General Certificate of Education
January 2004
Advanced Level Examination

ASSESSMENT and QUALIFICATIONS ALLIANCE

MATHEMATICS (SPECIFICATION A) **MAM2/W**
Unit Mechanics 2

Wednesday 21 January 2004 Afternoon Session

In addition to this paper you will require:
- an 8-page answer book;
- the AQA booklet of formulae and statistical tables.

You may use a graphics calculator.

Time allowed: 1 hour 20 minutes

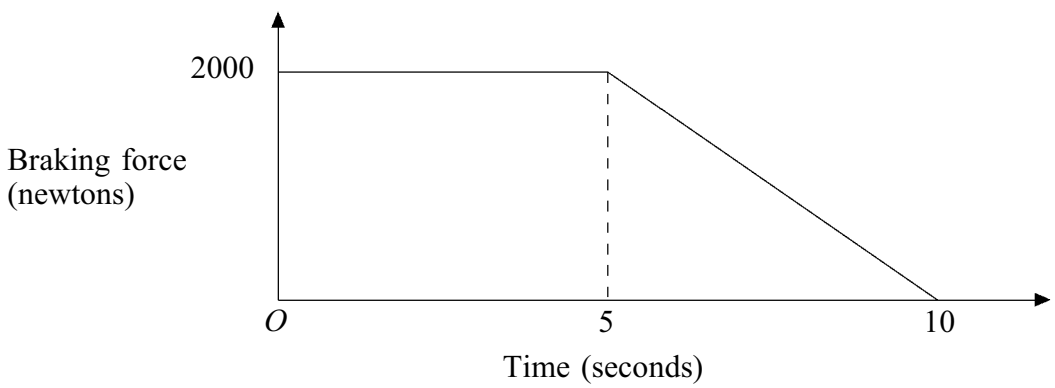
Instructions
- Use blue or black ink or ball-point pen. Pencil should only be used for drawing.
- Write the information required on the front of your answer book. The *Examining Body* for this paper is AQA. The *Paper Reference* is MAM2/W.
- Answer **all** questions.
- Take $g = 9.8\,\text{m}\,\text{s}^{-2}$ unless otherwise stated.
- All necessary working should be shown; otherwise marks for method may be lost.
- The **final** answer to questions requiring the use of tables or calculators should normally be given to three significant figures.
- Tie loosely any additional answer sheets you have used to the back of your answer book before handing it to the invigilator.

Information
- The maximum mark for this paper is 60.
- Mark allocations are shown in brackets.

Advice
- Unless stated otherwise, formulae may be quoted, without proof, from the booklet.

Answer **all** questions.

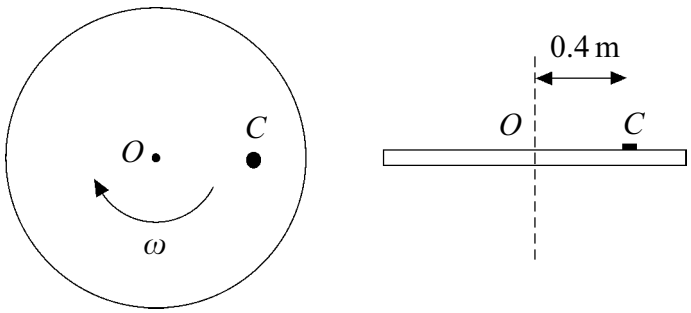
1 A car is being driven along a straight horizontal road. A braking force is applied to the car to bring it to rest after 10 seconds. It may be assumed that no other resistive forces act on the car during this time. A model for such a braking force is shown by the graph below.



(a) Show that the impulse acting on the car for the 10 second interval shown is of magnitude 15 000 N s. *(3 marks)*

(b) The car has a mass of 1000 kg. Find the speed of the car at the instant when the braking force is first applied. *(2 marks)*

2 A small coin, C, is placed on a rough horizontal turntable, as shown in the diagram.



Plan view **Side view**

The mass of the coin is 0.01 kg and it is placed at a distance of 0.4 m from O, the centre of the turntable.

The turntable rotates about a vertical axis through O, with a constant angular speed of ω radians per second. During this motion the coin does **not** slip.

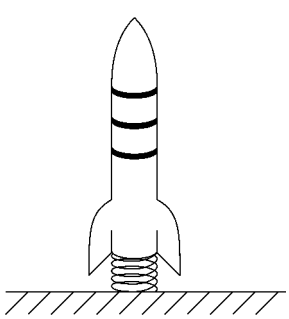
(a) Draw a diagram to show all the forces acting on the coin. *(1 mark)*

(b) Find, in terms of ω, an expression for the frictional force acting on the coin. *(2 marks)*

(c) The coefficient of friction between the coin and the turntable is 0.8. The coin is on the point of slipping. Show that the value of ω is approximately 4.43. *(4 marks)*

3 A child's pop-up toy rocket is of mass 20 grams. It is operated by pushing the rocket vertically downwards to compress a light spring underneath the rocket. The rocket is then released from rest.

Initially, the spring is compressed by 3 cm to the position shown in the diagram. The stiffness of the spring is $50\ \text{N m}^{-1}$.

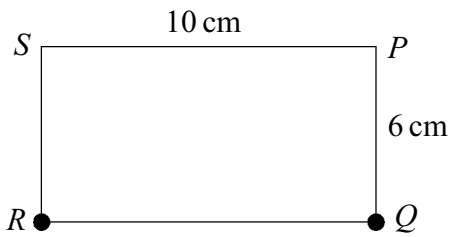


(a) Calculate the elastic potential energy of the compressed spring. *(2 marks)*

(b) When released, the rocket moves vertically upwards. Show that the speed of the rocket when the spring first reaches its natural length is approximately $1.29\ \text{m s}^{-1}$. *(4 marks)*

(c) Determine the height above the initial position, shown in the diagram, at which the rocket comes momentarily to rest. *(3 marks)*

4 A uniform rectangular plate, $PQRS$, has mass 1 kg. Particles of mass m kilograms are attached to the plate at Q and R. The plate is shown in the diagram below.



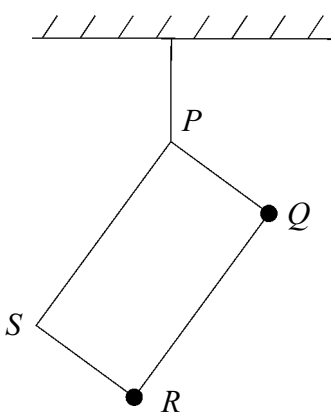
The dimensions of the plate are $PQ = SR = 6$ cm and $PS = QR = 10$ cm.

(a) State the distance of the centre of mass of the system from PQ. *(1 mark)*

(b) Show that the distance, in centimetres, of the centre of mass of the system from PS is

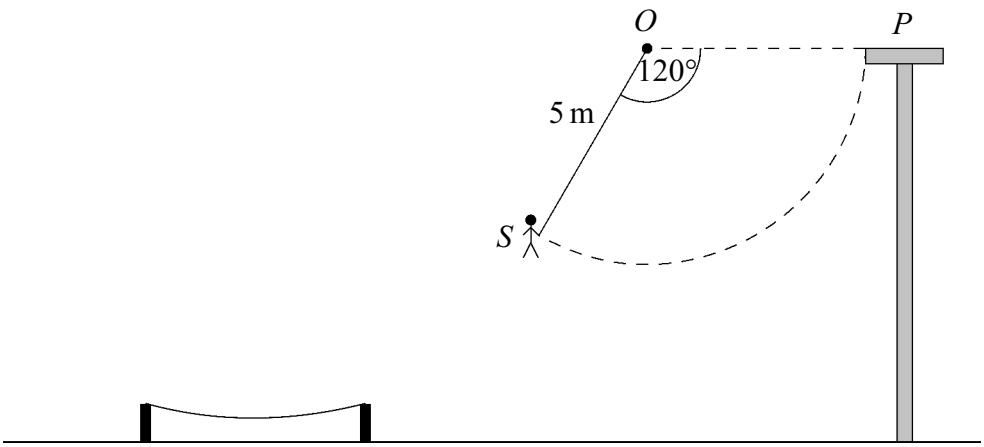
$$\frac{12m + 3}{2m + 1}.$$ *(3 marks)*

(c) The plate is freely suspended from P, as shown in the diagram below.



When the plate hangs in equilibrium, PS makes an angle of 45° with the downward vertical. Find the value of m. *(5 marks)*

5 A stuntman S stands initially on a platform P. He holds a rope which is attached to a fixed support O. The points O and P are at the same horizontal level. The man then steps off the platform with the rope taut and horizontal. He swings through a circular arc, as shown in the diagram below.



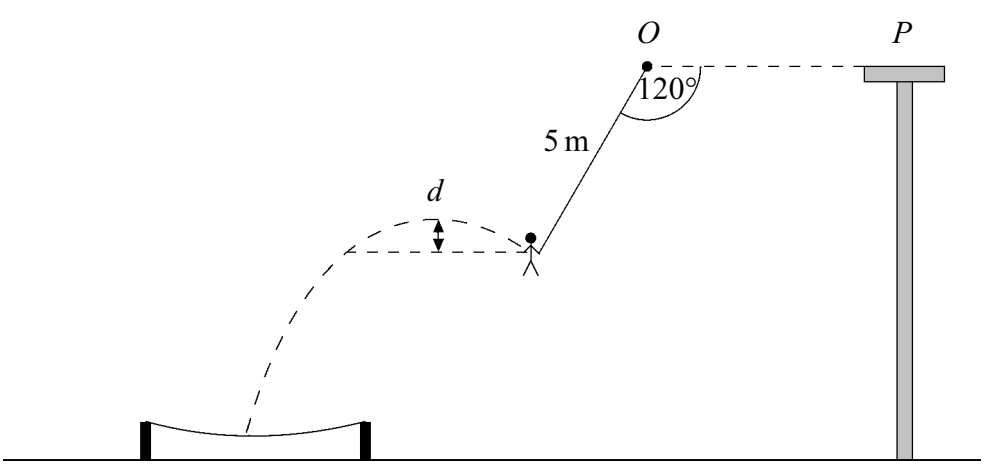
The mass of the man is 70 kg and the length of the rope is 5 m. The man may be modelled as a particle throughout the motion.

(a) The man releases his grip on the rope when it has swung through an angle of 120°.

(i) Show that the speed of the man when he is about to let go of the rope is approximately 9.21 m s^{-1}. *(4 marks)*

(ii) Find the tension in the rope when the man is about to let go of the rope. *(5 marks)*

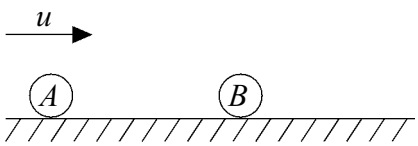
(b) After letting go of the rope, the stuntman moves freely under gravity.



He rises a distance d before beginning to fall into the safety net. Show that d is approximately 1 metre. *(4 marks)*

(c) Comment on the assumption that the man can be modelled as a particle. *(1 mark)*

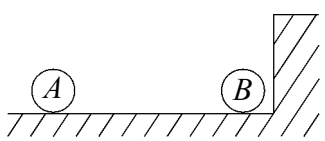
6 Two identical smooth spheres, A and B, are each of mass m. Sphere A moves with speed u on a smooth horizontal floor directly towards sphere B, which is at rest. The spheres are shown in the diagram.



The coefficient of restitution between A and B is e.

(a) Show that the speed of B immediately after the impact with A is $\frac{1}{2}u(1+e)$ and find the speed of A, in terms of u and e. *(6 marks)*

(b) Sphere B subsequently collides with a vertical wall which is perpendicular to the direction of motion of B.



The coefficient of restitution between B and the wall is $\frac{2}{3}$.

State, in terms of u and e, the speed of B immediately after it hits the wall. *(1 mark)*

(c) After B has hit the wall, A and B are moving directly towards each other with the same speed.

(i) Show that e, the coefficient of restitution between A and B, is $\frac{1}{5}$. *(2 marks)*

(ii) State the speed of A and B in terms of u. *(1 mark)*

(d) The first collision between A and B occurs at a distance d from the wall. By modelling the spheres as particles, determine, in terms of d, the distance of the second collision from the wall. *(6 marks)*

END OF QUESTIONS