



# Mark Scheme (**Results**)

Summer 2016

Pearson Edexcel GCE Statistics S3  
(6691/01)

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## General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the **candidate's response is not worthy of credit according to the mark scheme**.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to **a candidate's response, the team leader must be consulted**.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

## PEARSON EDEXCEL GCE MATHEMATICS

### General Instructions for Marking

1. The total number of marks for the paper is 75
2. The Edexcel Mathematics mark schemes use the following types of marks:
  - **M** marks: Method marks are awarded for 'knowing a method and attempting to apply it', unless otherwise indicated.
  - **A** marks: Accuracy marks can only be awarded if the relevant method (M) marks have been earned.
  - **B** marks are unconditional accuracy marks (independent of M marks)
  - Marks should not be subdivided.

### 3. Abbreviations

These are some of the traditional marking abbreviations that will appear in the mark schemes.

- bod – benefit of doubt
  - ft – follow through
  - the symbol  $\surd$  will be used for correct ft
  - cao – correct answer only
  - cso - correct solution only. There must be no errors in this part of the question to obtain this mark
  - isw – ignore subsequent working
  - awrt – answers which round to
  - SC: special case
  - oe – or equivalent (and appropriate)
  - d... or dep – dependent
  - indep – independent
  - dp decimal places
  - sf significant figures
  - \* The answer is printed on the paper or ag- answer given
  - $\square$  or d... The second mark is dependent on gaining the first mark
4. All A marks are 'correct answer only' (cao.), unless shown, for example, as A1 ft to indicate that previous wrong working is to be followed through. After a misread however, the subsequent A marks affected are treated as A ft, but manifestly absurd answers should never be awarded A marks.

5. For misreading which does not alter the character of a question or materially simplify it, deduct two from any A or B marks gained, in that part of the question affected.
6. If a candidate makes more than one attempt at any question:
  - If all but one attempt is crossed out, mark the attempt which is NOT crossed out.
  - If either all attempts are crossed out or none are crossed out, mark all the attempts and score the highest single attempt.
7. Ignore wrong working or incorrect statements following a correct answer.



Question Number	Scheme	Marks																																																
2	<p><math>H_0</math> : <b>Drug concentration</b> and catching <b>influenza</b> are independent / not associated</p> <p><math>H_1</math> : <b>Drug concentration</b> and catching <b>influenza</b> are not independent / associated</p> <table border="1" data-bbox="240 499 1370 795"> <thead> <tr> <th></th> <th><i>A</i></th> <th><i>B</i></th> <th><i>C</i></th> <th></th> </tr> </thead> <tbody> <tr> <td>Influenza</td> <td><math>\frac{50 \times 27}{110} = 12.272\dots</math></td> <td><math>\frac{50 \times 52}{110} = 23.636\dots</math></td> <td><math>\frac{50 \times 31}{110} = 14.090\dots</math></td> <td>50</td> </tr> <tr> <td>No influenza</td> <td><math>\frac{60 \times 27}{110} = 14.727\dots</math></td> <td><math>\frac{60 \times 52}{110} = 28.363\dots</math></td> <td><math>\frac{60 \times 31}{110} = 16.909\dots</math></td> <td>60</td> </tr> <tr> <td></td> <td>27</td> <td>52</td> <td>31</td> <td>110</td> </tr> </tbody> </table> <table border="1" data-bbox="240 853 1329 1155"> <thead> <tr> <th><i>O</i></th> <th><i>E</i></th> <th><math>\frac{(O - E)^2}{E}</math></th> <th><math>\frac{O^2}{E}</math></th> </tr> </thead> <tbody> <tr> <td>12</td> <td>12.272...</td> <td>0.0060...</td> <td>11.7333...</td> </tr> <tr> <td>29</td> <td>23.636...</td> <td>1.2171...</td> <td>35.5807...</td> </tr> <tr> <td>9</td> <td>14.090...</td> <td>1.8392...</td> <td>5.7483...</td> </tr> <tr> <td>15</td> <td>14.727...</td> <td>0.0050...</td> <td>15.2777...</td> </tr> <tr> <td>23</td> <td>28.363...</td> <td>1.0142...</td> <td>18.6506...</td> </tr> <tr> <td>22</td> <td>16.909...</td> <td>1.5327...</td> <td>28.6236...</td> </tr> </tbody> </table> <p><math>\sum \frac{(O - E)^2}{E} = 5.6145\dots</math> or <math>\sum \frac{O^2}{E} - N = 115.62\dots - 110 = 5.6145\dots</math> awrt 5.61-5.62</p> <p><math>\nu = (3 - 1)(2 - 1) = 2</math> , <math>\chi^2(10\%) = 4.605</math></p> <p>Reject <math>H_0</math></p> <p><b>Drug concentration</b> and catching <b>influenza</b> are not independent / are associated.</p>		<i>A</i>	<i>B</i>	<i>C</i>		Influenza	$\frac{50 \times 27}{110} = 12.272\dots$	$\frac{50 \times 52}{110} = 23.636\dots$	$\frac{50 \times 31}{110} = 14.090\dots$	50	No influenza	$\frac{60 \times 27}{110} = 14.727\dots$	$\frac{60 \times 52}{110} = 28.363\dots$	$\frac{60 \times 31}{110} = 16.909\dots$	60		27	52	31	110	<i>O</i>	<i>E</i>	$\frac{(O - E)^2}{E}$	$\frac{O^2}{E}$	12	12.272...	0.0060...	11.7333...	29	23.636...	1.2171...	35.5807...	9	14.090...	1.8392...	5.7483...	15	14.727...	0.0050...	15.2777...	23	28.363...	1.0142...	18.6506...	22	16.909...	1.5327...	28.6236...	<p>B1</p> <p>M1A1</p> <p>M1A1</p> <p>A1</p> <p>B1B1ft</p> <p>M1</p> <p>A1cao</p> <p>(10)</p> <p><b>Total</b> <b>10</b></p>
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Notes	<p>B1 hyps correct way around</p> <p>M1 for correct expression at least once</p> <p>A1 <b>all seen</b> and correct 2dp or better. Can be implied by test statistic of awrt 5.61-5.62.</p> <p>M1 either method at least one correct</p> <p>A1 at least 3 correct values. Can be implied by test statistic of awrt 5.61-5.62</p> <p>A1 awrt 5.61-5.62</p> <p>B1 cao</p> <p>B1 follow through their <math>\nu</math></p> <p>M1 must correctly reject / not reject the null hypothesis based on their test stat and cv oe</p>																																																	

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3 (a)	Variables do not have a (joint) normal distribution Relationship is not linear The given data is ordinal	Any 1 B1 (1)																																								
(b)	<table border="1" style="width: 100%; text-align: center;"> <thead> <tr> <th>Day</th> <th>Sun</th> <th>Mon</th> <th>Tues</th> <th>Weds</th> <th>Thurs</th> <th>Fri</th> <th>Sat</th> </tr> </thead> <tbody> <tr> <td>Ice-cream</td> <td>6</td> <td>4</td> <td>7</td> <td>5</td> <td>3</td> <td>2</td> <td>1</td> </tr> <tr> <td>Sunglasses rank</td> <td>6</td> <td>5</td> <td>7</td> <td>2</td> <td>3</td> <td>4</td> <td>1</td> </tr> <tr> <td><math>d</math></td> <td>0</td> <td>-1</td> <td>0</td> <td>3</td> <td>0</td> <td>-2</td> <td>0</td> </tr> <tr> <td><math>d^2</math></td> <td>0</td> <td>1</td> <td>0</td> <td>9</td> <td>0</td> <td>4</td> <td>0</td> </tr> </tbody> </table>	Day	Sun	Mon	Tues	Weds	Thurs	Fri	Sat	Ice-cream	6	4	7	5	3	2	1	Sunglasses rank	6	5	7	2	3	4	1	$d$	0	-1	0	3	0	-2	0	$d^2$	0	1	0	9	0	4	0	M1 M1A1 (3)
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(c)	$\sum d^2 = 14$ $r_s = 1 - \frac{6 \times 14}{7(49 - 1)} = 0.75$	B1 B1 M1 A1cao (4)																																								
(d)	$H_0 : \rho = 0, H_1 : \rho > 0$ 5% cv 0.7143 Reject $H_0$ Evidence of <b>positive</b> correlation between sales of <b>ice cream</b> and sales of <b>sunglasses</b> .	M1 M1A1 (3)																																								
(e)	(5% cv 0.6694) Accept $H_0$ Insufficient evidence of <b>positive</b> correlation between sales of ice cream and sales of sunglasses.	M1 A1cao (2)																																								
(e)	Suggests relationship might be non-linear.	B1 (1)																																								
Notes	(a) Accept 'already ranked' oe for ordinal Accept one variable is not normally distributed (b) M1 attempt to find $d$ , $d^2$ and sum. may be implied by sight of $\sum d^2 = 14$ M1 for use of the correct formula, follow through their $\sum d^2$ if clearly stated. If answer is not correct, a correct expression is required. A1 0.75 cao (c) 1st B1 for both hypotheses in terms of $\rho$ , one tail. Allow use of $\rho_s$ . <b>Only award</b> if no errors seen in hypotheses in part(c) <b>and</b> part(d) Hypotheses just in words e.g. "no correlation" score B0. B1 0.7143 cao M1 must correctly reject / not reject the null hypothesis based on their test stat and cv oe A1 Conclusion must mention ice cream and sunglasses (d) M1 for not rejecting / accepting null hyp A1 must mention ice cream and sunglasses	Total 11																																								

Question Number	Scheme	Marks
4 (a)	$X_i$ be rv 'weight of $i^{\text{th}}$ randomly chosen egg' $E(X_1 - X_2) = 0$ $\text{Var}(X_1 - X_2) = 2 \times 5^2 = 50$ $P( X_1 - X_2  > 2) = 2P(X_1 - X_2 > 2)$ $= 2P(Z > \frac{2}{\sqrt{50}})$ $= 2P(Z > 0.2828\dots)$ $= 2(1 - 0.6103) = 0.7794$	B1 B1 M1 dM1 awrt 0.777-0.779 A1 (5)
(b)	$W = C + X_1 + X_2 + \dots + X_{12}$ $E(W) = 40 + 12 \times 60 = 760$ $\text{Var}(W) = 1.5^2 + 12 \times 5^2$ $= 302.25$ Distribution is $N(760, 302.25)$	B1 M1 A1 (3)
(c)	$P(W > 800) = P\left(Z > \frac{800 - 760}{\sqrt{302.25}}\right)$ $= 1 - P(Z < 2.3007\dots)$ $= 0.0107$	M1 awrt 0.0107 A1 (2)
Notes (a)	B1 for 0 B1 for 50 M1 for $ X_1 - X_2  > 2$ seen. Accept $X_1 - X_2 > 2$ provided a subsequent doubling of the probability is seen. i.e. $0.3897 \times 2$ . dM1 standardise with their 0 and their $\sqrt{50}$ dependent on previous M. A1 awrt 0.777-0.779 (b) B1 for 760 M1 requires squares A1 cao (c) Must be finding correct probability (ie $P(W > 800)$ or $P(Z > 2.3007\dots)$ etc) and standardise with 800 and their 760 and their $\sqrt{302.25}$ A1 awrt 0.0107 from correct working.	Total 10

Question Number	Scheme	Marks
5(a)	$H_0 : \mu_e = \mu_n, H_1 : \mu_e > \mu_n$ $z = \frac{26.3 - 24.8}{\sqrt{\frac{12.2}{35} + \frac{10.1}{42}}} = \frac{1.5}{\sqrt{0.58904\dots}} = \frac{1.5}{0.76749\dots}$ $z = 1.9544\dots$ <p>awrt 1.95</p> <p>Critical value is 1.6449</p> <p>Reject <math>H_0</math>. Doctor's claim is supported.</p>	<p>B1</p> <p>M1M1</p> <p>A1</p> <p>B1</p> <p>A1</p> <p>(6)</p>
(b)	<p>Either assume <math>\bar{X}</math> has a normal distribution (for both samples) or assume sample sizes are large enough to use CLT</p> <p>Assume individual <b>results</b> are independent</p> <p>Assume <math>\sigma^2 = s^2</math> for <b>both</b> populations or a single general population</p>	<p>B1 B1</p> <p>(2)</p>
(c)	$\bar{x} = \left( \frac{35 \times 26.3 + 31.7}{36} = \frac{952.2}{36} \right) 26.45$ <p>For <math>n = 35</math>, <math>\sum x^2 = 34 \times 12.2 + 35 \times 26.3^2 (= 24\,623.95)</math></p> <p>For <math>n = 36</math>, <math>s^2 = \frac{25628.84 - 36 \times 26.45^2}{35} = 12.661\dots</math> awrt 12.7</p>	<p>B1</p> <p>M1</p> <p>dM1A1</p> <p>(4)</p> <p><b>Total 12</b></p>
Notes (a)	<p>Both hyps, one tailed only oe.</p> <p>Accept <math>\mu_1, \mu_2</math> or <math>\mu_A, \mu_B</math> etc if there is some indication of which is which.</p> <p>M1 for correct method for standard error</p> <p>M1 for whole expression</p> <p>A1 awrt 1.95</p> <p>B1 1.6449 or <math>p = 0.974\dots (&gt;0.95)</math></p> <p>A1 must mention doctor and claim or description of claim that includes 'mean lung capacity' and 'exercise'.</p>	
ALT (a)	<p>M1 for <math>\sqrt{\frac{12.2}{35} + \frac{10.1}{42}}</math></p> <p>M1 for <math>1.6449 = \frac{c}{\sqrt{\frac{12.2}{35} + \frac{10.1}{42}}}</math></p> <p>A1 for awrt <math>c = 1.26</math> seen</p> <p>B1 1.5</p>	
(c)	<p>M1 Attempt <math>\sum x^2 = 34 \times 12.2 + 35 \times 26.3^2</math></p> <p>or <math>\sum (x - \bar{x})^2 = 34 \times 12.2 + 35(26.45 - 26.3)^2 (= 415.5875)</math></p> <p>dM1 <math>s^2 = \frac{\sum x^2 + 31.7^2 - 36 \times 26.45^2}{35}</math> or <math>s^2 = \frac{415.5875 + (31.7 - 26.45)^2}{35}</math></p> <p>A1 awrt 12.7</p>	

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6(a)	<p><math>H_0</math> : Binomial with <math>p = 0.3</math> is a good fit. <math>H_1</math> : Binomial with <math>p = 0.3</math> is not a good fit.</p> <table border="1" data-bbox="229 271 1334 551"> <thead> <tr> <th></th> <th>0</th> <th>1</th> <th>2 or more</th> </tr> </thead> <tbody> <tr> <td>Observed</td> <td>6</td> <td>25</td> <td>19</td> </tr> <tr> <td>Expected</td> <td><math>50 \times 0.2401</math> =12.005 or <b>12.01</b> or 12.00</td> <td><math>50 \times 0.4116</math> =20.58</td> <td><math>50 \times 0.2646 + 50 \times 0.0756 + 50 \times 0.0081</math> =13.23+3.78+0.405 =17.415 or <b>17.41</b> or 17.42</td> </tr> <tr> <td><math>\frac{(O-E)^2}{E}</math></td> <td>3.003751</td> <td>0.949291</td> <td>0.144256</td> </tr> <tr> <td><math>\frac{O^2}{E}</math></td> <td>2.998751</td> <td>30.36929</td> <td>20.72926</td> </tr> </tbody> </table> <p><math>\sum \frac{(O-E)^2}{E} = 4.097... \text{ or } \sum \frac{O^2}{E} - N = 54.097... - 50 = 4.097... \quad \text{awrt } 4.09-4.1(0)</math></p> <p><math>\nu = 3 - 1 = 2</math>  <math>\chi^2_2(5\%) = 5.991 (&gt; 4.1(0))</math>                      Insufficient evidence to reject <math>H_0</math> (Accept <math>H_0</math>)                      Binomial with <math>p = 0.3</math> is a good fit.</p>		0	1	2 or more	Observed	6	25	19	Expected	$50 \times 0.2401$ =12.005 or <b>12.01</b> or 12.00	$50 \times 0.4116$ =20.58	$50 \times 0.2646 + 50 \times 0.0756 + 50 \times 0.0081$ =13.23+3.78+0.405 =17.415 or <b>17.41</b> or 17.42	$\frac{(O-E)^2}{E}$	3.003751	0.949291	0.144256	$\frac{O^2}{E}$	2.998751	30.36929	20.72926	<p>B1</p> <p>M1A1</p> <p>dM1A1</p> <p>B1ft</p> <p>B1ft</p> <p>A1</p> <p>(8)</p>										
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(b)	<p><math>\bar{x} = \frac{40 + 62 + 54 + 24}{100} = 1.8</math></p> <p><math>r = 26.78</math>  <math>s = 16.07</math></p>	<p>B1 cao</p> <p>B1 cao</p> <p>B1 cao</p> <p>(3)</p>																														
(c)	<p><math>H_0</math> : Poisson is a good fit. <math>H_1</math> : Poisson is not a good fit.</p> <table border="1" data-bbox="225 1099 1321 1413"> <thead> <tr> <th></th> <th>0</th> <th>1</th> <th>2</th> <th>3</th> <th>4 or more</th> </tr> </thead> <tbody> <tr> <td>Observed</td> <td>5</td> <td>40</td> <td>31</td> <td>18</td> <td>6</td> </tr> <tr> <td>Expected</td> <td>16.53</td> <td>29.75</td> <td>26.78</td> <td>16.07</td> <td>10.87</td> </tr> <tr> <td><math>\frac{(O-E)^2}{E}</math></td> <td><math>\frac{11.53^2}{16.53} = 8.042...</math></td> <td><math>\frac{10.25^2}{29.75} = 3.532...</math></td> <td><math>\frac{4.22^2}{26.78} = 0.665...</math></td> <td><math>\frac{1.93^2}{16.07} = 0.232...</math></td> <td><math>\frac{4.87^2}{10.87} = 2.182...</math></td> </tr> <tr> <td><math>\frac{O^2}{E}</math></td> <td><math>\frac{5^2}{16.53} = 1.512...</math></td> <td><math>\frac{40^2}{29.75} = 53.782...</math></td> <td><math>\frac{31^2}{26.78} = 35.885...</math></td> <td><math>\frac{18^2}{16.07} = 20.162...</math></td> <td><math>\frac{6^2}{10.87} = 3.312...</math></td> </tr> </tbody> </table> <p><math>\sum \frac{(O-E)^2}{E} = 14.65 - 14.66 \text{ or } \sum \frac{O^2}{E} - N = 114.65 - 100 = 14.65 - 14.66</math></p> <p><math>\nu = 5 - 1 - 1 = 3</math>  <math>\chi^2_3(1\%) = 11.345 (&lt; 14.65)</math>                      Sufficient evidence to reject <math>H_0</math>                      Poisson is not a good fit.</p>		0	1	2	3	4 or more	Observed	5	40	31	18	6	Expected	16.53	29.75	26.78	16.07	10.87	$\frac{(O-E)^2}{E}$	$\frac{11.53^2}{16.53} = 8.042...$	$\frac{10.25^2}{29.75} = 3.532...$	$\frac{4.22^2}{26.78} = 0.665...$	$\frac{1.93^2}{16.07} = 0.232...$	$\frac{4.87^2}{10.87} = 2.182...$	$\frac{O^2}{E}$	$\frac{5^2}{16.53} = 1.512...$	$\frac{40^2}{29.75} = 53.782...$	$\frac{31^2}{26.78} = 35.885...$	$\frac{18^2}{16.07} = 20.162...$	$\frac{6^2}{10.87} = 3.312...$	<p>B1</p> <p>M1A1</p> <p>B1 cao</p> <p>B1ft</p> <p>A1 cao</p> <p>(6)</p>
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$\frac{(O-E)^2}{E}$	$\frac{11.53^2}{16.53} = 8.042...$	$\frac{10.25^2}{29.75} = 3.532...$	$\frac{4.22^2}{26.78} = 0.665...$	$\frac{1.93^2}{16.07} = 0.232...$	$\frac{4.87^2}{10.87} = 2.182...$																											
$\frac{O^2}{E}$	$\frac{5^2}{16.53} = 1.512...$	$\frac{40^2}{29.75} = 53.782...$	$\frac{31^2}{26.78} = 35.885...$	$\frac{18^2}{16.07} = 20.162...$	$\frac{6^2}{10.87} = 3.312...$																											
Notes (a)	<p>B1 both including <math>p = 0.3</math>                      M1 with some combined columns and at least one <math>E</math> correct to 2sf                      A1 all correct to 2dp and total of expected values is 50.                      dM1 either method                      A1 awrt 4.09-4.1(0)                      B1 ft their columns -1                      B1 ft their                      A1 cao</p> <p>(c)                      B1 no parameters included                      M1 either method</p>	<p><b>Total 17</b></p>																														

	B1 ft their $\nu$	
Question Number	Scheme	Marks
7(a)	$19.5 \pm 1.6449 \times \frac{1.5}{\sqrt{50}}$ $= (19.151\dots, 19.848\dots)$	M1B1 A1A1 awrt 19.2, awrt 19.8 (4)
(b)	CI does not contain 20 oe Fast Food restaurant statement is too high; they should reduce the stated value.	M1 A1 (2)
(c)	$P( \bar{X} - \mu  < 0.5) = 0.9$ $\frac{0.5}{\frac{2}{\sqrt{n}}} = 1.6449$ $n = \left( 2 \times \frac{1.6449}{0.5} \right)^2 = 43.29\dots$ Sample size required is 44	M1A1 dM1A1 A1 (5)
<b>Total 11</b>		
Notes		
(a)	M1 correct with their $z$ i.e. $19.5 \pm (z \text{ value}) \times \frac{1.5}{\sqrt{50}}$ B1 for 1.6449 A1 awrt 19.2, A1 awrt 19.8(5)	
(b)	M1 Require 20 compared to their interval A1 Accept statement that relates to 20 being above the interval.	
(c)	M1 $\frac{0.5}{\frac{2}{\sqrt{n}}} = z \text{ value}$ or equivalent expression A1 All correct dM1 Attempt to solve $\frac{0.5}{\frac{2}{\sqrt{n}}} = \text{their } z \text{ value}$ A1 awrt 43.3 A1 44 cao	

