Centre Number						Candidate Number				
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Other Names										
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For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
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7	
8	
TOTAL	

General Certificate of Education
Advanced Level Examination
January 2011

Mathematics MM2B

Unit Mechanics 2B

Wednesday 26 January 2011 1.30 pm to 3.00 pm

For this paper you must have:
- 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.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- Write the question part reference (eg (a), (b)(i) etc) in the left-hand margin.
- You must answer the questions in the spaces provided. Do not write outside the box around each page.
- Show all necessary working; otherwise marks for method may be lost.
- Do all rough work in this book. Cross through any work that you do not want to be marked.
- 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.

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

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Answer **all** questions in the spaces provided.

1 The velocity of a particle at time t seconds is $\mathbf{v}\,\mathrm{m\,s^{-1}}$, where

$$\mathbf{v} = (4 + 3t^2)\mathbf{i} + (12 - 8t)\mathbf{j}$$

(a) When $t = 0$, the particle is at the point with position vector $(5\mathbf{i} - 7\mathbf{j})$ m.

Find the position vector, $\mathbf{r}$ metres, of the particle at time t. *(4 marks)*

(b) Find the acceleration of the particle at time t. *(2 marks)*

(c) The particle has mass 2 kg.

Find the magnitude of the force acting on the particle when $t = 1$. *(4 marks)*

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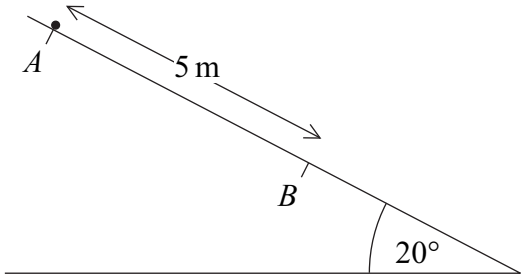
2 A particle is placed on a smooth plane which is inclined at an angle of 20° to the horizontal. The particle, of mass 4 kg, is released from rest at a point A and travels down the plane, passing through a point B. The distance AB is 5 m.



(a) Find the potential energy lost as the particle moves from point A to point B. *(2 marks)*

(b) Hence write down the kinetic energy of the particle when it reaches point B. *(1 mark)*

(c) Hence find the speed of the particle when it reaches point B. *(2 marks)*

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3 A pump is being used to empty a flooded basement.

In one minute, 400 litres of water are pumped out of the basement.

The water is raised 8 metres and is ejected through a pipe at a speed of $2\,\mathrm{m\,s^{-1}}$.

The mass of 400 litres of water is 400 kg.

(a) Calculate the gain in potential energy of the 400 litres of water. *(1 mark)*

(b) Calculate the gain in kinetic energy of the 400 litres of water. *(1 mark)*

(c) Hence calculate the power of the pump, giving your answer in watts. *(2 marks)*

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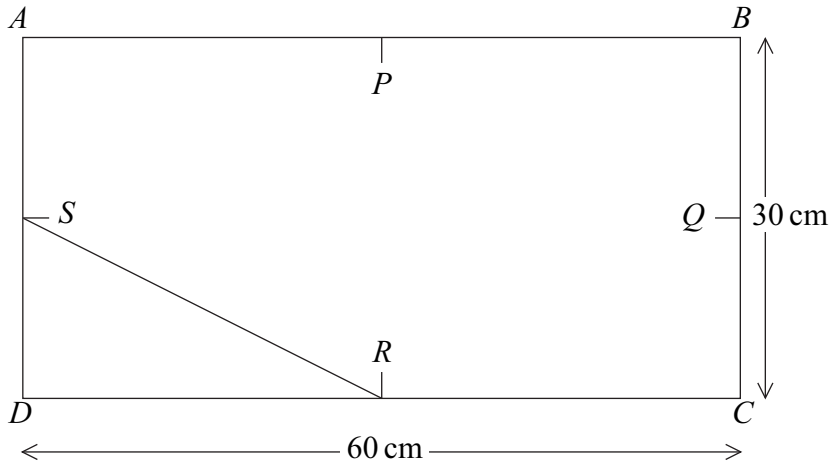
4 A uniform rectangular lamina $ABCD$ has a mass of 5 kg. The side AB has length 60 cm and the side BC has length 30 cm. The points P, Q, R and S are the mid-points of the sides, as shown in the diagram below.

A uniform triangular lamina SRD, of mass 4 kg, is fixed to the rectangular lamina to form a shop sign. The centre of mass of the triangular lamina SRD is 10 cm from the side AD and 5 cm from the side DC.



(a) Find the distance of the centre of mass of the shop sign from AD. *(3 marks)*

(b) Find the distance of the centre of mass of the shop sign from AB. *(3 marks)*

(c) The shop sign is freely suspended from P.

Find the angle between AB and the horizontal when the shop sign is in equilibrium. *(4 marks)*

(d) To ensure that the side AB is horizontal when the shop sign is freely suspended from point P, a particle of mass m kg is attached to the shop sign at point B.

Calculate m. *(3 marks)*

(e) Explain how you have used the fact that the rectangular lamina $ABCD$ is uniform in your solution to this question. *(1 mark)*

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5 (a) A shiny coin is on a rough horizontal turntable at a distance 0.8 m from its centre. The turntable rotates at a constant angular speed. The coefficient of friction between the shiny coin and the turntable is 0.3 .

Find the maximum angular speed, in radians per second, at which the turntable can rotate if the shiny coin is not going to slide. *(4 marks)*

(b) The turntable is stopped and the shiny coin is removed. An old coin is placed on the turntable at a distance 0.15 m from its centre. The turntable is made to rotate at a constant angular speed of 45 revolutions per minute.

(i) Find the angular speed of the turntable in radians per second. *(2 marks)*

(ii) The old coin remains in the same position on the turntable.

Find the least value of the coefficient of friction between the old coin and the turntable needed to prevent the old coin from sliding. *(4 marks)*

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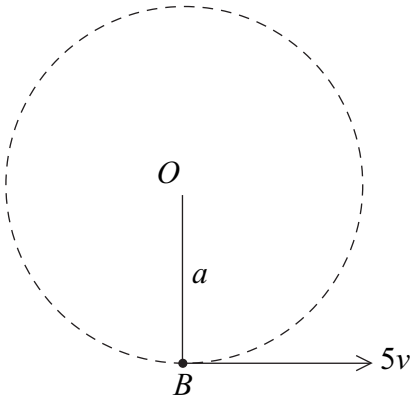
6 A light inextensible string, of length a, has one end attached to a fixed point O. A small bead, of mass m, is attached to the other end of the string. The bead is moving in a vertical circle, centre O. When the bead is at B, vertically below O, the string is taut and the bead is moving with speed $5v$.



(a) The speed of the bead at the highest point of its path is $3v$.

Find v in terms of a and g. *(4 marks)*

(b) Find the ratio of the greatest tension to the least tension in the string, as the bead travels around its circular path. *(5 marks)*

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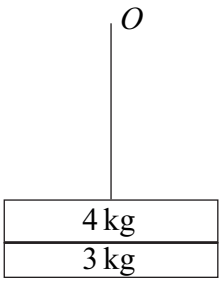
7 (a) An elastic string has natural length l and modulus of elasticity λ. The string is stretched from length l to length $l + e$.

Show, by integration, that the work done in stretching the string is $\dfrac{\lambda e^2}{2l}$. *(3 marks)*

(b) A block, of mass 4 kg, is attached to one end of a light elastic string. The string has natural length 2 m and modulus of elasticity 196 N. The other end of the string is attached to a fixed point O.

(i) A second block, of mass 3 kg, is attached to the 4 kg block and the system hangs in equilibrium, as shown in the diagram.



Find the extension in the string. *(3 marks)*

(ii) The block of mass 3 kg becomes detached from the 4 kg block and falls to the ground. The 4 kg block now begins to move vertically upwards.

Find the extension of the string when the 4 kg block is next at rest. *(6 marks)*

(iii) Find the extension of the string when the speed of the 4 kg block is a maximum. *(3 marks)*

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8 Vicky has mass 65 kg and is skydiving. She steps out of a helicopter and falls vertically. She then waits a short period of time before opening her parachute. The parachute opens at time $t = 0$ when her speed is $19.6\,\mathrm{m\,s^{-1}}$, and she then experiences an air resistance force of magnitude $260v$ newtons, where $v\,\mathrm{m\,s^{-1}}$ is her speed at time t seconds.

(a) When $t > 0$:

(i) show that the resultant downward force acting on Vicky is

$$65(9.8 - 4v) \text{ newtons}$$ *(1 mark)*

(ii) show that $\dfrac{\mathrm{d}v}{\mathrm{d}t} = -4(v - 2.45)$. *(2 marks)*

(b) By showing that $\displaystyle\int \frac{1}{v - 2.45}\,\mathrm{d}v = -\int 4\,\mathrm{d}t$, find v in terms of t. *(5 marks)*

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