General Certificate of Education
Advanced Subsidiary Examination
January 2010

Mathematics MM1B

Unit Mechanics 1B

Friday 15 January 2010 1.30 pm to 3.00 pm

For this paper you must have:
- an 8-page answer book
- the blue AQA booklet of formulae and statistical tables.

You may use a graphics calculator.

Time allowed
- 1 hour 30 minutes

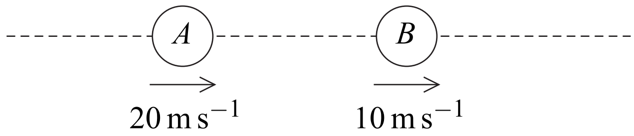
Instructions
- Use black ink or black ball-point pen. Pencil should only be used for drawing.
- Write the information required on the front of your answer book. The **Examining Body** for this paper is AQA. The **Paper Reference** is MM1B.
- Answer **all** questions.
- Show all necessary working; otherwise marks for method may be lost.
- The **final** answer to questions requiring the use of calculators should be given to three significant figures, unless stated otherwise.
- Take $g = 9.8\,\mathrm{m\,s^{-2}}$, unless stated otherwise.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 75.
- Unit Mechanics 1B has a **written paper only**.

Advice
- Unless stated otherwise, you may quote formulae, without proof, from the booklet.

Answer **all** questions.

1 Two particles, A and B, are travelling in the same direction along a straight line on a smooth horizontal surface. Particle A has mass 3 kg and particle B has mass 7 kg. Particle A has a speed of $20\,\mathrm{m\,s^{-1}}$ and particle B has a speed of $10\,\mathrm{m\,s^{-1}}$, as shown in the diagram.



Particle A and particle B collide and coalesce to form a single particle. Find the speed of this single particle after the collision. *(3 marks)*

2 A sprinter accelerates from rest at a constant rate for the first 10 metres of a 100-metre race. He takes 2.5 seconds to run the first 10 metres.

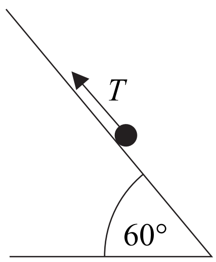
(a) Find the acceleration of the sprinter during the first 2.5 seconds of the race. *(3 marks)*

(b) Show that the speed of the sprinter at the end of the first 2.5 seconds of the race is $8\,\mathrm{m\,s^{-1}}$. *(2 marks)*

(c) The sprinter completes the 100-metre race, travelling the remaining 90 metres at a constant speed of $8\,\mathrm{m\,s^{-1}}$. Find the total time taken for the sprinter to travel the 100 metres. *(3 marks)*

(d) Calculate the average speed of the sprinter during the 100-metre race. *(2 marks)*

3 A particle of mass 3 kg is on a smooth slope inclined at 60° to the horizontal. The particle is held at rest by a force of T newtons parallel to the slope, as shown in the diagram.



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

(b) Show that the magnitude of the normal reaction acting on the particle is 14.7 newtons. *(2 marks)*

(c) Find T. *(2 marks)*

4 A ball is released from rest at a height of 15 metres above ground level.

(a) Find the speed of the ball when it hits the ground, assuming that no air resistance acts on the ball. *(3 marks)*

(b) In fact, air resistance does act on the ball. Assume that the air resistance force has a constant magnitude of 0.9 newtons. The ball has a mass of 0.5 kg.

(i) Draw a diagram to show the forces acting on the ball, including the magnitudes of the forces acting. *(1 mark)*

(ii) Show that the acceleration of the ball is $8\,\mathrm{m\,s^{-2}}$. *(3 marks)*

(iii) Find the speed at which the ball hits the ground. *(2 marks)*

(iv) Explain why the assumption that the air resistance force is constant may not be valid. *(1 mark)*

5 The constant forces $\mathbf{F}_1 = (8\mathbf{i} + 12\mathbf{j})$ newtons and $\mathbf{F}_2 = (4\mathbf{i} - 4\mathbf{j})$ newtons act on a particle. No other forces act on the particle.

(a) Find the resultant force acting on the particle. *(2 marks)*

(b) Given that the mass of the particle is 4 kg, show that the acceleration of the particle is $(3\mathbf{i} + 2\mathbf{j})\,\mathrm{m\,s^{-2}}$. *(2 marks)*

(c) At time t seconds, the velocity of the particle is $\mathbf{v}\,\mathrm{m\,s^{-1}}$.

(i) When $t = 20$, $\mathbf{v} = 40\mathbf{i} + 32\mathbf{j}$.

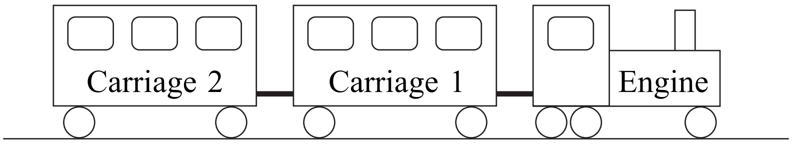
Show that $\mathbf{v} = -20\mathbf{i} - 8\mathbf{j}$ when $t = 0$. *(3 marks)*

(ii) Write down an expression for $\mathbf{v}$ at time t. *(1 mark)*

(iii) Find the times when the speed of the particle is $8\,\mathrm{m\,s^{-1}}$. *(6 marks)*

Turn over for the next question

6 A small train at an amusement park consists of an engine and two carriages connected to each other by light horizontal rods, as shown in the diagram.



The engine has mass 2000 kg and each carriage has mass 500 kg.

The train moves along a straight horizontal track. A resistance force of magnitude 400 newtons acts on the engine, and resistance forces of magnitude 300 newtons act on each carriage. The train is accelerating at $0.5\,\mathrm{m\,s^{-2}}$.

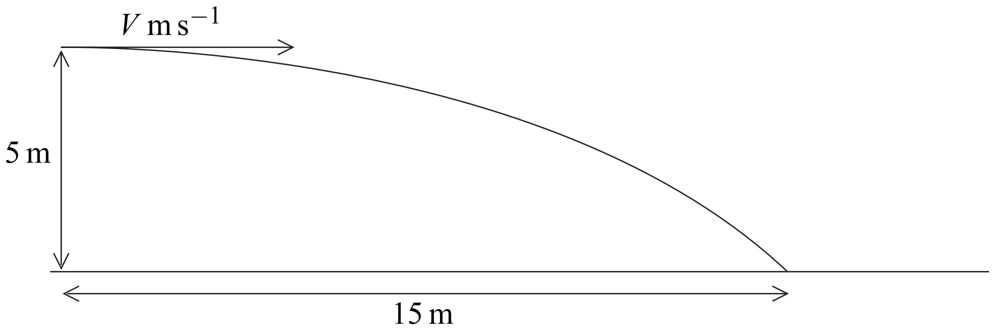
(a) Draw a diagram to show the **horizontal** forces acting on Carriage 2. *(1 mark)*

(b) Show that the magnitude of the force that the rod exerts on Carriage 2 is 550 newtons. *(2 marks)*

(c) Find the magnitude of the force that the rod attached to the engine exerts on Carriage 1. *(3 marks)*

(d) A forward driving force of magnitude P newtons acts on the engine. Find P. *(3 marks)*

7 A ball is projected horizontally with speed $V\,\mathrm{m\,s^{-1}}$ at a height of 5 metres above horizontal ground. When the ball has travelled a horizontal distance of 15 metres, it hits the ground.



(a) Show that the time it takes for the ball to travel to the point where it hits the ground is 1.01 seconds, correct to three significant figures. *(3 marks)*

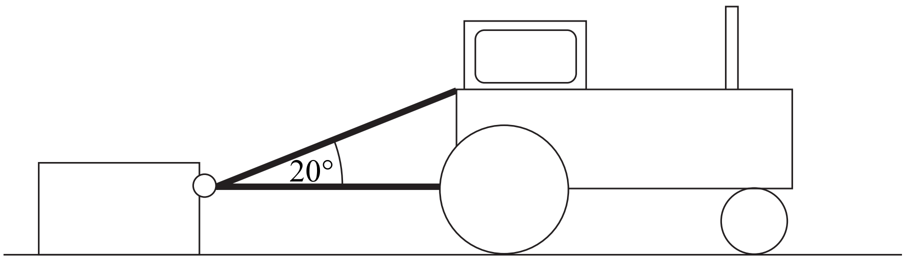
(b) Find V. *(2 marks)*

(c) Find the speed of the ball when it hits the ground. *(4 marks)*

(d) Find the angle between the velocity of the ball and the horizontal when the ball hits the ground. Give your answer to the nearest degree. *(3 marks)*

(e) State two assumptions that you have made about the ball while it is moving. *(2 marks)*

8 A crate, of mass 200 kg, is initially at rest on a rough horizontal surface. A smooth ring is attached to the crate. A light inextensible rope is passed through the ring, and each end of the rope is attached to a tractor. The lower part of the rope is horizontal and the upper part is at an angle of 20° to the horizontal, as shown in the diagram.



When the tractor moves forward, the crate accelerates at $0.3\,\mathrm{m\,s^{-2}}$. The coefficient of friction between the crate and the surface is 0.4 .

Assume that the tension, T newtons, is the same in both parts of the rope.

(a) Draw and label a diagram to show the forces acting on the crate. *(2 marks)*

(b) Express the normal reaction between the surface and the crate in terms of T. *(3 marks)*

(c) Find T. *(5 marks)*

END OF QUESTIONS

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