

Cambridge International AS & A Level

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MATHEMATICS

9709/41

Paper 4 Mechanics

October/November 2023

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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- 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 m 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 A particle of mass 1.6 kg is projected with a speed of 20 m s^{-1} up a line of greatest slope of a smooth plane inclined at α to the horizontal, where $\tan \alpha = \frac{3}{4}$.

Use an energy method to find the distance the particle moves up the plane before coming to instantaneous rest. [3]

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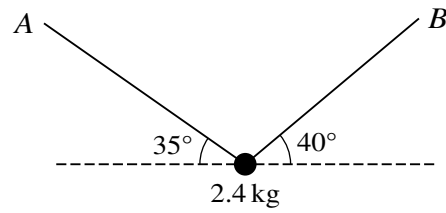
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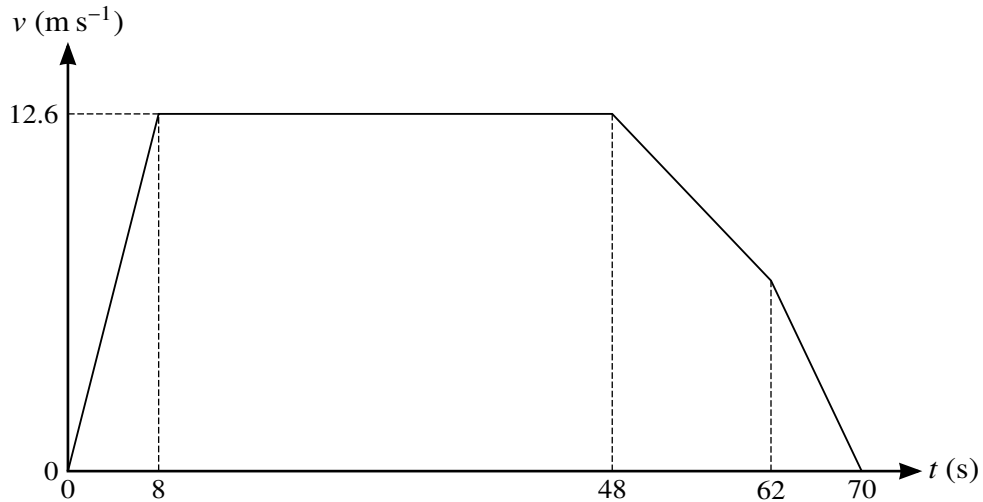
A particle of mass 2.4 kg is held in equilibrium by two light inextensible strings, one of which is attached to point A and the other attached to point B . The strings make angles of 35° and 40° with the horizontal (see diagram).

Find the tension in each of the two strings.

[5]

[illegible]

3



The diagram shows the velocity-time graph for the motion of a bus. The bus starts from rest and accelerates uniformly for 8 seconds until it reaches a speed of 12.6 m s^{-1} . The bus maintains this speed for 40 seconds. It then decelerates uniformly in two stages. Between 48 and 62 seconds the bus decelerates at $a \text{ m s}^{-2}$ and between 62 and 70 seconds it decelerates at $2a \text{ m s}^{-2}$ until coming to rest.

- (a) Find the distance covered by the bus in the first 8 seconds. [1]

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

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- (c) Find the average speed of the bus for the whole journey. [4]

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- 4 Two particles P and Q , of masses 6 kg and 2 kg respectively, lie at rest 12.5 m apart on a rough horizontal plane. The coefficient of friction between each particle and the plane is 0.4. Particle P is projected towards Q with speed 20 m s^{-1} .

(a) Show that the speed of P immediately before the collision with Q is $10\sqrt{3} \text{ m s}^{-1}$. [3]

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In the collision P and Q coalesce to form particle R .

(b) Find the loss of kinetic energy due to the collision. [4]

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The coefficient of friction between R and the plane is 0.4.

- (c) Find the distance travelled by particle R before coming to rest. [2]

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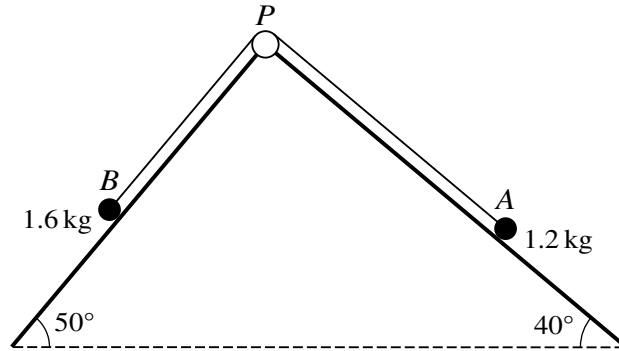
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The diagram shows a particle A , of mass 1.2 kg , which lies on a plane inclined at an angle of 40° to the horizontal and a particle B , of mass 1.6 kg , which lies on a plane inclined at an angle of 50° to the horizontal. The particles are connected by a light inextensible string which passes over a small smooth pulley P fixed at the top of the planes. The parts AP and BP of the string are taut and parallel to lines of greatest slope of the respective planes. The two planes are rough, with the same coefficient of friction, μ , between the particles and the planes.

Find the value of μ for which the system is in limiting equilibrium.

[7]

[illegible]

6 A car of mass 1300 kg is moving on a straight road.

(a) On a horizontal section of the road, the car has a constant speed of 30 m s^{-1} and there is a constant force of 650 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 increased **by** 9 kW, find the instantaneous acceleration of the car. [3]

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- (b)** On a section of the road inclined at $\sin^{-1} 0.08$ to the horizontal, the resistance to the motion of the car is $(1000 + 20v)$ N when the speed of the car is $v \text{ m s}^{-1}$. The car travels downwards along this section of the road at constant speed with the engine working at 11.5 kW.

Find this constant speed.

[4]

This image shows a full page of white paper with horizontal dotted lines. The lines are evenly spaced and run across the width of the page, providing a guide for handwriting practice. There are no margins, text, or other markings on the page.

- 7 A particle moves in a straight line starting from a point O before coming to instantaneous rest at a point X . At time t s after leaving O , the velocity v m s⁻¹ of the particle is given by

$$v = 7.2t^2 \quad 0 \leq t \leq 2,$$

$$v = 30.6 - 0.9t \quad 2 \leq t \leq 8,$$

$$v = \frac{1600}{t^2} + kt \quad 8 \leq t,$$

where k is a constant. It is given that there is no instantaneous change in velocity at $t = 8$.

Find the distance OX .

[9]

This image shows a full page of primary-ruled paper. It features multiple horizontal rows, each defined by two parallel dashed lines. The rows are evenly spaced across the entire page, providing a guide for handwriting practice. There are no margins, text, or other markings present.

[illegible]

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Cambridge International AS & A Level

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MATHEMATICS

9709/42

Paper 4 Mechanics

October/November 2023

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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- 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 m 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 block of mass 15 kg slides down a line of greatest slope of an inclined plane. The top of the plane is at a vertical height of 1.6 m above the level of the bottom of the plane. The speed of the block at the top of the plane is 2 m s^{-1} and the speed of the block at the bottom of the plane is 4 m s^{-1} .

Find the work done against the resistance to motion of the block.

[4]

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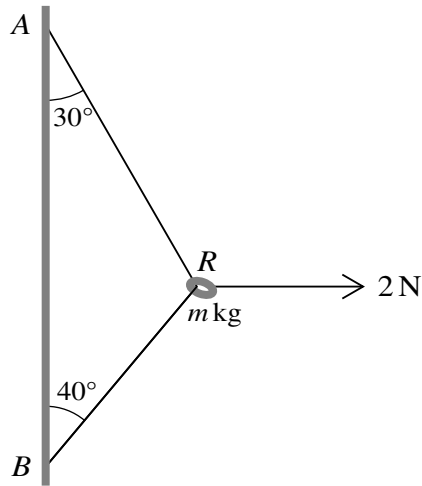
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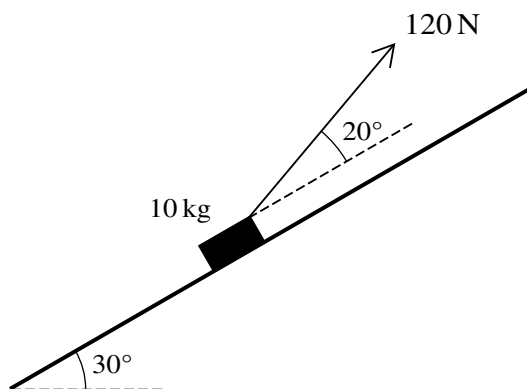


The diagram shows a smooth ring R , of mass m kg, threaded on a light inextensible string. A horizontal force of magnitude 2 N acts on R . The ends of the string are attached to fixed points A and B on a vertical wall. The part AR of the string makes an angle of 30° with the vertical, the part BR makes an angle of 40° with the vertical and the string is taut. The ring is in equilibrium.

Find the tension in the string and find the value of m .

[5]

[illegible]



A block of mass 10 kg is at rest on a rough plane inclined at an angle of 30° to the horizontal. A force of 120 N is applied to the block at an angle of 20° above a line of greatest slope (see diagram). There is a force resisting the motion of the block and 200 J of work is done against this force when the block has moved a distance of 5 m up the plane from rest.

Find the speed of the block when it has moved a distance of 5 m up the plane from rest. [5]

[illegible]

- 4** A particle P of mass 0.2 kg lies at rest on a rough horizontal plane. A horizontal force of 1.2 N is applied to P .

(a) Given that P is in limiting equilibrium, find the coefficient of friction between P and the plane. [3]

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(b) Given instead that the coefficient of friction between P and the plane is 0.3 , find the distance travelled by P in the third second of its motion. [4]

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5 A particle A of mass 0.5 kg is projected vertically upwards from horizontal ground with speed 25 m s^{-1} .

(a) Find the speed of A when it reaches a height of 20 m above the ground. [2]

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When A reaches a height of 20 m , it collides with a particle B of mass 0.3 kg which is moving downwards in the same vertical line as A with speed 32.5 m s^{-1} . In the collision between the two particles, B is brought to instantaneous rest.

(b) Show that the velocity of A immediately after the collision is 4.5 m s^{-1} downwards. [2]

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- (c) Find the time interval between A and B reaching the ground. You should assume that A does not bounce when it reaches the ground. [4]

This image shows a full page of white paper with horizontal dotted lines, typical of primary school writing paper. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

- 6** A railway engine of mass 120 000 kg is towing a coach of mass 60 000 kg up a straight track inclined at an angle of α to the horizontal where $\sin \alpha = 0.02$. There is a light rigid coupling, parallel to the track, connecting the engine and coach. The driving force produced by the engine is 125 000 N and there are constant resistances to motion of 22 000 N on the engine and 13 000 N on the coach.

(a) Find the acceleration of the engine and find the tension in the coupling. [5]

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At an instant when the engine is travelling at 30 m s^{-1} , it comes to a section of track inclined upwards at an angle β to the horizontal. The power produced by the engine is now $4\,500\,000 \text{ W}$ and, as a result, the engine maintains a constant speed.

- (b) Assuming that the resistance forces remain unchanged, find the value of β . [4]

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- 7 A particle X travels in a straight line. The velocity of X at time t s after leaving a fixed point O is denoted by $v \text{ m s}^{-1}$, where

$$v = -0.1t^3 + 1.8t^2 - 6t + 5.6.$$

The acceleration of X is zero at $t = p$ and $t = q$, where $p < q$.

- (a) Find the value of p and the value of q . [4]

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It is given that the velocity of X is zero at $t = 14$.

- (b) Find the velocities of X at $t = p$ and at $t = q$, and hence sketch the velocity-time graph for the motion of X for $0 \leq t \leq 15$. [3]

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[5]

[illegible]

[illegible]

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MATHEMATICS

9709/43

Paper 4 Mechanics

October/November 2023

1 hour 15 minutes

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INFORMATION

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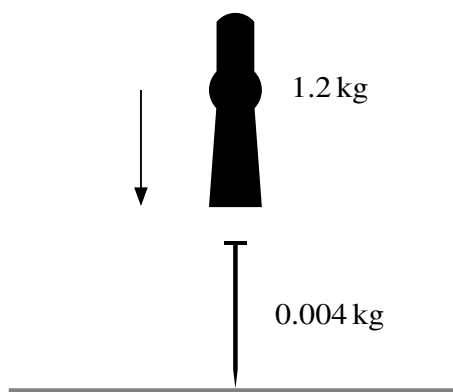
This document has **12** pages.

- 1** A particle is projected vertically upwards from horizontal ground with a speed of $u \text{ m s}^{-1}$. The particle has height $s \text{ m}$ above the ground at times 3 seconds and 4 seconds after projection.

Find the value of u and the value of s .

[3]

[illegible]



A machine for driving a nail into a block of wood causes a hammerhead to drop vertically onto the top of a nail. The mass of the hammerhead is 1.2 kg and the mass of the nail is 0.004 kg (see diagram). The hammerhead hits the nail with speed $v \text{ m s}^{-1}$ and remains in contact with the nail after the impact. The combined hammerhead and nail move immediately after the impact with speed 40 m s^{-1} .

- (a) Calculate v , giving your answer as an exact fraction. [2]

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- (b) The nail is driven 4 cm into the wood.

Find the constant force resisting the motion. [3]

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- 3** A block of mass 8 kg slides down a rough plane inclined at 30° to the horizontal, starting from rest. The coefficient of friction between the block and the plane is μ . The block accelerates uniformly down the plane at 2.4 m s^{-2} .

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

(b) Find the value of μ . [4]

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(c) Find the speed of the block after it has moved 3 m down the plane. [1]

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4 A car has mass 1600 kg.

- (a) The car is moving along a straight horizontal road at a constant speed of 24 m s^{-1} and is subject to a constant resistance of magnitude 480 N .

Find, in kW, the rate at which the engine of the car is working. [2]

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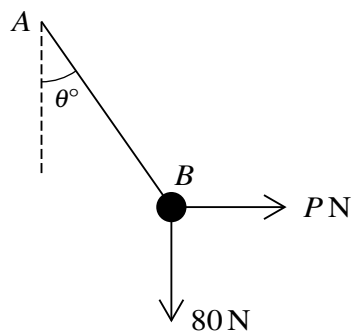
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The car now moves down a hill inclined at an angle of θ to the horizontal, where $\sin \theta = 0.09$. The engine of the car is working at a constant rate of 12 kW. The speed of the car is 24 m s^{-1} at the top of the hill. Ten seconds later the car has travelled 280 m down the hill and has speed 32 m s^{-1} .

- (b) Given that the resistance is not constant, use an energy method to find the total work done against the resistance during the ten seconds. [5]

This image shows a full page of white paper with horizontal dotted lines, typical of primary school writing paper. The lines are evenly spaced and run across the entire width of the page. There are no margins, text, or other markings present.



(a) It is given that $P = 32$ and the system is in equilibrium.

[4]

This image shows a full page of white paper designed for handwriting practice. It features 18 evenly spaced, horizontal dotted lines that run across the entire width of the page. The lines are thin and light gray, providing a guide for letter height and placement without being distracting. There is no text or other markings on the page.

- (b)** It is given instead that the tension in the string is 120 N and that the particle attached at B still has weight 80 N.

Find the value of P and the value of θ .

[4]

[illegible]

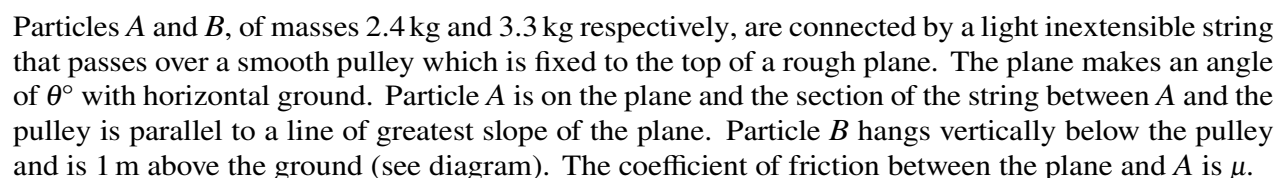
- 6** A particle moves in a straight line. At time t s, the acceleration, a m s^{-2} , of the particle is given by $a = 36 - 6t$. The velocity of the particle is 27 m s^{-1} when $t = 2$.

- (a) Find the values of t when the particle is at instantaneous rest. [4]

[illegible]

[4]

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- Show that $\mu = 1.01$ correct to 3 significant figures. [5]

This image shows a full page of a handwriting practice worksheet. It consists of multiple sets of three horizontal dashed lines, providing a guide for letter height and placement. The lines are evenly spaced across the entire page, which is otherwise blank.

- (b)** It is given instead that $\theta = 20$ and $\mu = 1.01$. The system is released from rest with the string taut.

Find the total distance travelled by A before coming to instantaneous rest. You may assume that A does not reach the pulley and that B remains at rest after it hits the ground. [8]

[illegible]

[illegible]

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