General Certificate of Education
January 2005
Advanced Subsidiary Examination

MATHEMATICS AND STATISTICS (SPECIFICATION B) Unit Mechanics 1

MBM1

Wednesday 12 January 2005 Afternoon Session

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

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 van accelerates uniformly from rest on a straight horizontal road. After it has travelled 80 metres, its speed is $20\,\text{m s}^{-1}$.

(a) (i) Find the time taken for the van to travel the 80 metres. *(2 marks)*

(ii) Show that the acceleration of the van is $2.5\,\text{m s}^{-2}$. *(2 marks)*

(b) The mass of the van is 1200 kg. The force produced by its engine has magnitude F newtons and acts on the van in its direction of motion.

(i) Find F, if there is no resistance to motion. *(2 marks)*

(ii) Find F, if there is a constant resistance force of 400 N. *(2 marks)*

2 A car is travelling along a straight horizontal road at a speed of $18\,\text{m s}^{-1}$ when the driver sees a red traffic light ahead. The car then slows down uniformly, so that 6 seconds later the speed of the car is $9\,\text{m s}^{-1}$.

(a) While the car is slowing down:

(i) show that its acceleration is $-1.5\,\text{m s}^{-2}$; *(3 marks)*

(ii) find the distance that it travels. *(2 marks)*

(b) After the car has slowed down for 6 seconds, the traffic lights change to green. The car then accelerates at a constant $1.2\,\text{m s}^{-2}$ and passes the traffic lights at a speed of $15\,\text{m s}^{-1}$.

(i) Show that the car accelerated for 5 seconds before reaching the traffic lights. *(2 marks)*

(ii) Find the distance of the car from the traffic lights when the car started to accelerate. *(3 marks)*

(c) Find the distance of the car from the traffic lights when the car began to slow down. *(1 mark)*

3 Two particles, A and B, are travelling towards each other along a straight line. Both particles have a speed of $5\,\text{m}\,\text{s}^{-1}$. The mass of A is 8 kg and the mass of B is 4 kg.

(a) If A is brought to rest by the collision, find the speed of B after the collision. *(4 marks)*

(b) If, after the collision, the speed of B is twice the speed of A, and both particles move in the same direction, find the speed of B. *(4 marks)*

4 A child travels down a slide at a **constant speed**. Model the slide as a rough plane inclined at an angle of 40° to the horizontal. Model the child as a particle of mass 20 kg and assume that there is no air resistance as the child moves.

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

(ii) Show that the magnitude of the normal reaction force acting on the child is approximately 150 N. *(2 marks)*

(iii) Find the magnitude of the friction force acting on the child and show that the coefficient of friction between the child and the slide is 0.84, correct to two significant figures. *(4 marks)*

(b) In reality, air resistance acts on the child as she slides at a constant speed. How would this affect the value of the coefficient of friction that you calculated in part (a)(iii)? *(1 mark)*

5 A uniform rod AB has length 4 m. Three particles are attached to the rod as listed below.

Mass of particle	**Distance from A**
3 kg	1 m
12 kg	2.5 m
15 kg	3 m

The mass of the rod is 10 kg.

(a) Show that the centre of mass of the rod and the particles is 2.45 metres from A. *(4 marks)*

(b) Ropes are attached to each end of the rod. Find the tension in each rope if the rod is supported in equilibrium by the ropes, with the rod horizontal and the ropes vertical. *(5 marks)*

6 A particle moves with constant acceleration in a horizontal plane. The unit vectors **i** and **j** are perpendicular and lie in the plane. At time $t = 0$, the particle is at rest at the origin. At time $t = 4$ seconds, the position vector of the particle is $(-16\mathbf{i} + 16\mathbf{j})$ metres.

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

(b) Find the speed of the particle when $t = 5$. *(4 marks)*

(c) The mass of the particle is 3 kg. Two horizontal forces **P** and **Q** act on the particle. If $\mathbf{P} = 20\mathbf{i} - 10\mathbf{j}$, find **Q**. *(4 marks)*

7 During a football match, a player kicks a ball from rest towards a goal, which is 12 metres from the ball. The ball is kicked with an initial velocity of $25\,\mathrm{m\,s^{-1}}$ at an angle of 17° above the horizontal.

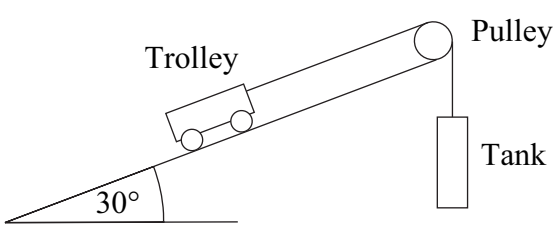
(a) Show that the time that it takes the ball to travel the horizontal distance of 12 metres is 0.502 seconds, correct to three significant figures. *(3 marks)*

(b) The ball hits the crossbar of the goal. Calculate the height of the crossbar. *(3 marks)*

(c) Find the angle between the velocity of the ball and the **vertical** just before the ball hits the crossbar. *(5 marks)*

(d) State two modelling assumptions that you have made. *(2 marks)*

8 A trolley, of mass 200 kg, is on a slope inclined at 30° to the horizontal. It is attached to a tank by a light, inextensible rope that passes over a smooth, light pulley. The tank can be filled with water. The situation is shown in the diagram below.



Model the tank and trolley as particles and assume that there is no resistance to motion.

(a) When the tank is filled with water, the total mass of the tank and the water is 150 kg. Show that the acceleration of the tank and trolley is $1.4\,\mathrm{m\,s^{-2}}$. *(7 marks)*

(b) When the tank is empty, the trolley can be set in motion, so that it moves with a constant speed up the slope. Find the mass of the empty tank. *(4 marks)*

END OF QUESTIONS