Cambridge International A Level

Cambridge International Examinations
Cambridge International Advanced Level

MATHEMATICS **9709/51**

Paper 5 Mechanics 2 **(M2)** **May/June 2015**

1 hour 15 minutes

* 8 4 4 6 3 0 9 0 3 0 *

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

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 an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

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 **4** printed pages.

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1 One end of a light elastic string of natural length 0.7 m is attached to a fixed point A on a smooth horizontal surface. The other end of the string is attached to a particle P of mass 0.3 kg which is held at a point B on the horizontal surface, where $AB = 1.2$ m. It is given that P is released from rest at B and that when $AP = 0.9$ m, the particle has speed $4\,\text{m}\,\text{s}^{-1}$. Calculate the modulus of elasticity of the string. [3]

2 A stone is projected from a point O on horizontal ground. The equation of the trajectory of the stone is

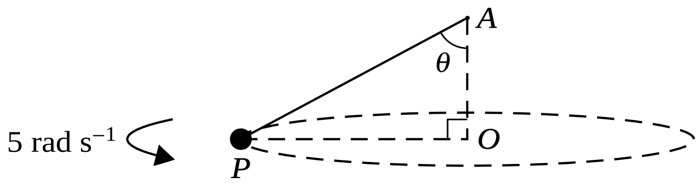
$$y = 1.2x - 0.15x^2,$$

where x m and y m are respectively the horizontal and vertically upwards displacements of the stone from O. Find

(i) the greatest height of the stone, [2]

(ii) the distance from O of the point where the stone strikes the ground. [2]

3

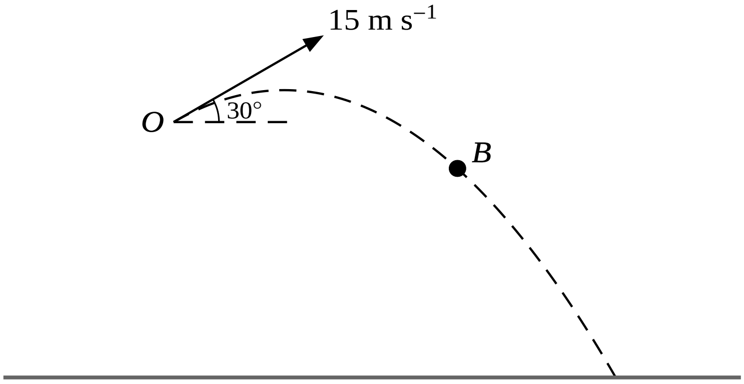


One end of a light inextensible string is attached to a fixed point A and the other end of the string is attached to a particle P. The particle P moves with constant angular speed $5\,\text{rad}\,\text{s}^{-1}$ in a horizontal circle which has its centre O vertically below A. The string makes an angle θ with the vertical (see diagram). The tension in the string is three times the weight of P.

(i) Show that the length of the string is 1.2 m. [3]

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

4



A small ball B is projected from a point O above horizontal ground, with initial speed $15\,\mathrm{m\,s^{-1}}$ at an angle of projection of $30°$ above the horizontal (see diagram). The ball strikes the ground 3 s after projection.

(i) Calculate the speed and direction of motion of the ball immediately before it strikes the ground. [5]

(ii) Find the height of O above the ground. [2]

5 A particle P of mass 0.3 kg is attached to one end of a light elastic string of natural length 0.9 m and modulus of elasticity 18 N. The other end of the string is attached to a fixed point O which is 3 m above the ground.

(i) Find the extension of the string when P is in the equilibrium position. [2]

P is projected vertically downwards from the equilibrium position with initial speed $6\,\mathrm{m\,s^{-1}}$. At the instant when the tension in the string is 12 N the string breaks. P continues to descend vertically.

(ii) **(a)** Calculate the height of P above the ground at the instant when the string breaks. [2]

(b) Find the speed of P immediately before it strikes the ground. [4]

6 A particle P of mass 0.1 kg moves with decreasing speed in a straight line on a smooth horizontal surface. A horizontal resisting force of magnitude $0.2\mathrm{e}^{-x}$ N acts on P, where x m is the displacement of P from a fixed point O on the line. The velocity of P is $v\,\mathrm{m\,s^{-1}}$ when its displacement from O is x m.

(i) Show that

$$v\frac{\mathrm{d}v}{\mathrm{d}x} = k\mathrm{e}^{-x},$$

where k is a constant to be found. [2]

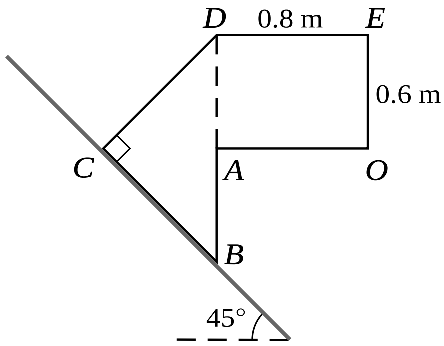
P passes through O with velocity $2.2\,\mathrm{m\,s^{-1}}$.

(ii) Calculate the value of x at the instant when the velocity of P is $2\,\mathrm{m\,s^{-1}}$. [4]

(iii) Show that the speed of P does not fall below $0.917\,\mathrm{m\,s^{-1}}$, correct to 3 significant figures. [2]

[Question 7 is printed on the next page.]

7



The diagram shows the cross-section *OABCDE* through the centre of mass of a uniform prism on a rough inclined plane. The portion *ADEO* is a rectangle in which $AD = OE = 0.6$ m and $DE = AO = 0.8$ m; the portion *BCD* is an isosceles triangle in which angle *BCD* is a right angle, and *A* is the mid-point of *BD*. The plane is inclined at 45° to the horizontal, *BC* lies along a line of greatest slope of the plane and *DE* is horizontal.

(i) Calculate the distance of the centre of mass of the prism from *BD*. [3]

The weight of the prism is 21 N, and it is held in equilibrium by a horizontal force of magnitude *P* N acting along *ED*.

(ii) (a) Find the smallest value of *P* for which the prism does not topple. [2]

(b) It is given that the prism is about to slip for this smallest value of *P*. Calculate the coefficient of friction between the prism and the plane. [3]

The value of *P* is gradually increased until the prism ceases to be in equilibrium.

(iii) Show that the prism topples before it begins to slide, stating the value of *P* at which equilibrium is broken. [5]