



**ADVANCED GCE
MATHEMATICS**

Mechanics 3

4730

Candidates answer on the answer booklet.

OCR supplied materials:

- 8 page answer booklet (sent with general stationery)
- List of Formulae (MF1)

Other materials required:

- Scientific or graphical calculator

**Monday 20 June 2011
Morning**

Duration: 1 hour 30 minutes



INSTRUCTIONS TO CANDIDATES

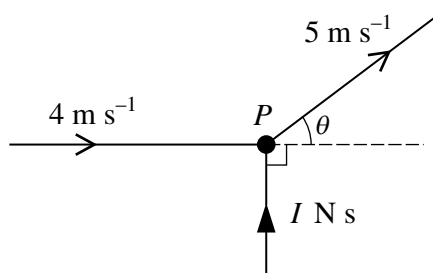
- Write your name, centre number and candidate number in the spaces provided on the answer booklet. Please write clearly and in capital letters.
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- Give non-exact numerical answers correct to 3 significant figures unless a different degree of accuracy is specified in the question or is clearly appropriate.
- The acceleration due to gravity is denoted by $g \text{ m s}^{-2}$. Unless otherwise instructed, when a numerical value is needed, use $g = 9.8$.
- You are permitted to use a scientific or 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 reminded of the need for clear presentation in your answers.**
- The total number of marks for this paper is **72**.
- This document consists of **4** pages. Any blank pages are indicated.

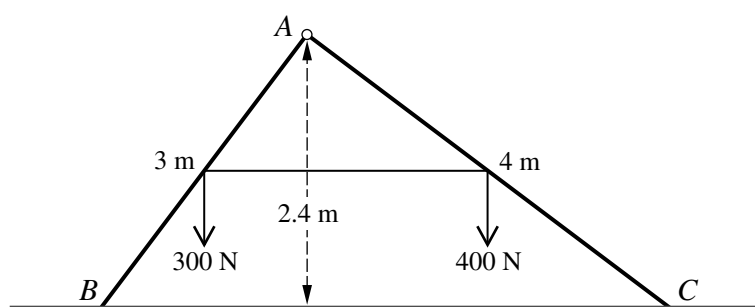
2

1



A particle P of mass 0.3 kg is moving in a straight line with speed 4 m s^{-1} when it is deflected through an angle θ by an impulse of magnitude $I \text{ N s}$. The impulse acts at right angles to the initial direction of motion of P (see diagram). The speed of P immediately after the impulse acts is 5 m s^{-1} . Show that $\cos \theta = 0.8$ and find the value of I . [4]

2



Two uniform rods AB and AC , of lengths 3 m and 4 m respectively, have weights 300 N and 400 N respectively. The rods are freely jointed at A . The mid-points of the rods are joined by a light inextensible string. The rods are in equilibrium in a vertical plane with the string taut and B and C in contact with a smooth horizontal surface. The point A is 2.4 m above the surface (see diagram).

(i) Show that the force exerted by the surface on AB is 374 N and find the force exerted by the surface on AC . [4]

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

(iii) Find the horizontal and vertical components of the force exerted on AB at A and state their directions. [3]

3 A particle P of mass 0.25 kg is projected horizontally with speed 5 m s^{-1} from a fixed point O on a smooth horizontal surface and moves in a straight line on the surface. The only horizontal force acting on P has magnitude $0.2v^2 \text{ N}$, where $v \text{ m s}^{-1}$ is the velocity of P at time $t \text{ s}$ after it is projected from O . This force is directed towards O .

(i) Find an expression for v in terms of t . [5]

The particle P passes through a point X with speed 0.2 m s^{-1} .

(ii) Find the average speed of P for its motion between O and X . [5]

3

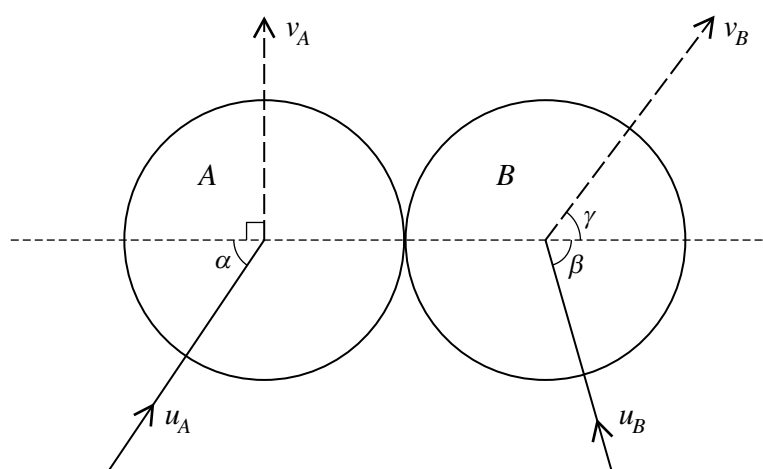
- 4 One end of a light inextensible string of length 2 m is attached to a fixed point O . A particle P of mass 0.2 kg is attached to the other end of the string. P is held at rest with the string taut so that OP makes an angle of 0.15 radians with the downward vertical. P is released and t seconds afterwards OP makes an angle of θ radians with the downward vertical.

(i) Show that $\frac{d^2\theta}{dt^2} = -4.9 \sin \theta$ and give a reason why the motion is approximately simple harmonic. [3]

Using the simple harmonic approximation,

- (ii) obtain an expression for θ in terms of t and hence find the values of t at the first and second occasions when $\theta = -0.1$, [5]
- (iii) find the angular speed of OP and the linear speed of P when $t = 0.5$. [3]

5



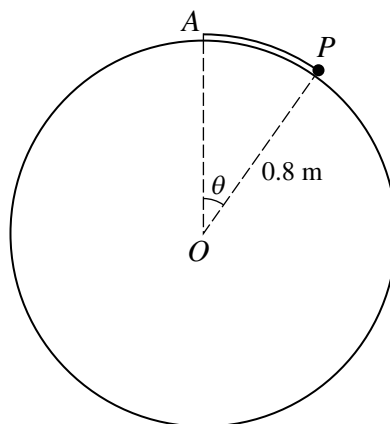
Two uniform smooth identical spheres A and B are moving towards each other on a horizontal surface when they collide. Immediately before the collision A and B are moving with speeds $u_A \text{ m s}^{-1}$ and $u_B \text{ m s}^{-1}$ respectively, at acute angles α and β , respectively, to the line of centres. Immediately after the collision A and B are moving with speeds $v_A \text{ m s}^{-1}$ and $v_B \text{ m s}^{-1}$ respectively, at right angles and at acute angle γ , respectively, to the line of centres (see diagram).

- (i) Given that $\sin \beta = 0.96$ and $\frac{v_B}{u_B} = 1.2$, find the value of $\sin \gamma$. [2]
- (ii) Given also that, before the collision, the component of A 's velocity parallel to the line of centres is 2 m s^{-1} , find the values of u_B and v_B . [5]
- (iii) Find the coefficient of restitution between the spheres. [3]
- (iv) Given that the kinetic energy of A immediately before the collision is $6.5m \text{ J}$, where $m \text{ kg}$ is the mass of A , find the value of v_A . [2]

[Questions 6 and 7 are printed overleaf.]

4

6



A particle P of weight 6 N is attached to the highest point A of a fixed smooth sphere by a light elastic string. The sphere has centre O and radius 0.8 m . The string has natural length $\frac{1}{10}\pi\text{ m}$ and modulus of elasticity 9 N . P is released from rest at a point X on the sphere where OX makes an angle of $\frac{1}{4}\pi$ radians with the upwards vertical. P remains in contact with the sphere as it moves upwards to A . At time t seconds after the release, OP makes an angle of θ radians with the upwards vertical (see diagram). When $\theta = \frac{1}{6}\pi$, P passes through the point Y .

(i) Show that as P moves from X to Y its gravitational potential energy increases by $2.4(\sqrt{3} - \sqrt{2})\text{ J}$ and the elastic potential energy in the string decreases by $0.4\pi\text{ J}$. [5]

(ii) Verify that the transverse acceleration of P is zero when $\theta = \frac{1}{6}\pi$, and hence find the maximum speed of P . [6]

7 One end of a light inextensible string of length 0.8 m is attached to a fixed point O . A particle P of mass 0.3 kg is attached to the other end of the string. P is projected horizontally from the point 0.8 m vertically below O with speed 5.6 m s^{-1} . P starts to move in a vertical circle with centre O . The speed of P is $v\text{ m s}^{-1}$ when the string makes an angle θ with the downward vertical.

(i) While the string remains taut, show that $v^2 = 15.68(1 + \cos \theta)$, and find the tension in the string in terms of θ . [7]

(ii) For the instant when the string becomes slack, find the value of θ and the value of v . [3]

(iii) Find, in either order, the speed of P when it is at its greatest height after the string becomes slack, and the greatest height reached by P above its point of projection. [4]

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