General Certificate of Education
January 2004
Advanced Subsidiary Examination

MATHEMATICS AND STATISTICS (SPECIFICATION B)
Unit Mechanics 1

MBM1

ASSESSMENT and QUALIFICATIONS ALLIANCE

Monday 12 January 2004 Afternoon Session

In addition to this paper you will require:
- a 12-page answer book;
- the AQA booklet of formulae and statistical tables;
- a ruler.

You may use a graphics calculator.

Time allowed: 1 hour 45 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 MBM1.
- Answer **all** questions.
- Take $g = 9.8\ \text{m s}^{-2}$ unless stated otherwise.
- 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.

Information
- The maximum mark for this paper is 80.
- Mark allocations are shown in brackets.

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

Answer **all** questions.

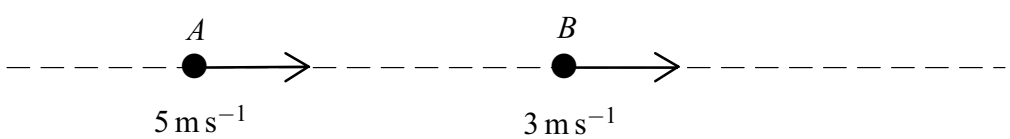
1 A car travels along a straight horizontal road. When it passes a set of traffic lights it is travelling at a speed of $3\,\text{m s}^{-1}$. The car then accelerates at a constant $1.2\,\text{m s}^{-2}$ until it reaches a speed of $9\,\text{m s}^{-1}$.

(a) Show that the car accelerates for 5 seconds. *(2 marks)*

(b) Find the distance that the car travels as it accelerates from $3\,\text{m s}^{-1}$ to $9\,\text{m s}^{-1}$. *(2 marks)*

(c) The mass of the car is 1200 kg. Calculate the magnitude of the resultant force acting on the car while it is accelerating. *(2 marks)*

2 Two particles, A and B, are moving with constant speeds in the same direction along a straight horizontal line. The velocity of A is $5\,\text{m s}^{-1}$ and its mass is 0.1 kg. The velocity of B is $3\,\text{m s}^{-1}$ and its mass is 0.4 kg. The two particles collide. The diagram shows the velocities before the collision.



(a) If the particles coalesce during the collision, find the velocity of the combined particle after the collision. *(3 marks)*

(b) If the particles do **not** coalesce during the collision, and the velocity of B increases to $3.5\,\text{m s}^{-1}$, find the velocity of A after the collision. *(4 marks)*

3 A rough plane is inclined at an angle of 40° to the horizontal. A particle, of mass 5 kg, is sliding down the plane.

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

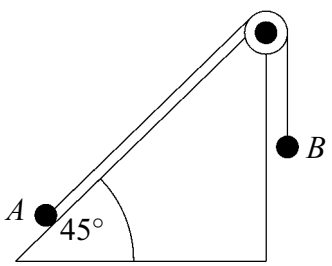
(b) Find the magnitude of the normal reaction force acting on the particle. *(2 marks)*

(c) The coefficient of friction between the particle and the plane is 0.2. Show that the magnitude of the friction force acting on the particle is 7.51 N, correct to three significant figures. *(2 marks)*

(d) Show that the acceleration of the particle is $4.80\,\text{m s}^{-2}$, correct to three significant figures. *(4 marks)*

(e) Find the distance that the particle travels as its speed increases from $2\,\text{m s}^{-1}$ to $10\,\text{m s}^{-1}$. *(3 marks)*

4 Two particles, A and B, are connected by a light inextensible string, which passes over a smooth light pulley. Particle A is on a smooth slope, at 45° to the horizontal, and particle B hangs with the string vertical, as shown in the diagram.

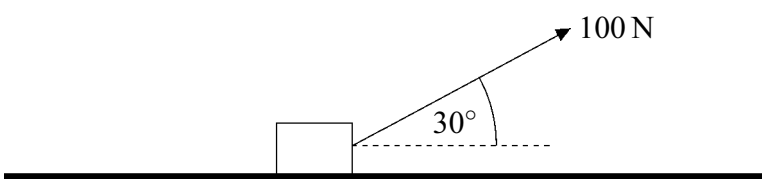


The mass of A is 14 kg and the mass of B is 6 kg.

(a) Using two equations of motion, show that the acceleration of the particles is $1.91\ \text{m s}^{-2}$, correct to three significant figures. *(6 marks)*

(b) Particle B is replaced by a particle C of mass m kg. After the particles have been set in motion, they move with a constant speed. Find m. *(4 marks)*

5 A crate, of mass 50 kg, is at rest on a warehouse floor. The floor is rough and horizontal. The coefficient of friction between the crate and the floor is μ. A rope is attached to the crate at an angle of 30° to the horizontal. The tension in the rope is 100 N. The crate is shown in the diagram.



Model the crate as a particle.

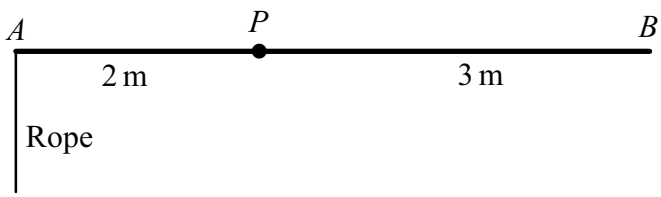
(a) Draw and label a diagram to show the forces acting on the crate. *(1 mark)*

(b) Show that the magnitude of the normal reaction force acting on the crate is 440 N. *(3 marks)*

(c) If the crate remains at rest, μ must satisfy the inequality $\mu \geqslant k$. Find k. *(3 marks)*

(d) If $\mu = 0.1$, find the acceleration of the crate. *(4 marks)*

6 A uniform beam AB has length 5 metres and mass 10 kg. It is freely pivoted at the point P which is 2 metres from A. A rope is attached to the beam at A and exerts a vertical force on the beam at A. The beam and rope are shown in the diagram.



(a) The beam is in equilibrium and at rest in a horizontal position.

(i) Show that the tension in the rope is 24.5 N. *(3 marks)*

(ii) A particle of mass 40 kg is then fixed to the beam at B. The tension in the rope is increased, so that the beam remains horizontal. Find the tension in the rope in this case. *(3 marks)*

(b) How would your answer to part (a)(ii) change if the beam had been in equilibrium at an angle to the horizontal, but with the rope still vertical? Explain why. *(2 marks)*

7 A ball is thrown so that it initially travels at $10\,\text{m}\,\text{s}^{-1}$ at an angle of 70° above the horizontal.

(a) A simple model assumes that the ball is thrown from ground level and lands at the same level. Find the time of flight and the range of the ball. *(5 marks)*

(b) A refined model assumes that the ball is at a height of 2 metres when it is thrown, and lands at ground level. Find the range of the ball based on this assumption. *(7 marks)*

8 A particle is initially at rest at the point A with position vector $(9\mathbf{i} + 10\mathbf{j})$ metres, with respect to an origin O. It moves with constant acceleration, and 10 seconds later is at the point B with position vector $(19\mathbf{i} - 25\mathbf{j})$ metres. The unit vectors $\mathbf{i}$ and $\mathbf{j}$ are perpendicular.

(a) Show that the acceleration of the particle is $(0.2\mathbf{i} - 0.7\mathbf{j})\,\text{m}\,\text{s}^{-2}$. *(4 marks)*

(b) Find the speed of the particle at B. *(4 marks)*

(c) Verify that the particle passes through the point with position vector $(15.4\mathbf{i} - 12.4\mathbf{j})$ m. *(4 marks)*

(d) Draw a diagram to show the path of the particle as it moves from A to B. You should include the unit vectors $\mathbf{i}$ and $\mathbf{j}$ on your diagram. *(2 marks)*

END OF QUESTIONS