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| Candidate surname | Other names |
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| | |

**Pearson Edexcel**
**International**
**Advanced Level**

Centre Number | | | | | |

Candidate Number | | | | |

# Tuesday 22 January 2019

Morning (Time: 1 hour 30 minutes) | Paper Reference **WME02/01**

# Mechanics M2

## Advanced/Advanced Subsidiary

**You must have:**
Mathematical Formulae and Statistical Tables (Blue)

Total Marks

**Candidates may use any calculator allowed by the regulations of the Joint Council for Qualifications. Calculators must not have the facility for symbolic algebra manipulation, differentiation and integration, or have retrievable mathematical formulae stored in them.**

## Instructions

- Use **black** ink or ball-point pen.
- If pencil is used for diagrams/sketches/graphs it must be dark (HB or B). Coloured pencils and highlighter pens must not be used.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions and ensure that your answers to parts of questions are clearly labelled.
- Answer the questions in the spaces provided
  – *there may be more space than you need.*
- You should show sufficient working to make your methods clear. Answers without working may not gain full credit.
- Whenever a numerical value of $g$ is required, take $g = 9.8$ m s$^{-2}$, and give your answer to either two significant figures or three significant figures.
- When a calculator is used, the answer should be given to an appropriate degree of accuracy.

## Information

- The total mark for this paper is 75.
- The marks for **each** question are shown in brackets
  – *use this as a guide as to how much time to spend on each question.*

## Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.

*Turn over* ▶

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**1.** Three particles of masses $3m$, $m$ and $2m$ are positioned at the points with coordinates $(a, 8)$, $(-4, 0)$ and $(5, -2)$ respectively.

Given that the centre of mass of the three particles is at the point with coordinates $(k, 2k)$, where $k$ is a constant, find the value of $a$.

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**Question 1 continued**

**Q1**

**(Total 5 marks)**

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**2.** A particle of mass 0.75 kg is moving with velocity $(4\mathbf{i} + \mathbf{j})$ m s$^{-1}$ when it receives an impulse $(-6\mathbf{i} + 4\mathbf{j})$ N s.

Find

(a) the velocity of the particle immediately after receiving the impulse,

**(3)**

(b) the size of the angle through which the path of the particle is deflected as a result of the impulse.

**(3)**

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**Question 2 continued**

**Q2**

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**3.** A car of mass 900 kg is moving on a straight road that is inclined at an angle $\theta$ to the horizontal, where $\sin\theta = \frac{1}{49}$. When the car is moving up the road, with the engine of the car working at a constant rate of 10.8 kW, the car has a constant speed of $v\,\text{m s}^{-1}$. The resistance to the motion of the car from non-gravitational forces is modelled as a constant force of magnitude $R$ newtons.

When the car is moving down the road, with the engine of the car working at a constant rate of 10.8 kW, the car has a constant speed of $2v\,\text{m s}^{-1}$. The resistance to the motion of the car is still modelled as a constant force of magnitude $R$ newtons.

Find

(i) the value of $R$,

(ii) the value of $v$.

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**Question 3 continued**

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**Question 3 continued**

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**Question 3 continued**

**Q3**

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**4.**

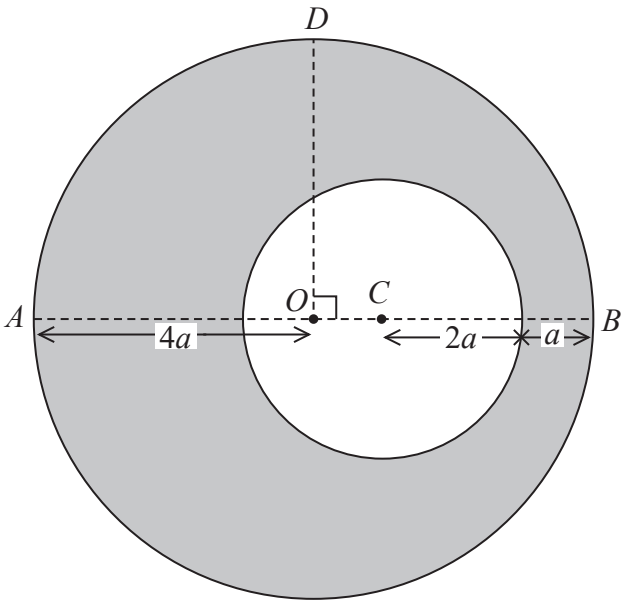


**Figure 1**

The uniform lamina $L$, shown shaded in Figure 1, is formed by removing a circular disc of radius $2a$ from a uniform circular disc of radius $4a$. The larger disc has centre $O$ and diameter $AB$. The radius $OD$ is perpendicular to $AB$. The smaller disc has centre $C$, where $C$ is on $AB$ and $BC = 3a$

(a) Show that the centre of mass of $L$ is $\frac{13}{3}a$ from $B$.

**(4)**

The mass of $L$ is $M$ and a particle of mass $kM$ is attached to $L$ at $B$. When $L$, with the particle attached, is freely suspended from point $D$, it hangs in equilibrium with $A$ higher than $B$ and $AB$ at an angle $\theta$ to the horizontal, where $\tan\theta = \frac{3}{4}$

(b) Find the value of $k$.

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**Question 4 continued**

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**Question 4 continued**

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**Question 4 continued**

**Q4**

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**5.** A particle moves along the $x$-axis. At time $t$ seconds, $t \geqslant 0$, the velocity of the particle is $v\,\text{ms}^{-1}$ in the direction of $x$ increasing, where $v = 2t^{\frac{3}{2}} - 6t + 2$

At time $t = 0$ the particle passes through the origin $O$. At the instant when the acceleration of the particle is zero, the particle is at the point $A$.

Find the distance $OA$.

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**Question 5 continued**

**Q5**

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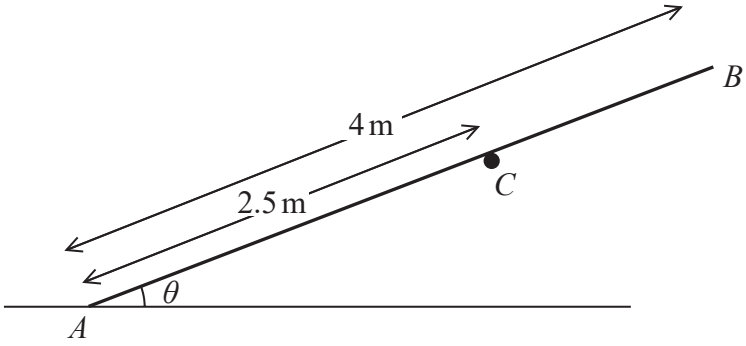


**Figure 2**

A plank $AB$ rests in equilibrium against a fixed horizontal pole. The plank has length 4 m and weight 20 N and rests on the pole at $C$, where $AC = 2.5$ m. The end $A$ of the plank rests on rough horizontal ground and $AB$ makes an angle $\theta$ with the ground, as shown in Figure 2. The coefficient of friction between the plank and the ground is $\frac{1}{4}$.

The plank is modelled as a uniform rod and the pole as a rough horizontal peg that is perpendicular to the vertical plane containing $AB$.

Given that $\cos\theta = \frac{4}{5}$ and that the friction is limiting at both $A$ and $C$,

(a) find the magnitude of the normal reaction on the plank at $C$,

**(3)**

(b) find the coefficient of friction between the plank and the pole.

**(8)**

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**Question 6 continued**

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**Question 6 continued**

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**Question 6 continued**

**Q6**

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**7.** A particle $P$ of mass $3m$ is moving in a straight line with speed $u$ on a smooth horizontal table. A second particle $Q$ of mass $2m$ is moving with speed $2u$ in the opposite direction to $P$ along the same straight line. Particle $P$ collides directly with $Q$. The coefficient of restitution between $P$ and $Q$ is $e$.

(a) Show that the direction of motion of $P$ is reversed as a result of the collision with $Q$.

**(3)**

(b) Find the range of values of $e$ for which the direction of motion of $Q$ is also reversed as a result of the collision.

**(5)**

Given that $e = \frac{1}{2}$

(c) find, in terms of $m$ and $u$, the kinetic energy lost in the collision between $P$ and $Q$.

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**Question 7 continued**

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**Question 7 continued**

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**Question 7 continued**

**Q7**

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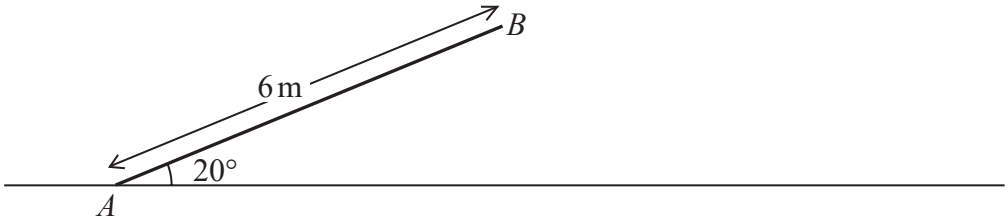


**Figure 3**

A rough ramp $AB$ is fixed to horizontal ground at $A$. The ramp is inclined at 20° to the ground. The line $AB$ is a line of greatest slope of the ramp and $AB = 6$ m. The point $B$ is at the top of the ramp, as shown in Figure 3. A particle $P$ of mass 3 kg is projected with speed 15 m s$^{-1}$ from $A$ towards $B$. At the instant $P$ reaches the point $B$ the speed of $P$ is 10 m s$^{-1}$. The force due to friction is modelled as a constant force of magnitude $F$ newtons.

(a) Use the work-energy principle to find the value of $F$.

**(6)**

After leaving the ramp at $B$, the particle $P$ moves freely under gravity until it hits the horizontal ground at the point $C$. The speed of $P$ as it hits the ground at $C$ is $w$ m s$^{-1}$.

Find

(b) (i) the value of $w$,

(ii) the direction of motion of $P$ as it hits the ground at $C$,

**(5)**

(c) the greatest height of $P$ above the ground as $P$ moves from $A$ to $C$.

**(4)**

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**Question 8 continued**

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Q8

**(Total 15 marks)**

**TOTAL FOR PAPER: 75 MARKS**

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