General Certificate of Education
January 2005
Advanced Level Examination

MATHEMATICS (SPECIFICATION A) MAM2/W
Unit Mechanics 2

Tuesday 25 January 2005 Morning 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 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.

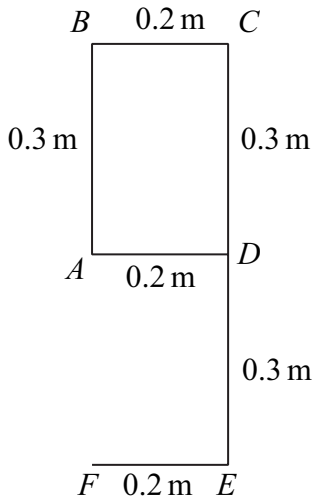
1 A particle of mass 2 kg is moving under the action of a single force, **F** newtons.

(a) Calculate the kinetic energy of the particle when its velocity is $3\mathbf{i} + 4\mathbf{j}\,\mathrm{m\,s^{-1}}$.

(2 marks)

(b) Given that $\mathbf{F} = 6\mathbf{i} - \mathbf{j}$, find the power of the force when the velocity of the particle is $3\mathbf{i} + 4\mathbf{j}\,\mathrm{m\,s^{-1}}$. *(2 marks)*

2 As part of an advertising display, a thin uniform rod of length 1.5 m is bent to form a figure $\square$. The diagram shows the figure in which $ABCD$ is a rectangle and angle ADE = angle $DEF = 90°$.



(a) The mass of BC is $2M$.

Express the total mass of the figure as a multiple of M. *(1 mark)*

(b) (i) Show that the centre of mass of the figure is at a distance of 0.27 m from BC. *(4 marks)*

(ii) Find the distance of the centre of mass of the figure from CE. *(3 marks)*

(c) When freely suspended from the point C, the side CE of the figure makes an angle θ with the vertical.

Determine the value of θ, giving your answer in degrees to one decimal place. *(3 marks)*

3 Alina, who has mass 50 kg, is attached to one end of an elastic cord. The cord has natural length 20 metres and stiffness $k\,\mathrm{N\,m^{-1}}$. The other end of the cord is attached to a bridge. Alina steps off the bridge at the point where the cord is attached and falls vertically. Throughout the subsequent motion, Alina can be modelled as a particle.

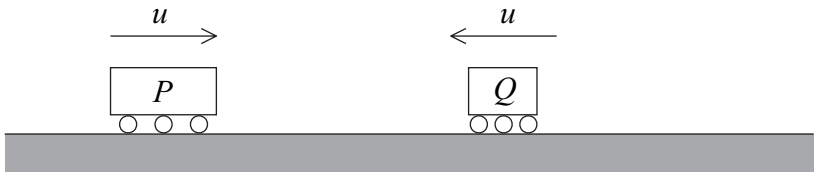
(a) Find Alina's speed when she passes through the point 20 metres vertically below the bridge. *(2 marks)*

(b) The cord stretches to a total length of 32 metres before Alina comes momentarily to rest.

(i) Show that the elastic potential energy of the cord at the instant when she is momentarily at rest is 15 680 J. *(2 marks)*

(ii) Hence find the stiffness of the cord. *(3 marks)*

4 Two toy train carriages, P and Q, have masses $2m$ and m respectively. They are moving directly towards each other, as shown in the diagram. Both carriages have speed u.



The carriages collide and subsequently Q moves in the same direction as P. The coefficient of restitution between P and Q is e.

(a) (i) Show that the speed of carriage P immediately after the collision is $\frac{u}{3}(1-2e)$ and find the speed of carriage Q. *(7 marks)*

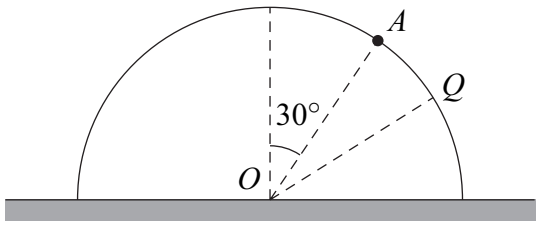
(ii) Deduce that $e < \frac{1}{2}$. *(2 marks)*

(b) The magnitude of the impulse on P due to the collision is I. Show that:

(i) $I = \frac{4mu}{3}(1+e)$; *(3 marks)*

(ii) $\frac{4mu}{3} \leqslant I < 2mu$. *(2 marks)*

5 A solid smooth hemisphere, of radius r, has its plane face fixed to a horizontal table. The centre of the plane face is O.



A particle P, of mass m, is released from rest at a point A on the surface of the hemisphere, where OA makes an angle of 30° with the upward vertical through O. The particle P slides freely down the surface. At the point Q on the surface, the particle has speed v and OQ makes an angle θ with the upward vertical through O.

(a) Show that $v^2 = gr\left(\sqrt{3} - 2\cos\theta\right)$. *(4 marks)*

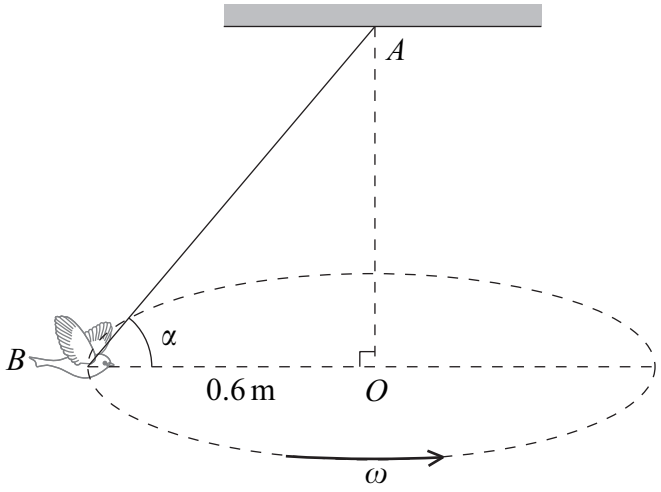
(b) Find, in terms of m, g and θ, an expression for the reaction force of the hemisphere on the particle at the point Q. *(5 marks)*

(c) When $\theta = \alpha$, the particle loses contact with the hemisphere.

Find the value of α, giving your answer to the nearest degree. *(2 marks)*

6 A toy bird, of mass 0.25 kg, is fixed to one end, B, of a light inextensible string. The other end, A, of the string is attached to a fixed point on a ceiling. The bird is set in motion, so that it describes a horizontal circle of radius 0.6 m. The centre of this circle is O, which is vertically below A, as shown in the diagram. The angle ABO is α.

The bird moves with a constant angular speed of ω radians per second.



The bird completes one full revolution every 1.5 seconds.

(a) Find ω, leaving your answer in terms of π. *(2 marks)*

(b) (i) Determine the magnitude of the acceleration of the bird. *(2 marks)*

(ii) Show the direction of this acceleration on a diagram. *(1 mark)*

(c) (i) Draw a diagram to show the forces acting on the bird. *(1 mark)*

(ii) Find the angle α, giving your answer to the nearest degree. *(6 marks)*

(d) State **one** modelling assumption used in this question. *(1 mark)*

END OF QUESTIONS

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