# Mark Scheme (Results)

## Summer 2022

## Pearson Edexcel GCE
## In Mathematics (9MA0)
## Paper 31 Statistics

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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.

# EDEXCEL GCE MATHEMATICS
## General Instructions for Marking

1. The total number of marks for the paper is 50.

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)
- dep – dependent
- indep – independent
- dp decimal places
- sf significant figures
- $*$ The answer is printed on the paper
- ⌐ The second mark is dependent on gaining the first mark

4. 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.

5. Where a candidate has made multiple responses and indicates which response they wish to submit, examiners should mark this response.
   If there are several attempts at a question which have not been crossed out, examiners should mark the final answer which is the answer that is the most complete.

6. Ignore wrong working or incorrect statements following a correct answer.

7. Mark schemes will firstly show the solution judged to be the most common response expected from candidates. Where appropriate, alternatives answers are provided in the notes. If examiners are not sure if an answer is acceptable, they will check the mark scheme to see if an alternative answer is given for the method used.

| Question | Scheme | | Marks | AOs |
|---|---|---|---|---|
| 1(a)(i) | $X \sim B(15, 0.48)$ | | M1 | 3.3 |
| | $P(X = 3) = 0.019668...$ awrt 0.0197 | | A1 | 3.4 |
| (ii) | $[P(X \geqslant 5) = 1 - P(X \leqslant 4)] = 0.92013...$ awrt 0.920 | | A1 | 1.1b |
| | | | **(3)** | |
| (b) | $Y$ is the number of hits | $M$ is the number of misses | | |
| | $Y \sim N(120, 62.4)$ | $M \sim N(130, 62.4)$ | B1 | 3.3 |
| | $P(X > 110) \approx P(Y > 110.5)$ $\left[= P\left(Z > \frac{110.5 - "120"}{\sqrt{"62.4"}}\right)\right]$ | $P(X > 110) \approx P(M < 139.5)$ $\left[= P\left(Z < \frac{139.5 - "130"}{\sqrt{"62.4"}}\right)\right]$ | M1 | 3.4 |
| | $= 0.88544\ldots$ | | A1 | 1.1b |
| | | | **(3)** | |
| | | | | **(6 marks)** |

**Notes:**

| | | |
|---|---|---|
| **(a)** | **M1** | Writing or using the binomial distribution in (i) or (ii) Allow for sight of B(15, 0.48) or in words: <u>binomial</u> with <u>$n = 15$</u> and <u>$p = 0.48$</u> may be implied in (i) or (ii) by one correct answer to 3sf <u>or</u> sight of $P(X \leqslant 4) = 0.07986\ldots$ i.e. awrt 0.0799.<br>Allow for ${}^{15}C_3 \times 0.48^3 \times 0.52^{12}$ as this is "correct use" Condone B(0.48, 15) |
| **(i)** | **A1** | awrt 0.0197 |
| **(ii)** | **A1** | awrt 0.920 (Allow 0.92) |
| **(b)** | **B1** | Setting up a correct Normal model**.** Allow sight of $N(120, 62.4)$ or $N(130, 62.4)$ or $N\left(120, \frac{312}{5}\right)$ or $N\left(130, \frac{312}{5}\right)$ or may be awarded if used correctly in standardisation<br>or in words: <u>Normal</u> with <u>mean = 120/130</u> and<br><u>variance = 62.4</u> or sd = $\sqrt{62.4}$ condone $N(120, \sqrt{62.4})$ or $N(130, \sqrt{62.4})$ or sd = 62.4<br>Look out for $\sigma = \frac{\sqrt{1560}}{5}$ or $\frac{2\sqrt{390}}{5}$ or awrt 7.90 (condone 7.9)<br>This may be implied by sight of 0.897 or 0.8854… |
| | **M1** | Sight of the continuity correction with a normal distribution |
| | | **110.5** or 111.5 or 109.5 / **139.5** or 140.5 or 138.5 |
| | | NB we will also allow **129.5** or 130.5 or 128.5 / NB we will also allow **120.5** or 119.5 or 121.5 |
| | | Continuity correction may be seen in standardisation<br>NB No continuity correction(CC) gives awrt 0.897 which is M0 unless CC seen |
| | **A1** | awrt 0.8854 or awrt 0.885 dependent on sight of >110.5 or <129.5 or < 139.5 or >120.5<br>Allow $\leqslant$ or $\geqslant$ instead of < or ><br>NB 0.885548… from B(250, 0.48) scores M0A0 |

| Qu | Scheme | Marks | AOs |
|---|---|---|---|
| 2(a) | $\left[\mathrm{P}\left(L<7.902\right)=0.025\Rightarrow\right]\ \dfrac{7.902-8}{x}=-1.96$ oe | M1 | 3.4 |
| | $\left[x=\right]0.05$* | A1cso* | 1.1b |
| | **SC** B1( mark as M0A1) for $\dfrac{7.902-8}{0.05}=-1.96\Rightarrow 0.024998$ | | |
| | | **(2)** | |
| (b) | $\mathrm{P}\left(7.94\leqslant L\leqslant 8.09\right)=0.8490\ldots$ **awrt 0.849** | B1 | 1.1b |
| | | **(1)** | |
| (c) | $[\mathrm{P}\left(L<7.94\right)=]\ 0.115069\ldots$(awrt 0.115) **or** $[\mathrm{P}\left(L>8.09\right)=]\ 0.03593\ldots$(awrt 0.036) | B1 | 1.1b |
| | $[\mathrm{P}\left(L<7.94\right)=]\ 0.115069\ldots$(awrt 0.115) **&** $[\mathrm{P}\left(L>8.09\right)=]\ 0.03593\ldots$**(**awrt 0.036) | B1 | 1.1b |
| | Expected income per 500 rods = $\sum\left(\text{Income}\times\text{probability}\times 500\right)$<br>$\left(500\times\text{"0.849"}\times 0.5\right)+\left(500\times\text{"0.1150..."}\times 0.05\right)+\left(500\times\text{"0.03593..."}\times 0.4\right)$ **or**<br>Expected profit per rod = $\sum\left(\text{Profit}\times\text{probability}\right)$<br>$0.30\times\text{"0.849"}+-0.15\times\text{"0.1150..."}+0.20\times\text{"0.03593..."}$ **[**$=0.2446..$] | M1 | 3.4 |
| | Expected profit per 500 rods<br>$500\times\sum\left(\text{Profit}\times\text{probability}\right)$ **or** $\sum\left(\text{Income}\times\text{probability}\times 500\right)-500\times 0.2$<br>$=500\times\text{"0.2446..."}$ **or** $=\ \text{"222.3"}-500\times 0.2$ | M1d | 3.1b |
| | $=$ [£]122.3… **awrt [£]122** | A1 | 1.1b |
| | | **(5)** | |
| (d) | Let $X\sim\mathrm{B}(200,0.015)$ | M1 | 3.3 |
| | $\mathrm{P}(X\leqslant 5)=$ $\quad$ $\mathrm{P}\left(X\geqslant 6\right)=$ | M1 | 1.1b |
| | 0.9176… $\quad$ 0.0824 | A1 | 1.1b |
| | Manufacturer is unlikely to achieve their aim since $\underline{0.9176<0.95}$ $\quad$ Manufacturer is unlikely to achieve their aim since $\underline{0.0824>0.05}$ | A1ft | 2.4 |
| | | **(4)** | |

**Notes:** **(12 marks)**

| | | |
|---|---|---|
| **(a)** | **M1** | Using the normal distribution to set up equation. Allow $\sigma$ for $x$ and awrt $\pm 1.96$ |
| | **A1*** | cso For a correct expression for $x$ followed by 0.05 or 0.05000… No incorrect working seen |
| **(b)** | **B1** | awrt 0.849 |
| **(c)** | **B1** | awrt 0.115 (Implied by awrt 57.5 for number of rods) **or** awrt 0.036 (Implied by awrt 18 for number of rods) |
| | **B1** | awrt 0.115 (Implied by awrt 57.5 for number of rods) **and** awrt 0.036 (Implied by awrt 18 for number of rods) |
| | **M1** | Correct method to find the total income of 500 rods. Attempt at all 3 with at least two correct and no extras<br>**or** Correct method to find sum of all three profits with at least two of 30, −15 or 20 correct. May work in pence but need to be consistent. Allow awrt 24.5 or 0.245 |
| | **M1d** | Dep on previous method for finding profit for 500 rods. May work in pence but need to be consistent. Allow $\text{"0.2446..."}\times 500$ or "their income" for 500 rods $-500\times 0.2$ (accept 499 or 501) |
| | **A1** | All previous marks must be awarded for awrt 122 awrt 12200p<br>**NB** if uses any integer values for numbers of rods then it is A0 other than for 18 for $L>8.09$ |
| **(d)** | **M1** | Selecting the appropriate model. May be seen or used. Allow B(200,0.985) or Po(3)<br>Condone B(0.015, 200) or B( 0.985, 200). |
| | **M1** | Writing or using $\mathrm{P}\left(X\leqslant 5\right)$ Do not accept $\mathrm{P}\left(X<6\right)$ unless found $\mathrm{P}\left(X\leqslant 5\right)$ $\quad$ Writing or using $\mathrm{P}\left(X\geqslant 6\right)$ Do not accept $\mathrm{P}\left(X>5\right)$ unless found $\mathrm{P}\left(X\geqslant 6\right)$ |
| | **A1** | 0.92 (Poisson 0.916…) $\quad$ 0.08 or better |
| | **A1ft** | Need at least one of the method marks to be awarded. Correct conclusion with the comparison (may be in words). Ft "their $p=0.9176\ldots$" as long as $p>0.9$ If "their 0.9176…"< 0.95 must … be unlikely… If "their 0.9176…"> 0.95 they must say … be likely... To ft the alternative then $p<0.1$ |

| Question | Scheme | Marks | AOs |
|---|---|---|---|
| 3(a) | tr | B1 | 1.2 |
| | | **(1)** | |
| (b)(i) | $\mu = \frac{174.9}{31} = 5.6419\ldots$ awrt 5.64 | B1 | 1.1b |
| (ii) | $\sigma_r = \sqrt{\frac{3523.283}{31} - \mu^2}$ | M1 | 1.1b |
| | $= 9.04559\ldots$ awrt 9.05 | A1 | 1.1b |
| | | **(3)** | |
| (c) | Leuchars is in the North and Camborne is in the South | M1 | 2.4 |
| | The mean is smaller for Leuchars than Camborne therefore there is no evidence that Dian's belief is true | A1ft | 2.2b |
| | | **(2)** | |
| (d) | eg $p = 0.27$ is unlikely to be constant. | B1 | 2.4 |
| | | **(1)** | |
| | | | **(7 marks)** |

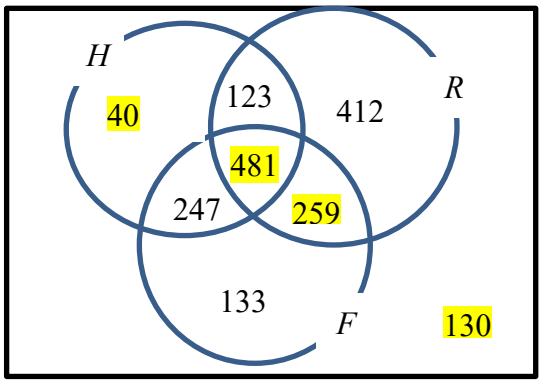
**Notes:**

| | | |
|---|---|---|
| **(a)** | **B1** | Allow Tr or trace or Trace |
| **(b)(i)** | **B1** | For a correct mean awrt 5.64 |
| **(ii)** | **M1** | For a correct expression for sd including the $\sqrt{}$ Ft their mean |
| | **A1** | awrt 9.05 (Allow $s = 9.1932\ldots$ awrt 9.19)<br>NB awrt to 9.05 or 9.19 with no working is M1 A1 |
| **(c)** | **M1** | For stating Leuchars is North of Camborne oe eg Camborne is further south |
| | **A1ft** | M1 must be awarded. A correct conclusion **and** correct comment about the means ft their mean in (b) Allow No |
| | **SC** | for No **and** there are only 2 places used so there is insufficient data. Mark as M0A1 on epen |
| **(d)** | **B1** | A correct reason referring to<br>• independence (needs context as to what is independent) eg consecutive 14 days unlikely to be independent.<br>• probability [of rain] not being constant.<br>• Allow a comment that conveys the idea that the proportion of days with no rain will be different over the year. |

| Question | Scheme | Marks | AOs |
|---|---|---|---|
| 4(a) | $H_0: p = 0.1$ $H_1: p \neq 0.1$ | B1 | 2.5 |
| | | **(1)** | |
| **(b)** | Use of $X \sim B(50, 0.1)$<br>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 $X \geqslant 10$ | A1 | 1.1b |
| | $X = 0$ and $X \geqslant 10$ plus<br>$P(X = 0) =$ awrt 0.0052 and $P(X \geqslant 10) =$ 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</u>**'s 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<br>Condone 10% but not 10 |
| **(b)** | **M1** | Using correct distribution to find the probability associated with one tail of the CR<br>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 $X = 0$ / $X < 1$ / $X \leqslant 0$ / [condone eg $P(X = 0)$ labelled as CR]<br>Or Upper CR $X \geqslant 10$ or $X > 9$ [condone $P(X \geqslant 10)$ oe labelled as CR] |
| | **A1** | Both CR's correct with the relevant probabilities Allow $\cup$ for "and" and $X > 9$, $X < 1$, $X \leqslant 0$ [**do not allow** $P(X = 0)$ or $P(X \geqslant 10)$ oe]<br>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<br>**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 $P(X \geqslant 15) = 0.0000738...$ and comparison with "their 0.0245"<br>**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>**<br>Condone increase rather than change<br>Do not allow contradicting statements.<br>NB No CR given in (b) then B0 |

| Question | Scheme | Marks | AOs |
|---|---|---|---|
| 5(a) | $\frac{365}{1825}$ or $\frac{1}{5}$ or 0.2 oe | B1 | 1.1b |
| | | **(1)** | |
| (b) | $\frac{170}{1825}$ or $\frac{34}{365}$ or awrt 0.093 | B1 | 1.1b |
| | | **(1)** | |
| (c) | $90\times0.4+80\times0.05[=40]$ or $90\times0.6+80\times0.95[=130]$ or $740\times0.65[=481]$ or $740\times0.35[=259]$   | M1<br><br><br><br><br><br>B1<br>B1<br>A1 | 3.1b<br><br><br><br><br><br>1.1b<br>1.1b<br>1.1b |
| | | **(4)** | |
| (d) | $P(R'\cap F)=\frac{380}{1825}\left[=\frac{76}{365}=0.208...\right]$ oe awrt 0.208 | B1 | 1.1b |
| | | **(1)** | |
| (e) | $\left[\frac{133\ +\ "130"}{1825}=\right]\frac{"263"}{1825}$ awrt 0.144 | B1ft | 1.1b |
| | | **(1)** | |
| (f) | $\frac{247+"481"}{247+"481"+123+"40"}$ | M1 | 3.4 |
| | $=\frac{728}{891}$ awrt 0.817 | A1 | 1.1b |
| | | **(2)** | |

**Notes:** **(10 marks)**

| | | |
|---|---|---|
| | | **Look out for answers given in the question. If you see answers in the question and in the answer space those in the answer space take precedence.** |
| **(a)** | **B1** | Allow equivalent |
| **(b)** | **B1** | Allow equivalent |
| **(c)** | **M1** | Correct method to find one of the values 40 or 130 or 481or 259<br>Implied by 40, 481, 259 or130 seen in correct place on diagram |
| | **B1** | One of the highlighted correct |
| | **B1** | A second value highlighted correct or their $("259"+"\ 481")=740$ or<br>their $("40"+"\ 481")=521$ or their $("40"+"130")=170$ |
| | **A1** | Fully correct |
| **(d)** | **B1** | 380/1825oe or awrt 0.208 |
| **(e)** | **B1ft** | Correct answer or<br>Ft their 130 ( > 0) do not allow if blank<br>Allow ft correct to 3 sf. |
| **(f)** | **M1** | For a single fraction with the numerator < denominator and *n* is an integer we will award for *n*/ 891 **or** *n*/(sum of their 4 values in *H*, each > 0) or awrt 0.817 |
| | **A1** | 728/891 oe or awrt 0.817 |

| 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**<br>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<br>$\log_{10} h = \log_{10} m^{-0.05} + 1.92$ or<br>$h = 10^{1.92 - 0.05 \log_{10} m}$ oe | $\log_{10} h = \log_{10} a + \log_{10} m^k$<br>or $\log_{10} a = 1.92$ | M1 | 2.1 |
| | $\log_{10} hm^{0.05} = 1.92$ or<br>$\log_{10}\left(\frac{h}{m^{-0.05}}\right) = 1.92$ or<br>$h = 10^{1.92} \times 10^{-0.05 \log_{10} m}$ 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<br>$h = 10^{1.92} \times 10^{\log_{10} m^{-0.05}}$ | $\log_{10} a = 1.92$ and $k = -0.05$ | M1 | 1.1b |
| | $h = 10^{1.92} m^{-0.05}$ or $h = 83.17... m^{-0.05}$ or $a$ = 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 $\rho < 0$<br>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 $\rho$ (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**<br>which mentions "pmcc/correlation/relationship" and less than 0/ negative or $\rho$ **< 0**<br>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**<br>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**<br>Method 1: Correct use of the power log rule **or** making $h$ the subject<br>Method 2 : Correct use of the addition/subtraction log rule |
| | **M1** | **This line implies M1M1M1**<br>Method 1: Correct use of the addition/subtraction log rule or eq$^n$ in the form $h = 10^{1.92} \times 10^{-0.05 \log m}$<br>Method 2: A second correct step for correct use of the power log rule |
| | **M1** | **This line implies M1M1M1M1**<br>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 $h$ = awrt $83.2m^{-0.05}$<br>NB award 5/5 for $a$ = awrt 83.2 and $k = -0.05$ or $h$ = awrt $83.2... m^{-0.05}$ or $h = 10^{1.92} m^{-0.05}$ |

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