OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced Subsidiary General Certificate of Education
Advanced General Certificate of Education

MEI STRUCTURED MATHEMATICS 2608/1

Mechanics 2

Tuesday **3 JUNE 2003** Afternoon 1 hour 20 minutes

Additional materials:
Answer booklet
Graph paper
MEI Examination Formulae and Tables (MF12)

TIME 1 hour 20 minutes

INSTRUCTIONS TO CANDIDATES

- Write your Name, Centre Number and Candidate Number in the spaces provided on the answer booklet.
- Answer **all** questions.
- You are permitted to use a graphical calculator in this paper.

INFORMATION FOR CANDIDATES

- The allocation 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.
- Take $g = 9.8\,\text{m}\,\text{s}^{-2}$ unless otherwise instructed.
- The total number of marks for this paper is 60.

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

1 My cat Jeoffry has a mass of 4 kg and is sitting on rough ground near a sledge of mass 8 kg. The sledge is on smooth, horizontal ice.

Initially, the sledge is at rest and Jeoffry jumps and lands on it when moving with a horizontal speed of 2.25 m s^{-1} parallel to the runners of the sledge. On landing, Jeoffry grips the sledge with his claws so that he does not move relative to the sledge in the subsequent motion.

(i) Show that, after Jeoffry lands on it, the sledge moves off with a speed of 0.75 m s^{-1}. [2]

With the sledge and Jeoffry moving at 0.75 m s^{-1}, the sledge collides *directly* with a stationary stone of mass 3 kg. The stone may move freely on the ice. The coefficient of restitution in the collision is $\frac{4}{15}$.

(ii) Calculate the speed of the sledge and Jeoffry after the collision. [6]

In a new situation, Jeoffry is initially at rest on the sledge when it is stationary. He then walks from the back to the front of the sledge.

(iii) Giving a brief reason for your answer, describe the motion of the common centre of mass of Jeoffry and the sledge during his walk. [2]

Jeoffry is sitting on the sledge when it is stationary. He now jumps off. After he has left the sledge, his horizontal speed relative to the sledge is 3 m s^{-1}.

(iv) With what speed is the sledge travelling after Jeoffry leaves it? [4]

[Total 14]

2 A roller-coaster car at a fairground has a mass of 380 kg.

At the start of a ride, the car is pulled up a slope at a steady speed of $v\,\mathrm{m\,s^{-1}}$ by a force of 2160 N. The power of the force is 3780 W.

(i) Calculate the value of v. [2]

The pulling force is removed. The car now moves under gravity and against resistances to its motion.

At a point P, the car is 20 m above horizontal ground and is travelling at $2\,\mathrm{m\,s^{-1}}$. It then travels 100 m along the track in 20 seconds to a point Q that is 5 m above the ground, as shown in Fig. 2. At Q it is travelling at $10\,\mathrm{m\,s^{-1}}$.

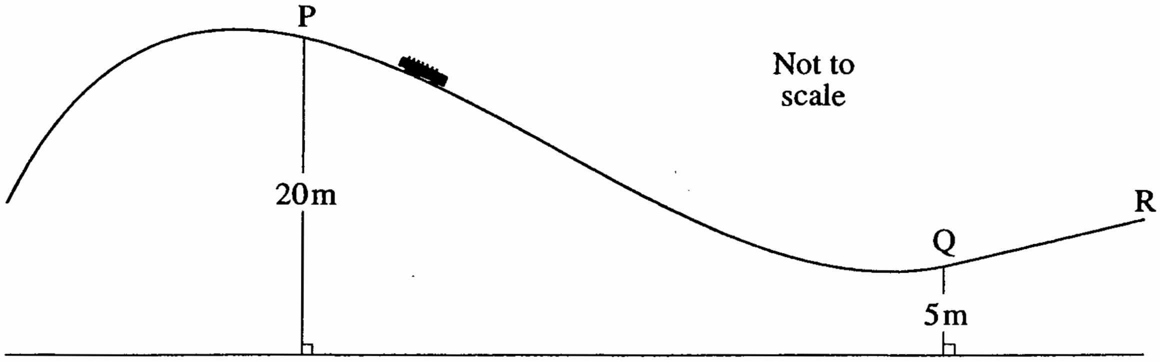


Fig. 2

(ii) For the motion from P to Q, calculate

(*A*) the change in the kinetic energy of the car,

(*B*) the change in the gravitational potential energy of the car,

in each case stating whether the change is a gain or loss. [5]

During the motion from P to Q, the average braking force over the distance is 150 N.

(iii) Show that the total work done against the resistances to motion *other than braking* is 22 620 J. [3]

At the point Q, the car goes up a uniform slope at 20° to the horizontal and comes instantaneously to rest at the point R. The average resistances to motion and the average braking force from Q to R are the same as in the motion from P to Q.

(iv) Calculate the vertical distance of R above Q. [6]

[Total 16]

3 An injured climber is tied to a stretcher AB of length 2.5 m. The total mass of the climber and the stretcher is 90 kg.

In each part of this question you should make the following modelling assumptions:

- the centre of mass, G, of the stretcher with climber is a distance 1.875 m from the end A of the stretcher, as shown in Fig. 3.1,
- all the forces acting on the system are in the same vertical plane.

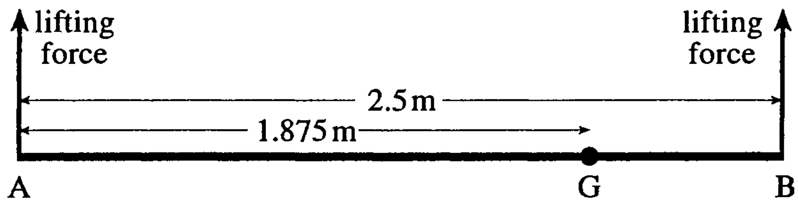


Fig. 3.1

In one situation, the lifting forces are each vertically upwards at the ends A and B of the stretcher, and the stretcher is held in horizontal equilibrium, as shown in Fig. 3.1.

(i) Calculate the values of the lifting forces. [5]

In another situation, the end A of the stretcher is resting on rough horizontal ground. The stretcher is held in equilibrium at 15° to the horizontal by a force at B that is at 65° to the horizontal, as shown in Fig. 3.2.

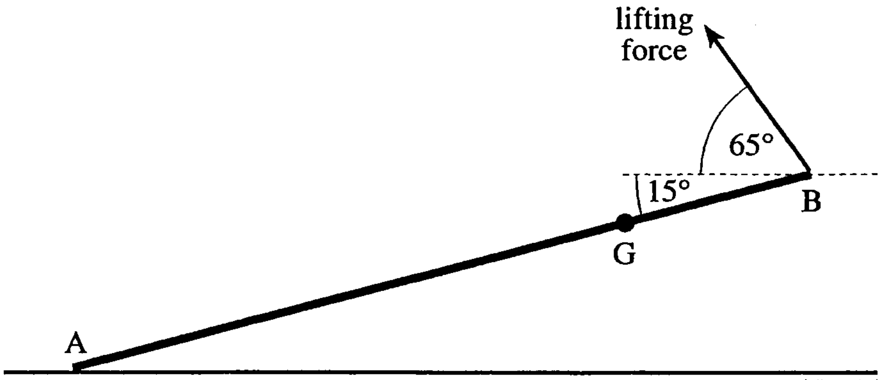


Fig. 3.2

(ii) Show that the lifting force is 649 N, correct to three significant figures. [6]

(iii) The stretcher is on the point of sliding. Calculate the coefficient of friction between the end of the stretcher and the ground. [5]

[Total 16]

4

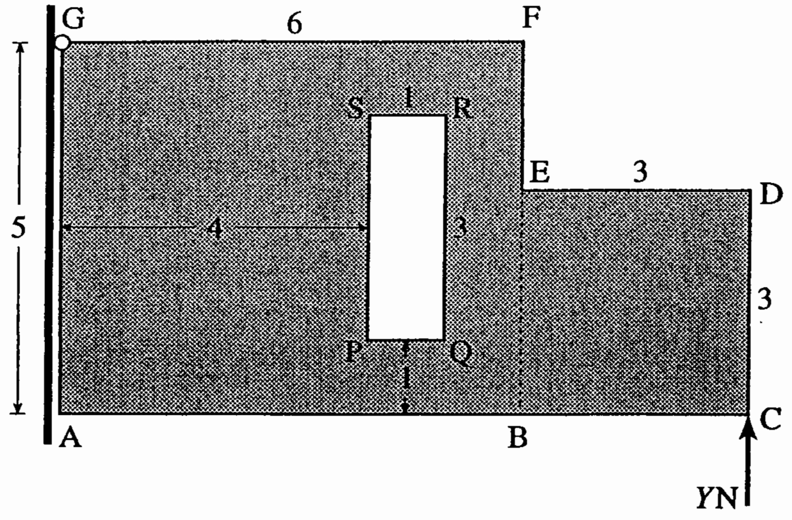


Fig. 4.1

Fig. 4.1 shows a pre-fabricated section of a building ABCDEFG. This section, which is shaded, is a lamina of uniform material made up of a rectangle ABFG (with a rectangle PQRS cut out) and a square BCDE. The dimensions of the section are shown in Fig. 4.1. The lengths are in metres.

The section is freely attached to a wall at G and is held in equilibrium by a vertical force Y N at C. The weight of the shaded section is 3150 N. AC is horizontal.

(i) Calculate the horizontal distance from the line AG of the centre of mass of the shaded section. [4]

(ii) Show that $Y = 1400$. [3]

The support at C is provided by a framework of light rods CH, HI and IC that are freely pin-jointed at C, H and I. The framework rests at H and I on smooth horizontal supports. HI is horizontal. The framework is shown in Fig. 4.2. Again the lengths are in metres.

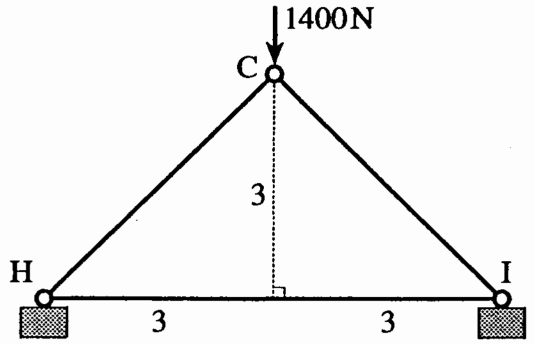


Fig. 4.2

(iii) Draw a diagram showing all of the forces acting on the pin-joints, including the internal forces in the rods.

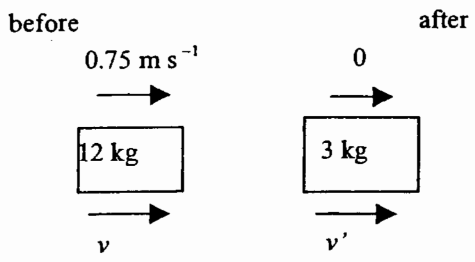
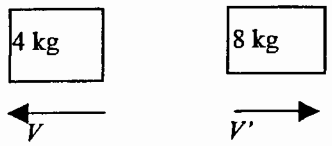
Calculate the normal reaction of the support on the framework at H.

Calculate also the internal forces in the rods CH and HI, stating whether these are tensions or thrusts. [7]

[Total 14]

Mark Scheme

Solutions and mark scheme

Q 1		Mark		
(i)	$4 \times 2.25 + 0 = 12v$	M1	Use of PCLM	
	$v = 0.75$ so 0.75 m s^{-1}	E1		2
(ii)		B1	Award if final answer correct	
	PCLM $\longrightarrow$			
	$9 = 12v + 3v'$ so $3 = 4v + v'$	M1 A1	Use of PCLM. Allow coalescence. Any form	
	NEL $\longrightarrow$			
	$\dfrac{v'-v}{0-0.75} = -\dfrac{4}{15}$ so $v'-v = 0.2$	M1 A1	Use of NEL Any form	
	Solving $v = 0.56$ so 0.56 m s^{-1} (in original direction)	A1	Cao. Direction not required.	6
(iii)	Does not move No horizontal external force acts on the cat-sledge system	B1 B1	No external force or momentum is zero or…	2
(iv)				
	PCLM	M1	Dealing with relative motion	
	$4V = 8V'$	A1		
	$V + V' = 3$	B1		
	Solving $V' = 1$ so 1m s^{-1}	A1		4
		Tot 14		

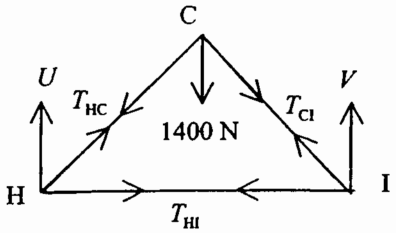
Solutions and mark scheme

Q 2		Mark		
(i)	$P = Fv$ so $3780 = 2160v$ and $v = 1.75$	M1 A1	Use of $P = Fv$	2
(ii) (A)	$\frac{1}{2}\times 380\times 10^2 - \frac{1}{2}\times 380\times 2^2$ $= 18240$ J (Gain)	M1 A1	$0.5mv^2$ used Gain not required	
(B)	$380\times 9.8\times 15$ $= 55860$ J (Loss)	M1 A1	mgh used Loss not required	
		B1	Gain/loss both correct	5
(iii)	$55860 - 18240 - 150\times 100$	M1 B1	All terms present (accept wrong signs) 15000. Accept WW.	
	$= 22620$ J	E1		3
(iv)	**Either** $0.5\times 380\times 10^2$ $= 380\times 9.8\times h + \left(150 + \frac{22620}{100}\right)\times \frac{h}{\sin 20}$	M1 B1 B1 A1 A1	Use of WE inc GPE, KE and one resistance term 226.2 (FT their value for WD) $h/\sin 20$ Total WD against resistances correct. All terms correct but allow sign errors.	
	$h = 3.9386\ldots$ so 3.94 m (3 s. f.)	A1	cao	6
	or			
	$-380\times 9.8\sin 20 - 150 - 226.2 = 380a$	M1 B1 A1	Use of N2L with weight and at least one resistance term For 226.2 N All correct. Accept LHS terms all + ve	
	$a = -4.34179\ldots$	A1		
	$0^2 = 100 + 2\times -4.34179\ldots\times s$	F1	Accept lack of consistency with signs. FT wrong a.	
	$h = s\sin 20 = 3.9386\ldots$ so 3.94 m (3 s. f.)	A1	cao	
		Tot 16		

Solutions and mark scheme

Q 3		Mark		
(i)	a.c. moments about A			
	$T_B \times 2.5 - 90 \times 9.8 \times 1.875 = 0$	M1 A1	Attempt at moments	
	$T_B = 661.5$ so 661.5 N	A1		
	Resolve vert	M1	Resolve or moments about an appropriate point	
	$T_A + T_B = 90 \times 9.8$			
	$T_A = 220.5$ so 220.5 N	A1	[If g omitted; SC award M1 A0 A0 M1 F1 maximum]	5
(ii)	a.c. moments about A $T \times 2.5 \cos 10$ $= 90g \times 1.875 \cos 15$	M1 M1 A1 A1 A1	Moments about A Attempt at resolution. Allow $\sin \leftrightarrow \cos$ LHS; correct component of force or displacement RHS; correct component of weight or displacement All correct	
	$T = 648.816..$ so 649 N (3 s. f.)	E1	[If g omitted; SC award M1 M1 A1 F1 A0 E0 maximum]	6
(iii)	$R = 90g - T \cos 25$	M1	Attempt at R including a cpt of T	
	$= 293.9721\ldots$	A1		
	$F = T \cos 65 = 274.201\ldots$	B1	Allow for $T \cos 65$ seen	
	$\mu = \dfrac{274.201\ldots}{293.9721\ldots} = 0.9327..$	M1	Use of $F = \mu R$	
	so 0.933 (3 s. f.)	A1	cao	5
		Tot 16		

Solutions and mark scheme

Q 4		Mark		
(i)	Let distance be x $(30-3+9)\bar{x} = 30\times3 - 3\times4.5 + 9\times7.5$ $\bar{x} = 4$	M1 A1 A1 A1	Correct method for c.m. Masses correct At least 2 x values correct [Award 4/4 for $\bar{x}=4$ seen WW]	4
(ii)	a.c. moments about G $9Y - 4\times3150 = 0$ $Y = 1400$ so 1400 N	M1 A1 E1	Attempt at moments FT Clearly shown	3
(iii)	 $U = 700$	B1 B1	All forces present and suitably labelled $U = V$ accepted without reason	
	At H ↑ $700 + T_{HC}\cos 45 = 0$ $T_{HC} = -700\sqrt{2}$ At H → $T_{HC}\cos 45 + T_{HI} = 0$ $T_{HI} = 700$ so HC $700\sqrt{2}$ N thrust HI 700 N tension	M1 A1 A1 F1 F1 Tot 14	Attempt at equilibrium at a pin-joint At least one equation correct T/C correctly interpreted	7

Examiner’s Report

2608 Mechanics 2

General Comments

This paper appeared to be accessible to the majority of candidates; there were few who could not attempt some part of each question and very few who showed signs of time pressure. The standard of presentation of scripts was not as high as in some recent years with a large minority of candidates failing to include sufficient steps when *showing* and others failing to make clear the method of solution that they were applying. Many candidates did not use diagrams to illustrate or inform their answers and so errors with signs were quite common.

Comments on Individual Questions

Q.1 Momentum and impact

This was the least well answered question on the paper with relatively few candidates scoring full marks. The modal mark was about 8 with these marks being gained on the first two parts of the question.

Lack of a diagram led to some sign errors and inconsistent equations in part (ii) but most could establish the correct answer.

Few candidates could provide the explanation required in part (iii). Many ignored the question asked and did not say what would happen to the common centre of mass; others failed to give any reason for their answer. Very few appreciated that the common centre of mass does not move because no external horizontal force acts on the system.

Only a few candidates could cope with the concept of relative velocity required in part (iv).

(ii) 0.56 ms^{-1}; (iv) 1 ms^{-1}.

Q.2 Work-Energy

It was pleasing to see a much higher proportion of correct answers to this question than have been seen to similar questions in the past. Very few attempted to use Newton's second law and the *uvast* results and almost all of the candidates obtained the correct solutions to parts (i) and (ii).

A high proportion of the candidates correctly applied what they had already calculated to establish the answer to part (iii).

Part (iv) proved more challenging for many. It was common to see at least one resistance term missing from the work-energy equation and a number of candidates used the same letter to stand for the vertical distance moved and the distance moved up the slope. The simple trigonometry required here was too difficult for quite a few candidates. However, many candidates gained some credit for their efforts in this part.

(i) 1.75 ms^{-1}; (ii) 18240 J gain; 55860 J loss; (iv) 3.94 m.

Q.3 Forces and moments

This question was done well by the majority of the candidates.

Many scored full marks in part (i) although a few used mass instead of weight.

In part (ii), the majority of candidates recognised the need to take moments but some chose to do this at a point other than A and did not include all the relevant forces. Others found it difficult to establish the correct components of distance (or force) required. Many realised that they had made a mistake, recovered and finally obtained the given result.

Part (iii) was well done by many candidates. Some assumed that $\mu = \tan\lambda$ for some angle λ to be found on the diagram, as if they were dealing with an object about to slide down an inclined plane. Others failed correctly to calculate the normal reaction to the plane, assuming it to be 90g.

(i) 661.5 N; 220.5 N; (iii) 0.933 (3s.f.).

Q.4 Centres of Mass

There were many completely correct solutions to this question.

The concepts involved in establishing the centre of mass in part (i) were well understood by most of the candidates although some arithmetic errors did creep in.

Part (ii) was equally well done.

A large number of candidates failed to obtain any credit for the diagram requested in part (iii). A common mistake was to omit the labels. Many candidates appreciated that, because of symmetry, the forces at H and I should be equal and that the internal forces in CH and CI would also be equal. The need to consider the equilibrium at a pin-joint was understood by almost all of the candidates but, mainly because of sign errors, many failed to obtain the correct answers.

(i) 4 m; (iii) 700 N; HC $700\sqrt{2}$ N thrust; HI 700 N tension.