (May be seen in a correct standardisation)	
	A1	For writing or using $N(56, 33.6)$ (May be seen in a correct standardisation)	
	M1	For standardising (allow $\pm$) using any letter, their "56" and "33.6" and putting = to z value, where $1 < z < 2$ Condone missing ± 0.5 Condone 1 – standardisation, using any letter, their "56" and "33.6" and putting = to z value, where $1 < z < 2$	
	M1	M1 for using a continuity correction -0.5 if using n or $+0.5$ if using $n - 1$. Either in their standardisation or after finding n (but not both) No need to put = to z value	
	B1	For using ± 1.98 or better (calc gives) 1.97914...	
	A1	45 – must see a correct continuity correction or an awrt 45.02 or awrt 45.03 45 from no working is 0/6	

Question Number	Scheme	Marks
6. (i)	$z = 1.25$ $\frac{187.5 - \mu}{\sigma} = 1.25$ $187.5 - \mu = 1.25\sigma$ $\mu = 225p$ $\sigma = \sqrt{225p(1-p)}$ $(187.5 - 225p)^2 = (1.25)^2 \times 225p(1-p)$ <u>or</u> $(150 - 180p)^2 = 225p(1-p)$ (o.e.) e.g. $900(5 - 6p)^2 = 225(p - p^2) \Rightarrow 4(25 - 60p + 36p^2) = p - p^2$ Leading to $145p^2 - 241p + 100 = 0$ *	B1 M1 M1 A1 M1 M1 M1 A1*
(ii)	$[(29p - 25)(5p - 4) = 0 \Rightarrow] \quad p = 0.8 \quad \text{or} \quad p = \frac{25}{29}$ (accept: 0.862(0689...)) $[p =] \underline{0.8}$ because 0.862 gives a mean greater than 188 (oe)	M1 A1 (10)
Total 10		
Notes		
(i)	B1: for 1.25 or better (calculator gives: 1.25027...)	
	1st M1: for attempting to use a continuity correction i.e. for sight of 188 ± 0.5	
	2nd M1: for standardising using μ and σ <u>or</u> np and $\sqrt{np(1-p)}$ (Condone letter n or any integer > 0)	
	1st A1: for a correct equation with compatible signs, allow 1.250... If using a value for n it must be 225	
	3rd M1: for $\mu = 225p$ seen at any stage in the working.	
	4th M1: for $\sigma = \sqrt{225p(1-p)}$ seen at any stage in the working. Must be for σ not $\sigma^2 = 225p(1-p)$	
	5th M1: for squaring to get a quadratic equation in p	
	2nd A1*: dep on all previous Ms and use of 1.25 (with correct sign) for at least 1 correct intermediate step from a correct quadratic equation e.g one of those in scheme for 5 th M1	
(ii)	M1: for solving the quadratic correctly—leading to $p = \dots$ <u>or</u> implied by 0.8 <u>or</u> awrt 0.862	
	A1: for 0.8 <u>and</u> a correct reason to eliminate 0.862	

Question Number	Scheme		Marks
7(a)	$\frac{97.5 - \mu}{\sigma} = 1.25$	$\frac{85.5 - \mu}{\sigma} = -0.75$	M1 M1 M1 M1 M1
	$2\sigma = 12$		M1
	$\sigma = 6^*$ $[\mu = 90]$		dA1*
			(7)
(b)	$np = 90$ and $np(1 - p) = 36$		M1
	$1 - p = 0.4$		M1
	$p = 0.6$ and $n = 150$		A1
			(3)
Notes			Total 10
NB Condone use of np for μ and $\sqrt{np(1 - p)}$ for σ			
(a)	M1	For standardising using 96.5/97/97.5 and = z value, where $1 < z < 1.5$	
	M1	For standardising using 85.5/86/86.5 and = z value, where $-1 < z < -0.5$	
	M1	For use of a correct continuity correction in either equation	
	M1	For a correct z value used in either equation	
	M1	An attempt at both equations with one fully correct	
	M1	For solving simultaneously eliminating μ or σ As this is a show that question then working must be seen.	
	dA1	Dependent on all previous M marks being awarded $\sigma = 6^*$	
(b)	M1	For $np = \mu$ and $np(1 - p) = \sigma^2$ Follow through their μ (Condone $npq = \sigma^2$)	
	M1	For solving simultaneously. May be implied by a correct value for p and n	
	A1	Both $p = 0.6$ and $n = 150$	

Question Number	Scheme	Marks
1. (a)(i)	$X \sim B(50, 0.4)$ $P(X = 26) = 0.9686 - 0.9427$ or ${}^{50}C_{26} (0.4)^{26}(0.6)^{24}$ awrt 0.0259	M1 A1 (2)
(ii)	$P(X \geq 26) = 1 - P(X \leq 25)$ $= 1 - 0.9427 =$ awrt 0.0573	M1 A1 (2)
(iii)	(From tables) $k = \underline{19}$	B1 (1)
(b)(i)	$J \sim N(240, 144)$ $P(X \leq 222) \sim P(J < 222.5) = P\left(Z < \frac{222.5 - 240}{\sqrt{144}}\right)$ $P(Z < -1.46) = 1 - 0.9279 =$ awrt 0.0721 – 0.0724	M1A1 M1M1 A1 (5)
(ii)	n is large (oe) and p is close to 0.5	B1 (1)
[11 marks]		
Notes		
(a)(i)	M1 Use of tables or ${}^{50}C_{26}(p)^{26}(1-p)^{24}$ with $0 < p < 1$ allow alternative notations for ${}^{50}C_{26}$ A1 awrt 0.0259 (correct answer scores 2 out of 2)	
(ii)	M1 writing or using $1 - P(X \leq 25)$ A1 awrt 0.0573 (calc 0.0573437....) (correct answer scores 2 out of 2)	
(iii)	B1 19 cao $k \leq 19$ or $k \geq 19$ is B0	
(b)(i)	1 st M1 For writing or using $N(240, \dots)$ (May be seen in standardisation) 1 st A1 For writing or using $N(240, 144)$ (May be seen in standardisation) 2 nd M1 use of continuity correction 222 ± 0.5 3 rd M1 $\pm \left(\frac{222 \text{ or } 222.5 \text{ or } 221.5 - \text{their mean}}{\text{their sd}} \right)$ if distribution not clearly stated, then the mean and sd must be correct in the standardisation to score this mark 2 nd A1 awrt 0.0721 through to awrt 0.0724 (calc 0.0723743....) Answer in the range implies all previous marks unless clearly comes from wrong method [NB: Use of binomial distribution gives 0.0719]	
(ii)	B1 both conditions required for n is large allow in words e.g. ‘sample is large’ allow 0.4 in place of p condone ‘ $n > 30$ ’ (or any number > 30) Ignore comments about np	

Question Number	Scheme		Marks
1(a)	B(30, 0.05)		B1 (1)
(b)	The probability (oe) of an oyster surviving/not surviving is constant The survival of each oyster is independent of the others		B1 (1)
(c)(i)	${}^{30}C_{24} (0.05)^6 (0.95)^{24}$ oe		M1
	= 0.002708...	awrt 0.0027	A1
(ii)	P(Y ≥ 3) = 1 – P(Y ≤ 2) from Y ~ B(30, 0.05) or P(X ≤ 27) from X ~ B(30, 0.95)		M1
	= 1 – 0.8122		
	= 0.1878	awrt 0.188	A1
			(4)
(d)	A ~ Po(10)		B1
	P(A ≥ n) > 0.8		
	P(A ≤ n – 1) < 0.2 or P(A ≤ 6) = 0.1301....awrt 0.13 or P(A ≥ 7) = 0.8699....awrt 0.87		M1
	n = 7		A1cao
			(3)
(e)	H ₀ : p = 0.05, H ₁ : p > 0.05		B1
	Using C ~ B(25, 0.05) and P(C ≥ 4)	Using D ~ B(25, 0.95) and P(D ≤ 21)	M1
	P(C ≥ 4) = 0.0341 / CR C ≥ 4	P(D ≤ 21) = 0.0341 / CR D ≤ 21	A1
	Evidence to reject H ₀ , in the CR, significant		dM1
	There is evidence that the proportion of oysters not surviving has increased (oe)/ Jim's belief is supported.		A1cso
			(5)
			Total 14
Notes			
(a)	B1	Must include B(inomial), n = 25 and p = 0.05. Do not allow p = 0.95 in part (a)	
(b)	B1	For either correct assumption in context. Ignore extraneous non-contradicting comments.	
(c)(i)	M1	allow ${}^{30}C_6$ oe or P(X ≤ 6) – P(X ≤ 5) with one correct probability	
	A1	awrt 0.0027 (correct answer scores 2 out of 2)	
(ii)	M1	Writing/using 1 – P(Y ≤ 2) with B(30, 0.05) or writing/using P(X ≤ 27) with B(30, 0.95)	
	A1	awrt 0.188 (correct answer scores 2 out of 2)	
(d)	B1	Writing or using Po(10) (sight of 0.1301 or 0.8699 can imply this mark)	
	M1	Allow P(A < n) < 0.2 or P(A < 7) = awrt 0.13 or P(A > 6) = awrt 0.87	
	A1cao	n = 7 which must come from use of Po(10) or N(10, 9.5)	
	Note:	Use of normal approx. with μ = 10 and σ ² = 9.5 leading to n < 7.4...can score M1 Exact binomial gives P(A ≤ 6) = 0.14 / P(A ≥ 7) = 0.86 scores B0M0A0	
(e)	B1	Both hypotheses correct (allow use of p or π). Allow H ₀ : p = 0.95, H ₁ : p < 0.95	
	M1	Using B(25, 0.05) and writing/using P(C ≥ 4) or if CR given P(C ≥ 3) using B(25, 0.95) and writing/using P(D ≤ 21) or if CR given P(D ≤ 20)	
	A1	Correct probability to 3sf (must not go on and give incorrect CR) or correct CR (ignore upper tail)	
	dM1	(dep on 1 st M1) A correct non-contextual statement (do not allow contradicting non-contextual comments) which is consistent with their prob and 0.05 (If not stated, may be implied by A1)	
	A1cso	All previous marks must be awarded. Correct contextual conclusion with bold words (oe)	
SC:	2-tail	Use of two-tailed test can score max: B1M1A1M1A0, but must not reject H ₀ for 2 nd M1	

Question Number	Scheme	Marks												
Throughout the paper the candidates may use different letters to the ones given in the mark scheme.														
1. (a)	$[X \sim \text{the number of pansy seeds that do not germinate or } Y = \text{the number...that do germinate}]$ $X \sim B(20, 0.05)$ or $Y \sim B(20, 0.95)$	B1												
(i)	$P(X \leq 4) - P(X \leq 2) = 0.9974 - 0.9245$ or $\binom{20}{3} 0.05^3 \times 0.95^{17} + \binom{20}{4} 0.05^4 \times 0.95^{16} = 0.05958... + 0.01332...$ $= 0.072909...$ awrt 0.0729	M1 A1												
(ii)	$P(X \leq 1)$ or $P(Y \geq 19) = 20 \times (0.95)^{19} (0.05) + (0.95)^{20}$ $= 0.7358$ or $= 0.735839...$ awrt 0.736	M1 A1 (5)												
(b)	[Let W = no. of packets where $Y > 18$] $P(W = 5) = (0.7358...)^5$ $= 0.21573...$ awrt 0.216	M1 A1 (2)												
(c)	$H_0 : p = 0.05$ $H_1 : p > 0.05$	B1 (1)												
(d)	$[V = \text{no. of seeds that do not germinate } V \sim B(100, 0.05) \text{ approximates to } V \sim \text{Po}(5)]$ <table border="1"> <tr> <td></td><td>CR for 1-tail in (c)</td><td>CR for 2-tail in (c)</td></tr> <tr> <td>$P(V \geq 8) = 1 - P(V \leq 7)$</td><td>$P(V \geq 9) = 0.0681$</td><td>$P(V \geq 10) = 0.0318$</td></tr> <tr> <td>$= 1 - 0.8666$</td><td>$P(V \geq 10) = 0.0318$</td><td>$P(V \geq 11) = 0.0137$</td></tr> <tr> <td>$= 0.1334$</td><td>CR $V \geq 10$ oe</td><td>CR $V \geq 11$ oe</td></tr> </table> Accept H_0 or not significant or 8 does not lie in the critical region Data consistent with Spany's claim or Insufficient evidence for Jem's belief or insufficient evidence that percentage of seeds not germinating is more than 5% (o.e.)		CR for 1-tail in (c)	CR for 2-tail in (c)	$P(V \geq 8) = 1 - P(V \leq 7)$	$P(V \geq 9) = 0.0681$	$P(V \geq 10) = 0.0318$	$= 1 - 0.8666$	$P(V \geq 10) = 0.0318$	$P(V \geq 11) = 0.0137$	$= 0.1334$	CR $V \geq 10$ oe	CR $V \geq 11$ oe	M1A1 M1 A1 dM1 A1cso (6)
	CR for 1-tail in (c)	CR for 2-tail in (c)												
$P(V \geq 8) = 1 - P(V \leq 7)$	$P(V \geq 9) = 0.0681$	$P(V \geq 10) = 0.0318$												
$= 1 - 0.8666$	$P(V \geq 10) = 0.0318$	$P(V \geq 11) = 0.0137$												
$= 0.1334$	CR $V \geq 10$ oe	CR $V \geq 11$ oe												
		Total 14												
Notes														
(a)	B1: writing or using $B(20, 0.05)$ [Allow $Y \sim B(20, 0.95)$ if Y is clearly defined]. Implied by 1 correct prob.													
(i)	M1: for $P(X \leq 4) - P(X \leq 2)$ and one correct prob. or $P(X = 3) + P(X = 4)$ and 1 correct prob.													
(ii)	M1: for $P(X \leq 1)$ or $[20] \times (0.95)^{19} (0.05) + (0.95)^{20}$ - condone missing 20													
(b)	M1: for $(\text{their(a)(ii)})^5$													
(c)	B1: both hypotheses correct with p or π													
(d)	1st M1: for realising a Poisson approximation is appropriate. NB $\text{Po}(95)$ is M0A0 1st A1: writing or using $V \sim \text{Po}(5)$ i.e correct mean for the Poisson. 2nd M1: for writing or using $1 - P(V \leq 7)$ or $P(V \leq 7) = 0.8666$ or writing $P(V \geq 10) = 0.0318$ or $P(V \geq 9) = 0.0681$ or $P(V \geq 11) = 0.0137$ leading to a CR. Implied by correct CR or probability = awrt 0.133 2nd A1: for awrt 0.133 or $V \geq 10$ oe (e.g. $V > 9$) or $V \geq 11$ oe allow any letter but CR must match part(c) 3rd dM1: dep on 2 nd M1. fit their CR or probability. A correct statement based on comparing 8 with their CR or their prob with 0.05 or 0.025 [condone $0.866 < 0.95$] – contradicting non-contextual comments M0 3rd A1 cso: all previous marks must be awarded. A correct statement in context. Need Bold words . NB award M1A1 for a correct contextual statement on its own. If there are no hypotheses or they are the wrong way around, then 3 rd M0 3 rd A0 Normal approximation: Award marks in pairs with 2, 4 or 6 marks available													
SC1	Sight of $N(5 \text{ or } 95, \sqrt{4.75}^2)$ M1A1; probability awrt 0.125/6 M1A1; Correct contextual concl' dM1A1													
SC2	No approximation: Use of $B(100, 0.05)$ M0A0; probability awrt 0.128 or CR ≥ 10 M1A1; then M0A0													

Question Number	Scheme		Marks
5 (a)	B(n , 0.045)		B1
			(1)
(b)	<u>Applicants</u> are independent (no identical twins) or the <u>proportion/probability</u> identified as <u>colour blind</u> does not change over time		B1
			(1)
(c)	B(120, 0.045) $\Rightarrow$ Po(5.4)		B1
	$P(X = 5) = \frac{e^{-5.4} \times 5.4^5}{5!}$		M1
	= 0.1728... awrt 0.173		A1
			(3)
(d)	Binomial with large n		B1
	and very small p		B1
			(2)
(e)	$H_0 : p = 0.75 \quad H_1 : p \neq 0.75$		B1
	B(96, 0.75) $\Rightarrow$ N(72,18)		B1
	$Z = \frac{67.5 - 72}{\sqrt{18}} \quad \text{or} \quad \frac{x \pm 0.5 - 72}{\sqrt{18}}$		M1
	= -1.06066... or $\frac{x + 0.5 - 72}{\sqrt{18}} < -1.96$ or $\frac{x - 0.5 - 72}{\sqrt{18}} > 1.96$		A1
	P($z < -1.06$) = 0.1444... / 0.1446 or CR < 63.2 awrt 0.144 or 0.145		A1
	There is insufficient evidence to reject H_0		dM1
	Insufficient evidence against Jaymini's claim		A1
			(7)
ALT	Let p be the probability of an applicant fail to become a pilot.		
	$H_0 : p = 0.25 \quad H_1 : p \neq 0.25$		B1
	B(96, 0.25) $\Rightarrow$ N(24,18)		B1
	$Z = \frac{28.5 - 24}{\sqrt{18}} \quad \text{or} \quad \frac{x \pm 0.5 - 24}{\sqrt{18}}$		M1
	= 1.06066... or $\frac{x + 0.5 - 24}{\sqrt{18}} < -1.96$ or $\frac{x - 0.5 - 24}{\sqrt{18}} > 1.96$		A1
	P($z > 1.06$) = 0.1444... / 0.1446 or CR > 32.8 awrt 0.144 or 0.145		A1
	There is insufficient evidence to reject H_0		dM1
	Insufficient evidence against Jaymini's claim		A1
			(7)
	Notes		Total 14
5 (a)	B1	For binomial with correct parameters n and 0.045	
(b)	B1	For one of the given reasons. Must have context Allow equivalent statements Do not allow number for proportion/probability	
(c)	B1	Using or writing Po(5.4)	
	M1	For $\frac{e^{-\lambda} \lambda^5}{5!}$ with any value for λ	
	A1	awrt 0.173	
		NB A correct answer with no incorrect working scores 3/3	
(d)	B1	n is large (Allow number of trials for n)	

	B1	p is small (Allow probability for p)
(e)	B1	Both hypotheses correct in terms of p or π Must be attached to H_0 and H_1
	B1	For writing or using $N(72, 18)$ (May be implied by a correct standardisation expression)
	M1	Standardising using 67.5 or 67 or 66.5 or $x \pm 0.5$ with their mean and standard deviation (Allow $\pm$)
	A1	awrt -1.06 (may be implied by awrt 0.144 or 0.145) or a correct standardisation with ± 1.96 (ignore incorrect inequality symbol and allow =)
	A1	Using a probability route: awrt 0.144 or 0.145 or critical value of $z = \pm 1.96$ Using a critical region route: $CR < 63.2$
	dM1	Dependent on M1 A1. A correct statement – no context needed but do not allow contradicting non contextual comments. (Ignore any comparisons)
	A1	Correct conclusion in context. Must include the word claim. If they give an answer that refers to the claim then they must include the words applicants (oe), and pilots. No hypotheses then A0
		NB Award M1 A1 for a correct contextual statement on its own
ALT	B1	Both hypotheses correct in terms of p or π Must be attached to H_0 and H_1
	B1	For writing or using $N(24, 18)$ (May be implied by a correct standardisation expression)
	M1	Standardising using 28.5 or 29 or 29.5 or $x \pm 0.5$ with their mean and standard deviation (Allow $\pm$)
	A1	awrt 1.06 (may be applied by awrt 0.144 or 0.145) or a correct standardisation with ± 1.96 (ignore incorrect inequality symbol and allow =)
	A1	Using a probability route: awrt 0.144 or 0.145 or critical value of $z = \pm 1.96$ Using a critical region route: $CR < 32.8$
	dM1	Dependent on M1 A1. A correct statement – no context needed but do not allow contradicting non contextual comments. (Ignore any comparisons)
	A1	Correct conclusion in context. Must include the word claim. If they give an answer that refers to the claim then they must include the words applicants (oe), and pilots. No hypotheses then A0
		NB Award M1 A1 for a correct contextual statement on its own

Question Number	Scheme		Marks
5 (a)	$X \sim \text{Po}(5)$		
	$P(X \leq 5) = 0.6160$	awrt 0.616	M1 A1
			(2)
(b)	$X \sim B(4, "0.616")$		B1ft
	$P(X < 2) = P(X \leq 1)$		M1
	$= 0.384^4 + 4 \times 0.616 \times 0.384^3$		M1
	$= 0.16126\dots$	awrt 0.161	A1
			(4)
(c)	$X = \text{The number of defects per } x \text{ meters}$		
	$X \sim N\left(\frac{x}{16}, \frac{x}{16}\right)$		B1
	$P(X < 26) = P\left(Z < \frac{25.5 - \frac{x}{16}}{\sqrt{\frac{x}{16}}}\right) = 0.5398$		M1
	$\frac{25.5 - \frac{x}{16}}{\frac{1}{4}\sqrt{x}} = 0.1$		B1 M1 A1ft
	$\frac{1}{16}x + \frac{1}{40}\sqrt{x} - 25.5 = 0 \rightarrow \sqrt{x} = 20 \text{ (or } \sqrt{x} = -20.4)$		M1
	$(\sqrt{x})^2 = 20^2$		M1
	$x = 400$		A1
			(8)
Notes			Total 14
(a)	M1	For writing or using $P(X \leq 5)$	
	A1	awrt 0.616	
(b)	B1ft	For $X \sim B(4, 0.616)$ Follow through their part (a). May be implied by a correct ft expression for the 2 nd M1	
	M1	For writing or using $P(X \leq 1)$ (May be implied by 2 nd M1)	
	M1	For $= [{}^4C_0](1-p)^4 + {}^4C_1 \times p \times (1-p)^3 \quad 0 < p < 1$	
	A1	awrt 0.161 correct answer on its own scores 4 out of 4	
(c)	B1	For $X \sim N\left(\frac{x}{16}, \frac{x}{16}\right)$ May be implied by values in standardisation.	
	M1	For use of a continuity correction either 25.5 or 26.5 (Allow 24.5)	
	B1	$z = \pm 0.1$ Allow calculator value if seen $\pm 0.0999(2986\dots)$	
	M1	Standardising using either 24.5 or 25 or 25.5 or 26 or 26.5 and equate to a z value. Follow through their mean and variance	
	A1ft	A correct equation with compatible signs ft their mean and variance provided mean = variance	
	M1	For solving their 3 term equation by factorising, completing the square or use of formula. May be implied by -20.4 , otherwise if answer is incorrect working must be shown.	
	M1	For correct squaring of both sides. May be implied by 416[.16] from correct equation This mark may be scored prior to solving a 3TQ, e.g. $\left(25.5 - \frac{x}{16}\right)^2 = \left(\frac{1}{40}\sqrt{x}\right)^2$. Do not award if squaring each individual term	
	A1	$x = 400$ only. This is dependent upon all previous marks in (c).	
	SC	Use of $X \sim N\left(\frac{x}{16}, \frac{15x}{256}\right)$ leading to $x = 400$ scores max B0M1B1M1A0M1M1A0	



Question Number	Scheme		Marks
4(a)	Common Spotted-orchids occur singly/randomly/independently		B1
			(1)
(b)(i)	$S \sim \text{Po}(4.5)$		
	$P(S = 6) = \frac{e^{-4.5} 4.5^6}{6!}$ or $P(S \leq 6) - P(S \leq 5)$		M1
	$= 0.1281\dots$	awrt 0.128	A1
(ii)	$P(4 < S < 10) = P(S \leq 9) - P(S \leq 4)$ or $0.9829 - 0.5321$		M1
	$= 0.4508$	awrt 0.451	A1
			(4)
(c)	$H_0 : \lambda = 9 \quad H_1 : \lambda > 9$		B1
	$M \sim \text{Po}(9) \quad P(M \geq 11) = 1 - P(M \leq 10) \quad \text{or} \quad P(M \geq 15) = 0.0415$		M1
	$= 0.294$	or CR $M \geq 15$	A1
	Accept H_0 or insignificant or 11 does not lie in the critical region		dM1
	There is insufficient evidence to support Juan's belief		A1
			(5)
(d)	$T \sim N(90, 90)$		B1
	$P(T < 70) = P\left(Z < \pm \left(\frac{69.5 - 90}{\sqrt{90}}\right)\right)$ or $P(Z < \pm 2.160\dots)$		awrt 2.16 M1
	$= 0.0154$	awrt 0.0154	A1
			(3)
(e)	$V \sim \text{Po}(200 \times 0.012) = \text{Po}(2.4) \quad V \sim \text{Po}(2.4)$		M1
	$P(V = 0) + P(V = 1) = e^{-2.4}(1 + 2.4)$		dM1
	$= 0.30844\dots$	awrt 0.308	A1
			(3)
	Notes		Total 16
4(a)	B1	One of the given reasons. No context needed	
(b)(i)	M1	For $\frac{e^{-\lambda} \lambda^6}{6!}$ with any value for λ or writing or using $P(S \leq 6) - P(S \leq 5)$	
	A1	awrt 0.128	
(ii)	M1	Writing or using $P(S \leq 9) - P(S \leq 4)$	
	A1	awrt 0.451	
(c)	B1	Both hypotheses correct. Must be attached to H_0 and H_1 in terms of λ or μ . Allow 4.5 instead of 9.	
	M1	Writing or using $\text{Po}(9)$ and $1 - P(M \leq 10)$ or $P(M \geq 15) = 0.0415$ oe Implied by correct CR or awrt 0.3 or 0.29... or better (0.2940...)	
	A1	0.3 or 0.29... or better (0.2940...) or $M \geq 15$ oe SC: Condone $P(X \leq 10) = 0.7$ or better (0.705988....) for M1A1	
	dM1	Dep on M1 A1. A correct statement– no context needed but do not allow contradicting non contextual comments. Allow opposite conclusion if 2-tail hypotheses given.	
	A1	Correct conclusion. If H_0 is 2- tail the opposite conclusion must be given. No hypotheses or $H_0 \lambda < 9$ gets A0. Allow claim instead of belief. Alternative: There is insufficient evidence to support hat the number of Common Spotted-orchids has increased/ /is not 9/has changed oe (with the bold words included).	
(d)	B1	Writing or using $N(90, 90)$	
	M1	Standardising with 68.5 or 69.5 or 70.5 and their mean and sd	
	A1	awrt 0.0154 NB Poisson gives 0.01275...	
(e)	M1	Writing or using $\text{Po}(200 \times 0.012)$ Allow $\text{Po}(200 \times \text{"their d"})$	
	dM1	Dependent on using Poison. For using / writing $P(V = 0) + P(V = 1)$ or $e^{-\lambda}(1 + \lambda)$ or $P(V \leq 1)$ oe	
	A1	awrt 0.308 NB Binomial gives 0.3066	