Maths with Matt

Physics and maths resources

OCR A Level Mathematics B (MEI)

H640/02 - Pure Mathematics and Statistics

Thursday 12 June 2025

Questions and Fully Worked Model Solutions

This booklet places the **question and the solution together**. The mathematics is set out using proper fractions, powers, roots and exact notation, with extra written explanation so that a student can see *why* each step is being taken.

Solutions have been checked against the OCR Thursday 12 June 2025 mark scheme. The aim is a clear **full-mark model response**, not merely a list of final answers.

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Question 1

Question 1

The equation of a circle is $(x-4)^2+(y+5)^2-64=0$.
(a) State the coordinates of the centre of the circle. [1]
(b) State the radius of the circle. [1]

Model solution

Compare with $(x-a)^2+(y-b)^2=r^2$*, where the centre is* (a,b).

(a) Centre $(4,-5)$. *(1)*

The right-hand side is the square of the radius.

(b) Radius 8. *(1)*

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Question 2

Question 2

Determine the coefficient of x^3 in the expansion of $(1+2x)^{12}$. [2]

Model solution

The x^3 term in a binomial expansion is obtained by choosing $2x$ exactly three times.

$$\binom{12}{3}(2x)^3 = 220 \times 8x^3 = 1760x^3.$$

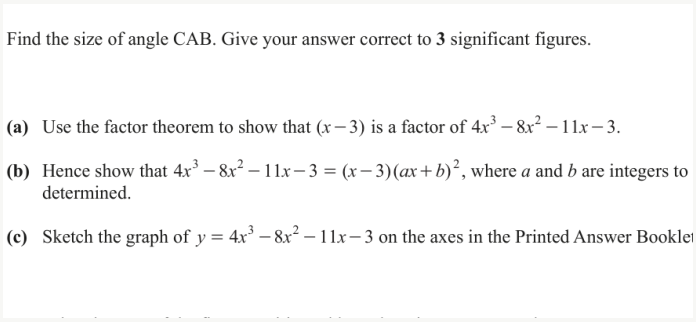
The coefficient is 1760. *(2)*

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Question 3

Question 3

The diagram shows triangle ABC. $AB = 4.7$ cm, $AC = 6.9$ cm and $BC = 11.2$ cm.



Find the size of angle CAB. Give your answer correct to 3 significant figures. [2]

Model solution

All three sides are known, so the cosine rule is the direct way to find the angle between AB and AC.

$$\cos \angle CAB = \frac{4.7^2 + 6.9^2 - 11.2^2}{2(4.7)(6.9)} = -0.859389\ldots$$

$$\angle CAB = \cos^{-1}(-0.859389\ldots) = 149.248\ldots^\circ.$$

$\angle CAB = 149^\circ$ *(3 s.f.).* *(2)*

Question 4

Question 4

(a) Use the factor theorem to show that $(x-3)$ is a factor of $4x^3 - 8x^2 - 11x - 3$. [1]

(b) Hence show that

$$4x^3 - 8x^2 - 11x - 3 = (x-3)(ax+b)^2,$$

where a and b are integers to be determined. [2]

(c) Sketch the graph of $y = 4x^3 - 8x^2 - 11x - 3$. [2]

Model solution

For the factor theorem, substitute the proposed root $x = 3$.

$$4(3)^3 - 8(3)^2 - 11(3) - 3 = 108 - 72 - 33 - 3 = 0.$$

(a) Since the value is 0, $x - 3$ is a factor. *(1)*

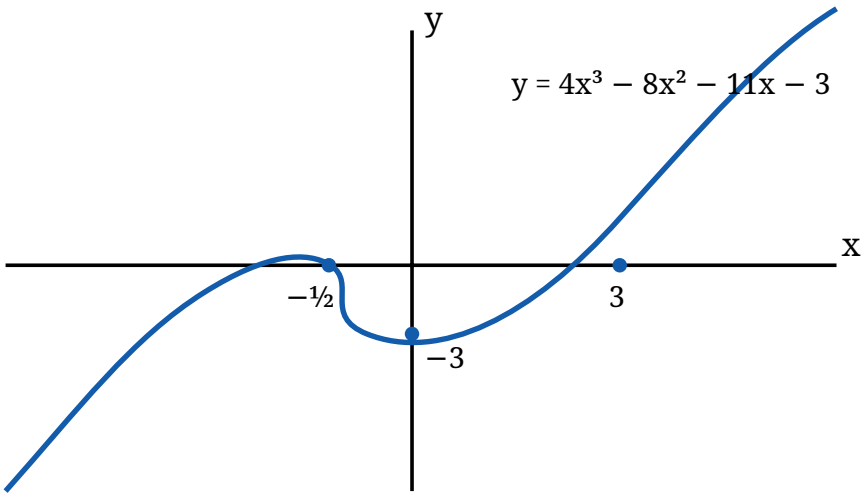
Dividing by $x - 3$ gives a quadratic; recognising it as a square gives the repeated root.

$$4x^3 - 8x^2 - 11x - 3 = (x-3)(4x^2 + 4x + 1) = (x-3)(2x+1)^2.$$

(b) $a = 2$, $b = 1$. *(2)*

The repeated factor means the curve touches, rather than crosses, the x-axis at $x = -\frac{1}{2}$. The simple factor gives the crossing at $x = 3$; the y-intercept is -3.

intercept	$(-\frac{1}{2}, 0)$	$(3, 0)$	$(0, -3)$
behaviour	*touches*	*crosses*	*on the y-axis*



(c) A cubic with a local maximum at $(-\frac{1}{2}, 0)$, decreasing to a local minimum in the fourth quadrant, then increasing to cross at $(3, 0)$, and passing through $(0, -3)$. *(2)*

Question 5

Question 5

Prove that the sum of the first n positive odd numbers is a square number. [3]

Model solution

The odd numbers form an arithmetic progression with first term 1, difference 2, and nth term $2n-1$. Apply the arithmetic-series formula.

$$1+3+5+\cdots+(2n-1)=\frac{n}{2}\big(1+(2n-1)\big)=\frac{n}{2}(2n)=n^2.$$

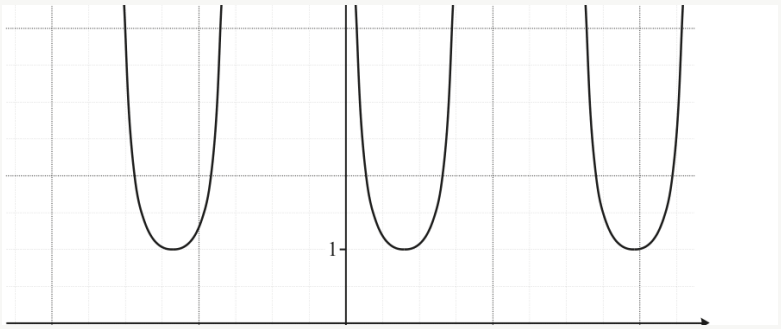
The sum is n^2, which is a square number. *(3)*

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Question 6

Question 6

The diagram shows part of the graph of $f(x) = \text{cosec}\, 2x$.



(a) State which of the following is the equation of the curve $y = \frac{1}{f(x)}$:

$$y = \cos 2x \qquad y = -\text{cosec}\, 2x \qquad y = \sin 2x \qquad y = \text{cosec}(-2x).$$

[1]

(b) State the exact equations of the asymptotes of $y = \text{cosec}\, 2x$ for $0 \leq x \leq \pi$. [1]

Model solution

Taking the reciprocal of $\text{cosec}\, 2x$ *gives* $\sin 2x$.

(a) $y = \sin 2x$. *(1)*

Vertical asymptotes occur where the denominator $\sin 2x$ *is zero.*

$$\sin 2x = 0 \implies 2x = 0, \pi, 2\pi.$$

(b) $x = 0$, $x = \frac{\pi}{2}$, $x = \pi$. *(1)*

Question 7

Question 7

Some people have blood type A and some have brown hair. A person is selected at random. Let A be the event "has blood type A" and B the event "has brown hair". You are given

$$P(A \cap B') = 0.3382, \qquad P(A' \cap B) = 0.0682, \qquad P((A \cup B)') = 0.5518.$$

(a) Show this information on a Venn diagram. [2]
(b) Determine whether A and B are independent events. [4]
(c) Explain whether A and B are mutually exclusive events. [1]

Model solution

The value outside both sets is already given. The fourth region is found because the four disjoint regions total 1.

$$P(A \cap B) = 1 - 0.3382 - 0.0682 - 0.5518 = 0.0418.$$

(a) A *only* $= 0.3382$, $A \cap B = 0.0418$, B *only* $= 0.0682$, *neither* $= 0.5518$. *(2)*

To test independence, compare $P(A \cap B)$ *with* $P(A)P(B)$.

$$P(A) = 0.3382 + 0.0418 = 0.38, \qquad P(B) = 0.0682 + 0.0418 = 0.11,$$

$$P(A)P(B) = 0.38(0.11) = 0.0418 = P(A \cap B).$$

(b) A *and* B *are independent.* *(4)*

Mutually exclusive events would have intersection probability zero.

(c) They are not mutually exclusive, since $P(A \cap B) = 0.0418 \neq 0$. *(1)*

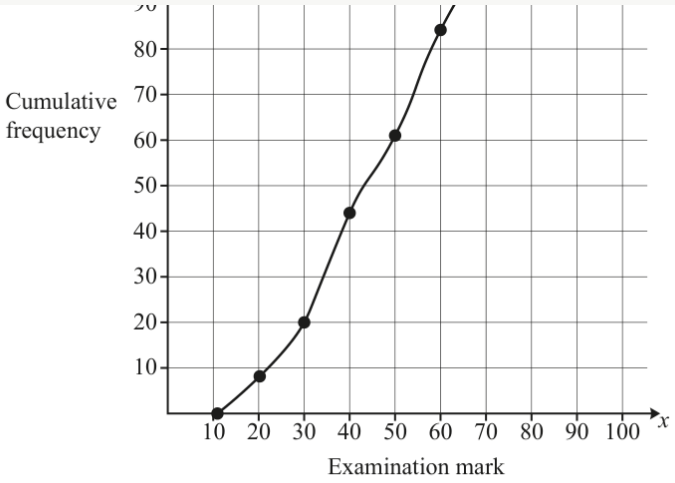
Question 8

Question 8

At Oakmount College, all 120 Year 8 pupils sit a mathematics examination. The 2024 marks are summarised below.

Mark	11–20	21–30	31–40	41–50	51–60	61–70	71–80	81–90	91–100
Frequency	8	12	24	17	23	16	10	7	3

The cumulative frequency curve is shown.



(a) It is proposed that the 30 pupils with the best marks in the examination are placed in the top set in Year 9.

(a) The 30 pupils with the best marks are placed in the top set. Use the curve to estimate the lowest mark needed. [2]

(b) Use the curve to estimate how many pupils are in the top set if the lowest mark is 75. [2]

Model solution

Thirty pupils above the cut-off means $120 - 30 = 90$ *pupils at or below it. Read across from cumulative frequency* 90*, then down to the mark axis.*

(a) Estimated lowest mark $= 63$ *(accept* 62 *to* 64*).* *(2)*

Read the cumulative frequency at 75*, about* 105*. Those above 75 are therefore* $120 - 105$*.*

$$120 - 105 = 15.$$

(b) About 15 *pupils (accept* 14 *to* 16*).* *(2)*

Question 9

Question 9

The position vectors of A and B are

$$\overrightarrow{OA} = \begin{pmatrix} -1 \\ -2 \\ 0 \end{pmatrix}, \qquad \overrightarrow{OB} = \begin{pmatrix} 2 \\ 1 \\ -3 \end{pmatrix}.$$

(a) Write down $\overrightarrow{AB}$. [1]

The point C lies on AB such that $2\overrightarrow{AC} = \overrightarrow{CB}$.

(b) Find $\overrightarrow{OC}$. [2]

Model solution

A displacement vector is final position minus initial position.

$$\overrightarrow{AB} = \overrightarrow{OB} - \overrightarrow{OA} = \begin{pmatrix} 3 \\ 3 \\ -3 \end{pmatrix}.$$

(a) $\overrightarrow{AB} = \begin{pmatrix} 3 \\ 3 \\ -3 \end{pmatrix}$. *(1)*

The condition says $AC : CB = 1 : 2$*, so* $\overrightarrow{AC} = \frac{1}{3}\overrightarrow{AB}$.

$$\overrightarrow{OC} = \overrightarrow{OA} + \frac{1}{3}\overrightarrow{AB} = \begin{pmatrix} -1 \\ -2 \\ 0 \end{pmatrix} + \frac{1}{3}\begin{pmatrix} 3 \\ 3 \\ -3 \end{pmatrix} = \begin{pmatrix} 0 \\ -1 \\ -1 \end{pmatrix}.$$

(b) $\overrightarrow{OC} = \begin{pmatrix} 0 \\ -1 \\ -1 \end{pmatrix} = -\mathbf{j} - \mathbf{k}$. *(2)*

Question 10

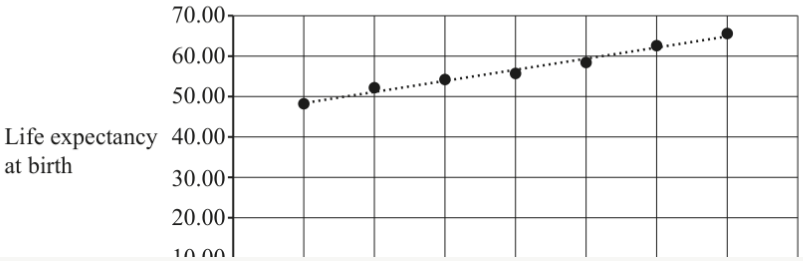
Question 10

The pre-release material contains life expectancy at birth for countries of the world at ten-year intervals from 1960 to 2020. For Sudan, Fig. 10.1 shows the data and a line of best fit, whose equation is $L = 0.275X - 490$, where X is year and L is life expectancy at birth in years.

0 The pre-release material contains information about life expectancy at birth for countries of the world at 10-year intervals from 1960 until 2020.

The life expectancy at birth of the population of Sudan for this period, together with a line of best fit, is shown in **Fig. 10.1**.

Fig. 10.1



(a) Estimate the life expectancy at birth in Sudan in 1975. [1]
(b) Explain whether this estimate is likely to be close to the true value. [1]
(c) Use the pre-release material to explain whether your answer to (a) is likely to be a close approximation to life expectancy at birth in the United Kingdom in 1975. [1]
The following table gives 2020 data for some African countries.

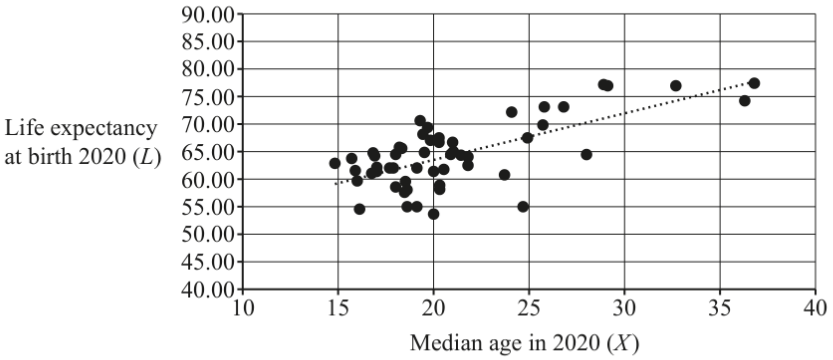
Country	Median age	Life expectancy at birth 2020
Nigeria	18.6	55.02
Rwanda	19.7	69.33
Saint Helena, Ascension and Tristan da Cunha	43.2	#N/A
Sao Tome and Principe	19.3	70.58
Senegal	19.4	68.21

(d) Explain how the table should be cleaned before it is included in a scatter diagram of life expectancy against median age for African countries. [1]
Fig. 10.2 is a scatter diagram for the cleaned data and has product moment correlation coefficient 0.680.

age in 2020 for the countries in Africa. It also shows a line of best fit.

The product moment correlation coefficient for these data is 0.680.

Fig. 10.2



(e) A student decides to use the line of best fit to estimate the life expectancy at birth in 2020 for Saint Helena, Ascension and Tristan da Cunha.

(e) A student uses the line of best fit to estimate the 2020 life expectancy for Saint Helena, Ascension and Tristan da Cunha. Explain whether this estimate is likely to be reliable. [1]

Model solution

Substitute the required year into the given linear model.

$$L = 0.275(1975) - 490 = 53.125.$$

(a) 53.125 *years.* *(1)*

1975 is within the period represented by the data, so this is interpolation; the plotted points are approximately linear.

(b) It is likely to be close to the true value. *(1)*

The model is specifically for Sudan. The pre-release data show that life expectancy in the United Kingdom is generally higher than in Sudan, so a Sudan estimate should not be transferred to the UK.

(c) No; it is not likely to be close for the United Kingdom. *(1)*

A scatter point needs both numerical coordinates. The row containing a non-numerical life expectancy cannot be plotted.

(d) Remove the row for Saint Helena, Ascension and Tristan da Cunha. *(1)*

Its median age, 43.2*, is outside the plotted data range, so using the line is extrapolation. Also* $r = 0.680$ *is not close to* 1*, so the linear fit is not especially strong.*

(e) The estimate is not reliable. *(1)*

Question 11

Question 11

Apples are sold in packets of 4. Ling and Sam record the number x of bruised apples in each packet and the frequency f.

Ling, Table 11.1

x	0	1	2	3	4
f	19	2	0	2	2

Sam, Table 11.2

x	0	1	2	3	4
f	39	1	0	3	7

(a) Explain why Sam's diagram is likely to be a better representation of the true distribution than Ling's. [1]

(b) Calculate the mean number of bruised apples per packet for Sam's data. [1]

Sam models bruising with a binomial distribution.

(c) Use (b) to calculate p, the probability that a randomly selected apple is bruised, for Sam's model. [1]

(d) Calculate the theoretical frequency distribution of bruised apples per packet for Sam's model, to 2 decimal places. [3]

(e) Comment on whether Sam's model appears to be a good fit. [1]

Model solution

A larger random sample is generally more representative because chance variation has less effect. Sam sampled 50 packets, compared with Ling's 25.

(a) Sam used the larger sample. **(1)**

Use the frequency-weighted mean.

$$\bar{x} = \frac{0(39) + 1(1) + 2(0) + 3(3) + 4(7)}{50} = \frac{38}{50} = 0.76.$$

(b) 0.76 bruised apples per packet. **(1)**

For $X \sim \mathrm{B}(4, p)$, the mean is $4p$. Equate this to the observed mean.

$$4p = 0.76 \quad \Longrightarrow \quad p = 0.19.$$

(c) $p = 0.19$. **(1)**

With $X \sim \mathrm{B}(4, 0.19)$, calculate $P(X = x) = \binom{4}{x}(0.19)^x(0.81)^{4-x}$, then multiply each probability by 50 packets.

x	0	1	2	3	4
$50P(X = x)$	21.52	20.19	7.11	1.11	0.07

(d) The theoretical frequencies are $21.52, 20.19, 7.11, 1.11, 0.07$ for $x = 0, 1, 2, 3, 4$ respectively. **(3)**

For example, the observed frequency at $x = 4$ is 7, whereas the model predicts only 0.07; the distributions differ substantially.

(e) It is a very poor fit. **(1)**

Question 12

Question 12

In this question you must show detailed reasoning.
Solve $3\sec^2\theta + 2\tan\theta - 4 = 0$ for $-180° \leq \theta \leq 180°$. [6]

Model solution

The equation contains $\sec^2\theta$ *and* $\tan\theta$. *Use* $\sec^2\theta = 1 + \tan^2\theta$ *to make a quadratic in* $\tan\theta$.

$$3(1 + \tan^2\theta) + 2\tan\theta - 4 = 0,$$

$$3\tan^2\theta + 2\tan\theta - 1 = 0,$$

$$(3\tan\theta - 1)(\tan\theta + 1) = 0.$$

$$\tan\theta = \frac{1}{3} \quad \textit{or} \quad \tan\theta = -1.$$

For $\tan\theta = -1$, *the reference angle is* $45°$, *giving* $-45°$ *and* $135°$ *in the stated interval. For* $\tan\theta = \frac{1}{3}$, *the principal angle is* $18.435\ldots°$; *tangent has period* $180°$.

$$\theta = 18.435\ldots°, \qquad 18.435\ldots° - 180° = -161.565\ldots°.$$

$\theta = -161.565\ldots°, -45°, 18.435\ldots°, 135°.$ ***(6)***

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Question 13

Question 13

In 2022, the proportion of people in England and Wales aged 16 or over who were married or in a civil partnership was 0.494. In 2024, a researcher takes a random sample of 78 such people and tests, at the 1% level, whether the proportion is lower.

(a) State the hypotheses, defining the parameter. [2]

(b) Determine the critical region. [3]

In the sample, 26 people were married or in a civil partnership.

(c) Carry out the hypothesis test. [3]

(d) State the probability that the null hypothesis is incorrectly rejected. [1]

Model solution

Let p be the population proportion of people aged 16 or over in England and Wales who are married or in a civil partnership. The wording "lower" makes this a lower-tailed test.

$$H_0 : p = 0.494, \qquad H_1 : p < 0.494.$$

(a) $H_0 : p = 0.494$, $H_1 : p < 0.494$, *with p as defined above.* *(2)*

Under H_0, the count X in a sample of 78 has $X \sim \mathrm{B}(78, 0.494)$. Find the largest lower-tail value whose probability is at most 0.01.

$$P(X \leq 27) = 0.005946\ldots < 0.01, \qquad P(X \leq 28) = 0.011\ldots > 0.01.$$

(b) Critical region: $X \leq 27$. *(3)*

The observed value 26 lies in the critical region.

(c) Reject H_0. There is sufficient evidence at the 1% level to suggest that the proportion is lower in 2024 than in 2022. *(3)*

The significance level is the maximum probability of a Type I error.

(d) 0.01. *(1)*

Question 14

Question 14

The equation of a curve is $y = \frac{16}{x^2} + \frac{3}{x}$.

(a) Determine the point where the curve cuts the x-axis. [2]

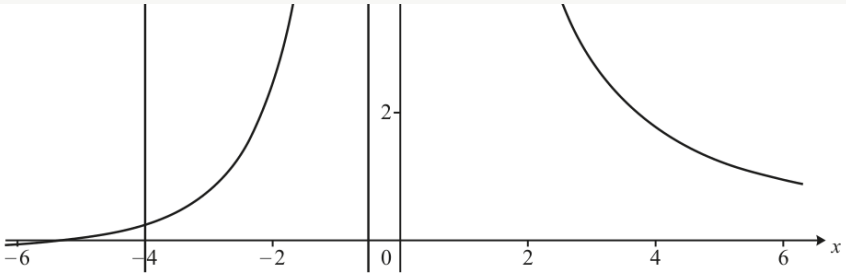
(b) (i) Find $\frac{dy}{dx}$. [2]

(ii) Hence determine the exact coordinates of the stationary point. [2]

(c) (i) Find $\frac{d^2y}{dx^2}$. [2]

(ii) Hence determine the values of x for which the curve is concave downwards. [2]

The diagram shows parts of the curve, the line $x = -4$, and the line $x = -\frac{1}{2}$.



(d) Determine the exact area bounded by the curve $y = \frac{16}{x^2} + \frac{3}{x}$, the x-axis and the lines $x = -4$ and $x = -\frac{1}{2}$. Give your answer in the form $a + b\ln 2$, where a and b are constants to be determined. **[5]**

(d) Determine the exact area bounded by the curve, the x-axis, and these two lines. Give your answer as $a + b\ln 2$. [5]

Model solution

At an x-intercept, $y = 0$. Multiplying by x^2 clears the fractions.

$$16 + 3x = 0 \quad \Longrightarrow \quad x = -\frac{16}{3}.$$

(a) $\left(-\frac{16}{3}, 0\right)$. *(2)*

Write the terms as powers of x, then use the power rule.

$$y = 16x^{-2} + 3x^{-1}, \qquad \frac{dy}{dx} = -32x^{-3} - 3x^{-2}.$$

(b)(i) $\frac{dy}{dx} = -\frac{32}{x^3} - \frac{3}{x^2}$. *(2)*

A stationary point has derivative zero.

$$-\frac{32}{x^3} - \frac{3}{x^2} = 0 \quad \Longrightarrow \quad -32 - 3x = 0 \quad \Longrightarrow \quad x = -\frac{32}{3}.$$

$$y = \frac{16}{(-32/3)^2} + \frac{3}{-32/3} = \frac{9}{64} - \frac{9}{32} = -\frac{9}{64}.$$

(b)(ii) $\left(-\frac{32}{3}, -\frac{9}{64}\right)$. *(2)*

Differentiate the first derivative once more.

$$\frac{d^2y}{dx^2} = 96x^{-4} + 6x^{-3} = \frac{96}{x^4} + \frac{6}{x^3}.$$

(c)(i) $\dfrac{d^2y}{dx^2} = \dfrac{96}{x^4} + \dfrac{6}{x^3}.$ **(2)**

Concave down means the second derivative is negative. Since $x^4 > 0$ for $x \neq 0$, multiply by x^4 without changing the inequality.

$$96 + 6x < 0 \quad \Longrightarrow \quad x < -16.$$

(c)(ii) $x < -16.$ **(2)**

The curve is above the x-axis between -4 and $-\frac{1}{2}$, so the area is the positive definite integral. An antiderivative is $-\frac{16}{x} + 3\ln|x|$.

$$\textbf{Area} = \left[-\frac{16}{x} + 3\ln|x|\right]_{-4}^{-1/2} = (32 - 3\ln 2) - (4 + 6\ln 2) = 28 - 9\ln 2.$$

(d) $28 - 9\ln 2.$ **(5)**

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Question 15

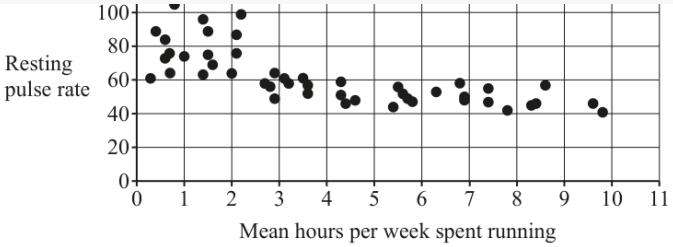
Question 15

A personal trainer investigates association between resting pulse rate (beats per minute) and mean hours per week spent running. In one week he asks 25 of his clients.

(a) (i) State the sampling technique. [1]

(ii) Explain why it may introduce bias. [1]

A biologist takes a random sample of 47, shown in the scatter diagram.



(b) Describe the association between resting pulse rate and mean hours per week spent running. **[1]**

(c) The biologist identifies two distinct regions on the scatter diagram. Identify these regions on the copy of the scatter diagram in the **Printed Answer Booklet** by drawing an appropriate **vertical** line between them. **[1]**

According to medical research, the normal resting pulse rate for an adult is between 60 and 110 beats per minute.

The biologist separates the data into a group to the left of the vertical line on the scatter diagram and a group to the right of the vertical line on the scatter diagram. She calculates Spearman's rank

(b) Describe the association. [1]

(c) Identify the two distinct regions by drawing a suitable vertical line between them. [1]

Normal adult resting pulse rate is between 60 and 110 beats per minute. After separating at the vertical line, the biologist obtains:

Group	r_s	p-value
Left of vertical line	0.20936	0.41998
Right of vertical line	−0.61349	0.00031

(d) With reference to both groups and the table, explain what may be inferred about the association. [6]

Model solution

The trainer selected people who were readily available to him: his own clients.

(a)(i) Opportunity (or convenience) sampling. (1)

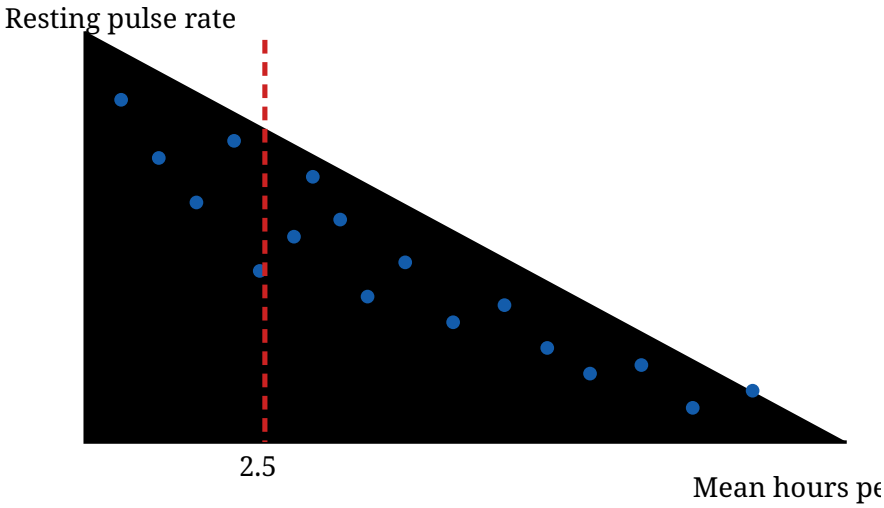
Clients of a personal trainer are likely to be fitter or to run more than the general population, so they need not be representative.

(a)(ii) The sample may be biased because it consists only of his clients. (1)

The overall downward trend means that larger running times tend to be paired with lower pulse rates.

(b) Negative association. *(1)*

The visible clusters separate at approximately 2.5 mean hours per week.



(c) Draw one vertical line at about $x = 2.5$. *(1)*

For the left group, $r_s = 0.20936$ is close to zero and the p-value 0.41998 is not small, so there is insufficient evidence of association. For the right group, $r_s = -0.61349$ is substantially closer to -1 than to zero and the p-value 0.00031 is very small.

(d) Left group: insufficient evidence of an association. Right group: sufficient evidence of a negative association between running time and resting pulse rate. *(6)*

Question 16

Question 16

In this question you must show detailed reasoning.
The population of puffins on a remote island is initially estimated to be $P = 58.5$, where P is measured in thousands. Following an oil spill it is modelled by

$$\frac{dP}{dt} = (72t - 108)e^{-0.8t},$$

where t is time in years after the incident.
(a) Determine P in terms of t. [7]
(b) Determine whether the model predicts that P recovers to 58.5. You may assume $\lim_{t\to\infty} e^{-0.8t} = 0$. [2]

Model solution

Integrate the rate of change with respect to time. Integration by parts is needed for the $te^{-0.8t}$ term.

$$P = \int (72t - 108)e^{-0.8t}\, dt.$$

$$\int 72te^{-0.8t}\, dt = 72\left(\frac{te^{-0.8t}}{-0.8} - \int \frac{e^{-0.8t}}{-0.8}\, dt\right) = -90te^{-0.8t} - 112.5e^{-0.8t}.$$

$$\int -108e^{-0.8t}\, dt = 135e^{-0.8t}.$$

$$P = -90te^{-0.8t} + 22.5e^{-0.8t} + c.$$

Use the initial condition $P = 58.5$ at $t = 0$ to determine the constant.

$$58.5 = 22.5 + c \quad \Longrightarrow \quad c = 36.$$

(a) $P = 36 + 22.5e^{-0.8t} - 90te^{-0.8t}$, in thousands of puffins. *(7)*

As $t \to \infty$, both $22.5e^{-0.8t}$ and $90te^{-0.8t}$ tend to zero.

$$P \to 36.$$

(b) No. The model approaches 36 thousand puffins, not 58.5 thousand. *(2)*

Question 17

Question 17

In this question you must show detailed reasoning.
Jars of honey have nominal mass 340 grams. The actual mass X grams is Normally distributed with mean 350 grams. A random sample of 50 jars gives

$$\sum x = 17367, \qquad \sum x^2 = 6036597, \qquad n = 50.$$

Carry out a hypothesis test at the 1% level to test whether there is evidence that the mean mass is less than 350 grams. [9]

Model solution

First calculate the sample mean and unbiased sample variance. The population variance is unknown, so the sample variance is used to model the sampling distribution of $\bar{X}$.

$$\bar{x} = \frac{17367}{50} = 347.34,$$

$$s^2 = \frac{6036597 - 50(347.34)^2}{49} = 88.637\ldots, \qquad s = 9.4147\ldots.$$

Let μ be the population mean mass of honey in a jar. The alternative is lower-tailed.

$$H_0 : \mu = 350, \qquad H_1 : \mu < 350.$$

Under H_0, the sampling distribution is approximately

$$\bar{X} \sim N\left(350, \frac{88.637\ldots}{50}\right).$$

Calculate the lower-tail probability of the observed sample mean.

$$P(\bar{X} < 347.34) = 0.02287\ldots \approx 0.023.$$

This is greater than 0.01, so the result is not significant at the 1% level.

Do not reject H_0. There is insufficient evidence at the 1% level to suggest that the mean mass of honey in a jar is less than 350 grams. **(9)**