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AS/A LEVEL GCE

Examiners' report

MATHEMATICS (MEI)

3895-3898, 7895-7898

4761/01 Summer 2018 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. 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 can be downloaded from OCR.

Paper 4761/01 series overview

This paper covers the first of the four mechanics modules in the MEI AS and A Level Mathematics and Further Mathematics.

Successful candidates have a good understanding of the whole content of this module and are able to answer questions that combine the different topics in the specification, as well as drawing on relevant pure mathematics. In addition to being competent with the various techniques, candidates are expected to be able to use the mechanics to model real world situations and to answer questions that involve problem solving.

The specification content for Mechanics 1 covers the following topics:

- Modelling
- Vectors
- Kinematics
- Force
- Newton's laws of motion
- Projectiles

The examination paper has two 36 mark sections. Section A has a number of short questions no more than 8 marks each. Section B has two long questions each carrying about 18 marks. Most, but not all, of the questions are split into a number of parts.

In this examination, many candidates scored more highly on the questions in Section A than on those in Section B.

Section A overview

Many candidates obtained nearly all the marks on the five questions in Section A.

Questions 1, 3 and 4 could be described as "routine" and many candidates provided succinct correct answers to them.

Questions 2 and, particularly, 5 both involved some problem solving and so candidates needed to devise strategies for solving them.

AfL

Questions 2 and 5 showed that some candidates did not have good examination techniques for problem solving questions. Instead of thinking first and analysing the situations, they seem to have rushed into the questions and only later realised that they were not getting anywhere. It was common to see a lot of crossing out of work for these questions, which was then replaced by correct work. Even though such candidates may have obtained the marks for these questions, many of them seem to have run out of time for the Section B questions. Advice to future candidates might be: "If a question involves problem solving, pause and think it through first before answering the question."

Question 1 (i)

1 Fig. 1 shows a block of mass 10 kg on a rough horizontal table.

One end of a string is attached to the block. The string passes over a smooth pulley and the other end is attached to a sphere of mass 5 kg which is hanging freely. The string makes an angle of 30° with the vertical. The string is light and inextensible.

The system is in equilibrium.

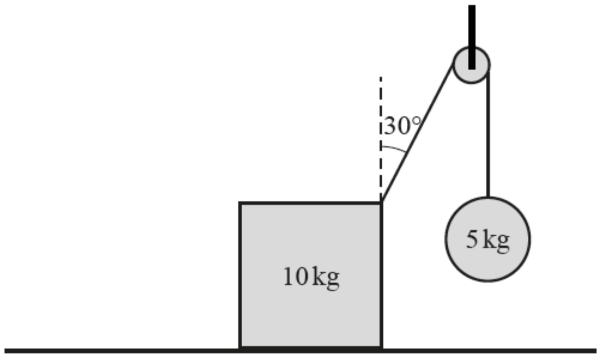


Fig. 1

(i) Draw a diagram showing all the forces acting on the block. **[3]**

Question 1 was about the forces acting on a block in equilibrium. Part (i) involved drawing a force diagram and was generally well answered. The most common mistake was to omit the frictional force. The three marks were given for correct forces, labels and arrows.

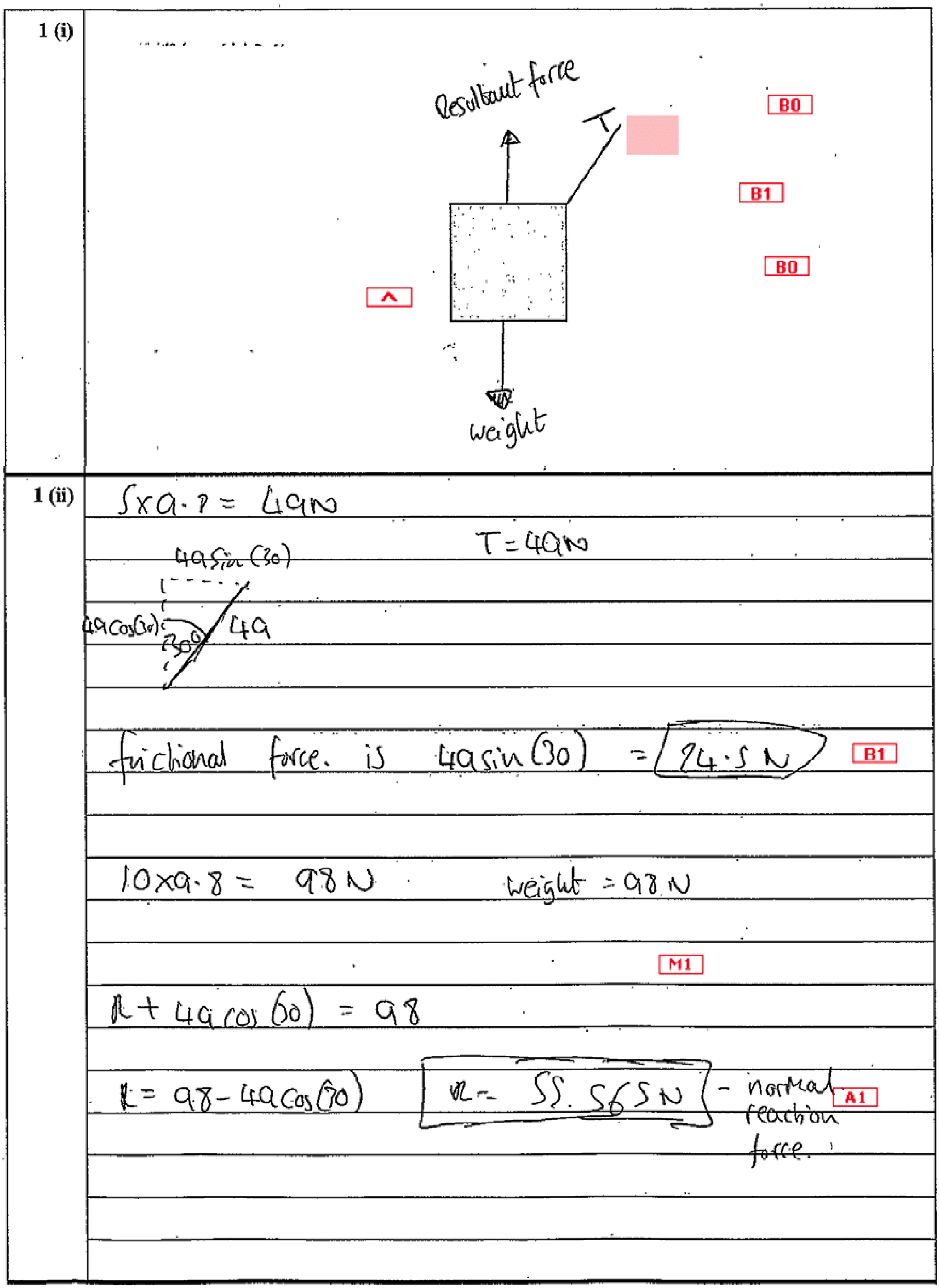
Question 1 (ii)

(ii) Calculate the normal reaction of the table on the block.

Calculate also the frictional force acting on the block. **[3]**

In part (ii) candidates were asked to find the normal reaction and the frictional force acting on the block. Most candidates got full marks for this part. There were quite a few mistakes over the normal reaction; a common error was to omit the vertical component of the tension in the string and so equate the normal reaction with the weight of the block.

Exemplar 1 and 2


1 (i)

1 (ii)

$5 \times 9.8 = 49N$

$T = 49N$

$49\sin(30)$

$49\cos(30)$

$30°$

49

frictional force is $49\sin(30) = 24.5N$ B1

$10 \times 9.8 = 98N$ weight $= 98N$

M1

$R + 49\cos(60) = 98$

$R = 98 - 49\cos(30)$ $R = 55.565N$ – normal reaction force. A1

AfL The exemplar shows a common situation in which the candidate has omitted the frictional force from the diagram in part (i) and then found its value in part (ii). This suggests that such candidates may not fully appreciate how useful a force diagram is as a tool for solving mechanics problems.

Question 1 (iii)

(iii) Find the magnitude of the resultant of the forces that the table exerts on the block. **[2]**

In the final part of the question, candidates were required to find the resultant of the two forces they had found in the previous part. These forces were at right angles, and so a Pythagoras-type calculation was required. While most candidates were successful, a few seemed to be unfamiliar with this technique.

Question 2 (i)

2 In this question you should use the standard projectile model with $g = 9.8\,\mathrm{m\,s^{-2}}$.

Fig. 2 illustrates a situation in a cricket match.

A batsman has hit the ball in the air from the point B, 1 metre above the ground at P, towards the boundary at Q. The ground is horizontal and the distance PQ is 70 m. A fielder is standing at Q.

The initial velocity of the ball is $28\,\mathrm{m\,s^{-1}}$ at 30° to the horizontal.

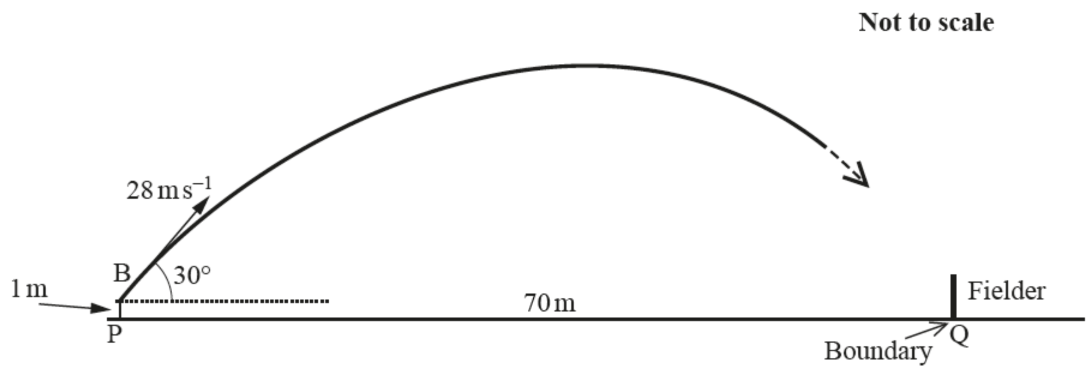


Fig. 2

(i) Find the greatest height of the ball above the ground during its flight. **[4]**

Question 2 was about projectiles, using the flight of a cricket ball as a context. In the first part, candidates were asked to find the greatest height of the ball. It was well answered with many candidates obtaining all 4 marks. The most common mistake was to omit the initial height of the ball, an error that was only penalised once across both parts of the question.

Question 2 (ii)

The height of the ball above the ground when it reaches the boundary at Q is denoted by h metres.

- If $h > 2.2$, the batsman will score 6 runs.
- If $0 \leqslant h \leqslant 2.2$, the fielder will catch the ball and the batsman will be out.
- If the ball hits the ground before it reaches Q, the fielder will stop it, and the batsman will score 1 run.

(ii) Determine what happens. **[4]**

The second part of this question involved some problem solving. Candidates had to realise that it was effectively asking for the height of the ball when it had travelled 70 metres horizontally. This part too was well answered. However, some candidates found where the ball would have landed, and so did not actually address the problem they were being asked to solve.

Question 3 (i)

3 Fig. 3 illustrates a car towing a trailer. They are connected by a light horizontal tow-bar and are travelling in a straight line along a horizontal road.

- The mass of the car is 1000 kg and the mass of the trailer is 600 kg.
- The resistance to motion is 300 N for the car and 100 N for the trailer.
- The driving force exerted by the car is D N.

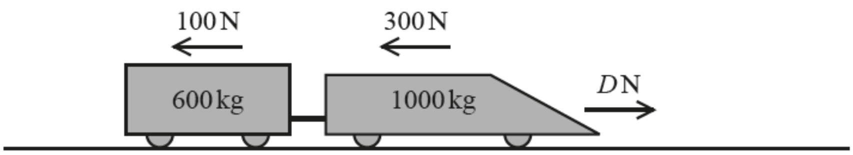


Fig. 3

(i) Initially $D = 1200$.

Find the acceleration of the car and the tension in the tow-bar. **[4]**

Question 3 was about connected particles. The context involved a car and a trailer on a straight horizontal road. In part (i) the car was exerting a driving force and candidates were asked to find the acceleration and the force in the tow-bar. It was well answered with most candidates obtaining all 4 marks.

Question 3 (ii)

(ii) After some time the driving force is removed so that $D = 0$.

Find the new force in the tow-bar, stating whether it is a tension or a thrust. **[4]**

In part (ii) the driving force was removed and the new force in the tow-bar was to be found. This part too was well answered. There were different ways the question could be approached but most candidates started by finding the acceleration which turned out to be negative. Perhaps therefore, sign errors were quite common when they went on to find the force in the tow-bar. Another common mistake occurred when candidates did not realise that in this new situation the acceleration they had found in part (i) was no longer relevant.

Question 4 (i)

4 Salome takes a lift from the ground floor of a building vertically upwards to the floor where her office is situated. Her velocity, v, at time t is shown in Fig. 4. She stands still in the lift.

Salome's mass is 50 kg.

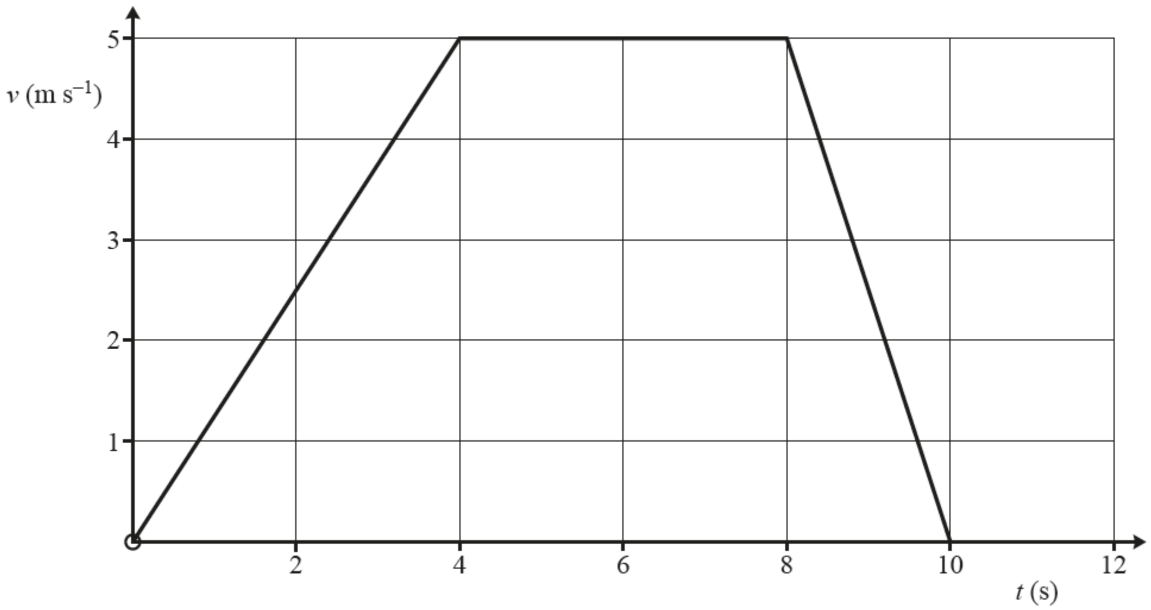


Fig. 4

(i) Find Salome's acceleration in each of the three phases of her motion. **[2]**

This question was about the forces acting on a person in a lift. Part (i) was based on the velocity-time graph for the lift and candidates were asked to use it to find the acceleration in each phase of the motion. Nearly all candidates answered it correctly.

Question 4 (ii)

(ii) Find the greatest force that the floor of the lift exerts on Salome. **[2]**

In part (ii) candidates were asked to find the greatest force that the lift exerted on the person. This was not well answered with only a minority of candidates giving the correct answer. The most common mistake was to forget about the weight of the person in the lift when applying Newton's second law.

Question 5

5 Alice is driving along a straight narrow country road when she sees that a tree has fallen across the road in front of her. She applies the car's brakes with ever increasing firmness as she approaches the tree.

- The car's initial speed is $21\,\mathrm{m\,s^{-1}}$.
- The tree is 75 m from the front of Alice's car when she first applies the brakes.
- The car's acceleration, $a\,\mathrm{m\,s^{-2}}$, is given by $a = -2 - \frac{1}{2}t$ where t s is the time since Alice first applies the brakes.

Does Alice's car hit the tree? **[8]**

This question involved a considerable amount of problem solving, in a context that involved motion with variable acceleration.

There were many right answers but these included those from some candidates who spent a long time doing unsuccessful work, which they then crossed out and replaced by a correct solution. Some of these candidates then ran short of time towards the end of the paper.

The most common mistake was to use the constant acceleration formulae instead of calculus. Candidates who did this within a correct problem solving structure could receive up to 3 method marks for taking the following steps:

- finding the velocity at time t
- finding the time when the velocity is zero
- finding the distance the car has travelled at that time.

However, candidates who used constant acceleration formulae did not receive any other marks.

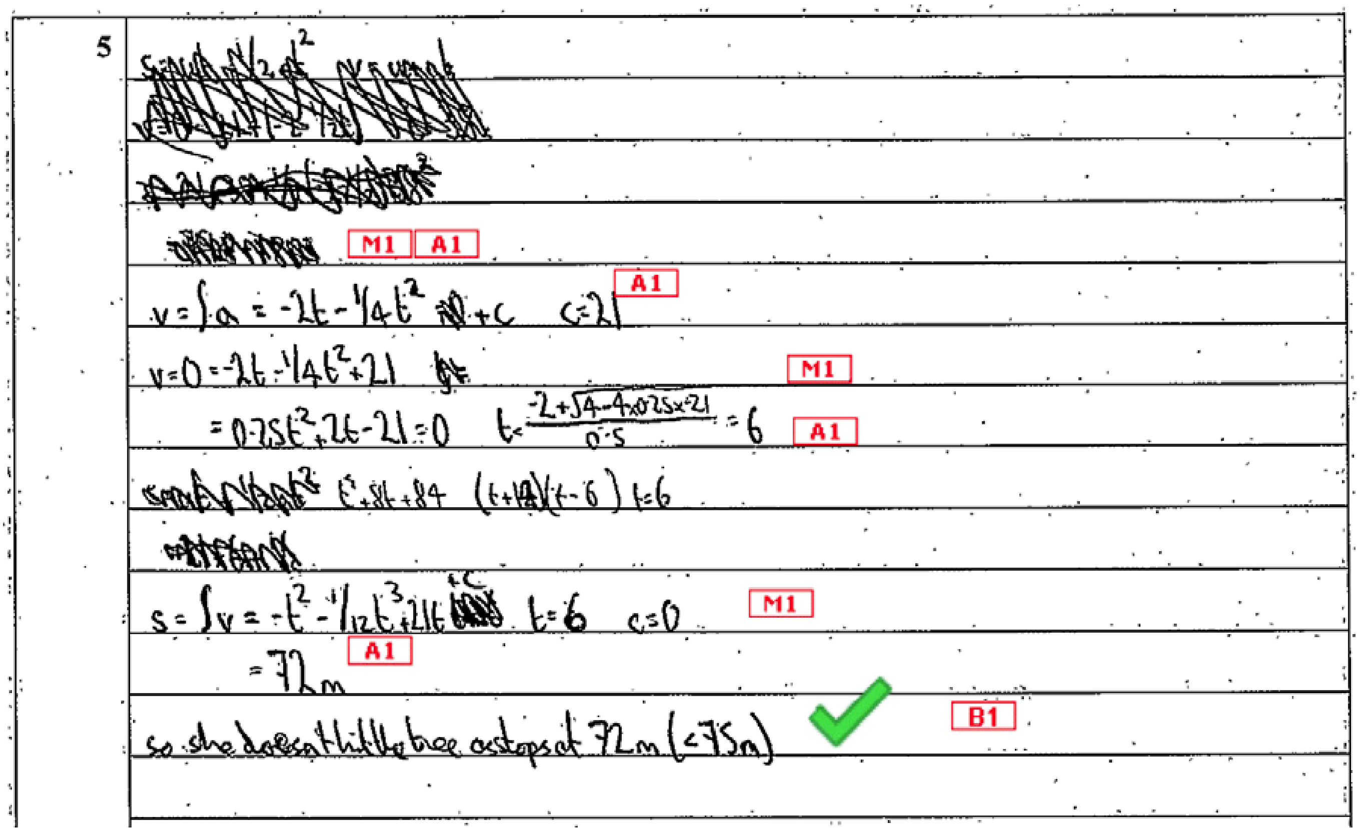
Exemplar 3 shows a fully correct answer and Exemplar 4 shows an incorrect one based on constant acceleration formulae.

OCR support Support from OCR and MEI is available for teachers wanting to address problem solving in their mathematics classes.

OCR support pack
http://www.ocr.org.uk/Images/83327-problem-solving-support-pack.pdf

MEI problem solving guide
http://mei.org.uk/problem-solving-guide.

Exemplar 3


5

M1 A1

$v = \int a = -2t - \frac{1}{4}t^2 + c \quad c = 21$ A1

$v = 0 = -2t - \frac{1}{4}t^2 + 21$ M1

$= 0.25t^2 + 2t - 21 = 0 \quad t = \frac{-2 + \sqrt{4 - 4 \times 0.25 \times -21}}{0.5} = 6$ A1

$t^2 + 8t + 84 \quad (t+14)(t-6) \quad t = 6$

$s = \int v = -t^2 - \frac{1}{12}t^3 + 21t + c \quad t = 6 \quad c = 0$ M1

$= 72m$ A1

so she doesn't hit the tree as stops at 72m (<75m) B1

Exemplar 4

5

s u v a t

x 21 0 $-2-\frac{1}{2}t$?

$v = u + at$ ✗ M1

$0 = 21 + (-2-\frac{1}{2}t)t$

$21 - 2t - \frac{1}{2}t^2 = 0$

$t = 4.78$ M1

s u v a t

21 0 x 4.78

?

$s = \frac{u+v}{2}t$

$s = \frac{21}{2} \times 4.78$ M1

$s = 50.21$

$50.21 < 75$ ∴ She doesn't hit the tree. B0

Section B overview

Those candidates who spent longer than necessary on the problem solving questions in Section A appeared to have run short on time when answering the questions in Section B. There were many no responses, particularly to parts (ii), (iii) and (iv) of Question 7.

Question 6 (i)

6 Two beetles, A and B, are on a large patio which is modelled as a flat horizontal surface.

Cartesian axes are defined relative to an origin near the middle of the patio; the direction of the x-axis is East and the direction of the y-axis is North.

The unit vectors $\begin{pmatrix} 1 \\ 0 \end{pmatrix}$ and $\begin{pmatrix} 0 \\ 1 \end{pmatrix}$ are in the x- and y- directions.

The unit for distance is 1 metre. Time, t, is measured in seconds and $0 \leqslant t \leqslant 5$.

The position vector, $\mathbf{r}_\mathbf{A}$ m, of beetle A at time t is given by $\mathbf{r}_\mathbf{A} = \begin{pmatrix} t-1 \\ t^2-2 \end{pmatrix}$.

(i) Write down A's velocity and acceleration at time t. **[3]**

Question 6 was about motion of two beetles in two dimensions and the use of vectors was required throughout. The first part involved using a given position vector to find velocity and acceleration of one beetle. The acceleration turned out to be constant and so the answers could be obtained using either calculus or constant acceleration formulae. It was well answered by almost all candidates.

Question 6 (ii)

Beetle B is initially at the point $(-1, 10)$ and is initially moving with velocity $\begin{pmatrix} 1 \\ -4 \end{pmatrix}$ m s^{-1}. It has constant acceleration $\begin{pmatrix} 0 \\ 2 \end{pmatrix}$ m s^{-2}.

(ii) Find the velocity and position vector of beetle B at time t. **[4]**

Part (ii) involved finding expression for velocity and position at time *t* of the other beetle. Its acceleration, which was constant, and the initial conditions were given. It was well answered. The most common mistake was to miss out the initial conditions.

Question 6 (iii)

(iii) Show that the two beetles meet once and give the coordinates of the place where this happens. **[4]**

In this part candidates were required to investigate if and when the two beetles met. Most candidates knew how to go about it, equating the position vectors of the two beetles. However, many did not realised that both the *x*- and *y*- components had to be considered.

Question 6 (iv)

(iv) Show that the directions of travel of the two beetles are never parallel. **[4]**

In the last two parts candidates were asked about times when the two beetles were moving in parallel directions (part (iv)) and had the same speed (part (v)) Neither of these parts were well answered. Quite a lot of candidates missed out part (iv) completely. A common mistake was to compare the position vectors of the two beetles rather than their velocities. Among the responses from those who did compare the velocities, invalid arguments were common.

Question 6 (v)

(v) Prove that there is one, and only one, time at which the speeds of the two beetles are the same. Find the speed at that time. **[3]**

This question tested the relationship between velocities, expressed as vectors, and speeds. While there were some good answers most candidates were not successful.

Question 7 (i)

7 This question is about a place where there is a steep cliff with flat horizontal ground at the bottom of it. A railway line runs along this flat ground. The railway line is parallel to the bottom of the cliff and at a distance of 100 m from it.

Hari is surveying the situation to see if stones falling down the cliff present any danger to the trains. Fig. 7 is his illustration of the place. He uses it for three models of a stone sliding down from the top of the cliff and across the flat horizontal ground towards the railway.

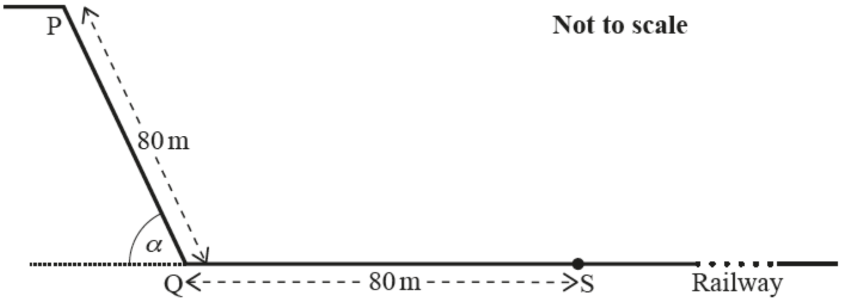


Fig. 7

He makes the following assumptions in all three models.

- The cliff PQ is a uniform plane making an angle α with the horizontal where $\sin\alpha = 0.8$.
- A stone loses no speed at the bottom of the cliff when it changes direction at Q.
- The mass of a stone is 5 kg.

To test his models, Hari places a flat stone at P and observes its motion sliding down the cliff and along the ground. After 11.4 seconds it comes to rest at S, 80 metres from Q.

In **Model A**, it is also assumed that all the surfaces are smooth.

(i) Show that Model A predicts that the speed of the stone at Q will be $35.4\,\text{m}\,\text{s}^{-1}$. Write down the predicted speed of the stone when it is at S.

Give one reason why Model A is not suitable. **[6]**

Question 7 involved modelling in the context of motion in two stages, down a slope and along the horizontal. Three models of increasing complexity were considered in the course of the various parts of the question.

Part (i) was based on the simplest model in which friction was negligible. While there were many fully correct answers to this part, there were a significant number that demonstrated little, if any, understanding of the mechanics of motion down a slope. Candidates were asked to show that a stone starting at rest and sliding down a smooth slope of given length and angle reached the bottom with a particular speed. Many did not show a knowledge of the underlying mechanics, failing to find the component of the stone's weight down the slope and then apply Newton's second law.

AfL In this question, candidates were asked to show a given answer: that the speed of the stone at the bottom of the slope is $35.4\,\text{m}\,\text{s}^{-1}$. In a large number of responses various numbers were manipulated to produce the given number 35.4 but without any explanation or any clear logical path. Candidates should be made aware that when an answer is given, a high standard of explanation or argument is needed to obtain the marks. Coming out with the right number will not be sufficient.

Question 7 (ii)

In **Model B**, it is assumed that the stone is subject to a constant resistance force throughout the motion.

(ii) Show that, if the resistance force is 19.6 N, Model B predicts that the stone will come to rest at S. **[4]**

In part (ii), the question then went on to consider a different model for the motion of the stone, in which there was a given constant frictional force. Many of those candidates who had been successful in part (i) had realised the two-stage nature of the motion in this question and used that understanding to proceed to answer this part well. Those who did not demonstrate an understanding that the motion involved two stages received no credit in this part.

Question 7 (iii)

Hari calculates the stone's time from P to S based on Model B and a resistance of 19.6 N. He finds it is not the same as the observed time and so he refines the model further.

In **Model C** it is assumed that the resistance forces are different, but constant, during each of the two stages of the motion: F_1 N between P and Q; F_2 N between Q and S. As a result of a further experiment Hari estimates that $F_2 = 24.5$ N and this value is assumed in Model C.

(iii) Given that Model C predicts that the stone stops at S, find the value of F_1. **[4]**

In part (iii), the model involved different resistance forces acting on the stone on the slope and on the horizontal. Those candidates who had been successful in part (ii) were usually also successful in this part. However, there were many others who offered no response at all.

Question 7 (iv)

(iv) Find the time taken for the stone to travel from P to S as predicted by Model C. **[3]**

This part continued with the same model as part (iii) and asked about the times taken on the two stages of the motion. Many of the candidates who had been successful in parts (ii) and (iii) were also successful in this part. However, many others provided no response.

Question 7 (v)

(v) Give one reason why the trains might not be as safe as Model C suggests. **[1]**

Question 7 involved three simple models for a real situation on the railway network. The last part invited candidates to consider the limitations of the third, and most sophisticated, of the models. Candidates produced a variety of acceptable answers, including the fact that stones are likely to bounce as well as slide, and so be liable to less resistance and travel further.

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