UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education Advanced Level

MATHEMATICS **9709/53**

Paper 5 Mechanics 2 **(M2)** **May/June 2013**

1 hour 15 minutes

Additional Materials: Answer Booklet/Paper
Graph Paper
List of Formulae (MF9)

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READ THESE INSTRUCTIONS FIRST

If you have been given an Answer Booklet, follow the instructions on the front cover of the Booklet.
Write your Centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** the questions.
Give non-exact numerical answers correct to 3 significant figures, or 1 decimal place in the case of angles in degrees, unless a different level of accuracy is specified in the question.
Where a numerical value for the acceleration due to gravity is needed, use $10\,\mathrm{m\,s^{-2}}$.
The use of an electronic calculator is expected, where appropriate.
You are reminded of the need for clear presentation in your answers.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.
The total number of marks for this paper is 50.
Questions carrying smaller numbers of marks are printed earlier in the paper, and questions carrying larger numbers of marks later in the paper.

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1 A particle P is projected with speed $15\,\mathrm{m\,s^{-1}}$ at an angle of $60°$ above the horizontal. Find the direction of motion of P at the instant $0.9\,\mathrm{s}$ after projection. [4]

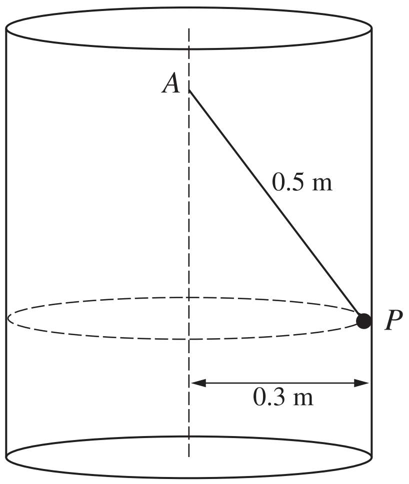
2 A particle P of mass $0.3\,\mathrm{kg}$ is attached to one end of a light elastic string of natural length $0.6\,\mathrm{m}$ and modulus of elasticity $45\,\mathrm{N}$. The other end of the string is attached to a fixed point O. The particle P is released from rest at O and falls vertically. Find the extension of the string when P is at its lowest position. [4]

3 A ball is projected horizontally with speed $5\,\mathrm{m\,s^{-1}}$ from the top of a tower which is $30\,\mathrm{m}$ high. The tower stands on horizontal ground.

(i) Find the speed and direction of motion of the ball when it reaches the ground. [3]

(ii) Calculate the distance from the foot of the tower to the point where the ball reaches the ground. [3]

4



A smooth hollow cylinder of internal radius $0.3\,\mathrm{m}$ is fixed with its axis vertical. One end of a light inextensible string of length $0.5\,\mathrm{m}$ is fixed to a point A on the axis. The other end of the string is attached to a particle P of mass $0.2\,\mathrm{kg}$ which moves in a horizontal circle on the surface of the cylinder (see diagram).

(i) Find the tension in the string. [3]

(ii) Find the least angular speed of P for which the motion is possible. [2]

(iii) Calculate the magnitude of the force exerted on P by the cylinder given that the speed of P is $1.8\,\mathrm{m\,s^{-1}}$. [3]

5 One end of a light elastic string S_1 of modulus of elasticity 20 N and natural length 0.5 m is attached to a fixed point O. The other end of S_1 is attached to a particle P of mass 0.4 kg. P hangs in equilibrium vertically below O.

(i) Find the distance OP. [2]

The opposite ends of a light inextensible string S_2 of length l m are now attached to O and P respectively. The elastic string S_1 remains attached to O and P. The particle P hangs in equilibrium vertically below O.

(ii) Find the tension in the inextensible string S_2 for each of the following cases:

(a) $l < 0.5$;

(b) $l > 0.6$;

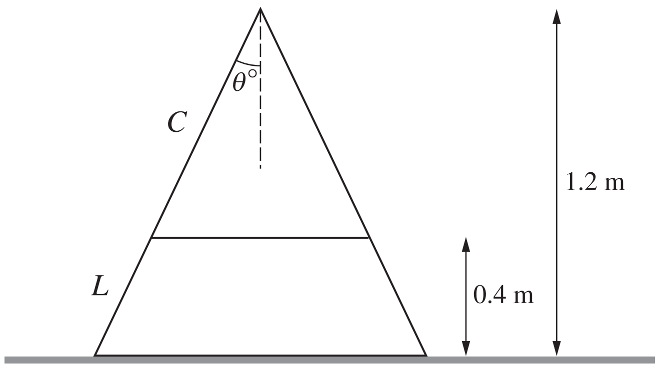
(c) $l = 0.54$.

[4]

In the case $l = 0.54$, the inextensible string S_2 suddenly breaks and P begins to descend vertically.

(iii) Calculate the greatest speed of P in the subsequent motion. [3]

6



A uniform solid cone of height 1.2 m and semi-vertical angle $\theta°$ is divided into two parts by a cut parallel to and 0.4 m from the circular base. The upper conical part, C, has weight 16 N, and the lower part, L, has weight 38 N. The two parts of the solid rest in equilibrium with the larger plane face of L on a horizontal surface and the smaller plane face of L covered by the base of C (see diagram).

(i) Calculate the distance of the centre of mass of L from its larger plane face. [3]

An increasing horizontal force is applied to the vertex of C. Equilibrium is broken when the magnitude of this force first exceeds 4 N, and C begins to slide on L.

(ii) By considering the forces on C,

(a) find the coefficient of friction between C and L, [1]

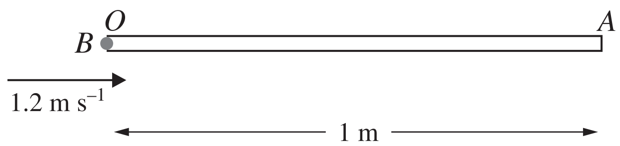
(b) show that $\theta > 14.0$, correct to 3 significant figures. [2]

C is removed and L is placed with its curved surface on the horizontal surface.

(iii) Given that L is on the point of toppling, calculate θ. [3]

7 A small ball B of mass 0.2 kg moves in a narrow fixed smooth cylindrical tube OA of length 1 m, closed at the end A. When the ball has displacement x m from O, it has velocity $v\,\mathrm{m\,s^{-1}}$ in the direction OA and experiences a resisting force of magnitude $\dfrac{k}{1-x}$ N.

(i)



The tube is fixed in a horizontal position and B is projected from O towards A with velocity $1.2\,\mathrm{m\,s^{-1}}$ (see diagram). Given that B comes to instantaneous rest after travelling 0.55 m, show that $k = 0.1803$, correct to 4 significant figures. [6]

(ii) The tube is now fixed in a vertical position with O above A. The ball B is released from rest at O. Calculate the speed of B after it has descended 0.1 m. [4]