UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education
Advanced Subsidiary Level and Advanced Level

# Mathematics (9709)

## Paper 4: Mechanics 1 (M1)

2020-2021

UNIVERSITY of CAMBRIDGE
International Examinations

Cambridge Assessment International Education

# Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

*8787335916*

**MATHEMATICS** **9709/42**

Paper 4 Mechanics **February/March 2020**

**1 hour 15 minutes**

You must answer on the question paper.

You will need: List of formulae (MF19)

**INSTRUCTIONS**

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
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- Where a numerical value for the acceleration due to gravity ($g$) is needed, use $10\,\text{m}\,\text{s}^{-2}$.

**INFORMATION**

- The total mark for this paper is 50.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **16** pages. Blank pages are indicated.

**1** A lorry of mass 16 000 kg is travelling along a straight horizontal road. The engine of the lorry is working at constant power. The work done by the driving force in 10 s is 750 000 J.

**(a)** Find the power of the lorry's engine. [1]

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**(b)** There is a constant resistance force acting on the lorry of magnitude 2400 N.

Find the acceleration of the lorry at an instant when its speed is 25 m $s^{-1}$. [3]

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**2** A particle $P$ of mass 0.4 kg is on a rough horizontal floor. The coefficient of friction between $P$ and the floor is $\mu$. A force of magnitude 3 N is applied to $P$ upwards at an angle $\alpha$ above the horizontal, where $\tan\alpha = \frac{3}{4}$. The particle is initially at rest and accelerates at $2\,\text{m}\,\text{s}^{-2}$.

**(a)** Find the time it takes for $P$ to travel a distance of 1.44 m from its starting point. [2]

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**(b)** Find $\mu$. [4]

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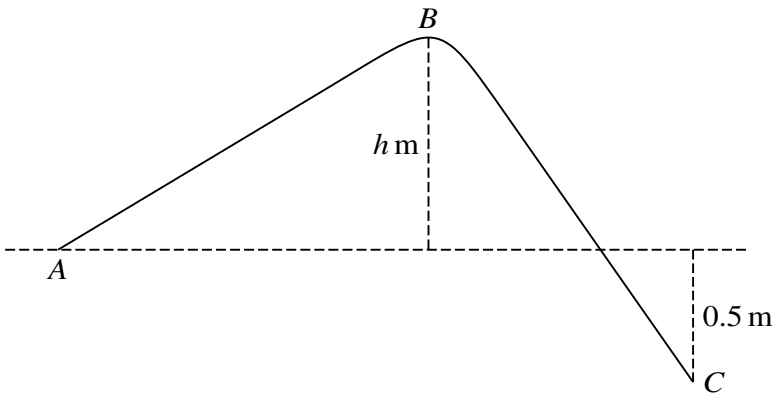


The diagram shows the vertical cross-section of a surface. $A$, $B$ and $C$ are three points on the cross-section. The level of $B$ is $h$ m above the level of $A$. The level of $C$ is 0.5 m below the level of $A$. A particle of mass 0.2 kg is projected up the slope from $A$ with initial speed 5 m s$^{-1}$. The particle remains in contact with the surface as it travels from $A$ to $C$.

**(a)** Given that the particle reaches $B$ with a speed of 3 m s$^{-1}$ and that there is no resistance force, find $h$. [3]

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**(b)** It is given instead that there is a resistance force and that the particle does 3.1 J of work against the resistance force as it travels from $A$ to $C$.

Find the speed of the particle when it reaches $C$. [3]

**4** A cyclist travels along a straight road with constant acceleration. He passes through points $A$, $B$ and $C$. The cyclist takes 2 seconds to travel along each of the sections $AB$ and $BC$ and passes through $B$ with speed $4.5\,\text{m s}^{-1}$. The distance $AB$ is $\frac{4}{5}$ of the distance $BC$.

**(a)** Find the acceleration of the cyclist. [5]

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**(b)** Find $AC$. [2]

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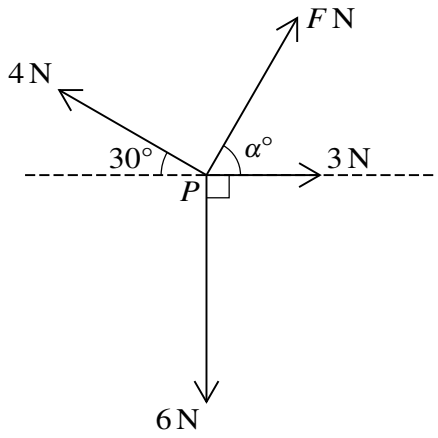


Coplanar forces, of magnitudes $F$ N, 3 N, 6 N and 4 N, act at a point $P$, as shown in the diagram.

**(a)** Given that $\alpha = 60$, and that the resultant of the four forces is in the direction of the 3 N force, find $F$. [3]

**(b)** Given instead that the four forces are in equilibrium, find the values of $F$ and $\alpha$. [5]

**6** On a straight horizontal test track, driverless vehicles (with no passengers) are being tested. A car of mass 1600 kg is towing a trailer of mass 700 kg along the track. The brakes are applied, resulting in a deceleration of $12\,m\,s^{-2}$. The braking force acts on the car only. In addition to the braking force there are constant resistance forces of 600 N on the car and of 200 N on the trailer.

**(a)** Find the magnitude of the force in the tow-bar. [2]

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**(b)** Find the braking force. [2]

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**(c)** At the instant when the brakes are applied, the car has speed $22\,m\,s^{-1}$. At this instant the car is 17.5 m away from a stationary van, which is directly in front of the car.

Show that the car hits the van at a speed of $8\,m\,s^{-1}$. [2]

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**(d)** After the collision, the van starts to move with speed $5\,m\,s^{-1}$ and the car and trailer continue moving in the same direction with speed $2\,m\,s^{-1}$.

Find the mass of the van. [3]

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**7** A particle moves in a straight line through the point $O$. The displacement of the particle from $O$ at time $t$ s is $s$ m, where

$$s = t^2 - 3t + 2 \qquad \text{for } 0 \leqslant t \leqslant 6,$$

$$s = \frac{24}{t} - \frac{t^2}{4} + 25 \quad \text{for } t \geqslant 6.$$

**(a)** Find the value of $t$ when the particle is instantaneously at rest during the first 6 seconds of its motion. [2]

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At $t = 6$, the particle hits a barrier at a point $P$ and rebounds.

**(b)** Find the velocity with which the particle arrives at $P$ and also the velocity with which the particle leaves $P$. [3]

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**(c)** Find the total distance travelled by the particle in the first 10 seconds of its motion. [5]

Cambridge Assessment International Education

# Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER | | | | | |

CANDIDATE NUMBER | | | | |

*8733449616*

**MATHEMATICS** **9709/41**

Paper 4 Mechanics **May/June 2020**

**1 hour 15 minutes**

You must answer on the question paper.

You will need: List of formulae (MF19)

**INSTRUCTIONS**

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
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- You must show all necessary working clearly; no marks will be given for unsupported answers from a calculator.
- Give non-exact numerical answers correct to 3 significant figures, or 1 decimal place for angles in degrees, unless a different level of accuracy is specified in the question.
- Where a numerical value for the acceleration due to gravity ($g$) is needed, use $10\,\text{m}\,\text{s}^{-2}$.

**INFORMATION**

- The total mark for this paper is 50.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **16** pages. Blank pages are indicated.

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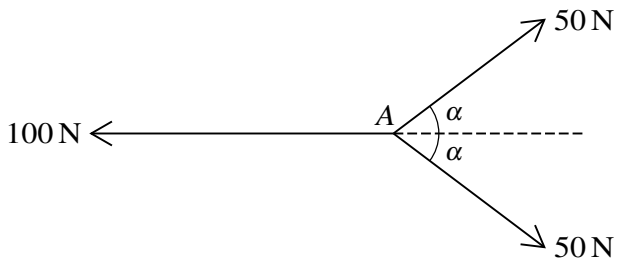
**1**




Three coplanar forces of magnitudes 100 N, 50 N and 50 N act at a point $A$, as shown in the diagram. The value of $\cos\alpha$ is $\frac{4}{5}$.

Find the magnitude of the resultant of the three forces and state its direction. [3]

**2** A car of mass 1800 kg is towing a trailer of mass 400 kg along a straight horizontal road. The car and trailer are connected by a light rigid tow-bar. The car is accelerating at $1.5\,\text{m}\,\text{s}^{-2}$. There are constant resistance forces of 250 N on the car and 100 N on the trailer.

**(a)** Find the tension in the tow-bar. [2]

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**(b)** Find the power of the engine of the car at the instant when the speed is $20\,\text{m}\,\text{s}^{-1}$. [3]

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**3** A particle $P$ is projected vertically upwards with speed $5\,\text{m}\,\text{s}^{-1}$ from a point $A$ which is 2.8 m above horizontal ground.

**(a)** Find the greatest height above the ground reached by $P$. [3]

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**(b)** Find the length of time for which $P$ is at a height of more than 3.6 m above the ground. [4]

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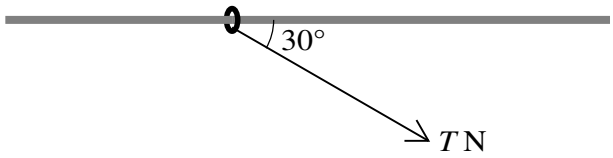


The diagram shows a ring of mass 0.1 kg threaded on a fixed horizontal rod. The rod is rough and the coefficient of friction between the ring and the rod is 0.8. A force of magnitude $T$ N acts on the ring in a direction at 30° to the rod, downwards in the vertical plane containing the rod. Initially the ring is at rest.

**(a)** Find the greatest value of $T$ for which the ring remains at rest. [4]

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**(b)** Find the acceleration of the ring when $T = 3$. [3]

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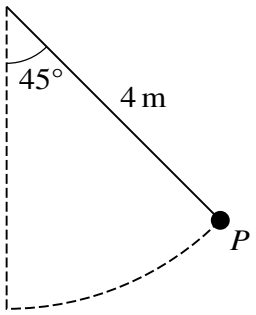


A child of mass 35 kg is swinging on a rope. The child is modelled as a particle $P$ and the rope is modelled as a light inextensible string of length 4 m. Initially $P$ is held at an angle of 45° to the vertical (see diagram).

**(a)** Given that there is no resistance force, find the speed of $P$ when it has travelled half way along the circular arc from its initial position to its lowest point. [4]

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**(b)** It is given instead that there is a resistance force. The work done against the resistance force as $P$ travels from its initial position to its lowest point is $X$ J. The speed of $P$ at its lowest point is $4\,\text{m}\,\text{s}^{-1}$.

Find $X$. [3]

**6** A particle moves in a straight line $AB$. The velocity $v$ m s$^{-1}$ of the particle $t$ s after leaving $A$ is given by $v = k(t^2 - 10t + 21)$, where $k$ is a constant. The displacement of the particle from $A$, in the direction towards $B$, is 2.85 m when $t = 3$ and is 2.4 m when $t = 6$.

**(a)** Find the value of $k$. Hence find an expression, in terms of $t$, for the displacement of the particle from $A$. [7]

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**(b)** Find the displacement of the particle from $A$ when its velocity is a minimum. [4]

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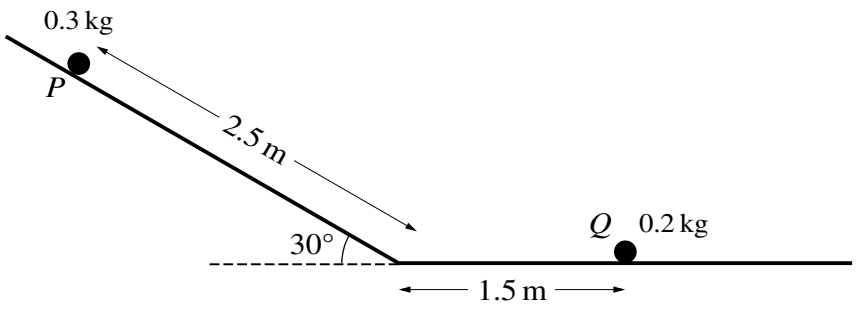


A particle $P$ of mass 0.3 kg, lying on a smooth plane inclined at 30° to the horizontal, is released from rest. $P$ slides down the plane for a distance of 2.5 m and then reaches a horizontal plane. There is no change in speed when $P$ reaches the horizontal plane. A particle $Q$ of mass 0.2 kg lies at rest on the horizontal plane 1.5 m from the end of the inclined plane (see diagram). $P$ collides directly with $Q$.

**(a)** It is given that the horizontal plane is smooth and that, after the collision, $P$ continues moving in the same direction, with speed $2\,\text{m}\,\text{s}^{-1}$.

Find the speed of $Q$ after the collision. [5]

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**(b)** It is given instead that the horizontal plane is rough and that when $P$ and $Q$ collide, they coalesce and move with speed $1.2\,\text{m}\,\text{s}^{-1}$.

Find the coefficient of friction between $P$ and the horizontal plane. [5]

Cambridge Assessment International Education

# Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

*4422423969 4*

**MATHEMATICS** **9709/42**

Paper 4 Mechanics **May/June 2020**

**1 hour 15 minutes**

You must answer on the question paper.

You will need: List of formulae (MF19)

**INSTRUCTIONS**

- Answer **all** questions.
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**INFORMATION**

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This document has **12** pages. Blank pages are indicated.

**1** A tram starts from rest and moves with uniform acceleration for 20 s. The tram then travels at a constant speed, $V$ m s$^{-1}$, for 170 s before being brought to rest with a uniform deceleration of magnitude twice that of the acceleration. The total distance travelled by the tram is 2.775 km.

**(a)** Sketch a velocity-time graph for the motion, stating the total time for which the tram is moving. [2]

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**(b)** Find $V$. [2]

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**(c)** Find the magnitude of the acceleration. [2]

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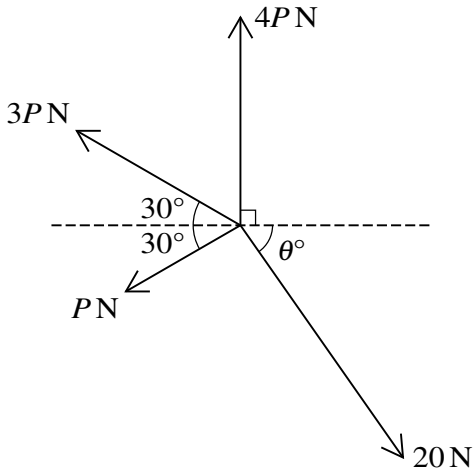
**2**




Coplanar forces of magnitudes 20 N, $P$ N, $3P$ N and $4P$ N act at a point in the directions shown in the diagram. The system is in equilibrium.

Find $P$ and $\theta$. [6]

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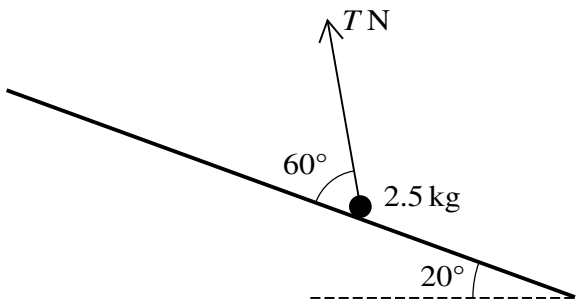


A particle of mass 2.5 kg is held in equilibrium on a rough plane inclined at 20° to the horizontal by a force of magnitude $T$ N making an angle of 60° with a line of greatest slope of the plane (see diagram). The coefficient of friction between the particle and the plane is 0.3.

Find the greatest and least possible values of $T$. [8]

**4** Small smooth spheres $A$ and $B$, of equal radii and of masses 4 kg and 2 kg respectively, lie on a smooth horizontal plane. Initially $B$ is at rest and $A$ is moving towards $B$ with speed $10\,\text{m}\,\text{s}^{-1}$. After the spheres collide $A$ continues to move in the same direction but with half the speed of $B$.

**(a)** Find the speed of $B$ after the collision. [2]

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A third small smooth sphere $C$, of mass 1 kg and with the same radius as $A$ and $B$, is at rest on the plane. $B$ now collides directly with $C$. After this collision $B$ continues to move in the same direction but with one third the speed of $C$.

**(b)** Show that there is another collision between $A$ and $B$. [3]

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**(c)** *A* and *B* coalesce during this collision.

Find the total loss of kinetic energy in the system due to the three collisions. [5]

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**5** A car of mass 1250 kg is moving on a straight road.

**(a)** On a horizontal section of the road, the car has a constant speed of 32 m $s^{-1}$ and there is a constant force of 750 N resisting the motion.

**(i)** Calculate, in kW, the power developed by the engine of the car. [2]

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**(ii)** Given that this power is suddenly decreased by 8 kW, find the instantaneous deceleration of the car. [3]

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**(b)** On a section of the road inclined at $\sin^{-1} 0.096$ to the horizontal, the resistance to the motion of the car is $(1000 + 8v)$ N when the speed of the car is $v\,\text{m}\,\text{s}^{-1}$. The car travels up this section of the road at constant speed with the engine working at 60 kW.

Find this constant speed. [5]

**6** A particle $P$ moves in a straight line. The velocity $v$ m s$^{-1}$ at time $t$ s is given by

$$\begin{aligned} v &= 2t + 1 \qquad \text{for } 0 \leqslant t \leqslant 5, \\ v &= 36 - t^2 \qquad \text{for } 5 \leqslant t \leqslant 7, \\ v &= 2t - 27 \qquad \text{for } 7 \leqslant t \leqslant 13.5. \end{aligned}$$

**(a)** Sketch the velocity-time graph for $0 \leqslant t \leqslant 13.5$. [3]

**(b)** Find the acceleration at the instant when $t = 6$. [2]

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**(c)** Find the total distance travelled by $P$ in the interval $0 \leqslant t \leqslant 13.5$. [5]

Cambridge Assessment International Education

# Cambridge International AS & A Level

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|---|---|---|---|---|---|---|---|---|---|
| CANDIDATE NAME | | | | | | | | | |
| CENTRE NUMBER | | | | | | CANDIDATE NUMBER | | | |

*9540061596*

**MATHEMATICS** **9709/43**

Paper 4 Mechanics **May/June 2020**

**1 hour 15 minutes**

You must answer on the question paper.

You will need: List of formulae (MF19)

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**INFORMATION**

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**1** Particles $P$ of mass $m$ kg and $Q$ of mass 0.2 kg are free to move on a smooth horizontal plane. $P$ is projected at a speed of $2\,\text{m s}^{-1}$ towards $Q$ which is stationary. After the collision $P$ and $Q$ move in opposite directions with speeds of $0.5\,\text{m s}^{-1}$ and $1\,\text{m s}^{-1}$ respectively.

Find $m$. [3]

**2** A minibus of mass 4000 kg is travelling along a straight horizontal road. The resistance to motion is 900 N.

**(a)** Find the driving force when the acceleration of the minibus is $0.5\,\text{m s}^{-2}$. [2]

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**(b)** Find the power required for the minibus to maintain a constant speed of $25\,\text{m s}^{-1}$. [2]

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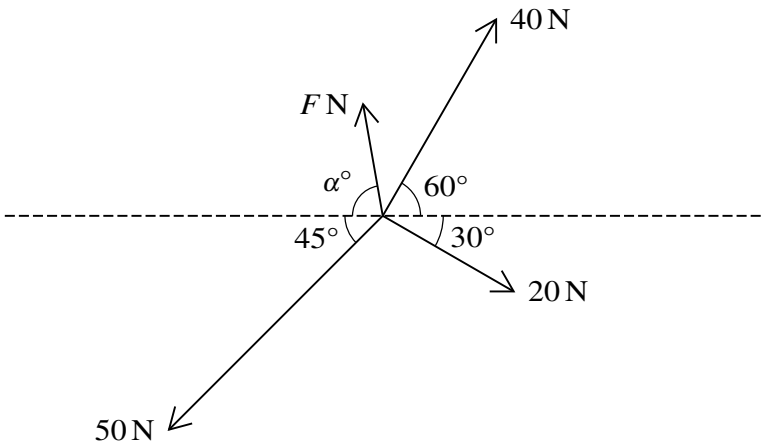


Four coplanar forces of magnitudes 40 N, 20 N, 50 N and $F$ N act at a point in the directions shown in the diagram. The four forces are in equilibrium.

Find $F$ and $\alpha$. [6]

**4** A car starts from rest and moves in a straight line with constant acceleration $a\,\text{m s}^{-2}$ for a distance of 50 m. The car then travels with constant velocity for 500 m for a period of 25 s, before decelerating to rest. The magnitude of this deceleration is $2a\,\text{m s}^{-2}$.

**(a)** Sketch the velocity-time graph for the motion of the car. [1]


**(b)** Find the value of $a$. [3]

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**(c)** Find the total time for which the car is in motion. [3]

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**5** A block $B$ of mass 4 kg is pushed up a line of greatest slope of a smooth plane inclined at 30° to the horizontal by a force applied to $B$, acting in the direction of motion of $B$. The block passes through points $P$ and $Q$ with speeds $12\,\text{m s}^{-1}$ and $8\,\text{m s}^{-1}$ respectively. $P$ and $Q$ are 10 m apart with $P$ below the level of $Q$.

**(a)** Find the decrease in kinetic energy of the block as it moves from $P$ to $Q$. [2]

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**(b)** Hence find the work done by the force pushing the block up the slope as the block moves from $P$ to $Q$. [3]

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**(c)** At the instant the block reaches $Q$, the force pushing the block up the slope is removed.

Find the time taken, after this instant, for the block to return to $P$. [4]

**6** A particle travels in a straight line $PQ$. The velocity of the particle $t$ s after leaving $P$ is $v$ m s$^{-1}$, where

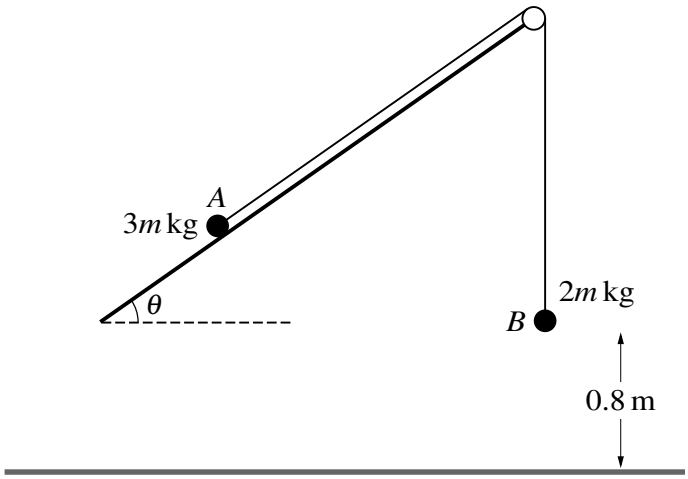
$$v = 4.5 + 4t - 0.5t^2.$$

**(a)** Find the velocity of the particle at the instant when its acceleration is zero. [3]

The particle comes to instantaneous rest at $Q$.

**(b)** Find the distance $PQ$. [6]

**7**




Two particles $A$ and $B$, of masses $3m$ kg and $2m$ kg respectively, are attached to the ends of a light inextensible string. The string passes over a fixed smooth pulley which is attached to the edge of a plane. The plane is inclined at an angle $\theta$ to the horizontal. $A$ lies on the plane and $B$ hangs vertically, 0.8 m above the floor, which is horizontal. The string between $A$ and the pulley is parallel to a line of greatest slope of the plane (see diagram). Initially $A$ and $B$ are at rest.

**(a)** Given that the plane is smooth, find the value of $\theta$ for which $A$ remains at rest. [3]

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It is given instead that the plane is rough, $\theta = 30°$ and the acceleration of $A$ up the plane is $0.1\ \text{m s}^{-2}$.

**(b)** Show that the coefficient of friction between $A$ and the plane is $\frac{1}{10}\sqrt{3}$. [5]

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**(c)** When $B$ reaches the floor it comes to rest.

Find the length of time after $B$ reaches the floor for which $A$ is moving up the plane. [You may assume that $A$ does not reach the pulley.] [4]

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Cambridge Assessment International Education

# Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER | | | | | |

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*7958355328*

**MATHEMATICS** **9709/41**

Paper 4 Mechanics **October/November 2020**

**1 hour 15 minutes**

You must answer on the question paper.

You will need: List of formulae (MF19)

**INSTRUCTIONS**

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
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- Do **not** write on any bar codes.
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- You should use a calculator where appropriate.
- You must show all necessary working clearly; no marks will be given for unsupported answers from a calculator.
- Give non-exact numerical answers correct to 3 significant figures, or 1 decimal place for angles in degrees, unless a different level of accuracy is specified in the question.
- Where a numerical value for the acceleration due to gravity ($g$) is needed, use $10\,\text{m}\,\text{s}^{-2}$.

**INFORMATION**

- The total mark for this paper is 50.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **12** pages. Blank pages are indicated.

**1** A particle $B$ of mass 5 kg is at rest on a smooth horizontal table. A particle $A$ of mass 2.5 kg moves on the table with a speed of $6\,\text{m}\,\text{s}^{-1}$ and collides directly with $B$. In the collision the two particles coalesce.

**(a)** Find the speed of the combined particle after the collision. [2]

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**(b)** Find the loss of kinetic energy of the system due to the collision. [3]

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**2** A car of mass 1400 kg is moving along a straight horizontal road against a resistance of magnitude 350 N.

**(a)** Find, in kW, the rate at which the engine of the car is working when it is travelling at a constant speed of $20\,\text{m}\,\text{s}^{-1}$. [2]

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**(b)** Find the acceleration of the car when its speed is $20\,\text{m}\,\text{s}^{-1}$ and the engine is working at 15 kW. [3]

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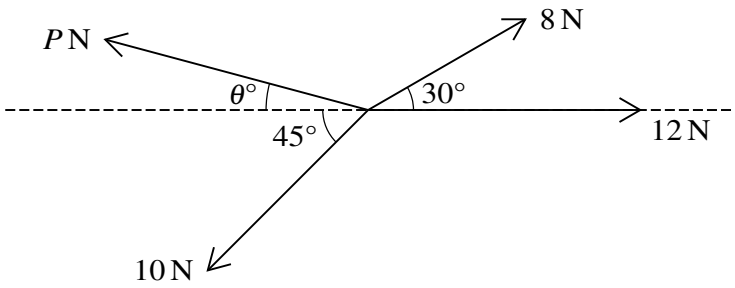


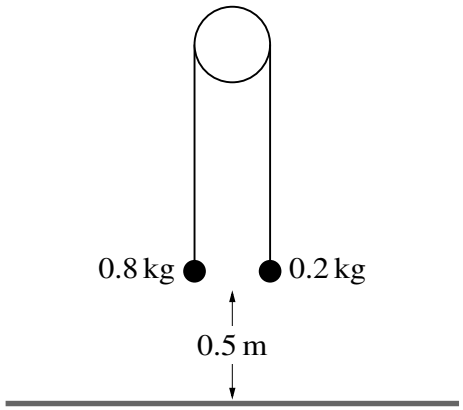

Coplanar forces of magnitudes 8 N, 12 N, 10 N and $P$ N act at a point in the directions shown in the diagram. The system is in equilibrium.

Find $P$ and $\theta$. [6]

**4** A particle $P$ moves in a straight line. It starts from rest at a point $O$ on the line and at time $t$ s after leaving $O$ it has acceleration $a$ m s$^{-2}$, where $a = 6t - 18$.

Find the distance $P$ moves before it comes to instantaneous rest. [6]

**5**




Two particles of masses 0.8 kg and 0.2 kg are connected by a light inextensible string that passes over a fixed smooth pulley. The system is released from rest with both particles 0.5 m above a horizontal floor (see diagram). In the subsequent motion the 0.2 kg particle does not reach the pulley.

**(a)** Show that the magnitude of the acceleration of the particles is $6\,\text{m}\,\text{s}^{-2}$ and find the tension in the string. [4]

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**(b)** When the 0.8 kg particle reaches the floor it comes to rest.

Find the greatest height of the 0.2 kg particle above the floor. [3]

**6** A car of mass 1500 kg is pulling a trailer of mass 750 kg up a straight hill of length 800 m inclined at an angle of $\sin^{-1} 0.08$ to the horizontal. The resistances to the motion of the car and trailer are 400 N and 200 N respectively. The car and trailer are connected by a light rigid tow-bar. The car and trailer have speed $30\,\text{m s}^{-1}$ at the bottom of the hill and $20\,\text{m s}^{-1}$ at the top of the hill.

**(a)** Use an energy method to find the constant driving force as the car and trailer travel up the hill. [5]

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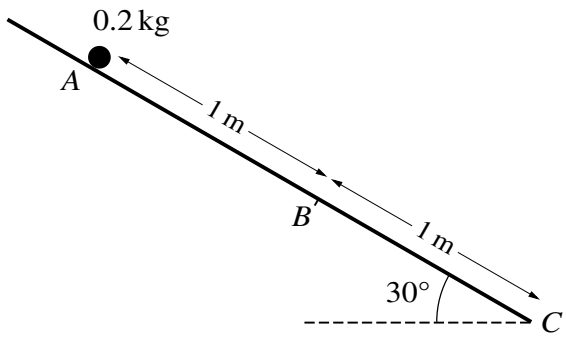
After reaching the top of the hill the system consisting of the car and trailer travels along a straight level road. The driving force of the car's engine is 2400 N and the resistances to motion are unchanged.

**(b)** Find the acceleration of the system and the tension in the tow-bar. [4]

**7**




Three points $A$, $B$ and $C$ lie on a line of greatest slope of a plane inclined at an angle of 30° to the horizontal, with $AB = 1$ m and $BC = 1$ m, as shown in the diagram. A particle of mass 0.2 kg is released from rest at $A$ and slides down the plane. The part of the plane from $A$ to $B$ is smooth. The part of the plane from $B$ to $C$ is rough, with coefficient of friction $\mu$ between the plane and the particle.

**(a)** Given that $\mu = \frac{1}{2}\sqrt{3}$, find the speed of the particle at $C$. [8]

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**(b)** Given instead that the particle comes to rest at $C$, find the exact value of $\mu$. [4]

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Cambridge Assessment International Education

# Cambridge International AS & A Level

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| CANDIDATE NAME | | | | | | | | | |
| CENTRE NUMBER | | | | | | CANDIDATE NUMBER | | | |

*4968591686*

**MATHEMATICS** **9709/42**

Paper 4 Mechanics **October/November 2020**

**1 hour 15 minutes**

You must answer on the question paper.

You will need: List of formulae (MF19)

**INSTRUCTIONS**

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
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- You should use a calculator where appropriate.
- You must show all necessary working clearly; no marks will be given for unsupported answers from a calculator.
- Give non-exact numerical answers correct to 3 significant figures, or 1 decimal place for angles in degrees, unless a different level of accuracy is specified in the question.
- Where a numerical value for the acceleration due to gravity ($g$) is needed, use $10\,\text{m}\,\text{s}^{-2}$.

**INFORMATION**

- The total mark for this paper is 50.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **16** pages. Blank pages are indicated.

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**1** Two particles $P$ and $Q$, of masses 0.2 kg and 0.5 kg respectively, are at rest on a smooth horizontal plane. $P$ is projected towards $Q$ with speed $2\,\text{m s}^{-1}$.

**(a)** Write down the momentum of $P$. [1]

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**(b)** After the collision $P$ continues to move in the same direction with speed $0.3\,\text{m s}^{-1}$.

Find the speed of $Q$ after the collision. [2]

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**2** A car of mass 1800 kg is travelling along a straight horizontal road. The power of the car's engine is constant. There is a constant resistance to motion of 650 N.

**(a)** Find the power of the car's engine, given that the car's acceleration is $0.5\,\text{m}\,\text{s}^{-2}$ when its speed is $20\,\text{m}\,\text{s}^{-1}$. [3]

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**(b)** Find the steady speed which the car can maintain with the engine working at this power. [2]

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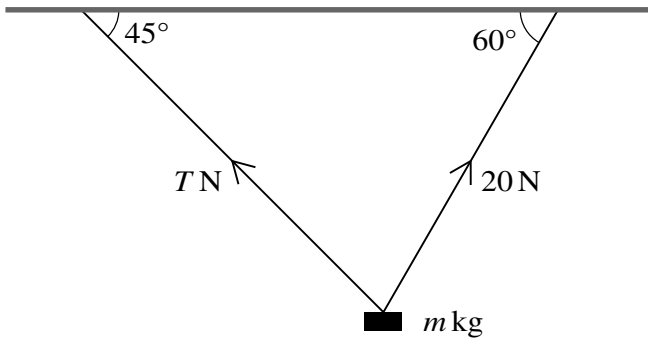
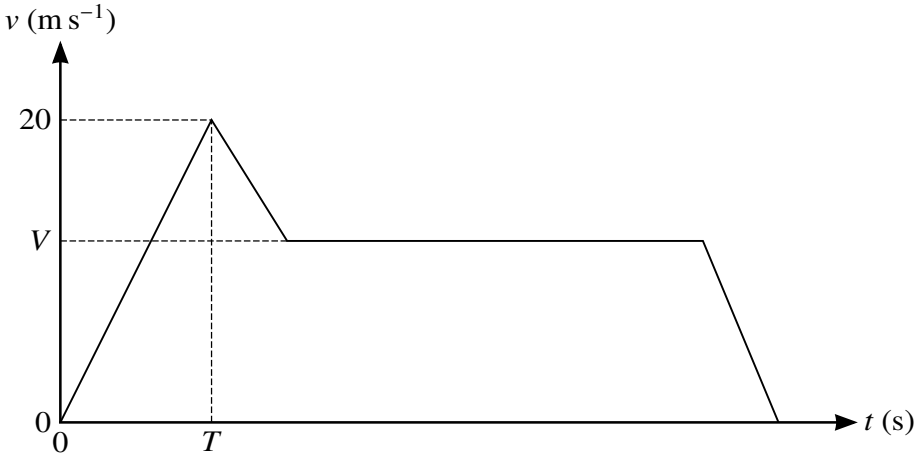



A block of mass $m$ kg is held in equilibrium below a horizontal ceiling by two strings, as shown in the diagram. One of the strings is inclined at 45° to the horizontal and the tension in this string is $T$ N. The other string is inclined at 60° to the horizontal and the tension in this string is 20 N.

Find $T$ and $m$. [5]

**4**




The diagram shows a velocity-time graph which models the motion of a car. The graph consists of four straight line segments. The car accelerates at a constant rate of $2\,\text{m s}^{-2}$ from rest to a speed of $20\,\text{m s}^{-1}$ over a period of $T$ s. It then decelerates at a constant rate for 5 seconds before travelling at a constant speed of $V\,\text{m s}^{-1}$ for 27.5 s. The car then decelerates to rest at a constant rate over a period of 5 s.

**(a)** Find $T$. [1]

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**(b)** Given that the distance travelled up to the point at which the car begins to move with constant speed is one third of the total distance travelled, find $V$. [4]

**5** A particle is projected vertically upwards with speed $40\,\text{m}\,\text{s}^{-1}$ alongside a building of height $h$ m.

**(a)** Given that the particle is above the level of the top of the building for 4 s, find $h$. [4]

**(b)** One second after the first particle is projected, a second particle is projected vertically upwards from the top of the building with speed $20\,\text{m}\,\text{s}^{-1}$.

Denoting the time after projection of the first particle by $t$ s, find the value of $t$ for which the two particles are at the same height above the ground. [4]

**6** A block of mass 5 kg is placed on a plane inclined at 30° to the horizontal. The coefficient of friction between the block and the plane is $\mu$.

**(a)**

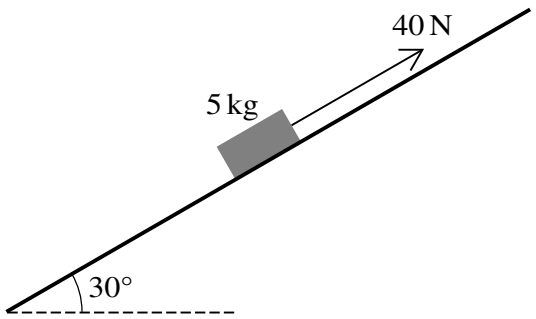


**Fig. 6.1**

When a force of magnitude 40 N is applied to the block, acting up the plane parallel to a line of greatest slope, the block begins to slide up the plane (see Fig. 6.1).

Show that $\mu < \frac{1}{5}\sqrt{3}$. [4]

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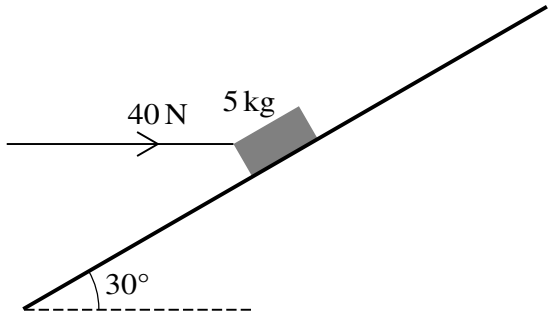


**Fig. 6.2**

When a force of magnitude 40 N is applied horizontally, in a vertical plane containing a line of greatest slope, the block does not move (see Fig. 6.2).

Show that, correct to 3 decimal places, the least possible value of $\mu$ is 0.152. [4]

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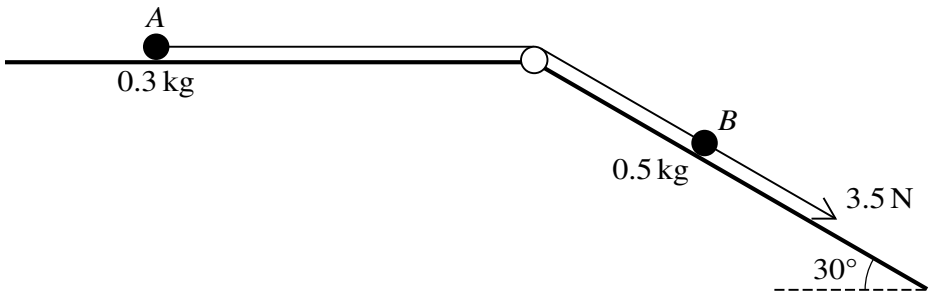
**7** A particle $P$ moves in a straight line, starting from a point $O$ with velocity $1.72\,\text{m s}^{-1}$. The acceleration $a\,\text{m s}^{-2}$ of the particle, $t$ s after leaving $O$, is given by $a = 0.1t^{\frac{3}{2}}$.

**(a)** Find the value of $t$ when the velocity of $P$ is $3\,\text{m s}^{-1}$. [4]

**(b)** Find the displacement of $P$ from $O$ when $t = 2$, giving your answer correct to 2 decimal places. [3]

**8**




Two particles $A$ and $B$, of masses 0.3 kg and 0.5 kg respectively, are attached to the ends of a light inextensible string. The string passes over a fixed smooth pulley which is attached to a horizontal plane and to the top of an inclined plane. The particles are initially at rest with $A$ on the horizontal plane and $B$ on the inclined plane, which makes an angle of 30° with the horizontal. The string is taut and $B$ can move on a line of greatest slope of the inclined plane. A force of magnitude 3.5 N is applied to $B$ acting down the plane (see diagram).

**(a)** Given that both planes are smooth, find the tension in the string and the acceleration of $B$. [5]

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**(b)** It is given instead that the two planes are rough. When each particle has moved a distance of 0.6 m from rest, the total amount of work done against friction is 1.1 J.

Use an energy method to find the speed of $B$ when it has moved this distance down the plane. [You should assume that the string is sufficiently long so that $A$ does not hit the pulley when it moves 0.6 m.] [4]

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Cambridge Assessment International Education

# Cambridge International AS & A Level

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| CANDIDATE NAME | | | | | | | | | |
| CENTRE NUMBER | | | | | | CANDIDATE NUMBER | | | |

*0187019651*

**MATHEMATICS** **9709/43**

Paper 4 Mechanics **October/November 2020**

**1 hour 15 minutes**

You must answer on the question paper.

You will need: List of formulae (MF19)

**INSTRUCTIONS**

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
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- You must show all necessary working clearly; no marks will be given for unsupported answers from a calculator.
- Give non-exact numerical answers correct to 3 significant figures, or 1 decimal place for angles in degrees, unless a different level of accuracy is specified in the question.
- Where a numerical value for the acceleration due to gravity ($g$) is needed, use $10\,\text{m}\,\text{s}^{-2}$.

**INFORMATION**

- The total mark for this paper is 50.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **12** pages. Blank pages are indicated.

**1** A particle $P$ is projected vertically upwards with speed $v$ m s$^{-1}$ from a point on the ground. $P$ reaches its greatest height after 3 s.

**(a)** Find $v$. [1]

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**(b)** Find the greatest height of $P$ above the ground. [2]

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**2** A box of mass 5 kg is pulled at a constant speed a distance of 15 m up a rough plane inclined at an angle of 20° to the horizontal. The box moves along a line of greatest slope against a frictional force of 40 N. The force pulling the box is parallel to the line of greatest slope.

**(a)** Find the work done against friction. [1]

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**(b)** Find the change in gravitational potential energy of the box. [2]

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**(c)** Find the work done by the pulling force. [1]

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**3** A string is attached to a block of mass 4 kg which rests in limiting equilibrium on a rough horizontal table. The string makes an angle of 24° above the horizontal and the tension in the string is 30 N.

**(a)** Draw a diagram showing all the forces acting on the block. [1]

**(b)** Find the coefficient of friction between the block and the table. [5]

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**4** Two small smooth spheres $A$ and $B$, of equal radii and of masses 4 kg and $m$ kg respectively, lie on a smooth horizontal plane. Initially, sphere $B$ is at rest and $A$ is moving towards $B$ with speed $6\,\text{m}\,\text{s}^{-1}$. After the collision $A$ moves with speed $1.5\,\text{m}\,\text{s}^{-1}$ and $B$ moves with speed $3\,\text{m}\,\text{s}^{-1}$.

Find the two possible values of the loss of kinetic energy due to the collision. [6]

**5** A particle $P$ moves in a straight line. It starts at a point $O$ on the line and at time $t$ s after leaving $O$ it has velocity $v$ m s$^{-1}$, where $v = 4t^2 - 20t + 21$.

**(a)** Find the values of $t$ for which $P$ is at instantaneous rest. [2]

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**(b)** Find the initial acceleration of $P$. [2]

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**(c)** Find the minimum velocity of $P$. [2]

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**(d)** Find the distance travelled by $P$ during the time when its velocity is negative. [4]

**6** A car of mass 1600 kg is pulling a caravan of mass 800 kg. The car and the caravan are connected by a light rigid tow-bar. The resistances to the motion of the car and caravan are 400 N and 250 N respectively.

**(a)** The car and caravan are travelling along a straight horizontal road.

**(i)** Given that the car and caravan have a constant speed of 25 m $s^{-1}$, find the power of the car's engine. [2]

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**(ii)** The engine's power is now suddenly increased to 39 kW. Find the instantaneous acceleration of the car and caravan and find the tension in the tow-bar. [5]

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**(b)** The car and caravan now travel up a straight hill, inclined at an angle of $\sin^{-1} 0.05$ to the horizontal, at a constant speed of $v$ m s$^{-1}$. The car's engine is working at 32.5 kW.

Find $v$. [3]

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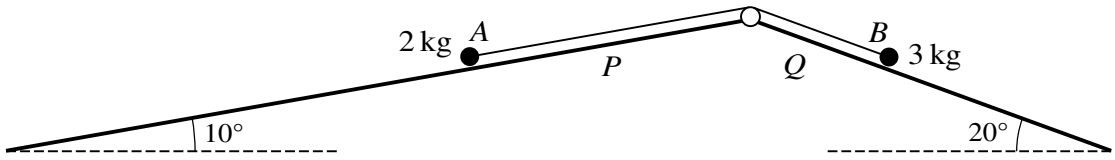


As shown in the diagram, particles $A$ and $B$ of masses 2 kg and 3 kg respectively are attached to the ends of a light inextensible string. The string passes over a small fixed smooth pulley which is attached to the top of two inclined planes. Particle $A$ is on plane $P$, which is inclined at an angle of 10° to the horizontal. Particle $B$ is on plane $Q$, which is inclined at an angle of 20° to the horizontal. The string is taut, and the two parts of the string are parallel to lines of greatest slope of their respective planes.

**(a)** It is given that plane $P$ is smooth, plane $Q$ is rough, and the particles are in limiting equilibrium.

Find the coefficient of friction between particle $B$ and plane $Q$. [5]

**(b)** It is given instead that both planes are smooth and that the particles are released from rest at the same horizontal level.

Find the time taken until the difference in the vertical height of the particles is 1 m. [You should assume that this occurs before $A$ reaches the pulley or $B$ reaches the bottom of plane $Q$.] [6]

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Cambridge Assessment International Education

# Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

*9303616557*

**MATHEMATICS** **9709/42**

Paper 4 Mechanics **February/March 2021**

**1 hour 15 minutes**

You must answer on the question paper.

You will need: List of formulae (MF19)

**INSTRUCTIONS**

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
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- Give non-exact numerical answers correct to 3 significant figures, or 1 decimal place for angles in degrees, unless a different level of accuracy is specified in the question.
- Where a numerical value for the acceleration due to gravity ($g$) is needed, use $10\,\text{m}\,\text{s}^{-2}$.

**INFORMATION**

- The total mark for this paper is 50.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **16** pages. Any blank pages are indicated.

**1** Two particles $P$ and $Q$ of masses 0.2 kg and 0.3 kg respectively are free to move in a horizontal straight line on a smooth horizontal plane. $P$ is projected towards $Q$ with speed $0.5\,\text{m s}^{-1}$. At the same instant $Q$ is projected towards $P$ with speed $1\,\text{m s}^{-1}$. $Q$ comes to rest in the resulting collision.

Find the speed of $P$ after the collision. [3]

**2** A car of mass 1400 kg is travelling at constant speed up a straight hill inclined at $\alpha$ to the horizontal, where $\sin\alpha = 0.1$. There is a constant resistance force of magnitude 600 N. The power of the car's engine is 22 500 W.

**(a)** Show that the speed of the car is $11.25\,\text{m}\,\text{s}^{-1}$. [3]

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The car, moving with speed $11.25\,\text{m}\,\text{s}^{-1}$, comes to a section of the hill which is inclined at 2° to the horizontal.

**(b)** Given that the power and resistance force do not change, find the initial acceleration of the car up this section of the hill. [3]

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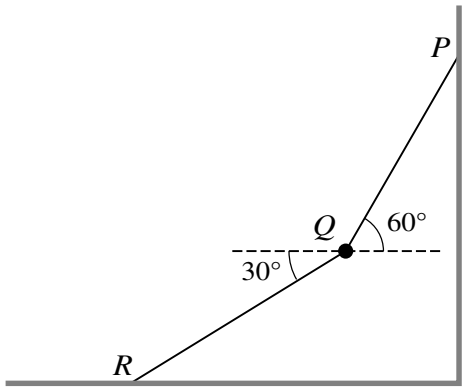
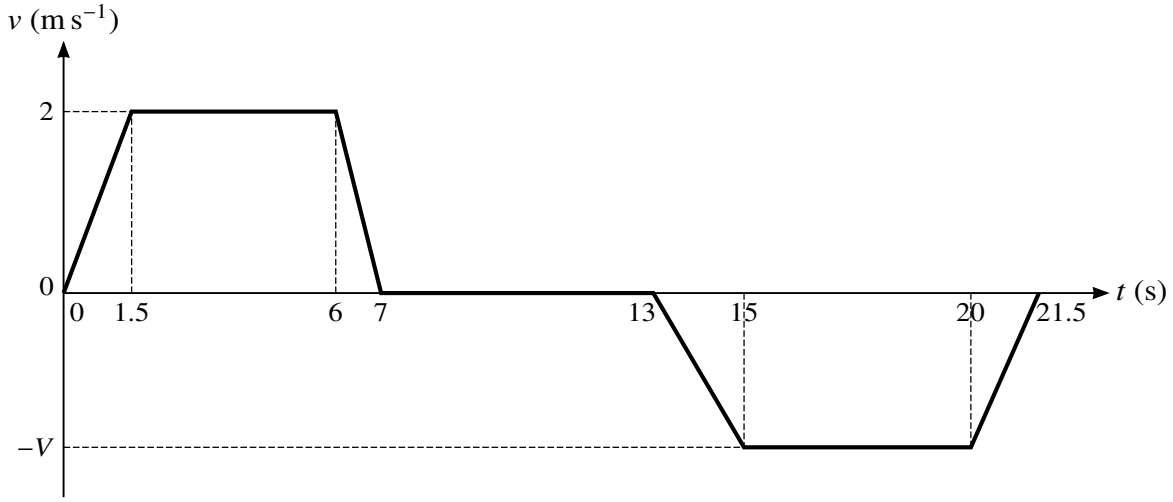



A particle $Q$ of mass 0.2 kg is held in equilibrium by two light inextensible strings $PQ$ and $QR$. $P$ is a fixed point on a vertical wall and $R$ is a fixed point on a horizontal floor. The angles which strings $PQ$ and $QR$ make with the horizontal are 60° and 30° respectively (see diagram).

Find the tensions in the two strings. [5]

**4**




An elevator moves vertically, supported by a cable. The diagram shows a velocity-time graph which models the motion of the elevator. The graph consists of 7 straight line segments.

The elevator accelerates upwards from rest to a speed of $2\,\text{m s}^{-1}$ over a period of 1.5 s and then travels at this speed for 4.5 s, before decelerating to rest over a period of 1 s.

The elevator then remains at rest for 6 s, before accelerating to a speed of $V\,\text{m s}^{-1}$ downwards over a period of 2 s. The elevator travels at this speed for a period of 5 s, before decelerating to rest over a period of 1.5 s.

**(a)** Find the acceleration of the elevator during the first 1.5 s. [1]

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**(b)** Given that the elevator starts and finishes its journey on the ground floor, find $V$. [2]

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**(c)** The combined weight of the elevator and passengers on its upward journey is 1500 kg. Assuming that there is no resistance to motion, find the tension in the elevator cable on its upward journey when the elevator is decelerating. [3]

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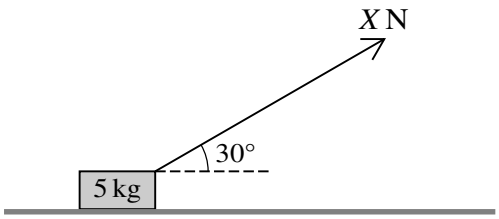


A block of mass 5 kg is being pulled along a rough horizontal floor by a force of magnitude $X$ N acting at 30° above the horizontal (see diagram). The block starts from rest and travels 2 m in the first 5 s of its motion.

**(a)** Find the acceleration of the block. [2]

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**(b)** Given that the coefficient of friction between the block and the floor is 0.4, find $X$. [4]

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The block is now placed on a part of the floor where the coefficient of friction between the block and the floor has a different value. The value of $X$ is changed to 25, and the block is now in limiting equilibrium.

**(c)** Find the value of the coefficient of friction between the block and this part of the floor. [3]

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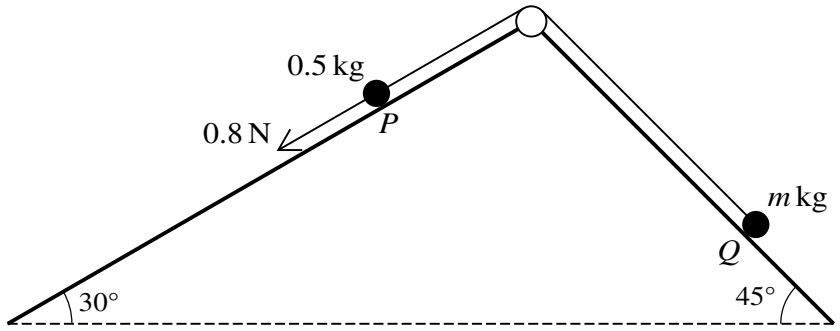
**6** A particle moves in a straight line. It starts from rest from a fixed point $O$ on the line. Its velocity at time $t$ s after leaving $O$ is $v$ m s$^{-1}$, where $v = t^2 - 8t^{\frac{3}{2}} + 10t$.

**(a)** Find the displacement of the particle from $O$ when $t = 1$. [4]

**(b)** Show that the minimum velocity of the particle is $-125\,\text{m}\,\text{s}^{-1}$. [7]

**7**




Two particles $P$ and $Q$ of masses 0.5 kg and $m$ kg respectively are attached to the ends of a light inextensible string. The string passes over a fixed smooth pulley which is attached to the top of two inclined planes. The particles are initially at rest with $P$ on a smooth plane inclined at 30° to the horizontal and $Q$ on a plane inclined at 45° to the horizontal. The string is taut and the particles can move on lines of greatest slope of the two planes. A force of magnitude 0.8 N is applied to $P$ acting down the plane, causing $P$ to move down the plane (see diagram).

**(a)** It is given that $m = 0.3$, and that the plane on which $Q$ rests is smooth.

Find the tension in the string. [5]

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**(b)** It is given instead that the plane on which $Q$ rests is rough, and that after each particle has moved a distance of 1 m, their speed is $0.6\,\text{m}\,\text{s}^{-1}$. The work done against friction in this part of the motion is 0.5 J.

Use an energy method to find the value of $m$. [5]

Cambridge Assessment International Education

# Cambridge International AS & A Level

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| CANDIDATE NAME | | | | | | | | | |
| CENTRE NUMBER | | | | | | CANDIDATE NUMBER | | | |

*2776439369*

**MATHEMATICS** **9709/41**

Paper 4 Mechanics **May/June 2021**

**1 hour 15 minutes**

You must answer on the question paper.

You will need: List of formulae (MF19)

**INSTRUCTIONS**

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- If additional space is needed, you should use the lined page at the end of this booklet; the question number or numbers must be clearly shown.
- You should use a calculator where appropriate.
- You must show all necessary working clearly; no marks will be given for unsupported answers from a calculator.
- Give non-exact numerical answers correct to 3 significant figures, or 1 decimal place for angles in degrees, unless a different level of accuracy is specified in the question.
- Where a numerical value for the acceleration due to gravity ($g$) is needed, use $10\,\text{m}\,\text{s}^{-2}$.

**INFORMATION**

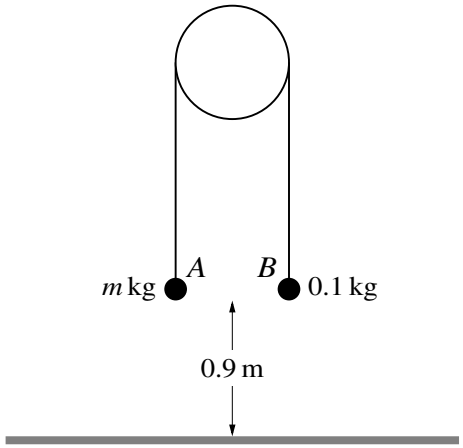
- The total mark for this paper is 50.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **12** pages.

**1** A winch operates by means of a force applied by a rope. The winch is used to pull a load of mass 50 kg up a line of greatest slope of a plane inclined at 60° to the horizontal. The winch pulls the load a distance of 5 m up the plane at constant speed. There is a constant resistance to motion of 100 N.

Find the work done by the winch. [3]

**2**




Two particles $A$ and $B$ have masses $m$ kg and 0.1 kg respectively, where $m > 0.1$. The particles are attached to the ends of a light inextensible string. The string passes over a fixed smooth pulley and the particles hang vertically below it. Both particles are at a height of 0.9 m above horizontal ground (see diagram). The system is released from rest, and while both particles are in motion the tension in the string is 1.5 N. Particle $B$ does not reach the pulley.

**(a)** Find $m$. [4]

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**(b)** Find the speed at which $A$ reaches the ground. [2]

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**3** Three particles $P$, $Q$ and $R$, of masses 0.1 kg, 0.2 kg and 0.5 kg respectively, are at rest in a straight line on a smooth horizontal plane. Particle $P$ is projected towards $Q$ at a speed of $5\,\text{m s}^{-1}$. After $P$ and $Q$ collide, $P$ rebounds with speed $1\,\text{m s}^{-1}$.

**(a)** Find the speed of $Q$ immediately after the collision with $P$. [3]

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$Q$ now collides with $R$. Immediately after the collision with $Q$, $R$ begins to move with speed $V\,\text{m s}^{-1}$.

**(b)** Given that there is no subsequent collision between $P$ and $Q$, find the greatest possible value of $V$. [3]

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**4** Two cyclists, Isabella and Maria, are having a race. They both travel along a straight road with constant acceleration, starting from rest at point $A$.

Isabella accelerates for 5 s at a constant rate $a\,\text{m s}^{-2}$. She then travels at the constant speed she has reached for 10 s, before decelerating to rest at a constant rate over a period of 5 s.

Maria accelerates at a constant rate, reaching a speed of $5\,\text{m s}^{-1}$ in a distance of 27.5 m. She then maintains this speed for a period of 10 s, before decelerating to rest at a constant rate over a period of 5 s.

**(a)** Given that $a = 1.1$, find which cyclist travels further. [5]

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**(b)** Find the value of $a$ for which the two cyclists travel the same distance. [2]

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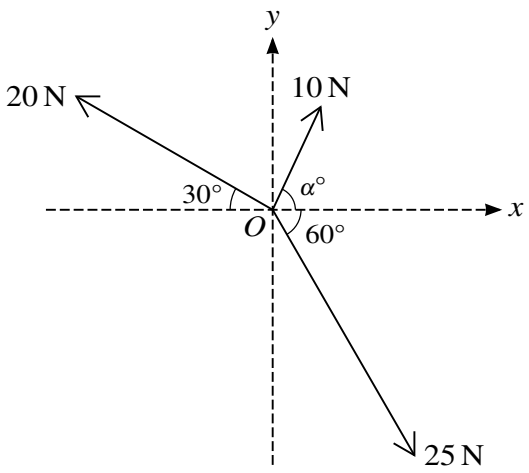
**5** A particle moving in a straight line starts from rest at a point $A$ and comes instantaneously to rest at a point $B$. The acceleration of the particle at time $t$ s after leaving $A$ is $a$ m s$^{-2}$, where

$$a = 6t^{\frac{1}{2}} - 2t.$$

**(a)** Find the value of $t$ at point $B$. [3]

**(b)** Find the distance travelled from $A$ to the point at which the acceleration of the particle is again zero. [5]

**6**




Three coplanar forces of magnitudes 10 N, 25 N and 20 N act at a point $O$ in the directions shown in the diagram.

**(a)** Given that the component of the resultant force in the $x$-direction is zero, find $\alpha$, and hence find the magnitude of the resultant force. [4]

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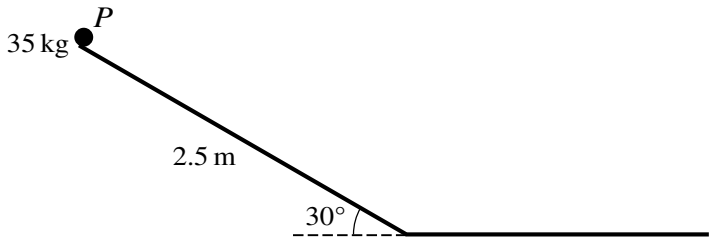
**(b)** Given instead that $\alpha = 45$, find the magnitude and direction of the resultant of the three forces. [5]

**7**




A slide in a playground descends at a constant angle of 30° for 2.5 m. It then has a horizontal section in the same vertical plane as the sloping section. A child of mass 35 kg, modelled as a particle $P$, starts from rest at the top of the slide and slides straight down the sloping section. She then continues along the horizontal section until she comes to rest (see diagram). There is no instantaneous change in speed when the child goes from the sloping section to the horizontal section.

The child experiences a resistance force on the horizontal section of the slide, and the work done against the resistance force on the horizontal section of the slide is 250 J per metre.

**(a)** It is given that the sloping section of the slide is smooth.

**(i)** Find the speed of the child when she reaches the bottom of the sloping section. [3]

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**(ii)** Find the distance that the child travels along the horizontal section of the slide before she comes to rest. [2]

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**(b)** It is given instead that the sloping section of the slide is rough and that the child comes to rest on the slide 1.05 m after she reaches the horizontal section.

Find the coefficient of friction between the child and the sloping section of the slide. [6]

Cambridge Assessment International Education

# Cambridge International AS & A Level

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| CANDIDATE NAME | | | | | | | | | |
| CENTRE NUMBER | | | | | | CANDIDATE NUMBER | | | |

*4405618753*

**MATHEMATICS** **9709/42**

Paper 4 Mechanics **May/June 2021**

**1 hour 15 minutes**

You must answer on the question paper.

You will need: List of formulae (MF19)

**INSTRUCTIONS**

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
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- You should use a calculator where appropriate.
- You must show all necessary working clearly; no marks will be given for unsupported answers from a calculator.
- Give non-exact numerical answers correct to 3 significant figures, or 1 decimal place for angles in degrees, unless a different level of accuracy is specified in the question.
- Where a numerical value for the acceleration due to gravity ($g$) is needed, use $10\,\text{m}\,\text{s}^{-2}$.

**INFORMATION**

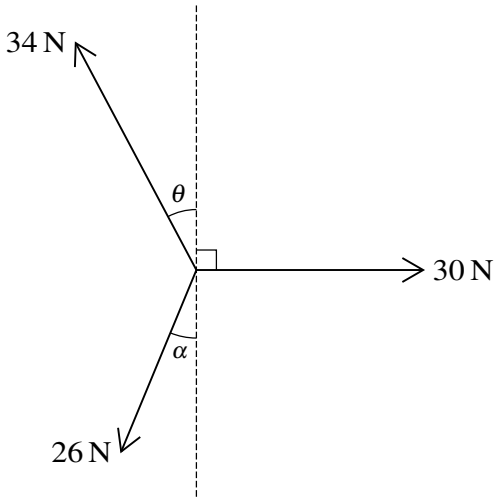
- The total mark for this paper is 50.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **12** pages.

**1** A particle of mass 0.6 kg is projected with a speed of $4\ \text{m s}^{-1}$ down a line of greatest slope of a smooth plane inclined at 10° to the horizontal.

Use an energy method to find the speed of the particle after it has moved 15 m down the plane. [3]

**2**




Coplanar forces of magnitudes 34 N, 30 N and 26 N act at a point in the directions shown in the diagram.

Given that $\sin\alpha = \frac{5}{13}$ and $\sin\theta = \frac{8}{17}$, find the magnitude and direction of the resultant of the three forces. [6]

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**3** A ring of mass 0.3 kg is threaded on a horizontal rough rod. The coefficient of friction between the ring and the rod is 0.8. A force of magnitude 8 N acts on the ring. This force acts at an angle of 10° above the horizontal in the vertical plane containing the rod.

Find the time taken for the ring to move, from rest, 0.6 m along the rod. [6]

**4** A particle of mass 12 kg is stationary on a rough plane inclined at an angle of 25° to the horizontal. A pulling force of magnitude $P$ N acts at an angle of 8° above a line of greatest slope of the plane. This force is used to keep the particle in equilibrium. The coefficient of friction between the particle and the plane is 0.3.

Find the greatest possible value of $P$. [6]

**5** A car of mass 1250 kg is pulling a caravan of mass 800 kg along a straight road. The resistances to the motion of the car and caravan are 440 N and 280 N respectively. The car and caravan are connected by a light rigid tow-bar.

**(a)** The car and caravan move along a horizontal part of the road at a constant speed of $30\,\text{m}\,\text{s}^{-1}$.

**(i)** Calculate, in kW, the power developed by the engine of the car. [2]

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**(ii)** Given that this power is suddenly decreased by 8 kW, find the instantaneous deceleration of the car and caravan and the tension in the tow-bar. [4]

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**(b)** The car and caravan now travel along a part of the road inclined at $\sin^{-1} 0.06$ to the horizontal. The car and caravan travel up the incline at constant speed with the engine of the car working at 28 kW.

**(i)** Find this constant speed. [3]

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**(ii)** Find the increase in the potential energy of the caravan in one minute. [2]

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**6** A particle $A$ is projected vertically upwards from level ground with an initial speed of $30\,\text{m}\,\text{s}^{-1}$. At the same instant a particle $B$ is released from rest 15 m vertically above $A$. The mass of one of the particles is twice the mass of the other particle. During the subsequent motion $A$ and $B$ collide and coalesce to form particle $C$.

Find the difference between the two possible times at which $C$ hits the ground. [8]

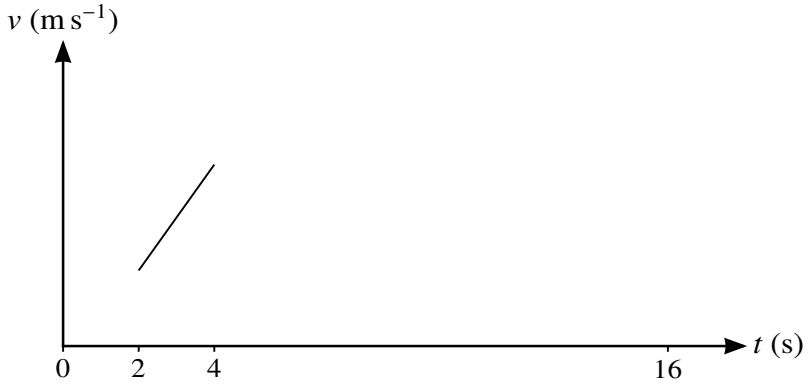
**7** A particle $P$ moving in a straight line starts from rest at a point $O$ and comes to rest 16 s later. At time $t$ s after leaving $O$, the acceleration $a$ m s$^{-2}$ of $P$ is given by

$$\begin{aligned} a &= 6 + 4t \qquad 0 \leqslant t < 2, \\ a &= 14 \qquad\quad 2 \leqslant t < 4, \\ a &= 16 - 2t \qquad 4 \leqslant t \leqslant 16. \end{aligned}$$

There is no sudden change in velocity at any instant.

**(a)** Find the values of $t$ when the velocity of $P$ is 55 m s$^{-1}$. [5]

**(b)** Complete the sketch of the velocity-time diagram. [2]




**(c)** Find the distance travelled by $P$ when it is decelerating. [3]

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Cambridge Assessment International Education

# Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER | | | | | |

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*9782984789*

**MATHEMATICS** **9709/43**

Paper 4 Mechanics **May/June 2021**

**1 hour 15 minutes**

You must answer on the question paper.

You will need: List of formulae (MF19)

**INSTRUCTIONS**

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
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- You should use a calculator where appropriate.
- You must show all necessary working clearly; no marks will be given for unsupported answers from a calculator.
- Give non-exact numerical answers correct to 3 significant figures, or 1 decimal place for angles in degrees, unless a different level of accuracy is specified in the question.
- Where a numerical value for the acceleration due to gravity ($g$) is needed, use $10\,\text{m}\,\text{s}^{-2}$.

**INFORMATION**

- The total mark for this paper is 50.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **12** pages.

**1** Particles $P$ of mass 0.4 kg and $Q$ of mass 0.5 kg are free to move on a smooth horizontal plane. $P$ and $Q$ are moving directly towards each other with speeds $2.5\,\text{m s}^{-1}$ and $1.5\,\text{m s}^{-1}$ respectively. After $P$ and $Q$ collide, the speed of $Q$ is twice the speed of $P$.

Find the two possible values of the speed of $P$ after the collision. [4]

**2** A cyclist is travelling along a straight horizontal road. She is working at a constant rate of 150 W. At an instant when her speed is $4\,\text{m}\,\text{s}^{-1}$, her acceleration is $0.25\,\text{m}\,\text{s}^{-2}$. The resistance to motion is 20 N.

**(a)** Find the total mass of the cyclist and her bicycle. [3]

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The cyclist comes to a straight hill inclined at an angle $\theta$ above the horizontal. She ascends the hill at constant speed $3\,\text{m}\,\text{s}^{-1}$. She continues to work at the same rate as before and the resistance force is unchanged.

**(b)** Find the value of $\theta$. [2]

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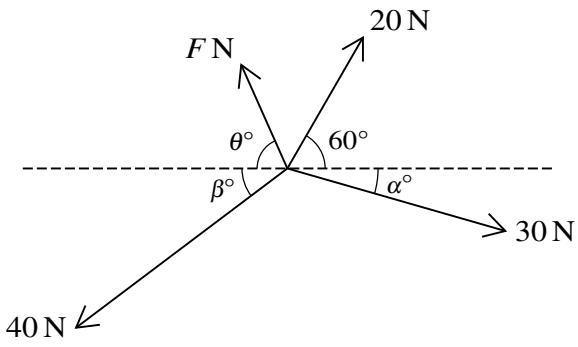


Four coplanar forces act at a point. The magnitudes of the forces are 20 N, 30 N, 40 N and $F$ N. The directions of the forces are as shown in the diagram, where $\sin \alpha° = 0.28$ and $\sin \beta° = 0.6$.

Given that the forces are in equilibrium, find $F$ and $\theta$. [6]

**4** A particle is projected vertically upwards with speed $u$ m s$^{-1}$ from a point on horizontal ground. After 2 seconds, the height of the particle above the ground is 24 m.

**(a)** Show that $u = 22$. [2]

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**(b)** The height of the particle above the ground is more than $h$ m for a period of 3.6 s.

Find $h$. [4]

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**5** A car of mass 1400 kg is towing a trailer of mass 500 kg down a straight hill inclined at an angle of 5° to the horizontal. The car and trailer are connected by a light rigid tow-bar. At the top of the hill the speed of the car and trailer is $20\,m\,s^{-1}$ and at the bottom of the hill their speed is $30\,m\,s^{-1}$.

**(a)** It is given that as the car and trailer descend the hill, the engine of the car does 150 000 J of work, and there are no resistance forces.

Find the length of the hill. [5]

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**(b)** It is given instead that there is a resistance force of 100 N on the trailer, the length of the hill is 200 m, and the acceleration of the car and trailer is constant.

Find the tension in the tow-bar between the car and trailer. [4]

**6** A particle moves in a straight line and passes through the point $A$ at time $t = 0$. The velocity of the particle at time $t$ s after leaving $A$ is $v$ m s$^{-1}$, where

$$v = 2t^2 - 5t + 3.$$

**(a)** Find the times at which the particle is instantaneously at rest. Hence or otherwise find the minimum velocity of the particle. [4]

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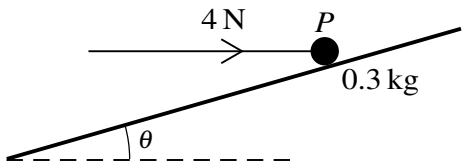
**(b)** Sketch the velocity-time graph for the first 3 seconds of motion. [3]

**(c)** Find the distance travelled between the two times when the particle is instantaneously at rest. [3]

**7**




A particle $P$ of mass 0.3 kg rests on a rough plane inclined at an angle $\theta$ to the horizontal, where $\sin\theta = \frac{7}{25}$. A horizontal force of magnitude 4 N, acting in the vertical plane containing a line of greatest slope of the plane, is applied to $P$ (see diagram). The particle is on the point of sliding up the plane.

**(a)** Show that the coefficient of friction between the particle and the plane is $\frac{3}{4}$. [4]

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The force acting horizontally is replaced by a force of magnitude 4 N acting up the plane parallel to a line of greatest slope.

**(b)** Find the acceleration of $P$. [3]

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**(c)** Starting with $P$ at rest, the force of 4 N parallel to the plane acts for 3 seconds and is then removed.

Find the total distance travelled until $P$ comes to instantaneous rest. [3]

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Cambridge Assessment International Education

# Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

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*3333132430*

**MATHEMATICS** **9709/41**

Paper 4 Mechanics **October/November 2021**

**1 hour 15 minutes**

You must answer on the question paper.

You will need: List of formulae (MF19)

**INSTRUCTIONS**

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
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- You should use a calculator where appropriate.
- You must show all necessary working clearly; no marks will be given for unsupported answers from a calculator.
- Give non-exact numerical answers correct to 3 significant figures, or 1 decimal place for angles in degrees, unless a different level of accuracy is specified in the question.
- Where a numerical value for the acceleration due to gravity ($g$) is needed, use $10\,\text{m}\,\text{s}^{-2}$.

**INFORMATION**

- The total mark for this paper is 50.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **12** pages.

**1** A bus moves from rest with constant acceleration for 12 s. It then moves with constant speed for 30 s before decelerating uniformly to rest in a further 6 s. The total distance travelled is 585 m.

**(a)** Find the constant speed of the bus. [2]

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**(b)** Find the magnitude of the deceleration. [1]

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**2** Two small smooth spheres $A$ and $B$, of equal radii and of masses $km$ kg and $m$ kg respectively, where $k > 1$, are free to move on a smooth horizontal plane. $A$ is moving towards $B$ with speed $6\,\text{m s}^{-1}$ and $B$ is moving towards $A$ with speed $2\,\text{m s}^{-1}$. After the collision $A$ and $B$ coalesce and move with speed $4\,\text{m s}^{-1}$.

**(a)** Find $k$. [3]

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**(b)** Find, in terms of $m$, the loss of kinetic energy due to the collision. [2]

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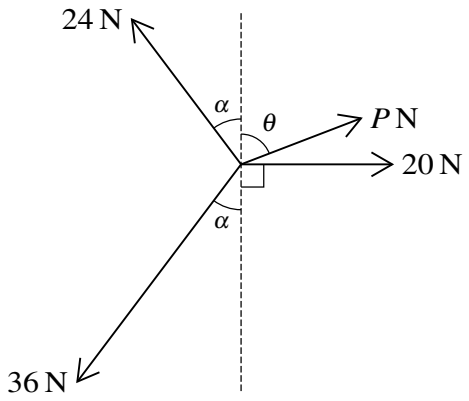


Coplanar forces of magnitudes 24 N, $P$ N, 20 N and 36 N act at a point in the directions shown in the diagram. The system is in equilibrium.

Given that $\sin\alpha = \frac{3}{5}$, find the values of $P$ and $\theta$. [6]

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**4** A particle of mass 12 kg is stationary on a rough plane inclined at an angle of 25° to the horizontal. A force of magnitude $P$ N acting parallel to a line of greatest slope of the plane is used to prevent the particle sliding down the plane. The coefficient of friction between the particle and the plane is 0.35.

**(a)** Draw a sketch showing the forces acting on the particle. [1]

**(b)** Find the least possible value of $P$. [5]

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**5** A car of mass 1600 kg travels at constant speed $20\,\text{m}\,\text{s}^{-1}$ up a straight road inclined at an angle of $\sin^{-1} 0.12$ to the horizontal.

**(a)** Find the change in potential energy of the car in 30 s. [3]

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**(b)** Given that the total work done by the engine of the car in this time is 1960 kJ, find the constant force resisting the motion. [3]

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**(c)** Calculate, in kW, the power developed by the engine of the car. [2]

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**(d)** Given that this power is suddenly decreased by 15%, find the instantaneous deceleration of the car. [3]

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**6** A particle $P$ moves in a straight line starting from a point $O$ and comes to rest 14 s later. At time $t$ s after leaving $O$, the velocity $v$ m s$^{-1}$ of $P$ is given by

$$v = pt^2 - qt \qquad 0 \leqslant t \leqslant 6,$$
$$v = 63 - 4.5t \qquad 6 \leqslant t \leqslant 14,$$

where $p$ and $q$ are positive constants.

The acceleration of $P$ is zero when $t = 2$.

**(a)** Given that there are no instantaneous changes in velocity, find $p$ and $q$. [3]

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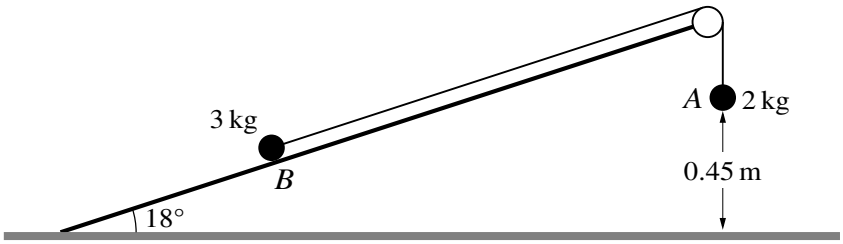
**(b)** Sketch the velocity-time graph. [3]

**(c)** Find the total distance travelled by $P$ during the 14 s. [5]

**7**




Two particles $A$ and $B$ of masses 2 kg and 3 kg respectively are connected by a light inextensible string. Particle $B$ is on a smooth fixed plane which is at an angle of 18° to horizontal ground. The string passes over a fixed smooth pulley at the top of the plane. Particle $A$ hangs vertically below the pulley and is 0.45 m above the ground (see diagram). The system is released from rest with the string taut. When $A$ reaches the ground, the string breaks.

Find the total distance travelled by $B$ before coming to instantaneous rest. You may assume that $B$ does not reach the pulley. [8]

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## Additional Page

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Cambridge Assessment International Education

# Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

*7615155884*

**MATHEMATICS** **9709/42**

Paper 4 Mechanics **October/November 2021**

**1 hour 15 minutes**

You must answer on the question paper.

You will need: List of formulae (MF19)

**INSTRUCTIONS**

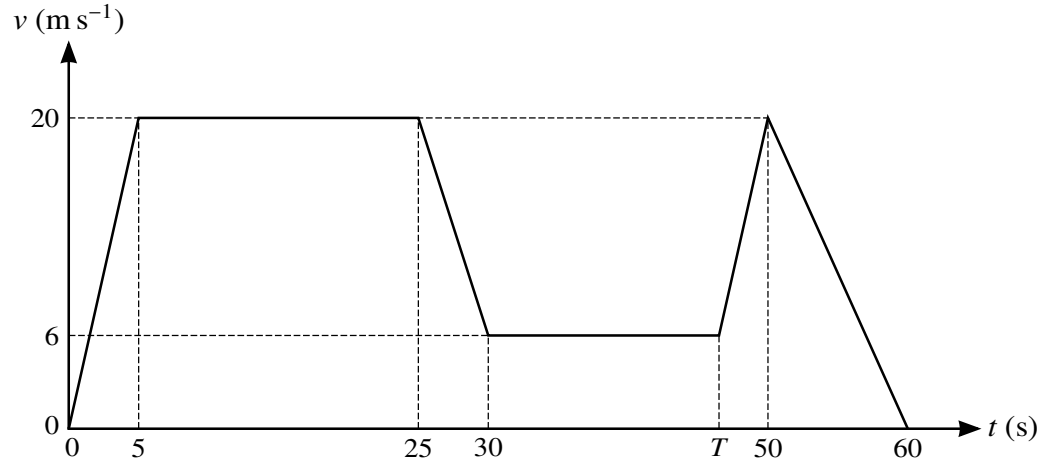
- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- If additional space is needed, you should use the lined page at the end of this booklet; the question number or numbers must be clearly shown.
- You should use a calculator where appropriate.
- You must show all necessary working clearly; no marks will be given for unsupported answers from a calculator.
- Give non-exact numerical answers correct to 3 significant figures, or 1 decimal place for angles in degrees, unless a different level of accuracy is specified in the question.
- Where a numerical value for the acceleration due to gravity ($g$) is needed, use $10\,\text{m}\,\text{s}^{-2}$.

**INFORMATION**

- The total mark for this paper is 50.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **12** pages.

**1**




The diagram shows a velocity-time graph which models the motion of a car. The graph consists of six straight line segments. The car accelerates from rest to a speed of $20\,\text{m s}^{-1}$ over a period of 5 s, and then travels at this speed for a further 20 s. The car then decelerates to a speed of $6\,\text{m s}^{-1}$ over a period of 5 s. This speed is maintained for a further $(T - 30)$ s. The car then accelerates again to a speed of $20\,\text{m s}^{-1}$ over a period of $(50 - T)$ s, before decelerating to rest over a period of 10 s.

**(a)** Given that during the two stages of the motion when the car is accelerating, the accelerations are equal, find the value of $T$. [2]

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**(b)** Find the total distance travelled by the car during the motion. [2]

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**2** A van of mass 3600 kg is towing a trailer of mass 1200 kg along a straight horizontal road using a light horizontal rope. There are resistance forces of 700 N on the van and 300 N on the trailer.

**(a)** The driving force exerted by the van is 2500 N.

Find the tension in the rope. [4]

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The driving force is now removed and the van driver applies a braking force which acts only on the van. The resistance forces remain unchanged.

**(b)** Find the least possible value of the braking force which will cause the rope to become slack. [2]

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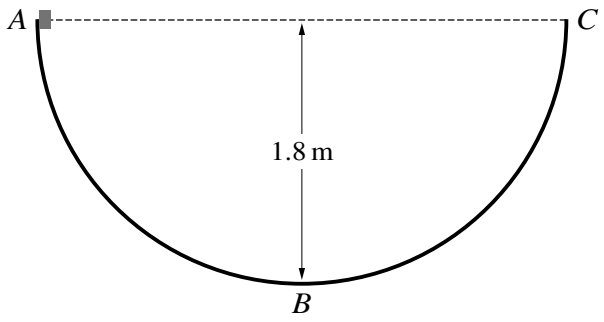
**3**




The diagram shows a semi-circular track $ABC$ of radius 1.8 m which is fixed in a vertical plane. The points $A$ and $C$ are at the same horizontal level and the point $B$ is at the bottom of the track. The section $AB$ is smooth and the section $BC$ is rough. A small block is released from rest at $A$.

**(a)** Show that the speed of the block at $B$ is $6\,\text{m}\,\text{s}^{-1}$. [2]

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The block comes to instantaneous rest for the first time at a height of 1.2 m above the level of $B$. The work done against the resistance force during the motion of the block from $B$ to this point is 4.5 J.

**(b)** Find the mass of the block. [3]

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**4** A cyclist starts from rest at a point $A$ and travels along a straight road $AB$, coming to rest at $B$. The displacement of the cyclist from $A$ at time $t$ s after the start is $s$ m, where

$$s = 0.004(75t^2 - t^3).$$

**(a)** Show that the distance $AB$ is 250 m. [4]

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**(b)** Find the maximum velocity of the cyclist. [3]

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**5** A railway engine of mass 75 000 kg is moving up a straight hill inclined at an angle $\alpha$ to the horizontal, where $\sin\alpha = 0.01$. The engine is travelling at a constant speed of $30\,\text{m}\,\text{s}^{-1}$. The engine is working at 960 kW. There is a constant force resisting the motion of the engine.

**(a)** Find the resistance force. [3]

The engine comes to a section of track which is horizontal. At the start of the section the engine is travelling at $30\,\text{m s}^{-1}$ and the power of the engine is now reduced to 900 kW. The resistance to motion is no longer constant, but in the next 60 s the work done against the resistance force is 46 500 kJ.

**(b)** Find the speed of the engine at the end of the 60 s. [4]

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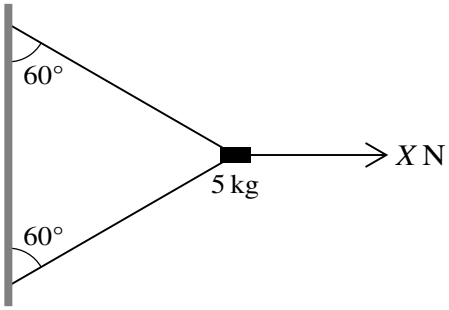


A block of mass 5 kg is held in equilibrium near a vertical wall by two light strings and a horizontal force of magnitude $X$ N, as shown in the diagram. The two strings are both inclined at 60° to the vertical.

**(a)** Given that $X = 100$, find the tension in the lower string. [4]

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**(b)** Find the least value of $X$ for which the block remains in equilibrium in the position shown. [4]

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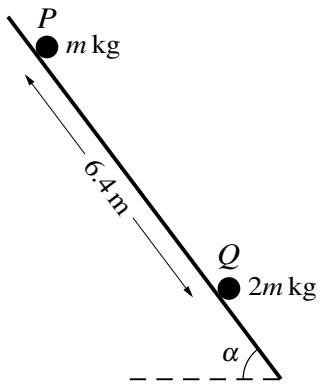


Particles $P$ and $Q$ have masses $m$ kg and $2m$ kg respectively. The particles are initially held at rest 6.4 m apart on the same line of greatest slope of a rough plane inclined at an angle $\alpha$ to the horizontal, where $\sin\alpha = 0.8$ (see diagram). Particle $P$ is released from rest and slides down the line of greatest slope. Simultaneously, particle $Q$ is projected up the same line of greatest slope at a speed of $10\,\text{m s}^{-1}$. The coefficient of friction between each particle and the plane is 0.6.

**(a)** Show that the acceleration of $Q$ up the plane is $-11.6\,\text{m s}^{-2}$. [4]

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**(b)** Find the time for which the particles are in motion before they collide. [5]

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**(c)** The particles coalesce on impact.

Find the speed of the combined particle immediately after the impact. [4]

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## Additional Page

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Cambridge Assessment International Education

# Cambridge International AS & A Level

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| CANDIDATE NAME | | | | | | | | | |
| CENTRE NUMBER | | | | | | CANDIDATE NUMBER | | | |

*2275268691*

**MATHEMATICS** **9709/43**

Paper 4 Mechanics **October/November 2021**

**1 hour 15 minutes**

You must answer on the question paper.

You will need: List of formulae (MF19)

**INSTRUCTIONS**

- Answer **all** questions.
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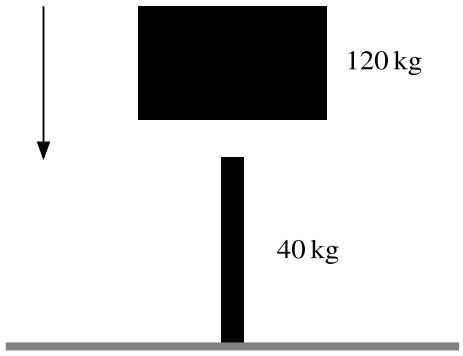
**1**




A metal post is driven vertically into the ground by dropping a heavy object onto it from above. The mass of the object is 120 kg and the mass of the post is 40 kg (see diagram). The object hits the post with speed $8\,m\,s^{-1}$ and remains in contact with it after the impact.

**(a)** Calculate the speed with which the combined post and object moves immediately after the impact. [2]

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**(b)** There is a constant force resisting the motion of magnitude 4800 N.

Calculate the distance the post is driven into the ground. [3]

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**2** A particle of mass 8 kg is suspended in equilibrium by two light inextensible strings which make angles of 60° and 45° above the horizontal.

**(a)** Draw a diagram showing the forces acting on the particle. [1]

**(b)** Find the tensions in the strings. [6]

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**3** A ball of mass 1.6 kg is released from rest at a point 5 m above horizontal ground. When the ball hits the ground it instantaneously loses 8 J of kinetic energy and starts to move upwards.

**(a)** Use an energy method to find the greatest height that the ball reaches after hitting the ground. [3]

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**(b)** Find the total time taken, from the initial release of the ball until it reaches this greatest height. [3]

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**4** A car of mass 1400 kg is moving on a straight road against a constant force of 1250 N resisting the motion.

**(a)** The car moves along a horizontal section of the road at a constant speed of $36\,m\,s^{-1}$.

**(i)** Calculate the work done against the resisting force during the first 8 seconds. [2]

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**(ii)** Calculate, in kW, the power developed by the engine of the car. [2]

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**(iii)** Given that this power is suddenly increased by 12 kW, find the instantaneous acceleration of the car. [3]

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**(b)** The car now travels at a constant speed of $32\,\text{m}\,\text{s}^{-1}$ up a section of the road inclined at $\theta°$ to the horizontal, with the engine working at 64 kW.

Find the value of $\theta$. [2]

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**5** A particle $P$ moves in a straight line, starting from rest at a point $O$ on the line. At time $t$ s after leaving $O$ the acceleration of $P$ is $k(16 - t^2)$ m s$^{-2}$, where $k$ is a positive constant, and the displacement from $O$ is $s$ m. The velocity of $P$ is 8 m s$^{-1}$ when $t = 4$.

**(a)** Show that $s = \frac{1}{64}t^2(96 - t^2)$. [5]

**(b)** Find the speed of $P$ at the instant that it returns to $O$. [3]

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**(c)** Find the maximum displacement of the particle from $O$. [3]

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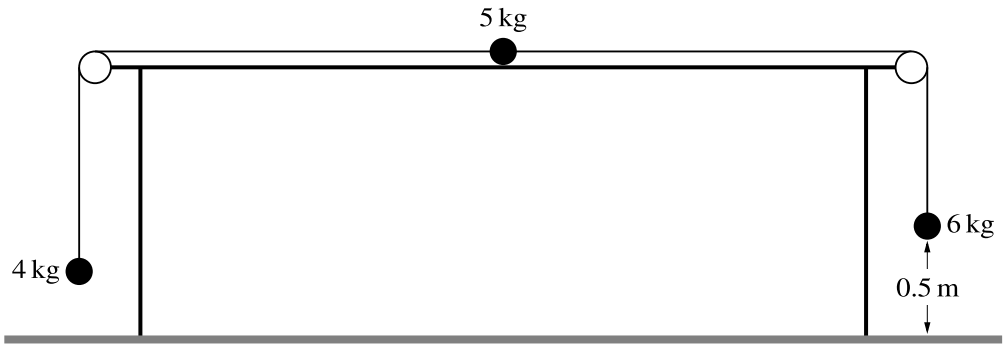


The diagram shows a particle of mass 5 kg on a rough horizontal table, and two light inextensible strings attached to it passing over smooth pulleys fixed at the edges of the table. Particles of masses 4 kg and 6 kg hang freely at the ends of the strings. The particle of mass 6 kg is 0.5 m above the ground. The system is in limiting equilibrium.

**(a)** Show that the coefficient of friction between the 5 kg particle and the table is 0.4. [2]

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The 6 kg particle is now replaced by a particle of mass 8 kg and the system is released from rest.

**(b)** Find the acceleration of the 4 kg particle and the tensions in the strings. [5]

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**(c)** In the subsequent motion the 8 kg particle hits the ground and does not rebound.

Find the time that elapses after the 8 kg particle hits the ground before the other two particles come to instantaneous rest. (You may assume this occurs before either particle reaches a pulley.) [5]

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