General Certificate of Education
November 2004
Advanced Subsidiary Examination

# MATHEMATICS AND STATISTICS (SPECIFICATION B)
# Unit Mechanics 1

**MBM1**

ASSESSMENT and QUALIFICATIONS ALLIANCE

Tuesday 2 November 2004 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 $g = 9.8\,\text{m}\,\text{s}^{-2}$ 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 train accelerates uniformly from rest along a straight horizontal track. After it has travelled 400 metres, its speed is $16\,\mathrm{m\,s^{-1}}$.

(a) (i) Show that the acceleration of the train is $0.32\,\mathrm{m\,s^{-2}}$. *(2 marks)*

(ii) Find the time that it takes the train to travel the 400 metres. *(2 marks)*

(b) When the train has reached a speed of $16\,\mathrm{m\,s^{-1}}$, its acceleration is increased to $0.5\,\mathrm{m\,s^{-2}}$.

(i) Find the distance that the train travels as its speed increases from $16\,\mathrm{m\,s^{-1}}$ to $30\,\mathrm{m\,s^{-1}}$. *(2 marks)*

(ii) Find the total time that the train has been moving when it reaches a speed of $30\,\mathrm{m\,s^{-1}}$. *(3 marks)*

**2** A block of wood has mass 4 kg. It is placed on a rough horizontal surface and is pulled by a horizontal string. The coefficient of friction between the block and the surface is 0.4.

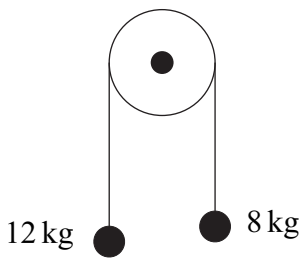
(a) Draw a diagram to show the forces acting on the block. *(1 mark)*

(b) Calculate the magnitude of the normal reaction force acting on the block. *(1 mark)*

(c) If the acceleration of the block is $2\,\mathrm{m\,s^{-2}}$, find the tension in the string. *(3 marks)*

(d) If the tension in the string is 20 N, find the acceleration of the block. *(2 marks)*

**3** A light, inextensible string has a particle of mass 8 kg attached to one end and a particle of mass 12 kg attached to the other end. The string passes over a smooth, light pulley. The particles are released from rest with the string taut and vertical on each side of the pulley. The diagram shows the pulley and the particles.




(a) By forming an equation of motion for each particle, show that the acceleration of the particles is $1.96\,\mathrm{m\,s^{-2}}$. *(5 marks)*

(b) Find the tension in the string. *(2 marks)*

(c) Find the time that it takes for the particles to reach a speed of $7\,\mathrm{m\,s^{-1}}$. *(2 marks)*

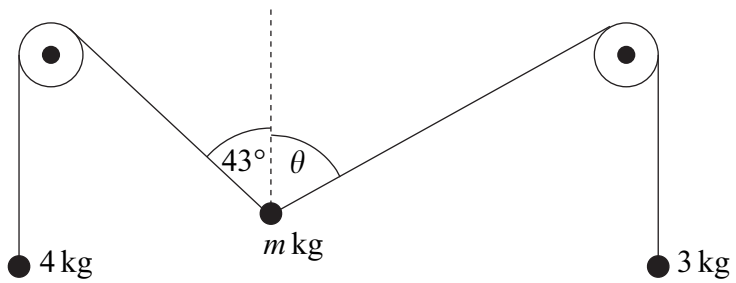
**4** A child of mass 25 kg is sitting in a trolley of mass 13 kg. The trolley is initially at rest on a horizontal surface. A ball of mass 2 kg is thrown towards the child, who catches it. The ball is travelling horizontally at $5\,\mathrm{m\,s^{-1}}$ just before it is caught. Assume that there is no resistance to the motion of the trolley.

(a) Find the speed of the child and the trolley after the ball has been caught. *(2 marks)*

(b) The child places the ball in the trolley. A second, identical ball is thrown, in the same direction as the first ball, and the child catches it. This ball is travelling horizontally at $6\,\mathrm{m\,s^{-1}}$ just before it is caught. Find the speed of the child and the trolley after the second ball has been caught. *(3 marks)*

**TURN OVER FOR THE NEXT QUESTION**

**5** Two light, inextensible strings are attached to a particle of mass $m$ kg. Each string passes over a fixed, smooth, light pulley. The other end of one string is attached to a particle of mass 4 kg. The other end of the second string is attached to a particle of mass 3 kg. The diagram shows the system in its equilibrium position. The angles marked on the diagram are between the strings and the vertical.

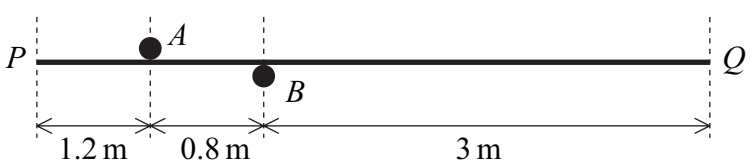



(a) Calculate the tension in each of the strings. *(2 marks)*

(b) Show that $\theta = 65.4°$, correct to three significant figures. *(5 marks)*

(c) Find $m$. *(4 marks)*

**6** A uniform beam, $PQ$, has length 5 metres and mass 40 kg. It is placed between two fixed horizontal bars, $A$ and $B$, so that the beam remains horizontal, as shown in the diagram.




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

(b) Show that the force exerted on the beam by bar $A$ has magnitude 245 N. *(3 marks)*

(c) Find the magnitude of the force exerted on the beam by bar $B$. *(2 marks)*

(d) An object of mass 5 kg is placed on the beam at $Q$. Find the forces now exerted on the beam by the bars $A$ and $B$. *(6 marks)*

**7** A model aeroplane moves in a horizontal plane with a constant acceleration. Initially the aeroplane is at the origin and has velocity $(35\mathbf{i} + 45\mathbf{j})\,\text{m s}^{-1}$. After accelerating for 8 seconds, the velocity of the aeroplane is $(19\mathbf{i} + 13\mathbf{j})\,\text{m s}^{-1}$. The unit vectors **i** and **j** are perpendicular and lie in the horizontal plane.

(a) Show that the acceleration of the aeroplane is $(-2\mathbf{i} - 4\mathbf{j})\,\text{m s}^{-2}$. *(3 marks)*

(b) Find an expression for the position vector of the aeroplane at time $t$ seconds. *(3 marks)*

(c) Find the time when the position vector of the aeroplane is $(300\mathbf{i} + 225\mathbf{j})\,\text{m}$. *(7 marks)*

**8** A football is kicked from horizontal ground. It initially moves with speed $20\,\text{m s}^{-1}$ at an angle of 30° above the horizontal.

(a) (i) Show that the ball hits the ground approximately 2.04 seconds after it has been kicked. *(4 marks)*

(ii) Hence find the range of the ball. *(2 marks)*

(b) In fact the ball comes into contact with a player's head when it is at a height of 2 metres. Find the speed of the ball at this height. *(8 marks)*

**END OF QUESTIONS**