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**Examiners' report**

# MATHEMATICS B (MEI)

**H630**

For first teaching in 2017

## H630/01 Summer 2024 series

Version 1

# Contents

# Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates.

The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. A selection of candidate answers is also provided. The reports will also explain aspects that caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report.

A full copy of the question paper and the mark scheme can be downloaded from OCR.

# Paper 1 series overview

This paper was seen to be accessible to most candidates and some very good responses were given. Most candidates were able to complete the paper in the time allowed.

The modelling questions proved the most challenging, especially for candidates in the lowest quartile and a surprising number of students struggled with the first question. Questions about polynomials were more accessible to everyone.

In questions that didn't require detailed reasoning, some candidates seemed reluctant to use their calculator to solve simultaneous and quadratic equations. Others lost accuracy marks through making errors in their algebra.

| **Candidates who did well on this paper generally:** | **Candidates who did less well on this paper generally:** |
|---|---|
| • structured their work in a way that the examiner could follow<br>• used their calculator sensibly<br>• were able to compare the outcomes of a mathematical model with reality<br>• completed a mathematical argument with conclusions in words. | • made errors in routine algebra and arithmetic, which were not corrected<br>• did not demonstrate an understanding of mathematical modelling<br>• struggled with the problem-solving aspect of some questions<br>• did not complete an argument from the evidence they had found in their working. |

## Question 1

**1** The triangle ABC has an obtuse angle at A. The angle at B is $15°$. The length of AC is $10\,\text{cm}$ and the length of BC is $13\,\text{cm}$.

Calculate the size of the angle at A. **[2]**

Most candidates realised that the sine rule was the appropriate method here, but many just gave the acute angle that their calculator gave them even though the question stated that the angle was obtuse. Some tried to 'correct' this by adding 90°, however this does not give the correct angle.

**Misconception**

?

Many candidates were not able to find the obtuse angle from its sine. It is worth highlighting that solving an equation of the form $\sin A = k$ and $A = \sin^{-1} k$ is not equivalent.

## Question 2

**2** Two forces $\mathbf{F}_1$ N and $\mathbf{F}_2$ N are given by $\mathbf{F}_1 = -6\mathbf{i} + 2\mathbf{j}$ and $\mathbf{F}_2 = -8\mathbf{i} + \mathbf{j}$.

Show that the magnitude of the resultant of these two forces is $\sqrt{205}\,\text{N}$. **[2]**

Most candidates evaluated the resultant force as $-14\mathbf{i} + 3\mathbf{j}$ and attempted to find the magnitude of that. As the response was given, the marking was very strict on correct notation and $-14^2 + 3^2 = 205$ was not sufficient for the A mark.

**Misconception**

?

Some candidates found the magnitude of each of the vectors separately and added their responses; this does not give the magnitude of the resultant force.

## Question 3

**3** Prove that, when $n$ is an even number, $n^3 + 4$ is a multiple of 4 but not a multiple of 8. **[3]**

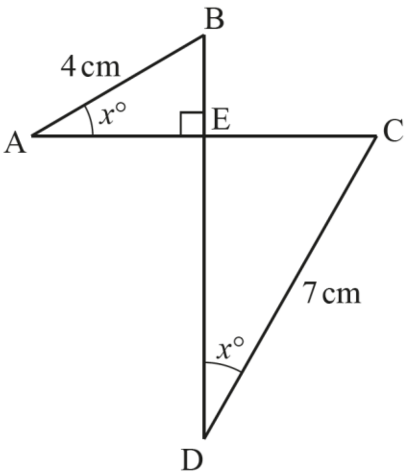
Many good proofs were seen from candidates who used $n = 2k$ where $k$ is an integer and most factorised to show that the resulting expression was a multiple of 4. Some attempts to explain why it would not be a multiple of 8 were however too vague to be given the final mark. No marks were given for trying out specific values.

**Assessment for learning**

To prove a statement about an infinite set on numbers, it is not sufficient to substitute values and comment on the values obtained. A general explanation in words or an algebraic proof is expected.

## Question 4

4 The perpendicular lines AC and BD intersect at E as shown in the diagram. The point E is the midpoint of AC. The angles BAC and BDC are each equal to $x°$. The lengths of AB and CD are 4 cm and 7 cm respectively.




Determine the value of $x$. **[4]**

This question was not well answered, although candidates should have been familiar with the techniques needed to answer the question. Candidates who were clear about which lengths they were finding in terms of *x* and equated AE and ED were mostly successful. Some candidates reached 4 cos*x* = 7 sin*x* and then could then not finish the question. Some candidates realised that the triangles were similar and identified the scale factor, but few were able to use this successfully to evaluate *x*. A number of candidates used the sine rule or the cosine rule unnecessarily in the right-angled triangles.

## Question 5 (a)

5 **In this question you must show detailed reasoning.**

**(a)** Show that the gradient of the curve $y = \sqrt{x}\left(\frac{1}{x^2} - 2x\right)$ at the point $\left(\frac{1}{4}, \frac{31}{4}\right)$ is $-\frac{99}{2}$. **[4]**

This question was well answered and most candidates had a good understanding of how to differentiate negative and fractional powers. The most common error was to multiply powers instead of adding when removing the brackets from the expression $x^{\frac{1}{2}}(x^{-2} - 2x)$, however those obtaining $x^{-1} - 2x^{\frac{1}{2}}$ were still able to get 2 marks for differentiating their expression and substituting $x = \frac{1}{4}$ into the result.

## Question 5 (b)

**(b)** Find the equation of the tangent to the curve at $\left(\frac{1}{4}, \frac{31}{4}\right)$ giving your answer in the form $ax + by + c = 0$, where $a$, $b$ and $c$ are integers. **[2]**

Many candidates used the given response to find the equation of the tangent successfully, although some didn't convert it into the requested form or struggled to clear the fractions accurately. The most common error was using the negative reciprocal of the given gradient to find the normal instead; this received no credit.

## Question 6 (a)

**6** The polynomial $x^3 - 4x^2 + 10x - 21$ is denoted by $f(x)$.

**(a)** Use the factor theorem to show that $(x - 3)$ is a factor of $f(x)$. **[2]**

Most candidates used the method required and evaluated f(3) = 0. For full marks candidates needed to go on and state that meant ($x$ – 3) was a factor. Nothing was given here for algebraic division (even if the zero remainder was clear), but if done then the work was credited in part (b), even if it wasn't repeated there.

**Assessment for learning**

When a question specifies a method, it is likely that no marks will be given for using an alternative method, even if it is correct. In requesting a method, the examiners are testing a specific point in the specification.

## Question 6 (b)

**(b)** The polynomial $f(x)$ can be written as $(x - 3)(x^2 + bx + c)$ where $b$ and $c$ are constants.

Find the values of $b$ and $c$. **[2]**

Many fully correct responses were seen using either long division or a table method. It is easier to follow a table method when at least two lines are drawn into the working to help examiners follow the thinking.

## Question 6 (c)

**(c)** Show that $x = 3$ is the only real root of the equation $f(x) = 0$. **[2]**

This is a 'Show that…' question, but the mark scheme is quite generous to candidates who did not write explicitly that $x$ = 3 comes from the linear factor and that other roots would have to come from $x^2 - x + 7 = 0$. Most realised that the discriminant of this equation would indicate the existence of other roots, but some candidates did not write that their discriminant was negative and lost a mark for the conclusion. Candidates who attempted to solve the quadratic equation using their calculator could obtain full marks if they commented that the roots were not real (or complex).

## Question 7 (a)

**7** The velocity of a particle moving in a straight line is modelled by $v = 0.6t^2 - 2.1t + 1.5$ where $v$ is the velocity in metres per second and $t$ is the time in seconds.

**(a)** Determine the times at which the particle is stationary. **[2]**

Most candidates answered this successfully. Some differentiated the expression for $v$ before setting it equal to zero and this was given no marks.

### Exemplar 1

| | |
|---|---|
| **7(a)** | $\cancel{\frac{dv}{dt} = 1.2t - 2.1 = 0}$ |
| | $\cancel{1.2t = 2.1}$ |
| | $\cancel{t = 1.75}$ |
| | $2.1^2 = 4.41$ |
| | $0 = 0.6t^2 - 2.1t + 1.5$     $3.6$ |
| | $\frac{-(-2.1) \pm \sqrt{(-2.1^2) - 4(1.5 \times 0.6)}}{1.2} = t$ |
| | $t = \frac{2.1 + \sqrt{0.81}}{1.2} = 2.5$   $t = \frac{2.1 - \sqrt{0.81}}{1.2} = 1$ |

Exemplar 1's crossed out work shows the most common error. It also shows how much time could have been potentially saved by solving this equation using a calculator.

## Question 7 (b)

**(b)** Find the acceleration of the particle at the first of the times at which it is stationary. **[2]**

This was very well answered. Some candidates gave the acceleration at both times, but no marks were deducted for that.

## Question 7 (c)

**(c)** Find the distance travelled by the particle between the times at which it is stationary. **[2]**

Most candidates realised that integration was needed. The definite integral gives a negative answer, which is not correct for the distance. Some candidates recognised that the distance should not be negative and just crossed out the negative sign, meaning their response did not follow from their working. Others found two displacements and subtracted the smaller from the larger, which gained full credit.

**Misconception**

?

The quadratic expression for *v* indicates that the acceleration is not constant, so it is not appropriate to use the *suvat* equations to calculate displacement.

## Question 8 (a)

**8** A circle with centre C has equation $x^2 + y^2 - 6x - 16y + 48 = 0$.

**(a)** Find the coordinates of C. **[2]**

This is a very standard question that most candidates were able to do well. There were some errors with signs.

## Question 8 (b)

A line has equation $y = x - 2$ and intersects the circle at the points A and B. The midpoints of AC and BC are $A'$ and $B'$ respectively.

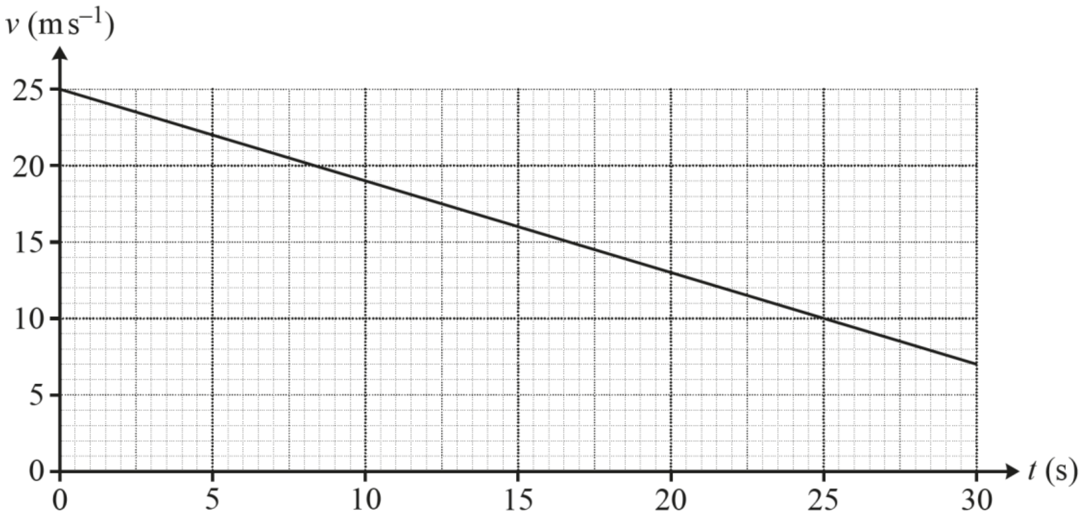
**(b)** Determine the exact distance $A'B'$. **[8]**

There were many fully correct responses to this question with well-structured thinking on display. Substituting for *y* in the equation of the circle gave a quadratic with integer roots, however many responses were marred by slips in the algebra and arithmetic making the question much harder than it ought to have been. There was little evidence that candidates had a strategy to check their work before moving on to the later part of the question. Of those that found the points of intersection, some lost their way at this point, however several different methods were used successfully by others.

## Question 9 (a)

**9** Two trains are travelling in the same direction on parallel straight tracks and train A overtakes train B. At time $t$ seconds after the front of train A overtakes the front of train B the velocities of trains A and B are $v_A \mathrm{~m~s^{-1}}$ and $v_B \mathrm{~m~s^{-1}}$ respectively.

The velocity of train A is modelled by $v_A = 25 - 0.6t$. The velocity-time graph of train A is shown below.




**(a)** A student argues that the speed of train A changes by $18 \mathrm{~m~s^{-1}}$ in 30 seconds so its acceleration is $0.6 \mathrm{~m~s^{-2}}$.

Comment on the validity of the student's argument. **[1]**

Candidates found this question difficult and many just commented about acceleration rather than answering the question. A minority thought the argument was valid, not recognising the significance of the decrease in velocity.

## Exemplar 2

**9(a)** Here

$V_A = 25 - 0.6t$

$v = u + at$

$7 = 25 + a \times 30$

$7 - 25 = 30a$

$-18 = 30a$

$a = -0.6\ ms^{-2}$

The speed of train A goes from $25\ ms^{-1}$ to $7\ ms^{-1}$ which give us the difference of $18\ ms^{-1}$

This exemplar shows good work calculating the acceleration, but the comment does not address the validity of the given argument and so received no marks.

## Question 9 (b)

**(b)** When the front of train A overtakes the front of train B, train B has a velocity of $10\,\mathrm{m\,s^{-1}}$. The acceleration of train B is constant and is modelled as $0.15\,\mathrm{m\,s^{-2}}$.

Write down the equation for $v_B$ in terms of $t$ that models the velocity of train B. **[1]**

A significant number of candidates mixed up the signs here and wrote $v = 10 - 0.15t$ (similar to the given equation for the other train); follow through marks were available in the subsequent parts for this error. It was pleasing to see that almost every candidate had a full equation beginning $v_B = \ldots$.

## Question 9 (c)

**(c)** Draw the velocity-time graph of train B on the copy of the diagram in the Printed Answer Booklet. **[1]**

This was generally well answered, with candidates following through their equation from part (b).

## Question 9 (d)

**(d)** Determine the distance between the fronts of the trains at the time when the trains are travelling at the same velocity. **[3]**

Where candidates had reasonable graphs, they were generally able to find the time at which the trains had the same velocity. For those incorrectly using $v = 10 - 1.5t$, the point of intersection of the lines was beyond the axes of the given graph, which perhaps should have alerted them to their previous error. Most could use *suvat* equations to calculate distances leading to a correct response. Few realised that the simplest method was to calculate the area between the lines on the graph.

## Question 9 (e)

**(e)** Explain why the model for train A would not be valid for large values of $t$. **[1]**

Many candidates recognised that the velocity would be negative, but didn't relate this in the context that the train would be travelling backwards. They needed to explain why a negative velocity caused a discrepancy with the reality for trains travelling in the same direction.

## Question 10 (a)

**10** A boat pulls a water skier of mass 65 kg with a light inextensible horizontal towrope. The mass of the boat is 985 kg. There is a driving force of 2400 N acting on the boat. There are horizontal resistances to motion of 400 N and 1200 N acting on the skier and the boat respectively.

**(a)** Draw a diagram showing all the horizontal forces acting on the skier and the boat. **[2]**

There were many fully correct responses here, but often the tension was omitted. Another common error was to attach the resistances or the driving force to the wrong object in the diagram. All vertical forces were ignored in responses, so full marks were given where the weight was incorrect or where the upward vertical forces were not included with the weight.

### Assessment for learning

The ability to draw an accurate force diagram is an indicator that candidates understand how forces work. Time spent understanding which forces act on which body is key to understanding the motion of connected particles.

The tension is specifically mentioned later in the question, but for some candidates that had missed it from their force diagram, it did not prompt them to go back and put it into their diagram.

## Question 10 (b) (i) and (ii)

**(b)** **(i)** Write down the equation of motion of the skier. **[1]**

**(ii)** Find the equation of motion of the boat. **[2]**

This question specifically tests understanding of the phrase 'equation of motion', which in this case comes from Newton's second law for each object separately. A few candidates tried to write an equation linking velocity and acceleration when these were not mentioned in the question. It is set as part (i) and part (ii) to avoid making a double request and to emphasise that two separate equations are required.

No marks were given to equations that used weight in the place of mass.

## Question 10 (c)

**(c)** Find the acceleration of the skier and the boat. **[1]**

This was well done by most candidates who had correct equations in part (b) by adding the equations. Some candidates started again by treating the boat and skier as a single object, which is also an acceptable method.

## Question 10 (d)

The driving force of the boat is increased. The skier can only hold on to the towrope when the tension is no greater than her weight.

**(d)** Determine her greatest acceleration, assuming that the resistances to motion stay the same. **[2]**

The key to this was to realise that the tension needs to be greater to produce a bigger acceleration, so the maximum occurs when the tension has the same magnitude as the weight.

## Question 11 (a)

**11** A student records the time a pendulum takes to swing for different lengths of pendulum.

The student decides to plot a graph of $\log_{10} T$ against $\log_{10} l$ where $T$ is the time in seconds that the pendulum takes to return to its start position and $l$ is the length in metres of the pendulum. They use a model for $\log_{10} T$ in terms of $\log_{10} l$ of the form $\log_{10} T = \log_{10} k + n\log_{10} l$.

The student records the following data points.

| | | |
|---|---|---|
| $\log_{10} l$ | –0.097 | 0.146 |
| $\log_{10} T$ | 0.254 | 0.376 |

**(a)** Determine the values of $k$ and $n$ that best model the data. Give your values correct to **2** significant figures. **[4]**

This question proved quite difficult for many candidates, who did not appreciate that the values given in the table were the logs of *l* and *T*. Some used the logs of the given numbers instead. Of those using the data correctly, some calculated the gradient and intercept, but the question was more successfully done by setting up and solving simultaneous equations for *n* and log *k* (some of these however did not go on to use their value for log *k* to give a value for *k*). Many candidates did not attempt this question.

## Question 11 (b)

**(b)** Using these values of $k$ and $n$, write the student's model as an equation expressing $T$ in terms of $l$. **[2]**

This question is the reverse of a more standard reduction to linear form question and the responses suggested many candidates had not thought about rearranging this way round.

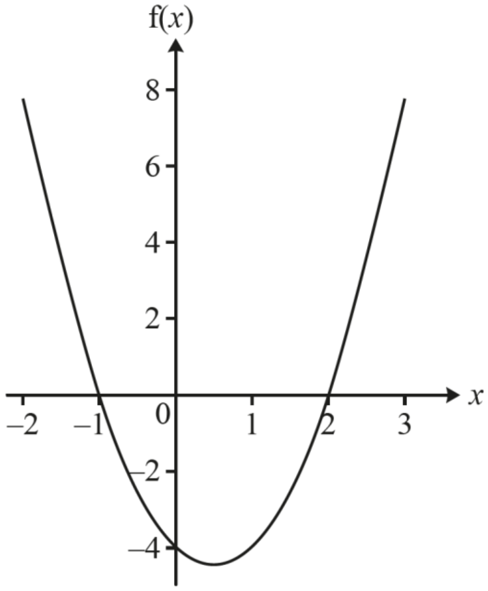
### Exemplar 3

| | |
|---|---|
| **11(b)** | $\log_{10} T = \log_{10} 2.0 + 0.5\log_{10} l$ |
| | $\log_{10} l^{0.5}$ |
| | |
| | $T = 2.0 + l^{0.5}$ |

It was common to see the law of logs for powers used correctly, but the rule for products was often forgotten. Both rules were needed to obtain the method mark here.

## Question 12 (a)

**12** The diagram shows the graph of $\mathrm{f}(x) = k(x-p)(x-q)$ where $k$, $p$ and $q$ are constants. The graph passes through the points $(-1, 0)$, $(0, -4)$ and $(2, 0)$.




**(a)** Find $\mathrm{f}(x)$ in the form $ax^2 + bx + c$. **[3]**

Most responses included the factors $(x + 1)(x - 2)$ and some candidates did not realise that this gives a different *y*-intercept. Some candidates then tried to add or subtract terms to give the intercept and then lost the factors. Sometimes the expression was not written in the correct form so the final mark was lost.

## Question 12 (b)

A cubic curve has gradient function $\mathrm{f}(x)$. This cubic curve passes through the point $(0, 8)$.

**(b)** Find the equation of the cubic curve. **[4]**

Most candidates realised they needed to integrate their expression for the $\mathrm{f}(x)$. Follow through marks were given if there had been an error in part (a). Some candidates did not use the given information that the curve passes through $(0, 8)$, missing out on the second 2 marks.

**Assessment for learning**

It is important to understand the difference between an expression and an equation. If '$y$ =' is missing here, it is not an equation and will not get full marks.

## Question 12 (c)

**(c)** Determine the coordinates of the stationary points of the cubic curve. **[3]**

Most candidates knew that the stationary points occur when the gradient function is zero, but some unnecessarily differentiated their expression for *y*, giving extra scope for errors. Some candidates struggled with the fractions when evaluating the *y*-coordinates.

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