OCR
Oxford Cambridge and RSA

Friday 15 June 2018 – Afternoon

AS GCE MATHEMATICS (MEI)

4761/01 Mechanics 1

QUESTION PAPER

Candidates answer on the Printed Answer Book.

OCR supplied materials:
- Printed Answer Book 4761/01
- MEI Examination Formulae and Tables (MF2)

Other materials required:
- Scientific or graphical calculator

Duration: 1 hour 30 minutes

7312986697

INSTRUCTIONS TO CANDIDATES

These instructions are the same on the Printed Answer Book and the Question Paper.

- The Question Paper will be found inside the Printed Answer Book.
- Write your name, centre number and candidate number in the spaces provided on the Printed Answer Book. Please write clearly and in capital letters.
- **Write your answer to each question in the space provided in the Printed Answer Book**. Additional paper may be used if necessary but you must clearly show your candidate number, centre number and question number(s).
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the barcodes.
- You are permitted to use a scientific or graphical calculator in this paper.
- Final answers should be given to a degree of accuracy appropriate to the context.
- The acceleration due to gravity is denoted by $g\,\mathrm{m\,s^{-2}}$. Unless otherwise instructed, when a numerical value is needed, use $g = 9.8$.

INFORMATION FOR CANDIDATES

This information is the same on the Printed Answer Book and the Question Paper.

- The number of marks is given in brackets **[ ]** at the end of each question or part question on the Question Paper.
- You are advised that an answer may receive **no marks** unless you show sufficient detail of the working to indicate that a correct method is being used.
- The total number of marks for this paper is **72**.
- The Printed Answer Book consists of **16** pages. The Question Paper consists of **8** pages. Any blank pages are indicated.

INSTRUCTION TO EXAMS OFFICER/INVIGILATOR

- Do not send this Question Paper for marking; it should be retained in the centre or recycled. Please contact OCR Copyright should you wish to re-use this document.

Section A (36 marks)

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.

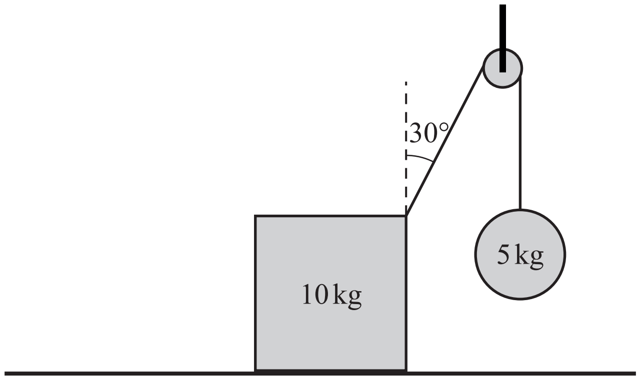

Fig. 1

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

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

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

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

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

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 $28\,\text{m}\,\text{s}^{-1}$ at 30° to the horizontal.

Not to scale

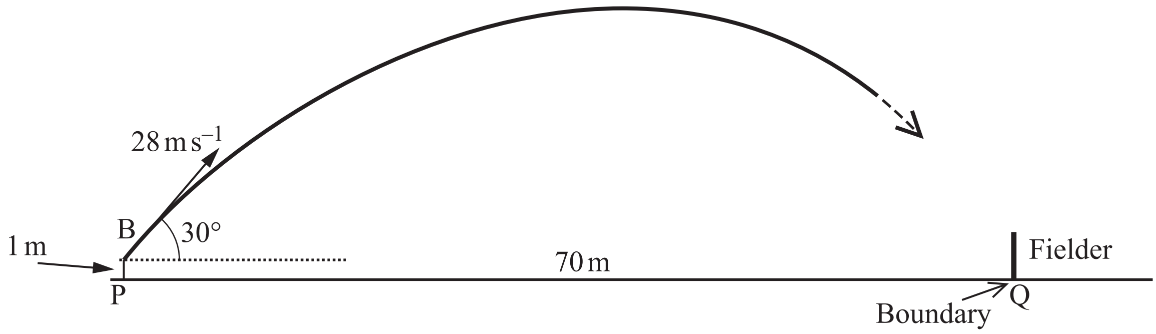

Fig. 2

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

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]**

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.

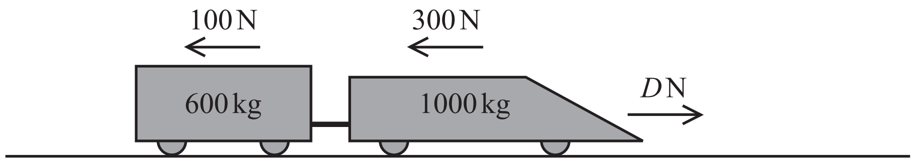

Fig. 3

(i) Initially $D = 1200$.

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

(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]**

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.

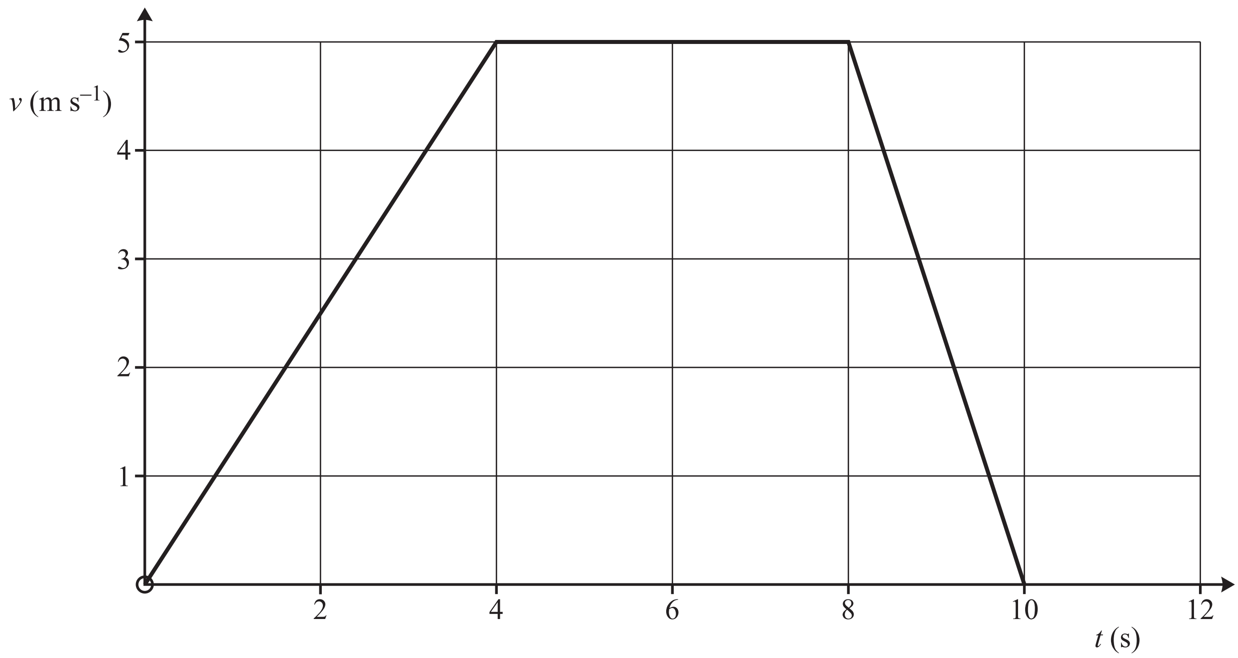

Fig. 4

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

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

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 $21\,\text{m s}^{-1}$.
- The tree is 75 m from the front of Alice's car when she first applies the brakes.
- The car's acceleration, $a\,\text{m s}^{-2}$, 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]**

Section B (36 marks)

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

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

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]**

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

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

(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]**

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.

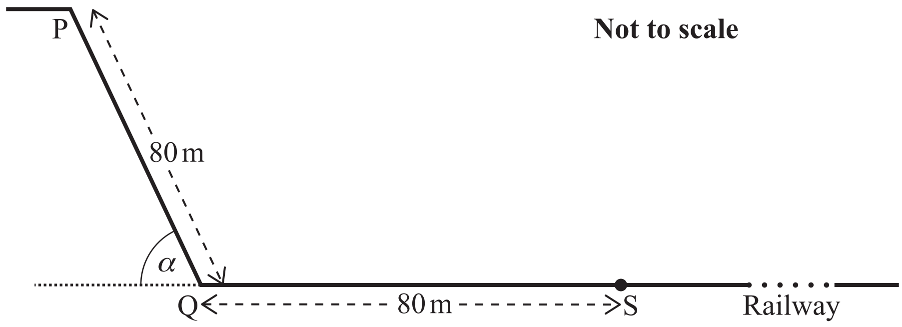

Fig. 7

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]**

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]**

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]**

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

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

END OF QUESTION PAPER