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ANSWER BOOK

Choosing, carrying out and concluding a statistical test

Scientific method and quantitative biology · Unit B00

AQA 3.6.1.1 (taxes and kineses), 3.7.1 (chi-squared against a predicted ratio), MS 1.2, MS 1.3, MS 1.5–1.7, MS 1.9–1.11 · OCR A Module 1.1.4; mathematical requirements (statistics) Edexcel A Mathematical skills appendix (statistics) · Edexcel B 8.2 vi, 10.1 vi CAIE 16.2 (chi-squared), 17.1 (the t-test), 18.2 (Spearman and Pearson), Paper 5 (analysis, conclusions and evaluation)

15 questions · 52 marks

NAVY EDITION

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SECTION A · Short, 1 to 2 marks

A1 CCO-Q13

B1 chi-squared works on raw counts of individuals falling into categories, and a volume of oxygen produced is a continuous measurement rather than a count in a category. **B1** comparing two sets of continuous, roughly normally distributed measurements, each scattered about a mean, calls for a t-test rather than chi-squared. [2]

A2 CCO-Q14

B1 the four equal readings are each given the mean of the ranks, or positions, they would otherwise have occupied between them. **B1** for example, if they would have occupied positions 3, 4, 5 and 6, each is given the rank 4.5, and the next distinct value still takes position 7. [2]

A3 CCO-Q15

B1 in everyday use 'significant' means important or noticeable, but in statistics it has a precise, technical meaning: that a calculated value has exceeded a critical value at a stated probability. **B1** that meaning can only be assigned once a test has actually been carried out and compared with a critical value, so calling a result 'significant' before running the test asserts something not yet established. [2]

SECTION B · Standard, 3 to 5 marks

B1 CCO-Q4

B1 the comparison: state both values, for example 'the calculated value of 9.49 is greater than the critical value of 7.81'. **B1** the conditions: give the probability level and degrees of freedom used, for example 'at $p = 0.05$ with 3 degrees of freedom'. **B1** the decision: state plainly that the null hypothesis is rejected. **B1** the biology: state what the result means for the organisms or variables in question, in a sentence about the biology rather than only the numbers. [4]

B2 CCO-Q5

B1 chi-squared, because the data are counts of individuals in categories being compared with a predicted ratio. **B1** O is the observed number of plants counted in each flower-colour category, and E is the number expected in each category if the 1:2:1 ratio held exactly. **B1** degrees of freedom = number of categories - 1 = 3 - 1 = 2. [3]

B3 CCO-Q6

B1 there is no significant association between vaccination status and the severity of illness. **B1** chi-squared needs raw counts of individuals in categories, never percentages or proportions. **B1** every expected value in the table should be at least 5 for the result to be trusted. [3]

B4 CCO-Q7 [3]

B1 the A-level two-sample t-test formula assumes the two samples have roughly the same amount of spread, and here the two standard deviations differ by more than five times. **B1** the test can still be carried out and a value obtained, but the formula's assumption is clearly not well met by this data, so the result is only approximate. **B1** an evaluation should state that the two groups are very differently variable and that this limits confidence in the calculated value of t, even though the direction of any conclusion may still be informative.

B5 CCO-Q8 [3]

B1 failing to reach the critical value means the null hypothesis is not rejected, which shows only that the data available did not provide enough evidence of a difference. **B1** it does not show that no difference exists: a real but small difference could easily be missed by a small sample, so 'not rejected' is not the same as 'proved equal'. **B1** the safer statement is that there is no significant difference between the means at this sample size and probability level, leaving open that a larger study might detect one.

B6 CCO-Q9 [3]

B1 Pearson's linear correlation coefficient. **B1** the scatter is a straight line and both variables are continuous measurements that look roughly normally distributed, which are exactly the conditions Pearson's r assumes. **B1** Pearson's uses the actual measurements rather than only their order, so with data that meet its conditions it can detect a real association from a smaller sample than Spearman's would need.

B7 CCO-Q10 [3]

B1 chi-squared against a predicted ratio: degrees of freedom = number of categories - 1. **B1** the t-test: degrees of freedom = n1 + n2 - 2, the total number of individuals in both samples minus two. **B1** Spearman's rank: no degrees-of-freedom figure is used; instead the critical value is read against n, the number of pairs.

B8 CCO-Q11 [3]

B1 with only 4 plants per group the test has very little power, so a real difference between the two locations could easily fail to be detected. **B1** a t-test assumes continuous, roughly normally distributed measurements, and a count of ladybirds is a discrete number that may not meet this condition, especially checked from only 4 values. **B1** for the test to be appropriate the ladybird counts would need to be roughly continuous or normally distributed in shape, and the two groups' spreads would need to be roughly similar.

B9 CCO-Q12 [3]

B1 the expected value for the rarest phenotype, 1 part out of 16, is 48 ÷ 16 = 3, which is below the minimum of 5 that chi-squared requires for a trustworthy result. **B1** with an expected value this small the calculated chi-squared value would not reliably follow the distribution the critical-value table assumes, so a conclusion drawn from it would not be trustworthy. **B1** the fix is to combine categories, for example the two smaller phenotype classes, or to collect more offspring so that every expected value reaches at least 5, and then repeat the test.

SECTION C · Long, 6 marks or more

C1 CCO-Q1

M1 expected number in each of the four classes = 160 ÷ 4 = 40, all comfortably above 5. **M1** $(48 - 40)^2 \div 40 = 1.6$ and $(38 - 40)^2 \div 40 = 0.10$. **M1** $(34 - 40)^2 \div 40 = 0.90$ and $(40 - 40)^2 \div 40 = 0$. **A1** chi-squared = 1.6 + 0.1 + 0.9 + 0 = 2.6. **B1** degrees of freedom = 4 categories - 1 = 3, and the critical value at $p = 0.05$ is 7.81; 2.6 is less than 7.81. **B1** the null hypothesis is not rejected: the observed numbers do not differ significantly from a 1:1:1:1 ratio, consistent with the two genes assorting independently. [6]

C2 CCO-Q2

M1 $s1^2/n1 = 8^2 \div 12 = 5.33$ and $s2^2/n2 = 9^2 \div 12 = 6.75$. **M1** adds the two: 5.33 + 6.75 = 12.08, then takes the square root: $\sqrt{12.08} = 3.48$. **M1** difference between the means = 92 - 85 = 7 g. **A1** t = 7 ÷ 3.48 = 2.01. **B1** degrees of freedom = 12 + 12 - 2 = 22, and the critical value at $p = 0.05$ is 2.07; the calculated value of 2.01 is less than 2.07. **B1** the null hypothesis is not rejected: there is no significant difference between the mean fruit masses of the two varieties at $p = 0.05$, on the evidence of these 12 plants of each. [6]

C3 CCO-Q3

M1 $\Sigma d^2 = 0 + 1 + 1 + 4 + 1 + 0 + 1 + 4 = 12$. **M1** $n(n^2 - 1) = 8 \times (64 - 1) = 8 \times 63 = 504$. **M1** $6 \times \Sigma d^2 = 6 \times 12 = 72$. **A1** rs = 1 - 72 ÷ 504 = 1 - 0.14 = 0.86. **B1** the critical value for n = 8 at $p = 0.05$ is 0.738, and 0.86 is greater than 0.738. **B1** the null hypothesis is rejected: there is a significant positive correlation between moss cover and the number of springtails. [6]

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