

Cambridge International AS & A Level

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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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- Where a numerical value for the acceleration due to gravity (g) is needed, use 10 m s^{-2} .

INFORMATION

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- 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.

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(b) Find the magnitude of the deceleration.

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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 m s^{-1} and B is moving towards A with speed 2 m s^{-1} . After the collision A and B coalesce and move with speed 4 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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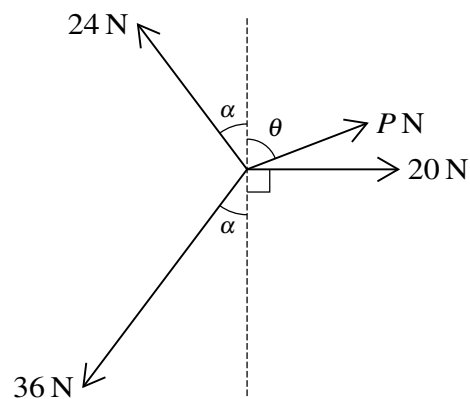
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Given that $\sin \alpha = \frac{3}{5}$, find the values of P and θ . [6]

[illegible]

- 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 m 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 $v \text{ m s}^{-1}$ of P is given by

$$v = pt^2 - qt \quad 0 \leq t \leq 6,$$

$$v = 63 - 4.5t \quad 6 \leq t \leq 14,$$

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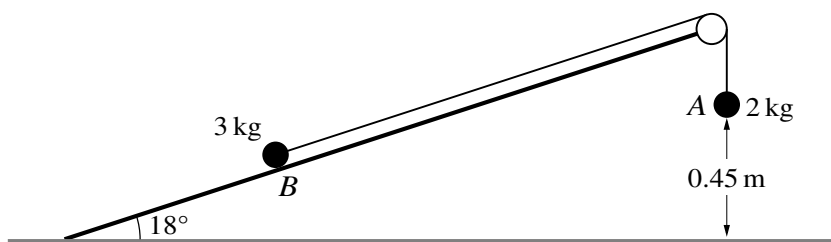
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- (b) Sketch the velocity-time graph. [3]

[Turn over



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]

[illegible]

[illegible]

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MATHEMATICS

9709/42

Paper 4 Mechanics

October/November 2021

1 hour 15 minutes

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You will need: List of formulae (MF19)

INSTRUCTIONS

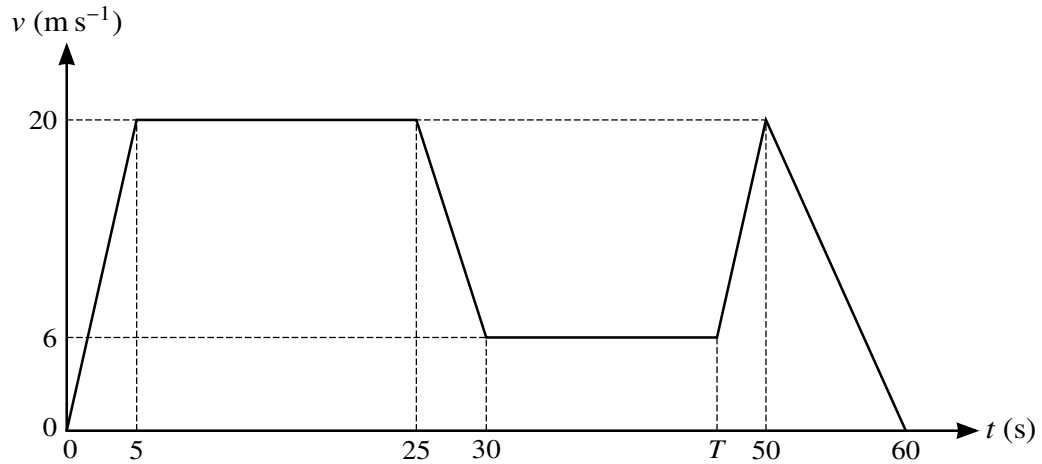
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1



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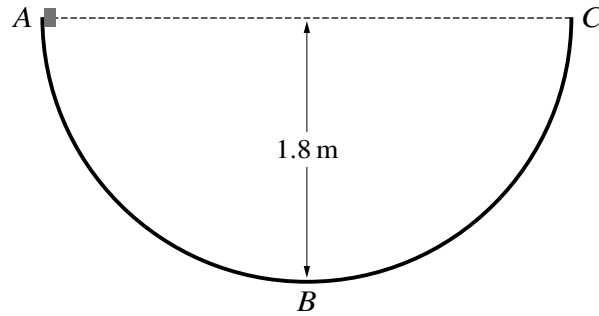
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The diagram shows a semi-circular track ABC of radius 1.8 m which is fixed in a vertical plane. The points A and C are at the same horizontal level and the point B is at the bottom of the track. The section AB is smooth and the section BC is rough.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

- (a) Show that the speed of the block at B is 6 m 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.

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- (b) Find the maximum velocity of the cyclist.

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- 5** A railway engine of mass 75 000 kg is moving up a straight hill inclined at an angle α to the horizontal, where $\sin \alpha = 0.01$. The engine is travelling at a constant speed of 30 m 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.

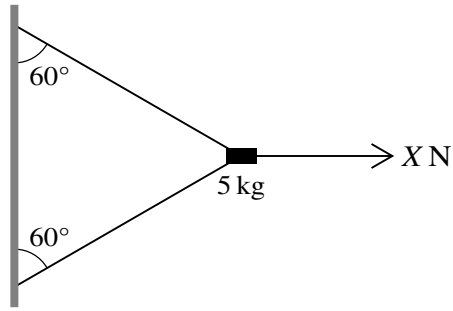
[3]

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The engine comes to a section of track which is horizontal. At the start of the section the engine is travelling at 30 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 $46\,500 \text{ kJ}$.

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

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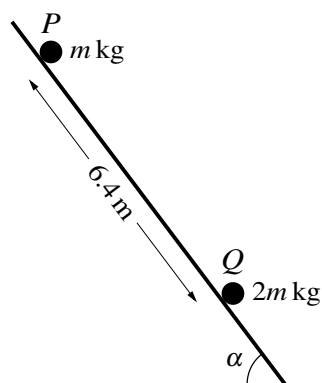
A block of mass 5 kg is held in equilibrium near a vertical wall by two light strings and a horizontal force of magnitude X N, as shown in the diagram. The two strings are both inclined at 60° to the vertical.

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

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7



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 α 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 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 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.

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[illegible]

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MATHEMATICS

9709/43

Paper 4 Mechanics

October/November 2021

1 hour 15 minutes

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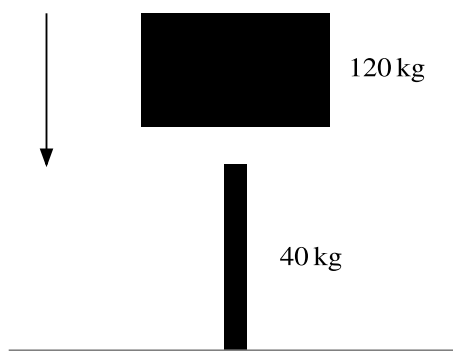
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A metal post is driven vertically into the ground by dropping a heavy object onto it from above. The mass of the object is 120 kg and the mass of the post is 40 kg (see diagram). The object hits the post with speed 8 m s^{-1} and remains in contact 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 m s^{-1} up a section of the road inclined at θ° to the horizontal, with the engine working at 64 kW.

Find the value of θ . [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]

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- (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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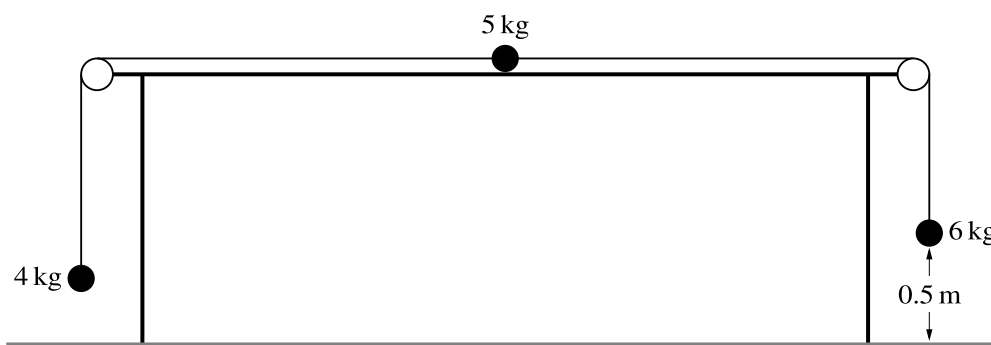
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The diagram shows a particle of mass 5 kg on a rough horizontal table, and two light inextensible strings attached to it passing over smooth pulleys fixed at the edges of the table. Particles of masses 4 kg and 6 kg hang freely at the ends of the strings. 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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