

Cambridge International AS & A Level

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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.
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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 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 [].

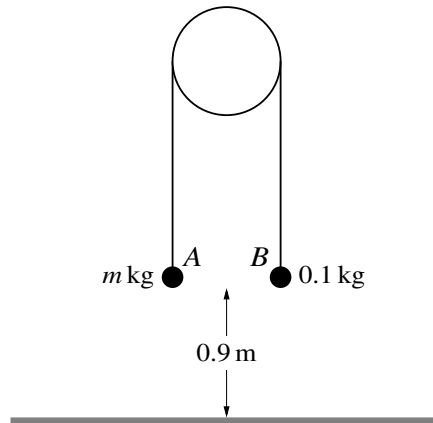
This document has **12** pages.

- 1 A 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]

[illegible]



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 m s^{-1} . After P and Q collide, P rebounds with speed 1 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 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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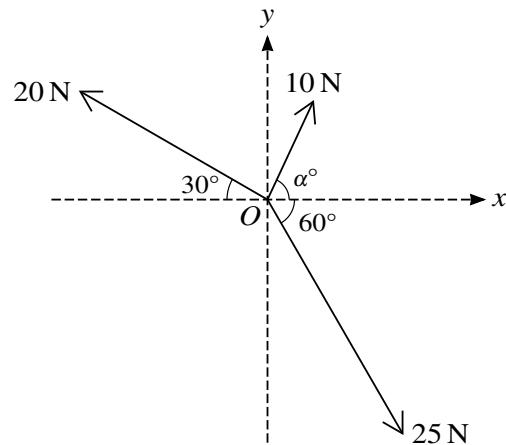
- 5 A particle moving in a straight line starts from rest at a point A and comes instantaneously to rest at a point B . The acceleration of the particle at time t s after leaving A is $a \text{ m s}^{-2}$, where

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

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

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[illegible]



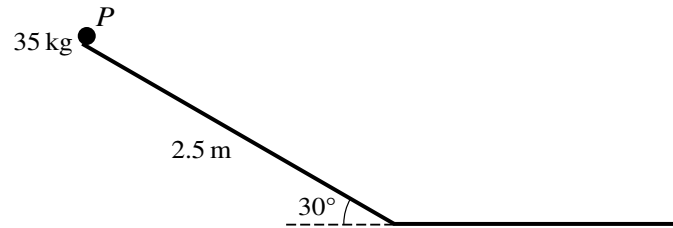
Three coplanar forces of magnitudes 10 N, 25 N and 20 N act at a point O in the directions shown in the diagram.

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

[illegible]

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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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[illegible]

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9709/41/M/J/21



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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)

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INFORMATION

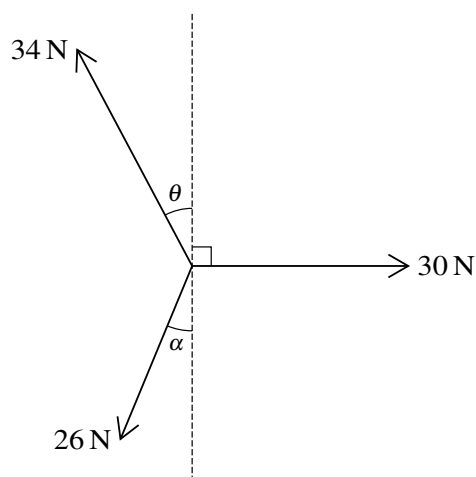
- The total mark for this paper is 50.
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This document has **12** pages.

- 1** A particle of mass 0.6 kg is projected with a speed of 4 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]

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 or typing. There are no margins, text, or other markings on the page.



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]

[illegible]

[illegible]

- 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]

[illegible]

- 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 m 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 m 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]

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- 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 $a \text{ m s}^{-2}$ of P is given by

$$a = 6 + 4t \quad 0 \leq t < 2,$$

$$a = 14 \quad 2 \leq t < 4,$$

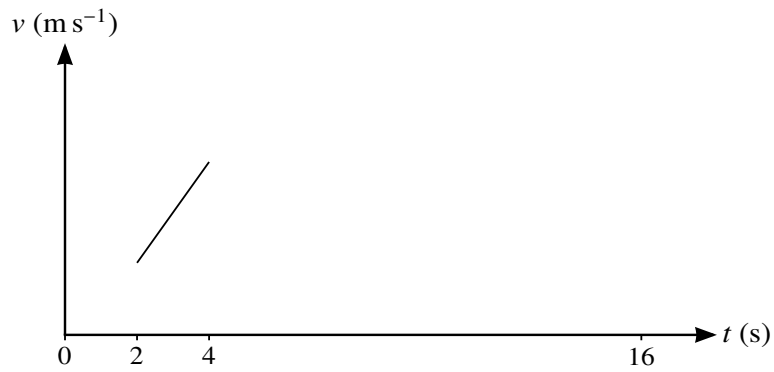
$$a = 16 - 2t \quad 4 \leq t \leq 16.$$

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]

[illegible]

- (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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MATHEMATICS

9709/43

Paper 4 Mechanics

May/June 2021

1 hour 15 minutes

You must answer on the question paper.

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- 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 m s^{-1} , her acceleration is 0.25 m 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 θ above the horizontal. She ascends the hill at constant speed 3 m s^{-1} . She continues to work at the same rate as before and the resistance force is unchanged.

(b) Find the value of θ . [2]

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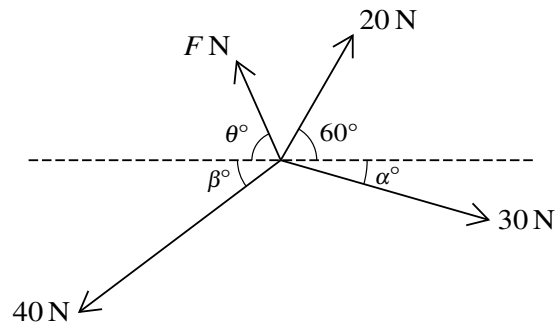
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Four coplanar forces act at a point. The magnitudes of the forces are 20 N, 30 N, 40 N and F N. The directions of the forces are as shown in the diagram, where $\sin \alpha^\circ = 0.28$ and $\sin \beta^\circ = 0.6$.

Given that the forces are in equilibrium, find F and θ .

[6]

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- 4 A particle is projected vertically upwards with speed $u \text{ m s}^{-1}$ 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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- 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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[illegible]

- 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 $v \text{ m s}^{-1}$, 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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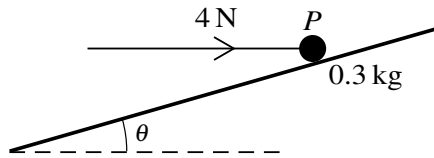
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- (b) Sketch the velocity-time graph for the first 3 seconds of motion. [3]

[illegible]

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A particle P of mass 0.3 kg rests on a rough plane inclined at an angle θ 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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