UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education Advanced Level

MATHEMATICS **9709/53**

Paper 5 Mechanics 2 **(M2)** **May/June 2012**

1 hour 15 minutes

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

* 5 5 9 5 4 6 6 9 4 9 *

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 $10\,\text{m}\,\text{s}^{-2}$.
The use of an electronic calculator is expected, where appropriate.
You are reminded of the need for clear presentation in your answers.

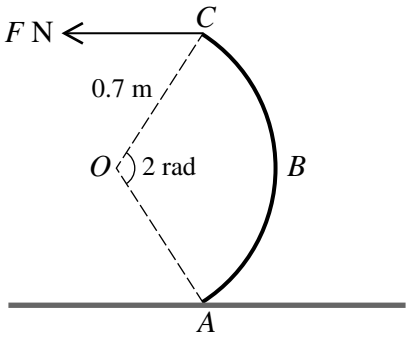
At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.
The total number of marks for this paper is 50.
Questions carrying smaller numbers of marks are printed earlier in the paper, and questions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

This document consists of **3** printed pages and **1** blank page.

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1 A particle P is projected with speed $25\,\text{m s}^{-1}$ at an angle of 30° above the horizontal from a point O on horizontal ground. Calculate the distance OP at the instant 2 s after projection. [4]

2



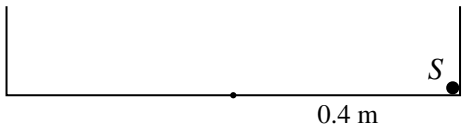
The diagram shows a uniform object ABC of weight 3 N in the form of an arc of a circle with centre O and radius 0.7 m. The angle AOC is 2 radians. The object rests in equilibrium with A on a horizontal surface and C vertically above A. Equilibrium is maintained by a horizontal force of magnitude F N applied at C in the plane of the object. Calculate F. [4]

3 A particle P of mass 0.2 kg is projected horizontally from a fixed point O, and moves in a straight line on a smooth horizontal surface. A force of magnitude $0.4x$ N acts on P in the direction PO, where x m is the displacement of P from O.

(i) Given that P comes to instantaneous rest when $x = 2.5$, find the initial kinetic energy of P. [4]

(ii) Find the value of x on the first occasion when the speed of P is $2\,\text{m s}^{-1}$. [2]

4



A small sphere S of mass m kg is moving inside a fixed smooth hollow cylinder whose axis is vertical. S moves with constant speed in a horizontal circle of radius 0.4 m and is in contact with both the plane base and the curved surface of the cylinder (see diagram).

(i) Given that the horizontal and vertical forces exerted on S by the cylinder have equal magnitudes, calculate the speed of S. [3]

S is now attached to the centre of the base of the cylinder by a horizontal light elastic string of natural length 0.25 m and modulus of elasticity 13 N. The sphere S is set in motion and moves in a horizontal circle with constant angular speed $\omega\,\text{rad s}^{-1}$ and is in contact with both the plane base and the curved surface of the cylinder.

(ii) It is given that the magnitudes of the horizontal and vertical forces exerted on S by the cylinder are equal if $\omega = 8$. Calculate m. [3]

(iii) For the value of m found in part **(ii)**, find the least possible value of ω for the motion. [2]

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5 A light elastic string has natural length 3 m and modulus of elasticity 45 N. A particle P of mass 0.6 kg is attached to the mid-point of the string. The ends of the string are attached to fixed points A and B which lie on a line of greatest slope of a smooth plane inclined at 30° to the horizontal. The distance AB is 4 m, and A is higher than B.

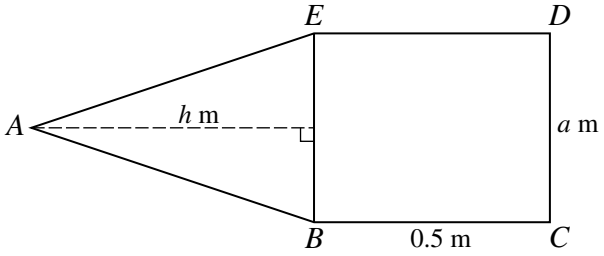
(i) Calculate the distance AP when P rests on the slope in equilibrium. [3]

P is released from rest at the point between A and B where $AP = 2.5$ m.

(ii) Find the maximum speed of P. [4]

(iii) Show that P is at rest when $AP = 1.6$ m. [2]

6



A uniform lamina $ABCDE$ consists of a rectangle $BCDE$ and an isosceles triangle ABE joined along their common edge BE. For the triangle, $AB = AE$, $BE = a$ m and the perpendicular height is h m. For the rectangle, $BC = DE = 0.5$ m and $CD = BE = a$ m (see diagram).

(i) Show that the distance in metres of the centre of mass of the lamina from BE towards CD is

$$\frac{3 - 4h^2}{12 + 12h}.$$ [4]

The lamina is freely suspended at E and hangs in equilibrium.

(ii) Given that DE is horizontal, calculate h. [2]

(iii) Given instead that $h = 0.5$ and AE is horizontal, calculate a. [3]

7 The equation of the trajectory of a projectile is $y = 0.6x - 0.017x^2$, referred to horizontal and vertically upward axes through the point of projection.

(i) Find the angle of projection of the projectile, and show that the initial speed is $20\ \text{m s}^{-1}$. [3]

(ii) Find the speed and direction of motion of the projectile when it is at a height of 5.2 m above the level of the point of projection for the second time. [7]

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