OCR
RECOGNISING ACHIEVEMENT

Friday 25 January 2013 – Afternoon

A2 GCE MATHEMATICS (MEI)

4767/01 Statistics 2

QUESTION PAPER

Candidates answer on the Printed Answer Book.

OCR supplied materials:
- Printed Answer Book 4767/01
- MEI Examination Formulae and Tables (MF2)

Other materials required:
- Scientific or graphical calculator

Duration: 1 hour 30 minutes

INSTRUCTIONS TO CANDIDATES

These instructions are the same on the Printed Answer Book and the Question Paper.

- The Question Paper will be found in the centre of the Printed Answer Book.
- Write your name, centre number and candidate number in the spaces provided on the Printed Answer Book. Please write clearly and in capital letters.
- **Write your answer to each question in the space provided in the Printed Answer Book**. Additional paper may be used if necessary but you must clearly show your candidate number, centre number and question number(s).
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- You are permitted to use a scientific or graphical calculator in this paper.
- Final answers should be given to a degree of accuracy appropriate to the context.

INFORMATION FOR CANDIDATES

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- The number of marks is given in brackets **[ ]** at the end of each question or part question on the Question Paper.
- You are advised that an answer may receive **no marks** unless you show sufficient detail of the working to indicate that a correct method is being used.
- The total number of marks for this paper is **72**.
- The Printed Answer Book consists of **12** pages. The Question Paper consists of **4** pages. Any blank pages are indicated.

INSTRUCTION TO EXAMS OFFICER / INVIGILATOR

- Do not send this Question Paper for marking; it should be retained in the centre or recycled. Please contact OCR Copyright should you wish to re-use this document.

1 A manufacturer of playground safety tiles is testing a new type of tile. Tiles of various thicknesses are tested to estimate the maximum height at which people would be unlikely to sustain injury if they fell onto a tile. The results of the test are as follows.

Thickness (t mm)	20	40	60	80	100
Maximum height (h m)	0.72	1.09	1.62	1.97	2.34

(i) Draw a scatter diagram to illustrate these data. **[3]**

(ii) State which of the two variables is the independent variable, giving a reason for your answer. **[1]**

(iii) Calculate the equation of the regression line of maximum height on thickness. **[5]**

(iv) Use the equation of the regression line to calculate estimates of the maximum height for thicknesses of

(A) 70 mm,

(B) 120 mm.

Comment on the reliability of each of these estimates. **[4]**

(v) Calculate the value of the residual for the data point at which $t = 40$. **[3]**

(vi) In a further experiment, the manufacturer tests a tile with a thickness of 200 mm and finds that the corresponding maximum height is 2.96 m. What can be said about the relationship between tile thickness and maximum height? **[3]**

2 John is observing butterflies being blown across a fence in a strong wind. He uses the Poisson distribution with mean 2.1 to model the number of butterflies he observes in one minute.

(i) Find the probability that John observes

(A) no butterflies in a minute, **[2]**

(B) at least 2 butterflies in a minute, **[2]**

(C) between 5 and 10 butterflies inclusive in a period of 5 minutes. **[3]**

(ii) Use a suitable approximating distribution to find the probability that John observes at least 130 butterflies in a period of 1 hour. **[5]**

In fact some of the butterflies John observes being blown across the fence are being blown in pairs.

(iii) Explain why this invalidates one of the assumptions required for a Poisson distribution to be a suitable model. **[1]**

John decides to revise his model for the number of butterflies he observes in one minute. In this new model, the number of pairs of butterflies is modelled by the Poisson distribution with mean 0.2, and the number of single butterflies is modelled by an independent Poisson distribution with mean 1.7.

(iv) Find the probability that John observes no more than 3 butterflies altogether in a period of one minute. **[5]**

3 The amount of data, X megabytes, arriving at an internet server per second during the afternoon is modelled by the Normal distribution with mean 435 and standard deviation 30.

(i) Find

(A) $\mathrm{P}(X < 450)$, **[3]**

(B) $\mathrm{P}(400 < X < 450)$. **[3]**

(ii) Find the probability that, during 5 randomly selected seconds, the amounts of data arriving are all between 400 and 450 megabytes. **[2]**

The amount of data, Y megabytes, arriving at the server during the evening is modelled by the Normal distribution with mean μ and standard deviation σ.

(iii) Given that $\mathrm{P}(Y < 350) = 0.2$ and $\mathrm{P}(Y > 390) = 0.1$, find the values of μ and σ. **[5]**

(iv) Find values of a and b for which $\mathrm{P}(a < Y < b) = 0.95$. **[4]**

4 **(a)** A random sample of 60 students studying mathematics was selected. Their grades in the Core 1 module are summarised in the table below, classified according to whether they worked less than 5 hours per week or at least 5 hours per week. Test, at the 5% significance level, whether there is any association between grade and hours worked.

		Hours worked	
		Less than 5	At least 5
Grade	A or B	20	11
	C or lower	13	16

[9]

(b) At a canning factory, cans are filled with tomato purée. The machine which fills the cans is set so that the volume of tomato purée in a can, measured in millilitres, is Normally distributed with mean 420 and standard deviation 3.5. After the machine is recalibrated, a quality control officer wishes to check whether the mean is still 420 millilitres. A random sample of 10 cans of tomato purée is selected and the volumes, measured in millilitres, are as follows.

417.2 422.6 414.3 419.6 420.4 410.0 418.3 416.9 418.9 419.7

Carry out a test at the 1% significance level to investigate whether the mean is still 420 millilitres. You should assume that the volumes are Normally distributed with unchanged standard deviation. **[9]**

THERE ARE NO QUESTIONS PRINTED ON THIS PAGE.

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4767/01 Statistics 2

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Duration: 1 hour 30 minutes

Candidate forename		Candidate surname	

Centre number						Candidate number				

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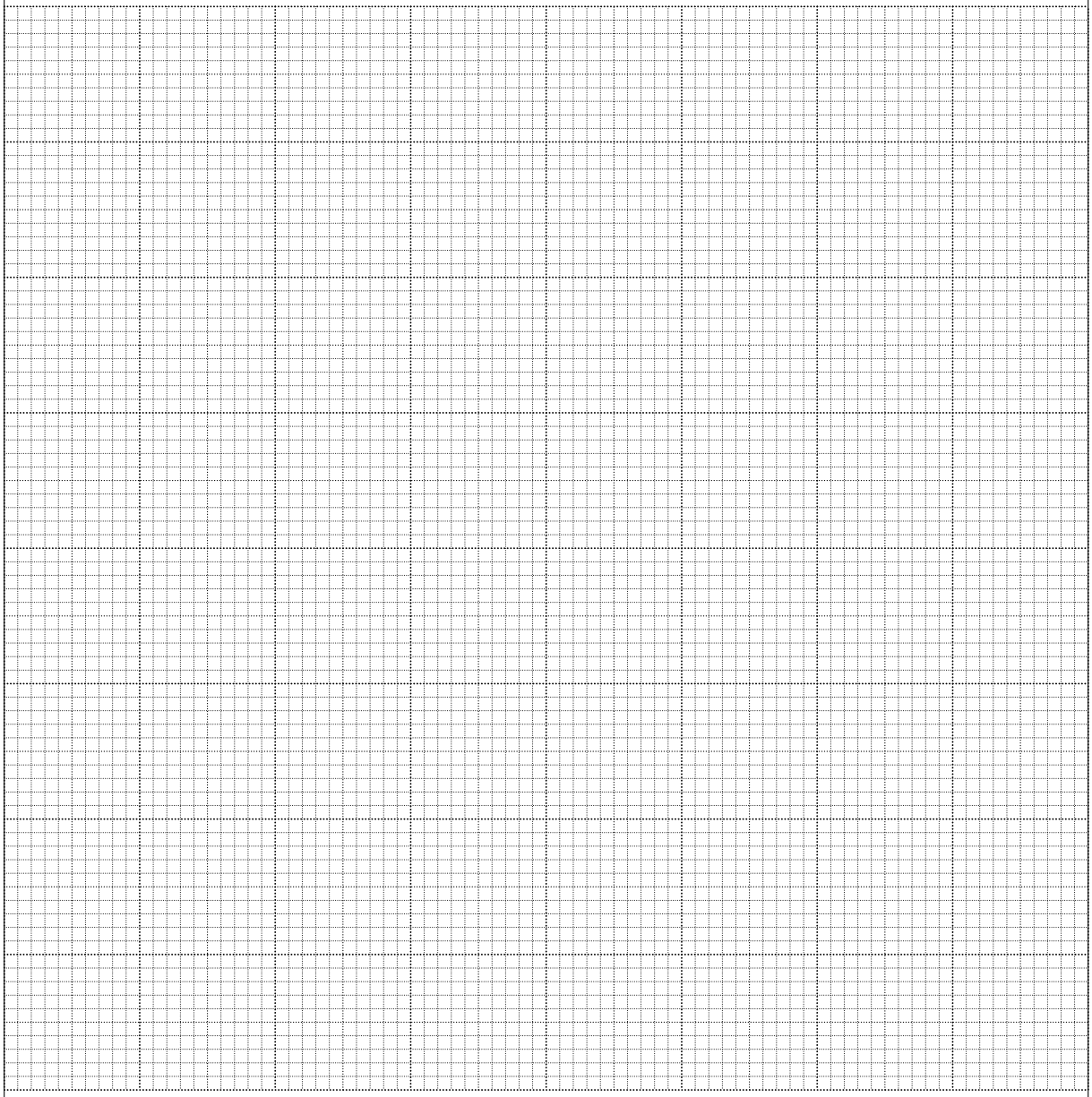
1 (i)



1 (ii)

1 (iii)	
1 (iv) (*A*)	
1 (iv) (*B*)	

1 (v)	
1 (vi)	
2 (i) (A)	
2 (i) (B)	

2 (i) (C)	
2 (ii)	

2 (iii)	
2 (iv)	

3 (i) (*A*)

3 (i) (*B*)

3 (ii)

3 (iii)	

3 (iv)	

4 (a)

4 (b)

(answer space continued on next page)

4 (b)	(continued)

OCR
RECOGNISING ACHIEVEMENT

GCE

Mathematics (MEI)

Advanced GCE

Unit **4767:** Statistics 2

Mark Scheme for January 2013

Oxford Cambridge and RSA Examinations

OCR (Oxford Cambridge and RSA) is a leading UK awarding body, providing a wide range of qualifications to meet the needs of candidates of all ages and abilities. OCR qualifications include AS/A Levels, Diplomas, GCSEs, Cambridge Nationals, Cambridge Technicals, Functional Skills, Key Skills, Entry Level qualifications, NVQs and vocational qualifications in areas such as IT, business, languages, teaching/training, administration and secretarial skills.

It is also responsible for developing new specifications to meet national requirements and the needs of students and teachers. OCR is a not-for-profit organisation; any surplus made is invested back into the establishment to help towards the development of qualifications and support, which keep pace with the changing needs of today's society.

This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

OCR will not enter into any discussion or correspondence in connection with this mark scheme.

Annotations and abbreviations

Annotation in scoris	**Meaning**
✓and ✖	
BOD	Benefit of doubt
FT	Follow through
ISW	Ignore subsequent working
M0, M1	Method mark awarded 0, 1
A0, A1	Accuracy mark awarded 0, 1
B0, B1	Independent mark awarded 0, 1
SC	Special case
^	Omission sign
MR	Misread
Highlighting	
Other abbreviations in mark scheme	**Meaning**
E1	Mark for explaining
U1	Mark for correct units
G1	Mark for a correct feature on a graph
M1 dep*	Method mark dependent on a previous mark, indicated by *
cao	Correct answer only
oe	Or equivalent
rot	Rounded or truncated
soi	Seen or implied
www	Without wrong working

Subject-specific Marking Instructions for GCE Mathematics (MEI) Statistics strand

a Annotations should be used whenever appropriate during your marking.

The A, M and B annotations must be used on your standardisation scripts for responses that are not awarded either 0 or full marks. It is vital that you annotate standardisation scripts fully to show how the marks have been awarded.

For subsequent marking you must make it clear how you have arrived at the mark you have awarded.

b An element of professional judgement is required in the marking of any written paper. Remember that the mark scheme is designed to assist in marking incorrect solutions. Correct *solutions* leading to correct answers are awarded full marks but work must not be judged on the answer alone, and answers that are given in the question, especially, must be validly obtained; key steps in the working must always be looked at and anything unfamiliar must be investigated thoroughly.

Correct but unfamiliar or unexpected methods are often signalled by a correct result following an *apparently* incorrect method. Such work must be carefully assessed. When a candidate adopts a method which does not correspond to the mark scheme, award marks according to the spirit of the basic scheme; if you are in any doubt whatsoever (especially if several marks or candidates are involved) you should contact your Team Leader.

c The following types of marks are available.

M
A suitable method has been selected and *applied* in a manner which shows that the method is essentially understood. Method marks are not usually lost for numerical errors, algebraic slips or errors in units. However, it is not usually sufficient for a candidate just to indicate an intention of using some method or just to quote a formula; the formula or idea must be applied to the specific problem in hand, eg by substituting the relevant quantities into the formula. In some cases the nature of the errors allowed for the award of an M mark may be specified.

A
Accuracy mark, awarded for a correct answer or intermediate step correctly obtained. Accuracy marks cannot be given unless the associated Method mark is earned (or implied). Therefore M0 A1 cannot ever be awarded.

B
Mark for a correct result or statement independent of Method marks.

E
A given result is to be established or a result has to be explained. This usually requires more working or explanation than the establishment of an unknown result.

Unless otherwise indicated, marks once gained cannot subsequently be lost, eg wrong working following a correct form of answer is ignored. Sometimes this is reinforced in the mark scheme by the abbreviation isw. However, this would not apply to a case where a candidate passes through the correct answer as part of a wrong argument.

d When a part of a question has two or more 'method' steps, the M marks are in principle independent unless the scheme specifically says otherwise; and similarly where there are several B marks allocated. (The notation 'dep *' is used to indicate that a particular mark is dependent on an earlier, asterisked, mark in the scheme.) Of course, in practice it may happen that when a candidate has once gone wrong in a part of a question, the work from there on is worthless so that no more marks can sensibly be given. On the other hand, when two or more steps are successfully run together by the candidate, the earlier marks are implied and full credit must be given.

e The abbreviation ft implies that the A or B mark indicated is allowed for work correctly following on from previously incorrect results. Otherwise, A and B marks are given for correct work only – differences in notation are of course permitted. A (accuracy) marks are not given for answers obtained from incorrect working. When A or B marks are awarded for work at an intermediate stage of a solution, there may be various alternatives that are equally acceptable. In such cases, exactly what is acceptable will be detailed in the mark scheme rationale. If this is not the case please consult your Team Leader.

Sometimes the answer to one part of a question is used in a later part of the same question. In this case, A marks will often be 'follow through'. In such cases you must ensure that you refer back to the answer of the previous part question even if this is not shown within the image zone. You may find it easier to mark follow through questions candidate-by-candidate rather than question-by-question.

f Wrong or missing units in an answer should not lead to the loss of a mark unless the scheme specifically indicates otherwise.

Candidates are expected to give numerical answers to an appropriate degree of accuracy. 3 significant figures may often be the norm for this, but this always needs to be considered in the context of the problem in hand. For example, in quoting probabilities from Normal tables, we generally expect *some* evidence of interpolation and so quotation to 4 decimal places will often be appropriate. But even this does not always apply – quotations of the standard critical points for significance tests such as 1.96, 1.645, 2.576 (maybe even 2.58 – but not 2.57) will commonly suffice, especially if the calculated value of a test statistic is nowhere near any of these values. Sensible discretion *must* be exercised in such cases.

Discretion must also be exercised in the case of small variations in the degree of accuracy to which an answer is given. For example, if 3 significant figures are expected (either because of an explicit instruction or because the general context of a problem demands it) but only 2 are given, loss of an accuracy ("A") mark is likely to be appropriate; but if 4 significant figures are given, this should not normally be penalised. Likewise, answers which are slightly deviant from what is expected in a very minor manner (for example a Normal probability given, after an attempt at interpolation, as 0.6418 whereas 0.6417 was expected) should not be penalised. However, answers which are *grossly* over- or under-specified should normally result in the loss of a mark. This includes cases such as, for example, insistence that the value of a test statistic is (say) 2.128888446667 merely because that is the value that happened to come off the candidate's calculator. Note that this applies to answers that are given as final stages of calculations; intermediate working should usually be carried out, and quoted, to a greater degree of accuracy to avoid the danger of premature approximation.

The situation regarding any particular cases where the accuracy of the answer may be a marking issue should be detailed in the mark scheme rationale. If in doubt, contact your Team Leader.

g Rules for replaced work

If a candidate attempts a question more than once, and indicates which attempt he/she wishes to be marked, then examiners should do as the candidate requests.

If there are two or more attempts at a question which have not been crossed out, examiners should mark what appears to be the last (complete) attempt and ignore the others.

NB Follow these maths-specific instructions rather than those in the assessor handbook.

h Genuine misreading (of numbers or symbols, occasionally even of text) occurs. If this results in the object and/or difficulty of the question being considerably changed, it is likely that all the marks for that question, or section of the question, will be lost. However, misreads are often such that the object and/or difficulty remain substantially unaltered; these cases are considered below.

The simple rule is that *all* method ("M") marks [and of course all independent ("B") marks] remain accessible but at least some accuracy ("A") marks do not. It is difficult to legislate in an overall sense beyond this global statement because misreads, even when the object and/or difficulty remains unchanged, can vary greatly in their effects. For example, a misread of 1.02 as 10.2 (perhaps as a quoted value of a sample mean) may well be catastrophic; whereas a misread of 1.6748 as 1.6746 may have so slight an effect as to be almost unnoticeable in the candidate's work.

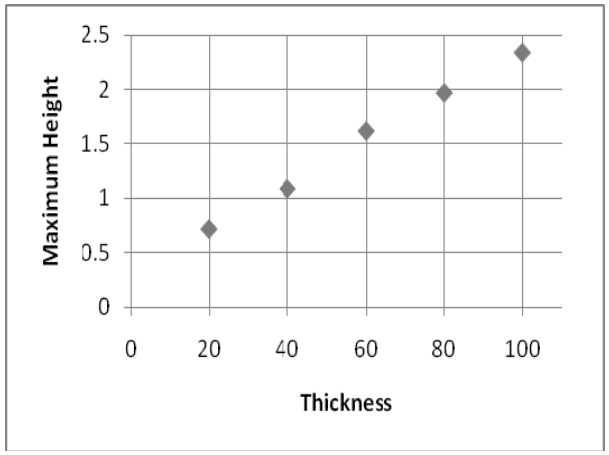
A misread should normally attract *some* penalty, though this would often be only 1 mark and should rarely if ever be more than 2. Commonly in sections of questions where there is a numerical answer either at the end of the section or to be obtained and commented on (eg the value of a test statistic), this answer will have an "A" mark that may actually be designated as "cao" [correct answer only]. This should be interpreted *strictly* – if the misread has led to failure to obtain this value, then this "A" mark must be withheld even if all method marks have been earned. It will also often be the case that such a mark is implicitly "cao" even if not explicitly designated as such.

On the other hand, we commonly allow "fresh starts" within a question or part of question. For example, a follow-through of the candidate's value of a test statistic is generally allowed (and often explicitly stated as such within the marking scheme), so that the candidate may exhibit knowledge of how to compare it with a critical value and draw conclusions. Such "fresh starts" are not affected by any earlier misreads.

A misread may be of a symbol rather than a number – for example, an algebraic symbol in a mathematical expression. Such misreads are more likely to bring about a considerable change in the object and/or difficulty of the question; but, if they do not, they should be treated as far as possible in the same way as numerical misreads, *mutatis mutandis*. This also applied to misreads of text, which are fairly rare but can cause major problems in fair marking.

The situation regarding any particular cases that arise while you are marking for which you feel you need detailed guidance should be discussed with your Team Leader.

Note that a miscopy of the candidate's own working is not a misread but an accuracy error.

Question			Answer	Marks	Guidance	
1	(i)			G1 G2,1,0 **[3]**	G1 For axes suitably labelled with some indication of **linear** scale provided. G2 for points plotted correctly. G1 if 4 points plotted correctly. G0 if two or more incorrectly plotted/omitted points. Special Case SC1 for points visibly correct on axes where no indication of scale has been provided.	Allow x & y Allow axes reversed.
1	(ii)		Thickness is the independent variable since the values of 'Thickness' are not subject to random variation, but are determined by the manufacturer.	E1 **[1]**	Allow explanations referring to thickness being "controlled" by the manufacturer. Allow equivalent interpretations.	
1	(iii)		$\bar{t} = 60,\ \bar{h} = 1.548$ $b = \frac{S_{th}}{S_{tt}} = \frac{546.8 - (300 \times 7.74/5)}{22000 - 300^2/5} = \frac{82.4}{4000} =$ 0.0206	B1 M1* A1	For $\bar{t}$ and $\bar{h}$ used. SOI (e.g. can be implied by $b = 0.0206$) For attempt at **calculating** gradient (b) for h on t. For 0.0206 cao	
			OR $b = \frac{546.8/5 - (60 \times 1.548)}{22000/5 - 60^2} = \frac{16.48}{800} =$ 0.0206 hence least squares regression line is: $h - \bar{h} = b(t - \bar{t})$			

Question			Answer	Marks	Guidance	
			$\Rightarrow \quad h - 1.548 = 0.0206\,(t - 60)$	M1 dep*	For equation of line, using their b, $b > 0$, and passing through their $(\bar{t}, \bar{h})$	
			$\Rightarrow \quad h = 0.0206\,t + 0.312$	A1 **[5]**	Final equation must have h as the subject. **CAO** Allow $h = 0.021\,t + 0.31$, Allow $h = 0.021\,t + 0.288$ NOTE If equation given in terms of y and x then A0 unless x & y defined appropriately	
1	**(iv)**	**(*A*)**	$(0.0206 \times 70) + 0.312 = 1.754$	B1	Allow 1.75 FT their equation provided $b > 0$	
			Likely to be reliable as interpolation	E1 **[2]**		
1	**(iv)**	**(*B*)**	$(0.0206 \times 120) + 0.312 = 2.784$	B1	Allow 2.78 FT their equation provided $b > 0$	
			Could be unreliable as extrapolation	E1 **[2]**	Condone "reliable as 120 is not too far away from the data used to produce the equation"	
1	**(v)**		Thickness = 40 $\Rightarrow$ predicted max height			
			$= (0.0206 \times 40) + 0.312 = 1.136$	M1	For prediction. FT their equation provided $b > 0$	
			Residual = 1.09 – 1.136	M1	For difference between 1.09 and prediction.	
			= –0.046	A1 **[3]**	Allow –0.05	
1	**(vi)**		Regression line gives a prediction of $(0.0206 \times 200) + 0.312 = 4.432$	B1*	B1 for obtaining a prediction from regression equation or from graph	
			This is **well above** the observed value.	E1 dep*	E1 for noting the large difference between prediction and actual value	
			It could be that the relationship breaks down for larger thickness, or that the relationship is not linear	E1 **[3]**	E1 for suitable interpretation regarding the relationship between maximum height and thickness	

Question			Answer	Marks	Guidance	
2	(i)	(*A*)	$P(X = 0) = \frac{e^{-2.1}2.1^0}{0!}$	M1	For calculation	
			$= 0.1225$	A1	**CAO** Allow 0.122	
			Or from tables $P(X = 0) = 0.1225$			
				[2]		
2	(i)	(*B*)	$P(X \geq 2) = 1 - P(X \leq 1) = 1 - 0.3796$	M1	M1 for **use of** correct structure. i.e. M0 for use of $1 - P(X \leq 2)$ or $1 - 0.6796$ Using $\lambda = 2.0$ leading to $1 - 0.4060$ gets M1	
			$= 0.6204$	A1	CAO Allow 0.6203, 0.620	
				[2]		
2	(i)	(*C*)	New $\lambda = 5 \times 2.1 = 10.5$	B1	For mean (SOI)	
			P(Between 5 and 10 in 5 mins)			
			$= 0.5207 - 0.0211$	M1	For $P(X \leq 10) - P(X \leq 4)$ used.	e.g. $1 - 0.9379$ leads to B0M1A0
			$= 0.4996$	A1	CAO Allow 0.500, 0.50. Condone 0.5 www.	
				[3]		
2	(ii)		Mean number in 60 minutes = $60 \times 2.1 = 126$			
			Using Normal approx. to the Poisson,	B1	For Normal approx.	
			$X \sim N(126, 126)$	B1	For correct parameters (SOI)	
			$P(X \geq 130) = P\left(Z \geq \frac{129.5 - 126}{\sqrt{126}}\right)$	B1	For correct continuity correction	
			$= P(Z > 0.3118) = 1 - \Phi(0.3118)$	M1	For correct probability structure	
			$= 1 - 0.6224$			
			$= 0.3776$	A1	CAO**, (**Do not FT wrong or omitted CC). Allow 0.378www & 0.3775	
				[5]		

Question			Answer	Marks	Guidance	
2	(iii)		(Because if butterflies are blown in pairs,) the events will no longer be occurring singly.	E1 **[1]**		Accept 'not independent'
2	(iv)		P(3 or fewer) = P(3 or fewer individuals and no pairs) + P(0 or 1 individual and 1 pair)	M1	For P(0 pairs) (= 0.8187)	
			= (0.9068 × 0.8187) + (0.4932 × (0.9825 – 0.8187))	M1	For P(1 pair) (= 0.1638 or 0.1637)	First two M1s can be awarded for 0.9825
			= (0.9068 × 0.8187) + (0.4932 × 0. 1638)	M2	For structure M2 for correct 6 combinations identified and their probabilities added, M1 for 5 combinations identified and their probabilities added.	
			= 0.7424 + 0.0808			
			= 0.8232	A1	CAO Allow awrt 0.823	
			Or using D for the number of pairs and S for the number of singles			
			$P(D = 0) \times P(S = 0) = e^{-0.2} \times e^{-1.7}$ = 0.1495…			
			$P(D = 0) \times P(S = 1) = e^{-0.2} \times 1.7e^{-1.7}$ = 0.2542…			
			$P(D = 0) \times P(S = 2) = e^{-0.2} \times 1.7^2e^{-1.7} \div 2$ = 0.2161…			
			$P(D = 0) \times P(S = 3) = e^{-0.2} \times 1.7^3e^{-1.7} \div 3!$ = 0.1224…			
			$P(D = 1) \times P(S = 0) = 0.2e^{-0.2} \times e^{-1.7}$ = 0.0299…			
			$P(D = 1) \times P(S = 1) = 0.2e^{-0.2} \times 1.7e^{-1.7}$ = 0.0508…			
			Or $P(D = 0) \times P(S = 3) + P(D = 1) \times P(S = 1)$		P(3 butterflies) (= 0.1733…)	
			$P(D = 0) \times P(S = 2) + P(D = 1) \times P(S = 0)$		P(2 butterflies) (= 0.2460…)	
			$P(D = 0) \times P(S = 1)$		P(1 butterfly) (= 0.2542…)	
			$P(D = 0) \times P(S = 0)$		P(0 butterflies) (= 0.1495…)	

Question			Answer	Marks	Guidance	
			Or $P(D \leq 1) \times P(S \leq 1) = 0.98247 \times 0.49324$ $D(D = 0) \times P(S = 2) = 0.21613$ $D(D = 0) \times P(S = 3) = 0.12247$	**[5]**		
3	**(i)**	**(*A*)**	$P(X < 450) = P\left(Z < \frac{450 - 435}{30}\right)$	M1	For standardising. M0 if 'continuity correction' applied	
			$= P(Z < 0.5) = \Phi(0.5)$	M1	For correct structure	
			$= 0.6915$	A1 **[3]**	CAO Allow 0.692	
3	**(i)**	**(*B*)**	$P(400 < X < 450)$ $= P\left(\frac{400 - 435}{30} < Z < \frac{450 - 435}{30}\right)$ $= P(-1.1667 < X < 0.5)$			
			$= \Phi(0.5) - \Phi(-1.1667)$	M1	For correct structure	
			$= 0.6915 - 0.1216$	B1	For use of difference column to obtain 0.8784, 0.8783, 0.1216 or 0.1217. Condone 0.8782 or 0.1218	
			$= 0.5699$	A1 **[3]**	FT "their 0.6915" – 0.1216 (or 0.1217)	
3	**(ii)**		P(all 5 between 400 and 450) $= 0.5699^5$	M1		
			$= 0.0601$	A1 **[2]**	FT Allow 0.060	

Question			Answer	Marks	Guidance	
3	(iii)		$P(Y < 350) = 0.2$, $P(Y > 390) = 0.1$			
			$P(Z < \frac{350-\mu}{\sigma}) = 0.2$			
			$\Phi^{-1}(0.2) = -0.8416$			
			$\frac{350-\mu}{\sigma} = -0.8416$	M1	For equation as seen or equivalent with their –ive z value	If 'continuity corrections' applied allow M marks but do not award final A marks
			$P(Z > \frac{390-\mu}{\sigma}) = 0.1$			
			$\Phi^{-1}(0.9) = 1.282$	B1	For 1.282 or -0.8416	
			$\frac{390-\mu}{\sigma} = 1.282$	M1	For equation as seen or equivalent with their +ive z value	
			$350 = \mu - 0.8416\,\sigma$			
			$390 = \mu + 1.282\,\sigma$			
			$2.1236\,\sigma = 40$			
			$\sigma = 18.84$	A1	Allow 18.8	Answers to max 2 d.p.
			$\mu = 350 + (0.8416 \times 18.84) = 365.85$	A1	Allow 365.86, 366, 365.9	
				[5]		
3	(iv)		$\Phi^{-1}(0.975) = 1.96$	B1	For using a suitable pair of z values e.g. ± 1.96	
			$a = 365.85 - (1.96 \times 18.84)$	M1	For either equation provided that a suitable pair of z-values is used. e.g. +2.326 and –1.751	
			$= 328.9$	A1	FT their μ and σ to 2 d.p. (A0 if 'continuity correction' used)	Accept any correct values of a and b.
			$b = 365.85 + (1.96 \times 18.84)$			
			$= 402.8$	A1	FT their μ and σ to 2 d.p. (A0 if 'continuity correction' used)	
				[4]		

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>Guidance</th><th></th></tr>
<tr><td>4</td><td>(a)</td><td></td><td>H_0: no association between grade and hours worked
H_1: some association between grade and hours worked;

<table><tr><td></td><td>Less than 5hrs</td><td>At least 5hrs</td></tr><tr><td>A or B</td><td>17.05</td><td>13.95</td></tr><tr><td>C or lower</td><td>15.95</td><td>13.05</td></tr></table>
<table><tr><td></td><td>Less than 5hrs</td><td>At least 5hrs</td></tr><tr><td>A or B</td><td>0.5104</td><td>0.6238</td></tr><tr><td>C or lower</td><td>0.5456</td><td>0.6669</td></tr></table>
$X^2 = 2.347$
Refer to χ_1^2
Critical value at 5% level = 3.841

Result is not significant.
There is insufficient evidence to suggest that there is any association between hours worked and grade.</td><td>B1

M1
A1

M1
A1

B1
M1
A1

E1

[9]</td><td>Hypotheses in context

Any row/column correct
For expected values (to 2 dp)

For valid attempt at $(O-E)^2/E$. Any row column correct.
For all correct

For 1 deg of freedom. No FT from here if wrong.
CAO for cv or p-value = 0.1255. SC1 for cv or p-value if 1 dof not seen.

For conclusion in context. NB if H_0 H_1 reversed, or ‘correlation’ mentioned, do not award first B1 or final E1</td><td>NB These M1A1 marks cannot be implied by a correct final value of X^2</td></tr>
</table>

Question			Answer	Marks	Guidance	
4	(b)		$\bar{x} = 417.79$	B1	For $\bar{x}$	
			H_0: $\mu = 420$;	B1	For use of 420 in hypotheses. Hypotheses in words must refer to population. Do not allow alternative symbols unless clearly defined as the population mean.	
			H_1 : $\mu \neq 420$	B1	For both correct	
			Where μ denotes the mean volume of the cans of tomato purée (in the population)	B1	For definition of μ. Condone omission of "population" if correct notation μ is used, but if μ is defined as the **sample** mean then award **B0**.	
			Test statistic $= \frac{417.79 - 420}{3.5/\sqrt{10}} = \frac{-2.21}{1.107} = -1.997$	M1* A1	must include √10 FT their $\bar{x}$	
			Lower 1% level 2 tailed critical value of z = – 2.576	B1*	For –2.576 Must be –2.576 unless it is clear that absolute values are being used.	
			–1.997 > – 2.576	M1 dep*	For sensible comparison leading to a conclusion.	
			So not significant. There is insufficient evidence to reject H0			
			There is insufficient evidence to suggest that the average volumes of the cans of tomato purée is not 420ml	A1 **[9]**	For conclusion in words in context provided that correct cv used. FT only candidate's test statistic.	

ADDITIONAL NOTES REGARDING QUESTION 4 (b)

Critical Value Method
$420 - 2.576 \times 3.5 \div \sqrt{10}$ gets M1*B1*
= 417.148… gets A1
417.79 > 417.148.. gets M1dep* for sensible comparison
A1 still available for correct conclusion in words & context

Confidence Interval Method
CI centred on 417.79 + or $- 2.5756 \times 3.5 \div \sqrt{10}$ gets M1* B1*
= (414.93…, 420.64..) gets A1
NOTE that the final M1dep* A1 available only if 2.576 used.
"Contains 420" gets M1dep*
A1 still available for correct conclusion in words & context

Probability Method
Finding P(sample mean < 417.79) = 0.0229 gets M1* A1 B1*
0.0229 > **0.005*** gets M1dep* for a sensible comparison if a conclusion is made.
A1 available for a correct conclusion in words & context.
Condone P(sample mean > 417.79) = 0.9771 for M1* but only allow A1 B1* if sensible comparison made, at which point the final M1dep* and A1 are still available

ADDITIONAL NOTE REGARDING OVER-SPECIFICATION OF ANSWERS
Over-specification by providing final answers correct to 5 or more significant figures will be penalised. When this applies, candidates may lose no more than 2 marks per question and no more than 4 marks in total. The only exception to this rule is in Question 3 parts (iii) & (iv) – see guidance notes.

OCR (Oxford Cambridge and RSA Examinations)
1 Hills Road
Cambridge
CB1 2EU

OCR Customer Contact Centre

Education and Learning
Telephone: 01223 553998
Facsimile: 01223 552627
Email: general.qualifications@ocr.org.uk

www.ocr.org.uk

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OCR (Oxford Cambridge and RSA Examinations)
Head office
Telephone: 01223 552552
Facsimile: 01223 552553

4767 Statistics 2

General Comments

Once again, the overall level of ability shown by candidates taking this paper was high. Responses to questions requiring statistical interpretation were, on the whole, good. The majority of candidates coped well with the questions involving probability calculations. Question 4, involving hypothesis tests, was particularly well done; it was pleasing to see many suitably non-assertive conclusions. Over-specification of answers was seen, though most worked to appropriate levels of accuracy. Few candidates were penalised for under-specification.

Comments on Individual Questions

1(i) Most candidates produced an accurately drawn scatter diagram with suitably labelled axes. Few candidates neglected to label their axes. Those using unusual scales on the vertical axis often incorrectly plotted the second or third point.

(ii) This was well answered. The majority of candidates identified "thickness" as the independent variable and provided a suitable reason for their choice; this often involved describing an element of control over the thickness of tile used.

(iii) Most candidates obtained the correct equation for h on t (though many used variables y & x instead of h & t). A small number of candidates estimated the gradient of the line using points on the graph rather than the least squares regression formula provided in the Examination Formulae booklet. Few arithmetic slips were seen. Most candidates opted to give their gradient and intercept values correct to 3 significant figures. Candidates calculating the least squares regression line for t on h were few in number.

(ivA&) Well answered. Most candidates showed awareness of interpolation and extrapolation, and provided suitable comments

(v) This question was generally well answered. Many candidates scored full marks. A few candidates calculated the residual as "predicted value – observed value".

(vi) After calculating the predicted height for a tile of thickness 200 mm, most candidates realised that the linear relationship was reliable for thicknesses within the range of values of the data provided, and that the relationship appeared to break down for larger thicknesses. Most of these candidates communicated this idea well, but those candidates simply stating that the (overall) relationship was non-linear did not earn the final mark. A small proportion of candidates managed to make a suitable comment without showing that they had calculated the prediction for the 200 mm tile. Many candidates seemed unaware of the differences between linear relationships and relationships where one variable is proportional to another.

2(iA) This was well answered with most candidates obtaining both marks.

(iB) Also well answered though occasional mistakes using tables, such as looking up the value of $P(X \leq 1)$ using $\lambda = 2.0$, were seen.

(iC) Most candidates realised that the new mean, $\lambda = 10.5$, was to be used. Many correct answers were seen through a variety of incorrect methods for finding $P(5 \leq X \leq 10)$ followed; of which "$P(X \leq 10) - P(X \leq 5)$" and "$P(X \geq 5) - P(X \leq 10)$" were typical.

(ii) Many candidates obtained full marks here though some failed to apply the required continuity correction. A few candidates lost the final accuracy mark through premature rounding of their *z*-value prior to using Normal tables.

(iii) Most candidates provided a suitable comment here, with remarks about "independence" being the most popular.

(iv) This proved to be one of the most challenging parts of the paper. Despite answering part (iii) correctly many candidates reverted back to the inappropriate model by combining the means rather than considering the different combinations of "pairs" and "singles". Of those attempting to consider combinations of pairs and singles only a small proportion obtained a fully correct solution; a variety of approaches was seen and those working systematically were the most successful.

3(iA) Well answered, though inappropriate "continuity corrections" were seen on occasion.

(iB) Well answered, though arithmetic errors were quite common. In several cases, –1.667 was used rather than –1.1667 often as a result of candidates misreading their own figures. A few candidates lost accuracy by prematurely rounding their *z*-value before using the Normal tables.

(ii) Very well answered. Most candidates scored both marks.

(iii) On the whole, this was well answered. Many candidates provided clear, accurate methods leading to correct final answers. Some candidates started out with one of the required equations containing a sign error which was not picked up, even when the error led to a negative value for σ. Most candidates identified the correct *z*-values. In the poorest answers, continuity corrections were attempted and *z*-values were changed to absurd values, such as "1 – 0.8416", before substitution into equations. Over-specification of final answers was seen, on occasion, here.

(iv) Though one of the more challenging parts, many candidates scored full marks here. A variety of correct, "non-symmetrical" solutions were seen though most opted to use *z*-values of ± 1.96.

4(a) This question was well answered. Many candidates scored full marks. Marks lost typically for over-assertive conclusions, typically containing words such as "not enough evidence to prove that…". The small number of candidates referring to correlation in their hypotheses often lost the first and last marks. Most candidates managed to accurately calculate the test statistic though some did not show all working as required. Most candidates stated the correct number of degrees of freedom and identified the correct critical value, though some thought that this was a 2-tailed test.

(b) Well answered. Most candidates accurately calculated the sample mean and provided hypotheses in terms of μ. Note that candidates should be discouraged from referring to the "sample population mean" when defining μ. In carrying out the test, the test statistic method proved the most popular; those who "reversed their numerator" needed to be very careful how they used their test statistic. Many appropriate, non-assertive conclusions were seen though some failed to include context in the final comments.