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AS/A LEVEL GCE

Examiners' report

MATHEMATICS (MEI)

3895-3898, 7895-7898

4767/01 Summer 2018 series

Version 1

Contents

Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates. The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report. A full copy of the question paper can be downloaded from OCR.

Paper 4767/01 series overview

This was the final assessment series for the unitised 3895-3898, 7895-7898 GCE Mathematics (MEI) specification. There will be a resit opportunity in the summer 2019.

Statistics 2 (4767) is an A2 GCE component taken as part of the Mathematics (MEI) specification, which can be used with Statistics 1 (4766) in A Level Mathematics (7895), as one of the optional components in AS Further Mathematics (3896) or A Level Further Mathematics (7896), or (occasionally) as part of AS Further Mathematics (Additional) (3897) or A Level Further Mathematics (Additional) (7897).

To do well in this paper, candidates need an:

- ability to calculate probabilities and statistics accurately,
- awareness of any assumptions necessary for applying the statistical models,
- ability to provide concise, clear explanations when required.

Candidates also need a clear understanding of the difference between sample and population and should take care in their explanations when reference to either of these is required. Candidates should also make reference to context in explanations, definitions of parameters and in conclusions to hypothesis tests.

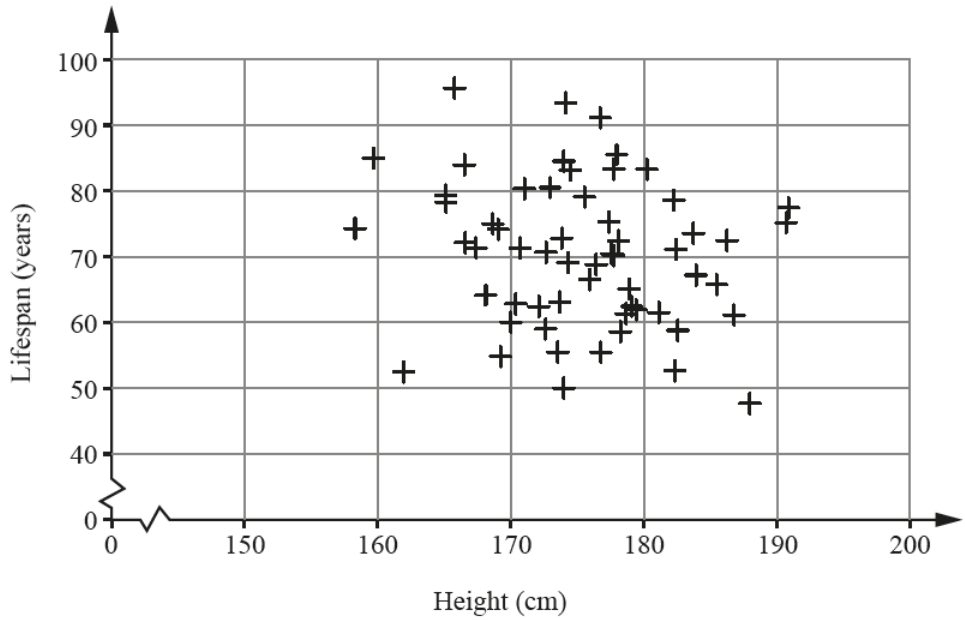
This paper proved to be readily accessible to all candidates. There was no evidence of candidates having insufficient time to complete all questions. A wide range of marks was seen. None of the four questions stood out as being either particularly difficult or particularly easy. Higher ability candidates showed both the ability to choose and apply appropriate calculations and to provide clear, concise explanations when required. Lower ability candidates had some difficulty in selecting appropriate calculations or critical values and in providing suitable wording in parts where explanations were required or in hypothesis tests. The vast majority of candidates kept to the guidelines regarding accuracy of final answers – few candidates were penalised for over-specification. Some cases of incorrect or premature rounding were seen. Premature rounding caused loss of marks for some candidates in calculation of the sample product moment correlation coefficient and in questions where accurate use of Normal probability tables was required.

Key

AfL Guidance to offer for future teaching and learning practice.

Question 1 (i)

1 A medical student thinks that there may be some correlation between the heights and lifespans of people in the area in which she lives. She has access to the medical records, going back many years, of deceased people. The scatter diagram below shows the heights x cm and lifespans y years of a random sample of 60 deceased people from the area.



Summary statistics for these data are as follows:

$n = 60$, $\Sigma x = 10\,524$, $\Sigma y = 4219$, $\Sigma x^2 = 1\,849\,100$, $\Sigma y^2 = 303\,700$, $\Sigma xy = 739\,140$.

(i) Calculate the sample product moment correlation coefficient. **[5]**

This question provided a routine introduction to the assessment with only the occasional arithmetic error resulting in a few candidates not scoring full marks.

Question 1 (ii)

(ii) The medical student uses these data to test her theory. Carry out a hypothesis test at the 5% significance level to investigate whether her theory may be correct. **[6]**

This question was well answered by most candidates. The most common reasons for losing marks include - use of an incorrect critical value, imprecise definition of rho, providing vague hypotheses in words not concise symbols and providing overly assertive conclusions.

Question 1 (iii)

(iii) State the distributional assumption which is necessary for this test to be valid. State, with a reason, whether the assumption appears to be valid. **[2]**

Most candidates understood the need for an underlying population which follows a bivariate Normal distribution and that this can be seen from the shape formed by the points in the scatter diagram. Candidates who stated that the **data** follow a bivariate Normal distribution were penalised. Some candidates who provided a suitable comment about the shape formed by the points did not complete their answers with a judgement regarding validity.

Exemplar 1

1 (iii) Has to show a bivariate normal distribution
and it has to be elliptical

This candidate does not provide a judgement regarding whether the assumption appears to be valid.

Question 1 (iv)

(iv) A friend of the medical student proposes to carry out a similar test using data from a different area. However, a doctor tells the friend that it is known that the correlation coefficient between x and y for the whole population in this other area is –0.134. Explain why it is not sensible for the friend to carry out the proposed test. **[2]**

Very few candidates showed that they understood the significance of the word 'population' here.

Exemplar 2

1 (iv) Because the test won't be significant as
it is smaller than the value worked out
for this data which was not significant.

This answer is typical of many seen. The candidate appears not to appreciate that since the correlation coefficient for the whole population is known then a test would not be needed.

Question 1 (v)

(v) The student's friend suggests that being tall causes a person to have a shorter life. Comment on this suggestion. **[2]**

Candidates should reflect on the fact that just because there is a correlation, this does not imply a direct causation; there could be other factors involved.

Question 2 (i)

2 At a manufacturing plant, work on a production line often has to be stopped due to faults with machinery.

(i) State conditions required for a Poisson distribution to be a suitable model for the number of faults which occur in a day. **[2]**

This question was well answered. Candidates who referred to 'events' in their answer, in place of the word 'faults', were penalised.

Question 2 (ii)

You may assume that these conditions are satisfied. You are given that the faults occur at an average rate of 8.4 per day.

(ii) State the variance of the distribution of the number of faults per day. **[1]**

This was correctly stated by the majority of candidates.

Question 2 (iii)

(iii) Find the probability of at least 8 faults in a randomly chosen day. **[2]**

Candidates answered this part well.

Question 2 (iv)

(iv) Use a suitable approximating distribution to find the probability that there are at least 40 faults in a 5-day week. Explain briefly whether any additional assumption needs to be made in order to calculate this probability. **[6]**

Most candidates used the correct Normal approximating distribution and provided a correct answer. Some candidates did not use a continuity correction. Others found the probability for 'at most 40 faults' rather than 'at least 40 faults'. Few candidates who realised that no additional assumptions were needed managed to provide a suitable explanation.

Question 2 (v) (*A*)

One of the machines on the production line produces steel rods. The length of a rod is denoted by Xmm, where X has a Normal distribution with mean 103.2 and variance 0.36.

(v) (*A*) Find $P(103 < X < 104)$. **[3]**

Most candidates managed to obtain the associated *z*-values and calculate the probability to an acceptable degree of accuracy. Some candidates did not manage to use the Normal distribution table successfully.

Question 2 (v) (*B*)

(*B*) Rods which are shorter than 102 mm have to be rejected. It is proposed, by reducing the variance, to reduce the proportion of rods which are rejected to 0.5%. Assuming that the mean is unchanged, find the new value of the variance. **[4]**

The candidates obtaining 2.576 from the table for the inverse Normal function tended to obtain full marks here. Some candidates lost marks through inaccurate working – typically writing an equation which would lead to a negative value for the standard deviation. Candidates who worked with 95% rather than 99.5% gained no more than 2 marks.

Question 3 (i)

3 A machine manufactures analgesic (pain-killing) tablets. The tablets are sold in packets. On the packet it states that each tablet contains 500 milligrams of active ingredient. The random variable X represents the amount, in milligrams, of the active ingredient in each tablet. It is known that X is Normally distributed with mean 504.7 and variance 16.

(i) Show that $P(X > 500) = 0.8800$, correct to 4 decimal places. **[2]**

Since this was a "show that …" with the answer given, candidates needed to write a clear justification to gain full credit.

Question 3 (ii)

(ii) Calculate the probability that in a random sample of 10 tablets, at least 9 contain more than the amount of active ingredient stated on the packet. **[2]**

Candidates either scored full marks or zero. Candidates using their calculator without showing any working risk scoring zero if the response is incorrect.

The standard advice with regard the use of calculators should always be; to write down explicitly any expressions, parameters and variables, and to use correct mathematical notation.

Question 3 (iii)

(iii) Use a suitable approximation to find the probability that in a random sample of 100 tablets, at least 90 contain more than the amount stated on the packet. **[5]**

A good proportion of candidates scored full marks on this calculation. Errors in arithmetic resulted in some candidates dropping a couple of marks.

Question 3 (iv)

The machine which manufactures the tablets is serviced. In order to check if the mean amount of active ingredient is still 504.7 milligrams, a random sample of 25 tablets is selected. The total amount of active ingredient in the 25 tablets is 12 580 milligrams. You should assume that the variance for individual tablets is still 16.

(iv) Carry out a hypothesis test at the 5% significance level to check whether the mean amount is still 504.7 milligrams. **[9]**

This question was well answered by most candidates.

- Most candidates successfully worked out the sample mean, framed their hypotheses in terms of μ, and correctly defined μ as the mean amount of active ingredient.
- Test statistics were generally worked out correctly though some candidates did not use the correct variance.
- Some candidates went on to use a wrong critical value, usually -1.645.
- Comparisons were well done on the whole. Inappropriate comparisons were seen, e.g. -1.875 < -1.96 and -1.875 < 1.96
- Conclusions were generally very good though errors were made either in being too assertive, by claiming that the evidence showed that the value had not changed from 504.7, or in framing the conclusion in terms of H_0 by claiming that the result suggested the mean was still 504.7.

Exemplar 3

3 (iv)

$X \sim N(504.7, 16)$

$\mu = 504.7 \quad \sigma = 4$

$H_0 : \mu = 504.7$ $\quad$ μ is the population mean

$H_1 : \mu \neq 504.7$ $\quad$ amount of active ingredient.

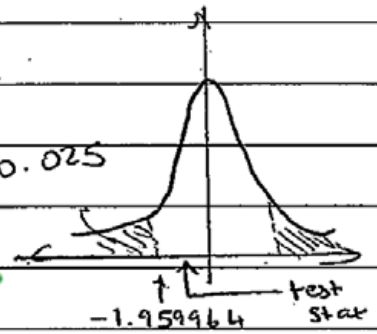
5% significance level $\quad$ $n = 25$ $\quad$ 2-tailed test

$\bar{x} = 12580/25 = 503.2$

Test statistic $= \dfrac{503.2 - 504.7}{4/\sqrt{25}} = -1.875$

critical value: -1.959964

$= -1.960$ (4sf)



~~N.95~~

$-1.960 < -1.875$

The result is not significant at the 5% significance level. There is insufficient evidence to reject H_0. There is insufficient evidence to suggest that the mean amount of active ingredient has changed.

This is a model answer. It even includes a diagram showing critical values and test statistic. Such a diagram can be used to count as a sensible comparison without seeing the statement -1.96 < -1.875 though both are provided here.

Exemplar 4

3(iv)

$X \sim N(504.7, 16)$

Let μ represents mean ~~actual~~ amount of active ingredient in tablets

$H_0: \mu = 504.7$

$H_1: \mu \neq 504.7$

$\bar{x} = \frac{12580}{25} = 503.2$

$z = \frac{503.2 - 504.7}{\sqrt{\frac{16}{25}}} = \cancel{-1.80}\ -1.875$

Critical value at 5% significance, two tail test $= -1.960$

~~-1.875~~

~~$-1.80 > -1.960$, Result is insignificant~~

$-1.875 > -1.960$, Result is insignificant

There is insufficient evidence at 5% significance level to reject H_0. So we conclude that the mean amount of active ingredient is still 504.7mg because $\mu = 504.7$.

This candidate's conclusion, 'so we conclude that the mean…', is overly assertive and also refers to the null rather than alternative hypothesis.

Question 3 (v)

(v) Given that in fact the population mean is now 503.8 milligrams, comment briefly on the result of the test. What change could have been made to the test procedure, without changing the significance level, to make it more likely to detect this change in the mean? **[2]**

As with Question 1(iv) very few candidates showed that they understood the word 'population' here – many treated 503.8 as a sample mean. Most commented that increasing the sample size would make it more likely to detect the change, often without knowing why.

Exemplar 5

3(v) $z = \frac{503.2 - 503.8}{4 \div 5} = |-0.75|$

$|-0.75| < 1.96$ ∴ the result would have been the same, still accept H_0

Change in proceedure: increase sample size

This candidate's response is typical of many seen

Question 4 (i)

4 The year in which a car was registered can often be identified from its number plate. A motoring correspondent is investigating whether there is any association between the age of cars and their location. She chooses three locations, a motorway, a supermarket car park and a housing estate, and selects a random sample of cars from each location. The correspondent classifies the ages according to year of registration, 2001–2007, 2008–2012, 2013–2017 and also 'unknown' for those cars for which the number plate does not identify the year of registration.

(i) Write down null and alternative hypotheses for a test to examine whether there is any association between location and age category. **[1]**

This was answered well.

Question 4 (ii)

(ii) You are given that the value of the test statistic for the usual χ^2 test for the motoring correspondent's data is 8.752 correct to 3 decimal places. Carry out the test at the 10% significance level. **[4]**

Most candidates answered this well. Some candidates did not identify the correct number of degrees of freedom – possibly by looking at the table below rather than reading the information above - and were thus penalised.

Question 4 (iii)

The correspondent thinks that she should carry out another test, but this time taking a new sample which excludes the cars of unknown age. The numbers of cars for the three other age categories are given in the table below.

	2001–2007	2008–2012	2013–2017
Motorway	41	29	16
Supermarket car park	35	22	14
Housing estate	12	24	7

(iii) Calculate the expected frequency for cars on the Housing estate registered in 2001–2007. Verify the corresponding contribution, 2.5310, to the test statistic. **[3]**

Almost all the candidates scored full marks on this part, with only a couple of dropped marks due to arithmetic errors.

Question 4 (iv)

The contributions to the test statistic are shown in the table below. The figures are rounded to 4 decimal places.

	2001–2007	2008–2012	2013–2017
Motorway	0.2639	0.3275	0.0005
Supermarket car park	0.4525	0.8034	0.0570
Housing estate	2.5310	3.8459	0.1146

(iv) Using the same hypotheses as in part **(i)**, complete this new test at the 10% significance level. **[3]**

The number of degrees of freedom was identified with better success than in part (ii). Most candidates earned all three marks here. Some made mistakes when adding the contributions to produce the test statistic. Some provided overly assertive conclusions.

Question 4 (v)

(v) For each location, comment briefly on how the ages of the cars compare with what would be expected if there were no association. You should calculate any expected frequencies that you need in order to make these comments. **[4]**

Few candidates achieved all of the 4 available marks here. Some correctly commented on the large and small contributions to the test statistic and made appropriate comments regarding the observed frequencies. Some made comparisons without reference to the contributions and were thus penalised. Most candidates calculated the expected frequency of 16.125 for the housing estate for years 2008-2012 but some appeared not to notice this request. Others worked out all the expected frequencies not just the ones needed.

Exemplar 6

4(v)

fe	2001-2007	2008-2012	2013-2017
motorway	37-84	26-625	15-91
supermarket car park	31-24	26-625	13-135
Housing estate	18-92	16-125	7-955

motorway.
smaller contributions of 0.2639 and 0.3275, so ~~significantly~~ only slightly more 2001-2007 and 2008-2012 than expected.
Very small contribution of 0.0005, so no 2013-2017 cars as expected.

Supermarket car park.
large contribution of 0.8034, so less 2008-2012 cars than expected.
small contribution of 0.0570, so no 2013-2017 cars more or less as expected.

Housing estate.
large contributions of 2.5310 and 3.8459, so significantly less 2001-2007 and significantly more 2008-2012 than expected
small contribution of 0.1146, so no 2013-2017 more or less as expected

This candidate's response is typical of many. For cells containing low contributions, candidates are expected to state that the observed results are as expected. They should not use expressions such as 'slightly more than expected' or 'slightly less than expected'.

Question 4 (vi)

(vi) A colleague suggests that the motoring correspondent should have subdivided the ages of the cars into more than three categories. Give one advantage and one disadvantage of doing that. **[2]**

Very few candidates managed to provide acceptable comments here.

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