Cambridge International A Level

**Cambridge International Examinations**
Cambridge International Advanced Level

**MATHEMATICS** **9709/51**

Paper 5 Mechanics 2 **(M2)** **October/November 2015**

**1 hour 15 minutes**

Additional Materials: Answer Booklet/Paper
Graph Paper
List of Formulae (MF9)

*2492175147*

**READ THESE INSTRUCTIONS FIRST**

If you have been given an Answer Booklet, follow the instructions on the front cover of the Booklet.
Write your Centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** the questions.
Give non-exact numerical answers correct to 3 significant figures, or 1 decimal place in the case of angles in degrees, unless a different level of accuracy is specified in the question.
Where a numerical value for the acceleration due to gravity is needed, use $10\,\text{m}\,\text{s}^{-2}$.
The use of an electronic calculator is expected, where appropriate.
You are reminded of the need for clear presentation in your answers.

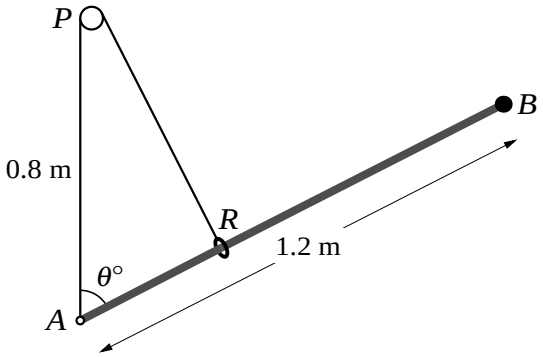
At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.
The total number of marks for this paper is 50.
Questions carrying smaller numbers of marks are printed earlier in the paper, and questions carrying larger numbers of marks later in the paper.




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**1** A particle $P$ moves in a straight line and passes through a point $O$ of the line with velocity $2\,\text{m s}^{-1}$. At time $t$ s after passing through $O$, the velocity of $P$ is $v\,\text{m s}^{-1}$ and the acceleration of $P$ is given by $e^{-0.5v}\,\text{m s}^{-2}$. Calculate the velocity of $P$ when $t = 1.2$. [4]

**2**




A uniform rigid rod $AB$ of length 1.2 m and weight 8 N has a particle of weight 2 N attached at the end $B$. The end $A$ of the rod is freely hinged to a fixed point. One end of a light elastic string of natural length 0.8 m and modulus of elasticity 20 N is attached to the hinge. The string passes over a small smooth pulley $P$ fixed 0.8 m vertically above the hinge. The other end of the string is attached to a small light smooth ring $R$ which can slide on the rod. The system is in equilibrium with the rod inclined at an angle $\theta°$ to the vertical (see diagram).

**(i)** Show that the tension in the string is $20 \sin \theta$ N. [1]

**(ii)** Explain why the part of the string attached to the ring is perpendicular to the rod. [1]

**(iii)** Find $\theta$. [3]

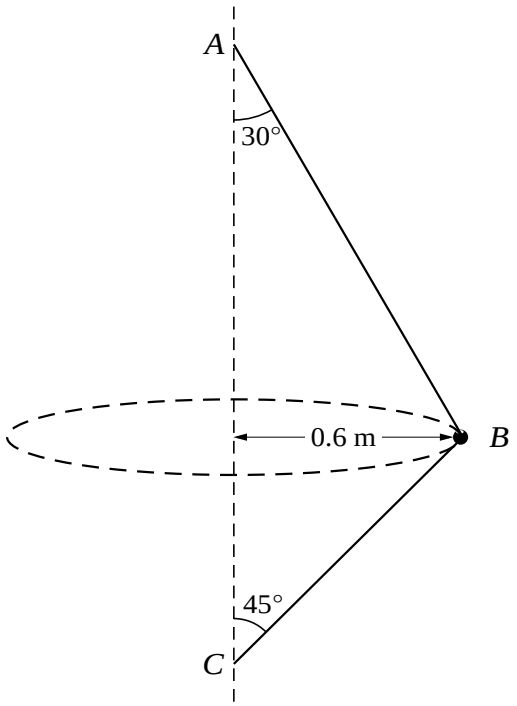
**3** A particle $P$ of mass 0.3 kg moves in a straight line on a smooth horizontal surface. $P$ passes through a fixed point $O$ of the line with velocity $8\,\text{m s}^{-1}$. A force of magnitude $2x$ N acts on $P$ in the direction $PO$, where $x$ m is the displacement of $P$ from $O$.

**(i)** Show that $v\dfrac{\text{d}v}{\text{d}x} = kx$ and state the value of the constant $k$. [2]

**(ii)** Find the value of $x$ at the instant when $P$ comes to instantaneous rest. [3]

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**4**




One end of a light inextensible string is attached to a fixed point $A$. The string passes through a smooth bead $B$ of mass 0.3 kg and the other end of the string is attached to a fixed point $C$ vertically below $A$. The bead $B$ moves with constant speed in a horizontal circle of radius 0.6 m which has its centre between $A$ and $C$. The string makes an angle of 30° with the vertical at $A$ and an angle of 45° with the vertical at $C$ (see diagram).

**(i)** Calculate the speed of $B$. [5]

The lower end of the string is detached from $C$, and $B$ is now attached to this end of the string. The other end of the string remains attached to $A$. The bead is set in motion so that it moves with angular speed 3 rad $s^{-1}$ in a horizontal circle which has its centre vertically below $A$.

**(ii)** Calculate the tension in the string. [3]

**5** A particle $P$ of mass 0.2 kg is attached to one end of a light elastic string of natural length 0.75 m and modulus of elasticity 21 N. The other end of the string is attached to a fixed point $A$ which is 0.8 m vertically above a smooth horizontal surface. $P$ rests in equilibrium on the surface.

**(i)** Find the magnitude of the force exerted on $P$ by the surface. [2]

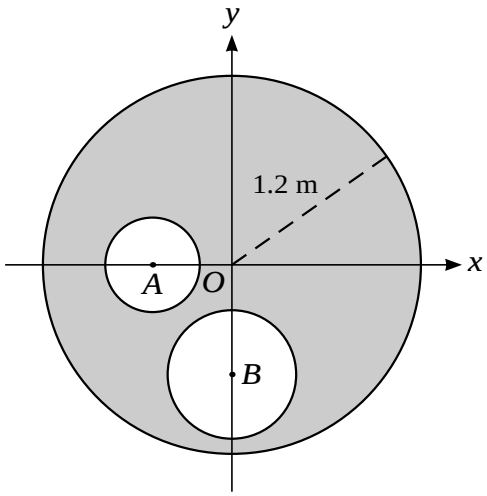
$P$ is now projected horizontally along the surface with speed 3 m $s^{-1}$.

**(ii)** Calculate the extension of the string at the instant when $P$ leaves the surface. [3]

**(iii)** Hence find the speed of $P$ at the instant when it leaves the surface. [3]

**[Questions 6 and 7 are printed on the next page.]**

**6**




A uniform circular disc has centre $O$ and radius 1.2 m. The centre of the disc is at the origin of $x$- and $y$-axes. Two circular holes with centres at $A$ and $B$ are made in the disc (see diagram). The point $A$ is on the negative $x$-axis with $OA = 0.5$ m. The point $B$ is on the negative $y$-axis with $OB = 0.7$ m. The hole with centre $A$ has radius 0.3 m and the hole with centre $B$ has radius 0.4 m. Find the distance of the centre of mass of the object from

**(i)** the $x$-axis, [4]

**(ii)** the $y$-axis. [3]

The object can rotate freely in a vertical plane about a horizontal axis through $O$.

**(iii)** Calculate the angle which $OA$ makes with the vertical when the object rests in equilibrium. [2]

**7** A particle $P$ is projected with speed $V$ m s$^{-1}$ at an angle of 60° above the horizontal from a point $O$. At the instant 1 s later a particle $Q$ is projected from $O$ with the same initial speed at an angle of 45° above the horizontal. The two particles collide when $Q$ has been in motion for $t$ s.

**(i)** Show that $t = 2.414$, correct to 3 decimal places. [3]

**(ii)** Find the value of $V$. [4]

The collision occurs after $P$ has passed through the highest point of its trajectory.

**(iii)** Calculate the vertical distance of $P$ below its greatest height when $P$ and $Q$ collide. [4]

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