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EDEXCEL INTERNATIONAL A LEVEL MATHS: QUESTIONS BY TOPIC

Hypothesis Testing (S2.3)

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

20 questions · 252 marks · Mark schemes included

Past papers October 2020 - June 2025 · 1 sub-topic

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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

20 questions · 252 marks · 1 sub-topic

SUB-TOPIC S2.3a

HYPOTHESIS TESTS & CRITICAL REGIONS

Sub-topic S2.3a · 20 questions · 252 marks · lowest tariff first



Question 3 continued

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Question 3 continued

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Question 3 continued

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(Total 9 marks)

Q3



Question 4 continued

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Question 4 continued

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Question 4 continued

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(Total for Question 4 is 9 marks)



3. A company produces packets of sunflower seeds. Each packet contains 40 seeds. The company claims that, on average, only 35% of its sunflower seeds do not germinate.

A packet is selected at random.

- (a) Using a 5% level of significance, find an appropriate critical region for a two-tailed test that the proportion of sunflower seeds that do not germinate is 0.35. You should state your hypotheses clearly and state the probability, which should be as close as possible to 2.5%, for each tail of your critical region.

(4)

- (b) Write down the actual significance level of this test.

(1)

Past records suggest that 2.8% of the company's sunflower seeds grow to a height of more than 3 metres.

A random sample of 250 of the company's sunflower seeds is taken and 11 of them grow to a height of more than 3 metres.

- (c) Using a suitable approximation test, at the 5% level of significance, whether or not there is evidence that the proportion of sunflower seeds that grow to a height of more than 3 metres is now greater than 2.8%
State your hypotheses clearly.

(5)







(Total for Question 3 is 10 marks)



5. A meteor shower occurs for several weeks every summer. One Monday night during this meteor shower, Chris goes out to look for meteors and sees an average of 15 meteors per hour.

- (a) Find the probability that in a random 20-minute period of time on this Monday night Chris sees

- (i) at least 6 meteors
- (ii) no more than 3 meteors.

(4)

Chris is told by the local astronomy club that there will be more meteors to be seen per hour on the following Friday night than on Monday night.

Chris decides to use data from the Friday night to test, at a 5% significance level, if there is evidence to support the claim of the local astronomy club.

Chris plans to spend 30 minutes looking for meteors on the Friday night.

- (b) Write down suitable null and alternative hypotheses that Chris can use.

(1)

- (c) Find the critical region for the test and state its associated probability.

(3)

On the Friday night, Chris sees 12 meteors in the 30 minutes.

- (d) State the conclusion to the test that can be made using this observation. Give a reason for your answer.

(2)



(Total for Question 3 is 10 marks)



- (f) Comment on this finding in the light of your critical region found in part (d) (2)





Question 2 continued

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(Total for Question 2 is 16 marks)



(Total for Question 1 is 11 marks)







(Total for Question 3 is 11 marks)



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 9 is 11 marks)



3. Rowan believes that 35% of type A vacuum tubes shatter when exposed to alternating high and low temperatures.

Rowan takes a random sample of 15 of these type *A* vacuum tubes and uses a two-tailed test, at the 5% level of significance, to test his belief.

- (a) Give **two** assumptions, in context, that Rowan needs to make for a binomial distribution to be a suitable model for the number of these type *A* vacuum tubes that shatter when exposed to alternating high and low temperatures.

(2)

- (b) Using a binomial distribution, find the critical region for the test.
You should state the probability of rejection in each tail, which should be as close as possible to 0.025

(3)

- (c) Find the actual level of significance of the test based on your critical region from part (b)

(1)

Rowan records that in the latest batch of 15 type *A* vacuum tubes exposed to alternating high and low temperatures, 4 of them shattered.

- (d) With reference to part (b), comment on Rowan's belief. Give a reason for your answer.

(1)

Rowan changes to type B vacuum tubes. He takes a random sample of 40 type B vacuum tubes and finds that 8 of them shatter when exposed to alternating high and low temperatures.

- (e) Test, at the 5% level of significance, whether or not there is evidence that the proportion of type *B* vacuum tubes that shatter when exposed to alternating high and low temperatures is lower than 35%
You should state your hypotheses clearly.

(5)







(Total for Question 9 is 12 marks)



2. A multiple-choice test consists of 25 questions, each having 5 responses, only one of which is correct.

Each correct answer gains 4 marks but each incorrect answer loses 1 mark.

Sam answers all 25 questions by choosing at random one response for each question.

Let X be the number of correct answers that Sam achieves.

- (a) State the distribution of X

(1)

Let M be the number of marks that Sam achieves.

- (b) (i) State the distribution of M in terms of X

- (ii) Hence, show clearly that the number of marks that Sam is expected to achieve is zero.

(4)

In order to pass the test at least 30 marks are required.

- (c) Find the probability that Sam will pass the test.

(3)

Past records show that when the test is done properly, the probability that a student answers the first question correctly is 0.5

A random sample of 50 students that did the test properly was taken.

Given that the probability that more than n but at most 30 students answered the first question correctly was 0.9328 to 4 decimal places,

- (d) find the value of n

(4)





(Total for Question 2 is 12 marks)



4. (a) Given n is large, state a condition for which the binomial distribution $B(n, p)$ can be reasonably approximated by a Poisson distribution.

(1)

A manufacturer produces candles. Those candles that pass a quality inspection are suitable for sale.

It is known that 2% of the candles produced by the manufacturer are not suitable for sale.

A random sample of 125 candles produced by the manufacturer is taken.

- (b) Use a suitable approximation to find the probability that no more than 6 of the candles are **not** suitable for sale.

(4)

The manufacturer also produces candle holders.

Charlie believes that 5% of candle holders produced by the factory have minor defects.

The manufacturer claims that the true proportion is less than 5%

To test the manufacturer's claim, a random sample of 30 candle holders is taken and none of them are found to contain minor defects.

- (c) (i) Carry out a test of the manufacturer's claim using a 5% level of significance. You should state your hypotheses clearly.

(5)

- (ii) Give a reason why this is **not** an appropriate test.

(1)

Ashley suggests changing the sample size to 50

- (d) Comment on whether or not this change would make the test appropriate. Give a reason for your answer.

(2)



Question 4 continued

Lined area for writing the answer to Question 4 continued.



Question 4 continued

Lined area for writing the answer to Question 4 continued.



(Total for Question 4 is 15 marks)



Question 1 continued

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Question 1 continued

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Question 1 continued

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(Total for Question 1 is 13 marks)



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1. A research project into food purchases found that 35% of people who buy eggs do **not** buy free range eggs.

A random sample of 30 people who bought eggs is taken. The random variable F denotes the number of people who do **not** buy free range eggs.

- (a) Find $P(F \geq 12)$
- (2)**

- (b) Find $P(8 \leq F < 15)$
- (2)**

A farm shop gives 3 loyalty points with every purchase of free range eggs. With every purchase of eggs that are **not** free range the farm shop gives 1 loyalty point. A random sample of 30 customers who buy eggs from the farm shop is taken.

- (c) Find the probability that the total number of points given to these customers is less than 70
- (3)**

The manager of the farm shop believes that the proportion of customers who buy eggs but do **not** buy free range eggs is more than 35%

In a survey of 200 customers who buy eggs, 86 do **not** buy free range eggs.

Using a suitable test and a normal approximation,

- (d) determine, at the 5% level of significance, whether there is evidence to support the manager's belief. State your hypotheses clearly. (7)



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Question 1 continued

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(Total 14 marks)

Q1

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7. When purchasing a pair of glasses from an optician, customers are offered insurance to cover accidental damage.

Past records from the optician show that 30% of customers buy insurance when they purchase a pair of glasses.

In a random sample of 40 customers who have purchased a pair of glasses, X represents the number who buy insurance.

- (a) State a suitable model for the distribution of X (1)

- (b) State a necessary assumption for the model in part (a) to be valid. (1)

The probability that fewer than r customers who have purchased a pair of glasses buy insurance is less than 0.05

- (c) Find the largest possible value of r (2)

A second random sample of 200 customers who have purchased a pair of glasses is taken.

Using a normal approximation, the probability that at least t of these 200 customers buy insurance is 0.9474, correct to 4 decimal places.

- (d) Find the value of t
You must show your working. (5)

The optician decided to introduce a special offer in which customers who purchase a pair of glasses get the first three months of insurance free if they buy insurance.

Following this, a random sample of 25 customers who purchase a pair of glasses is taken and 11 of them buy insurance.

- (e) Test, at the 10% level of significance, whether or not there is evidence that the proportion of customers who buy insurance when purchasing a pair of glasses has increased. State your hypotheses clearly. (5)



Question 7 continued

Lined area for writing the answer to Question 7 continued.





TOTAL FOR PAPER IS 75 MARKS



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Question 3 continued

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Question 3 continued

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(Total 15 marks)

Q3	



Question 2 continued

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(Total for Question 2 is 15 marks)

Question 4 continued

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Question 4 continued

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Question 4 continued

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(Total 15 marks)

Q4



- 3 Jian owns a large group of shops. She decides to visit a random sample of the shops to check if the stocktaking system is being used incorrectly.

(a) Suggest a suitable sampling frame for Jian to use.

(1)

(b) Identify the sampling units.

(1)

(c) Give one advantage and one disadvantage of taking a sample rather than a census.

(2)

Jian believes that the stocktaking system is being used incorrectly in 40% of the shops.

To investigate her belief, a random sample of 30 of the shops is taken.

(d) Using a 5% level of significance, find the critical region for a two-tailed test of Jian's belief.

You should state the probability in each tail, which should each be as close as possible to 2.5%

(3)

The total number of shops, in the sample of 30, where the stocktaking system is being used incorrectly is 20

(e) Using the critical region from part (d), state what this suggests about Jian's belief. Give a reason for your answer.

(1)

Jian introduces a new, simpler, stocktaking system to all the shops.

She takes a random sample of 150 shops and finds that in 47 of these shops the new stocktaking system is being used incorrectly.

(f) Using a suitable approximation, test, at the 5% level of significance, whether or not there is evidence that the proportion of shops where the stocktaking system is being used incorrectly is now **less than** 0.4

You should state your hypotheses and show your working clearly.

(7)

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 9 is 15 marks)







Question 5 continued

(Total for Question 5 is 16 marks)



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Question 3 continued

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Question 3 continued

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(Total 17 marks)

Q3



MARK SCHEMES

official mark schemes, in the same order as the questions



Question Number	Scheme		Marks
3 (a)	We can assume breakdowns are [rare], independent events occurring at a constant rate.		B1
			(1)
(b)	$H_0 : \lambda = 8 \quad H_1 : \lambda \neq 8$		B1
			(1)
(c)	$X \sim \text{Po}(8)$		
	$P(X \leq 2) = 0.0138$ oe $P(X \leq 3) = 0.0424$ oe		M1
	$P(X \geq 14) = 0.0342$ oe $P(X \geq 15) = 0.0173$ oe		M1
	$X \leq 2 \cup X \geq 15$ oe		A1
			(3)
(d)	“0.0138” + “0.0173”		M1
	=“0.0311”		A1ft
			(2)
(e)	“[4 is] not in the critical region”		M1
	So there is insufficient evidence that refurbishment has changed the mean breakdown rate		A1
			(2)
	Notes		Total 9
3 (a)	B1	A correct statement which include the words independent or constant rate or singly. No context needed	
(b)	B1	Both hypotheses correct. Must be attached to H_0 and H_1 in terms of λ or μ .	
(c)	M1	Use of Po(8) to find the lower critical value. May be implied by either 0.0138 or 0.0424 or $X \leq 2$ if no probabilities shown (Calculator values: 0.01375... and 0.04238...)	
	M1	Use of Po(8) to find the upper critical value. May be implied by 0.0342 or 0.0173 or 0.9658 or 0.9827 or $X \geq 15$ if no probabilities shown (Calculator values: 0.03418... and 0.01725... and 0.96581... and 0.98274...)	
	A1	$X \leq 2$ oe $[\cup] X \geq 15$ oe Condone the use of and/or Do not allow as probability statements Allow $[0, 2]$ or $[0, 3]$ and $[15, \infty]$ or $[15, \infty)$ or $(14, \infty]$ or $(14, \infty)$	
(d)	M1	Adding the two probabilities for their critical region	
	A1ft	0.0311 Allow 3.11 or awrt 3.1[0] or awrt 0.031[0] ft their critical region	
		NB 3.11 or 0.0311 or awrt 3.1[0] or awrt 0.031[0] will score 2/2	
(e)	M1	A correct statement ft their critical region e.g. Do not reject H_0 /Accept H_0 /not significant – no context needed but do not allow contradicting non contextual comments	
	A1	Correct conclusion in context. Must include rate/number of breakdown (Allow decreased for changed)	
		NB Award M1 A1 for a correct contextual statement on its own	

Question	Scheme	Marks
4. (a)	$[P(Y = 0) < 0.05]$	
	$(1 - 0.07)^n < 0.05$	M1
	$n \log(0.93) < \log(0.05)$	M1
	$n > 41.28 \dots \quad n = 42$	A1
		(3)
(b)	$H_0: p = 0.08 \quad H_1: p \neq 0.08$	B1
	$X \sim B(75, 0.08) \rightarrow \text{Po}(6)$	M1
	$P(X \leq 11) = 1 - P(X \geq 10)$	M1
	$= 1 - 0.9574 = 0.0426 [> 0.025]$	A1
	Do not Reject H_0 or not significant or 11 does not lie in the CR	dM1
	There is not significant evidence to suggest that the proportion of pears weighing more than 180g has changed	A1
		(6)
		[9 marks]
	Notes	
(a)	1 st M1 For 0.93^n or 0.93^{42} or 0.93^{41} 2 nd M1 for $n \log(0.93) < \log(0.05)$ or $\log_{0.93} 0.05$, n Allow = or „ condone $>$ or ... or $0.93^{42} = 0.0474 \dots$ or 0.0475 (min 4 dp) Implied by $41.28 \dots$ or awrt 41.3 A1 42 cao NB An answer of 42 gains 3/3	
	SC condone for M1 M0 A0 ($[e^{-3}] = 0.04978 \dots$ (min 4dp) and $-0.07n = -3$)	
(b)	B1 both hypotheses correct (may use p or π but do not allow $p(x)$) Allow 8% connected to H_0 and H_1 correctly 1 st M1 writing or using Poisson approximation with mean 6. 2 nd M1 for writing or using $1 - P(X \geq 10)$ or for a CR method (must give a CR) giving $P(X \geq 11) = 0.9799$ or $P(X \leq 12) = 0.0201$ Implied by awrt 0.0426 or correct CR 1 st A1 for 0.0426 or CR: $X \leq 12$ ignore lower CR. NB M1A1 for $P(X \geq 10) = 0.9574$ on its own 3 rd dM1 Independent of their hypotheses dependent on 2 nd M1 but A correct statement i.e. not significant/do not reject H_0 /Not in CR/reject H_1 Do not allow non-contextual conflicting statements. 2 nd A1 For a correct contextual statement. Need proportion oe and changed oe Allow the farmers belief (oe) is not supported (bold words) Do not accept contradicting statements. No hypotheses is A0 NB Award d M1A1 for a correct contextual statement on its own SC1: Use of one-tailed test may score B0M1M1A1M1A0 for rejecting H_0 SC2: Use of Binomial throughout max (3/6) B1M0M1A0dM1A0 SC3: normal approximation prob = 0.0277 (maximum 3 out of 6) B1 M0 M1 for writing or using $1 - P(X \geq 10.5)$ allow $<$ implied by awrt $0.027/0.028$ A0 dM1A0	

Question Number	Scheme		Marks
3(a)	$H_0: p = 0.35 \quad H_1: p \neq 0.35$		B1
	$P(X, 8) = \text{awrt } 0.0303$ or $P(X \dots 21) = \text{awrt } 0.0173$ or $P(X, 20) = \text{awrt } 0.9827$		M1
	$[P(X, 8) =] \text{awrt } 0.0303$ and $[P(X \dots 21) =] \text{awrt } 0.0173$		A1
	CR $X, 8$ and $X \dots 21$		A1
			(4)
(b)	0.0476		B1ft
			(1)
(c)	$H_0: p = 0.028 \quad H_1: p > 0.028$		B1
	$Y \sim B(250, 0.028) \Rightarrow Y \sim \text{Po}(7)$		M1
	$P(Y \dots 11) = 1 - P(Y, 10)$ or $P(Y \dots 13) = 1 - 0.973$		M1
	$= 0.0985$ or Critical region $Y \dots 13$		A1
	There is insufficient evidence to suggest that the <u>proportion</u> of sunflower <u>seeds</u> that grow to a height of more than 3 metres is now <u>greater</u> than 0.028		A1
		(5)	
Notes			Total 10
(a)	B1	Both hypotheses in terms of p or π	
	M1	One of the correct probability statements. Implied by a correct critical region	
	A1	awrt 0.0303 and awrt 0.0173	
	A1	Both parts of the critical region given. Allow alternative notation e.g. $X < 9$ and $X > 20$ Do not allow as probability statements.	
(b)	B1	For 0.0476 Allow awrt 0.0475 (calculator) or ft their two critical regions provided probabilities are seen in part (a) Common ft is for $X, 7$ and $X \dots 21$ gives 0.0297	
(c)	B1	Both hypotheses in terms of p or π – If already lost the mark in (a) for incorrect letter allow any letter	
	M1	Po(7) written or used	
	M1	Writing or using $1 - P(Y, 10)$ or $1 - 0.9015$ or $1 - 0.973$ (May be implied by 0.0985) or may be implied by $Y \dots 13$ provided Po(7) seen or used If using $N(7, 6.804)$ or $N(7, 7)$ allow use of $1 - P(Y, 10)$ or $1 - P(Y, 10.5)$ $B(250, 0.028)$ gives 0.09549... and implies M1 $N(7, 6.804)$ gives awrt 0.09 (Calc gives 0.08983...) or awrt 0.13 (Calc gives 0.125...) and implies M1 $N(7, 7)$ gives awrt 0.09 (Calc gives 0.09293...) or awrt 0.13 (Calc gives 0.1284...) and implies M1	
	A1	awrt 0.0985 or CR: $Y \dots 13$ provided Po(7) seen or used (Allow any letter for the CR)	
	A1	Independent of the hypotheses but dependent on the previous M1A1 being awarded. A correct conclusion in context. Allow amount/number for proportion, sunflowers for seeds and increased oe for greater. Ignore any non-contextual statements	

Question Number	Scheme		Marks
5(a)	No of meteors in 20 mins, $M \sim \text{Po}(5)$ oe		B1
(i)	$P(M \leq 6) = 1 - P(M \geq 5)$ $= 1 - 0.6160 = 0.3840$		M1
	awrt 0.384		A1
(ii)	$P(M \geq 3)$ $= 0.2650$		
	awrt 0.265		A1
			(4)
(b)	$H_0 : \lambda = 15 \quad H_1 : \lambda > 15$		B1
			(1)
(c)	For 30 mins use $X \sim \text{Po}(7.5) \quad P(X \leq 12) = 0.9573$		M1
	Correct probability statement: $P(X \leq 13) = 0.0427$		A1
	Critical Region $X \leq 13$		B1
			(3)
(d)	Test statistic $x = 12$ is not in critical region oe (so insufficient evidence to reject H_0 / insignificant result) No significant evidence that the number of meteors to be seen has increased /no significant evidence to support the astronomy club's claim		M1
			A1
			(2)
			Total 10
(a)	B1	Po(5) seen, used or implied by correct answer in (i) or (ii). Sight (to 3sf) of any of 0.265(0) (or 0.765(0), 0.4405 (or 0.5595), 0.616(0) (or 0.384(0)), 0.7622 (or 0.2378) implies this mark.	
(i)	M1	For an attempt at calculating $1 - P(M \geq 5)$ with a Poisson distribution. Imp. by correct answer	
	A1	awrt 0.384 (condone $\frac{48}{125}$)	
(ii)	A1	awrt 0.265 (independent of the M mark in (i) so B1M0A0A1 is possible)	
(b)	B1	written in terms of λ or μ only (accept 7.5 instead of 15 if consistently used for both)	
(c)	M1	evidence of Po(7.5) stated or used. Sight of any of 0.0203 or 0.9208 (or 0.0792), 0.9573 (or 0.0427), 0.9784 (or 0.0216), 0.9897 (or 0.0103) to 2sf with probability statement or 3sf on their own implies this mark.	
	A1	correct probability statement $P(X \leq 13)$ oe and awrt 0.0427 oe (awrt 4.27%).	
	B1	correct critical region $X \leq 13$ (or $X > 12$) only , with or without probability given and independent of their (b). Allow a different letter for X but do not allow CR.	
(d)	M1	For a correct comparison fit their CR $X \leq a$ oe (may be written as $P(X \leq a)$) where $a \leq 13$ indicating 12 is not in the critical region. e.g. $12 < "13"$ so accept H_0 Alternatively compares e.g. $P(X \leq 12) = 0.0792 (> 0.05)$ or $P(X \leq 11) = 0.9208 < 0.95$ and indicates do not reject H_0 . Do not ignore contradictory non-contextual statements. Allow if they have a 2-tail CR provided upper CR is $P(X \leq a)$ oe where $a \leq 13$	
	A1	Correct conclusion indep. of hypotheses and must be in context. Must mention meteors and increase OR the club's claim oe e.g. insufficient evidence to suggest the number of meteors is greater. Condone e.g. there are not more meteors / the number of meteors has not changed.	

Question Number	Scheme		Marks
1(a)	[F(1) = 1 so] $k(6 \times 1^2 - 1^4) = 1$ leading to $k = \frac{1}{5}^*$		B1*
			(1)
(b)	$[1 - F(0.6) =] 1 - \frac{1}{5}(6 \times 0.6^2 - 0.6^4)$		M1
	$= 0.59392$ awrt 0.594		A1
			(2)
(c)(i)	$\frac{1}{5}(6m^2 - m^4) = \frac{1}{2}$		M1
	$2m^4 - 12m^2 + 5 = 0$ oe		A1
(ii)	$m = 0.6711\dots$ awrt 0.671		A1
			(3)
(d)	$\left[\frac{d}{dx} \left(\frac{6}{5}x^2 - \frac{1}{5}x^4 \right) = \right] \frac{12}{5}x - \frac{4}{5}x^3$		M1
	$\left[\frac{d}{dx} \left(\frac{12}{5}x - \frac{4}{5}x^3 \right) = \right] \frac{12}{5} - \frac{12}{5}x^2 = 0$		M1
	$x = 1$		A1
			(3)
(e)	Mean < “Median” < “Mode”		M1
	So negative [skew]		A1ft
			(2)
	Notes		Total 11
(a)	B1*	for use of F(1) = 1 leading to the given answer (minimum required is $k(6 - 1) = 1$) Allow use of F(1) – F(0) = 1 e.g. $k(6 - 1) - k(0 - 0) = 1$ The answer is given so no incorrect working can be seen	
(b)	M1	for using $1 - F(0.6)$ May be implied by $1 - \frac{1269}{3125}$ or $\frac{1856}{3125}$	
	A1	awrt 0.594 Allow $\frac{1856}{3125}$	
(c)(i)	M1	for setting F(m) = 0.5 Allow any letter (including x)	
	A1	for a correct 3TQ oe NB the values of a, b and c must be integers	
(ii)	A1	awrt 0.671 Allow $\sqrt{\frac{6 - \sqrt{26}}{2}}$ (must reject other roots if seen) NB It is possible to score M1A0A1	
(d)	M1	for differentiating F(x) with at least one $x^n \rightarrow x^{n-1}$ May be left in terms of k eg. $k(12x - 4x^3)$ Condone missing k	
	M1	for differentiating twice with at least one $x^n \rightarrow x^{n-1}$ and setting = 0 oe May be left in terms of k eg. $k(12 - 12x^2) = 0$ Condone missing k	
	A1	Cao (Must reject $x = -1$ if seen)	
(e)	M1	a correct justification using the Mean and their Median and/or their Mode. This must be correct for their values Allow use of figures e.g. $0.64 < “0.671” < “1”$ Allow comparisons of “median” and “mode” on its own. Comparison with 0.5 is M0 unless 0.5 is their median or mode	
	A1ft	a correct conclusion based on their comparison (Do not allow a conclusion that is not fully supported by their comparison)	

Question Number	Scheme		Marks
2(a)	Poisson with $\lambda = 10$		B1
			(1)
(b)	Customers [enter the shop] singly/randomly/independently/at a constant rate		B1
			(1)
(c)	$H_0 : \lambda = "10"$ $H_1 : \lambda \neq "10"$		B1ft
			(1)
(d)	$[P(X,, 3) =]$ awrt 0.0103 $[P(X,, 4) =]$ awrt 0.0293		M1
	$[P(X...17) =]$ awrt 0.0270 $[P(X...18) =]$ awrt 0.0143		M1
	$X,, 3 \cup X...18$ oe		A1
			(3)
(e)	$0.0103 + 0.0143 = 0.0246$		M1
	So 2.46%		A1ft
			(2)
(f)	[16 is] not in the CR/Do not reject H_0 /Not significant		M1
	There is insufficient evidence to suggest that the rate/number/amount of customers entering the shop has changed /[is] different oe		A1ft
			(2)
	Notes		Total 10
(a)	B1	for Poisson/Po and $\lambda = 10$	
(b)	B1	for a correct assumption (must have context of customers/people) Ignore irrelevant or incorrect statements	
(c)	B1ft	both hypotheses correct. Must be correctly attached to H_0 and H_1 in terms of λ or μ ft part a Allow $H_0 : \lambda = 20$ $H_1 : \lambda \neq 20$	
(d)	M1	for use of Po(10) to find the lower critical value. May be implied by awrt 0.0103 or awrt 0.0293 or a correct lower critical region (These must be seen in part (d))	
	M1	for use of Po(10) to find the upper critical value. May be implied by awrt 0.027 or awrt 0.0143 or awrt 0.973 or awrt 0.9857 or a correct upper critical region (These must be seen in part (d))	
	A1	for a correct critical region oe e.g. $X < 4$ and $X > 17$ Allow $0 \leq x \leq 3$ and $18 \leq x \leq 20$ or $\{0, 1, 2, 3\}$ $\{18, 19, \dots\}$ Condone use of () or [] for {} Do not allow if written as probability statements Allow any letter. Accept $CR \leq 3$ $CR \geq 18$	
(e)	M1	for adding the probabilities for the 2 tails of their CR together May be implied by a correct answer	
	A1ft	awrt 0.0246 or ft their CR	
(f)	M1	dependent on having found a 2 tailed CR in part (d) for a correct statement (ft their 2 tailed CR) – no context needed but do not allow contradicting non contextual comments. May be implied by a correct contextual statement on its own. We ignore any comparison of numbers/probabilities	
	A1ft	correct conclusion in context (ft their 2 tailed CR). Must contain the words in bold oe. No hypotheses in part (c) then A0 Allow equivalent statements e.g. The mean rate has not changed /still 10	

Question Number	Scheme		Marks
1 (a)	Po(isson) with $(\lambda =)4$		B1
			(1)
(b)	Pairs of shoes (are sold) singly/randomly/independently/at a constant (average) rate		B1
			(1)
(c) (i)	$X = \text{number of sales per hour} \Rightarrow X \sim \text{Po}(4)$		
	$P(X > 4) = 1 - P(X \leq 4)$		M1
	$= 0.3712$	awrt 0.371	A1
(ii)	$(0.3712)^3$		M1
	$= 0.051147...$	0.05115 or awrt 0.0511	A1
			(4)
(d)	$H_0 : \lambda = '4'$ $H_1 : \lambda > '4'$		B1ft
	$P(X \geq 7) = 1 - P(X \leq 6)$ or $P(X \geq 9) = 1 - P(X \leq 8) = 0.0214$		M1
	$= 0.1107$ or CR $X \geq 9$	awrt 0.111	A1
	Not significant/Do not reject H_0 /Not in the critical region		M1
	There is insufficient evidence of an <u>increase</u> in <u>sales</u> following the appearance of the advert/ <u>manager's belief</u> is not supported.		dA1
			(5)
	Notes		Total 11
(a)	B1	For Po or Poisson and 4 must be seen in part (a). Do not allow P(4)	
(b)	B1	For one of the given assumptions in context (must have context of shoes or sales). Ignore extraneous non-contradictory comments.	
(c) (i)	M1	For writing or using $P(X > 4) = 1 - P(X \leq 4)$	
	A1	awrt 0.371	
(ii)	M1	'part (i)' ³	
	A1	0.05115 or awrt 0.0511 (Calculator gives 0.051132...)	
(d)	B1ft	Both hypotheses correct. Must be in terms of λ or μ ft their λ from part (a) Must be attached to H_0 and H_1	
	M1	For writing or using $P(X \geq 7) = 1 - P(X \leq 6)$ If a CR approach is taken then award M1 for $P(X \geq 9) = 1 - P(X \leq 8)$ written or used This mark may be implied by a correct p -value or CR	
	A1	awrt 0.111 or CR $X \geq 9$	
	M1	Any correct ft statement consistent with their p -value and 0.05 or their CR and 7 – no context needed but do not allow contradicting non contextual comments. The comparison of their p -value and the significance level is not counted as a non contextual statement. May be implied by a correct ft conclusion in context.	
	dA1	Dependent on 1 st M1 - Correct conclusion in context which must be not rejecting H_0 . Must include the underlined words (oe).	

Question Number	Scheme		Marks
3 (a) (i)	$X \sim B(10, 0.1)$		
	$P(X \geq 4) = 1 - P(X \leq 3) = 1 - 0.9872$		M1
	$= 0.0128$ awrt 0.0128		A1
	$P(1 < X < 5) = P(X \leq 4) - P(X \leq 1) = 0.9984 - 0.7361$		M1
	or $P(X = 2) + P(X = 3) + P(X = 4) = 0.1937 + 0.0574 + 0.0112$		A1
	$= 0.2623$ awrt 0.262		(4)
(b)	$H_0 : p = 0.1 \quad H_1 : p < 0.1$		B1
	$X \sim B(50, 0.1)$		
	$P(X \leq 2) = 0.1117 \quad \text{or} \quad CR \ X \leq 1$		B1
	Do not reject H_0 /Not in the critical region		M1
	There is insufficient evidence to suggest that this result supports the managing <u>director's claim</u> /not enough evidence to suggest a <u>reduction</u> in the probability of a tennis ball <u>failing</u> the bounce <u>test</u>		A1
			(4)
(c)	$X \sim B(n, 0.1)$ and we reject H_0 if $P(X = 0) < 0.01$		
	$P(X = 0) = \left[{}^n C_0 \times 0.1^0 \right] \times 0.9^n < 0.01$		M1
	$0.9^{44} = 0.00969... [< 0.01]$	$n > \frac{\ln 0.01}{\ln 0.9} \Rightarrow n > 43.7$	M1
	$n = 44$		A1
			(3)
Notes			Total 11
(a) (i)	M1	for writing or using $P(X \geq 4) = 1 - P(X \leq 3)$	
	A1	awrt 0.0128	
(ii)	M1	for writing or using $P(X \leq 4) - P(X \leq 1)$	
	A1	or for writing or using $P(X = 2) + P(X = 3) + P(X = 4)$ awrt 0.262	
(b)	B1	Both hypotheses correct. Must be in terms of p or π Must be attached to H_0 and H_1	
	B1	awrt 0.112 or $CR \leq 1$	
	M1	A correct ft statement consistent with their p -value and 0.05 or their CR and 2- no context needed but do not allow contradicting non contextual comments. The comparison of their p -value and the significance level is not counted as a non contextual statement. May be implied by a correct ft conclusion in context. Must have a p -value or CR to access this mark.	
	A1	Correct conclusion in context which must be not rejecting H_0 . Must use underlined words (oe). No hypotheses then A0	
(c)	M1	For recognising $P(X=0)=0.9^n$	
	M1	For $0.9^{44}(=0.00969...)$ or $0.9^{43}(=0.01077...)$ or rearranging to $n > \frac{\ln 0.01}{\ln 0.9} \dots$ (Allow =) $n > \text{awrt } 43.7$ implies M1M1 (Allow $n = \text{awrt } 43.7$ for M1M1)	
	A1	Cao	
	SC	Use of tables only, $n = 40, p = 0.0148$ and $n = 50, p = 0.0052$ scores M1M0A0	

Question Number	Scheme		Marks
3 (a)	Po(7)		B1
			(1)
(b)	Customers enter the shop occur singly/randomly/independently/ constant (average) rate		B1, B1
			(2)
(c)	$H_0: \lambda = '7'$ $H_1: \lambda \neq '7'$		B1ft
			(1)
(d)	$P(X, \mathbf{2}) = \text{awrt } 0.0073$ $P(X, \mathbf{2}) = \text{awrt } 0.0296$		M1
	$P(X \dots 13) = \text{awrt } 0.0270$ $P(X \dots 14) = \text{awrt } 0.0128$		M1
	$X, \mathbf{2} \cup X \dots 14$		A1
			(3)
(e)	$0.0073 + 0.0128 = 0.0201$		M1
	So 2.01%		A1ft
			(2)
(f)	12 is not in the critical region		M1
	So, there is insufficient evidence that rate of customers entering the shop has changed		A1
			(2)
	Notes		Total 11
(a)	B1	Correct distribution fully specified. Po(isson) and $\lambda = 7$	
(b)	B1, B1	For two of the given assumptions (must have context of customers/people) Context only needs to be stated once. (B1B0 for one assumption in context or for two assumptions with no context)	
(c)	B1ft	Both hypotheses correct. Must be attached to H_0 and H_1 in terms of λ or μ Ft their 7 from part (a) in the hypotheses	
(d)	M1	Use of Po(7) to find the lower critical value. May be implied by either awrt 0.0073 or awrt 0.0296 seen (must be seen in part (d)) Also implied by $X = 1$ or $X, \mathbf{2}$	
	M1	Use of Po(7) to find the upper critical value. May be implied by awrt 0.0270 or awrt 0.0128 or awrt 0.973 or awrt 0.987 seen (must be seen in part (d)) Also implied by $X = 14$ or $X \dots 14$	
	A1	$X, \mathbf{2}, X \dots 14$ correct CR scores 3 out of 3 but $14, \mathbf{2}, X, \mathbf{2}$ is M1M1A0 Allow equivalent forms e.g. $X < 2, X > 13$ Must be a CR and not a probability statement $P(X, \mathbf{2}), P(X \dots 14)$ scores M1M1A0	
(e)	M1	Adding the two probabilities (each must be less than 0.05) for their critical region	
	A1ft	awrt 0.0201 or awrt 2.01% ft the sum of their two selected probability tails	
(f)	M1	For a correct comparison of 12 with their CR (or their implied CR if one is not explicitly stated), 12 is not in the CR condone $12 < '14'$ Finding $P(X = 12)$ is M0 Finding $P(X \dots 12)$ on its own is M0, they must state 12 is not in the CR	
	A1	Correct conclusion in context. Must be a rate, e.g. number in/per 10-minute period (not number on its own). No hypotheses in part (c) then A0 Do not allow comments about the manager's claim on its own, e.g. The manager's claim is not supported. This is not a ft mark.	

Question Number	Scheme		Marks
3 (a)	The vacuum tubes shatter independently		B1
	The probability of a vacuum tube shattering is constant		B1
			(2)
(b)	$C \sim B(15, 0.35)$ plus $[P(C \leq 9) = 0.0142 \text{ or } [P(C \leq 10) = 0.0124 \text{ or } [P(C \leq 9) = 0.9876$		M1
	Critical regions $[0, \dots, C \leq 1 \text{ or } 10 \leq C \leq 15]$		M1
	$[0, \dots, C \leq 1 \text{ and } 10 \leq C \leq 15]$ plus $P(C \leq 9) = 0.0142 \text{ and } P(C \leq 10) = 0.0124$		A1
			(3)
(c)	0.0266		B1ft
			(1)
(d)	[4 is not in the CR therefore] there is no evidence to reject Rowan's belief		B1ft
			(1)
(e)	$F \sim B(40, 0.35)$		
	$H_0: p = 0.35$ and $H_1: p < 0.35$		B1
	$P(F \leq 8) = 0.0303$ or CR $F \leq 8$		M1A1
	Sufficient evidence to reject H_0 or significant or 8 lies in the Critical region		M1
	There is sufficient evidence to support that the proportion of type <i>B</i> vacuum tubes that shatter when exposed to alternating high and low temperatures is less than 35%		A1
			(5)
Notes			Total 12
(a)	B1	for one correct reason which must mention tube(s) and shatter/shattering or 2 correct reasons not in context	
	B1	for 2 correct reasons which must mention tube(s) and shatter/shattering at least once	
(b)	M1	for using the correct distribution to find awrt 0.0142 or awrt 0.0124 or awrt 0.988 Allow $B(15, 0.35)$ is written and one of awrt 0.014 or awrt 0.012 or awrt 0.99 is seen	
	M1	for lower CR or $C \leq 1$ or e.g. $C < 2$ or upper CR $C \leq 10$ or e.g. $C > 9$ Allow other notation and any letter(s) for CR Do not allow CR written as a probability statement	
	A1	for both CR correct with the relevant probabilities (3 sf and must be seen in part (b)). Do not allow CR written as a probability statement	
(c)	B1ft	for awrt 0.0266 or 2.66% or ft the sum of the probabilities in (b) for "their 2 critical regions" if seen. If no probabilities for their CR given then the answer must be 0.0266	
(d)	B1ft	for a correct statement consistent with their CR Must mention Rowan/his/her or a correct conclusion based on Rowan's belief with the words highlighted in bold e.g. no evidence to suggest that the proportion/probability/number/amount (allow 35% as proportion) of tubes that shatter has changed or	
	B1	for both hypotheses correct in terms of p or π	
	M1	for using or writing $P(F \leq 8)$ or awrt 0.0303	
	A1	for awrt 0.0303 or correct CR Allow $F \leq 8$ or $F < 9$ but not if part of a probability statement	
	M1	for a correct conclusion – need not be in context. ft their probability or CR. Ignore hypotheses. do not allow contradicting non contextual comments. May be implied by a correct contextual statement on its own	
	A1	for a correct conclusion – must be in context, with words highlighted in bold. ft their probability or CR only. Independent of hypotheses. Do not allow contradicting statements. Allow probability/number/amount/35% for proportion. Allow decreased for less than 35%	

Question	Scheme	Marks
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Question Number	Scheme		Marks
2 (a)	$B\left(25, \frac{1}{5}\right)$		B1
			(1)
(b)(i)	$[M =]4X - (25 - X) [= 5X - 25]$		B1
(ii)	$E(M) = '5'E(X) - '25'$		M1
	$E(X) = np = 25 \times \frac{1}{5} = 5$		M1
	$E(M) = 5 \times 5 - 25 = 0^*$		A1*
			(4)
(c)	$M \dots 30 \Rightarrow '5'X - '25' \dots 30 [\Rightarrow X \dots 11]$		M1
	$[P(X \dots '11') = 1 - P(X, '10')] = 1 - '0.9944'$		M1
	$= 0.0056$	awrt 0.0056	A1
			(3)
(d)	$Y \square B(50, 0.5)$		
	$P(n < Y, 30) = 0.9328$		M1
	$P(Y, 30) - P(Y, n) = 0.9328$		M1
	$P(Y, n) = 0.0077$		M1
	$n = 16$		A1
			(4)
	Notes		Total 12
(a)	B1	Correct distribution fully specified. Allow in words e.g. Binomial with $n = 25$ and $p = 0.2$ Must be seen in part (a)	
Mark parts (b)(i) and (b)(ii) together			
(b)(i)	B1	For a correct expression for M Allow unsimplified	
(ii)	M1	For either $'5'E(X) - '25'$ or $E(M) = 5 \times \left(25 \times \frac{1}{5}\right) - 25$ or $'4'E(X) - 1('25' - E(X))$ This must be an expectation statement with the expectation stated in symbol or in words. $5 \times 5 - 25 = 0$ or $4 \times 5 - 1 \times 20 = 0$ on its own is M0	
	M1	For sight of $25 \times \frac{1}{5}$ or stating $E(X) = 5$	
	A1*	Fully correct solution with $E(M) = 0$ stated. This may be stated in words. The answer is given so no incorrect working can be seen	
SC		M1M1 [Expected number of marks (per question) =] $4 \times \frac{1}{5} - 1 \times \frac{4}{5}$ A1 therefore $E(M) = 0$	
(c)	M1	For substitution of their M into a linear inequality in terms of X implied by $X \dots 11$	
	M1	For use of correct probability statement from their '11'	
	A1	awrt 0.0056 (calc 0.0055549...)	
(d)	M1	For a correct probability equation (implied by 2 nd M1)	
	M1	For $P(Y, 30) - P(Y, n) = 0.9328$ or $0.9405 - P(Y, n) = 0.9328$	
	M1	For $P(Y, n) = 0.0077$	
	A1	Cao	
SC		$P(n < Y, 30) = 0.9328$ $P(Y, 30) - P(Y, n - 1) = 0.9328$ $P(Y, n - 1) = 0.0077$ scores M1M0M1A0	

Question Number	Scheme	Marks
4. (a)	p is small	B1 (1)
(b)	Let N = number of candles not suitable for sale $N \sim B(125, 0.02)$ $\approx C \sim \text{Po}(2.5)$ $P(C \leq 6)$ $= 0.9858$ awrt <u>0.986</u>	M1 A1 M1 A1 (4)
(c)(i)	$H_0 : p = 0.05$ $H_1 : p < 0.05$ $D \sim B(30, 0.05)$ $P(D = 0) = 0.2146$ Do not reject H_0 / not significant The <u>manufacturer</u> 's claim is not supported/There is not enough evidence to suggest that the <u>proportion</u> (oe) of candle <u>holders</u> with minor <u>defects</u> is less than 5%/ <u>Charlie</u> 's claim is supported	B1 M1 A1 M1 A1 (5)
(ii)	Impossible to reject H_0 (since $P(D = 0) > 0.05$)	B1 (1)
(d)	$0.95^{50} [=0.0769\dots]$ <u>or</u> $X \sim B(50, 0.05)$, $P(X = 0)$ (is still) > 0.05 (so still not possible to reject H_0) hence Ashley's change does not make the test appropriate.	M1 A1 (2)
[13 marks]		
Notes		
(a)	B1 correct condition allow ' p is close to 0' allow ' $p < 0.1$ ' or any value less than 0.1 (condone $np < 10$ or $np \leq 10$)	
(b)	1 st M1 recognising Binomial distribution (may be implied by Po(2.5)) 1 st A1 correct distribution Po(2.5) 2 nd M1 writing or using $P(C \leq 6)$ from Poisson distribution 2 nd A1 awrt 0.986 from correct distribution used (calc : 0.9858126....) [NB : Use of binomial gives 0.98678....] Answer only 0.9858 or better scores 4 out of 4, but answer of 0.986 must see Po(2.5) to award full marks.	
(c)(i)	B1 correct hypotheses in terms of p or π 1 st M1 writing or using $B(30, 0.05)$ (may be implied by 1 st A1) 1 st A1 awrt 0.215 2 nd M1 a correct ft statement consistent with their p -value and 0.05 No context needed but do not allow contradicting non contextual comments. 2 nd A1 correct conclusion in context which must be not rejecting H_0 . Must use underlined words (oe) No hypotheses then A0 Condone e.g. '5% of candle holders have minor defects'	
(ii)	B1 correct reasoning which implies there is no critical region/ H_0 cannot be rejected Sample size is too small on its own is B0.	
(d)	M1 for 0.95^{50} <u>or</u> for $X \sim B(50, 0.05)$ and $P(X = 0) > 0.05$ A1 test is (still) not appropriate with M1 scored	

Question	Scheme		Marks
1(a)	The random variable M is such that $M \sim \text{Po}(2)$		
(i)	$P(M \leq 3) =$	awrt 0.857	B1
(ii)	$P(M \leq 6) = 1 - P(M \leq 5)$		M1
	$= 0.0166$ (calc 0.016563...)	awrt 0.0166	A1
			(3)
(b)	$Q \sim \text{Po}(6)$		M1
	$P(4 \leq Q \leq 7) = P(Q \leq 7) - P(Q \leq 3) [= 0.5928]$		M1
	$X \sim \text{B}(20, "0.5928")$ and $P(X = 15)$ or ${}^{20}C_{15} ("0.5928")^{15} (1 - "0.5928")^5$		M1
	$= 0.06809...$		awrt 0.068
			(4)
(c)	$H_0: \lambda = 2 \quad H_1: \lambda > 2$		B1
	$R \sim \text{Po}(5) : P(R \leq 10) \text{ or } 1 - P(R \leq 9)$		M1
	$= 0.0318$ or CR: $R \leq 10$		A1
	Reject H_0 or Significant or in the critical region		M1
	There is evidence to support the manager's belief / rate of customers arriving at the garage has increased		A1
			(5)
(d)	The number of tyres bought is likely not to occur singly/tyres are not sold independently.		B1
			(1)
	Notes		Total 13
(a)	B1	awrt 0.857	
	M1	for $1 - P(M \leq 5)$ or $1 - 0.9834$ Do not allow $1 - P(M < 6)$ unless $1 - P(M \leq 5)$ is used	
	A1	awrt 0.0166 correct answer scores 2 out of 2	
(b)	M1	for writing or using $\text{Po}(6)$	
	M1	for $P(Q \leq 7) - P(Q \leq 3)$ or $0.7440 - 0.1512$ or awrt 0.593	
	M1	For $\text{B}(20, "0.5928")$ and $P(X = 15)$ or ${}^{20}C_{15} (p)^{15} (1 - p)^5$ (implied by awrt 0.068)	
	A1	awrt 0.068	
(c)	B1	for correct hypotheses in terms of λ or μ Allow 5 instead of 2. These must be attached to H_0 and H_1 correctly	
	M1	for writing or using $\text{Po}(5)$ and $P(R \leq 10)$ or $1 - P(R \leq 9)$ (may be implied by awrt 0.0318 or correct CR)	
	A1	awrt 0.0318 allow CR: $[R] \leq 10$ allow any letter or no letter for CR	
	M1	for a correct ft statement consistent with their p -value and 0.05 or with 10 and their CR Need not be contextual but there must be no contradicting non-contextual comments	
	A1	dep on 1 st and 2 nd M1 for a correct conclusion in context which must be rejecting H_0 Must use bold words (oe)	
(d)	B1	for the idea that tyres may be bought in e.g. pairs oe/the idea that tyre sales are not independent	

Question Number	Scheme		Marks
Throughout the paper the candidates may use different letters to the ones given in the mark scheme.			
1(a)	$P(F \leq 12) = 1 - P(F \geq 11)$		M1
	$= 0.34517...$	awrt 0.345	A1
			(2)
(b)	$P(8 \leq F < 15) = P(F \leq 14) - P(F \leq 7)$		M1
	$= 0.81104...$	awrt 0.811	A1
			(2)
(c)	$3(30 - F) + F < 70$ or $F > 10$	$3(R) + 30 - R < 70$ or $R < 20$	M1
	$P(F > 10) = 1 - P(F \leq 10)$	$P(R < 20) = P(R \leq 19)$	M1
	$= 0.4922...$		awrt 0.492
			(3)
(d)	$H_0: p = 0.35$ $H_1: p > 0.35$		B1
	Let Y be the number of customers who do not buy free range eggs. $Y \sim N(70, 45.5)$		M1
	$P(Y \leq 86) \approx P\left(Z > \frac{85.5 - 70}{\sqrt{45.5}}\right)$ or $\pm \frac{x - 0.5 - 70}{\sqrt{45.5}} = 1.6449$		M1 M1
	$\approx 0.01078...$ or $81.595...$		A1
	There is evidence to reject H_0 . In the critical region		dM1
	There is evidence to support the manager's belief / There is evidence to support the <u>proportion</u> of customers who <u>do not buy free range eggs</u> is <u>more than 35%</u> (o.e)		A1
			(7)
Total 14			
(a)	M1	Writing or using $1 - P(F \leq 11)$	
	A1	awrt 0.345	
(b)	M1	$P(F \leq 14) - P(F \leq 7)$	
	A1	awrt 0.811	
(c)	M1	Allow equation instead of inequality (may be implied by 2 nd M1)	
	M1	Writing or using $1 - P(F \leq 10)$ ft their 10 but must be finding the correct tail.	
	A1	awrt 0.492	
(d)	B1	Both hypotheses in terms of p or π	
	M1	Writing or using a normal distribution with a mean of 70	
	M1	Standardising using 85.5/86/86.5, their mean and their sd	
	M1	Using a continuity correction 86 ± 0.5	
	A1	Correct probability awrt 0.0108 or awrt 0.0107 or x value of awrt 82 or allow awrt 2.29... and 1.6449 seen	
		NB exact Binomial 0.01156 Po approx. awrt 0.0352	
	dM1	(dep on 1 st M1) A correct statement based on comparing 86 with their CR or their prob with 0.05 [condone $0.989 > 0.95$]– contradicting non-contextual comments M0	
	A1	A correct statement in context.	
		NB award M1A1 for a correct contextual statement on its own.	

Question Number	Scheme		Marks
7(a)	$X \sim B(40, 0.3)$		B1
			(1)
(b)	Constant probability of buying insurance or Customers buy insurance independently		B1
			(1)
(c)	$[P(X \leq 7) = P(X < 8) =] 0.0553$ $[P(X \leq 6) = P(X < 7) =] 0.0238$		M1
	So $r = 7$		A1
			(2)
(d)	$B(200, 0.3)$ implies $N(60, 42)$		M1
	$\frac{t - 0.5 - "60"}{\sqrt{"42"}} = -1.62$ or $\frac{"60" - t + 0.5}{\sqrt{"42"}} = 1.62$		M1M1 B1
	$[t = 50.001 \dots \text{ so } t = 50]$		A1
			(5)
(e)	$H_0 : p = 0.3$ $H_1 : p > 0.3$		B1
	$[P(X \leq 11) =] 1 - P(X \leq 10)$		M1
	$= 0.0978$ or $CR \geq 11$		A1
	Reject H_0 /Significant/In CR		M1
	Evidence to suggest that percentage/proportion/probability/number/amount of customers who buy insurance has increased or		A1ft
			(5)
	Notes		Total 14
(a)	B1	Allow Binomial $n = 40$ $p = 0.3$	
(b)	B1	for a suitable assumption in context. Must include ‘insurance’ If multiple reasons given ignore any irrelevant or incorrect reasons provided, they are non-contradictory	
(c)	M1	for either probability. May be implied by $r = 7$	
	A1	Cao	
(d)	M1	for writing or using $N(60, 42)$ May be seen in a standardisation. If $N(60, \sqrt{42})$ written but 60 and $\sqrt{42}$ used in a standardisation then award M1	
	M1	for standardising using t or $t - 0.5$ or $t + 0.5$ with their mean and their standard deviation	
	M1	for a fully correct standardisation with their mean and their standard deviation	
	B1	for ± 1.62 or better (calc: 1.620150314) seen or used. Must be compatible with their standardisation	
	A1	Cao Do not allow $t = 50$ from incorrect working	
(e)	B1	for both hypotheses in terms of p or π	
	M1	for writing or using $1 - P(X \leq 10)$ May be implied by a correct CR	
	A1	for 0.0978 or correct CR	
	M1	for a correct non contextual conclusion. ft their probability/CR provided a binomial distribution is used. Do not allow contradictory statements. May be implied by a correct contextual statement on its own.	
	A1ft	a correct contextual statement with words in bold (Allow equivalent statements) ft their probability/CR provided a binomial distribution is used	
	SC	If a two tailed test is used, then it is possible to score B0M1A1M1A1 $H_0 : p = 0.3$ $H_1 : p \neq 0.3$ B0 $[P(X \leq 11) =] 1 - P(X \leq 10)$ or $[P(X \leq 12) =] 1 - P(X \leq 11)$ M1 $= 0.0978$ or $CR \geq 12$ A1 Do not reject H_0 /Not significant/Not in CR M1 Proportion who buy insurance has not increased or A1	

Question Number	Scheme	Marks
1 (a)	$\int_1^2 k \left(\frac{1}{2}x^3 - 3x^2 + ax + 1 \right) dx [= 1]$	M1
	$k \left[\frac{1}{8}x^4 - x^3 + \frac{1}{2}ax^2 + x \right]_1^2 [= 1]$	A1
	$k(2-8+2a+2) - k\left(\frac{1}{8}-1+\frac{1}{2}a+1\right) = 1$ or $k(2a-4) - k\left(\frac{1}{8}+\frac{1}{2}a\right) = 1$	dM1
	$-\frac{33}{8}k + \frac{3}{2}ka = 1 \therefore k(12a-33) = 8 *$	A1 *
		(4)
(b)	$\frac{df(x)}{dx} = k \left(\frac{3}{2}x^2 - 6x + a \right)$	M1
	$\frac{3}{2}x^2 - 6x + 5 = 0$ or $\frac{4}{9}x^2 - \frac{16}{9}x + \frac{40}{27} = 0$	dM1
	$x = \frac{6 \pm \sqrt{6^2 - 4 \times 1.5 \times 5}}{3}$	M1
	$x = 2 - \frac{\sqrt{6}}{3}$ oe or 1.183... awrt 1.18	A1
		(4)
Notes		Total 8
1(a)	M1	Attempting to integrate f(x), (at least one term $x^n \rightarrow x^{n+1}$). Ignore limits. No Need to equate to 1
	A1	Fully correct integration. Allow not simplified. Ignore limits and accept any letters. Allow + C No Need to equate to 1
	dM1	Dep on 1 st M1. Subst in correct limits, subtracting results and equate to 1 Allow if they have + C the use of F(2) = 1 and F(1) = 0 to form 2 equations and solve to eliminate + C
	A1*	Answer is given. Correct solution only. At least one correct line of working required between $k(2a-4) - k\left(\frac{1}{8}+\frac{1}{2}a\right) = 1$ and the final given answer.
(b)	M1	Attempting to differentiate f(x), (at least one term $x^n \rightarrow x^{n-1}$). Condone missing k or incorrect value for k
	dM1	Dependent on first Method mark being awarded. Putting their differential (or multiple of) = 0 May be implied by awrt 1.18 or awrt 2.82
	M1	Correct method for solving their 3 term quadratic equation. May be implied by awrt 1.18 or awrt 2.82 Minimum for method if final answer is incorrect is of the form $\frac{6 \pm \sqrt{6}}{3}$
	A1	Allow equivalent exact answer. awrt 1.18 Must eliminate the 2.816... or clearly indicate which of the 2 solutions is their answer

Question Number	Scheme		Marks
2(a)	$f(w) = \begin{cases} \frac{1}{8} & -1.4 < w < 6.6 \\ 0 & \text{otherwise} \end{cases}$		M1 A1
			(2)
(b)	$E(W) = 2.6$ oe		B1
			(1)
(c)	$(1.6 - \alpha) \times \frac{1}{8} = 0.35$		M1
	$\alpha = -1.2$ oe		A1cso
			(2)
(d)	$P(1.2 < W < 2.4) = (2.4 - 1.2) \times \frac{1}{8}$		M1
	$= \frac{3}{20}$ or 0.15 oe		A1ft
			(2)
(e)	$P(W > 2 \mid 1.2 < W < 2.4) = \frac{0.4 \times \frac{1}{8}}{0.15}$		M1
	$= \frac{1}{3}$ awrt 0.333		A1
			(2)
(f)	The random variable Y is the number of days the train is late $Y \sim B(40, "0.15")$		M1
	$P(Y \geq 10) = 1 - P(Y \leq 9)$ or $1 - 0.9328$		M1
	$= 0.0672$ awrt 0.0672		A1 (3)
	Notes		Total 12
2(a)	M1	pdf of the form $[f(w) =] \begin{cases} p & -1.4 < w < 6.6 \\ 0 & \text{otherwise} \end{cases}$ where p is a probability allow use of $\leq$ instead of one/both $<$ signs. Allow equivalent for the 0 otherwise. Allow any letter/mix of letters	
	A1	Fully correct allow use of $\leq$ instead of one/both $<$ signs. Allow any letter but must be consistent.	
(b)	B1	2.6 oe	
(c)	M1	setting up equation $(1.6 - \alpha) \times \text{"their } p\text{"} = 0.35$ with $0 < p < 1$ or $\frac{7}{20} = \frac{2.8}{8}$ and $\alpha = 1.6 - \text{"2.8"}$ or $F(1.6) - F(\alpha) = 0.35$ using their $F(w)$ in the form $bw + c$ where $0 < b < 1$ Allow for $\int_{\alpha}^{1.6} \text{"their } f(w)\text{"} dw = 0.35$ oe with an attempt to integrate (at least one term correct).	
	A1 cso	If using $F(1.6) - F(\alpha) = 0.35$ then $F(w)$ must be correct. Allow different letters	
(d)	M1	$(2.4 - 1.2) \times \text{"their } p\text{"}$ where $\text{"their } \frac{1}{8}\text{"}$ is a probability or $F(2.4) - F(1.2)$ using their $F(w)$ in the form $bw + c$ where $0 < b < 1$ Implied by 0.15 Allow for $\int_{1.2}^{2.4} \text{"their } f(w)\text{"} dw$ with an attempt to integrate (at least one term correct).	
	A1ft	Ft their p as long as the answer is a probability	
(e)	M1	$\frac{0.4 \times \text{"their } \frac{1}{8}\text{"}}{\text{"their (d)"}}$ or $\frac{0.4}{\text{"1.2"}}$ implied by $\frac{1}{3}$ Allow for $\int_2^{2.4} \text{"their } f(w)\text{"} dw$ with an attempt to integrate (at least one term correct) for numerator	
	A1	Allow 0.3 or 0.33	
(f)	M1	Writing or using $B(40, \text{"their 0.15"})$ Implied by mean of $40 \times \text{"their (d)"}$	
	M1	Writing or using $1 - P(Y \leq 9)$ Allow for $1 - P\left(z \leq \frac{9.5 \text{ or } 9 - \text{"their mean"}}{\text{"their sd"}}\right)$	
	A1	awrt 0.0672	

Question Number	Scheme		Marks
3(a)(i)	$X \sim B(10, 0.45)$		M1
	$P(X \leq 1) = 0.0233$	awrt 0.0233	A1
(ii)	$P(X \geq 6) = 1 - P(X \leq 5)$ or $1 - 0.7384$		M1
	$= 0.2616...$	awrt 0.262	A1
			(4)
(b)	$F \sim N(54, 29.7)$		M1A1
	$\frac{c + 0.5 - 54}{\sqrt{29.7}} \leq -1.6449$ or $\frac{d - 0.5 - 54}{\sqrt{29.7}} \geq 1.6449$		M1M1B1 A1
	$c = 44$ and $d = 64$		A1cso
			(7)
(c)	$H_0: p = 0.45$ $H_1: p < 0.45$		B1
	$Y \sim B(30, 0.45)$ therefore $P(Y \leq 8) = 0.03...$ or CR $Y \leq 8$		B1
	8 is in the critical region or Reject H_0 oe or significant		dM1
	therefore the data collected supports the manufacturer's claim .		A1
			(4)
	Notes		Total 15
(a)(i)	M1	Writing or using $B(10, 0.45)$ in (i) or (ii) implied by a correct answer to (i) or (ii)	
	A1	awrt 0.0233	
(ii)	M1	For writing or using $1 - P(X \leq 5)$ oe	
	A1	awrt 0.262	
(b)	M1	For writing or using $N(54, ...)$	
	A1	For writing or using $N(54, 29.7)$	
	M1	For standardising (allow $\pm$) using their "54" and "29.7" and putting $=$ to z value where $1 < z < 2$ Condone missing ± 0.5	
	M1	M1 for using a continuity correction ± 0.5 in standardisation. No need to put $=$ to z value	
	B1	For using 1.6449 or better (calc gives) 1.64485... Allow if written then gone on to use 1.65 or 1.64 or better in equation	
	A1	One correct inequality. Allow written as an equation. Allow with 1.65/1.64 or better	
	A1cso	All previous marks awarded. Both c and d correct integers	
		NB: c and d correct with no working can be awarded full marks	
(c)	B1	Both hypotheses correct in terms of p or π Must be attached to H_0 and H_1	
	B1	0.03 or better (0.03120...) or CR stated as $Y \leq 8$ oe do not accept $P(Y \leq 8) = ...$ for CR Condone 0.97 or better (0.96879...)	
	dM1	Dep on 2 nd B1 A correct statement – need not be contextual but do not allow contradicting non contextual comments. Allow opposite conclusion if 2-tail hypotheses given.	
	A1	Correct conclusion for their H_1 . If H_1 is 2- tail the opposite conclusion must be given. No hypotheses or $H_1 p > 0.45$ is A0. Allow belief instead of claim. Allow the data collected supports that the proportion/percentage/probability/number/amount oe of flawed plates has decreased/reduced/is not 0.45/has changed oe	

Question Number	Scheme	Marks
2. (a)	$[X = \text{number of faults in } 4 \text{ m}^2 \text{ so } X \sim \text{Po}(3)]$ $P(X = 5) = P(X \leq 5) - P(X \leq 4) [= 0.9161 - 0.8153] \quad \text{or} \quad \frac{e^{-3} 3^5}{5!} \quad (\text{allow } \lambda \text{ instead of } 3)$ $= 0.1008 \quad \text{or} \quad 0.100818... \quad \text{awrt } \underline{0.101}$	M1 A1 (2)
(b)	$[Y = \text{number of faults in } 6 \text{ m}^2 \text{ so } Y \sim \text{Po}(4.5) \text{ and } [P(Y > 5)] = 1 - P(Y \leq 5) [= 1 - 0.7029]$ $= 0.2971 \quad \text{or (calc)} \quad 0.29706956... \quad \text{awrt } \underline{0.297}$	M1 A1 (2)
(c)	<u>0.101</u> (or ft their answer to (a)) Faults occur independently/ randomly	B1ft B1 (2)
(d)	$[F = \text{number of faults in a small rug } F \sim \text{Po}(0.9)$ $e^{-0.9} n \times 80 + (1 - e^{-0.9}) n \times 60 \geq 4000 \quad \text{or} \quad (\text{awrt } 0.407) n \times 80 + (\text{awrt } 0.593) n \times 60 \geq 4000$ $n \geq \frac{4000}{20e^{-0.9} + 60} = 58.71...$ $n = \underline{59}$	B1 M1 M1 A1 (4)
(e)	$H_0 : \lambda = 9 \quad H_1 : \lambda > 9$ $R \sim \text{Po}(9 \times 10) \text{ and } [P(R \geq 13)] = 1 - P(R \leq 12) [= 1 - 0.8758]$ $P(R \leq 13) = 0.9261 \quad \text{or} \quad P(R \geq 14) = 0.0739 \quad \text{or} \quad P(R \leq 14) = 0.9585 \quad \text{or} \quad P(R \geq 15) = 0.0415$ $[P(R \geq 13)] = 0.1242 \quad \text{awrt } 0.124 \quad \text{or} \quad \text{CR } R \geq 15 \text{ (oe)}$ so insufficient evidence to reject H_0 /not significant/ not in critical region There is insufficient evidence that the rate at which faults occur is higher for Rhiannon	B1 M1 A1 M1 A1 (5)
Total 15		
Notes		
(a)	M1: for using or writing $P(X \leq 5) - P(X \leq 4) \quad \text{or} \quad \frac{e^{-\lambda} \lambda^5}{5!}$ (Accept letter λ or any value of λ)	
(b)	M1: writing or using $\text{Po}(4.5)$ and sight of $[P(Y > 5)] = 1 - P(Y \leq 5)$ Implied by sight of $1 - 0.7029$	
(c)	2nd B1: for a comment about faults occurring randomly/independently or Poisson has “no memory”	
(d)	B1: writing or using $\text{Po}(0.9)$ May be implied by sight of 0.407 or 0.593 1st M1: for $e^{-\lambda} n \times 80 + (1 - e^{-\lambda}) n \times 60 > 4000$ any value for λ . Allow = 4000 2nd M1: for solving their equation leading to a positive value of n . Allow any value of λ and allow $n = ...$ A1: for an answer of 59 only	
(e)	B1: both hypotheses correct with λ or μ . Allow 3 or 0.75 or 0.9 instead of 9 1st M1: for writing or using $\text{Po}(“9”)$ and writing or using $1 - P(R \leq 12)$ (implied by $1 - 0.8758$) or one of: $P(R \leq 13) = 0.9261, P(R \geq 14) = 0.0739, P(R \leq 14) = 0.9585, P(R \geq 15) = 0.0415$ leading to a CR 1st A1: for probability = awrt 0.124 or CR of $R \geq 15$ oe e.g. $R > 14$ 2nd M1: for a correct conclusion based on their prob & 0.05 or their CR & 13. Assume correct hypotheses. Do not allow contradicting conclusions 2nd A1: dep on both Ms for a correct contextual comment including the words in bold.	

Question Number	Scheme		Marks
4(a)	$P(X = 8) = \frac{e^{-6} 6^8}{8!}$ or 0.8472 – 0.7440		M1
	$= 0.10325\dots$ awrt 0.103		A1
			(2)
(b)	$[X \sim \text{Po}(6) \dots] P(X \leq n) < 0.05$ for $P(X \leq n-1) > 0.95$ r		M1
	$n = 11$		A1cao
			(2)
(c)	$K \sim \text{Po}(0.6m)$ and $P(K = 0) < 0.05$ r/ $e^{-0.6m} < 0.05$ / $-0.6m < \ln 0.05$ oe or $\lambda = 3$		M1
	$m = 5$		A1cao
			(2)
(d)	$Y \sim \text{Po}(3)$		B1
	$P(Y \leq 1) = 1 - P(Y = 0)$		M1
	$= 0.9502$		A1
			(3)
(e)	$[W \sim \text{Po}(18)] P(W = 15) = \frac{e^{-18} 18^{15}}{15!} [= 0.078575\dots]$	$Y \sim B(15, \frac{5}{30})$	M1
	$\frac{P(Y = 1 [Y \sim \text{Po}(3)]) \times P(T = 14 [T \sim \text{Po}(15)])}{\text{"0.078575\dots"}}$	$P(Y = 1)$	dM1
	$\frac{(e^{-3} \times 3) [= 0.149\dots] \times \left(\frac{e^{-15} 15^{14}}{14!} \right) [= 0.102\dots]}{\text{"0.078575\dots"}}$	$= 15(\frac{1}{6})(\frac{5}{6})^{14}$	dM1
	$= 0.1947\dots$	awrt 0.195	A1
			(4)
(f)	$J \sim \text{Po}(9)$		M1
	$P(J \leq 13) = 0.9261$		
	$P(J \leq 14) = 0.9585$		
	So critical region is $J \geq 15$		A1
			(2)
		Total 15	
Notes			
(a)	M1	Correct formula or correct use of tables	
	A1	awrt 0.103	
(b)	M1	A correct probability statement. Implied by correct answer	
	A1	cao	
(c)	M1	Forming an equation or inequality or identifying $\lambda = 3$	
	A1	cao	
(d)	B1	Writing Po(3) [implied by 0.0498... or correct answer]	
	M1	Writing or using $1 - P(Y = 0)$	
	A1	Allow 0.95 or better	
(e)	M1	Using Po(18) to find $P(W = 15)$	
	dM1	(dep on 1 st M1) Attempt at conditional probability with $P(Y = 1) \times P(T = 14)$ (any value of λ) on num. and their $P(W = 15)$ on denom. (may be implied)	
	dM1	(dep on 2 nd M1) Correct ratio of probabilities	
	A1	awrt 0.195	
ALT:		Use of Binomial: 1 st M1 correct distribution, 2 nd dM1 $P(Y = 1)$, 3 rd dM1 correct expression	
(f)	M1	Writing or using Po(9) Implied by correct CR	
	A1	Cao. Allow $J > 14$. Do not allow as part of a probability statement.	

Question	Scheme		Marks
2(a)	$\frac{3}{10}d - \frac{1}{75}d^2 - \frac{2}{3} = 1$		M1
	$45d - 2d^2 - 100 = 150$ or $\frac{3}{10}d - \frac{1}{75}d^2 - \frac{5}{3} = 0 \rightarrow 2d^2 - 45d + 250 = 0^*$		A1*
			(2)
(b)	$P(1 < H < 4.5) = \left(\frac{4.5}{6} - \frac{1}{3}\right) - \left(\frac{1}{48}\right) = \frac{19}{48}$ or 0.39583...		M1
	$P(1 < H < 1.5) = \left(\frac{1.5^2}{48}\right) - \left(\frac{1}{48}\right) = \frac{5}{192}$ or 0.02604...		M1
	$P(H < 1.5 1 < H < 4.5) = \frac{"0.02604..."}{"0.3958..."}$		M1
	$= \frac{5}{76}$ or 0.06578... awrt 0.0658		A1
			(4)
(c)	$[f(h) =] \begin{cases} \frac{h}{24} & 0 < h, 4 \\ \frac{1}{6} & 4 < h, 5 \\ \frac{3}{10} - \frac{2}{75}h & 5 < h, d \\ 0 & otherwise \end{cases}$		M1 M1 A1
			(3)
	Notes		Total 9
(a)	M1	for $\frac{3}{10}d - \frac{1}{75}d^2 - \frac{2}{3} = 1$	
	A1*	cso at least one step seen before given answer e.g. removing the denominator or correct 3 term quadratic = 0	
(b)	M1	correct method to find $P(1 < H < 4.5)$ implied by $\frac{19}{48}$ or awrt 0.396	
	M1	for writing or finding $P(1 < H < 1.5)$ implied by $\frac{5}{192}$ or awrt 0.026	
	M1	for $\frac{p}{"0.3958"}$ where $0 < p < "0.3958"$	
	A1	awrt 0.0658	
(c)	M1	for one of row 1, 2 or 3 correct. Allow any letters. Condone missing/incorrect range	
	M1	for any two rows correct with ranges. Allow any letters and < for ,, signs	
	A1	Fully correct. all the same letter in rows 1 to 3 Allow < for ,, signs condone $d = 10$ but not $d = 12.5$	

Question	Scheme		Marks
3(a)	A list of all the shops		B1
			(1)
(b)	The shops		B1
			(1)
(c)	Advantage - A sample is quicker/ cheaper / easier to process		B1
	Disadvantage – less accurate/ may be biased / may not be representative		B1
			(2)
(d)	P(X ≤ 6) = 0.0172 or P(X ≤ 18) = 0.0212 or P(X ≤ 17) = 0.9788 or X ≤ 6 or X ≤ 18		M1
	[P(X ≤ 6)] = 0.0172 and [P(X ≤ 18)] = 0.0212		A1
	CR: [0 ≤ X ≤ 6, 18 ≤ X ≤ 30]		A1
			(3)
(e)	20 is in the critical region therefore there is evidence that Jian's belief is incorrect		B1ft
			(1)
(f)	H ₀ : p = 0.4 H ₁ : p < 0.4		B1
	J ~ B(150, 0.4) ⇒ ≈ N(60, 36)		M1A1
	P(J ≤ 47) ≈ P(Z ≤ $\frac{47.5 - 60}{6}$ [= -2.08333...])	$\frac{(n + 0.5) - 60}{6} = -1.6449$	M1 M1
	= 0.0188 (calc 0.018610...)	CR: J < awrt 49.6	A1
	There is sufficient evidence to suggest that the proportion of shops where the stocktaking system is being used incorrectly is less than 0.4/decreased		A1
			(7)
	Notes		Total 15
(a)	B1	for the idea of a list/database(of) of all shops list of all stocktaking systems is B0	
(b)	B1	for allow shop or store(s) the number of shops is B0 the stocktaking systems at each shop is B0	
(c)	B1	for a correct advantage for a sample oe eg allow census take longer than a sample e.g. 'a sample is more uncertain' on its own is B0	
	B1	for a correct disadvantage for a sample oe eg a census is more accurate than a sample	
		If there is no reference to sample or census assume referring to sample. Ignore extraneous non-contradictory comments	
(d)	M1	for one of these probability statements correct or awrt 0.017 or awrt 0.021 or awrt 0.98 or one correct CR	
	A1	for both probabilities awrt 0.0172 and awrt 0.0212	
	A1	for both CR correct oe e.g. X < 7, X > 17 ignore any symbol used between the two CR tails allow any or no letter (do not allow CR stated as probabilities)	
(e)	B1ft	for stating 20 is in the CR and give correct statement. Allow the belief in words. Only ft if their CR is in the form X ≤ C ₁ ∪ X ≥ C ₂ (allow as probability statements)	
(f)	B1	for both hypotheses correct, using p or π. Must be attached to H ₀ and H ₁	
	M1	for writing or using N(60,...)	
	A1	for writing or using N(60, 36)	
	M1	for standardising (allow ±) using their "60" and "6" with either 46.5, 47 or 47.5 for CR method n, n + 0.5 or n – 0.5 and equate to –1.6449 or better	
	M1	for using the correct continuity correction 47.5 or (n + 0.5)	
	A1	for awrt 0.019 or CR: J < awrt 49.6 or J + 0.5 < awrt 50.1 Exact binomial gives 0.01756...and scores M0A0M0M0A0	
	A1	dep on previous A1 for a correct conclusion in context using bold word (oe) Do not allow 'number' for 'proportion'	

Question Number	Scheme		Marks
5 (a)	Complaints received are independent or occurring at a constant rate or singly		B1
			(1)
(b)(i)	$\left[P(X < 3 X \sim \text{Po}(6)) = \right]$ 0.0620	awrt 0.062	B1
(ii)	$\left[P(X \geq 6) = \right]$ $1 - P(X \leq 5)$ or $1 - 0.4457 = 0.5543$	awrt 0.554	M1A1
			(3)
(c)	$H_0 : \lambda = 6 \quad H_1 : \lambda > 6$		B1
	$P(X \geq 12) = 1 - P(X \leq 11) = [1 - 0.9799]$ or $P(X \geq 11) = 1 - P(X \leq 10) = [1 - 0.9574]$		M1
	$= 0.0201$ or $CR \geq 11$		A1
	Reject H_0 /In the CR/Significant		M1
	There is sufficient evidence to suggest that the mean number of complaints received is greater than 6 per week		A1ft
			(5)
(d)	$H_0 : \lambda = 6 \quad H_1 : \lambda < 6$		B1
	6 week period is $\text{Po}(36) \Rightarrow N(36, 36)$		B1
	$P(Y \leq 26) \approx P(Y < 26.5) = P\left(Z < \frac{26.5 - 36}{6}\right)$ or $\frac{x + 0.5 - 36}{\sqrt{36}} < -1.6449$		M1 M1
	$\left[P(Z < -1.583...) \right] = 0.0571$ (Calculator 0.05667...) or $x < 25.63...$		A1
	awrt 0.057	awrt 25.6	
	Do not reject H_0 /Not in the CR/Not significant		M1
	There is insufficient evidence to suggest that the mean number of complaints received after the changes made is less than 6 per week		A1ft
			(7)
Notes			Total 16
(a)	B1	A correct assumption. Must be in context so need ‘complaints’ and then independent/random or constant rate or singly	
(b)(i)	B1	awrt 0.062	
(ii)	M1	For writing or using $1 - P(X \leq 5)$ May be implied by awrt 0.554	
	A1	awrt 0.554	
(c)	B1	Both hypotheses correct. Must be attached to H_0 and H_1 in terms of λ or μ	
	M1	For writing or using $1 - P(X \leq 11)$ or $1 - P(X \leq 10)$	
	A1	For 0.0201 or $CR \geq 11$	
	M1	A correct statement – no context needed but do not allow contradicting non contextual comments	
	A1ft	Correct conclusion in context with the words highlighted in bold	
(d)	B1	Both hypotheses correct. Must be attached to H_0 and H_1 in terms of λ or μ Allow use of 36 rather than 6	
	B1	For writing or using $N(36, 36)$	
	M1	For standardising using 25.5/26/26.5, their mean and their standard deviation or standardising using $x - 0.5/x + 0.5$, their mean and their standard deviation and setting equal to -1.6449	
	M1	For a correct continuity correction written or used e.g. 26.5 or $x + 0.5$	
	A1	awrt 0.057 (NB Poisson used gives 0.0512685... and scores M0M0A0) or $CR < \text{awrt } 25.6$ (Allow $\leq$)	
	M1	A correct statement – no context needed but do not allow contradicting non contextual comments	
	A1ft	Correct conclusion in context with the words in bold (Allow The mean number of complaints has stayed the same/not changed oe)	

Question Number	Scheme		Marks
3(a)	$P(X \neq 4) = 1 - P(X = 4)$ oe $\left(= 1 - \frac{e^{-7} 7^4}{4!} \quad \text{or} \quad 1 - (0.1730 - 0.0818) \right)$		M1
	$= 0.90877\dots$	awrt 0.909	A1
			(2)
(b)	$P(Y=1) = (1 - "0.90877\dots") ("0.90877\dots")^4 \times {}^5C_1$		M1M1
	$= 0.311\dots$		A1
			(3)
(c)(i)	$\lambda = 0.07n$		B1
	$A \sim N(0.07n, 0.07n)$		M1
	$\frac{3.5 - "0.07n"}{\sqrt{"0.07n"}}$		M1
	$\frac{3.5 - 0.07n}{\sqrt{0.07n}} = -1.55 \quad \text{or} \quad "0.07n" - (1.55\sqrt{0.07})\sqrt{n} - 3.5 = 0$		B1
	$n - \left(\frac{1.55}{0.07} \sqrt{0.07} \right) \sqrt{n} - \frac{3.5}{0.07} = 0 \Rightarrow n - 1.55 \sqrt{\frac{n}{0.07}} - 50 = 0$		A1cso
			(5)
(ii)	$\sqrt{n} = \frac{\frac{1.55}{\sqrt{0.07}} \pm \sqrt{\left(\frac{1.55}{\sqrt{0.07}} \right)^2 + 4 \times 50}}{2} = \text{awrt } -4.72\dots \text{ or awrt } 10.6\dots (4\sqrt{7})$		M1
	$n = 112$		A1cao
			(2)
(d)	$H_0 : \lambda = 7 \quad H_1 : \lambda > 7$		B1
	$P(X \geq 15) = 1 - P(X \leq 14) \quad P(X \geq 14) = 0.0128$		M1
	$= 1 - 0.9943 \quad P(X \geq 15) = 0.0057$		
	$= 0.0057 \quad \text{CR } X \geq 15$		A1
	Reject H_0 , in the CR, Significant		dM1
	There is evidence that the number of water fleas per 100 ml of the pond water has increased		A1
			(5)
Total 17			
Notes			
(a)	M1	For $1 - P(X = 4)$ or $1 - P(X \leq 4) + P(X \leq 3)$ oe	
(b)	M1	$(1 - "their 0.909")^4 ("their 0.909")$ or $(1 - "their 0.909") ("their 0.909")^4$ allow their values to 2s.f.	
	M1	$P(Y=1) = (1 - "their 0.909") ("their 0.909")^4 \times {}^5C_1$ allow their values to 2s.f.	
	A1	awrt 0.312 or awrt 0.311	
(c)(i)	B1	Writing or using mean as 0.07n	
	M1	Normal with the mean = variance which must be in terms of n (may be implied by correct standardisation).	
	M1	Standardising with their mean and their $\sqrt{\text{var}}$. If not stated they must be correct. Allow 2.5, 3, 3.5, 4, 4.5 (A correct standardisation implies B1M1M1)	
	B1	Their standardisation = ± 1.55	
	A1cso	Must come from compatible signs in standardisation. Need at least one step between standardisation indicating division by 0.07 and correct equation.	
(ii)	M1	Correct method to solve given quadratic or sight of awrt -4.72 or awrt 10.6	
	A1cao	112 only (must reject 2nd answer if found) (an answer of 112 only scores M1A1)	
(d)	B1	Both hypotheses correct in terms of λ or μ [using p scores B0]	
	M1	For $1 - P(X \leq 14)$ or for CR: one of $P(X \geq 14) = 0.0128$ or $P(X \geq 15) = 0.0057$	
	A1	awrt 0.0057 or correct CR allow $X > 14$	
	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 0.01. (If not stated, may be implied by A1)	
	A1	All previous marks must be awarded. Correct context. conclusion with increase(oe) and fleas	