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Examiners' report

MATHEMATICS B (MEI)

H640

For first teaching in 2017

H640/01 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 which 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

The paper was accessible to all candidates. Those candidates with the most successful responses were able to secure very high marks – and many did – demonstrating its accessibility. The more challenging items were Question 5 (b), Question 7 (b), Question 9 (b), Question 14 (a) and Question 16.

The paper gave most candidates sufficient time to fully answer all the questions, although there was evidence of possibly rushed responses at the end of the paper.

Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
• had good algebraic skills and correct use of arithmetic • wrote a few words to convey their method to the examiner • had a sound grasp of the mathematical concepts being examined • were able to draw on techniques from one topic to help problem solving.	• made errors in the arithmetic and algebraic manipulation which were not corrected • did not complete the mathematical argument even when the evidence needed had been found • did not write their responses in a way that the examiner could easily recognise what they were trying to do • showed evidence of misconceptions and an insecure understanding of some of the topics.

Section A overview

The questions in Section A are designed to be fairly routine procedural and require little reading or understanding of contexts. However, the solutions are not always simple, for example Question 6 requires careful and accurate algebra to establish a gradient function from first principles.

Question 1

1 A student states that $1+x^2 < (1+x)^2$ for all values of x.

Using a counter example, show that the student is wrong. **[2]**

Most candidates were successful in finding a zero or negative counterexample. A small number of candidates solved the algebraic inequality to help them find their value. Some candidates lost marks for an incomplete response.

Key point: complete the argument

It is not enough to work out both values for $1 + x^2$ and $(1 + x)^2$ without making an explicit comparison between them. There has to be evidence that the candidate realises their value is a counterexample.

Question 2 (a)

2 A car of mass 1400 kg pulls a trailer of mass 400 kg along a straight horizontal road. The engine of the car produces a driving force of 6000 N. A resistance of 800 N acts on the car. A resistance of 300 N acts on the trailer. The tow-bar between the car and the trailer is light and horizontal.

(a) Draw a force diagram showing all the horizontal forces on the car and the trailer. **[2]**

Many fully correct diagrams were seen. The most common error was to omit the tension in the towbar, despite the detail in the question about the towbar. A few candidates did not correctly attach the resistances to the individual parts of the system and so lost a mark.

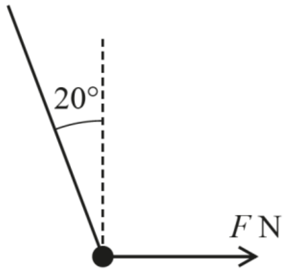
Question 2 (b)

(b) Calculate the acceleration of the car and trailer. **[3]**

A lot of correct responses were seen both from treating the whole system as a single object with a total mass of 1800kg and by combining separate equations of motion for the two parts separately. No marks were given for solutions which used weight in the place of mass in the Newton's second law equation.

Question 3 (a)

3 A particle hangs at the end of a string. A horizontal force of magnitude F N acting on the particle holds it in equilibrium so that the string makes an angle of 20° with the vertical, as shown in the diagram. The tension in the string is 12 N.



(a) Find the value of F. **[2]**

This is a straightforward question requiring candidates to resolve the tension horizontally. Most candidates were successful although some had their calculator set to radians and some interchanged $\sin 20$ for $\cos 20$.

Question 3 (b)

(b) Find the mass of the particle. **[3]**

Most candidates were able to calculate the weight and then find the mass of the particle. A small proportion of candidates applied a triangle of force method, with the majority of these successful.

Question 4

4 The vectors $\mathbf{v}_1$ and $\mathbf{v}_2$ are defined by $\mathbf{v}_1 = 2a\mathbf{i} + b\mathbf{j}$ and $\mathbf{v}_2 = b\mathbf{i} - 3\mathbf{j}$ where a and b are constants.

Given that $3\mathbf{v}_1 + \mathbf{v}_2 = 22\mathbf{i} - 9\mathbf{j}$, find the values of a and b. **[4]**

Most candidates were able to manipulate the vectors and separate the components to find equations for a and b. The most common error was to equate $3b - 3$ with 9 instead of -9.

Question 5 (a)

5 **(a)** Make y the subject of the formula $\log_{10}(y-k) = x\log_{10}2$, where k is a positive constant. **[2]**

It was clear that those candidates who were comfortable with the laws of logs readily came to a correct solution. However, , a variety of misconceptions about logarithms were seen. There was a lot of incorrect logarithmic work, such as equating $\log(y-k)$ to $\log y - \log k$ or $\log y / \log k$. Common wrong responses were $y = k \times 2^x$, $y = 2^x - k$, $y = 2 \times 10^x + k$, $y = 20^x + k$.

Question 5 (b)

(b) Sketch the graph of y against x. **[3]**

The shape of the exponential curve was usually correct, and the *y* intercept was often indicated correctly. Not very many showed a horizontal asymptote at $y = k$ perhaps suggesting that candidates thought that this showed a stretch of the graph of $y = 2^x$ but rather than a translation.

Question 6

6 Given that $f(x) = 2x^2 + 3$, show from first principles that $f'(x) = 4x$. **[4]**

Many fully correct solutions were seen showing that many candidates had a good understanding of the first principles method. Errors in algebraic manipulation spoiled some responses, in particular missing brackets led to mistakes or work that was not fully consistent. Sometimes candidates muddled $h \to 0$ and $h = 0$.

It was rare to see an expression for $f'(x)$ by using the rules for differentiation, possibly because the response was given in the question.

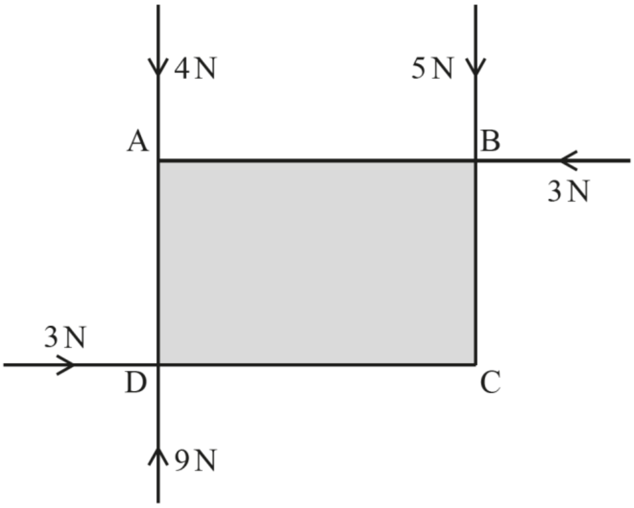
Section B overview

The questions in section B require more interpretation from the candidates. Many candidates found this accessible. The final two Mechanics questions were more challenging and some candidates did not grasp the problem solving steps needed for these questions.

Question 7 (a)

7 A rectangular book ABCD rests on a smooth horizontal table. The length of AB is 28 cm and the length of AD is 18 cm. The following five forces act on the book, as shown in the diagram.

- 4 N at A in the direction AD
- 5 N at B in the direction BC
- 3 N at B in the direction BA
- 9 N at D in the direction DA
- 3 N at D in the direction DC



(a) Show that the resultant of the forces acting on the book has zero magnitude. **[2]**

Many candidates were able to establish a zero force in two directions which was sufficient for both marks here. Some candidates did not indicate where their equations came from, or simply stated that $3 = 3$ and $4 + 5 = 9$. It was rare to see candidates adding all the forces irrespective of direction – this got no marks. Some candidates launched into moment calculations without properly reading the question.

Question 7 (b)

(b) Find the total moment of the forces about the centre of the book. Give your answer in N m. **[3]**

It was common to see 2/3 marks given here to candidates who did not give their response in the correct units, after working with forces in Newtons and distances in centimetres. Some candidates did not have the total of a complete list of moments about the centre and so were given 1 out of 3 marks. Some did not calculate correct moments at all.

Misconception

A moment must be the product of the magnitude of a force and the perpendicular distance to the line of action of the force. Using the length of the diagonal of the rectangle or multiplying forces by distances in the same direction does not give a moment.

Question 7 (c)

(c) Describe how the book will move under the action of these forces. **[2]**

Some candidates assumed the book would be in equilibrium as the resultant force was zero. Most realised that there would be movement, but needed to use a word that indicated a rotation as well as direction, so 'move clockwise' was given B0B1.

Question 8 (a)

8 The equation of a curve is $y = \sqrt{\sin 4x} + 2\cos 2x$, where x is in radians.

(a) Show that, for small values of x, $y \approx 2\sqrt{x} + 2 - 4x^2$. **[2]**

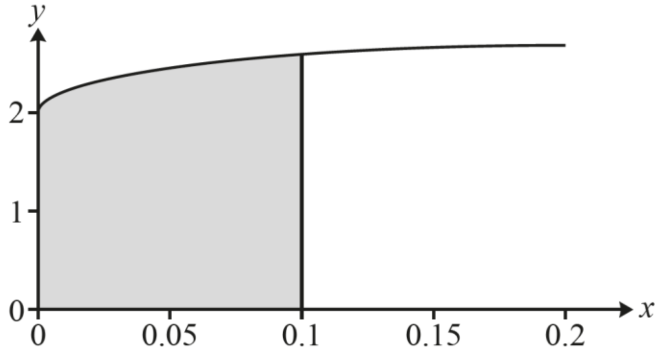
This question was sometimes answered well but often it was not clear how the coefficient of x^2 was obtained. Many responses could have been done by factorising the given response. It is important to show clearly the starting points and clear steps that lead to the given response.

Assessment for learning

When preparing candidates to answer 'show that…' questions, do not accept solutions which could have been obtained by working backwards. Here it is important to see $\sqrt{4x}$ which most candidates had, and evidence that the other terms arose from $1 - \frac{1}{2}(2x)^2$ as the approximation to $\cos 2x$. It is not enough to see $2(1 - 2x^2)$ which could have been obtained by factorising the given response. The fraction had to be seen explicitly for the method mark.

Question 8 (b)

The diagram shows the region bounded by the curve $y = \sqrt{\sin 4x} + 2\cos 2x$, the axes and the line $x = 0.1$.



(b) In this question you must show detailed reasoning.

Use the approximation in part **(a)** to estimate the area of this region. **[4]**

Many candidates were successful in setting up the definite integral and evaluating it accurately. It was rare to see candidates using anything other than the given response in part (a) to do this.

Most responses assumed that an approximation for an integral would be found using the trapezium rule but this was not necessary as the approximating function could be integrated exactly. Where one trapezium was used, a maximum of 2 marks was available, but a fully correct solution using two or more trapezia was given full credit.

Question 9 (a)

9 A child throws a pebble of mass 40 g vertically downwards with a speed of $6\,\text{m s}^{-1}$ from a point 0.8 m above a sandy beach.

(a) Calculate the speed at which the pebble hits the beach. **[2]**

Many candidates realised that the *suvat* equations should be used here. Common errors were made with signs where it had not been clearly established which direction was the positive direction.

Misconception

Some candidates used the weight of the pebble $0.04g$ as the acceleration, not realising that acceleration due to gravity is g irrespective of the mass of the object.

Question 9 (b)

The pebble travels 3 cm through the sand before coming to rest.

(b) Find the magnitude of the resistance force of the sand on the pebble, assuming it is constant. Give your answer correct to **3** significant figures. **[5]**

Many candidates realised that the link between the information and the magnitude of the force was the acceleration. The stopping distance is 3 cm and not 3 m so errors occurred because of this. Some candidates appear to have changed their work when the acceleration was very large (over 800 ms^{-2}). Omitting the weight in their Newton's second law equation was very common.

Misconception

Many candidates were able to find the acceleration and assumed that this value multiplied by the mass would give the resistance force to be found. Many did not realise that this was the resultant force of the resistance and the weight. The weight is quite small compared to the resistance, so the mistake made only a small difference to the response, but it cost 2 marks.

Question 10 (a)

10 Zac is measuring the growth of a culture of bacteria in a laboratory. The initial area of the culture is 8 cm^2. The area one day later is 8.8 cm^2.

At first, Zac uses a model of the form $A = a + bt$, where A cm^2 is the area t days after he begins measuring and a and b are constants.

(a) Find the values of a and b that best model the initial area and the area one day later. **[2]**

Almost all candidates were able to use the given information to find the correct values for a and b. Marks lost were usually for misinterpretation of the initial conditions leading to a value of 7.2 for a.

Question 10 (b)

(b) Calculate the value of t for which the model predicts an area of 15 cm^2. **[1]**

This was well answered especially as Follow Through was allowed where the values in (a) were incorrect.

Question 10 (c)

(c) Zac notices the area covered by the culture increases by 10% each day.

Explain why this model may not be suitable after the first day. **[1]**

This was generally not well answered. Candidates did not recognise the need to explicitly compare the initial model with Zac's observation. Many candidates stated that the model was linear and the observed result was exponential. Some evaluated the area on the second day using the model and using the 10% idea which are not the same. A few compared with the real situation which was not asked for as this is covered in Question 10 (f).

Key point: compare the model with the other information in the question

To explain why a model is not suitable, the response needs to say what the model predicts and points out the difference between that and the other information. This can be done with specific values or a general argument about the type of function being used in the model.

Question 10 (d)

Zac decides to use a different model for A. His new model is $A = Pe^{kt}$, where P and k are constants.

(d) Find the values of P and k that best model the initial area and the area one day later. **[3]**

Most candidates correctly substituted the values of *A* for $t = 0$ and $t = 1$. This generally led to P being found correctly. For some, a failure to take logs correctly let many candidates down when attempting to solve for *k*. Either the exact answer or a decimal equivalent were given full marks.

Question 10 (e)

(e) Calculate the value of t for which the area reaches 15 cm^2 according to this model. **[2]**

Most candidates knew that they needed to take logs, but some thought that $e^{(\ln 1.1)t}$ simplified to $1.1t$.

Question 10 (f)

(f) Explain why this model may not be suitable for large values of t. **[1]**

Overall, this question was answered better than part (c) as many candidates understood that for large values of t the model gives unrealistically large values of the area but many were not explicit in their comparison of the model with the real situation. Some candidates wrongly gave the same response to part (c) and part (f).

Question 11 (a)

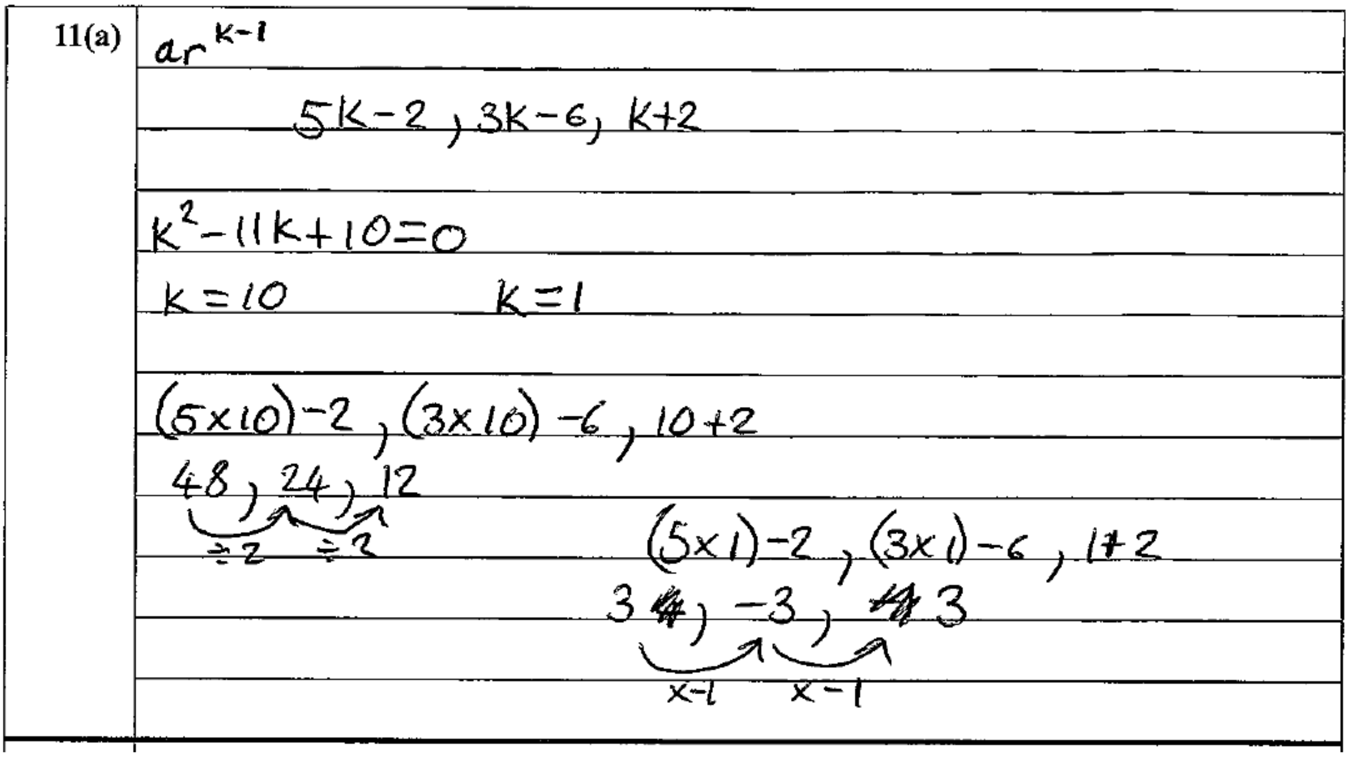
11 The first three terms of a geometric sequence are $5k-2$, $3k-6$, $k+2$, where k is a constant.

(a) Show that k satisfies the equation $k^2-11k+10=0$. **[3]**

The key to setting up the equation is to find an expression for the common ratio of the sequence from the first two terms and equating it to another from the second and third terms. There were some equivalent methods involving r^2 also seen. Candidates with good algebraic skills were then able to obtain the correct equation as their response.

Many candidates seemed to think that it was the solution of the equation that was needed rather than its derivation so gave $k=1, k=10$ for their response. This was required in part (b) and credit was given in part (b) even if the work was not redone in the answer space.

Exemplar 1


11(a)

ar^{k-1}

$5k-2, 3k-6, k+2$

$k^2-11k+10=0$

$k=10$ $k=1$

$(5\times10)-2, (3\times10)-6, 10+2$

$48, 24, 12$

$\div 2$ $\div 2$

$(5\times1)-2, (3\times1)-6, 1+2$

$3, -3, 3$

$x-1$ $x-1$

This exemplar shows how the SC was awarded. It shows how the roots of the equation give rise to numeric sequences and that those sequences were geometric. This is not equivalent to the given statement, as it does not demonstrate that there are no other values of k for which the sequences could be geometric.

Question 11 (b)

(b) When k takes the smaller of the two possible values, find the sum of the first 20 terms of the sequence. **[3]**

Most candidates could use $k = 1$ to generate the sequence 3, -3, 3, -3 … which can be summed without using the formula by grouping them into pairs. Many candidates used the formula correctly, while others made errors evaluating $1 - (-1)^{20}$ especially where the brackets were omitted, giving 3 for their response.

Question 11 (c)

(c) When k takes the larger of the two possible values, find the sum to infinity of the sequence. **[2]**

This was well answered. Occasionally candidates used $r = 10$ instead of calculating $r = \frac{1}{2}$ from the values of the sequence 48, 24, 12…

Question 12 (a)

12 In this question the unit vectors **i** and **j** are in the x- and y-directions respectively.

The velocity $\mathbf{v}\ \mathrm{m\,s^{-1}}$ of a particle is given by $\mathbf{v} = 3\mathbf{i} + (6t^2 - 5)\mathbf{j}$. The initial position of the particle is $7\mathbf{j}$ m.

(a) Find an expression for the position vector of the particle at time t s. **[4]**

Most candidates seemed comfortable working with vectors and calculus together, only rarely was the inappropriate use of $suvat$ equations seen. Candidates usually found the vector value of the arbitrary constant, although some had a mixture of vector and scalar terms in the same equation which was penalised.

Question 12 (b)

(b) Find the Cartesian equation of the path of the particle. **[2]**

Most candidates knew they had to eliminate the parameter t from the expressions for x and y they had obtained in their vector expression, and Follow Through was allowed where these had been incorrect.

Question 13 (a)

13 The curve with equation $y = px + \frac{8}{x^2} + q$, where p and q are constants, has a stationary point at (2, 7).

(a) Determine the values of p and q. **[5]**

Almost all candidates recognised the need to differentiate and make the first derivative equal to zero for the turning point. Most successfully handled the negative power. Errors that did occur were generally when candidates attempted to substitute for x to find p. Most were able to correctly find q from their value of p.

Question 13 (b)

(b) Find $\frac{\mathrm{d}^2y}{\mathrm{d}x^2}$. **[1]**

This was usually completed correctly by those who had found the correct first derivative. Notice this is independent of p and q so no Follow Through marks were needed here.

Question 13 (c)

(c) Hence determine the nature of the stationary point at (2, 7). **[2]**

Almost all candidates correctly substituted for x into their second derivative. However, many lost the final mark for failing to explicitly show that it was positive. There were a very few who having done so then incorrectly identified the nature of the turning point.

Question 14 (a)

14 A man runs at a constant speed of $4\,\text{m}\,\text{s}^{-1}$ along a straight horizontal road. A woman is standing on a bridge that spans the road. At the instant that the man passes directly below the woman she throws a ball with initial speed $u\,\text{m}\,\text{s}^{-1}$ at $\alpha°$ above the horizontal. The path of the ball is directly above the road. The man catches the ball 2.4 s after it is thrown. At the instant the man catches it, the ball is 3.6 m below the level of the point of projection.

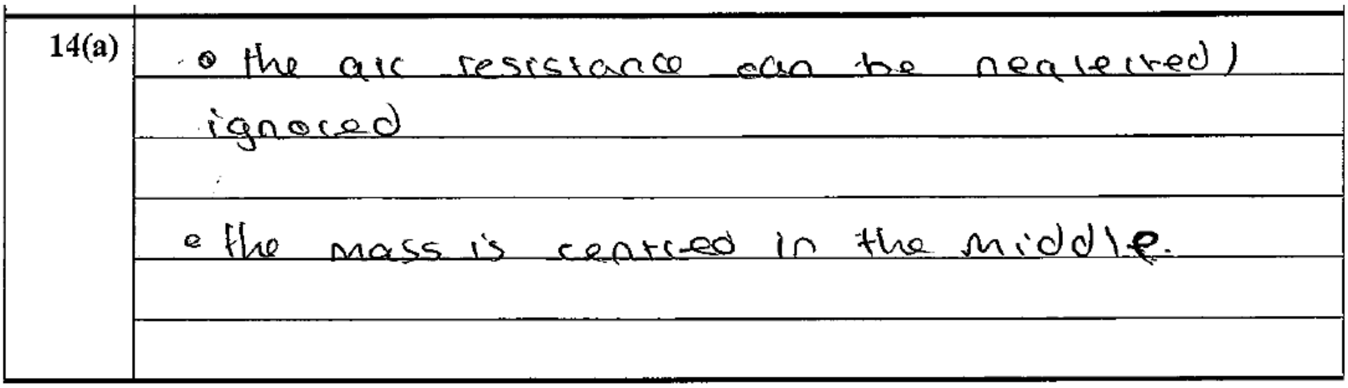
(a) Explain what it means that the ball is modelled as a particle. **[1]**

This question was not well answered as many candidates listed all the modelling assumptions for a standard projectile, rather than defining or explaining the particle model. What was important in this question is that the ball had no significant size or shape, so that the vertical displacement in the first 2.4 seconds was well defined.

It was not uncommon to see comments like 'there is negligible mass' or 'there are no external forces'.

A mixture of right and wrong comments got no marks here.

Exemplar 2



14(a)	• the air resistance can be neglected / ignored • the mass is centred in the middle.

The first bullet point is a modelling assumption used in standard projectile model, but not the one required. The second bullet point is not fully correct – it could be describing a uniform object.

Question 14 (b)

(b) Find the vertical component of the ball's initial velocity. **[2]**

This question expected candidates to find a value whereas many simply stated $u\sin\alpha$. This unexpected, correct response was rewarded with a special case mark, and where it was evaluated in part (c), fully rewarded.

Errors in direction for s did lead to sign errors. Where a simple diagram was shown, this mistake was usually avoided.

Question 14 (c)

(c) Find each of the following.
- The value of u
- The value of α **[4]**

The key to this problem is to realise that the horizontal component of the ball's velocity matches the velocity of the man, so the question then only required finding the magnitude and direction of the initial velocity from the two components. Follow Through marks were given for these steps from the candidate's components.

In rare cases, the correct work for (b) was seen in (c) with no further correct work, leading to the unusual situation of zero marks in a part question where there was correct work. The marks for finding $u \sin \alpha = 10.26$ will have been given in part (b).

Question 15

15 The circle $x^2 + y^2 + 2x - 14y + 25 = 0$ has its centre at the point C. The line $7y = x + 25$ intersects the circle at points A and B.

Prove that triangle ABC is a right-angled triangle. **[9]**

Most candidates had a good idea of how to go about this multi-step proof, finding the centre of the circle, the points of intersection and then using gradient information, Pythagoras, the cosine rule or vector methods from Further Maths to establish the right angle. Errors in the algebra, particularly from those who substituted $y = \frac{x+25}{7}$ were very common, often leading to surd values for the coordinates of A and B. Some had correct values for x and y and then put them together back-to-front to give incorrect coordinates. Sometimes responses had all the evidence for a right angle and missed the very last step explaining how their work proved that the triangle was right-angled.

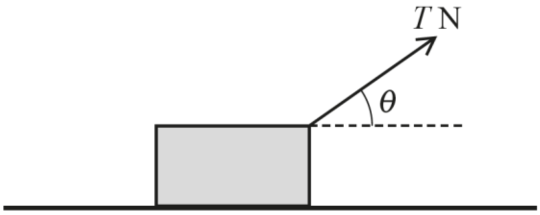
Assessment for learning

Encourage candidates to find the simplest way of tackling the algebra, for example using $x = 7y - 25$ to find the points of intersection.

Also where the roots of the resulting quadratic are not simple, encourage them to check their working before launching into the distance or gradient calculations.

Question 16 (a)

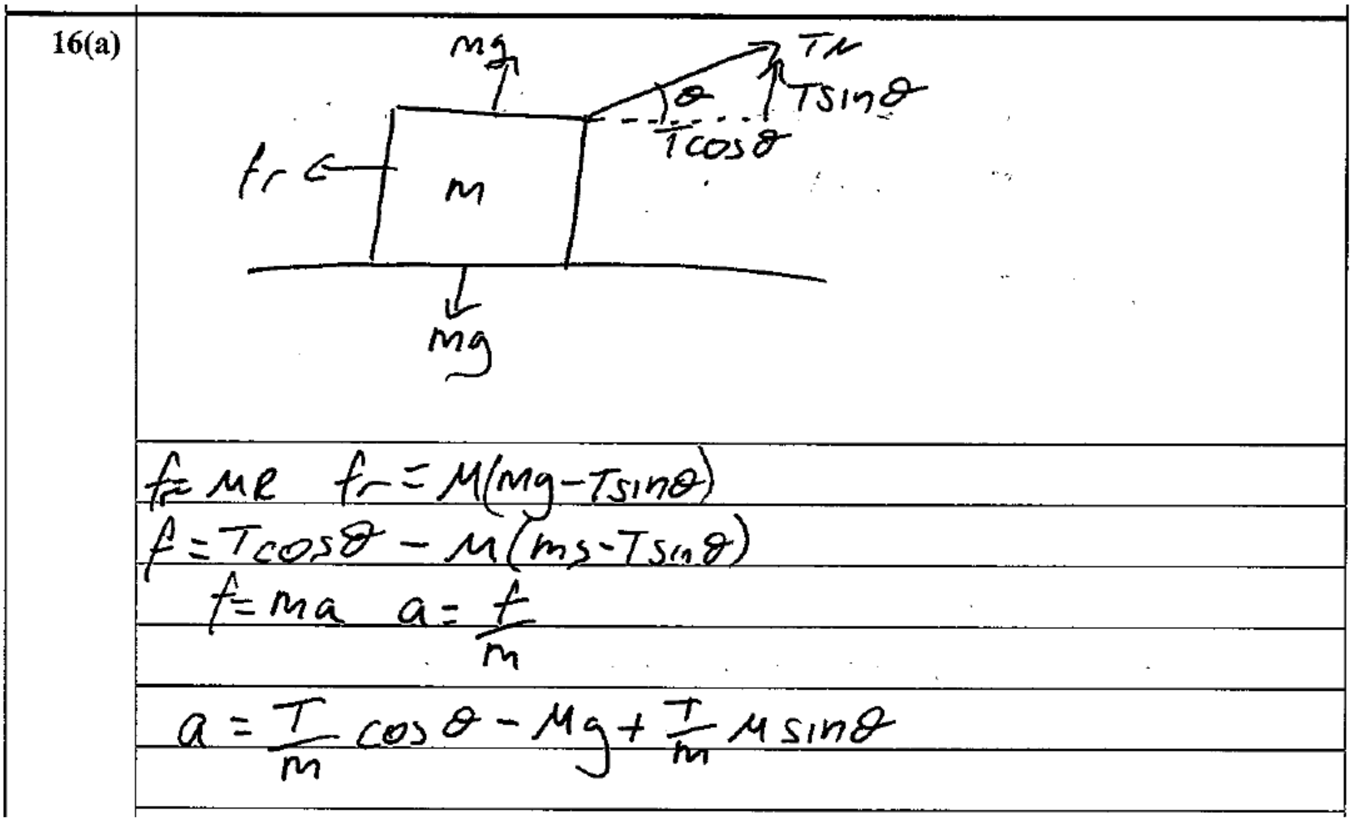
16 A block of mass m kg rests on rough horizontal ground. The coefficient of friction between the block and the ground is μ. A force of magnitude T N is applied at an angle θ radians above the horizontal as shown in the diagram and the block slides without tilting or lifting.



(a) Show that the acceleration of the block is given by $\frac{T}{m}\cos\theta - \mu g + \frac{T}{m}\mu\sin\theta$. **[4]**

Many candidates appeared to be working backwards and did not show independently how they found an expression for the normal reaction. Some candidates did seem to know what was needed, but sometimes they did not explicitly show expressions for the normal reaction and for the frictional force, so that it was not clear what they were doing. In a question like this where the answer is given, candidates must make sure that they show the starting points clearly and all the steps involved.

Exemplar 3



In this response, the candidate incorrectly labels the normal reaction as equal to mg, but does not use this in their working to find an expression for friction Fr. It is clear they know that the horizontal resultant force is $T\cos\theta - Fr$ which is equal to ma but nothing else is demonstrated. Following $F = mg$, the incorrect equation $T\cos\theta - \mu mg = ma$ would have been given 2/4 rather than the just 1 mark for this attempt.

Question 16 (b)

For a fixed value of T, the acceleration of the block depends on the value of θ. The acceleration has its greatest value when $\theta = \alpha$.

(b) Find an expression for α in terms of μ. **[3]**

This is a challenging final question which seemed unfamiliar to many candidates, and many did not attempt it. Only a small number realised that differentiation could be used to find a maximum value. A few used the form $R\cos(\theta - \beta)$, often successfully. Sometimes correct working was not given the final mark for not stating clearly that $\alpha = \arctan\mu$.

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