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EDEXCEL A LEVEL MATHEMATICS: QUESTIONS BY TOPIC

Statistical Hypothesis Testing (15)

A Level Mathematics Topic 15

10 questions · 77 marks · Mark schemes included

Pearson Edexcel A Level Mathematics (9MA0), June 2018 - June 2025

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HOW TO USE THIS BOOKLET

Questions are grouped by specification sub-topic and run from the lowest mark tariff to the highest within each one.

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.

Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

QUESTION	SOURCE		MARKS	PAGE	
15.1 HYPOTHESIS TESTING LANGUAGE AND CORRELATION TESTS			6 Qs · 44 marks	3	
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3. Q2	also Topic 12	Paper 3: Statistics and Mechanics	June2018	7	12
4. Q2	also Topic 11 & 12	Paper 3: Statistics and Mechanics	October2020	7	14
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15.2 BINOMIAL HYPOTHESIS TESTS			3 Qs · 18 marks	27	
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QUESTIONS

10 questions · 77 marks · 3 sub-topics



SUB-TOPIC 15.1

HYPOTHESIS TESTING LANGUAGE AND CORRELATION TESTS

Sub-topic 15.1 · 6 questions · 44 marks · lowest tariff first



2. Amar is studying the flight of a bird from its nest.

He measures the bird's height above the ground, h metres, at time t seconds for 10 values of t

Amar finds the equation of the regression line for the data to be $h = 38.6 - 1.28t$

- (a) Interpret the gradient of this line.

(1)

The product moment correlation coefficient between h and t is -0.510

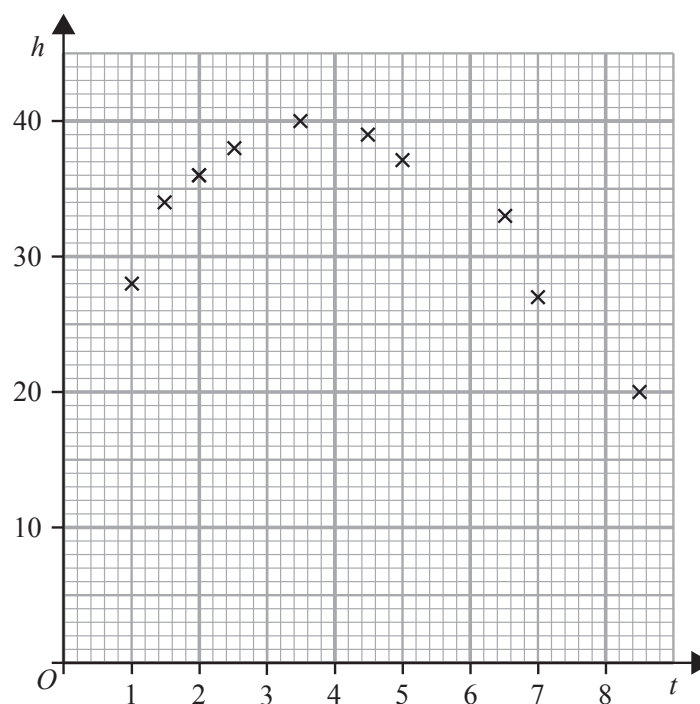
- (b) Test whether or not there is evidence of a negative correlation between the height above the ground and the time during the flight.

You should

- state your hypotheses clearly
- use a 5% level of significance
- state the critical value used

(3)

Jane draws the following scatter diagram for Amar's data.



- (c) With reference to the scatter diagram, state, giving a reason, whether or not the regression line $h = 38.6 - 1.28t$ is an appropriate model for these data.

(1)

Jane suggests an improved model using the variable $u = (t - k)^2$ where k is a constant.

She obtains the equation $h = 38.1 - 0.78u$

- (d) Choose a suitable value for k to write Jane's improved model for h in terms of t only.

(1)



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[illegible]

(Total for Question 2 is 6 marks)



- His results are shown in the scatter diagram on the next page.

- (1)

(1)

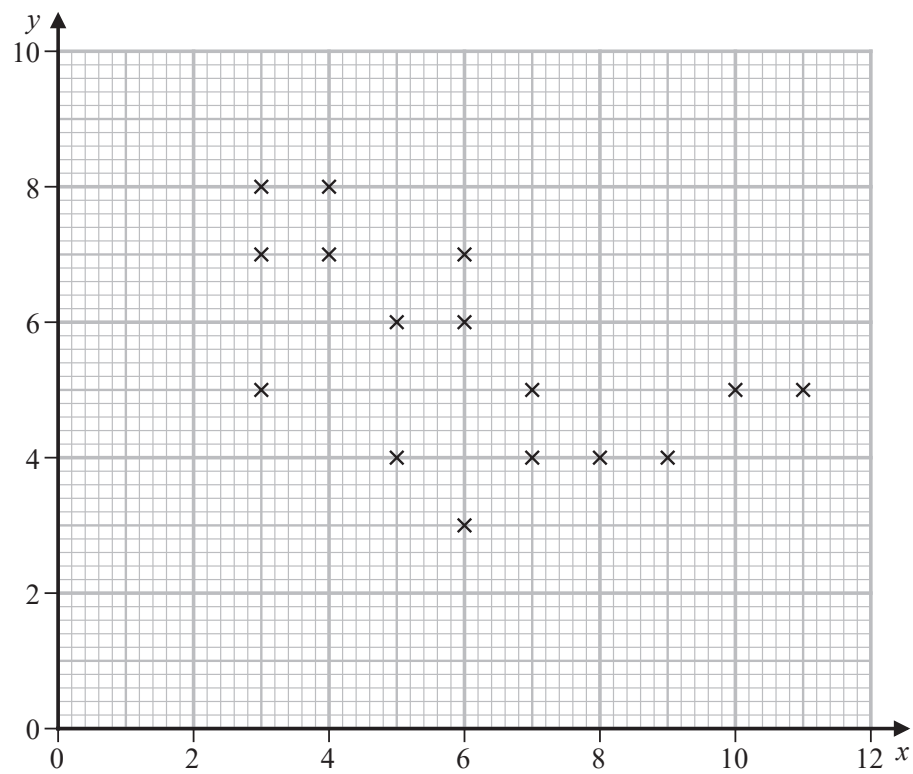
x	3	6	8	7	5	3	11	3	4	5	4	9	7	10	6	6
y	7	7	4	4	6	8	5	5	8	4	7	4	5	5	6	3

- (1)

- (3)



Question 2 continued.



Question 2 continued.



Question 2 continued.

(Total for Question 2 is 6 marks)



- (a) Stating your hypotheses clearly and using a 5% level of significance, test whether or not the correlation between sales figures and average weekly temperature is negative.

(3)

- (1)

(c) State, giving a reason, whether or not the correlation coefficient is consistent with Tessa's suggestion.

(1)

- (1)

(e) Give an interpretation of the gradient of this regression equation.

(1)



(Total for Question 2 is 7 marks)



2. A random sample of 15 days is taken from the large data set for Perth in June and July 1987. The scatter diagram in Figure 1 displays the values of two of the variables for these 15 days.

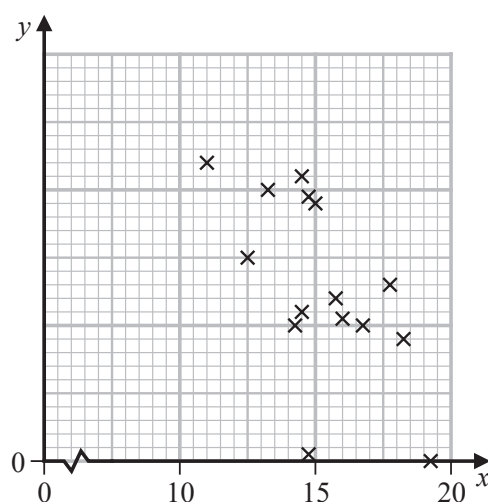


Figure 1

- (a) Describe the correlation.

(1)

The variable on the x -axis is Daily Mean Temperature measured in $^{\circ}\text{C}$.

- (b) Using your knowledge of the large data set,

- suggest which variable is on the y -axis,
- state the units that are used in the large data set for this variable.

(2)

Stav believes that there is a correlation between Daily Total Sunshine and Daily Maximum Relative Humidity at Heathrow.

He calculates the product moment correlation coefficient between these two variables for a random sample of 30 days and obtains $r = -0.377$

- (c) Carry out a suitable test to investigate Stav's belief at a 5% level of significance. State clearly

- your hypotheses
- your critical value

(3)

On a random day at Heathrow the Daily Maximum Relative Humidity was 97%

- (d) Comment on the number of hours of sunshine you would expect on that day, giving a reason for your answer.

(1)



Question 2 continued



Question 2 continued



Question 2 continued

(Total for Question 2 is 7 marks)



3. Barbara is investigating the relationship between average income (GDP per capita), x US dollars, and average annual carbon dioxide (CO_2) emissions, y tonnes, for different countries.

She takes a random sample of 24 countries and finds the product moment correlation coefficient between average annual CO_2 emissions and average income to be 0.446

- (a) Stating your hypotheses clearly, test, at the 5% level of significance, whether or not the product moment correlation coefficient for all countries is greater than zero.

(3)

Barbara believes that a non-linear model would be a better fit to the data.

She codes the data using the coding $m = \log_{10} x$ and $c = \log_{10} y$ and obtains the model $c = -1.82 + 0.89m$

The product moment correlation coefficient between c and m is found to be 0.882

- (b) Explain how this value supports Barbara's belief.

(1)

- (c) Show that the relationship between y and x can be written in the form $y = ax^n$ where a and n are constants to be found.

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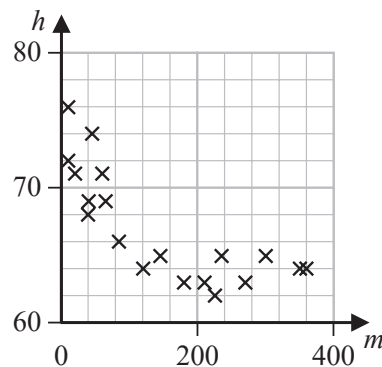
(Total for Question 3 is 9 marks)



6. Anna is investigating the relationship between exercise and resting heart rate. She takes a random sample of 19 people in her year at school and records for each person

- their resting heart rate, h beats per minute
- the number of minutes, m , spent exercising each week

Her results are shown on the scatter diagram.



- (a) Interpret the nature of the relationship between h and m

(1)

Anna codes the data using the formulae

$$x = \log_{10} m$$

$$y = \log_{10} h$$

The product moment correlation coefficient between x and y is -0.897

- (b) Test whether or not there is significant evidence of a negative correlation between x and y

You should

- state your hypotheses clearly
- use a 5% level of significance
- state the critical value used

(3)

The equation of the line of best fit of y on x is

$$y = -0.05x + 1.92$$

- (c) Use the equation of the line of best fit of y on x to find a model for h on m in the form

$$h = am^k$$

where a and k are constants to be found.

(5)









(Total for Question 6 is 9 marks)



SUB-TOPIC 15.2

BINOMIAL HYPOTHESIS TESTS

Sub-topic 15.2 · 3 questions · 18 marks · lowest tariff first



4. A dentist knows from past records that 10% of customers arrive late for their appointment.

A new manager believes that there has been a change in the proportion of customers who arrive late for their appointment.

A random sample of 50 of the dentist's customers is taken.

- (a) Write down

- a null hypothesis corresponding to no change in the proportion of customers who arrive late
- an alternative hypothesis corresponding to the manager's belief

(1)

- (b) Using a 5% level of significance, find the critical region for a two-tailed test of the null hypothesis in (a)

You should state the probability of rejection in each tail, which should be less than 0.025

(3)

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

(1)

The manager observes that 15 of the 50 customers arrived late for their appointment.

- (d) With reference to part (b), comment on the manager's belief.

(1)





4. The proportion of left-handed adults in a country is 10%
 Freya believes that the proportion of left-handed adults under the age of 25 in this country is different from 10%
 She takes a random sample of 40 adults under the age of 25 from this country to investigate her belief.

- (a) Find the critical region for a suitable test to assess Freya's belief.

You should

- state your hypotheses clearly
- use a 5% level of significance
- state the probability of rejection in each tail

(4)

- (b) Write down the actual significance level of your test in part (a)

(1)

In Freya's sample 7 adults were left-handed.

- (c) With reference to your answer in part (a) comment on Freya's belief.

(1)

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(Total for Question 4 is 6 marks)



3. A manufacturer makes components for the car industry.

On average 1.5% of the components made are defective.

- (a) Using a suitable model, find the probability that in a random sample of 36 components there are
- (i) exactly 2 defective components,
 - (ii) more than 3 defective components.

(3)

Once every six months, the manufacturer tests whether the proportion of defective components has changed using hypotheses $H_0: p = 0.015$ and $H_1: p \neq 0.015$

A random sample of 260 components is taken and 8 are found to be defective.

- (b) Using a 5% level of significance, complete the test.

(3)

Question 3 continued

(Total for Question 3 is 6 marks)



SUB-TOPIC 15.3

NORMAL MEAN HYPOTHESIS TESTS

Sub-topic 15.3 · 1 question · 15 marks · lowest tariff first



Question 5 continued



Question 5 continued

Question 5 continued



Question 5 continued

(Total for Question 5 is 15 marks)



MARK SCHEMES

official mark schemes



Qu 1	Scheme	Marks	AO
	2nd M1 for correct interpretation of “at least 12” and writing or using $1 - P(D \leq 11)$ We are <u>not</u> attempting to ft their incorrect 0.155 on our calculators here. A1 for awrt 0.212 [Answer only 3/3]		
(c)	B1 for 100 but must be seen in part (c) i.e. between (b) and (d)		
(d)	1st M1 for attempting normal with mean = 100 <u>or</u> ft their answer to (c) May be implied by the correct mean and a correctly labelled s.d. (σ) or var (σ^2)		
	1st A1 for correctly labelled standard deviation allow $\sqrt{\frac{250}{3}} = \sqrt{83.3...} = 9.1(28....)$ <u>or</u> correctly labelled variance. Implied by $N(\mu, \frac{250}{3})$ <u>or</u> correct answer.		
	2nd M1 for attempt at continuity correction i.e. sight of 95 ± 0.5 2nd A1 for awrt 0.689 [Answer only 4/4]		
NB	If they don't state the model for 1st M1 but just give probabilities with probability statements (Y is any letter):		
$\sigma = \frac{250}{3}$	1 st M1 implied by: $P(Y > 94.5) = 0.52(63...)$, $P(Y > 95) = 0.52(39...)$, $P(Y > 95.5) = 0.52(15..)$		
No cc	1st M1 1st A1 implied by: $P(T > 95) = 0.70(805...)$ 1st M1 1st A1 2nd M1 implied by: $P(T > 94.5) = 0.72(657...)$		
	Exact binomial gives 0.68567... and will likely score 0/4		

Qu 2	Scheme	Marks	AO
(a)	e.g. The <u>height</u> (h) <u>decreases</u> by about <u>1.28 m</u> for <u>each second</u> of the flight	B1 (1)	3.4
(b)	$H_0: \rho = 0$ $H_1: \rho < 0$ [5% 1-tail cv =] (+) 0.5494 [$r = -0.510$ not sig] there is <u>insufficient</u> (o.e.) evidence of a negative <u>correlation</u> between <u>height</u> (or h) and <u>time</u> (or t)	B1 M1 A1 (3)	2.5 1.1a 2.2b
(c)	No – since points seem to follow a curve/quadratic (rather than a line) or since points are “non-linear” but regression line/ model is linear or e.g. between ($t = 5$ and 7) height drops by much more than 2.56 m or e.g. gradient is positive up to $t = 3.5$ (line gradient < 0) or e.g. gradient is positive initially (line gradient < 0) or e.g. gradient is positive and then negative	B1 (1)	2.4
(d)	[$h = 38.1 - 0.78 (t - k)^2$ with] a suitable k i.e. in the range 3~4.5	B1 (1)	3.3
(6 marks)			
Notes			
(a)	B1 for a suitable interpretation in context [value can be 1.3 or 1.28 or “just over 1”] per sec Must have underlined words (o.e.) and units “m” or metres and “s” or seconds NB “descends” implies “height decreases” Condone e.g. “decreases by – 1.28 m”		
(b)	B1 for both hypotheses correct in terms of ρ [accept a p or p but not r or r] Must be attached to H_0 and H_1 M1 for a critical value corresponding to their H_1 : 1-tail: awrt ± 0.549 or 2-tail (B0 scored for H_1) : awrt ± 0.632 (tables 0.6319) If hypotheses are in words and can deduce whether one or two-tail then use their words. If no hypotheses or their H_1 is not clearly one or two-tail assume one-tail A1 a correct conclusion in context mentioning <u>correlation</u> and <u>height</u> and <u>time</u> A comparison or statement such as “not sig” is not needed but if seen must be correct. Do NOT award this A mark if contradictory comments or working seen e.g. “reject H_0 ” or comparison of 0.510 with significance level of 0.05 or e.g. $-0.549 > -0.510$ NB Can award B0M1A1		
SC	B0 (for 2-tail) M0 (for cv = ± 0.549) scored: Allow 1 mark (score as B0M0A1) for conclusion such as: “ <u>insufficient</u> evidence of (negative) <u>correlation</u> between <u>height</u> and <u>time</u> of flight”		
(c)	B1 for saying no and giving a suitable supporting reason Don’t allow “correlation” on its own instead of “gradient” B0 for simply saying “points don’t lie close to a straight line” Need mention of curve or some other feature of scatter plot that <u>differs</u> from regression line. B0 for just “non-linear” without mention of the model being linear B0 for simply comparing 1 or 2 points – need a comment about general pattern		
(d)	B1 for a value of k in the range [3, 4.5] Do not need $k = \dots$ Accept a value embedded in Jane’s model. ISW any errors in multiplying out bracket.		

Qu 2	Scheme	Marks	AO
(a)	Negative	B1 (1)	1.2
(b)	Marc’s suggestion <u>is compatible</u> because it’s <u>negative correlation</u>	B1 (1)	2.4
(c)	$(r =) - 0.54458266...$ awrt <u>–0.545</u>	B1 (1)	1.1b
(d)	$H_0 : \rho = 0 \quad H_1 : \rho < 0$ [5% 1-tail cv =] $(\pm) 0.4259$ (significant result / reject H_0)	B1 M1	2.5 1.1a
	There <u>is</u> evidence of negative <u>correlation</u> between the <u>number of letters</u> in (or <u>length</u> of) a student’s last <u>name</u> and their first <u>name</u>	A1 (3)	2.2b
		(6 marks)	
Notes			
(a)	B1 for “negative” Allow “slight” or “weak” etc Allow a description e.g. “as x increases y decreases” or in context e.g. “people with longer last names tend to have shorter first names” A comment of “negative skew” is B0 Need to see distinct or separate responses for (a) and (b)		
(b)	B1 for a comment that suggests data is compatible with the suggestion and a suitable reason such as “there is negative correlation” <u>or</u> a description in x and y or in context <u>or</u> the points lie close to a line with <u>negative gradient</u> <u>or</u> draw line $y = x$ and state that <u>more points below the line</u> so <u>supports (or is compatible with)</u> his suggestion A reason based on just a single point is B0 e.g. “ 11 letters in last name has only 5 in first name”		
(c)	B1 for awrt – 0.545		
(d)	B1 for both hypotheses correct in terms of ρ M1 for a critical value compatible with their H_1 : 1-tail: awrt ± 0.426 (condone ± 0.425) or 2-tail (B0 scored for H_1) : awrt ± 0.497 If hypotheses are in words and can deduce whether one or two-tail then use their words. If no hypotheses or their H_1 is not clearly one or two tail assume one-tail A1 for compatible signs between cv and r and a correct conclusion in context mentioning <u>correlation</u> and <u>number of letters</u> or <u>length</u> and <u>name</u> (ft their value from (c)) Do NOT award this A mark if contradictory comments or working seen e.g. “accept H_0 ” or comparison of 0.426 with significance level of 0.05 etc NB The M1A1 can be scored independently of the hypotheses		

Qu 1	Scheme	Marks	AO
(a)	1 st B1 for a correct set of values for c . Allow $\{\frac{1}{8}, \frac{2}{8}, \dots, \frac{8}{8}\}$ 2 nd B1ft for correct probs from their values for c , consistent with discrete uniform distrib'n Maybe as a prob. function. Allow $P(X = x) = \frac{1}{9}$ for $0 \leq x \leq 8$ provided $x = \{0, 1, 2, \dots, 8\}$ is clearly defined somewhere.		
(b)	B1 for using correct model to get $\frac{4}{9}$ (o.e.)		
SC	Sample space $\{1, \dots, 8\}$ If scored B0B1 in (a) for this allow $P(C < 4) = \frac{3}{8}$ to score B1 in (b)		
(c)	B1ft for comment that states that the model proposed is or is not a good one based on their model in part (a) and their probability in (b) $(b) - 0.315 > 0.05$ Allow e.g. “it is not suitable”; “it is not accurate” etc $(b) - 0.315 \leq 0.05$ Allow a comment that suggests it <u>is</u> suitable No prob in (b) Allow a comparison that mentions 50% or 0.5 and rejects the model No prob in (b) and no 50% or 0.5 or $(b) > 1$ scores B0 Ignore any comments about location or weather patterns.		
(d)	B1 for a sensible refinement considering variations in month or location Just saying “not uniform” is B0 Context & “non-uniform” Allow mention of different locations, months <u>and</u> non-uniform <u>or</u> use more locations to form a new distribution with probabilities based on frequencies Context & “binomial” Allow mention of different locations, months <u>and</u> binomial Just refined model Model must be outlined and discrete and non-uniform e.g. higher probabilities for more cloud cover <u>or</u> lower probabilities for less cloud cover Continuous model Any model that is based on a continuous distribution. e.g. normal is B0		

Qu 2	Scheme	Marks	AO
(a)	$H_0 : \rho = 0$ $H_1 : \rho < 0$ Critical value: -0.6215 (Allow any cv in range $0.5 < cv < 0.75$) $r < -0.6215$ so significant result and there is evidence of a negative correlation between w and t	B1 M1 A1 (3)	2.5 1.1a 2.2b
(b)	e.g. As temperature increases people spend more time on the beach and less time shopping (o.e.)	B1 (1)	2.4
(c)	Since r is close to -1 , it is consistent with the suggestion	B1 (1)	2.4
(d)	t will be the explanatory variable since sales are likely to depend on the temperature	B1 (1)	2.4
(e)	Every degree rise in temperature leads to a drop in weekly earnings of £171	B1 (1)	3.4
		(7 marks)	
Notes			
(a)	B1 for both hypotheses in terms of ρ M1 for the critical value: sight of ± 0.6215 or any cv such that $0.5 < cv < 0.75$ A1 must reject H_0 on basis of comparing -0.915 with -0.6215 (if $-0.915 < -0.6215$ is seen then A0 but may use $ r $ o.e. which is fine) <u>and</u> mention “negative”, “correlation/relationship” and at least “ w ” and “ t ”		
(b)	B1 for a suitable <u>reason to explain</u> negative correlation using the context given. e.g. “As temperature drops people are more likely to go shopping (than to the beach)” e.g. “As temperature increases people will be outside rather than in shops” A mere description in context of negative correlation is B0 SO e.g. “As temperature increases people don’t want to go shopping/buy clothes” is B0 e.g. “Less clothes needed as temp increases” is B0		
(c)	B1 for a suitable reason e.g. “strong”/”significant”/”near perfect” “correlation”, $ r $ close to 1 <u>and</u> saying it is consistent with the suggestion. Allow “yes” followed by the reason.		
(d)	B1 For identifying t <u>and</u> giving a suitable reason. Need idea that “ w <u>depends</u> on t ” or “ w <u>responds</u> to t ” or “ t <u>affects</u> w ” (o.e.) Allow t (temperature) <u>affects</u> the other variable etc Just saying “ t is the independent variable” or “ t <u>explains</u> change in w ” is B0 N. B. Suggesting causation is B0 e.g. “ t causes w to decrease”		
(e)	B1 for a description that conveys the idea of rate per degree Celsius. Must have 171, condone missing “£” sign.		

Qu 2	Scheme	Marks	AO
(a)	Negative	B1 (1)	1.2
(b)(i)	Rainfall	B1	2.2b
(ii)	mm <u>or</u> Pressure hPa or Pascals or hectopascals or mb or millibars	B1ft (2)	1.1b
(c)	$H_0: \rho = 0$ $H_1: \rho \neq 0$ Critical value: $-0.361(0)$ $r < -0.3610$ so significant result and there is evidence of a correlation between Daily Total <u>Sunshine</u> and Daily Maximum Relative <u>Humidity</u>	B1 M1 A1 (3)	2.5 1.1b 2.2b
(d)	Humidity is high and there is evidence of correlation and $r < 0$ So expect amount of sunshine to be <u>lower</u> than the <u>average</u> for Heathrow(oe)	B1 (1)	2.2b
(7 marks)			
Notes			
(a)	B1 for stating negative. “Negative skew” is B0 though		
(b)(i)	B1 for mentioning “rainfall” (allow “rain” <u>or</u> “precipitation”) <u>or</u> “pressure” (if more than 1 answer both must be correct) NB the other quantitative variable for Perth is: Daily Mean Wind Speed and scores B0 [Not allowed “wind speed” since $r = +0.15$ and in winter might expect wind to raise temp]		
(ii)	B1ft for giving the correct units. If Daily Mean Wind Speed (kn) or knots “Wind speed” and “knots” would score B0B1 but any other variable scores B0B0		
(c)	B1 for both hypotheses correct in terms of ρ M1 for the correct critical value compatible with their H_1 : allow $\pm 0.361(0)$ If the hypotheses are 1-tail then allow cv of ± 0.3061 e.g. Alternative hypothesis with $r < \pm 0.377$ implies a one-tail test <u>or</u> H_0 and H_1 in words saying “ H_0 : there is no correlation, H_1 : there is correlation” is two-tail If there are no hypotheses (or they are nonsensical) assume 2-tail so M1 for $\pm 0.361(0)$ A1 for a correct conclusion in context based on comparing -0.377 with their cv. Condone incorrect inequality e.g. $-0.3610 < -0.377$ as long as they reject H_0 Do not accept contradictory statements such as “accept H_0 so there is evidence of ...” Can say “support for Stav’s <u>belief</u> ”(o.e.e.g. “claim”) or “evidence of a correlation between <u>sunshine</u> and <u>humidity</u> ” condone “negative correlation” or comments such as “if humidity is high amount of sunshine will be low”		
(d)	B1 for stating <u>low</u> amount of sunshine (o. e.) and some reference to $r < 0$ or fog Check for the following 2 features: (i) low sunshine: allow ≤ 5 hrs (LDS mean for 2015 is 5.3, humidity 97% is 4.1, $\geq 97\%$ is 3.1) (ii) negative correlation may be described in words e.g. “high humidity gives low sunshine” <u>or</u> fog (LDS says $>95\%$ humidity is foggy) so less sunshine		



Question	Scheme		Marks	AOs
3(a)	$H_0 : \rho = 0 \qquad H_1 : \rho > 0$		B1	2.5
	Critical value 0.3438		M1	1.1a
	(0.446 > 0.3438) so there is evidence that the product moment correlation coefficient (pmcc) is greater than 0/there is positive correlation		A1	2.2b
			(3)	
(b)	The value is close(r) to 1 or there is strong(er) (positive) correlation		B1	2.4
			(1)	
(c)	$\log_{10} y = -1.82 + 0.89(\log_{10} x)$	$y = ax^n \rightarrow$ $\log_{10} y = \log_{10} (ax^n)$	M1	1.1b
	$y = 10^{-1.82+0.89(\log_{10} x)}$	$\log_{10} y = \log_{10} a + \log_{10} x^n$	M1	2.1
	$y = 10^{-1.82} \times 10^{0.89(\log_{10} x)}$ [$= 10^{-1.82} \times 10^{(\log_{10} x)^{0.89}}$]	$\log_{10} y = \log_{10} a + n \log_{10} x$ [$\log_{10} a = -1.82, n = 0.89$]	M1	1.1b
	$y = 0.015x^{0.89}$	$y = 0.015x^{0.89}$	A1A1	1.1b 1.1b
			(5)	
(9 marks)				
Notes				
(a)	B1: for both hypotheses correct in terms of ρ M1: for the critical value: sight of 0.3438 or any cv such that $0.25 < cv < 0.45$ A1: a comment suggesting a significant result/ H_0 is rejected on the basis of <u>seeing</u> +0.3438 and which mentions “pmcc/correlation/relationship” and “greater than 0/positive” (not just $\rho > 0$) or an answer in context e.g. ‘as “income”(o.e.) increases, “CO ₂ /emissions”(o.e.) increases’ A contradictory statement scores A0 e.g. ‘Accept H_0 , therefore positive correlation’			
(b)	B1: for suitable reason e.g. r is close(r) to 1 or “strong(er)”/“near perfect” “correlation” Do not allow ‘association’			
(c)	For both methods, once an M0 is scored, no further marks can be awarded and condone missing base 10 throughout Method 1: (working to the model) M1: Correct substitution for both c and m (may be implied by 2 nd M1 mark) M1: Making y the subject to give an equation in the form $y = 10^{a+b(\log_{10} x)}$ (may be implied by 3 rd M1 mark) M1: Correct multiplication to give an equation in the form $y = 10^a \times 10^{b(\log_{10} x)}$ (this line implies M1M1M1 provided no previous incorrect working seen) Method 2: (working from the model) M1: Taking the log of both sides (may be implied by 2 nd M1 mark) M1: Correct use of addition rule (may be implied by 3 rd M1 mark) M1: Correct multiplication of power (this line implies M1M1M1 provided no previous incorrect working seen) A1: $n = 0.89$ or $a = \text{awrt } 0.015$ or $y = ax^{0.89}$ or $y = \text{awrt } 0.015x^n$ (dep on M3) A1: $n = 0.89$ and $a = \text{awrt } 0.015$ / $y = \text{awrt } 0.015x^{0.89}$ (dep on M3) do not award the final A1 if answer is given in an incorrect form e.g. $y = 0.015 + x^{0.89}$			

Question	Scheme		Marks	AOs
6(a)	eg As the number of minutes <u>exercise</u> (m) increases the resting <u>heart rate</u> (h) decreases or the gradient of the curve is becoming flatter with increasing m : diminishing effect of each <u>additional minute</u> of <u>exercise</u>		B1	2.4
			(1)	
(b)	$H_0 : \rho = 0$ $H_1 : \rho < 0$		B1	2.5
	Critical value – 0.3887 (Allow $\pm$)		M1	1.1b
	There is evidence that the product moment <u>correlation</u> is <u>less than 0/</u> <u>there is a negative correlation</u>		A1	2.2b
			(3)	
(c)	$\log_{10} h = -0.05 \log_{10} m + 1.92$	$h = am^k \rightarrow \log_{10} h = \log_{10} am^k$	M1	1.1b
	$\log_{10} h = -\log_{10} m^{0.05} + 1.92$ or $\log_{10} h = \log_{10} m^{-0.05} + 1.92$ or $h = 10^{1.92 - 0.05 \log_{10} m}$ oe	$\log_{10} h = \log_{10} a + \log_{10} m^k$ or $\log_{10} a = 1.92$	M1	2.1
	$\log_{10} hm^{0.05} = 1.92$ or $\log_{10} \left(\frac{h}{m^{-0.05}} \right) = 1.92$ or $h = 10^{1.92} \times 10^{-0.05 \log_{10} m}$ oe	$\log_{10} h = \log_{10} a + k \log_{10} m$	M1	1.1b
	$hm^{0.05} = 10^{1.92}$ or $\frac{h}{m^{-0.05}} = 10^{1.92}$ or $h = 10^{1.92} \times 10^{\log_{10} m^{-0.05}}$	$\log_{10} a = 1.92$ and $k = -0.05$	M1	1.1b
	$h = 10^{1.92} m^{-0.05}$ or $h = 83.17...m^{-0.05}$ or $a = \text{awrt } 83.17$ and $k = -0.05$		A1	1.1b
			(5)	
Notes: (9 marks)				
(a)	B1	eg Idea as one increases the other decreases (in context). Allow use of m and h eg As m increases h decreases. Do not allow negative correlation with no context or $\rho < 0$ Allow there is a negative correlation/association/relationship/exponential between minutes <u>exercise</u> (m) and resting <u>heart rate</u> (h) oe		
(b)	B1	Both hypotheses correct in terms of ρ (allow p)		
	M1	For the cv of -0.3887 or any cv such that $0.3 < cv < 0.5$		
	A1	Independent of hypotheses. Correct conclusion that implies reject H_0 on basis of seeing -0.3887 or if they give 0.3887 we must see the comparison $0.3887 < 0.897$ and which mentions “pmcc/correlation/relationship” and less than 0/ negative or $\rho < 0$ A contradictory statement scores A0 eg Accept H_0 therefore negative correlation		
(c)		In this part once M0 is scored no more marks can be scored. Condone no base		
	M1	May be implied by 2nd M1 mark Method 1: Correct substitution for both x and y Method 2 : Taking the log of both sides		
	M1	May be implied by 3rd M1 mark Method 1: Correct use of the power log rule or making h the subject Method 2 : Correct use of the addition/subtraction log rule		
	M1	This line implies M1M1M1 Method 1: Correct use of the addition/subtraction log rule or eq ⁿ in the form $h = 10^{1.92} \times 10^{-0.05 \log m}$ Method 2: A second correct step for correct use of the power log rule		
	M1	This line implies M1M1M1M1 Method 1: Correct removal of logs or $h = 10^{1.92} \times 10^{\log m^{-0.05}}$ Method 2: Log a (or a) and k correct		
	A1	Allow $h = \text{awrt } 83.2m^{-0.05}$ NB award 5/5 for $a = \text{awrt } 83.2$ and $k = -0.05$ or $h = \text{awrt } 83.2...m^{-0.05}$ or $h = 10^{1.92} m^{-0.05}$		

Question		Scheme	Marks	AOs
4(a)		$H_0: p = 0.1 \quad H_1: p \neq 0.1$	B1	2.5
			(1)	
(b)		Use of $X \sim B(50, 0.1)$ implied by sight of one of awrt 0.0052 or awrt 0.9755 or awrt 0.0245	M1	3.4
		Critical regions $X = 0$ or $X \geq 10$	A1	1.1b
		$X = 0$ and $X \geq 10$ plus $P(X = 0) = \text{awrt } 0.0052$ and $P(X \geq 10) = \text{awrt } 0.0245$	A1	1.1b
		SC: Both CR correct with no probabilities and no distribution seen scores M0A1A0		
			(3)	
(c)		0.0297	B1ft	1.1b
			(1)	
(d)		15 is <u>in the critical region</u> therefore there is evidence to support the <u>manager's</u> belief	B1ft	2.2b
			(1)	
(6 marks)				
Notes				
(a)	B1	For both hypotheses in terms of p or π . Connected to H_0 and H_1 correctly Condone 10% but not 10		
(b)	M1	Using correct distribution to find the probability associated with one tail of the CR If the correct distribution is <u>stated</u> (may be seen in part(a)) allow for one tail of the correct CR or one of (awrt 0.025 or awrt 0.005 or awrt 0.975) seen connected to a correct probability statement		
	A1	Lower CR $X = 0$ / $X < 1$ / $X \leq 0$ / [condone eg $P(X = 0)$ labelled as CR] Or Upper CR $X \geq 10$ or $X > 9$ [condone $P(X \geq 10)$ oe labelled as CR]		
	A1	Both CR's correct with the relevant probabilities Allow $\cup$ for "and" and $X > 9$, $X < 1$, $X \leq 0$ [do not allow $P(X = 0)$ or $P(X \geq 10)$ oe] Allow CR in different form eg $(9, \infty)$, $[10, \infty)$		
(c)	B1ft	awrt 0.0297 or 2.97% or ft for the sum of the probabilities in (b) for "their 2 critical regions" if seen. If none seen it must be awrt 0.0297 SC M0 in (b) for a one tail test Allow B1ft for their one tail CR in (b) eg 0.0338 or 0.0245 or 0.0579		
(d)	B1ft	A correct statement about 15 and "their CR" or sight $P(X \geq 15) = 0.0000738...$ and comparison with "their 0.0245" and a compatible correct statement in context. eg There is evidence that there has been a change in the <u>proportion/probability</u> arriving <u>late</u> Condone increase rather than change Do not allow contradicting statements. NB No CR given in (b) then B0		

Qu 4	Scheme	Marks	AO
(a)	$H_0: p = 0.1$ $H_1: p \neq 0.1$ [Allow 10% for 0.1]	B1	2.5
	$[X \sim B(40, 0.1)] \Rightarrow P(X = 0) = 0.0148$ [Allow any letter for X]	M1	3.3
	$P(X \geq 9) = 1 - P(X \leq 8) = 1 - 0.9845 = 0.0155$	A1	1.1b
	Critical region is $\{X = 0\} \cup \{X \geq 9\}$ (o.e.)	A1	1.1b
		(4)	
(b)	$[“0.0148” + “0.0155”] = 0.0303$	B1ft	1.1b
		(1)	
(c)	[Provided 7 is not in their CR] insufficient evidence to support Freya’s belief	B1	2.2b
		(1)	
		(6 marks)	
Notes			
Mark (a) and (b) together for sight of the probabilities. (a) B1 for both hypotheses in terms of p or π. Must be attached to H_0 and H_1 M1 for <u>use</u> of the correct model. Implied by sight of at least one probability truncated or rounded to at least 2sf from: 0.0155, 0.0148, 0.0805, 0.9845, 0.9581, 0.9949 Implied by sight of fully correct CR (with no probs) so e.g. $X = 0$, $X > 8$ scores M1A0A0 1st A1 for at least one correct probability (to at least 3sf) with its probability statement i.e. for $P(X = 0) = \text{awrt } 0.0148$ <u>or</u> $P(X \geq 9) = \text{awrt } 0.0155$ 2nd A1(dep on M1 and 1st A1 but not on B1) for both correct probs (to at least 3 sf) <u>and</u> the correct critical region Do not need set notation. Allow $X < 1$ and $X > 8$ <u>or</u> words e.g. “0 or greater than 8” etc Allow “,” <u>or</u> “and” <u>or</u> “or” <u>or</u> “$\cap$” between $X \leq 0$ and $X \geq 9$ $P(X = 0)$ and $P(X \geq 9)$ is 2nd A0 (b) B1ft for awrt 3.03% <u>or</u> correct sum of their two probabilities (provided each is less than 0.5) Their probabilities must be to at least 2sf and relate to their CR To score in (c) they must have a CR of the form $(X = 0 \text{ or } X < a)$ and $X > b$, where b is ≥ 7 May be implied by $P(X < a)$ and $P(X > b)$ i.e. 2nd A0 in (a) but correct form. Need $b > a$ (c) B1 for a suitable comment in context that suggests <u>no support</u> for Freya’s <u>belief/claim</u> <u>or</u> e.g. <u>insufficient</u> evidence of change in <u>proportion/percentage</u> of <u>left-handed</u> adults <u>or</u> e.g. <u>proportion/percentage</u> of <u>left-handed</u> adults is <u>not different</u> from 10% (<u>or ...is 10%</u>) <u>or</u> e.g. <u>10%</u> of adults in the country are <u>left-handed</u> Do not allow contradictory comments e.g. “in CR so no support for Freya’s belief” is B0 NB A correct contextual answer in (c) using an acceptance region please send to review.			



Question	Scheme		Marks	AOs
3(a) (i) (ii)	[Let D = the number of defective components] $D \sim B(36, 0.015)$		M1	3.3
	[$P(D = 2) =]$ 0.084792... awrt 0.0848		A1	1.1b
	[$P(D > 3) = 1 - P(D \leq 3) = 1 - 0.9979... =]$ 0.002032... awrt 0.00203		A1	1.1b
			(3)	
3(b)	[Let X = the number of defective components] $X \sim B(260, 0.015)$		M1	3.3
	[$P(X \geq 8) =]$ 0.0441(1...)		A1	1.1b
	[0.04 > 0.025 so not significant] <u>Insufficient</u> evidence that <u>proportion/probability</u> of defective <u>components</u> has <u>changed</u> (o.e.)		A1	2.2b
			(3)	
(6 marks)				
Notes:				
(a) (i) (ii)	M1	for selecting $B(36, 0.015)$ sight of or use of. Must be $B(...)$ [Implied by sight of $Po(0.54)$] May be implied by sight of: 0.0848 <u>or</u> awrt 0.085 <u>or</u> 0.00203 <u>or</u> 0.998 <u>or</u> 0.002		
	A1	for awrt 0.0848		
	A1	for awrt 0.00203 [Allow 2.03×10^{-3}]		
	Use of Poisson $Po(0.54)$ (i) 0.08496 scores A0 (ii) 0.002309... awrt 0.00231 scores A1			
Notation: We do not accept “calculator speak” e.g. $N = 36, p = 0.015$ instead of $B(36, 0.015)$				
(b)	M1	for sight of $B(260, 0.015)$ may be implied by probability of awrt 0.0441 <u>or</u> awrt 0.0264 <u>or</u> awrt 0.956 <u>or</u> correct CR $X = 0$ [<u>or</u> ≤ 0] and $X \geq 9$ <u>or</u> $P(X \geq 8) = 0.04$ or better		
	A1	for probability of awrt 0.0441 (selected if more probabilities seen) Condone $P(X = 8) = 0.0441...$ If $P(X \geq 8)$ is explicitly seen allow 0.04 or better <u>or</u> for the correct CR $X = 0$ [<u>or</u> ≤ 0] and $X \geq 9$. Allow acceptance region $[1, 8]$ (o.e.)		
	A1	dep on M1A1 for a correct conclusion in context. Allow e.g: <u>proportion/probability</u> of defective <u>components</u> has <u>not changed</u> <u>proportion/probability</u> of defective <u>components</u> is still <u>0.015</u> Allow “defectives” instead of “components” If a comparison is seen (other than $0.956 < 0.975$) it must be with 0.025 Incorrect comparisons score A0 (condone missing comparison) Do not accept contradictory statements e.g. “significant so insufficient evidence of change in proportion” would score A0 “Insufficient evidence that $p \neq 0.015$ ” is A0, we need the words.		
SC	Poisson Approximation (If you see $Po(3.9)$ or probability 0.0454...)			
	B2 and mark as M0A1A1			
	B1	for probability of awrt 0.0454 <u>or</u> 0.04... if $P(X \geq 8)$ seen <u>or</u> CR as above		
	B1	for correct conclusion in context (same rules as above)		



Qu 5	Scheme	Marks	AO
(a)	{ Let X = time spent, $P(X > 15) = \}$ 0.105649... awrt 0.106	B1 (1)	1.1b
(b)	$H_0: \mu = 10$ $H_1: \mu > 10$ $\bar{X} \sim N\left(10, \left(\frac{4}{\sqrt{20}}\right)^2\right)$; $P(\bar{X} > 11.5) = 0.046766...$ [Condone 0.9532...] [This is significant (< 5%) so] there is evidence to support the complaint	B1 M1;A1 A1 (4)	2.5 3.3;3.4 2.2b
(c)(i)	$[P(T < 2) =]$ 0.1956... awrt 0.196	B1 (1)	1.1b
(ii)	Require $\frac{P(0 < T < 2)}{P(T > 0)} = \frac{0.119119...}{0.923436...}$; = 0.1289955... awrt 0.129	M1 A1;A1 (3)	3.4 1.1bx2
(iii)	The current model suggests non-negligible probability of T values < 0 which is impossible	B1 (1)	3.5b
(d)	Require t such that $P(T > t T > 2) = 0.5$ or $P(T < t T > 2) = 0.5$ e.g. $\frac{P(T > t)}{P(T > 2)} = 0.5$; so $P(T > t) = 0.5 \times [1 - (c)(i)]$ or $P(T > t) = 0.5 \times 0.8043..$ [i.e. $P(T > t) = 0.40...$ implies] $\frac{t-5}{3.5} = 0.2533$ or $P(T < t) = "0.5978.."$ $t = 5.886...$ or from calculator 5.867... so awrt 5.9	M1 M1; A1ft M1 A1 (5)	3.1b 1.1b 3.4 1.1b 1.1b
(15 marks)			
Notes			
(a)	B1 for awrt 0.106 (from calculator) [Allow 10.6%]		
(b)	B1 for both hypotheses correct in terms of μ . M1 for selection of a correct model (sight or use of correct normal- may not have label $\bar{X}$) 1 st A1 for use of this model to get probability allow 0.046~0.047 [Condone awrt 0.953]		
ALT	OR test statistic $z = 1.677...$ (awrt 1.68) and cv of 1.64 (or better) or CR $\bar{X} > 11.47..$		
	2 nd A1 (dep on 1 st A1 or at least $P(\bar{X} > 11.5) < 0.05$ (o.e.))		
	for a correct conclusion in context -must mention complaint /claim or time /mins is > 10		
SC	(M0 for $\bar{X} \sim N(11.5, ...)$ for correct probability and conclusion (score M0A0A1 on open)		
(c)(i)	B1 for awrt 0.196 (from calculator) [Allow 19.6%]		
(ii)	M1 for a correct probability ratio expression (may be implied by 1 st A1 scored) 1 st A1 for a correct ratio of probabilities (both correct or truncated to 2 dp) 2 nd A1 for awrt 0.129		
(iii)	B1 for a suitable explanation of why model is not suitable based on negative T values Must say that a significant proportion of values < 0 (o.e.) e.g. $P(T > 0)$ should be closer to 1 or Difference between $P(T < 2 T > 0)$ and $P(T < 2)$ is too big (o.e.)		
(d)	1 st M1 for a correct conditional probability statement to start the problem or $0.5 \times P(T > 2)$ 2 nd M1 for correct ratio of probability expressions [Must have $P(T > t)$ or $P(2 < T < t)$] 1 st A1ft for a correct equation for $P(T > t)$ (o.e.) ft their answer to part (c)[May be in a diagram] 3 rd M1 for attempt to find t (standardising and sight of 0.2533) or prepare to use calc (ft) Arriving at $P(T < \text{median}) = 1 - 0.5 \times \text{their } 0.8043$ will score 1 st 4 marks 2 nd A1 for awrt 5.9 Sight of awrt 5.9 and at least one M mark scores 5/5 [Answer only send to review]		

