MEI

Mathematics in Education and Industry

MEI STRUCTURED MATHEMATICS

MECHANICS 1, M1

Practice Paper M1-B

Additional materials: Answer booklet/paper
Graph paper
MEI Examination formulae and tables (MF12)

TIME 1 hour 30 minutes

INSTRUCTIONS

- Write your Name on each sheet of paper used or the front of the booklet used.
- Answer **all** the questions.
- You **may** use a graphical calculator in this paper.

INFORMATION

- The number of marks is given in brackets [] at the end of each question or part-question.
- 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.
- Final answers should be given to a degree of accuracy appropriate to the context.
- Unless otherwise specified, the value of g should be taken to be exactly 9.8 $\mathrm{m\,s^{-2}}$.
- The total number of marks for this paper is **72**.

Section A (36 marks)

1 Two forces, $\mathbf{F_1}$ and $\mathbf{F_2}$ are given by $\mathbf{F_1} = \begin{pmatrix} 3 \\ 2 \end{pmatrix}$ and $\mathbf{F_2} = \begin{pmatrix} -1 \\ 3 \end{pmatrix}$.

(i) Write down the sum of these two forces, $\mathbf{F_1} + \mathbf{F_2}$.

Find also the magnitude of $\mathbf{F_1} + \mathbf{F_2}$. [3]

(ii) Find p and q such that $\mathbf{F_1} + p\mathbf{F_2} = \begin{pmatrix} 0 \\ q \end{pmatrix}$. [4]

2 A block of mass 12 kg is held at rest on a smooth, horizontal table. Light, inextensible strings are attached to the sides of the box; they run parallel to the table and then over smooth pulleys at either side of the table. Objects of mass of 6 kg and 8 kg hang from the strings. Fig. 2 shows this system.

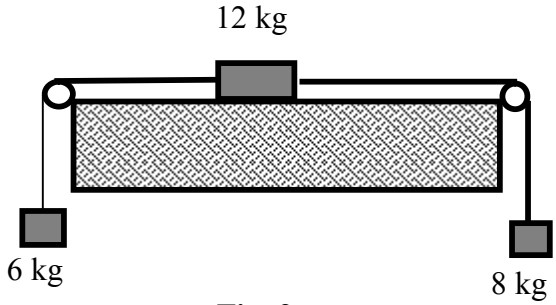

Fig. 2

The block is released and moves from rest.

(i) Draw three force diagrams, showing all the forces acting on the block and on each of the two hanging masses. [3]

(ii) Find the acceleration of the system. [3]

(iii) Find also the tensions in the two strings. [2]

3 A car is accelerating uniformly along a straight, horizontal road. As it passes a point A it is travelling at 8 m s^{-1}. When it later passes a point B it is travelling at 12 m s^{-1} in the same direction. The points A and B are 40 metres apart.

(i) Find the acceleration of the car. [2]

(ii) The car continues to accelerate at the same rate. Find the time it will take to cover the next 26 metres. [4]

4 A block of mass 5 kg hangs in equilibrium. It is held by two strings, AB and AC, fixed to a horizontal ceiling, as shown in Fig. 4. The strings make angles of 40^o and 60^o with the horizontal. The tension in the string AB is T_1 N and that in AC is T_2 N.

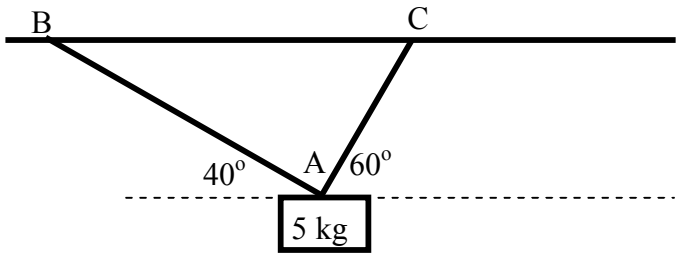

Fig. 4

(i) By considering the horizontal components of the forces acting on the block, show that $T_2 = 1.53T_1$, correct to 3 significant figures. [3]

(ii) By considering the vertical equilibrium of the block, find a second equation connecting T_1 and T_2.

Hence find the values of T_1 and T_2 correct to 2 decimal places. [5]

5 In this question distances are measured in metres and positions are expressed relative to an origin O. The unit vectors **i** and **j** are in the directions east and north respectively.

A radio-controlled model boat is put in a pond at the point O with initial velocity $0.6\mathbf{j}$ m s^{-1} and its velocity after 15 seconds is measured as $(10.5\mathbf{i} - 0.9\mathbf{j})$ m s^{-1}. The acceleration of the boat is modelled as constant.

(i) Show that the acceleration of the boat is $(0.7\mathbf{i} - 0.1\mathbf{j})$ m s^{-2}. [3]

(ii) Find an expression for the position of the boat at time t seconds after the start in the form $s = \mathrm{f}(t)\mathbf{i} + \mathrm{g}(t)\mathbf{j}$. [2]

(iii) For what value of t is the boat north-east of O?

[2]

Section B (36 marks)

6 A skateboarder sets off from rest down a hill. Her speed, t seconds after setting off, is v m s^{-1} where

$$v = 0.24t^2 - 0.02t^3.$$

This formula applies until she comes to rest again.

(i) Find an expression for her acceleration at time t. [2]

(ii) Calculate

(*A*) her acceleration when $t = 0$ and when $t = 12$, [2]

(*B*) the time when she comes to rest again, [2]

(*C*) her maximum speed. [2]

(iii) **(*A*)** Find an expression for the distance she has travelled at time t, given that the distance is measured from the moment that she sets off. [4]

(*B*) Calculate the distance she has travelled by the time she comes to rest again. [2]

(iv) Sketch a speed-time graph for $0 \leq t \leq 12$. Indicate how the distance travelled is related to this graph. [4]

7 In a game of cricket, a batsman hits a ball with initial velocity $18\sqrt{2}$ m s^{-1} at an angle of 45° to the horizontal from a point 1 metre above the ground. The origin, O, is on the ground vertically below the point where the ball is hit.

(i) Find expressions for the horizontal and vertical components of velocity and displacement of the ball from O, t seconds after it has been hit. [7]

(ii) Find the time when the ball hits the ground and its distance from O at this time. [6]

The boundary line is 63 metres from O.

(iii) Find the height of the ball when it crosses the boundary line. Hence determine whether a fielder, standing on the boundary line, can catch the ball if he can reach up to 3 metres from the ground. [5]