OCR
Oxford Cambridge and RSA

Friday 16 June 2017 – 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

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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 $g\,\text{m s}^{-2}$. 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 5 kg on a rough plane inclined at an angle α to the horizontal.

The block is in equilibrium.

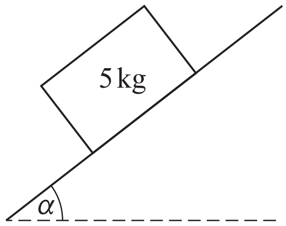

Fig. 1

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

(ii) The normal reaction of the plane on the block is 37.5 N.

Find α, giving your answer to the nearest degree.

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

2 In this question, $\begin{pmatrix}1\\0\end{pmatrix}$ and $\begin{pmatrix}0\\1\end{pmatrix}$ are unit vectors in the x- and y-directions.

A bird is flying in the vertical plane defined by these directions.

The origin is a point on the ground.

The position vector, $\mathbf{r}$ m, of the bird at time t seconds, where $t \geqslant 0$, is given by

$$\mathbf{r} = \begin{pmatrix}0\\8\end{pmatrix} + \begin{pmatrix}2\\-4\end{pmatrix}t + \begin{pmatrix}0\\1\end{pmatrix}t^2.$$

(i) Find the velocity of the bird when $t = 2.5$. **[3]**

(ii) Find the time at which the speed of the bird is $10\,\text{m}\,\text{s}^{-1}$. **[3]**

(iii) Find the times at which the bird is flying at an angle of 45° to the horizontal. **[2]**

3 Olga and Petya are using light ropes to pull a sledge across rough snow.

- The surface of the snow is horizontal.
- The mass of the sledge and its load is 430 kg.
- Both ropes are horizontal.
- Olga pulls with a force of 120 N at an angle of 20° to the line of motion of the sledge.
- Petya also pulls with a force of 120 N at an angle of 20° to the line of motion of the sledge.

This is illustrated in a plan view in Fig. 2.

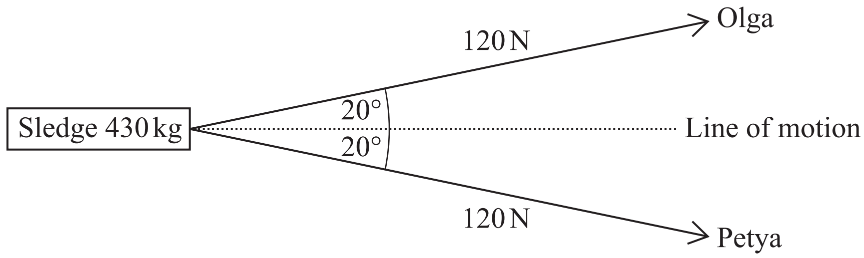

Fig. 2

(i) The sledge has acceleration $0.05\,\mathrm{m\,s^{-2}}$ in the direction of its line of motion.

Find the frictional force acting on the sledge. **[3]**

Olga and Petya then change to walking side by side. Their ropes, which are still horizontal, are now along the line of motion of the sledge. They maintain the forces on their ropes at 120 N and the frictional force remains the same.

(ii) Find the percentage increase in the acceleration of the sledge. **[4]**

4 Fig. 4 shows two small blocks, Q of mass 8 kg and R of mass 6 kg. They are connected by a light string which passes over a pulley.

The pulley is light and smooth. It is rigidly suspended from the ceiling.

The system is released from rest with the two blocks at the same height.

Initially the blocks are 2 m above the floor and 3 m below the pulley.

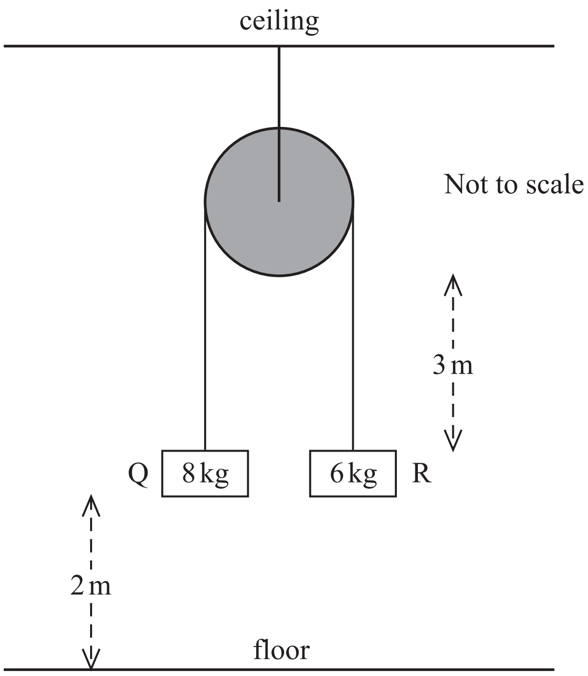

Fig. 4

(i) Draw diagrams showing the forces acting on each of the blocks Q and R. **[1]**

(ii) Write down the equations of motion of each of the blocks Q and R. **[2]**

(iii) Find the time between the system being released and one of the blocks reaching the floor. **[4]**

5 Two cars, A and B, are travelling in different lanes in the same direction along a straight road.

The initial situation is illustrated in Fig. 5.

- At this time, A is stationary at traffic lights at O. The lights have just turned green and A is on the point of moving off.
- B is travelling towards O with speed $20\,\mathrm{m\,s^{-1}}$. B is 75 m behind A.

Fig. 5

During the subsequent motion,

- A has constant acceleration $2\,\mathrm{m\,s^{-2}}$,
- the traffic lights remain green and B maintains a constant speed $20\,\mathrm{m\,s^{-1}}$.

In order to model the subsequent motion you should make two assumptions.

- The cars can overtake each other with no interference from other traffic.
- The position of a car is defined by a point at its front and so the length of the car need not be considered.

(i) Find the times at which the two cars are side by side. **[4]**

(ii) Find the distance A travels while it is behind B. **[2]**

(iii) There is a speed camera 400 m from O.
How fast is A travelling when it passes the speed camera? **[2]**

Section B (36 marks)

6 A train is travelling along a straight test track. It starts from rest and reaches its maximum speed after a time of 2 minutes and 21 seconds. During that time it travels 5 km.

Two models, A and B, are considered for its motion.

In Model A, it is assumed that the train has constant acceleration.

(i) Find the acceleration of the train and its maximum speed according to Model A. **[5]**

In Model B, it is assumed that the acceleration, $a\ \mathrm{m\,s^{-2}}$ at time t seconds after starting, is given by

$$a = 0.6 - 3 \times 10^{-5} \times t^2.$$

(ii) Show that, according to Model B, the time taken for the train to reach its maximum speed is 2 minutes 21.42 seconds (to the nearest 0.01 s). **[2]**

(iii) Find expressions for the speed of the train and the distance that it has travelled at time t, according to Model B. **[4]**

(iv) Hence show that Model B is consistent with the train travelling a distance of 5 km to attain maximum speed.

Find the maximum speed of the train according to this model. **[3]**

(v) When the train reaches its maximum speed it continues at that speed.
Draw the speed-time graphs for both models on the grid provided, labelling them A and B. **[4]**

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

Fig. 7 illustrates the trajectory of a tennis ball which has been served by a player. It is not drawn to scale.

- The ball must pass over the net and land in the service court.
- The player hits the ball at an angle of α above the horizontal.

Three junior members of a tennis club take turns to serve a tennis ball. They are Hamish (a beginner), Oscar (of medium standard) and Tara (a good player). They each stand at the same point and hit the ball in the same vertical plane at the same point P. The following figures apply to their serves.

- The player hits the ball from a height of 2.22 m.
- The height of the net is 0.995 m.
- The player is 12.5 m from the net.
- The ball must bounce within 6.5 m of the net.

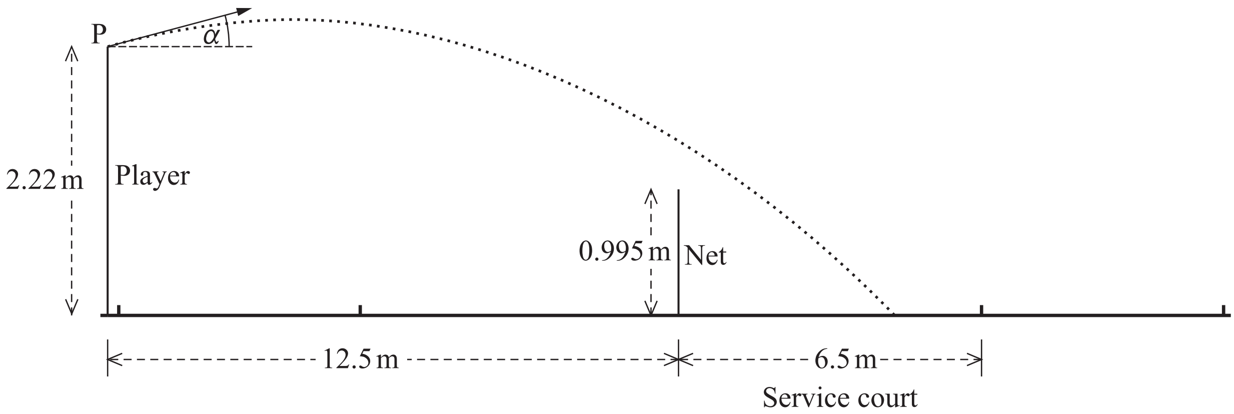

Fig. 7

Hamish serves the ball with components of velocity $10\,\text{m s}^{-1}$ horizontally and $5.5\,\text{m s}^{-1}$ vertically upwards.

(i) Find the speed of Hamish's serve and the value of α. **[2]**

(ii) Show that Hamish's serve passes over the net. **[3]**

(iii) Find the time at which Hamish's serve hits the ground.
Does it land in the service court? **[4]**

Oscar hits the ball horizontally, so $\alpha = 0$. The initial speed of the ball is $u\,\text{m s}^{-1}$.

(iv) Find the range of possible values of u for which the ball lands in the service court. **[6]**

Tara serves the ball at an angle of 2° below the horizontal. The ball clears the net and bounces after 0.57 seconds.

(v) Find the initial speed of Tara's serve. **[3]**

END OF QUESTION PAPER