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| Surname | Other names |
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**Pearson Edexcel**
**International**
**Advanced Level**

Centre Number | | | | | |

Candidate Number | | | | |

# Mechanics M3

## Advanced/Advanced Subsidiary

Thursday 14 January 2016 – Afternoon
**Time: 1 hour 30 minutes**

Paper Reference
**WME03/01**

**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.**

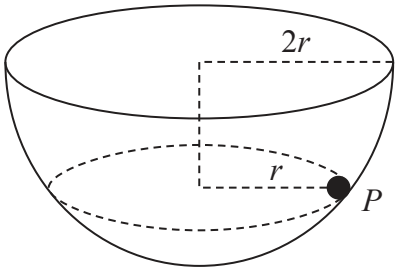


**Figure 1**

A hemispherical bowl of internal radius $2r$ is fixed with its circular rim horizontal. A particle $P$ is moving in a horizontal circle of radius $r$ on the smooth inner surface of the bowl, as shown in Figure 1. Particle $P$ is moving with constant angular speed $\omega$.

Show that $\omega = \sqrt{\dfrac{g\sqrt{3}}{3r}}$

**(6)**

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**Question 1 continued**

**Q1**

**(Total 6 marks)**

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**2.** A particle $P$ is moving in a straight line. At time $t$ seconds, the distance of $P$ from a fixed point $O$ on the line is $x$ metres and the acceleration of $P$ is $(6 - 2t)$ m s$^{-2}$ in the direction of $x$ increasing. When $t = 0$, $P$ is moving towards $O$ with speed 8 m s$^{-1}$

(a) Find the velocity of $P$ in terms of $t$.

**(3)**

(b) Find the total distance travelled by $P$ in the first 4 seconds.

**(5)**

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**Question 2 continued**

**Q2**

**(Total 8 marks)**

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**3.** A car of mass 800 kg is driven at constant speed $v$ m s$^{-1}$ round a bend in a race track. Around the bend, the track is banked at 20° to the horizontal and the path followed by the car can be modelled as a horizontal circle of radius 20 m. The car is modelled as a particle. The coefficient of friction between the car tyres and the track is 0.5

Given that the tyres do not slip sideways on the track, find the maximum value of $v$.

**(9)**

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**Question 3 continued**

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**Question 3 continued**

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**Question 3 continued**

**Q3**

**(Total 9 marks)**

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**4.** Fixed points $A$ and $B$ are on a horizontal ceiling, where $AB = 4a$. A light elastic string has natural length $3a$ and modulus of elasticity $\lambda$. One end of the string is attached to $A$ and the other end is attached to $B$. A particle $P$ of mass $m$ is attached to the midpoint of the string. The particle hangs freely in equilibrium at the point $C$, where $C$ is at a distance $\frac{3}{2}a$ vertically below the ceiling.

(a) Show that $\lambda = \frac{5mg}{4}$

**(5)**

The point $D$ is the midpoint of $AB$. The particle is now raised vertically upwards to $D$, and released from rest.

(b) Find the speed of $P$ as it passes through $C$.

**(5)**

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**Q4**

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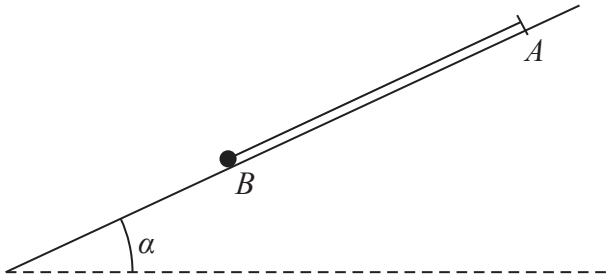


**Figure 2**

A particle $P$ of mass $m$ is attached to one end of a light elastic string, of natural length $l$ and modulus of elasticity $\lambda$. The other end of the string is attached to a fixed point $A$ on a smooth plane inclined at angle $\alpha$ to the horizontal, where $\sin\alpha = \frac{3}{5}$. The particle rests in equilibrium on the plane at the point $B$ with the string lying along a line of greatest slope of the plane, as shown in Figure 2.

Given that $AB = \frac{6}{5}l$

(a) show that $\lambda = 3mg$

**(3)**

The particle is pulled down the line of greatest slope to the point $C$, where $BC = \frac{1}{2}l$, and released from rest.

(b) Show that, while the string remains taut, $P$ moves with simple harmonic motion about centre $B$.

**(4)**

(c) Find the greatest magnitude of the acceleration of $P$ while the string remains taut.

**(2)**

The point $D$ is the midpoint of $BC$. The time taken by $P$ to move directly from $D$ to the point where the string becomes slack for the first time is $k\sqrt{\frac{l}{g}}$, where $k$ is a constant.

(d) Find, to 2 significant figures, the value of $k$.

**(4)**

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**Question 5 continued**

**Q5**

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**6.** (a) Use algebraic integration to show that the centre of mass of a uniform solid hemisphere of radius $r$ is at a distance $\frac{3}{8}r$ from the centre of its plane face.

[*You may assume that the volume of a sphere of radius r is* $\frac{4}{3}\pi r^3$]

**(5)**

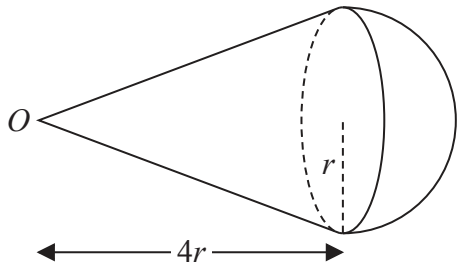


**Figure 3**

A uniform solid hemisphere of mass $m$ and radius $r$ is joined to a uniform solid right circular cone to form a solid $S$. The cone has mass $M$, base radius $r$ and height $4r$. The vertex of the cone is $O$. The plane face of the cone coincides with the plane face of the hemisphere, as shown in Figure 3.

(b) Find the distance of the centre of mass of $S$ from $O$.

**(4)**

The point $A$ lies on the circumference of the base of the cone. The solid is placed on a horizontal table with $OA$ in contact with the table. The solid remains in equilibrium in this position.

(c) Show that $M \geqslant \frac{1}{10}m$

**(5)**

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**Question 6 continued**

**Q6**

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**7.**

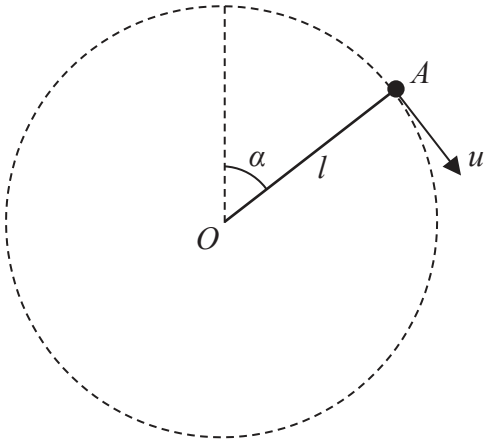


**Figure 4**

A particle of mass $m$ is attached to one end of a light rod of length $l$. The other end of the rod is attached to a fixed point $O$. The rod can turn freely in a vertical plane about a horizontal axis through $O$. The particle is projected with speed $u$ from a point $A$, where $OA$ makes an angle $\alpha$ with the upward vertical through $O$, as shown in Figure 4. The particle moves in complete vertical circles.

Given that $\cos\alpha = \frac{4}{5}$

(a) show that $u > \sqrt{\frac{2gl}{5}}$

**(4)**

As the rod rotates, the least tension in the rod is $T$ and the greatest tension is $4T$.

(b) Show that $u = \sqrt{\frac{17}{5}gl}$

**(11)**

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Q7

**(Total 15 marks)**

**TOTAL FOR PAPER: 75 MARKS**

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