Advanced Subsidiary General Certificate of Education
Advanced General Certificate of Education

MEI STRUCTURED MATHEMATICS 4762

Mechanics 2

Tuesday	**7 JUNE 2005**	Afternoon	1 hour 30 minutes

Additional materials:
  Answer booklet
  Graph paper
  MEI Examination Formulae and Tables (MF2)

TIME   1 hour 30 minutes

INSTRUCTIONS TO CANDIDATES

·   Write your name, centre number and candidate number in the spaces provided on the answer booklet.

·   Answer **all** the questions.

·   You are permitted to use a graphical calculator in this paper.

INFORMATION FOR CANDIDATES

·   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.

·   The acceleration due to gravity is denoted by g m s^{-2}. Unless otherwise instructed, when a numerical value is needed, use g = 9.8.

·   The total number of marks for this paper is 72.

This question paper consists of 5 printed pages and 3 blank pages.

1 **(a)** Roger of mass $70\,\text{kg}$ and Sheuli of mass $50\,\text{kg}$ are skating on a horizontal plane containing the standard unit vectors **i** and **j**. The resistances to the motion of the skaters are negligible. The two skaters are locked in a close embrace and accelerate from rest until they reach a velocity of $2\mathbf{i}\,\text{ms}^{-1}$, as shown in Fig. 1.1.
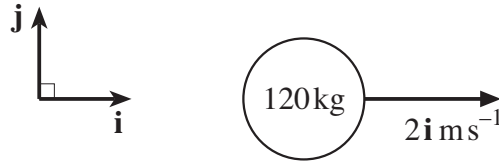
Fig. 1.1

   (i) What impulse has acted on them? [1]

During a dance routine, the skaters separate on three occasions from their close embrace when travelling at a constant velocity of $2\mathbf{i}\,\text{ms}^{-1}$.

  (ii) Calculate the velocity of Sheuli after the separation in the following cases.

      (*A*) Roger has velocity $\mathbf{i}\,\text{ms}^{-1}$ after the separation.

      (*B*) Roger and Sheuli have equal speeds in opposite senses after the separation, with Roger moving in the **i** direction.

      (*C*) Roger has velocity $4(\mathbf{i}+\mathbf{j})\,\text{ms}^{-1}$ after the separation. [6]

  (b) Two discs with masses $2\,\text{kg}$ and $3\,\text{kg}$ collide directly in a horizontal plane. Their velocities just before the collision are shown in Fig. 1.2. The coefficient of restitution in the collision is 0.5.
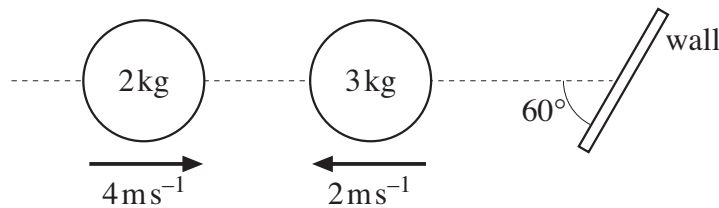
Fig. 1.2

   (i) Calculate the velocity of each disc after the collision. [6]

The disc of mass $3\,\text{kg}$ moves freely after the collision and makes a perfectly elastic collision with a smooth wall inclined at $60°$ to its direction of motion, as shown in Fig. 1.2.

  (ii) State with reasons the speed of the disc and the angle between its direction of motion and the wall after the collision. [4]

2   A car of mass $850\,\text{kg}$ is travelling along a road that is straight but not level.

On one section of the road the car travels at constant speed and gains a vertical height of $60\,\text{m}$ in 20 seconds. Non-gravitational resistances to its motion (e.g. air resistance) are negligible.

   (i) Show that the average power produced by the car is about $25\,\text{kW}$. [2]

On a *horizontal* section of the road, the car develops a constant power of exactly $25\,\text{kW}$ and there is a constant resistance of $800\,\text{N}$ to its motion.

   (ii) Calculate the maximum possible steady speed of the car. [3]

   (iii) Find the driving force and acceleration of the car when its speed is $10\,\text{m s}^{-1}$. [3]

When travelling along the horizontal section of road, the car accelerates from $15\,\text{m s}^{-1}$ to $20\,\text{m s}^{-1}$ in 6.90 seconds with the same constant power and constant resistance.

   (iv) By considering work and energy, find how far the car travels while it is accelerating. [6]

When the car is travelling at $20\,\text{m s}^{-1}$ up a constant slope inclined at $\arcsin(0.05)$ to the horizontal, the driving force is removed. Subsequently, the resistance to the motion of the car remains constant at $800\,\text{N}$.

   **(v)** What is the speed of the car when it has travelled a further $105\,\text{m}$ up the slope? [5]

3 Fig. 3.1 shows an object made up as follows. ABCD is a uniform lamina of mass 16 kg. BE, EF, FG, HI, IJ and JD are each uniform rods of mass 2 kg. ABCD, BEFG and HIJD are squares lying in the same plane. The dimensions in metres are shown in the figure.
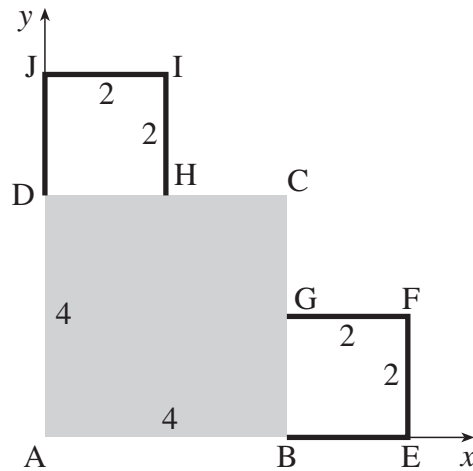
Fig. 3.1

(i) Find the coordinates of the centre of mass of the object, referred to the axes shown in Fig. 3.1. [5]

The rods are now re-positioned so that BEFG and HIJD are perpendicular to the lamina, as shown in Fig. 3.2.
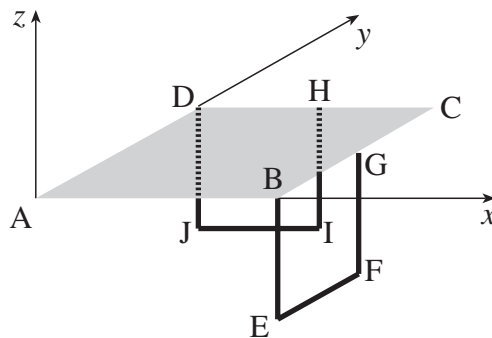
Fig. 3.2

(ii) Find the x-, y- and z-coordinates of the centre of mass of the object, referred to the axes shown in Fig. 3.2. Calculate the distance of the centre of mass from A. [8]

The object is now freely suspended from A and hangs in equilibrium with AC at $\alpha°$ to the vertical.

(iii) Calculate α. [4]

4 **(a)** A framework is made from light rods AB, BC and CA. They are freely hinged to each other at A, B and C and to a vertical wall at A. The hinge at B rests on a smooth, horizontal support. The rod AC is horizontal. A vertical load of L N acts at C. This information is shown in Fig. 4.1 together with the dimensions of the framework and the external forces U N, V N and R N acting on the framework.
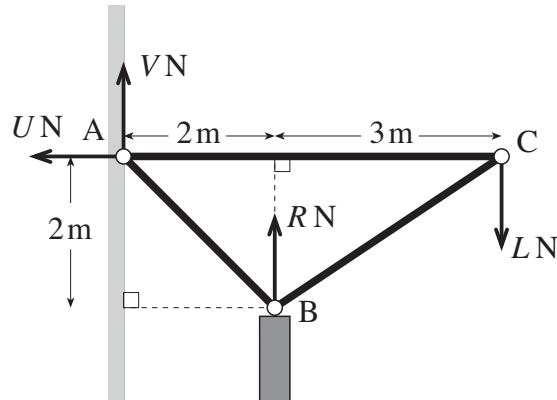

Fig. 4.1

   (i) Show that $R = 2.5L$, $U = 0$ and $V = -1.5L$. [4]

   (ii) Calculate the internal forces in the rods AB, AC and BC in terms of L, stating whether each of these rods is in tension or thrust (compression). [8]

(b) Fig. 4.2 shows a plank of weight W resting at the points A and B on two fixed supports. The plank is at an angle θ to the horizontal. Its centre of mass, G, is such that AG is 2 m and GB is 1 m.
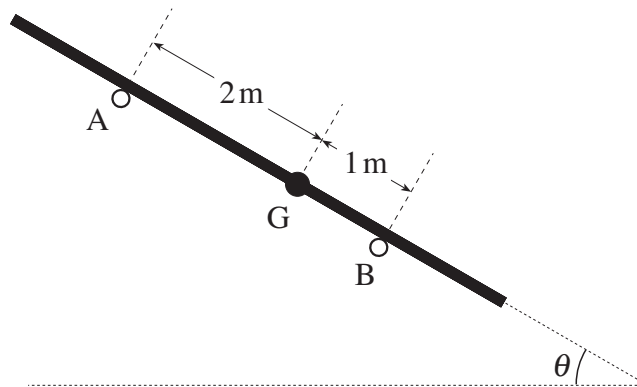

Fig. 4.2

The contact between the plank and the support at A is rough, but that at B is smooth. The plank is on the point of slipping.

   (i) Draw a diagram showing all the forces acting on the plank. [1]

   (ii) By taking moments about a suitable point, find an expression in terms of W and θ for the normal reaction at A of the support on the plank. [3]

   (iii) Find an expression in terms of θ for the coefficient of friction between the plank and the rough support. [3]

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