OCR
Oxford Cambridge and RSA

Tuesday 20 May 2025 – Afternoon

AS Level Further Mathematics A

Y533/01 Mechanics

Time allowed: 1 hour 15 minutes

You must have:
- the Printed Answer Booklet
- the Formulae Booklet for AS Level Further Mathematics A
- a scientific or graphical calculator

QP

INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided in the **Printed Answer Booklet**. If you need extra space use the lined page at the end of the Printed Answer Booklet. The question numbers must be clearly shown.
- Fill in the boxes on the front of the Printed Answer Booklet.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.
- Give non-exact numerical answers correct to **3** significant figures unless a different degree of accuracy is specified in the question.
- The acceleration due to gravity is denoted by $g\,\mathrm{m\,s^{-2}}$. When a numerical value is needed use $g = 9.8$ unless a different value is specified in the question.
- Do **not** send this Question Paper for marking. Keep it in the centre or recycle it.

INFORMATION
- The total mark for this paper is **60**.
- The marks for each question are shown in brackets **[ ]**.
- This document has **8** pages.

ADVICE
- Read each question carefully before you start your answer.

1 A cricket ball of mass 0.16 kg is at rest on rough horizontal ground when it is struck by a bat. Immediately after the ball is struck its speed is $15\,\mathrm{m\,s^{-1}}$ in a horizontal direction.

(a) Find the magnitude of the impulse exerted by the bat on the ball. **[1]**

The ball remains in contact with the ground and the resistance to the motion of the ball is modelled as constant.

The ball comes to rest again after it has travelled 30 m along the ground.

(b) Use the work-energy principle to find the magnitude of the resistance to the motion of the ball. **[3]**

2 Two particles, A of mass m kg and B of mass $2m$ kg, are connected by a light inextensible string. The particles are initially placed together at rest on a smooth horizontal surface with the string slack.

At a certain instant, A and B are projected along the surface, directly away from each other, with speeds of $3\,\mathrm{m\,s^{-1}}$ and $u\,\mathrm{m\,s^{-1}}$ respectively. You are given that $u < 1.5$.

(a) Find, in terms of u, the speed of A immediately after the string becomes taut. **[2]**

(b) **(i)** State the direction of motion of B immediately after the string becomes taut. **[1]**

(ii) Find, in terms of m and u, the magnitude of the impulse exerted on B as a result of the string becoming taut. **[2]**

(iii) Write down an expression for the impulse exerted on A as a result of the string becoming taut. **[1]**

(c) Show that the loss of kinetic energy as a result of the string becoming taut is $\dfrac{m(3+u)^2}{3}\,\mathrm{J}$. **[3]**

3 A car of mass 900 kg has an engine that is capable of working at a maximum power of 12 kW.

When the car is travelling along a straight horizontal road, the maximum constant speed that it can maintain is $40\,\mathrm{m\,s^{-1}}$.

In an initial model of the motion of the car it is assumed that the total resistance to motion is constant.

(a) **(i)** Show that when the car is travelling at $15\,\mathrm{m\,s^{-1}}$ along the horizontal road with the engine working at a constant rate of 10 kW, the acceleration of the car is $0.407\,\mathrm{m\,s^{-2}}$ correct to **3** significant figures. **[3]**

(ii) Find the speed of the car when it is accelerating at $0.2\,\mathrm{m\,s^{-2}}$ along the horizontal road with the engine working at a constant rate of 9.6 kW. **[2]**

(iii) The car now starts to **descend** a straight road which is inclined at $1°$ to the horizontal.

Find the power produced by the engine of the car when it is travelling along this road at a constant speed of $40\,\mathrm{m\,s^{-1}}$. **[2]**

In a refined model of the motion of the car it is assumed that the total resistance to motion is proportional to the speed of the car.

(b) **(i)** Show that the total resistance to the motion of the car is now given by $7.5v$ N where $v\,\mathrm{m\,s^{-1}}$ is the speed of the car. **[1]**

(ii) State **one** way in which the refined model is an improvement over the initial model. **[1]**

(iii) Find, according to the refined model, the speed of the car when it is accelerating at $0.2\,\mathrm{m\,s^{-2}}$ along the horizontal road with the engine working at a constant rate of 9.6 kW. **[3]**

4 Two particles, A of mass 4 kg and B of mass 2 kg, are free to move along the same straight line on a smooth horizontal surface. They are projected directly **towards** each other with speeds of $6\,\mathrm{m\,s^{-1}}$ and $5\,\mathrm{m\,s^{-1}}$ respectively.

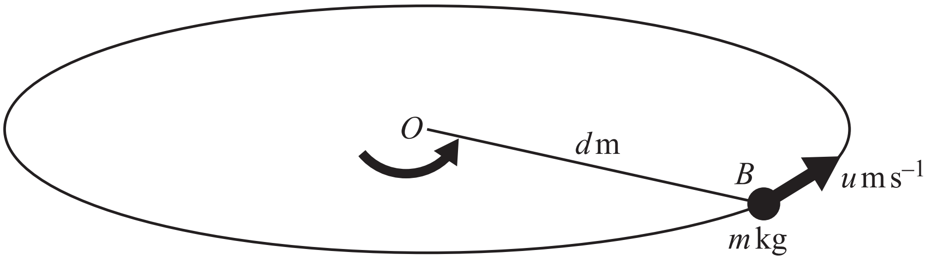
After A and B collide the speed of A is $1\,\mathrm{m\,s^{-1}}$.

(a) Determine the possible values of the coefficient of restitution between A and B. **[6]**

(b) State whether the collision between A and B is perfectly elastic. Justify your answer. **[1]**

5 One end of a light inextensible string of length d m is attached to a particle B of mass m kg. The other end of the string is attached to a fixed point O on a smooth horizontal plane.

Particle B moves on the plane with constant speed $u\,\mathrm{m\,s^{-1}}$ in a horizontal circle with centre O (see diagram).



The period, which is the time taken for B to complete one revolution, is denoted by p seconds and the tension in the string is F N.

(a) Use dimensional analysis to derive a formula for F in terms of d, m and p. You should define any other symbols used in your formula for F. **[4]**

(b) Explain why it was **not** necessary to consider the quantity u in the analysis in part **(a)**. **[1]**

(c) Instead, use Newton's second law to derive a formula for F in terms of d, m and p. **[3]**

(d) Considering your answers to part **(a)** and part **(c)**, state one **disadvantage** of using dimensional analysis to derive a formula for F. **[1]**

6 A disc of mass 2 kg is projected, with initial speed $16.4\,\mathrm{m\,s^{-1}}$, directly up a rough plane which is inclined at an angle of 15° to the horizontal. The coefficient of friction between the plane and the disc is 0.2.

(a) **(i)** Determine the average power generated by the frictional force in the first 3 seconds of the disc's motion. **[6]**

(ii) Explain the significance of the sign of your answer to part **(a)(i)**. **[1]**

(b) **Use an energy method** to find the distance the disc travels up the plane from the point where it is projected to the point where it comes to instantaneous rest. **[4]**

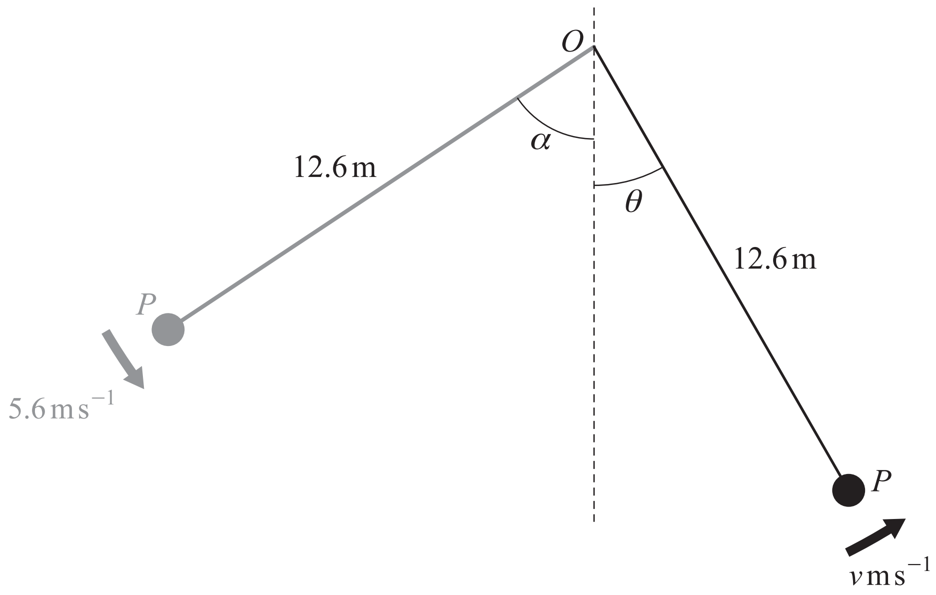
7 In this question you must show detailed reasoning.

A particle P of mass m kg is attached to one end of a light rod of length 12.6 m. The other end of the rod is attached to a fixed point O.

Particle P is initially held at a point so that OP makes an angle of α to the downward vertical through O, where $\cos\alpha = \frac{5}{9}$.

Particle P is then projected so that it instantaneously starts moving downwards at right angles to the rod with a speed of $5.6\,\mathrm{m\,s^{-1}}$ in a vertical circular path around O.

When the rod makes an angle of θ with the downward vertical, P has speed $v\,\mathrm{m\,s^{-1}}$ (see diagram).



(a) At a certain instant in P's motion, $v = 8.4\cos\theta$.

Determine the value of v at this instant. **[6]**

(b) Show that P does **not** describe complete circles around O. **[2]**

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