

Cambridge International AS & A Level

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MATHEMATICS

9709/41

Paper 4 Mechanics

May/June 2022

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.
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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.

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- 1** A car starts from rest and moves in a straight line with constant acceleration for a distance of 200 m, reaching a speed of 25 m s^{-1} . The car then travels at this speed for 400 m, before decelerating uniformly to rest over a period of 5 s.

(a) Find the time for which the car is accelerating. [2]

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(b) Sketch the velocity–time graph for the motion of the car, showing the key points. [2]

(c) Find the average speed of the car during its motion. [2]

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- 2** Two particles P and Q , of masses 0.5 kg and 0.3 kg respectively, are connected by a light inextensible string. The string is taut and P is vertically above Q . A force of magnitude 10 N is applied to P vertically upwards.

Find the acceleration of the particles and the tension in the string connecting them. [5]

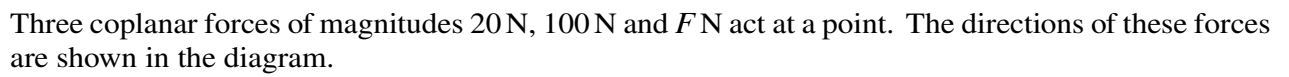
This image shows a full page of white paper with horizontal dashed lines, typical of primary school writing paper. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

- 3 A crate of mass 300 kg is at rest on rough horizontal ground. The coefficient of friction between the crate and the ground is 0.5. A force of magnitude X N, acting at an angle α above the horizontal, is applied to the crate, where $\sin \alpha = 0.28$.

Find the greatest value of X for which the crate remains at rest.

[5]

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

[illegible]

- 5 Two racing cars A and B are at rest alongside each other at a point O on a straight horizontal test track. The mass of A is 1200 kg . The engine of A produces a constant driving force of 4500 N . When A arrives at a point P its speed is 25 m s^{-1} . The distance OP is $d\text{ m}$. The work done against the resistance force experienced by A between O and P is $75\,000\text{ J}$.

(a) Show that $d = 100$.

[3]

[illegible]

Car B starts off at the same instant as car A . The two cars arrive at P simultaneously and with the same speed. The engine of B produces a driving force of 3200 N and the car experiences a constant resistance to motion of 1200 N .

- (b) Find the mass of B . [3]

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- (c) Find the steady speed which B can maintain when its engine is working at the same rate as it is at P . [3]

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- 6 A particle starts from a point O and moves in a straight line. The velocity $v \text{ m s}^{-1}$ of the particle at time $t \text{ s}$ after leaving O is given by

$$v = k(3t^2 - 2t^3),$$

where k is a constant.

- (a) Verify that the particle returns to O when $t = 2$. [4]

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- (b)** It is given that the acceleration of the particle is -13.5 m s^{-2} for the positive value of t at which $v = 0$.

Find k and hence find the total distance travelled in the first two seconds of motion. [6]

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 Two particles *A* and *B*, of masses 0.4 kg and 0.2 kg respectively, are moving down the same line of greatest slope of a smooth plane. The plane is inclined at 30° to the horizontal, and *A* is higher up the plane than *B*. When the particles collide, the speeds of *A* and *B* are 3 m s^{-1} and 2 m s^{-1} respectively. In the collision between the particles, the speed of *A* is reduced to 2.5 m s^{-1} .

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

After the collision, when B has moved 1.6 m down the plane from the point of collision, it hits a barrier and returns back up the same line of greatest slope. B hits the barrier 0.4 s after the collision, and when it hits the barrier, its speed is reduced by 90%. The two particles collide again 0.44 s after their previous collision, and they then coalesce on impact.

- (b)** Show that the speed of B immediately after it hits the barrier is 0.5 m s^{-1} . Hence find the speed of the combined particle immediately after the second collision between A and B . [7]

[illegible]

[illegible]

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MATHEMATICS

9709/42

Paper 4 Mechanics

May/June 2022

1 hour 15 minutes

You must answer on the question paper.

You will need: List of formulae (MF19)

INSTRUCTIONS

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- 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 [].

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- 1** Small smooth spheres A and B , of equal radii and of masses 5 kg and 3 kg respectively, lie on a smooth horizontal plane. Initially B is at rest and A is moving towards B with speed 8.5 m s^{-1} . The spheres collide and after the collision A continues to move in the same direction but with a quarter of the speed of B .

(a) Find the speed of B after the collision. [3]

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(b) Find the loss of kinetic energy of the system due to the collision. [2]

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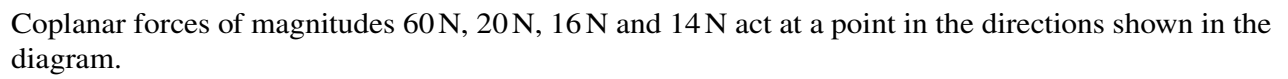
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[6]

[illegible]

- (a) Show that the tension in the string before A reaches the plane is 16 N and find the magnitude of the acceleration of the particles before A reaches the plane. [4]

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(b) Find the greatest height of B above the plane.

[3]

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- 4 A particle A , moving along a straight horizontal track with constant speed 8 ms^{-1} , passes a fixed point O . Four seconds later, another particle B passes O , moving along a parallel track in the same direction as A . Particle B has speed 20 ms^{-1} when it passes O and has a constant deceleration of 2 ms^{-2} . B comes to rest when it returns to O .

- (a) Find expressions, in terms of t , for the displacement from O of each particle t seconds after B passes O . [3]

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- (b) Find the values of t when the particles are the same distance from O . [3]

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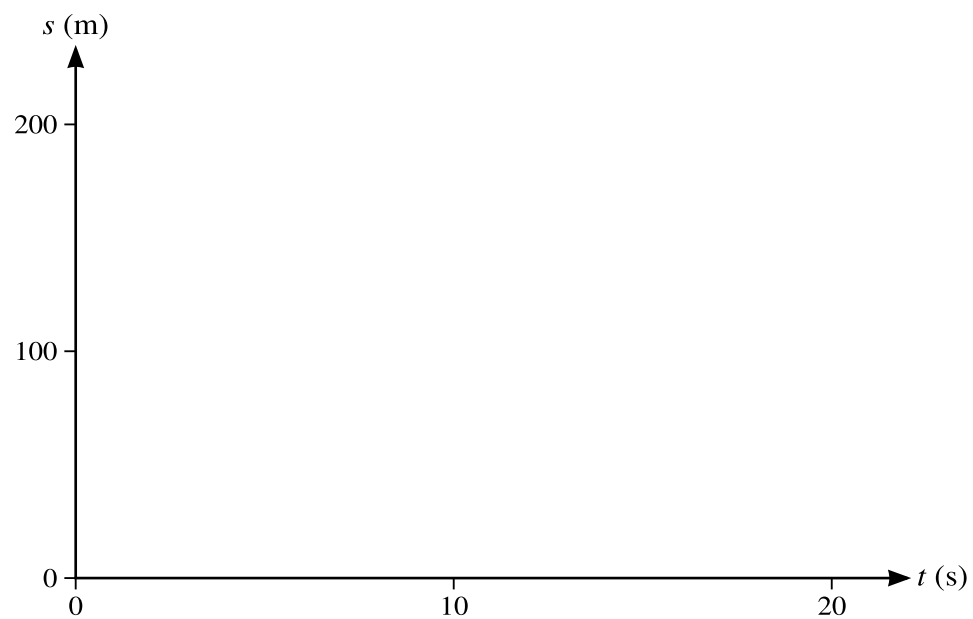
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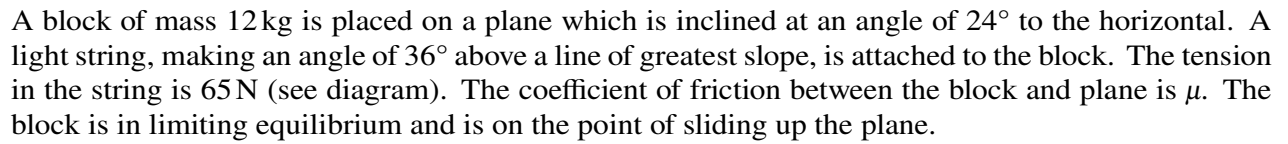
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- (c) On the given axes, sketch the displacement-time graphs for both particles, for values of t from 0 to 20. [3]





[6]

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- 6 A car of mass 900 kg is moving up a hill inclined at $\sin^{-1} 0.12$ to the horizontal. The initial speed of the car is 11 m s^{-1} . After 12 s, the car has travelled 150 m up the hill and has speed 16 m s^{-1} . The engine of the car is working at a constant rate of 24 kW.

(a) Find the work done against the resistive forces during the 12 s. [5]

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The car then travels along a straight horizontal road. There is a resistance to the motion of the car of $(1520 + 4v)$ N when the speed of the car is $v \text{ m s}^{-1}$. The car travels at a constant speed with the engine working at a constant rate of 32 kW.

(b) Find this speed.

[3]

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

$$\begin{aligned} v &= 0.5t && \text{for } 0 \leq t \leq 10, \\ v &= 0.25t^2 - 8t + 60 && \text{for } 10 \leq t \leq 20. \end{aligned}$$

- (a)** Show that there is an instantaneous change in the acceleration of the particle at $t = 10$. [3]

[illegible]

9709/42/M/J/22

[illegible]

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MATHEMATICS

9709/43

Paper 4 Mechanics

May/June 2022

1 hour 15 minutes

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You will need: List of formulae (MF19)

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INFORMATION

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

- 1 Two particles P and Q , of masses 0.3 kg and 0.2 kg respectively, are at rest on a smooth horizontal plane. P is projected at a speed of 4 m s^{-1} directly towards Q . After P and Q collide, Q begins to move with a speed of 3 m s^{-1} .

(a) Find the speed of P after the collision. [2]

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After the collision, Q moves directly towards a third particle R , of mass $m\text{ kg}$, which is at rest on the plane. The two particles Q and R coalesce on impact and move with a speed of 2 m s^{-1} .

(b) Find m . [2]

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- 2 A particle P is projected vertically upwards from horizontal ground. P reaches a maximum height of 45 m. After reaching the ground, P comes to rest without rebounding.

(a) Find the speed at which P was projected. [2]

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(b) Find the total time for which the speed of P is at least 10 m s^{-1} . [3]

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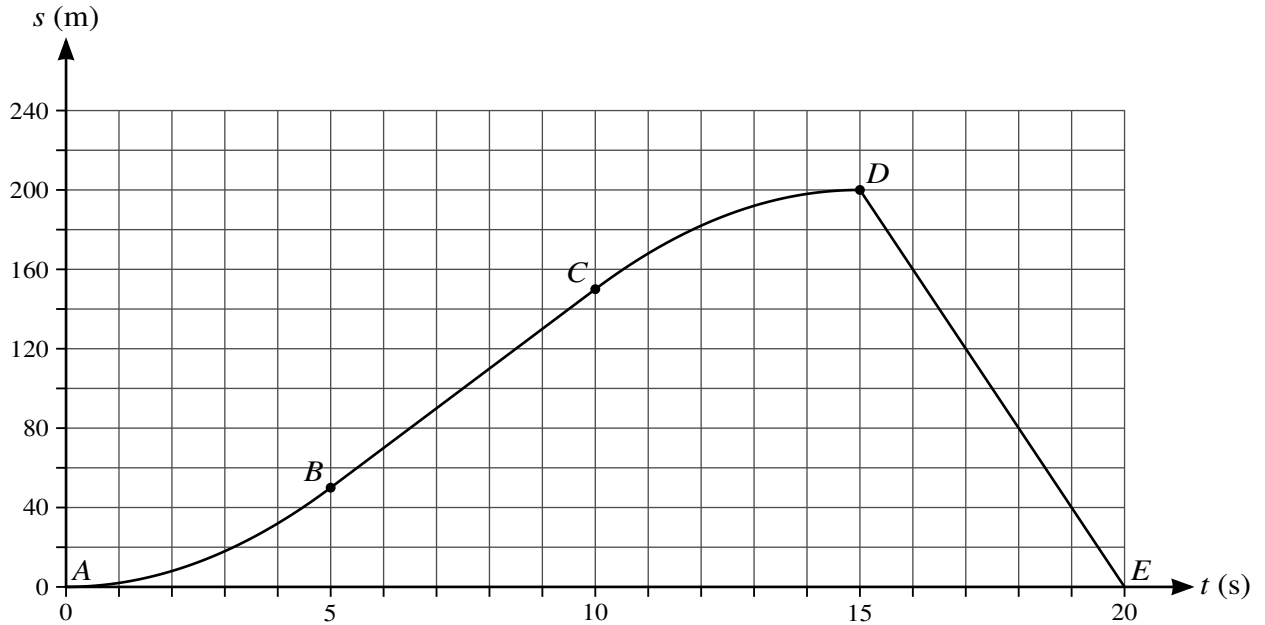
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The displacement of a particle moving in a straight line is s metres at time t seconds after leaving a fixed point O . The particle starts from rest and passes through points P , Q and R , at times $t = 5$, $t = 10$ and $t = 15$ respectively, and returns to O at time $t = 20$. The distances OP , OQ and OR are 50 m, 150 m and 200 m respectively.

The diagram shows a displacement-time graph which models the motion of the particle from $t = 0$ to $t = 20$. The graph consists of two curved segments AB and CD and two straight line segments BC and DE .

- (a) Find the speed of the particle between $t = 5$ and $t = 10$. [1]

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- (b) Find the acceleration of the particle between $t = 0$ and $t = 5$, given that it is constant. [2]

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- (c) Find the average speed of the particle during its motion. [2]

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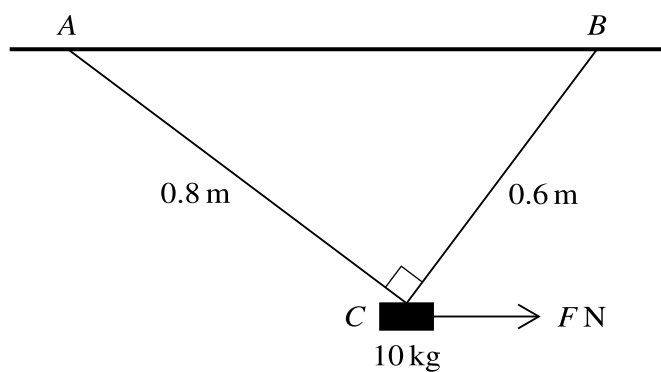
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The diagram shows a block of mass 10 kg suspended below a horizontal ceiling by two strings AC and BC , of lengths 0.8 m and 0.6 m respectively, attached to fixed points on the ceiling. Angle $ACB = 90^\circ$. There is a horizontal force of magnitude $F\text{ N}$ acting on the block. The block is in equilibrium.

- (a) In the case where $F = 20$, find the tensions in each of the strings. [5]

[illegible]

This image shows a full page of primary-ruled paper. It features approximately 20 horizontal dotted lines spaced evenly down the page, providing a guide for handwriting practice. The paper is otherwise blank, with no margins, text, or other markings.

- 5 A cyclist is riding along a straight horizontal road. The total mass of the cyclist and her bicycle is 70 kg. At an instant when the cyclist's speed is 4 m s^{-1} , her acceleration is 0.3 m s^{-2} . There is a constant resistance to motion of magnitude 30 N.

(a) Find the power developed by the cyclist.

[3]

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The cyclist comes to the top of a hill inclined at 5° to the horizontal. The cyclist stops pedalling and freewheels down the hill (so that the cyclist is no longer supplying any power). The magnitude of the resistance force remains at 30 N. Over a distance of d m, the speed of the cyclist increases from 6 m s^{-1} to 12 m s^{-1} .

- (b) Find the change in kinetic energy. [2]

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- (c) Use an energy method to find d . [3]

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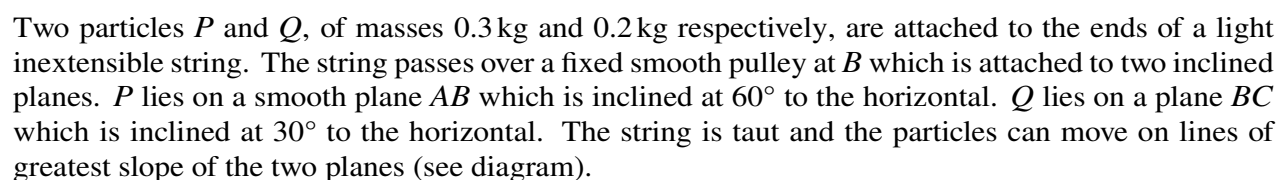
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- Find the tension in the string and the magnitude of the acceleration of the particles. [5]

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- (b) It is given instead that the plane BC is rough. A force of magnitude 3 N is applied to Q directly up the plane along a line of greatest slope of the plane.

Find the least value of the coefficient of friction between Q and the plane BC for which the particles remain at rest. [5]

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- 7** A particle P moves in a straight line through a point O . The velocity $v \text{ m s}^{-1}$ of P , at time $t \text{ s}$ after passing O , is given by

$$v = \frac{9}{4} + \frac{b}{(t+1)^2} - ct^2,$$

where b and c are positive constants. At $t = 5$, the velocity of P is zero and its acceleration is $-\frac{13}{12} \text{ m s}^{-2}$.

- (a) Show that $b = 9$ and find the value of c . [5]

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- (b)** Given that the velocity of P is zero only at $t = 5$, find the distance travelled in the first 10 seconds of motion. [5]

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