



Cambridge International AS & A Level

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MATHEMATICS**9709/41**

Paper 4 Mechanics

October/November 2024**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} .

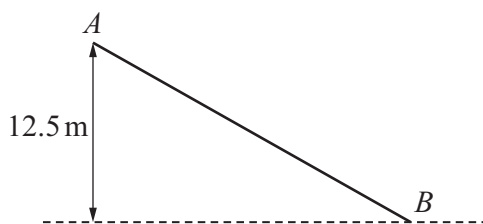
INFORMATION

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2



(a) Given that the plane is smooth, use an energy method to find the speed of the particle at B . [2]

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- Find the value of F . [3]





[1]





[illegible]



- 5 A particle, A , is projected vertically upwards from a point O with a speed of 80 m s^{-1} . One second later a second particle, B , with the same mass as A , is projected vertically upwards from O with a speed of 100 m s^{-1} . At time T s after the first particle is projected, the two particles collide and coalesce to form a particle C .

(a) Show that $T = 3.5$.

[4]

[illegible]

- (b)** Find the height above O at which the particles collide.

[1]

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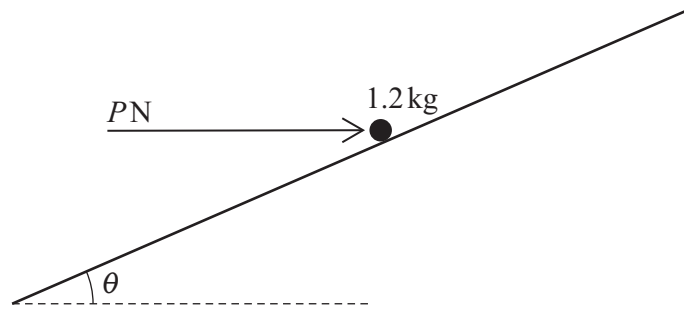
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[5]

[illegible]



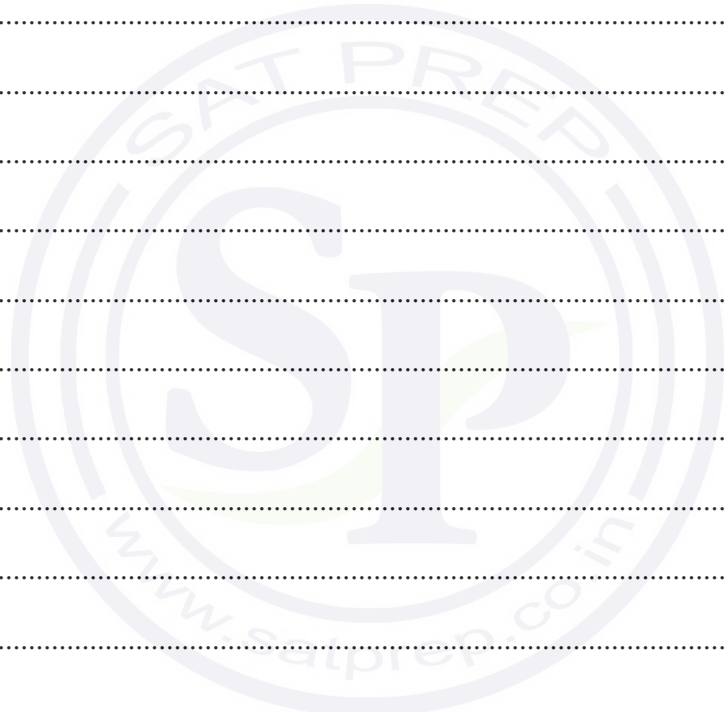
A particle of mass 1.2 kg is placed on a rough plane which is inclined at an angle θ to the horizontal, where $\sin \theta = \frac{7}{25}$. The particle is kept in equilibrium by a horizontal force of magnitude $P \text{ N}$ acting in a vertical plane containing a line of greatest slope (see diagram). The coefficient of friction between the particle and the plane is 0.15 .

Find the least possible value of P .

[6]

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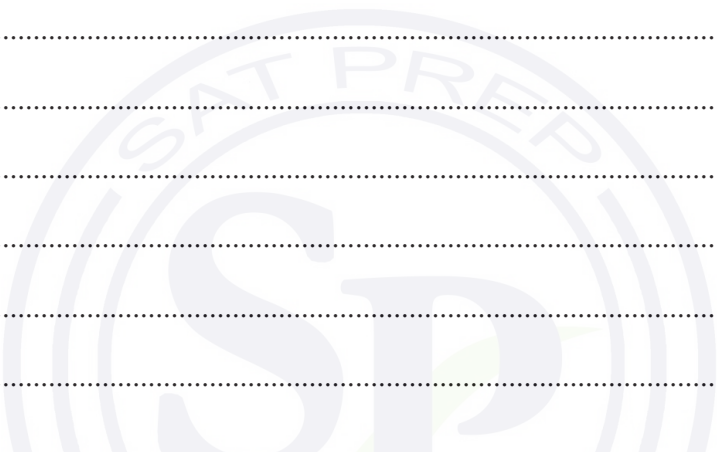
- 7 A car has mass 1200 kg. When the car is travelling at a speed of $v \text{ ms}^{-1}$, there is a resistive force of magnitude $kv \text{ N}$. The maximum power of the car's engine is 92.16 kW.

- (a)** The car travels along a straight level road.

- (i)** The car has a greatest possible constant speed of 48 m s^{-1} .

Show that $k = 40$.

[1]

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- (ii) At an instant when its speed is 45 m s^{-1} , find the greatest possible acceleration of the car. [3]

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[4]

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Cambridge International AS & A Level

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MATHEMATICS**9709/42**

Paper 4 Mechanics

October/November 2024**1 hour 15 minutes**

You must answer on the question paper.

You will need: List of formulae (MF19)

INSTRUCTIONS

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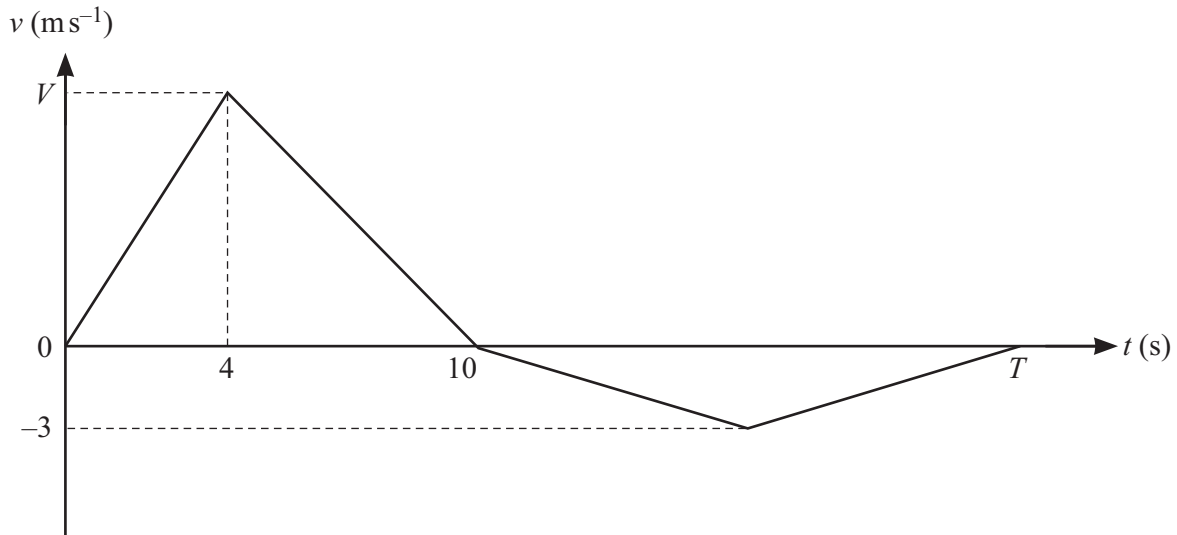
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1



The velocity of a particle moving in a straight line at time t seconds after leaving a fixed point O is $v \text{ ms}^{-1}$. The diagram shows a velocity-time graph which models the motion of the particle from $t = 0$ to $t = T$. The graph consists of four straight line segments. The particle accelerates from rest to a speed of $V \text{ ms}^{-1}$ over a period of 4 s, and then decelerates at $\frac{5}{3} \text{ ms}^{-2}$ to instantaneous rest over a period of 6 s. The particle then travels back towards O , reaching a maximum speed of 3 ms^{-1} before coming to rest at time $t = T$.

- (a) Find the value of V . [2]

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- (b) Given that the total distance travelled by the particle from $t = 0$ to $t = T$ is 68 m, find the value of T . [3]

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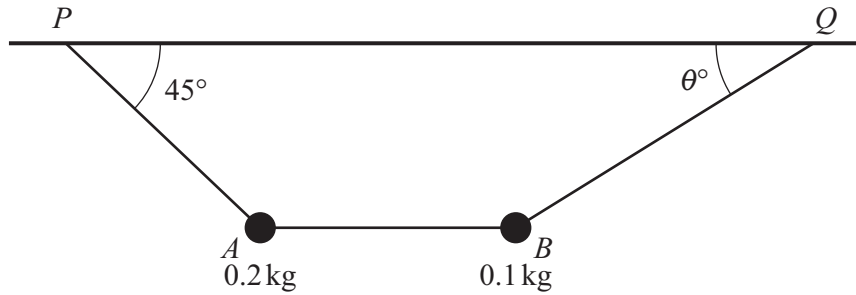
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- [illegible]

[illegible]



The diagram shows two particles, A and B , of masses 0.2 kg and 0.1 kg respectively. The particles are suspended below a horizontal ceiling by two strings, AP and BQ , attached to fixed points P and Q on the ceiling. The particles are connected by a horizontal string, AB . Angle $APQ = 45^\circ$ and $BQP = \theta^\circ$. Each string is light and inextensible. The particles are in equilibrium.

- (a) Find the value of the tension in the string AB . [2]

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[4]

[illegible]

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- Find the speed of P at the instant that it reaches the ground.

[5]

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6 A particle, P , travels in a straight line, starting from a point O with velocity 6 ms^{-1} . The acceleration of P at time t s after leaving O is $a \text{ ms}^{-2}$, where

$$a = -1.5t^{\frac{1}{2}} \quad \text{for } 0 \leq t \leq 1,$$

$$a = 1.5t^{\frac{1}{2}} - 3t^{-\frac{1}{2}} \quad \text{for } t > 1.$$

- (a) Find the velocity of P at $t = 1$. [3]

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- (b)** Given that there is no change in the velocity of P when $t = 1$, find an expression for the velocity of P for $t > 1$. [3]

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- (b) When B reaches the ground, it comes to rest.

Find the total distance that A travels down the plane from when it is released until it comes to rest.
You may assume that A does not reach the pulley. [4]



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Cambridge International AS & A Level

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MATHEMATICS**9709/43**

Paper 4 Mechanics

October/November 2024**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

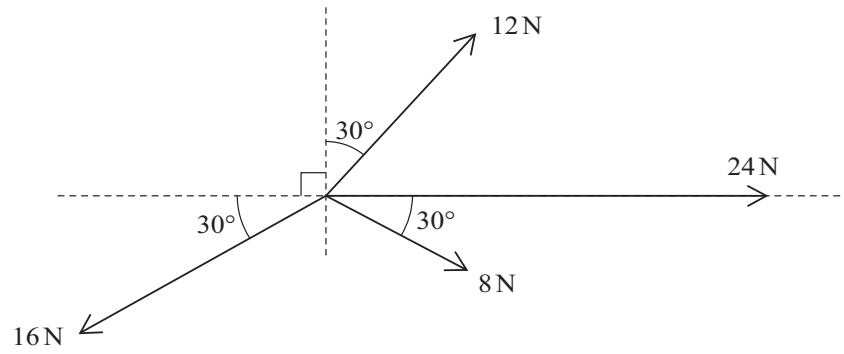
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- Find the value of m .

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Coplanar forces of magnitudes 16N, 12N, 24N and 8N act at a point in the directions shown in the diagram.

Find the magnitude and direction of the single additional force acting at the same point which will produce equilibrium. [6]

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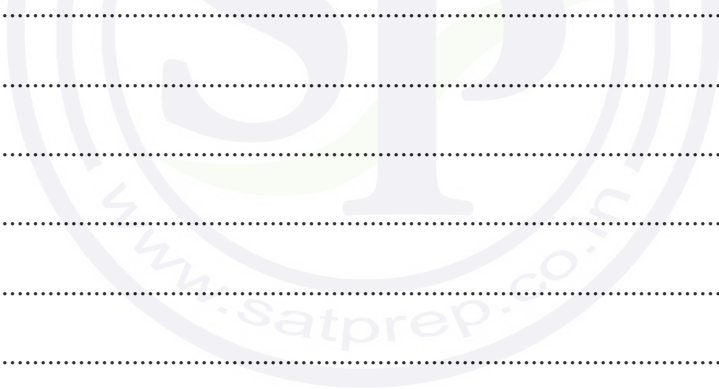


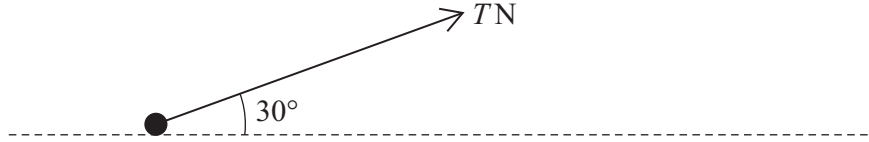


- (a)** It is given that the car travels at a constant speed of 32 ms^{-1} .

[3]

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A particle of mass 12 kg is going to be pulled across a rough horizontal plane by a light inextensible string. The string is at an angle of 30° above the plane and has tension $T\text{ N}$ (see diagram). The coefficient of friction between the particle and the plane is 0.5 .

- (a) Given that the particle is on the point of moving, find the value of T . [5]

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- (b) Given instead that the particle is accelerating at 0.2 m s^{-2} , find the value of T . [3]

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- 6 A particle moves in a straight line. It starts from rest, at time $t = 0$, and accelerates at $0.6t \text{ m s}^{-2}$ for 4 s, reaching a speed of $V \text{ m s}^{-1}$. The particle then travels at $V \text{ m s}^{-1}$ for 11 s, and finally slows down, with constant deceleration, stopping after a further 5 s.

(a) Show that $V = 4.8$. [1]

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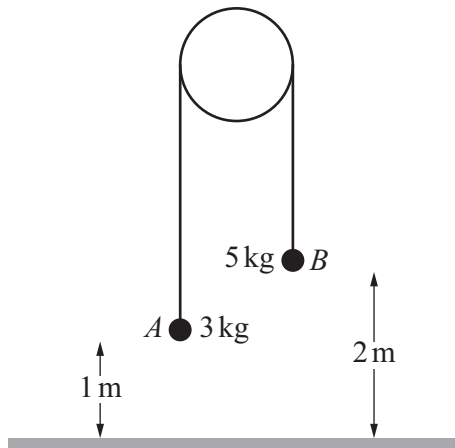
(b) Sketch a velocity-time graph for the motion. [3]





[2]

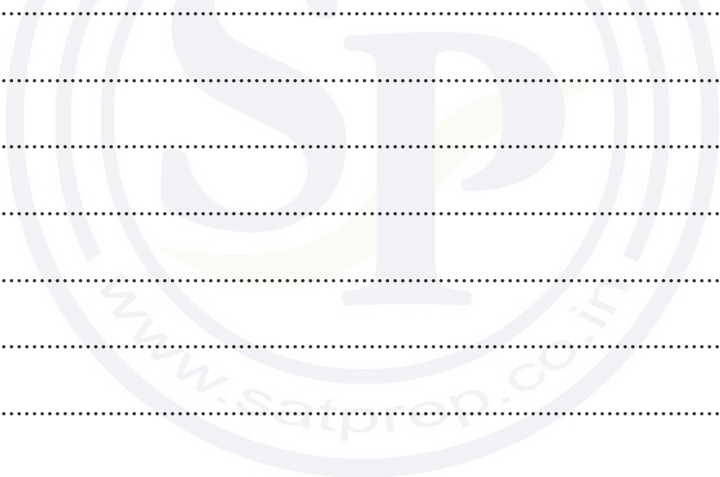
[4]



Two particles, A and B , of masses 3 kg and 5 kg respectively, are connected by a light inextensible string that passes over a fixed smooth pulley. The particles are held with the string taut and its straight parts vertical. Particle A is 1 m above a horizontal plane, and particle B is 2 m above the plane (see diagram).

The particles are released from rest. In the subsequent motion, A does not reach the pulley, and after B reaches the plane it remains in contact with the plane.

- (a) Find the tension in the string and the time taken for B to reach the plane. [6]





[4]



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CANDIDATE
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9709/41

May/June 2024

1 hour 15 minutes

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- 1 A car starts from rest and accelerates at 2 m s^{-2} for 10 s. It then travels at a constant speed for 30 s. The car then uniformly decelerates to rest over a period of 20 s.

(a) Sketch a velocity-time graph for the motion of the car.

[2]



(b) Find the total distance travelled by the car.

[2]

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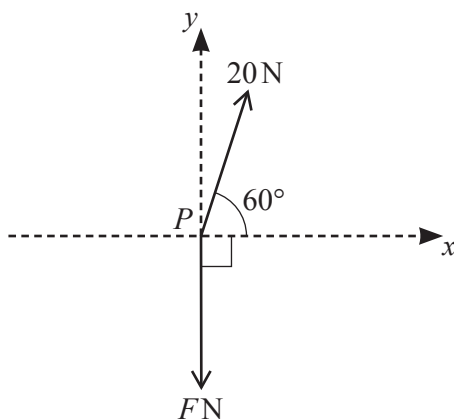
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(a) Given that the resultant force has no component in the y -direction, calculate the value of F . [2]



(b) Given instead that $F = 10$, find the magnitude and direction of the resultant force. [5]

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- 3** A train of mass 180 000 kg ascends a straight hill of length 1.5 km, inclined at an angle of 1.5° to the horizontal. As it ascends the hill, the total work done to overcome the resistance to motion is 12 000 kJ and the speed of the train decreases from 45 ms^{-1} to 40 ms^{-1} .

Find the work done by the engine of the train as it ascends the hill, giving your answer in kJ. [4]

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- 4 A car of mass 1700 kg is pulling a trailer of mass 300 kg along a straight horizontal road. The car and trailer are connected by a light inextensible cable which is parallel to the road. There are constant resistances to motion of 400 N on the car and 150 N on the trailer. The power of the car's engine is 14 000 W.

Find the acceleration of the car and the tension in the cable when the speed is 20 ms^{-1} . [6]

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- (a)** It is given that there is no resistance to the bobsled's motion.

[3]

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- (b)** It is given instead that the coefficient of friction between the bobsled and the slope is 0.03 .

Find the time that it takes for the bobsled to reach the bottom of the slope.

[5]

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- 6** A particle moves in a straight line, starting from a point O . The velocity of the particle at time t s after leaving O is $v \text{ ms}^{-1}$. It is given that $v = kt^{\frac{1}{2}} - 2t - 8$, where k is a positive constant. The maximum velocity of the particle is 4.5 ms^{-1} .

(a) Show that $k = 10$.

[5]

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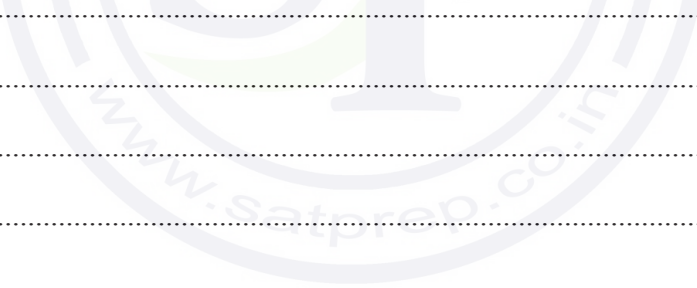
- (b) (i)** Verify that $v = 0$ when $t = 1$ and $t = 16$. [1]

- (ii) Find the distance travelled by the particle in the first 16 s. [5]

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- [illegible]

20 m above the ground it collides with a second particle Q which is moving upwards at 20 m s^{-1} . P is brought to instantaneous rest in the collision. Find the velocity of Q immediately after the collision.

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- 1 A cyclist and bicycle have a total mass of 72 kg. The cyclist rides along a horizontal road against a total resistance force of 28 N.

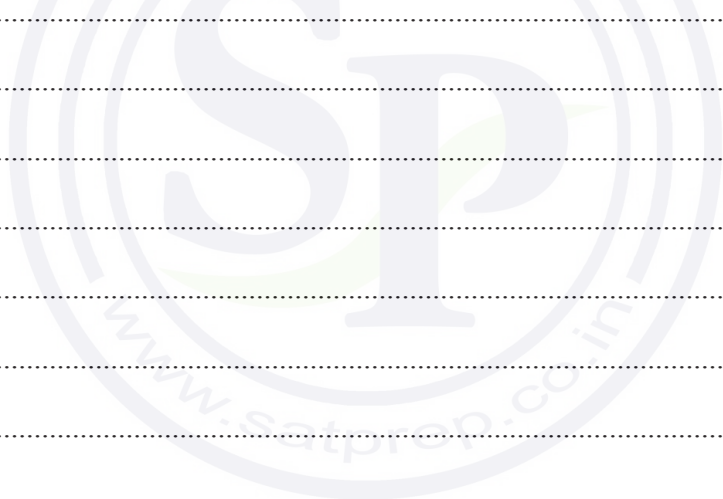
Find the total work done by the cyclist to increase his speed from 8 ms^{-1} to 16 ms^{-1} while travelling a distance of 100 metres. [3]

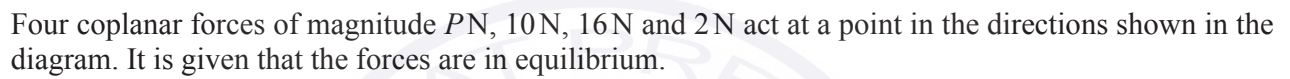
- 2** A particle P moves in a straight line. At time t s after leaving a point O on the line, P has velocity v ms^{-1} , where $v = 44t - 6t^2 - 36$.

- (a)** Find the set of values of t for which the acceleration of the particle is positive. [2]

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- (b)** Find the two values of t at which P returns to O . [3]





[6]



- 4 A car has mass 1400 kg. When the speed of the car is $v \text{ ms}^{-1}$ the magnitude of the resistance to motion is $kv^2 \text{ N}$ where k is a constant.

(a) The car moves at a constant speed of 24 ms^{-1} up a hill inclined at an angle of α to the horizontal where $\sin \alpha = 0.12$. At this speed the magnitude of the resistance to motion is 480 N.

(i) Find the value of k . [1]

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(ii) Find the power of the car's engine. [3]

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(b) The car now moves at a constant speed on a straight level road.

Given that its engine is working at 54 kW, find this speed. [3]

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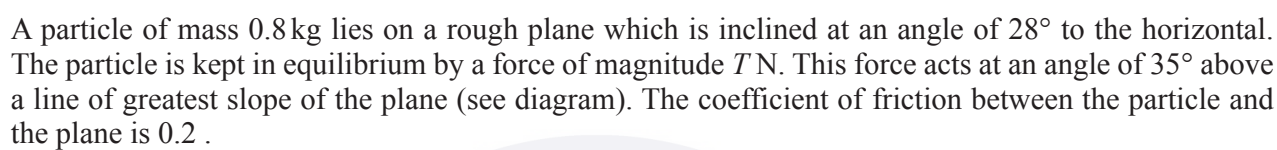
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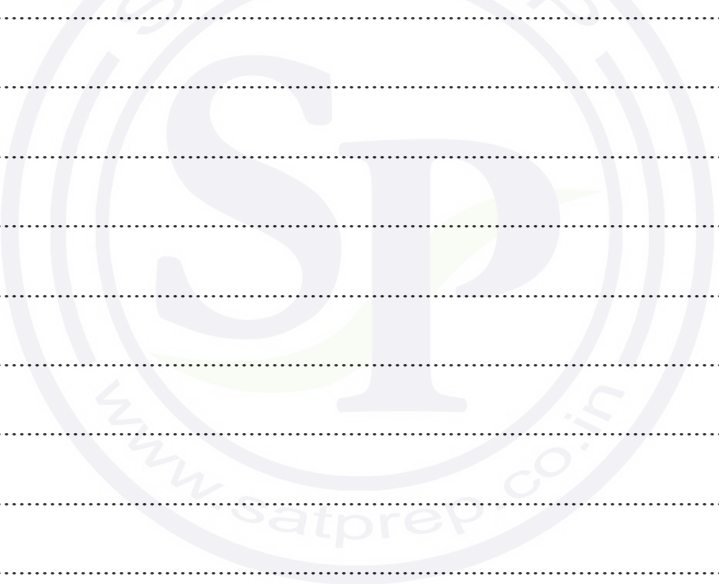
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[8]





- (a)** Show that after the second collision the speed of E is $\frac{15-v}{4} \text{ m s}^{-1}$. [3]



- Use the result from **(a)** to show that $v = 3$. [3]

[illegible]

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(c) It is given that the distance XY is 36 m and the distance YZ is 98 m.

(i) Find the time between the two collisions. [4]

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(ii) Find the time between the instant that A is projected from X and the instant that E reaches Z . [1]

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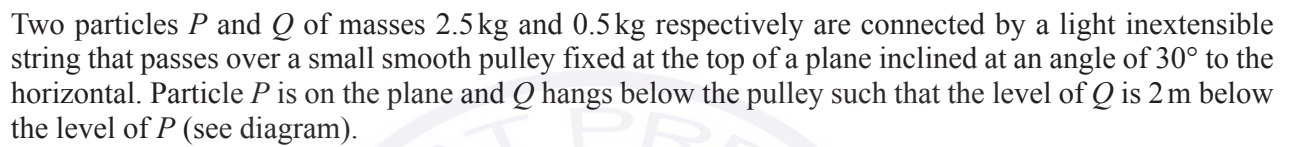
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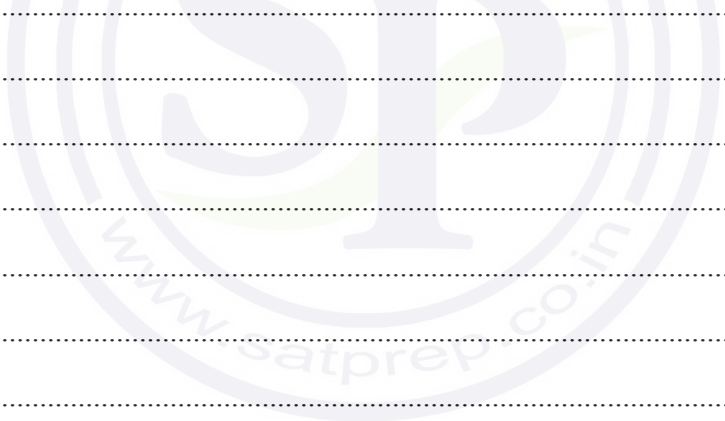
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(a) Find the acceleration of P . [5]

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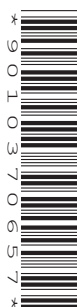
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Cambridge International AS & A Level

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MATHEMATICS
9709/43

Paper 4 Mechanics

May/June 2024
1 hour 15 minutes

You must answer on the question paper.

You will need: List of formulae (MF19)

INSTRUCTIONS

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- You must show all necessary working clearly; no marks will be given for unsupported answers from a calculator.
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- Where a numerical value for the acceleration due to gravity (g) is needed, use 10 ms^{-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 Two particles P and Q of masses 0.2 kg and 0.5 kg respectively are at rest on a smooth horizontal plane. Particle P is projected with a speed 6 m s^{-1} directly towards Q . After P and Q collide, P moves with a speed of 1 m s^{-1} .

Find the two possible speeds of Q after the collision.

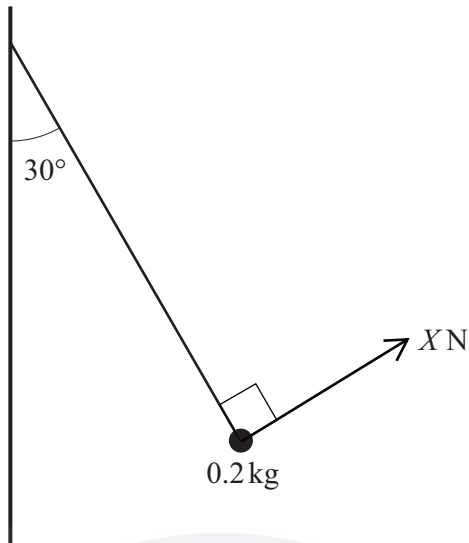
[3]

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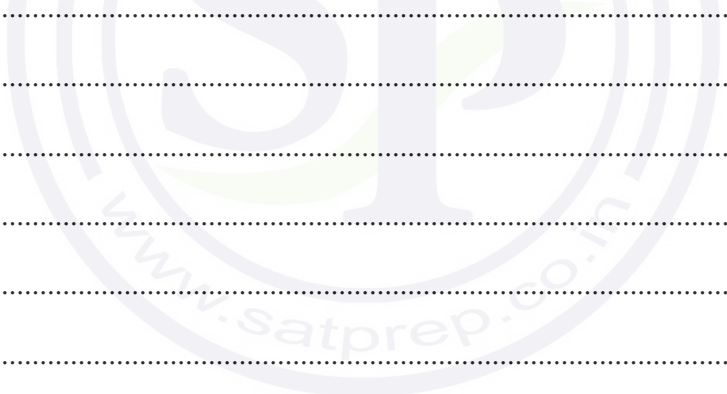
2



A particle of mass 0.2 kg is attached to one end of a light inextensible string. The other end of the string is attached to a fixed point on a vertical wall. The particle is held in equilibrium by a force of magnitude $X\text{ N}$, perpendicular to the string, with the string taut and making an angle of 30° with the wall (see diagram).

Find the tension in the string and the value of X .

[3]



- (a) Find u in terms of a .

[4]

[illegible]

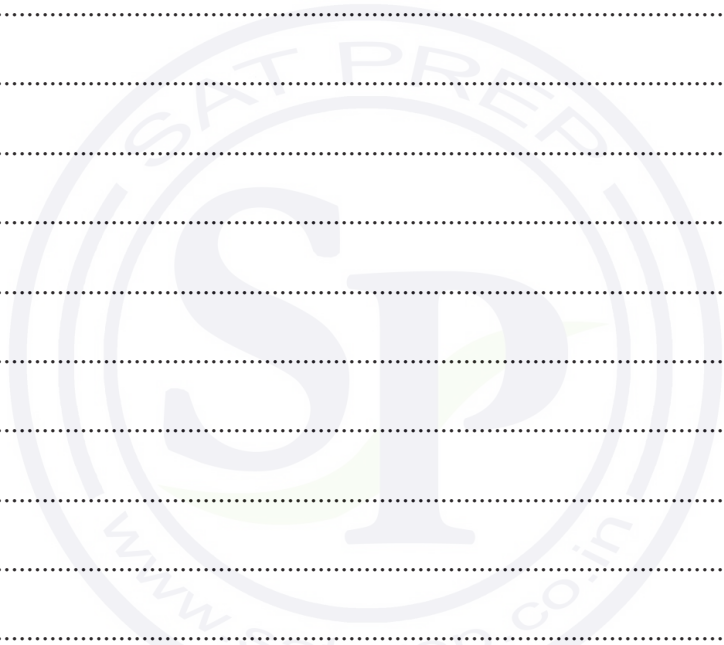
- [2]

[illegible]



- $$v = kt^2 - 4t + 3.$$

(a) Find the value of k . [4]



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- This image shows a full page of white paper with ten horizontal dashed lines, typical of primary school handwriting practice paper. The lines are evenly spaced and extend across the entire width of the page. There is no text or other markings on the paper.

- Find the acceleration of the trailer and the driving force of the van's engine. [4]

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(b) (i) Find the acceleration of the van and the tension in the tow-bar. [5]

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- [illegible]



(c) Given that the speed of the cyclist at the top of the hill is 7.5 m s^{-1} , find her speed at the bottom of the hill. [6]

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7



The diagram shows a track $ABCD$ which lies in a vertical plane. The section AB is a straight line inclined at an angle of 30° to the horizontal and is smooth. The section BC is a horizontal straight line and is rough. The section CD is a straight line inclined at an angle of 30° to the horizontal and is rough. The lengths AB , BC and CD are each 2 m.

A particle is released from rest at A . The coefficient of friction between the particle and both BC and CD is μ . There is no change in the speed of the particle when it passes through either of the points B or C .

- (a)** It is given that $\mu = 0.1$.

Find the distance which the particle has moved up the section CD when its speed is 1 m s^{-1} . [5]





- Find the value of μ and the speed of the particle at the instant that it passes C for the second time. [4]

[illegible]

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CANDIDATE
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9709/42

February/March 2024

1 hour 15 minutes

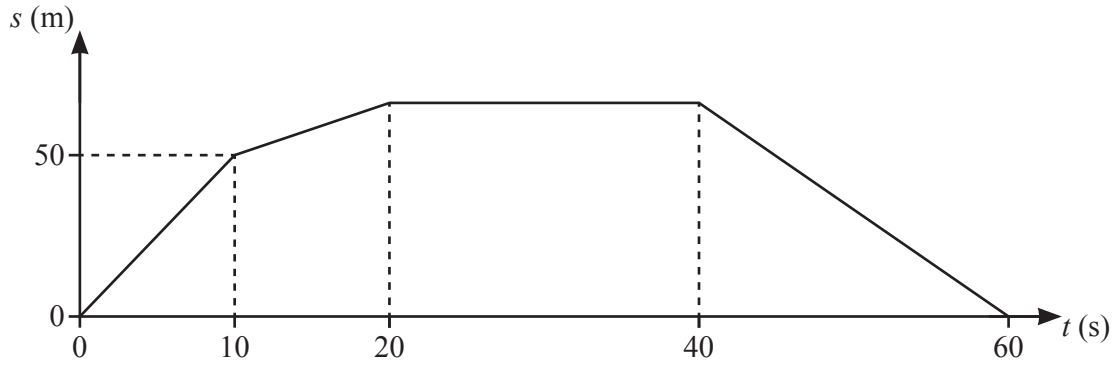
You will need: List of formulae (MF19)

- Answer **all** questions.
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- Write your name, centre number and candidate number in the boxes at the top of the page.
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- The total mark for this paper is 50.
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This document has **12** pages.

1



The displacement of a particle at time t s after leaving a fixed point O is s m. The diagram shows a displacement-time graph which models the motion of the particle. The graph consists of 4 straight line segments. The particle travels 50 m in the first 10 s, then travels at 2 m s^{-1} for a period of 10 s. The particle then comes to rest for a period of 20 s, before returning to its starting point when $t = 60$.

- (a) Find the velocity of the particle during the last 20 s of its motion. [2]

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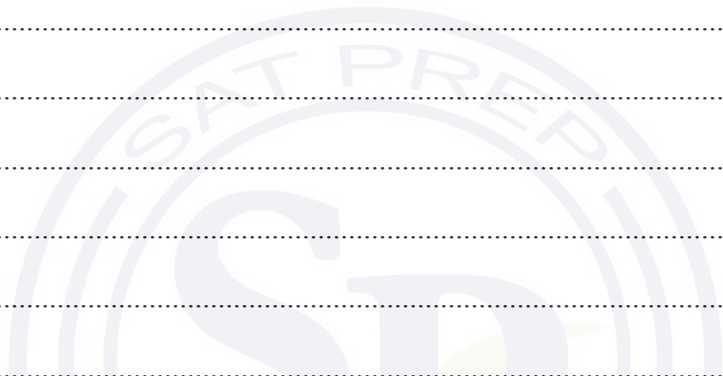
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- (b) Sketch a velocity-time graph for the motion of the particle from $t = 0$ to $t = 60$. [3]

- 2 A particle is projected vertically upwards from horizontal ground. The speed of the particle 2 seconds after it is projected is 5 m s^{-1} and it is travelling **downwards**.

(a) Find the speed of projection of the particle.

[2]



(b) Find the distance travelled by the particle between the two times at which its speed is 10 m s^{-1} . [2]

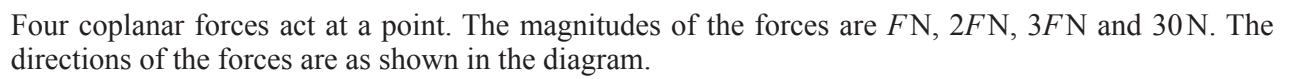
[illegible]

- 3 A crate of mass 600 kg is being pulled up a line of greatest slope of a rough plane at a constant speed of 2 m s^{-1} by a rope attached to a winch. The plane is inclined at an angle of 30° to the horizontal and the rope is parallel to the plane. The winch is working at a constant rate of 8 kW.

Find the coefficient of friction between the crate and the plane.

[5]

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

$$v = t^3 - \frac{9}{2}t^2 + 1 \text{ for } 0 \leq t \leq 4.$$

You may assume that the velocity of the particle is positive for $t < \frac{1}{2}$, is zero at $t = \frac{1}{2}$ and is negative for $t > \frac{1}{2}$.

- (a)** Find the distance travelled between $t = 0$ and $t = \frac{1}{2}$. [4]

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- (b)** Find the positive value of t at which the acceleration is zero. Hence find the total distance travelled between $t = 0$ and this instant. [4]

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- 6 A car of mass 1800 kg is towing a trailer of mass 300 kg up a straight road inclined at an angle α to the horizontal, where $\sin \alpha = 0.05$. The car and trailer are connected by a tow-bar which is light and rigid and is parallel to the road. There is a resistance force of 800 N acting on the car and a resistance force of F N acting on the trailer. The driving force of the car's engine is 3000 N.

- (a) It is given that $F = 100$.

Find the acceleration of the car and the tension in the tow-bar.

[5]

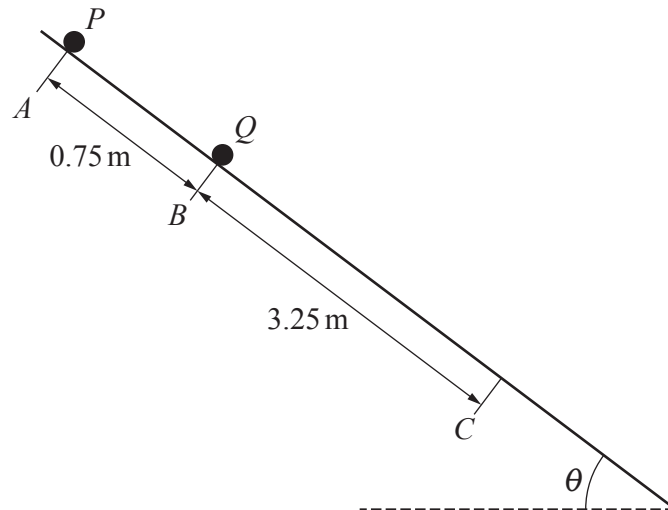
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- (b)** It is given instead that the total work done against F in moving a distance of 50 m up the road is 6000 J. The speed of the car at the start of the 50 m is 20 m s^{-1} .

Use an energy method to find the speed of the car at the end of the 50 m.

[5]

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The diagram shows two particles P and Q which lie on a line of greatest slope of a plane ABC . Particles P and Q are each of mass m kg. The plane is inclined at an angle θ to the horizontal, where $\sin \theta = 0.6$. The length of AB is 0.75 m and the length of BC is 3.25 m. The section AB of the plane is smooth and the section BC is rough. The coefficient of friction between each particle and the section BC is 0.25 . Particle P is released from rest at A . At the same instant, particle Q is released from rest at B .

- (a) Verify that particle P reaches B 0.5 s after it is released, with speed 3 m s^{-1} . [3]

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- (b) Find the time that it takes from the instant the two particles are released until they collide. [4]

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The two particles coalesce when they collide. The coefficient of friction between the combined particle and the plane is still 0.25 .

- (c) Find the time that it takes from the instant the particles collide until the combined particle reaches C . [5]

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

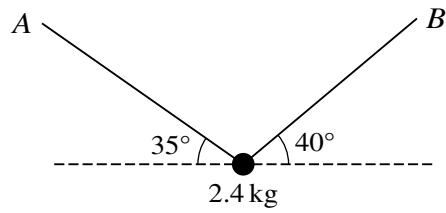
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- The number of marks for each question or part question is shown in brackets [].

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

[illegible]



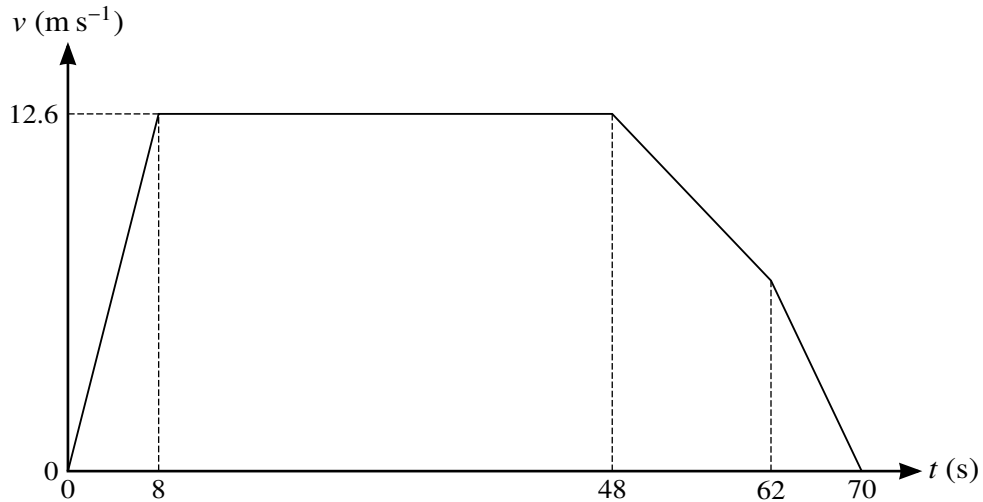
A particle of mass 2.4 kg is held in equilibrium by two light inextensible strings, one of which is attached to point A and the other attached to point B . The strings make angles of 35° and 40° with the horizontal (see diagram).

Find the tension in each of the two strings.

[5]

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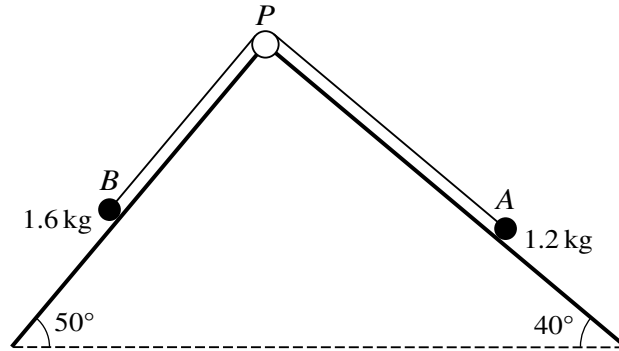
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The coefficient of friction between R and the plane is 0.4.

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

[2]



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]



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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- Find this constant speed. [4]

Find this constant speed.

[4]

[illegible]

- $$\begin{aligned} v &= 7.2t^2 & 0 \leq t \leq 2, \\ v &= 30.6 - 0.9t & 2 \leq t \leq 8, \\ v &= \frac{1600}{t^2} + kt & 8 \leq t, \end{aligned}$$

Find the distance OX . [9]

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[illegible]



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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.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
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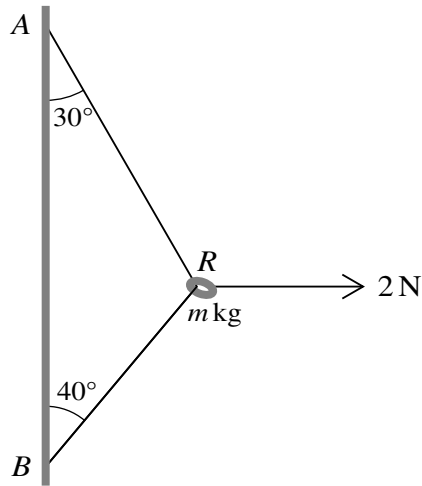
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- Find the work done against the resistance to motion of the block. [4]

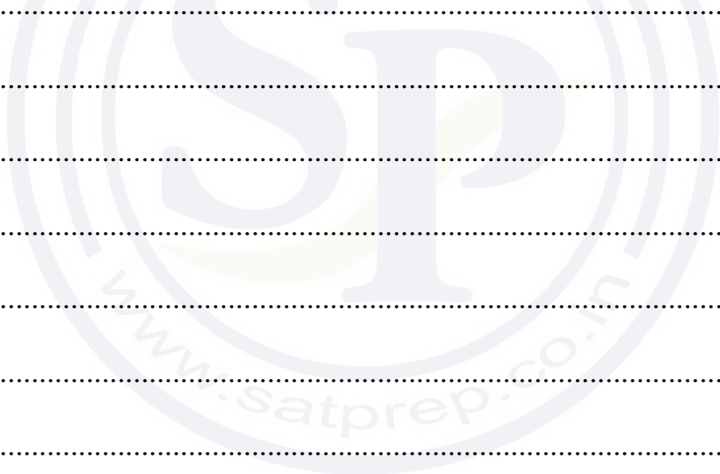
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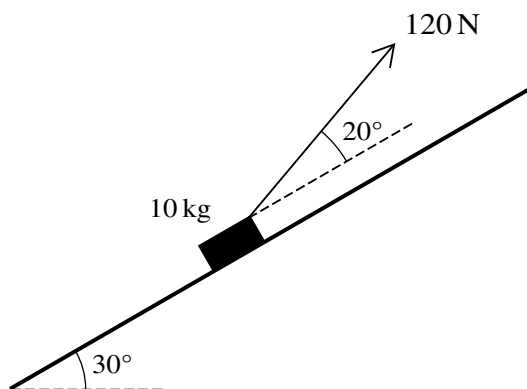


The diagram shows a smooth ring R , of mass m kg, threaded on a light inextensible string. A horizontal force of magnitude 2 N acts on R . The ends of the string are attached to fixed points A and B on a vertical wall. The part AR of the string makes an angle of 30° with the vertical, the part BR makes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

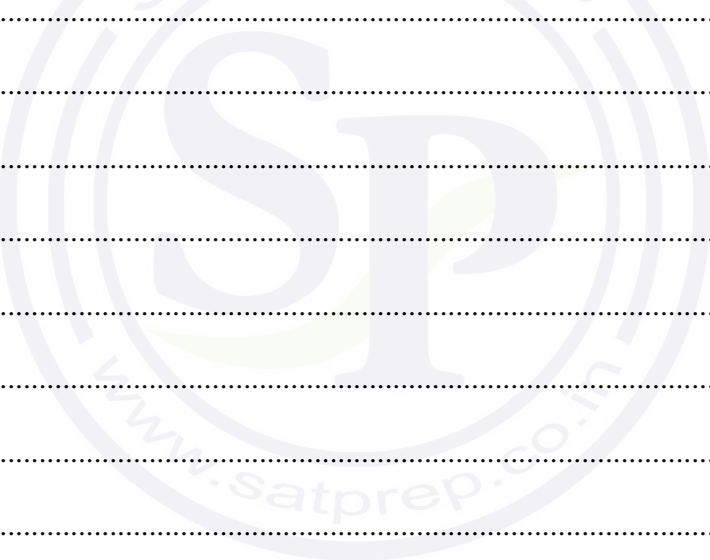
[5]





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]



- 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]

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- 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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- 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]

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MATHEMATICS

9709/43

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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- The number of marks for each question or part question is shown in brackets [].

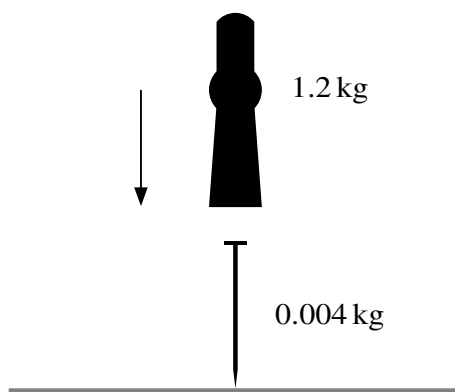
This document has **12** pages.

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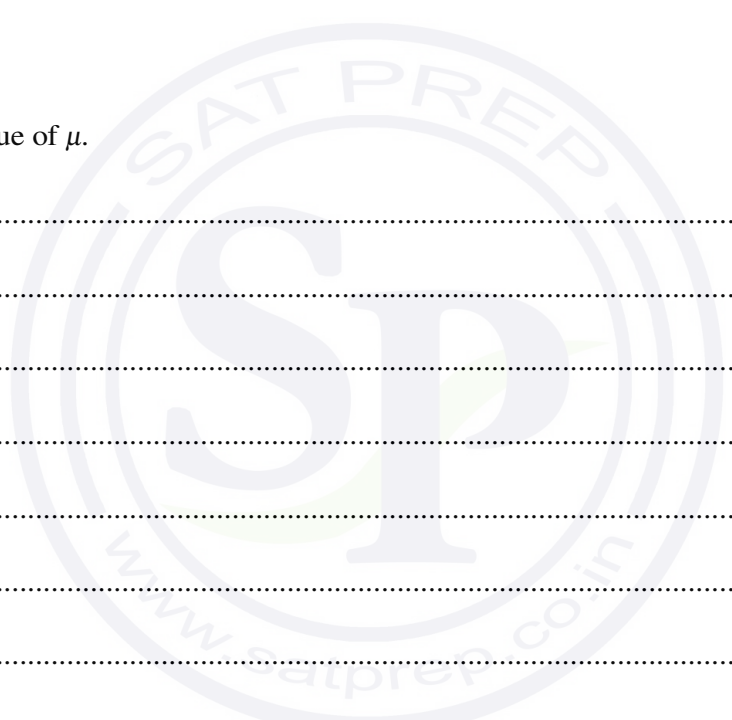
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- 3** A block of mass 8 kg slides down a rough plane inclined at 30° to the horizontal, starting from rest. The coefficient of friction between the block and the plane is μ . The block accelerates uniformly down the plane at 2.4 m s^{-2} .

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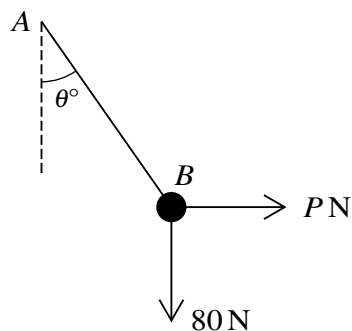
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The car now moves down a hill inclined at an angle of θ to the horizontal, where $\sin \theta = 0.09$. The engine of the car is working at a constant rate of 12 kW. The speed of the car is 24 m s^{-1} at the top of the hill. Ten seconds later the car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

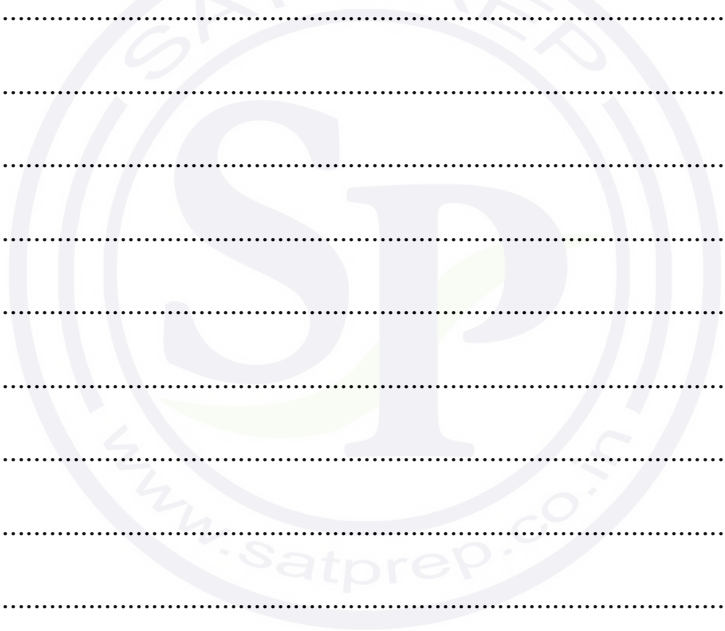
- (b) Given that the resistance is not constant, use an energy method to find the total work done against the resistance during the ten seconds. [5]

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

[4]



- (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]

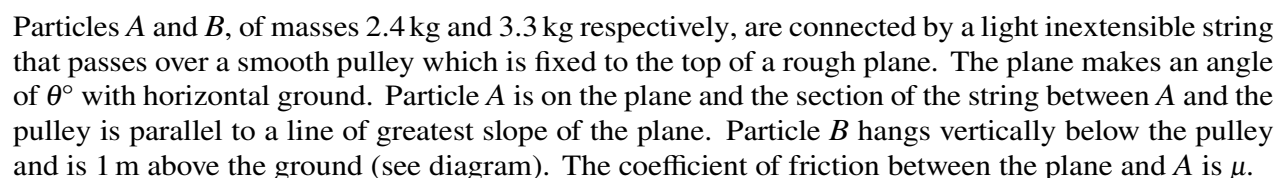
[illegible]

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

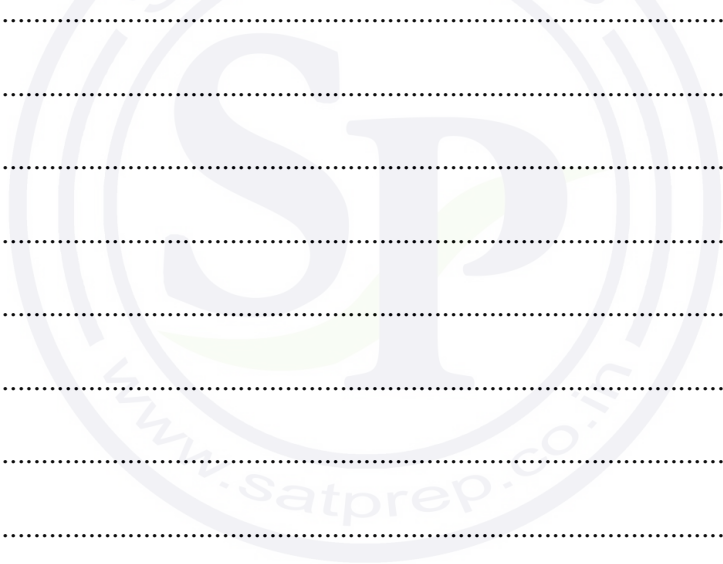
(a) Find the values of t when the particle is at instantaneous rest.

[4]

[illegible]



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



- 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]



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MATHEMATICS

9709/41

Paper 4 Mechanics

May/June 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.
- 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 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 Two particles P and Q , of masses m kg and 0.3 kg respectively, are at rest on a smooth horizontal plane. P is projected at a speed of 5 m s^{-1} directly towards Q . After P and Q collide, P moves with a speed of 2 m s^{-1} in the same direction as it was originally moving.

(a) Find, in terms of m , the speed of Q after the collision. [2]

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After this collision, Q moves directly towards a third particle R , of mass 0.6 kg, which is at rest on the plane. Q is brought to rest in the collision with R , and R begins to move with a speed of 1.5 m s^{-1} .

(b) Find the value of m . [2]

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the ground again, it bounces vertically upwards. At the
 .2 J of energy.

the between the first and second instants at which P hits the

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- 3** A particle moves in a straight line starting from rest. The displacement s m of the particle from a fixed point O on the line at time t s is given by

$$s = t^{\frac{5}{2}} - \frac{15}{4}t^{\frac{3}{2}} + 6.$$

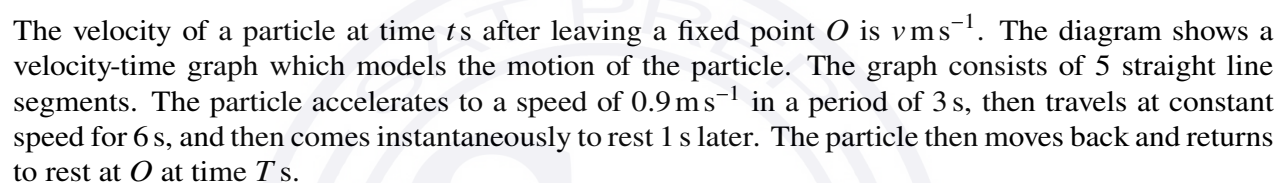
Find the value of s when the particle is again at rest.

[4]

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- (b) Given that $T = 12$, find the minimum velocity of the particle.

[2]

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- (c) Given instead that the greatest speed of the particle is 3 m s^{-1} , find the value of T and hence find the average speed of the particle for the whole of the motion.

[4]

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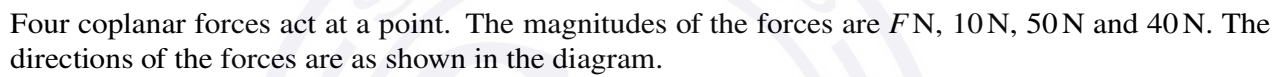
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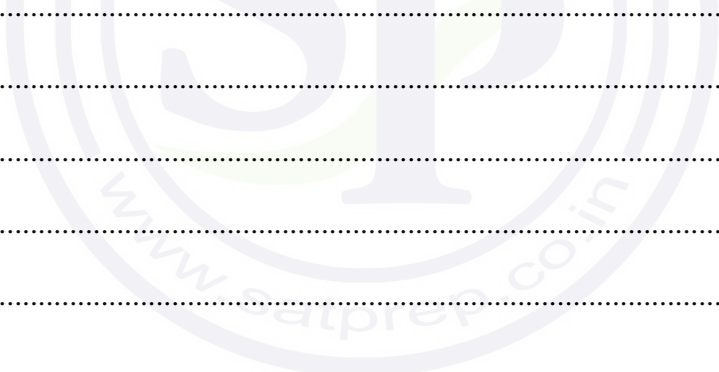
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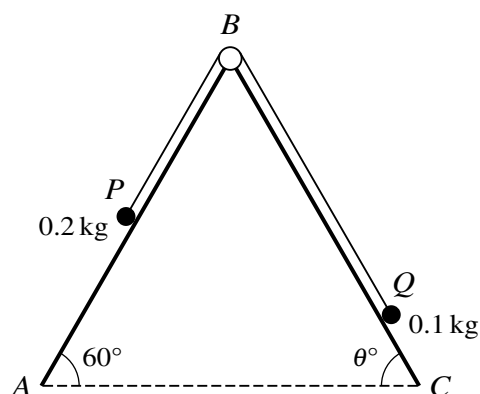
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- (b) Given instead that $F = 10\sqrt{2}$ and $\theta = 45$, find the direction and the exact magnitude the resultant force. [3]

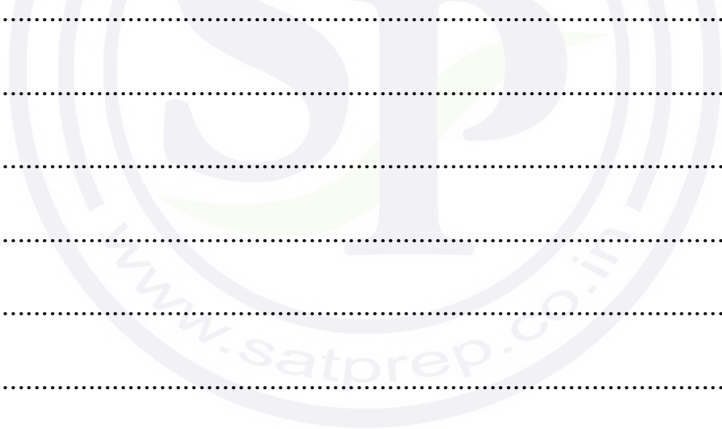


Two particles P and Q , of masses 0.2 kg and 0.1 kg respectively, are attached to the ends of a light inextensible string. The string passes over a fixed smooth pulley at B which is attached to two inclined planes. Particle P lies on a smooth plane AB which is inclined at 60° to the horizontal. Particle Q lies on a plane BC which is inclined at an angle of θ° to the horizontal. The string is taut and the particles can move on lines of greatest slope of the two planes (see diagram).

- (a) It is given that $\theta = 60^\circ$, the plane BC is rough and the coefficient of friction between Q and the plane BC is 0.7. The particles are released from rest.

Determine whether the particles move.

[4]



- Find the magnitude of the acceleration of P as it moves on the plane, and find the value of θ . [4]

[illegible]

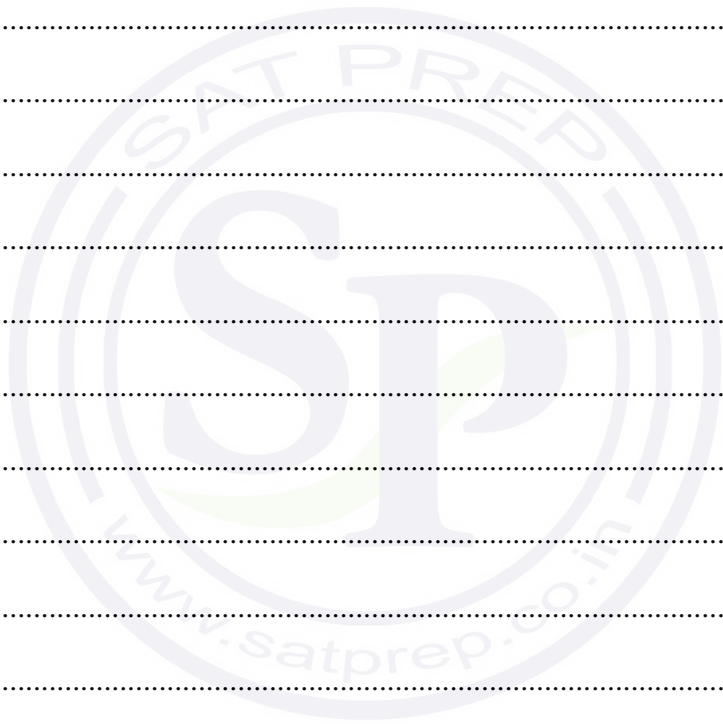
- (a) Find the acceleration of the car at an instant when its speed is 20 m s^{-1} . [3]

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- (b)** Assuming that the power and the resistance forces remain unchanged, find the steady speed at which the car can travel. [2]

[illegible]

(c) Given that the car is travelling at a speed of 20 m s^{-1} at the bottom of the hill, find its speed at the top of the hill. [6]

A large, light gray watermark logo is centered on the page. It consists of a circular emblem with the letters 'SAT PREP' at the top and 'www.satprep.co.in' at the bottom. In the center of the circle are the large letters 'SP' with a green leaf-like graphic behind them. The background of the page is white with horizontal dotted lines.

A large, light purple circular watermark is centered on the page. It contains the text "SAT PREP" at the top, a stylized "SP" in the middle, and "www.satprep.co.in" at the bottom.



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MATHEMATICS

9709/42

Paper 4 Mechanics

May/June 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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- 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 particle of mass 1.6 kg is dropped from a height of 9 m above horizontal ground. The speed of the particle at the instant before hitting the ground is 12 m s^{-1} .

Find the work done against air resistance.

[3]

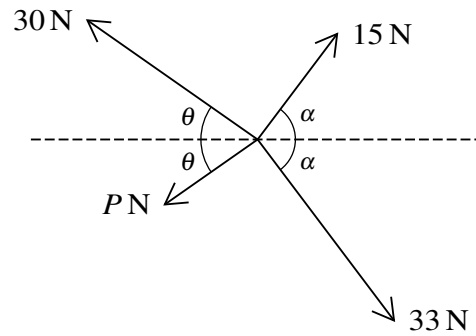
[illegible]

- (a) Find the value of v . [2]

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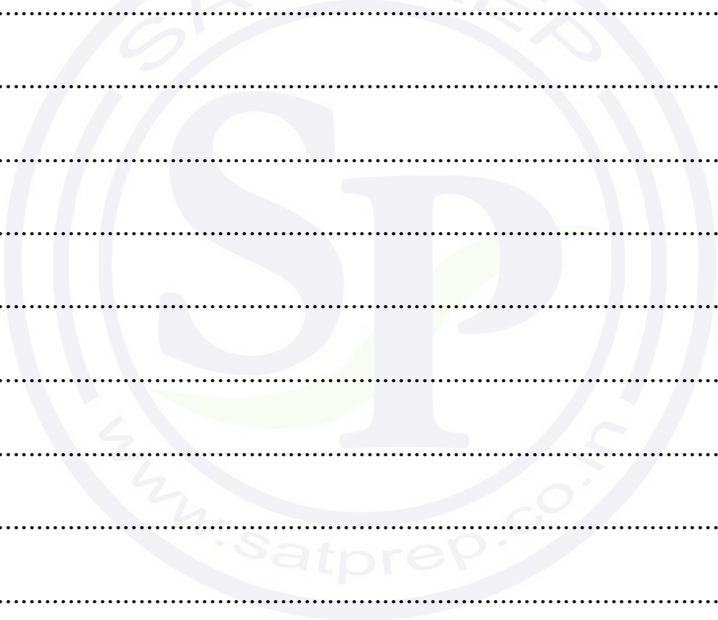
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Coplanar forces of magnitudes 30 N, 15 N, 33 N and P N act at a point in the directions shown in the diagram, where $\tan \alpha = \frac{4}{3}$. The system is in equilibrium.

- (a) Show that $\left(\frac{14.4}{30-P}\right)^2 + \left(\frac{28.8}{P+30}\right)^2 = 1$. [4]

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(a) Initially the road is horizontal and he runs at a constant speed of 3 m s^{-1} . The athlete produces a constant power of 60 W .

Find the resistive force which acts on the athlete. [1]

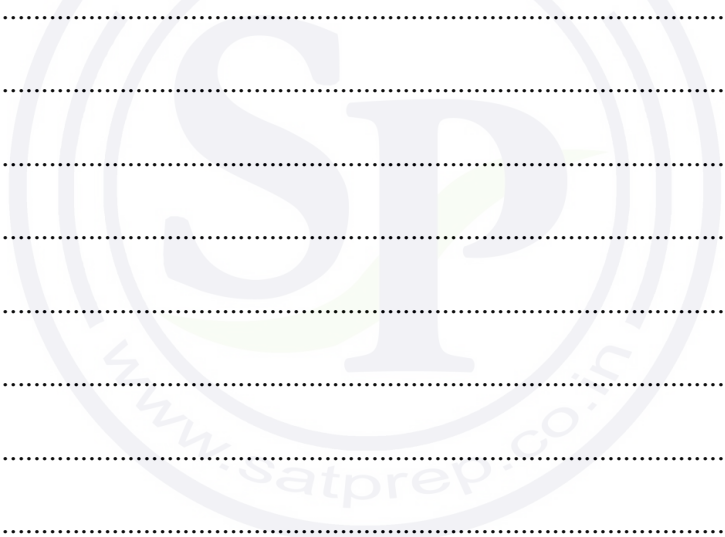
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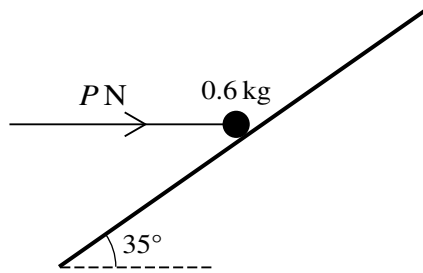
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(b) The athlete then runs up a 150 m section of the road which is inclined at 0.8° to the horizontal. The speed of the athlete at the start of this section of road is 3 ms^{-1} and he now produces a constant driving force of 24 N. The total resistive force which acts on the athlete along this section of road has constant magnitude 13 N.

Use an energy method to find the speed of the athlete at the end of the 150 m section of road. [6]





A particle of mass 0.6 kg is placed on a rough plane which is inclined at an angle of 35° to the horizontal. The particle is kept in equilibrium by a horizontal force of magnitude $P\text{ N}$ acting in a vertical plane containing a line of greatest slope (see diagram). The coefficient of friction between the particle and plane is 0.4 .

Find the least possible value of P .

[6]

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- 6** A particle P starts at rest and moves in a straight line from a point O . At time t s after leaving O , the velocity of P , $v \text{ m s}^{-1}$, is given by $v = bt + ct^{\frac{3}{2}}$, where b and c are constants. P has velocity 8 m s^{-1} when $t = 4$ and has velocity 13.5 m s^{-1} when $t = 9$.

(a) Show that $b = 3$ and $c = -0.5$. [1]

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(b) Find the acceleration of P when $t = 1$. [2]

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(c) Find the positive value of t when P is at instantaneous rest and find the distance of P from O at this instant. [5]

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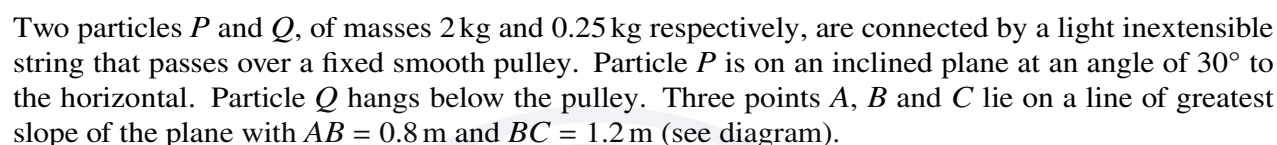
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(d) Find the speed of P at the instant it returns to O .

[3]



Particle P is released from rest at A with the string taut and slides down the plane. During the motion of P from A to C , Q does not reach the pulley. The part of the plane from A to B is rough, with coefficient of friction 0.3 between the plane and P . The part of the plane from B to C is smooth.

- (a) (i) Find the acceleration of P between A and B . [4]

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[5]

[illegible]

[4]



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MATHEMATICS

9709/43

Paper 4 Mechanics

May/June 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.
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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.

- Find the two possible values of the speed of P after the collision. [3]

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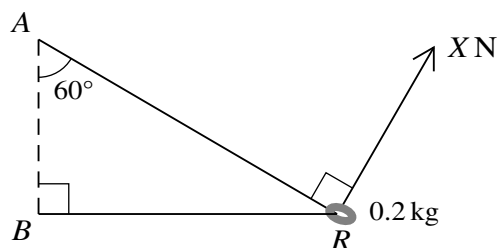
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- 2 A car of mass 1500 kg is towing a trailer of mass m kg along a straight horizontal road. The car and the trailer are connected by a tow-bar which is horizontal, light and rigid. There is a resistance force of F N on the car and a resistance force of 200 N on the trailer. The driving force of the car's engine is 3200 N, the acceleration of the car is 1.25 m s^{-2} and the tension in the tow-bar is 300 N.

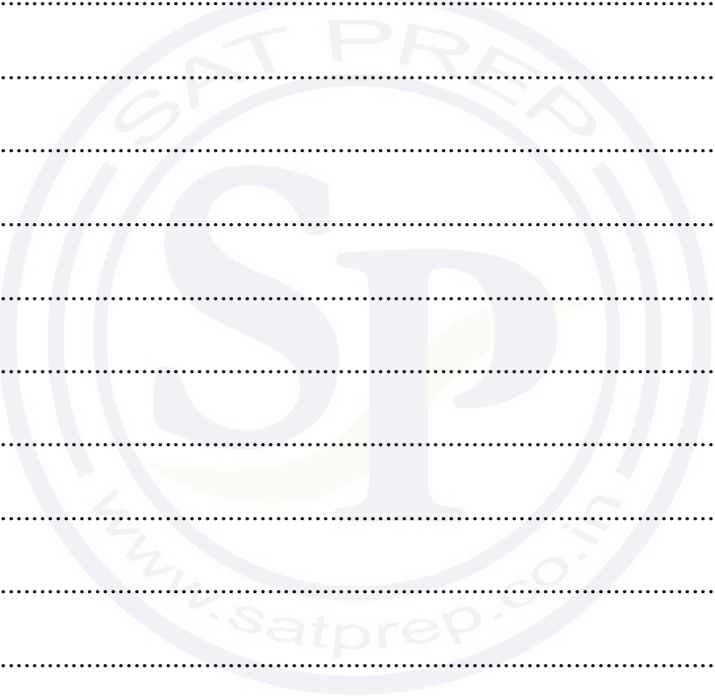
Find the value of m and the value of F .

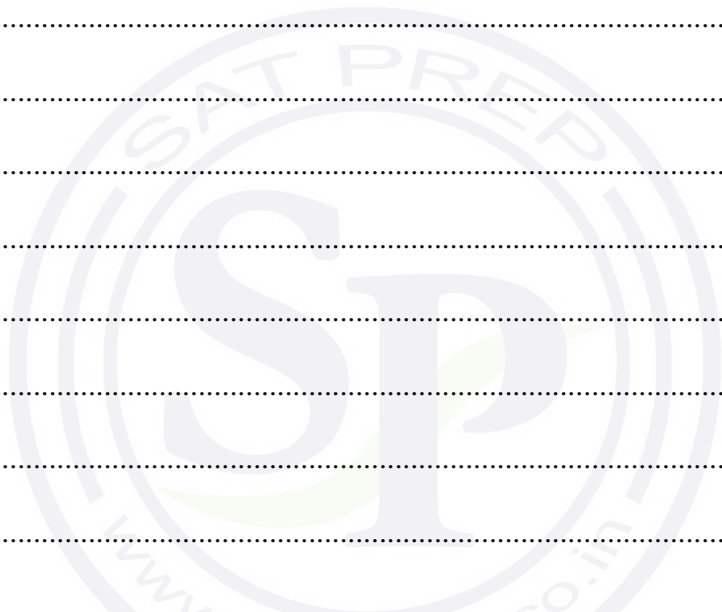
[4]

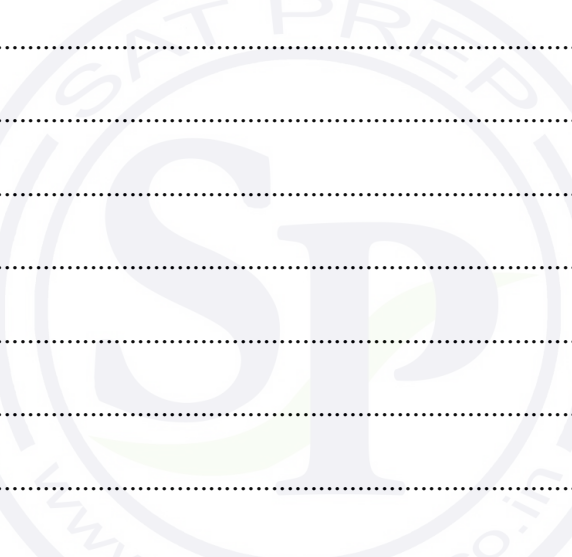
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Calculate the tension in the string and the value of X . [5]

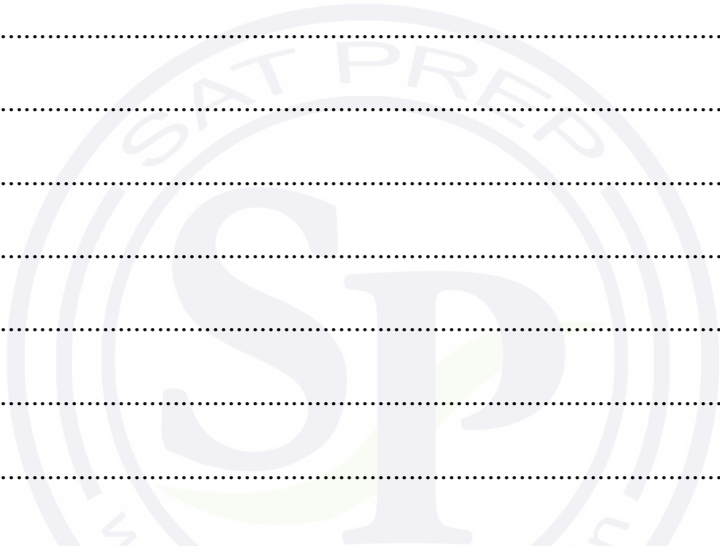
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- A large, light gray watermark logo is centered on the page. It consists of a circular emblem with the letters 'SAT PREP' curved along the top inner edge. In the center of the circle are the large, stylized letters 'SP'. Below the 'SP' is a green leaf-like graphic. Along the bottom inner edge of the circle, the text 'www.satprep.co.in' is visible.

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- (a) Show that $k = 0.1$. [3]



(b) Show that the distance travelled in the first 9 seconds is one tenth of the distance travelled between $t = 9$ and $t = 18$. [4]

[illegible]

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- 6** An elevator is pulled vertically upwards by a cable. The elevator accelerates at 0.4 m s^{-2} for 5 s, then travels at constant speed for 25 s. The elevator then decelerates at 0.2 m s^{-2} until it comes to rest.
- (a) Find the greatest speed of the elevator and hence draw a velocity-time graph for the motion of the elevator. [3]

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- (b) Find the total distance travelled by the elevator. [2]

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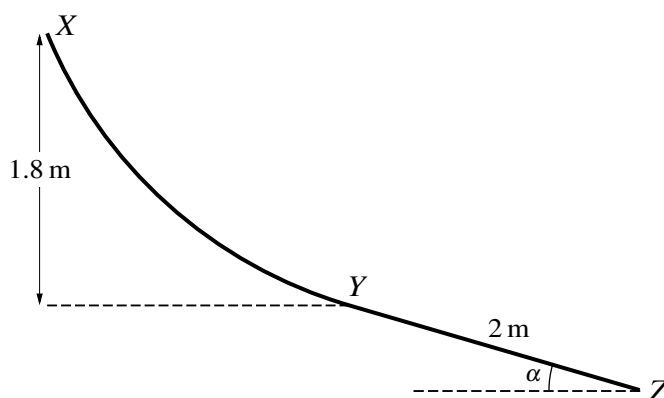
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(c) Given that the tension in the cable when the elevator is decelerating is 12250 N, find the value of m . [3]

[illegible]

- greatest magnitude of the force exerted on the crate by the floor

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The diagram shows the vertical cross-section XYZ of a rough slide. The section YZ is a straight line of length 2 m inclined at an angle of α to the horizontal, where $\sin \alpha = 0.28$. The section YZ is tangential to the curved section XY at Y , and X is 1.8 m above the level of Y . A child of mass 25 kg slides down the slide, starting from rest at X . The work done by the child against the resistance force in moving from X to Y is 50 J.

- (a) Find the speed of the child at Y . [4]

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(b) Use an energy method to find the coefficient of friction between the child and YZ , giving your answer as a fraction in its simplest form. [6]

[illegible]

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MATHEMATICS

9709/42

Paper 4 Mechanics

February/March 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.
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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 [].

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

- (a) Find the time that it takes for the crate to move a distance of 15 m. [2]

This image shows a blank sheet of white paper with horizontal ruling lines. The lines are evenly spaced and extend across the width of the page. At the bottom center, there is a faint, light blue watermark logo. The logo consists of a circular emblem containing a stylized letter 'C' or 'G'. Above the emblem, the words "SAT PREP" are written in a semi-circle. Below the emblem, there is some smaller, less legible text. The overall appearance is that of a clean, unused piece of stationery.

(b) Find the time taken, after the rope breaks, for the crate to come to rest. [3]

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2 A particle P is projected vertically upwards from horizontal ground with speed 15 m s^{-1} .

- (a) Find the speed of P when it is 10 m above the ground. [2]

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At the same instant that P is projected, a second particle Q is dropped from a height of 18 m above the ground in the same vertical line as P .

- (b) Find the height above the ground at which the two particles collide. [3]

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- 3** A particle moves in a straight line starting from rest from a point O . The acceleration of the particle at time t s after leaving O is $a \text{ m s}^{-2}$, where $a = 4t^{\frac{1}{2}}$.

(a) Find the speed of the particle when $t = 9$. [2]

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(b) Find the time after leaving O at which the speed (in metres per second) and the distance travelled (in metres) are numerically equal. [3]

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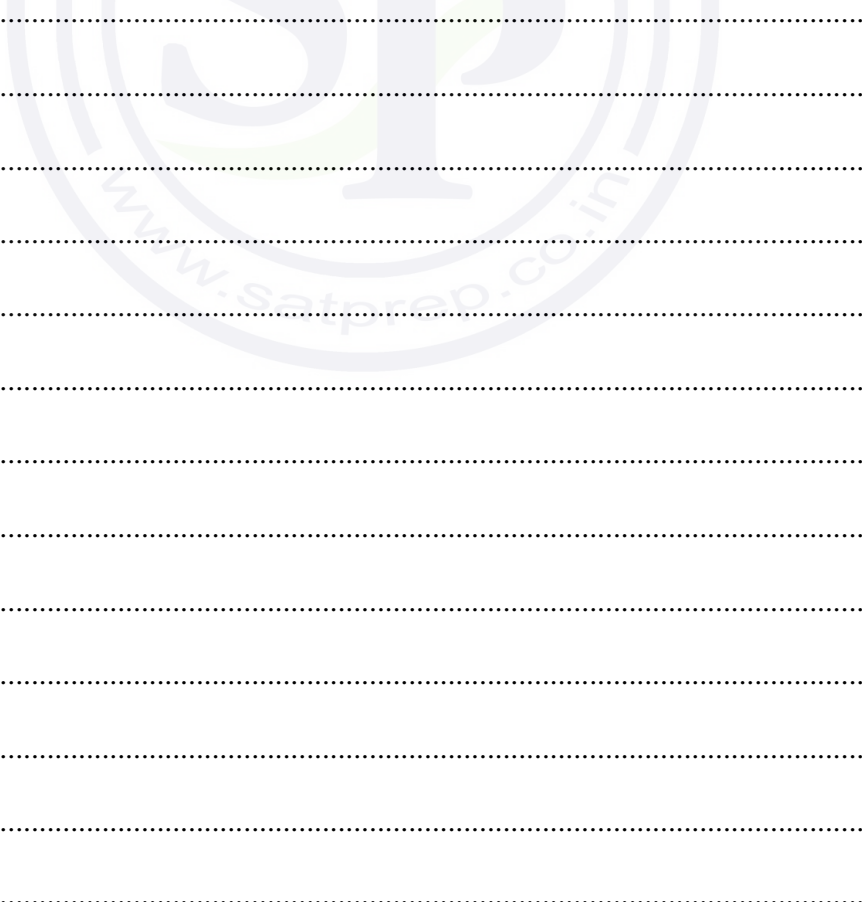
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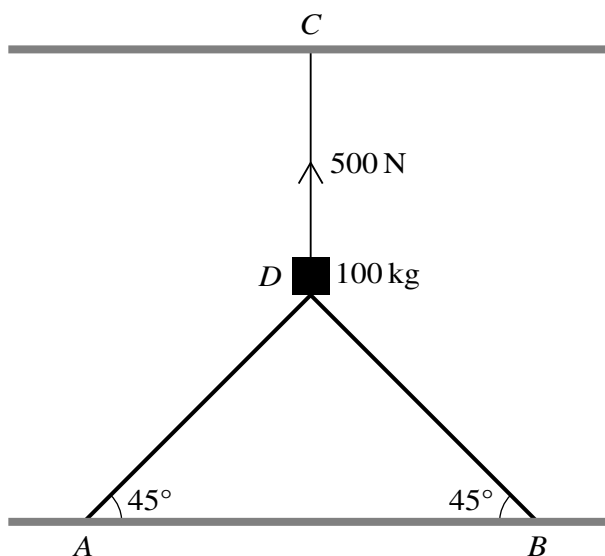
- (a) State the tension in the coupling. [1]

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- [illegible]

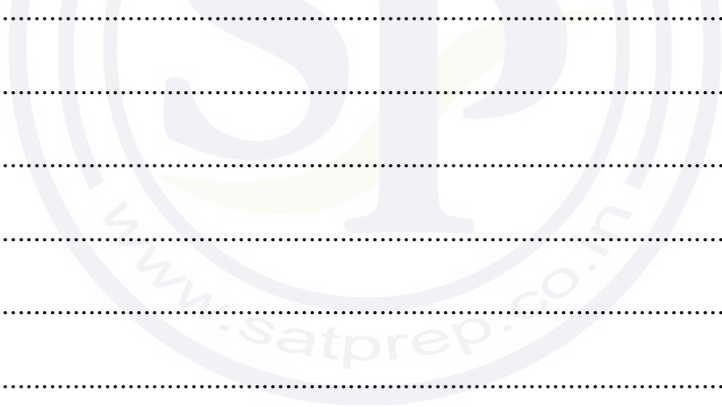
(c) Find the magnitude of the tension in the coupling at the instant that the locomotive begins to accelerate. [5]

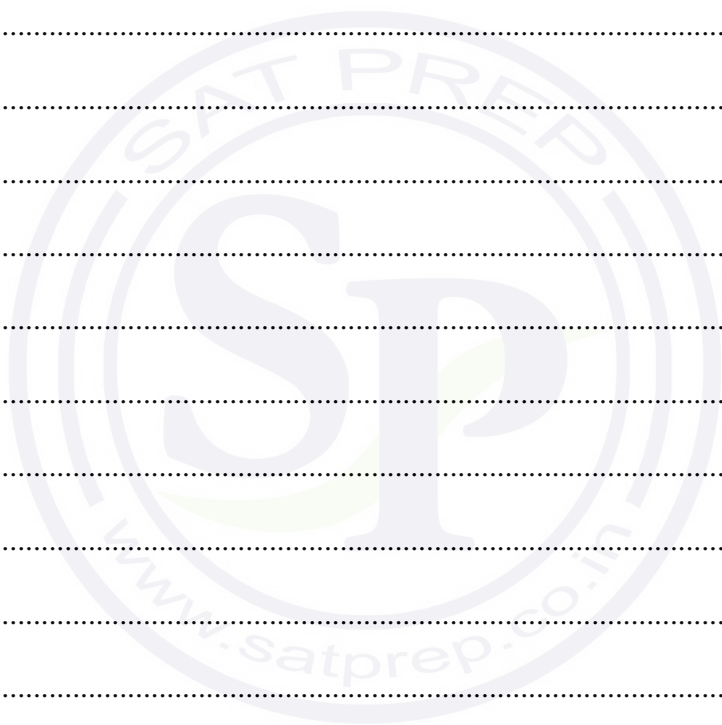


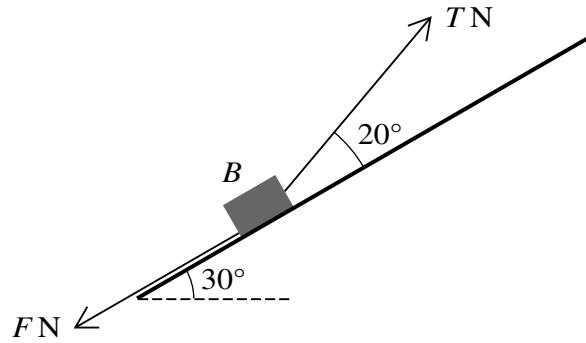


The diagram shows a block D of mass 100 kg supported by two sloping struts AD and BD , each attached at an angle of 45° to fixed points A and B respectively on a horizontal floor. The block is also held in place by a vertical rope CD attached to a fixed point C on a horizontal ceiling. The tension in the rope CD is 500 N and the block rests in equilibrium.

- (a) Find the magnitude of the force in each of the struts AD and BD . [3]



- 



A block B , of mass 2 kg , lies on a rough inclined plane sloping at 30° to the horizontal. A light rope, inclined at an angle of 20° above a line of greatest slope, is attached to B . The tension in the rope is $T\text{ N}$. There is a friction force of $F\text{ N}$ acting on B (see diagram). The coefficient of friction between B and the plane is μ .

(a) It is given that $F = 5$ and that the acceleration of B up the plane is 1.2 m s^{-2} .

(i) Find the value of T .

[3]

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(ii) Find the value of μ .

[3]

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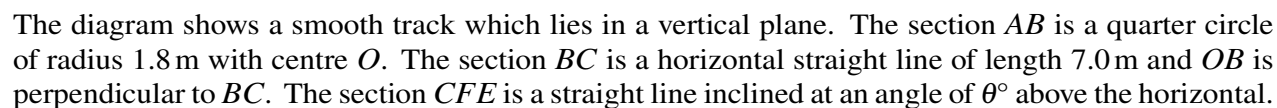
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[3]

[illegible]



(a) Show that the speed of Q immediately after the collision is 10 m s^{-1} . [4]

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(b) Given that the distance CF is 0.4 m, find the value of θ . [4]

[illegible]

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[5]

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[illegible]





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MATHEMATICS

9709/41

Paper 4 Mechanics

October/November 2022

1 hour 15 minutes

You must answer on the question paper.

You will need: List of formulae (MF19)

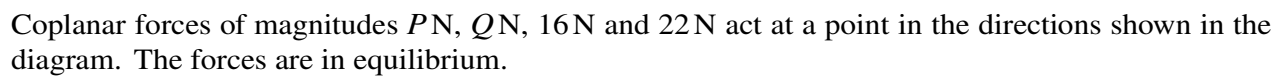
INSTRUCTIONS

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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 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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[5]

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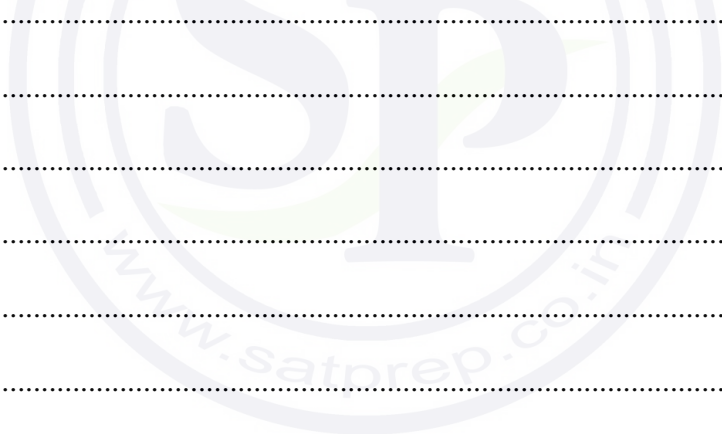
- Find the loss of kinetic energy of the system due to the collision. [5]

[illegible]

- (a)** The car is moving along a straight level road at a constant speed of 28 m s^{-1} .

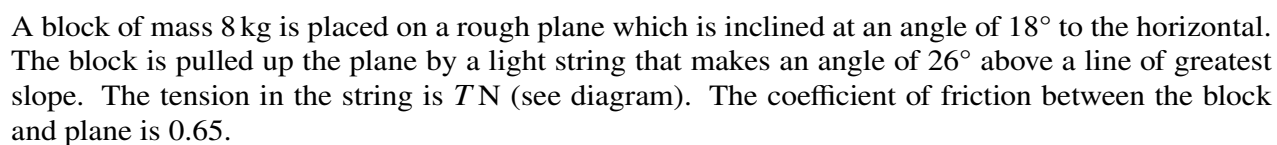
[2]

- [3]



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[4]



- Find T .

[7]

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(b) The block is initially at rest.

Find the distance travelled by the block during the fourth second of motion.

[2]

- 5 A particle P moves on the x -axis from the origin O with an initial velocity of -20 m s^{-1} . The acceleration $a \text{ m s}^{-2}$ at time $t \text{ s}$ after leaving O is given by $a = 12 - 2t$.

(a) Sketch a velocity-time graph for $0 \leq t \leq 12$, indicating the times when P is at rest. [5]

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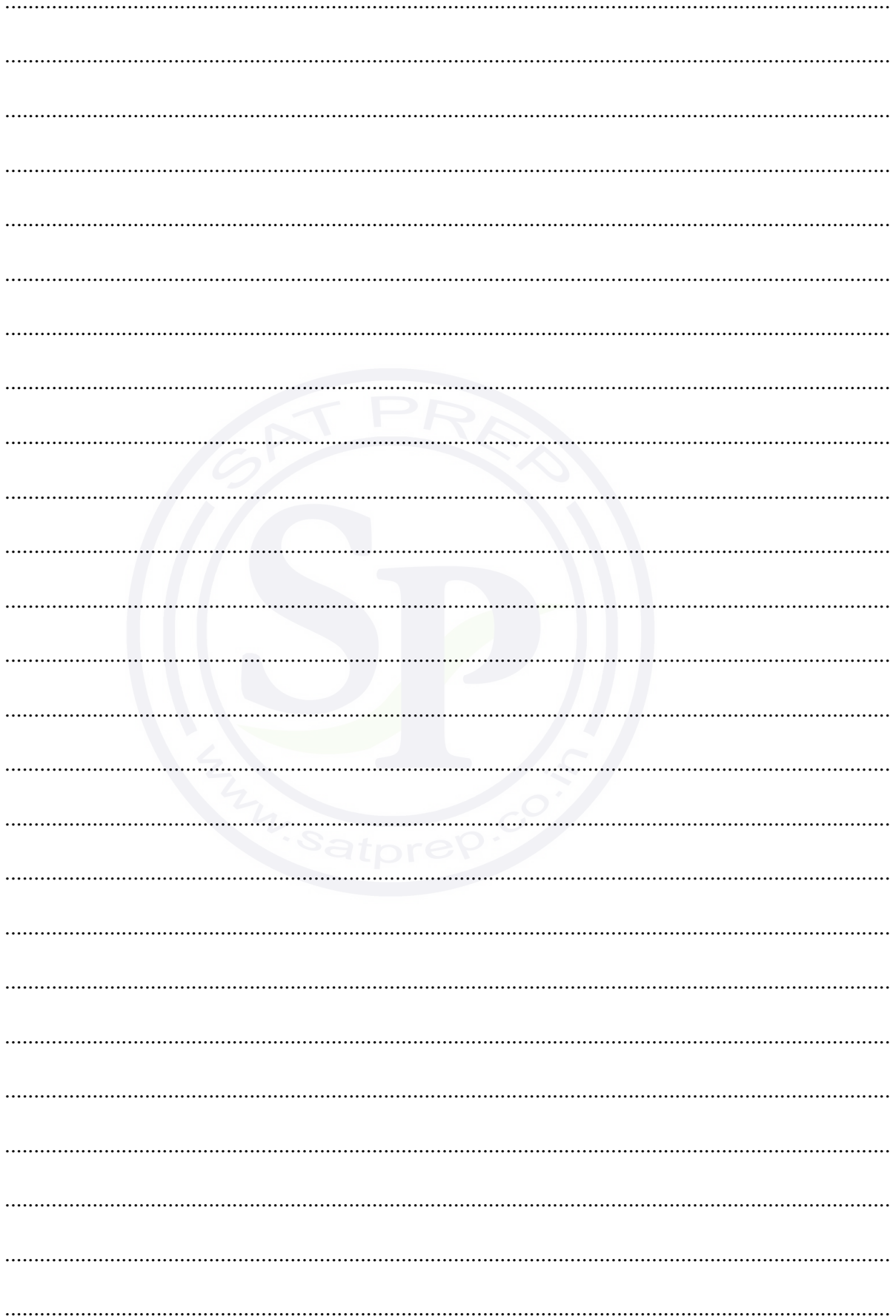
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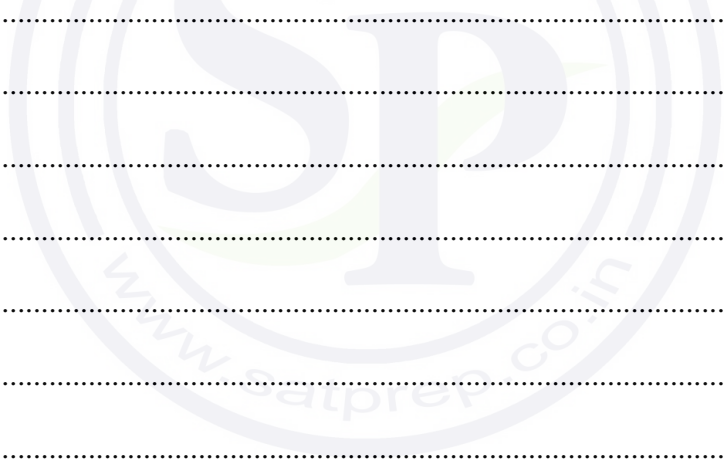
[5]





(a) It is given that the plane is rough and the particles are in limiting equilibrium.

[6]

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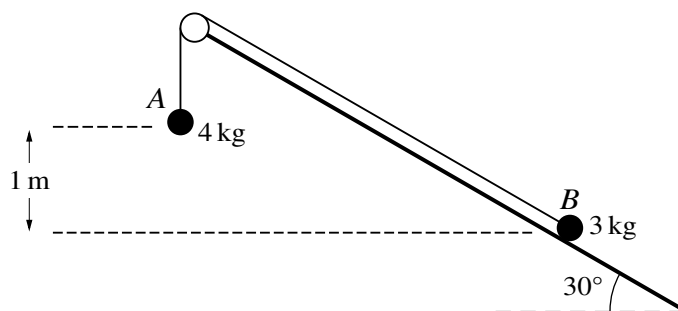


Fig. 6.2

Use an energy method to find the speed of the particles at the instant when the particles are at the same horizontal level. [6]



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MATHEMATICS

9709/42

Paper 4 Mechanics

October/November 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.
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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 [].

This document has **12** pages.

- Find the total mass of the cyclist and bicycle. [3]

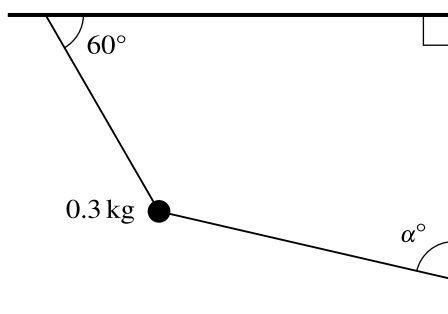
Find the total mass of the cyclist and bicycle.

[3]

[illegible]

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Find the tension in the string which is attached to the wall and find the value of α . [6]

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- 4** A car of mass 1200 kg is travelling along a straight horizontal road AB . There is a constant resistance force of magnitude 500 N. When the car passes point A , it has a speed of 15 m s^{-1} and an acceleration of 0.8 m s^{-2} .

(a) Find the power of the car's engine at the point A . [3]

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The car continues to work with this power as it travels from A to B . The car takes 53 seconds to travel from A to B and the speed of the car at B is 32 m s^{-1} .

(b) Show that the distance AB is 1362.6 m. [3]

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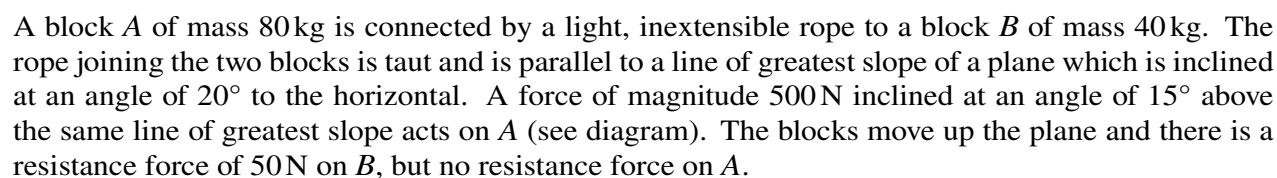
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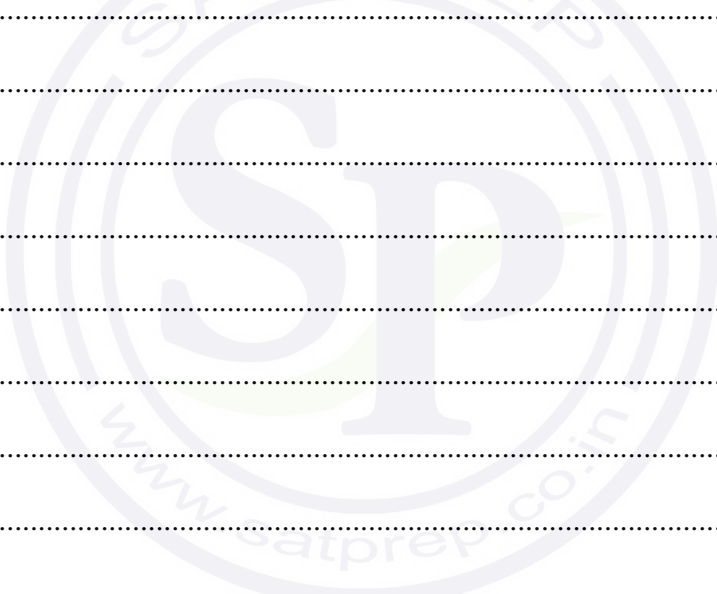
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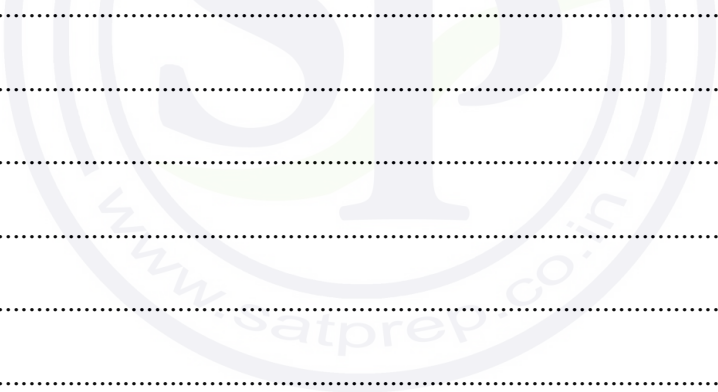


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- (b) Find the time that it takes for the blocks to reach a speed of 1.2 m s^{-1} from rest. [2]

- (a)** Show that the speed of B after the collision is 1.05 m s^{-1} . [2]

After the collision between A and B , B moves directly towards C . Particle B now collides with C . After this collision, the two particles coalesce and have a combined speed of 0.5 m s^{-1} .

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- $$\begin{aligned} a &= 0.3t^{\frac{1}{2}} && \text{for } 0 \leq t \leq 4, \\ a &= -kt^{-\frac{3}{2}} && \text{for } 4 < t \leq T, \end{aligned}$$

(a) Find the velocity of P at $t = 4$. [2]

Show that $k = 2.6$ and find an expression, in terms of t , for the velocity of P for $4 \leq t \leq T$. [4]

(d) Find the total distance travelled between $t = 0$ and $t = T$. [4]

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MATHEMATICS

9709/43

Paper 4 Mechanics

October/November 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.
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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 **16** pages. Any blank pages are indicated.

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

(a) Find u . [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 of 1.8 m s^{-1} for 15 s 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 change in gravitational potential energy of the box.

[2]

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(b) Find the work done by the pulling force.

[2]

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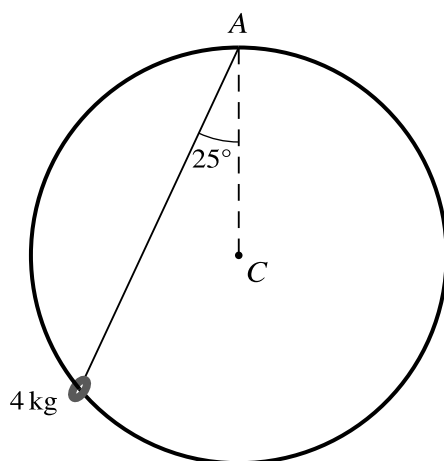
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Find the tension in the string and the magnitude of the normal reaction of the wire on the ring. [6]

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- (a) Find the initial speed and the acceleration of P . [5]

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- (b) Find the distance travelled by P during the first 10 seconds of its motion.

[2]

- At time t seconds after the particles start moving

- (a)** It is given that the velocities of X and Y are equal when they collide.

[6]

[illegible]

(b) It is given instead that $AB = 36$ m.

Verify that X and Y collide after 3 s.

[2]

- 6** A car of mass 1750 kg is pulling a caravan of mass 500 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 650 N and 150 N respectively.

(a) The car and caravan are moving along a straight horizontal road at a constant speed of 24 m s^{-1} .

(i) Find the power of the car's engine.

[2]

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(ii) The engine's power is now suddenly increased to 40 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 $\sin^{-1} 0.14$ to the horizontal, at a constant speed of $v \text{ m s}^{-1}$. The car's engine is working at 31 kW. The resistances to the motion of the car and caravan are unchanged.

Find v .

[3]

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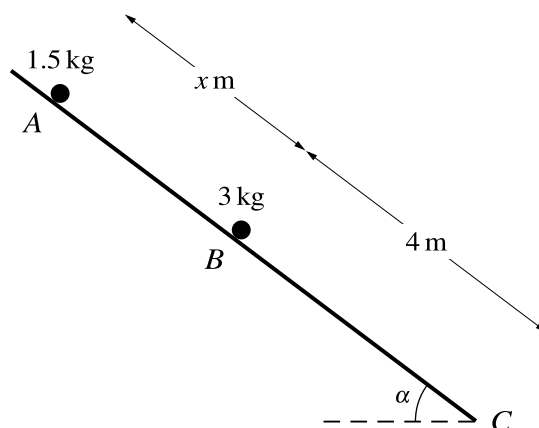
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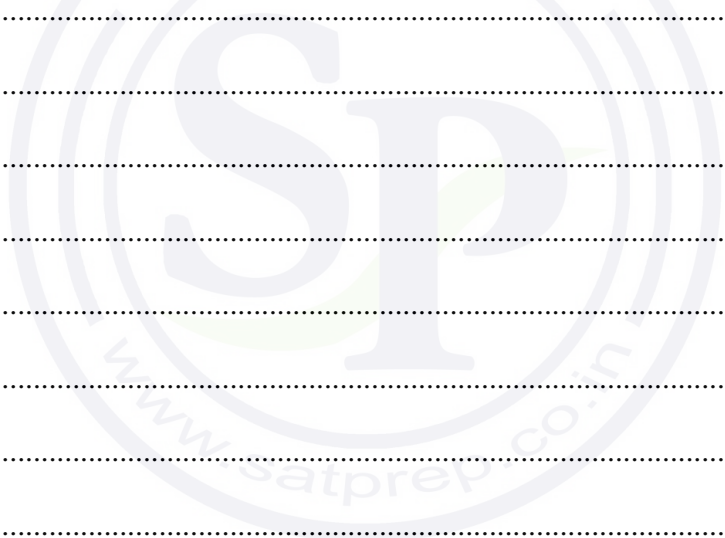
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The coefficient of friction between the particle at B and the plane is $\frac{1}{3}$.

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(b) Find x . [6]

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[illegible]

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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.
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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 [].

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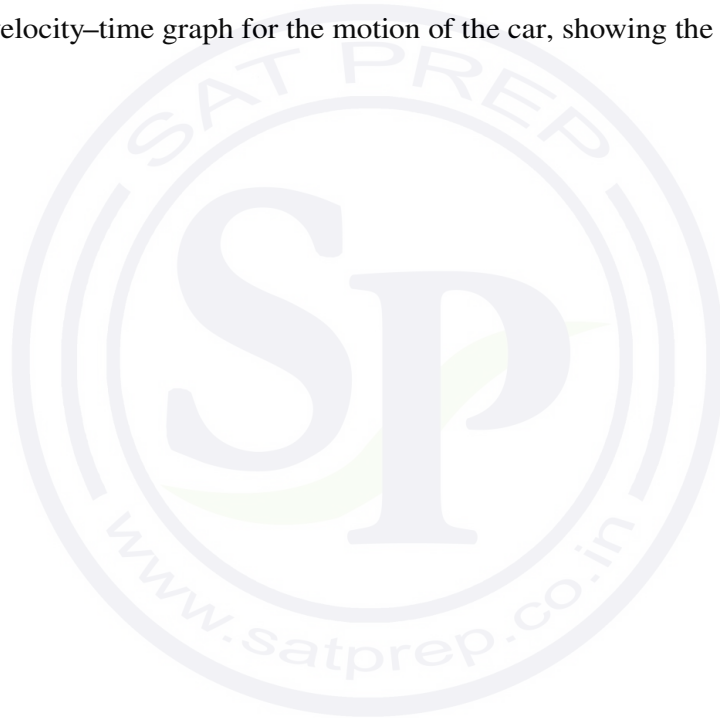
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(b) Sketch the velocity–time graph for the motion of the car, showing the key points. [2]



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

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

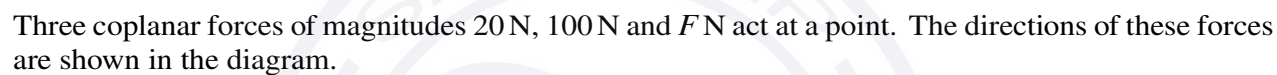
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- 3 A crate of mass 300 kg is at rest on rough horizontal ground. The coefficient of friction between the crate and the ground is 0.5. A force of magnitude X N, acting at an angle α above the horizontal, is applied to the crate, where $\sin \alpha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

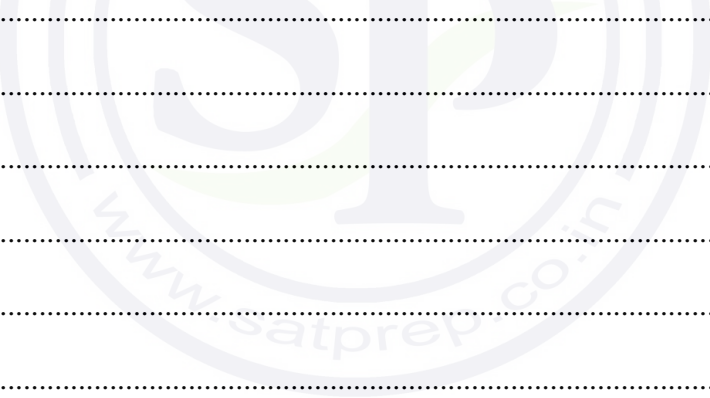
Find the greatest value of X for which the crate remains at rest.

[5]

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[6]



- (a) Show that $d = 100$. [3]

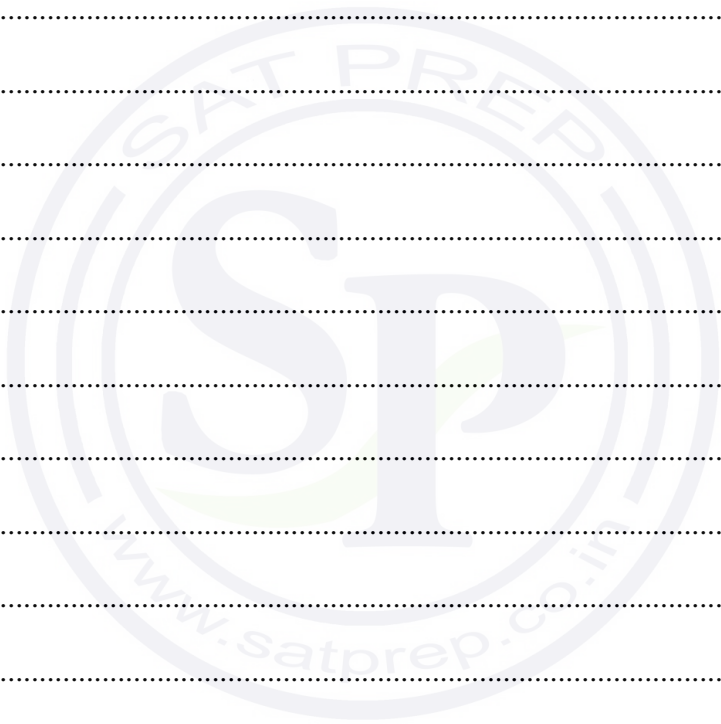
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(b) Find the mass of B . [3]

[illegible]

- 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]

[illegible]

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

[illegible]

(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]

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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

- Answer **all** questions.
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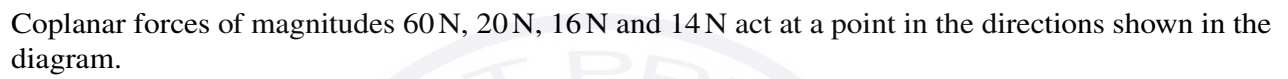
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- (a) Find the speed of B after the collision. [3]

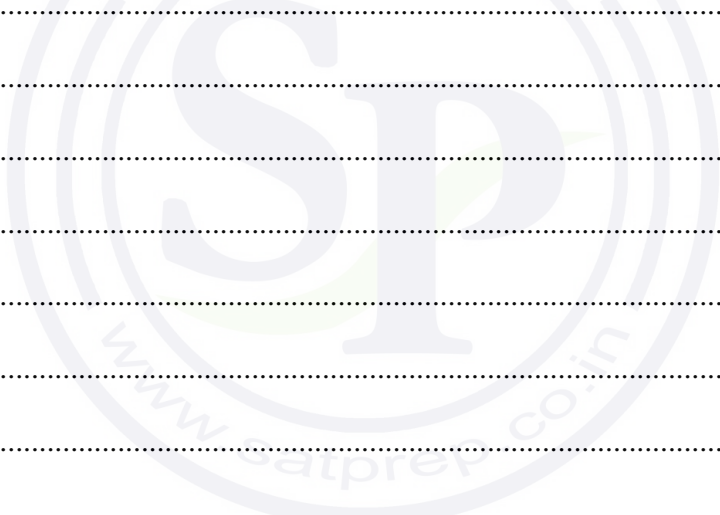
[illegible]

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

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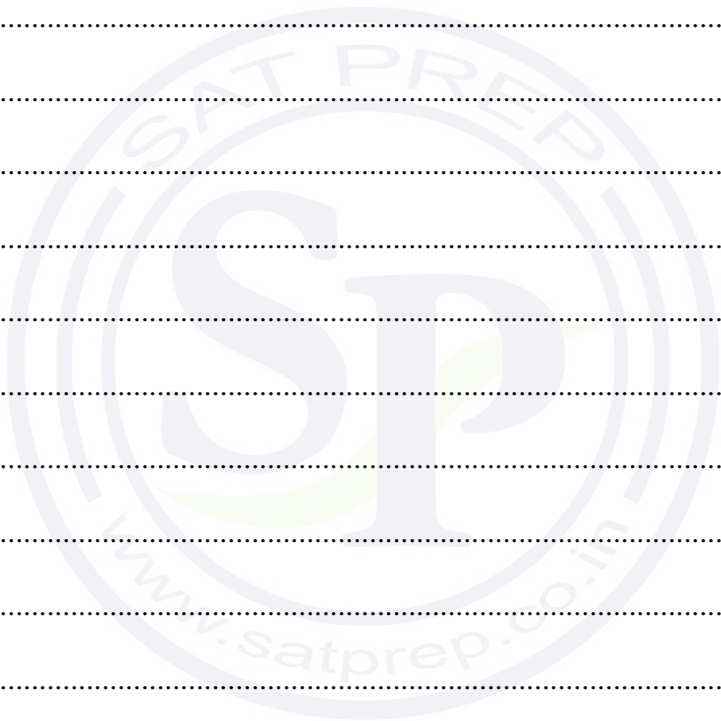
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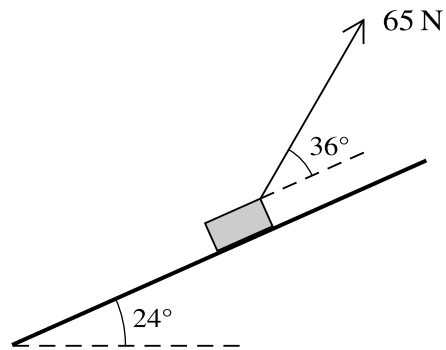
- (b) Find the greatest height of B above the plane.

[3]

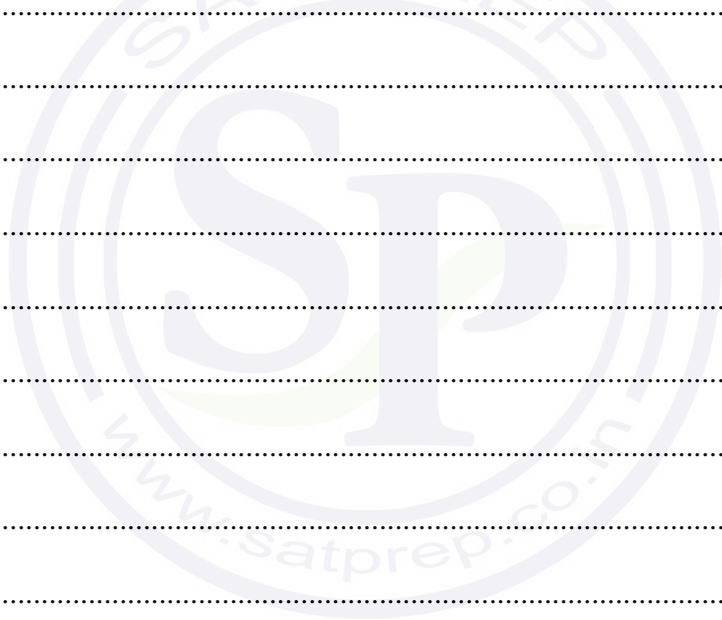
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Find μ .



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

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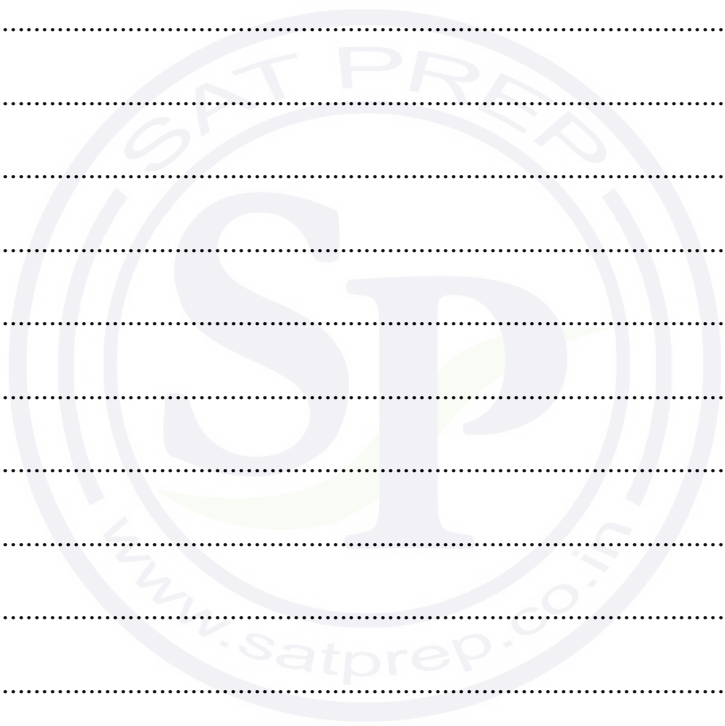
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The car then travels along a straight horizontal road. There is a resistance to the motion of the car of $(1520 + 4v)$ N when the speed of the car is $v \text{ m s}^{-1}$. The car travels at a constant speed with the engine working at a constant rate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

[6]

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MATHEMATICS

9709/43

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.
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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 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 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 ms^{-1} . [3]

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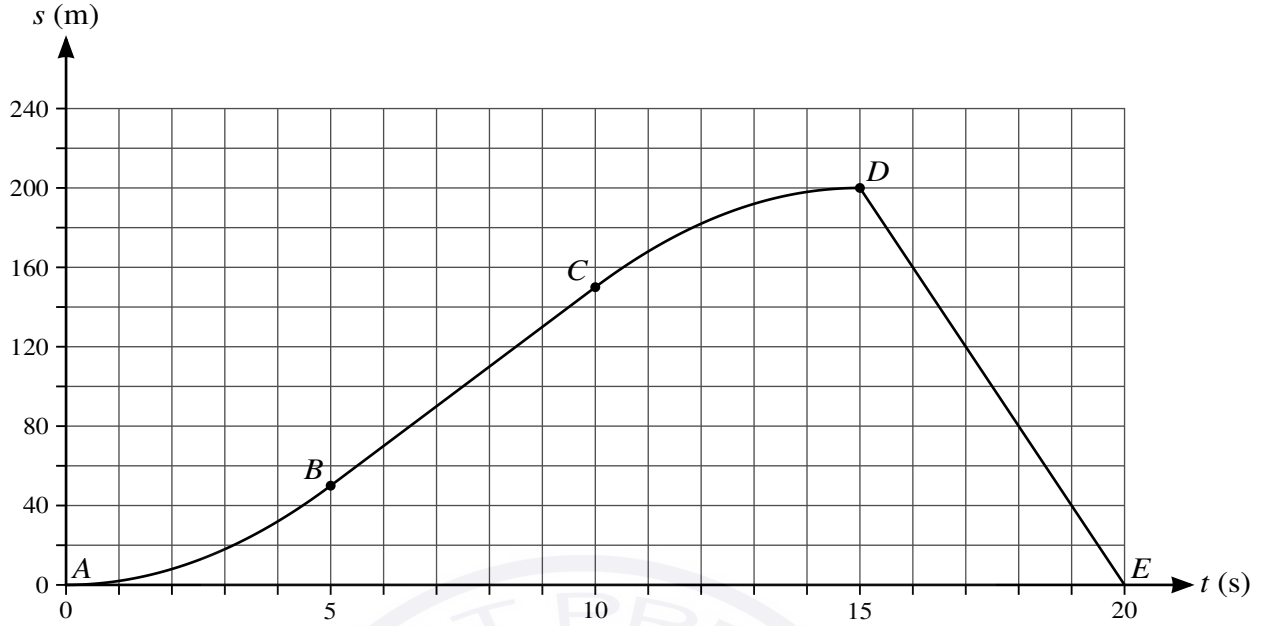
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The displacement of a particle moving in a straight line is s metres at time t seconds after leaving a fixed point O . The particle starts from rest and passes through points P , Q and R , at times $t = 5$, $t = 10$ and $t = 15$ respectively, and returns 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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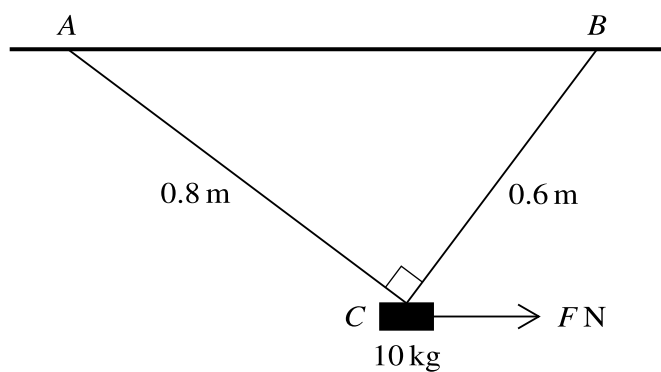
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- [illegible]

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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]

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- (b) Find the greatest value of F for which the block remains in equilibrium in the position shown. [3]

[illegible]

- (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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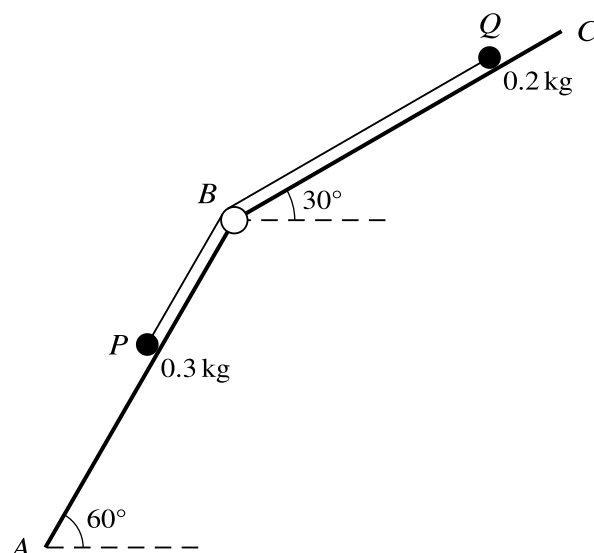
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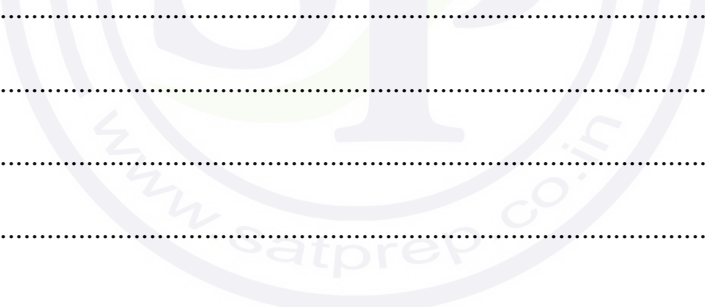
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Two particles P and Q , of masses 0.3 kg and 0.2 kg respectively, are attached to the ends of a light inextensible string. The string passes over a fixed smooth pulley at B which is attached to two inclined planes. P lies on a smooth plane AB which is inclined at 60° to the horizontal. Q lies on a plane BC which is inclined at 30° to the horizontal. The string is taut and the particles can move on lines of greatest slope of the two planes (see diagram).

- (a) It is given that the plane BC is smooth and that the particles are released from rest.

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]

- 7** A particle P moves in a straight line through a point O . The velocity $v \text{ ms}^{-1}$ 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]



- (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]

[illegible]

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MATHEMATICS

9709/42

Paper 4 Mechanics

February/March 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.
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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 [].

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

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- 1** A crane is used to raise a block of mass 600 kg vertically upwards at a constant speed through a height of 15 m. There is a resistance to the motion of the block, which the crane does 10 000 J of work to overcome.

(a) Find the total work done by the crane.

[2]

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- (b) Given that the average power exerted by the crane is 12.5 kW, find the total time for which the block is in motion. [2]

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- 2 A particle P is projected vertically upwards from horizontal ground with speed $u \text{ m s}^{-1}$. P reaches a maximum height of 20 m above the ground.

(a) Find the value of u . [2]

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(b) Find the total time for which P is at least 15 m above the ground. [3]

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- 3** A car of mass m kg is towing a trailer of mass 300 kg down a straight hill inclined at 3° to the horizontal at a constant speed. There are resistance forces on the car and on the trailer, and the total work done against the resistance forces in a distance of 50 m is 40 000 J. The engine of the car is doing no work and the tow-bar is light and rigid.

(a) Find the value of m . [3]

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The resistance force on the trailer is 200 N.

(b) Find the tension in the tow-bar between the car and the trailer. [2]

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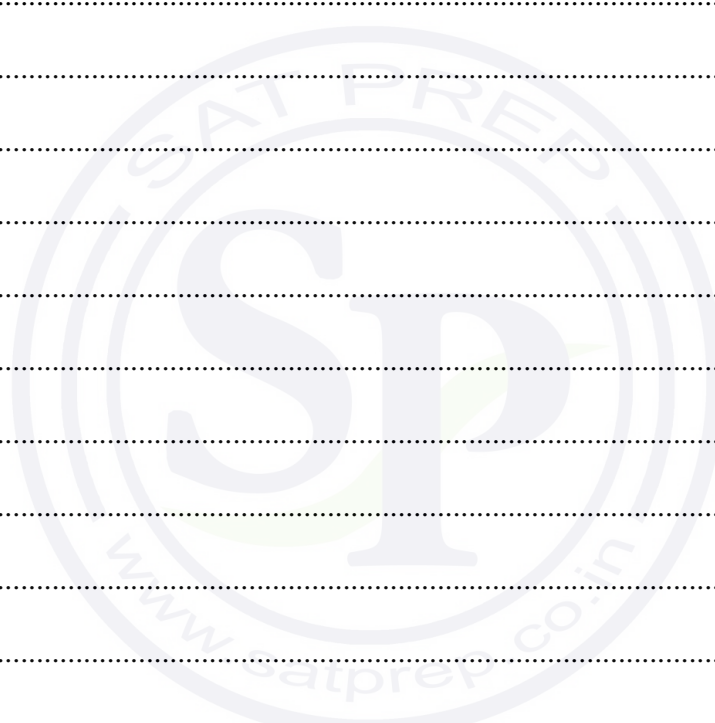
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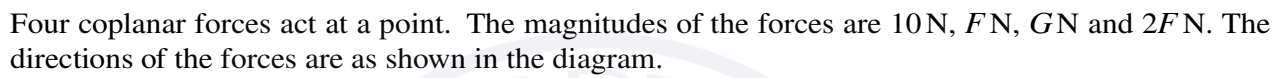
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- (a) Find the value of F . [4]



- (b)** Find the steady speed that the cyclist could maintain up the hill when working at this power. [2]

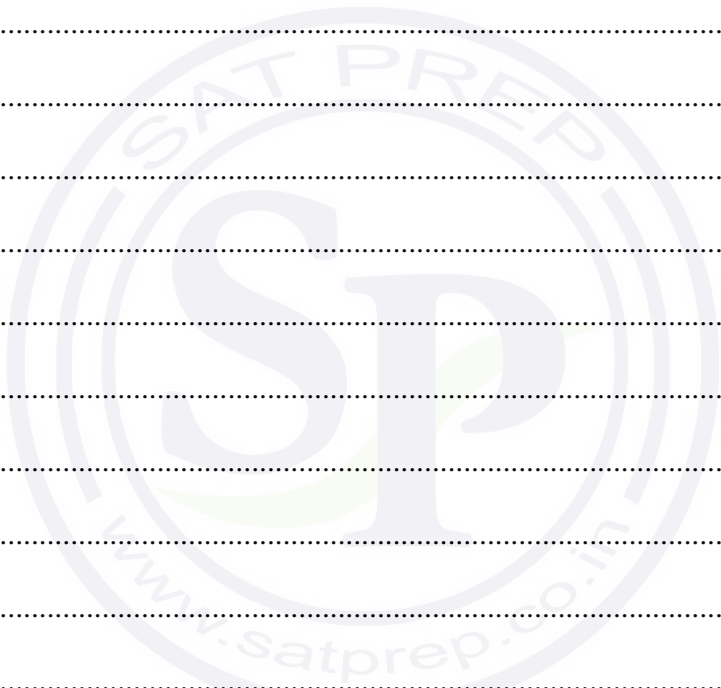
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- (b) Given instead that $F = 3$, find the value of G for which the resultant of the forces is perpendicular to the 10 N force. [2]

- (a)** Find the value of k . [4]

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- (c) Find an expression for the displacement from O in terms of t . Hence find the total distance travelled by the cyclist from the time at which she reaches her maximum speed until she comes to rest. [4]

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- 7 A bead, A , of mass 0.1 kg is threaded on a long straight rigid wire which is inclined at $\sin^{-1}(\frac{7}{25})$ to the horizontal. A is released from rest and moves down the wire. The coefficient of friction between A and the wire is μ . When A has travelled 0.45 m down the wire, its speed is 0.6 m s^{-1} .

(a) Show that $\mu = 0.25$.

[6]

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(b) Find the time from when the collision occurs until A collides with B again. [6]

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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.
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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 [].

This document has **12** pages.

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

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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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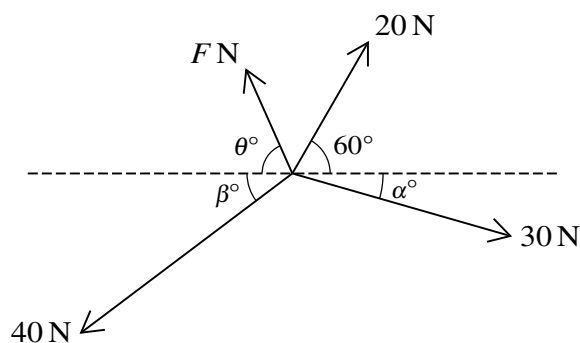
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Given that the forces are in equilibrium, find F and θ . [6]

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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) 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]

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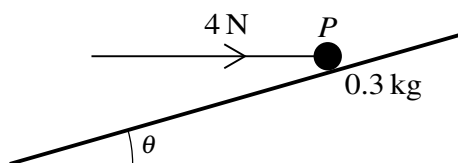
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- (b) Sketch the velocity-time graph for the first 3 seconds of motion. [3]

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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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MATHEMATICS

9709/42

Paper 4 Mechanics

May/June 2021

1 hour 15 minutes

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You will need: List of formulae (MF19)

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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 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]

[illegible]



- 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]

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

[illegible]

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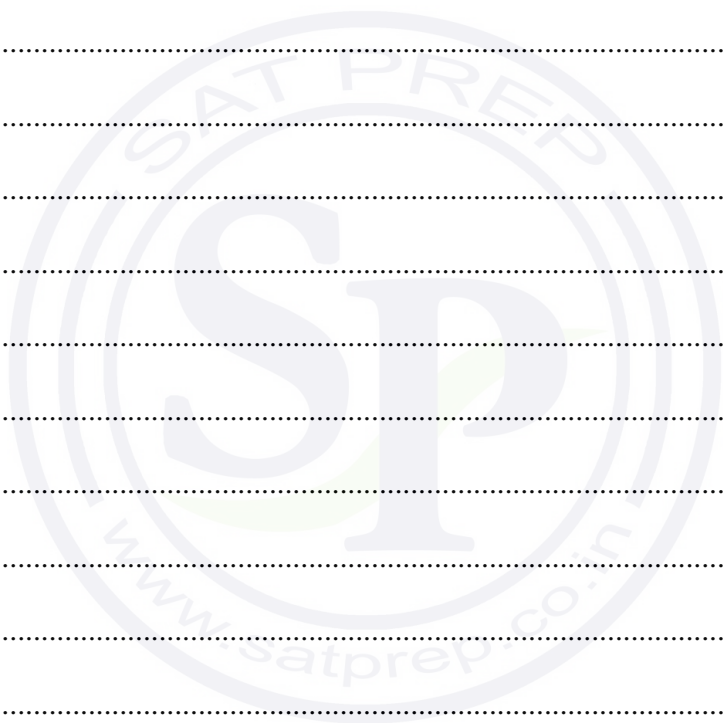
- Find the difference between the two possible times at which C hits the ground. [8]

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

$$\begin{array}{ll} a = 6 + 4t & 0 \leq t < 2, \\ a = 14 & 2 \leq t < 4, \\ a = 16 - 2t & 4 \leq t \leq 16. \end{array}$$

There is no sudden change in velocity at any instant.

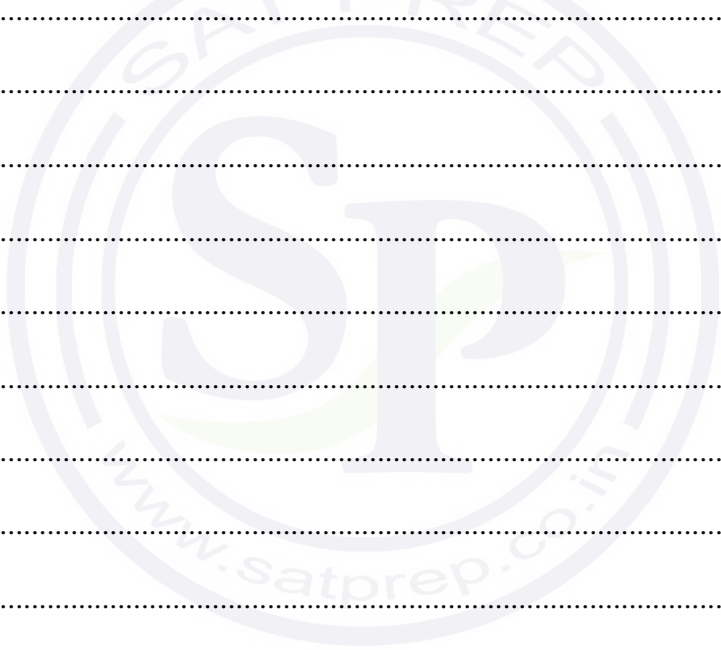
- (a) Find the values of t when the velocity of P is 55 m s^{-1} . [5]

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A velocity-time graph for a particle moving in a straight line. The vertical axis is labeled $v \text{ (m s}^{-1}\text{)}$ and the horizontal axis is labeled $t \text{ (s)}$. The horizontal axis has tick marks at 0, 2, 4, and 16. The graph shows a straight line segment starting at $(2, 0)$ and ending at $(4, 10)$.

(c) Find the distance travelled by P when it is decelerating.

[3]



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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

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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 [].

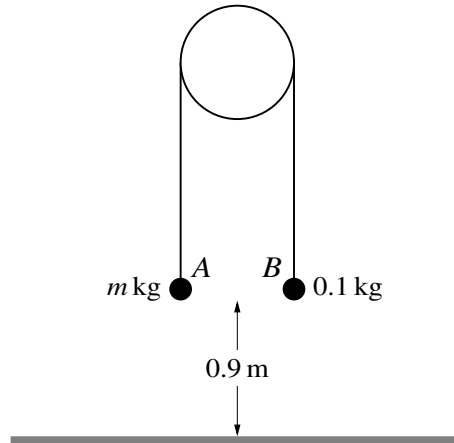
This document has **12** pages.

- 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]

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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 m s⁻², where

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

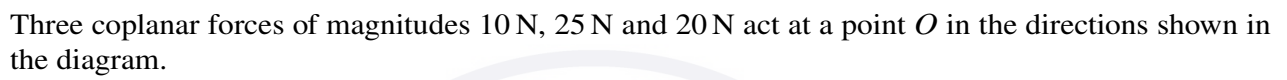
- (a)** Find the value of t at point B .

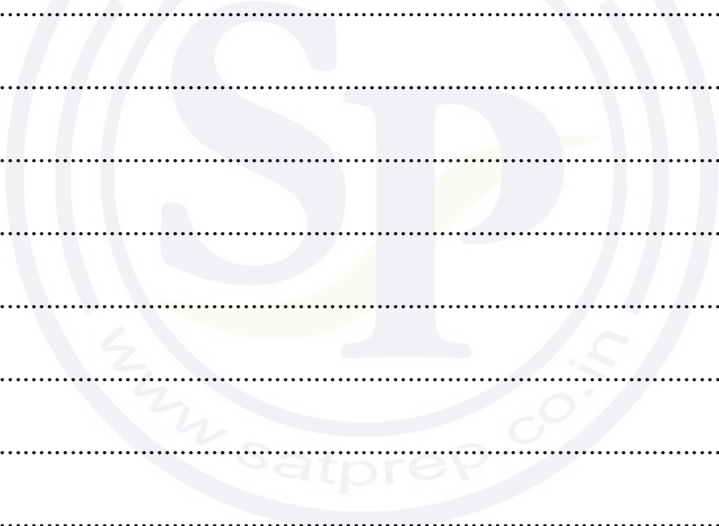
[3]

[illegible]

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

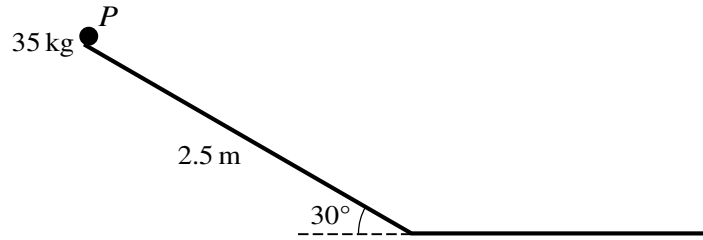
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7



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

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

[illegible]

- 2** A car of mass 1400 kg is travelling at constant speed up a straight hill inclined at α 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 m s^{-1} . [3]

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The car, moving with speed 11.25 m 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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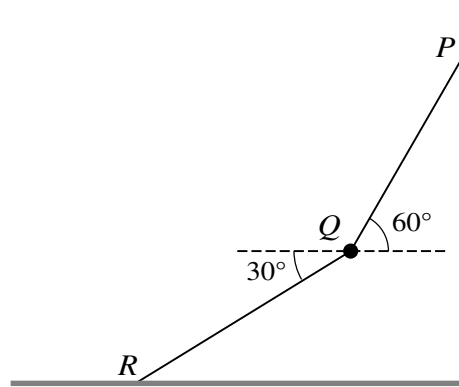
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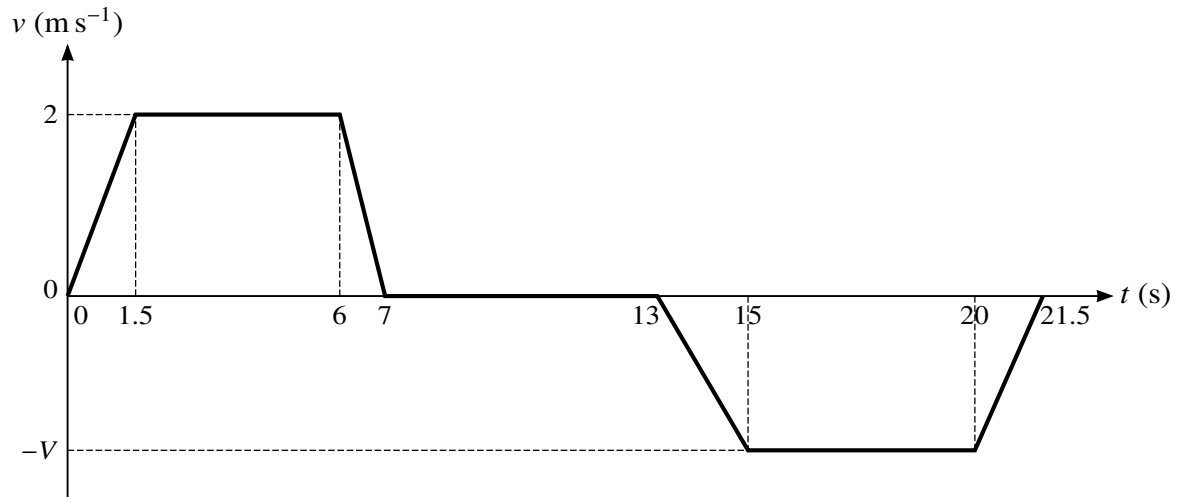
A particle Q of mass 0.2 kg is held in equilibrium by two light inextensible strings PQ and QR . P is a fixed point on a vertical wall and R is a fixed point on a horizontal floor. The angles which strings PQ and QR make with the horizontal are 60° and 30° respectively (see diagram).

Find the tensions in the two strings.

[5]

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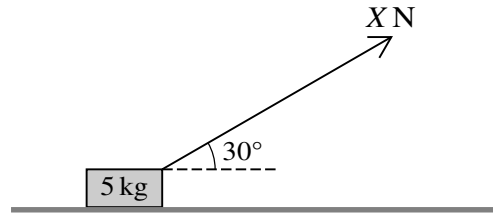
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- (c) The combined weight of the elevator and passengers on its upward journey is 1500 kg. Assuming that there is no resistance to motion, find the tension in the elevator cable on its upward journey when the elevator is decelerating. [3]

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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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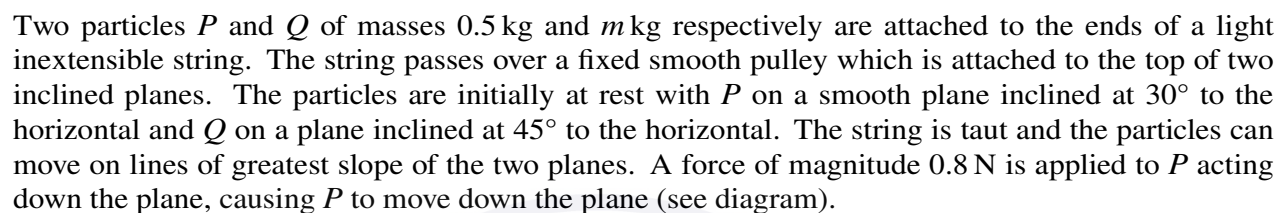
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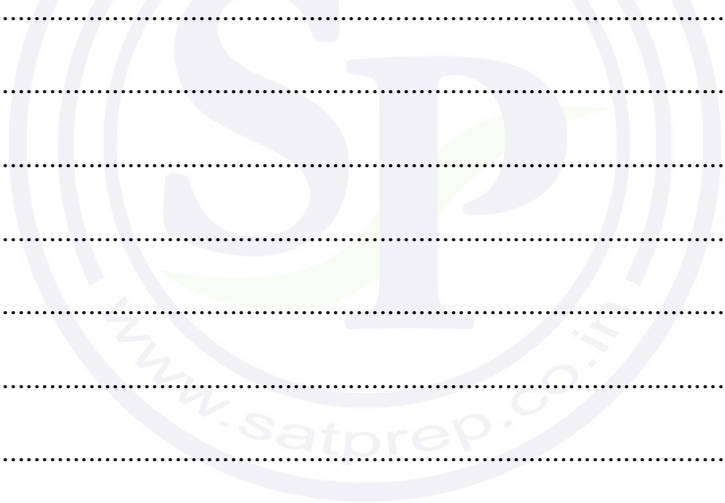
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- [illegible]

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- Find the tension in the string.



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

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 m 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 m s^{-1} . [2]

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

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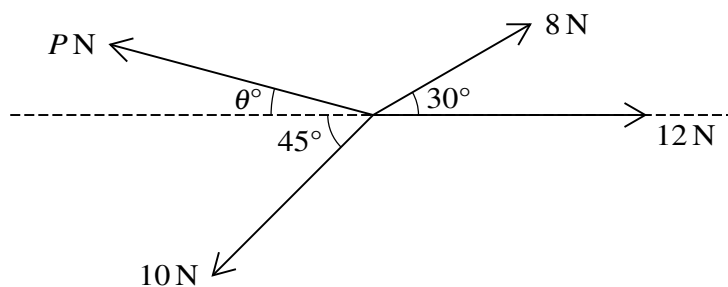
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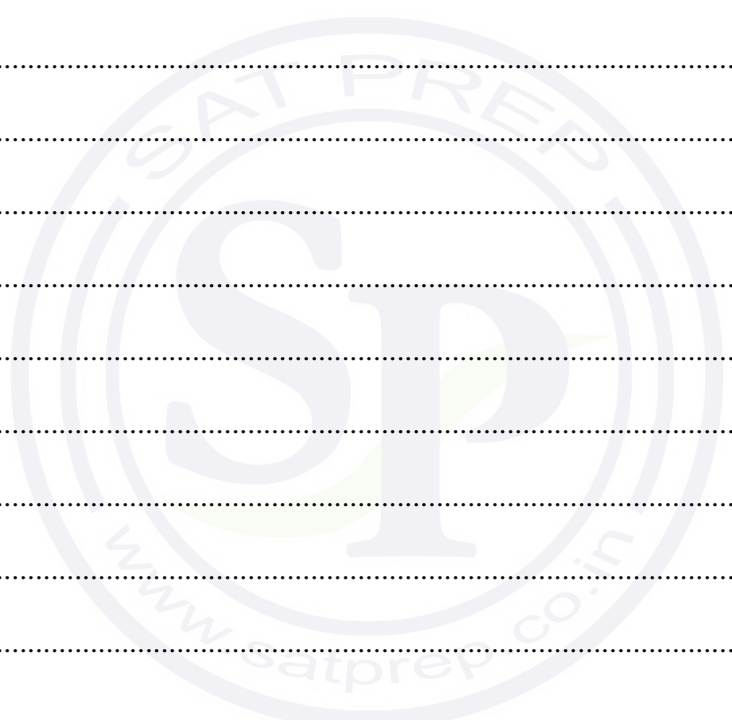
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Find P and θ .

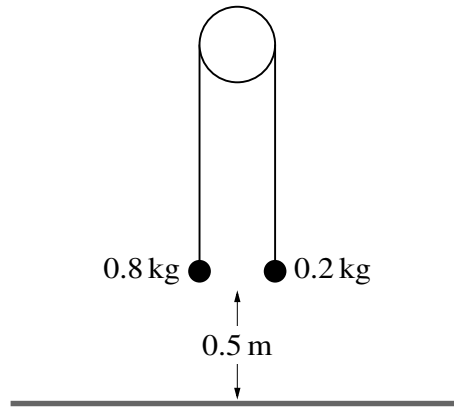
[6]

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- 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 $a \text{ m s}^{-2}$, where $a = 6t - 18$.

Find the distance P moves before it comes to instantaneous rest.

[6]



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 m s^{-2} and find the tension in the string. [4]



Find the greatest height of the 0.2 kg particle above the floor.

[3]

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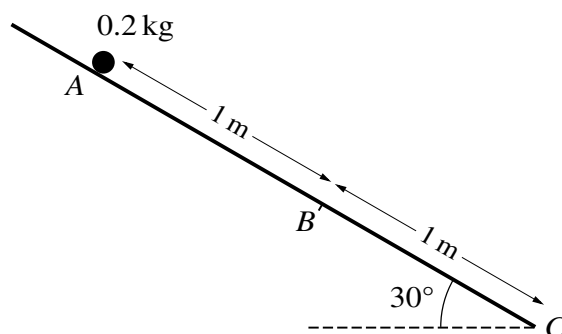
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After reaching the top of the hill the system consisting of the car and trailer travels along a straight level road. The driving force of the car's engine is 2400 N and the resistances to motion are unchanged.

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

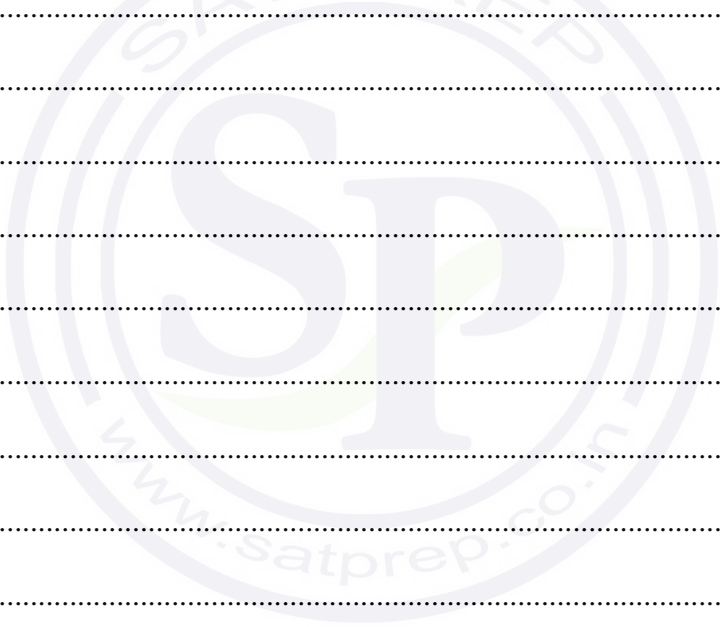
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Three points A , B and C lie on a line of greatest slope of a plane inclined at an angle of 30° to the horizontal, with $AB = 1$ m and $BC = 1$ m, as shown in the diagram. A particle of mass 0.2 kg is released from rest at A and slides down the plane.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

- (a) Given that $\mu = \frac{1}{5}\sqrt{3}$, find the speed of the particle at C . [8]

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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.
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INFORMATION

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- 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 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 m s^{-1} .

Find the speed of Q after the collision.

[2]

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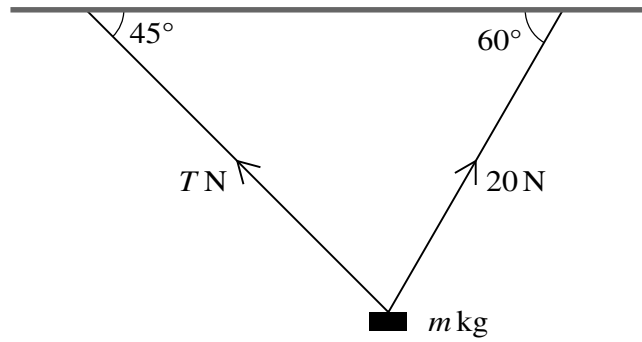
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- (a) Find the power of the car's engine, given that the car's acceleration is 0.5 m s^{-2} when its speed is 20 m s^{-1} . [3]

[illegible]

- [illegible]

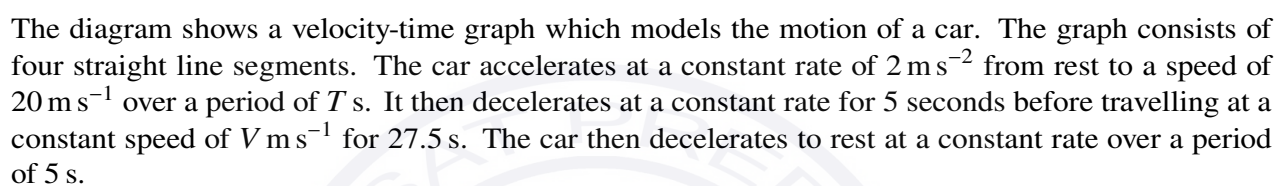


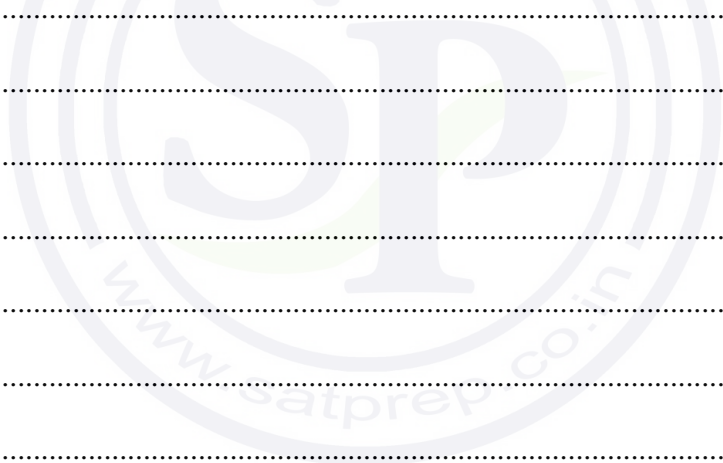
A block of mass m kg is held in equilibrium below a horizontal ceiling by two strings, as shown in the diagram. One of the strings is inclined at 45° to the horizontal and the tension in this string is T N. The other string is inclined at 60° to the horizontal and the tension in this string is 20 N.

Find T and m .

[5]

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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]

[illegible]

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

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

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- 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]

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- (a)**

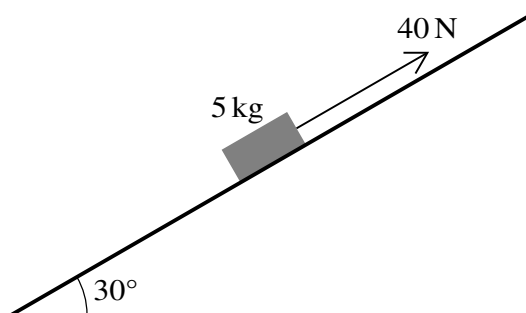


Fig. 6.1

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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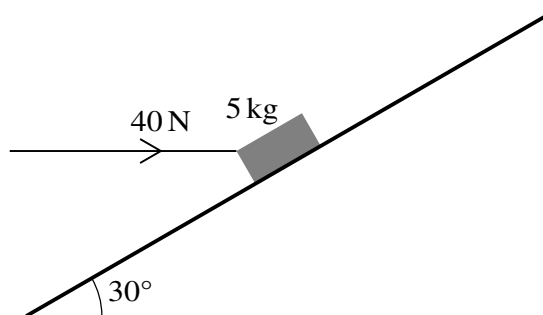


Fig. 6.2

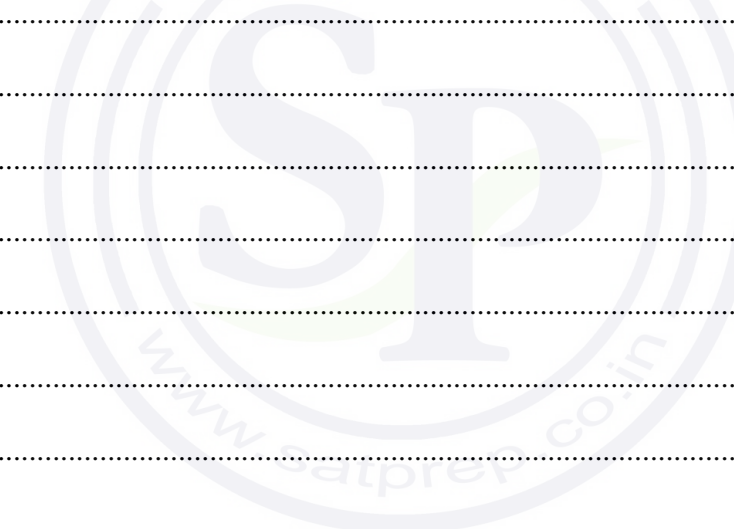
When a force of magnitude 40 N is applied horizontally, in a vertical plane containing a line of greatest slope, the block does not move (see Fig. 6.2).

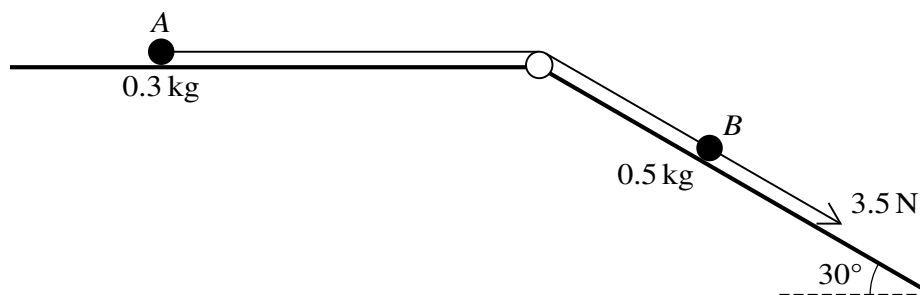
Show that, correct to 3 decimal places, the least possible value of μ is 0.152. [4]

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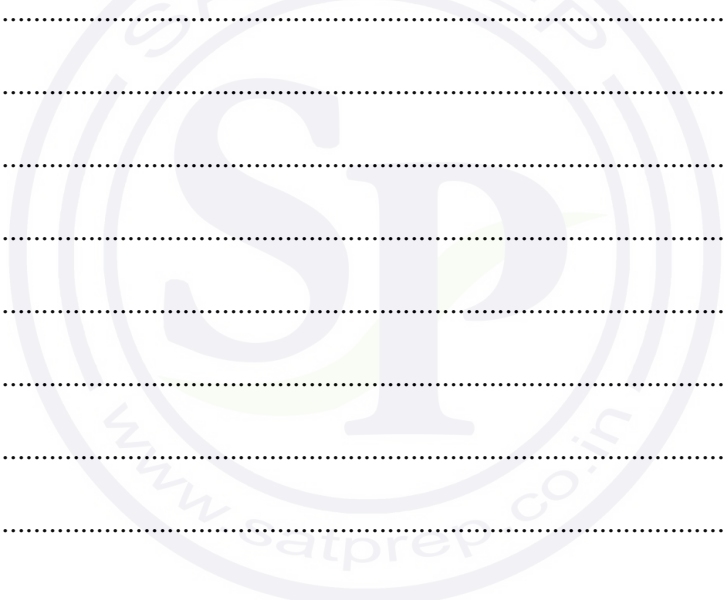
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- (b) Find the displacement of P from O when $t = 2$, giving your answer correct to 2 decimal places. [3]





Both planes are smooth, find the tension in the string and the

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- 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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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

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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 $v \text{ m s}^{-1}$ 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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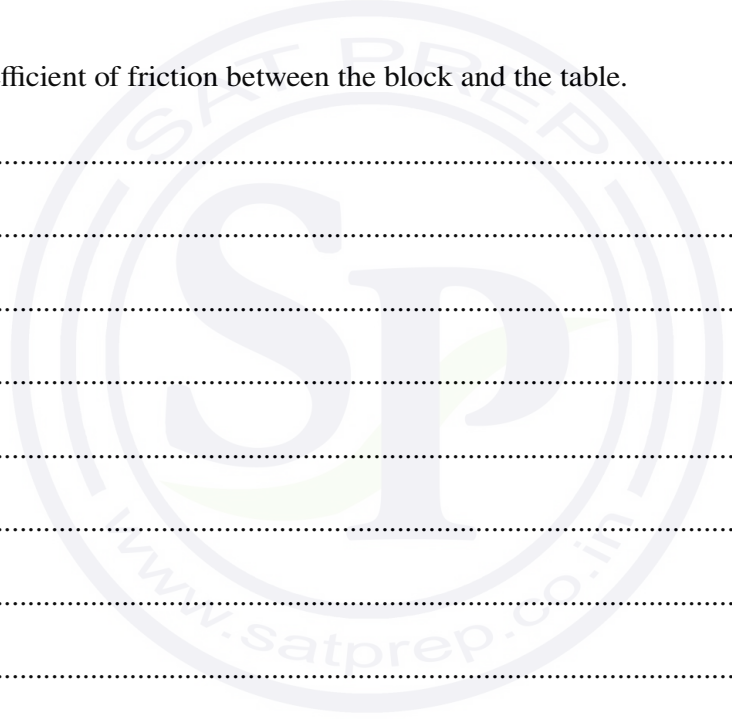
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- 3** A string is attached to a block of mass 4 kg which rests in limiting equilibrium on a rough horizontal table. The string makes an angle of 24° above the horizontal and the tension in the string is 30 N.

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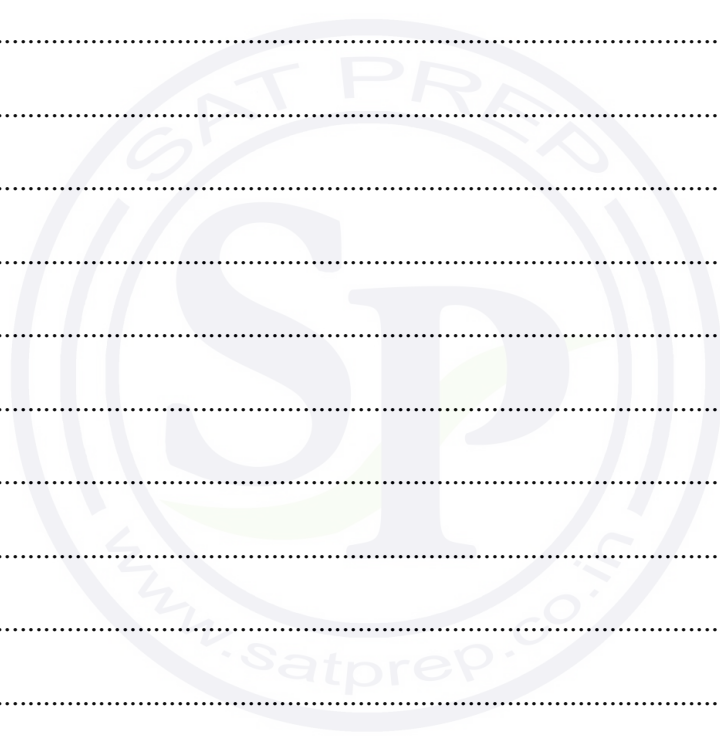
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- 4 Two small smooth spheres A and B , of equal radii and of masses 4 kg and $m\text{ kg}$ respectively, lie on a smooth horizontal plane. Initially, sphere B is at rest and A is moving towards B with speed 6 m s^{-1} . After the collision A moves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

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

[6]

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- 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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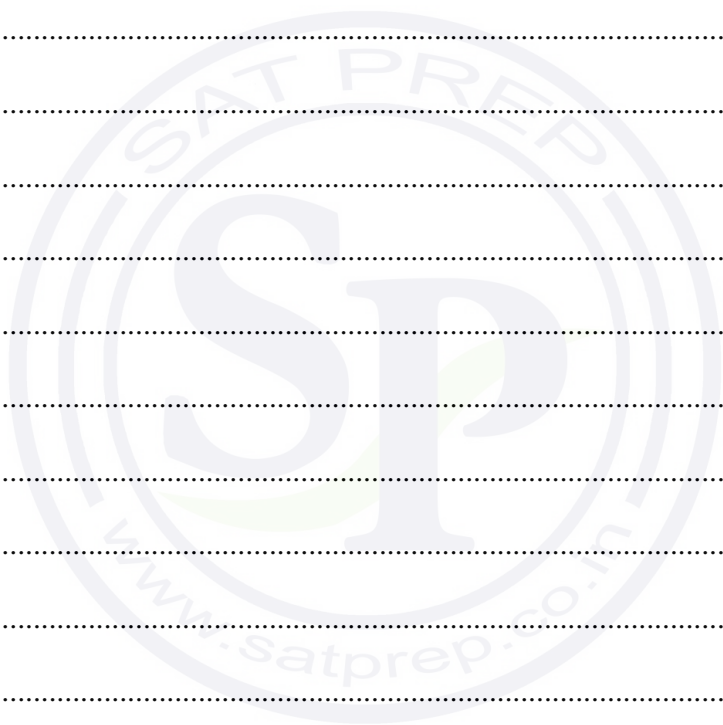
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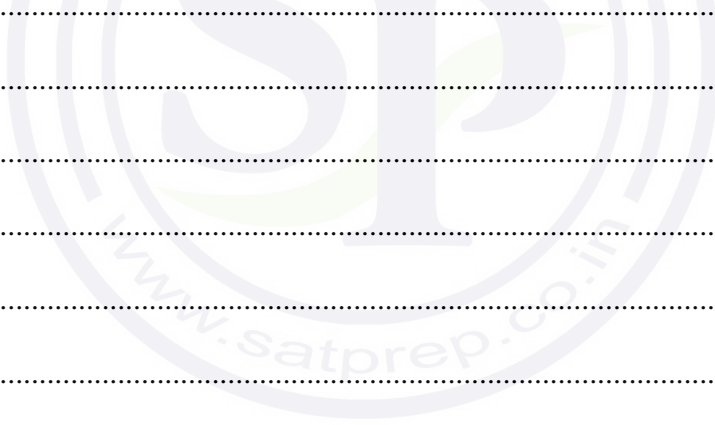
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- (a) The car and caravan are travelling along a straight horizontal road.
- (i) Given that the car and caravan have a constant speed of 25 m s^{-1} , find the power of the car's engine. [2]

[illegible]

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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 $v \text{ m s}^{-1}$. The car's engine is working at 32.5 kW.

Find v .

[3]

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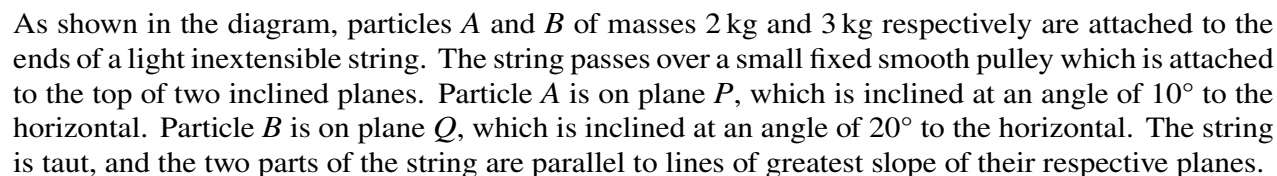
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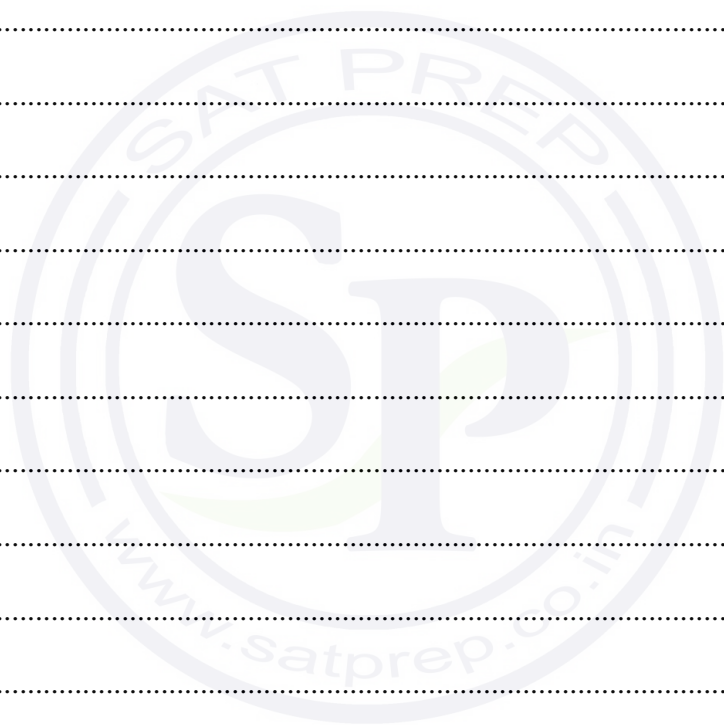
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- Find the coefficient of friction between particle B and plane Q . [5]

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- 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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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.
- 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 m s^{-2} .

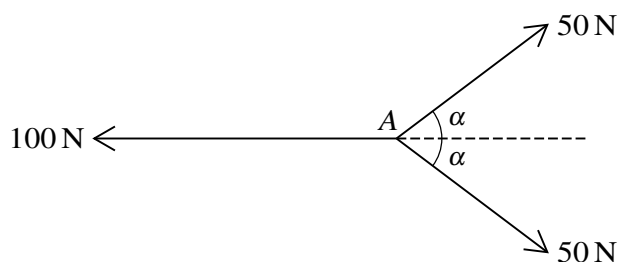
INFORMATION

- 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. Blank pages are indicated.

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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]

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- 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 m 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 m s^{-1} .

[3]

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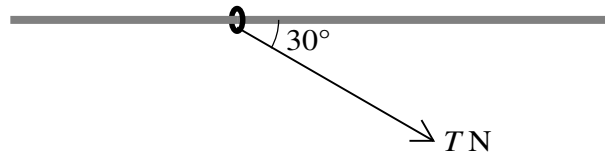
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- (a) Find the greatest height above the ground reached by P . [3]

[illegible]

- [illegible]



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 $T\text{ N}$ 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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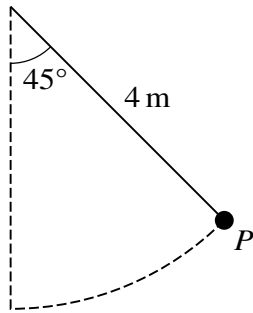
(b) Find the acceleration of the ring when $T = 3$.

[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]

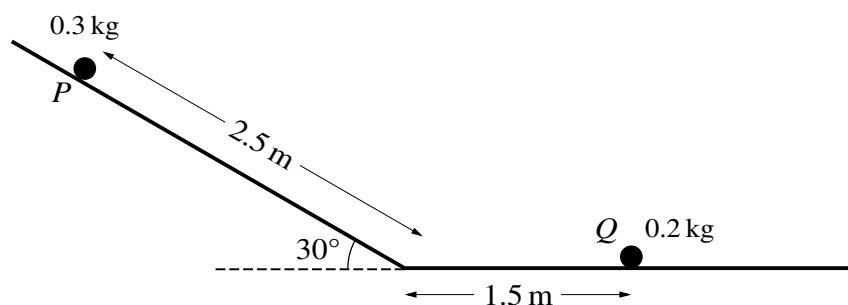
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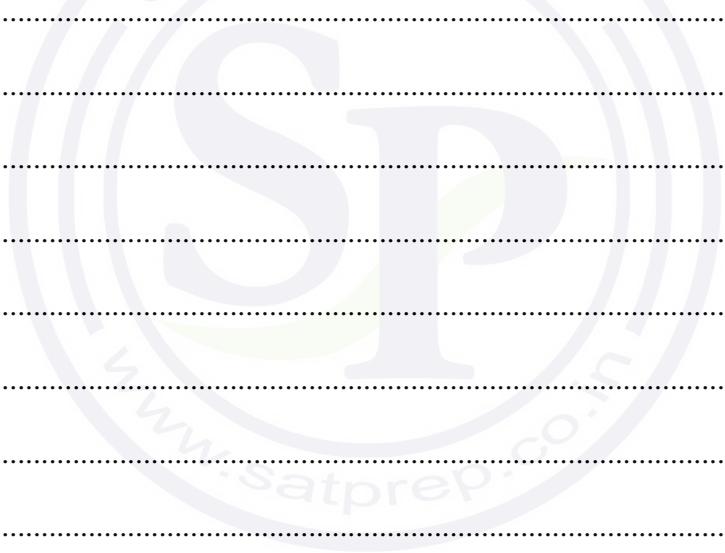


A particle P of mass 0.3 kg , lying on a smooth plane inclined at 30° to the horizontal, is released from rest. P slides down the plane for a distance of 2.5 m and then reaches a horizontal plane. There is no change in speed when P reaches the horizontal plane. A particle Q of mass 0.2 kg lies at rest 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 m s^{-1} .

Find the speed of Q after the collision.

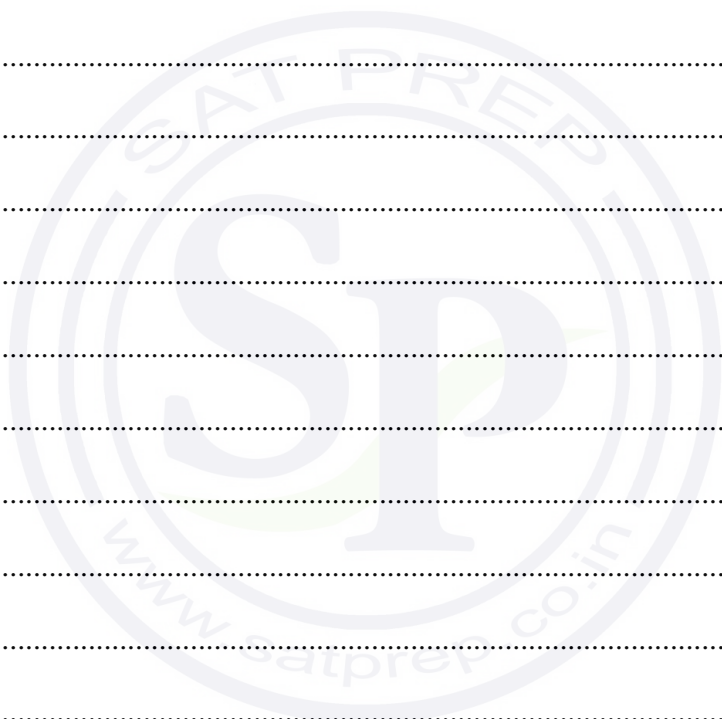
[5]



- (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 m s^{-1} .

Find the coefficient of friction between P and the horizontal plane.

[5]

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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.
- 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 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. 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, $V \text{ m s}^{-1}$, 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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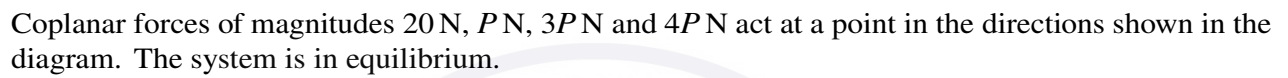
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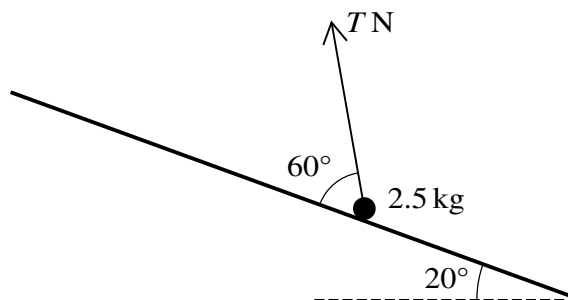
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[6]

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

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- 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 m 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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- Find the total loss of kinetic energy in the system due to the three collisions.

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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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[5]

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

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

- (a) Sketch the velocity-time graph for $0 \leq t \leq 13.5$.

[3]

- (b) Find the acceleration at the instant when $t = 6$.

[2]

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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)

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 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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- Find m . [3]

Find m .

[3]

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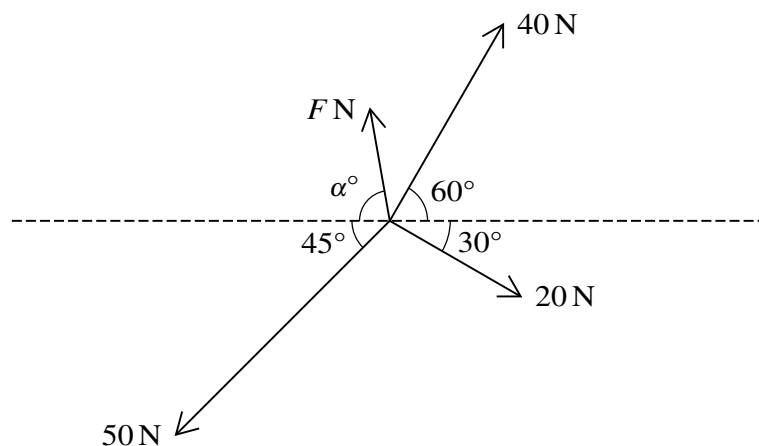
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- (a) Find the driving force when the acceleration of the minibus is 0.5 m s^{-2} . [2]

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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 α .

[6]

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

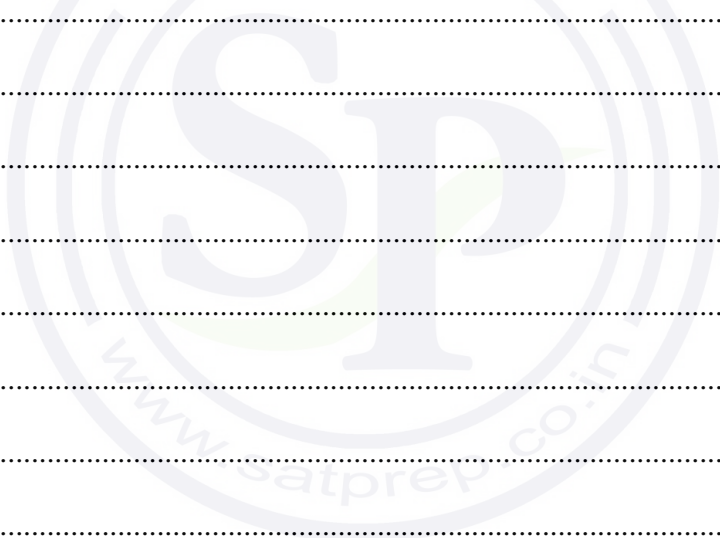
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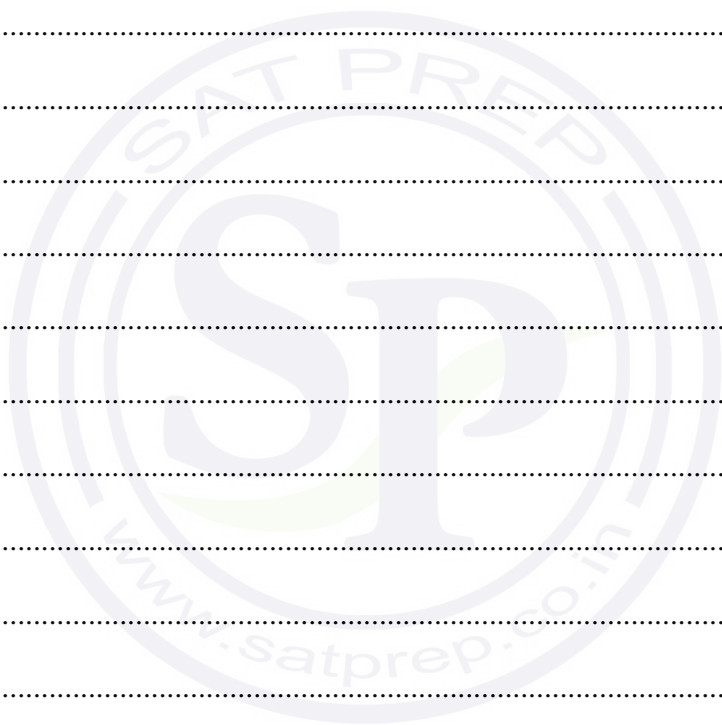
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Find the time taken, after this instant, for the block to return to P .

[4]



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

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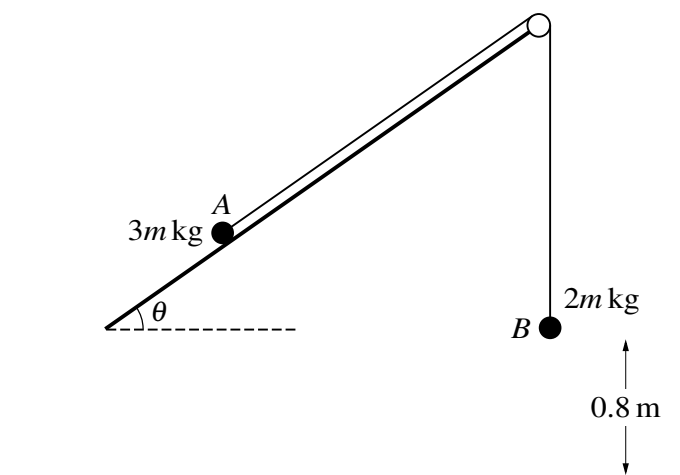
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[6]

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Two particles A and B , of masses $3m \text{ kg}$ and $2m \text{ kg}$ 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 θ 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 θ for which A remains at rest. [3]

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It is given instead that the plane is rough, $\theta = 30^\circ$ and the acceleration of A up the plane is 0.1 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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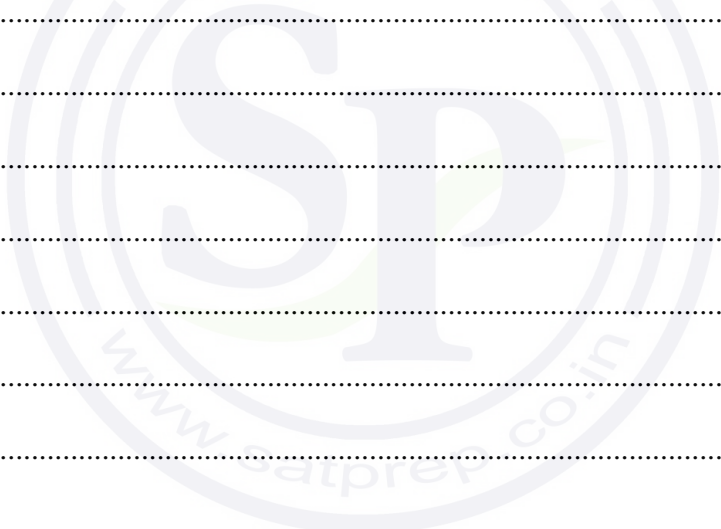
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- Find the length of time after B reaches the floor for which A is moving up the plane. [You may assume that A does not reach the pulley.] [4]

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

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



- 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 μ . A force of magnitude 3 N is applied to P upwards at an angle α above the horizontal, where $\tan \alpha = \frac{3}{4}$. The particle is initially at rest and accelerates at 2 m 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 μ . [4]

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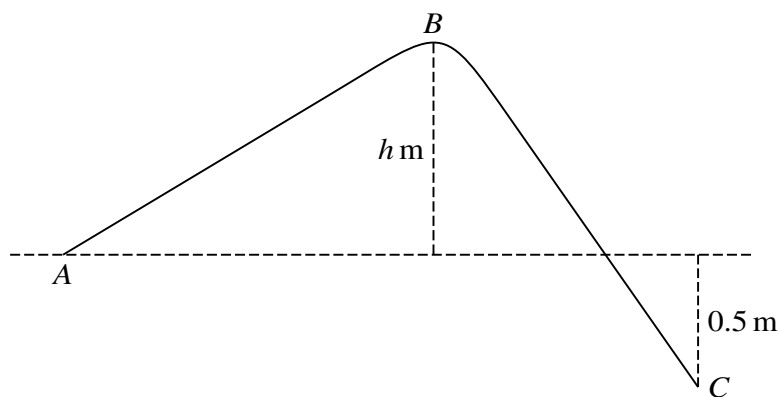
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The diagram shows the vertical cross-section of a surface. A , B and C are three points on the cross-section. The level of B is h m above the level of A . The level of C is 0.5 m below the level of A . A particle of mass 0.2 kg is projected up the 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]

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

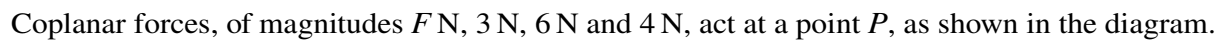
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- (a) Find the magnitude of the force in the tow-bar. [2]

[illegible]

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

[illegible]

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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MATHEMATICS

9709/41

Paper 4 Mechanics 1 (**M1**)

October/November 2019

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: List of Formulae (MF9)

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- 3** A block of mass 3 kg is at rest on a rough plane inclined at 60° to the horizontal. A force of magnitude 15 N acting up a line of greatest slope of the plane is just sufficient to prevent the block from sliding down the plane.

(i) Find the coefficient of friction between the block and the plane.

[5]

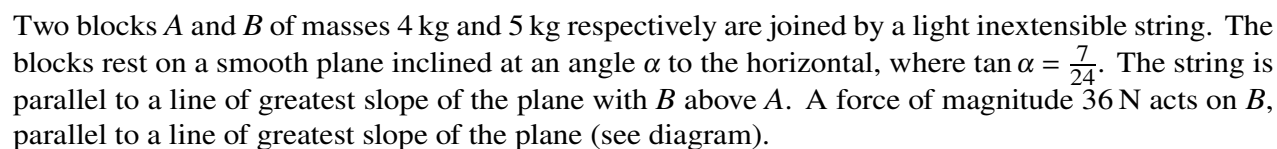
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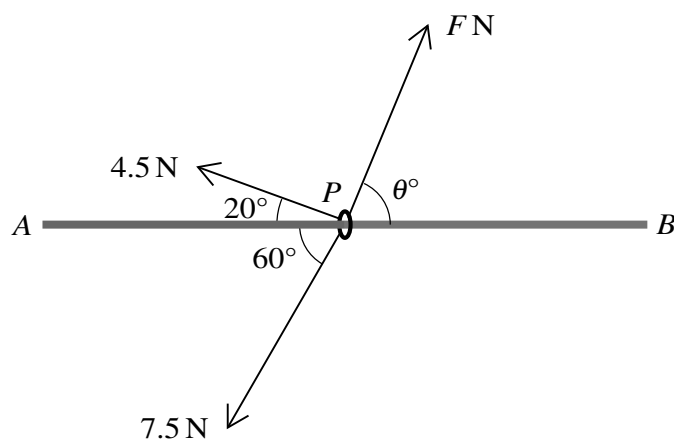
(ii) Find the greatest value of X for which the block does not move. [2]

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- (ii) At a particular instant, the speed of the blocks is 1 m s^{-1} . Find the time, after this instant, that it takes for the blocks to travel 0.65 m. [2]



A small ring P is threaded on a fixed smooth horizontal rod AB . Three horizontal forces of magnitudes 4.5 N , 7.5 N and $F\text{ N}$ act on P (see diagram).

- (i) Given that these three forces are in equilibrium, find the values of F and θ . [6]

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- (ii) It is given instead that the values of F and θ are 9.5 and 30 respectively, and the acceleration of the ring is 1.5 m s^{-2} . Find the mass of the ring. [2]

- 6 A particle of mass 0.4 kg is released from rest at a height of 1.8 m above the surface of the water in a tank. There is no instantaneous change of speed when the particle enters the water. The water exerts an upward force of 5.6 N on the particle when it is in the water.

(i) Find the velocity of the particle at the instant when it reaches the surface of the water. [2]

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(ii) Find the time that it takes from the instant when the particle enters the water until it comes to instantaneous rest in the water. You may assume that the tank is deep enough so that the particle does not reach the bottom of the tank. [4]

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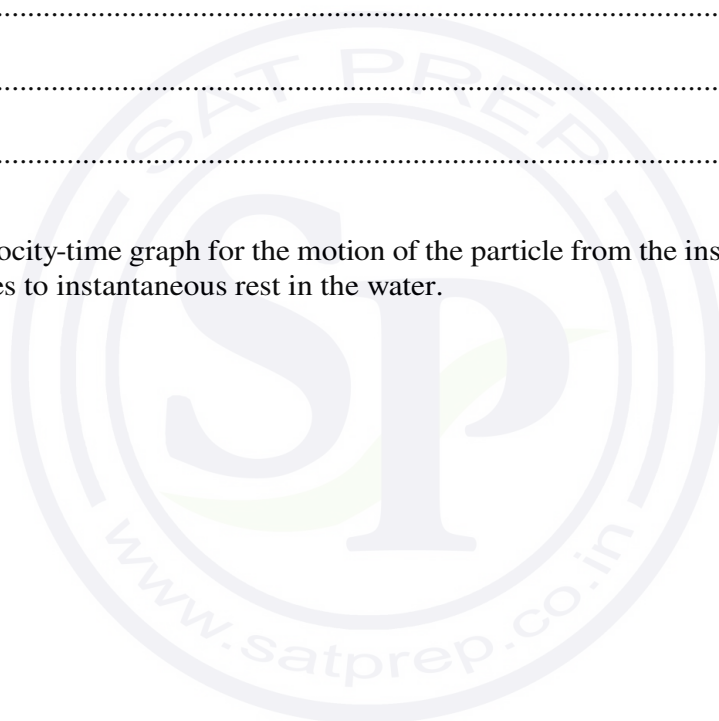
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- (iii) Sketch a velocity-time graph for the motion of the particle from the instant at which it is released until it comes to instantaneous rest in the water. [3]



- 7** A particle moves in a straight line, starting from rest at a point O , and comes to instantaneous rest at a point P . The velocity of the particle at time t s after leaving O is v m s⁻¹, where

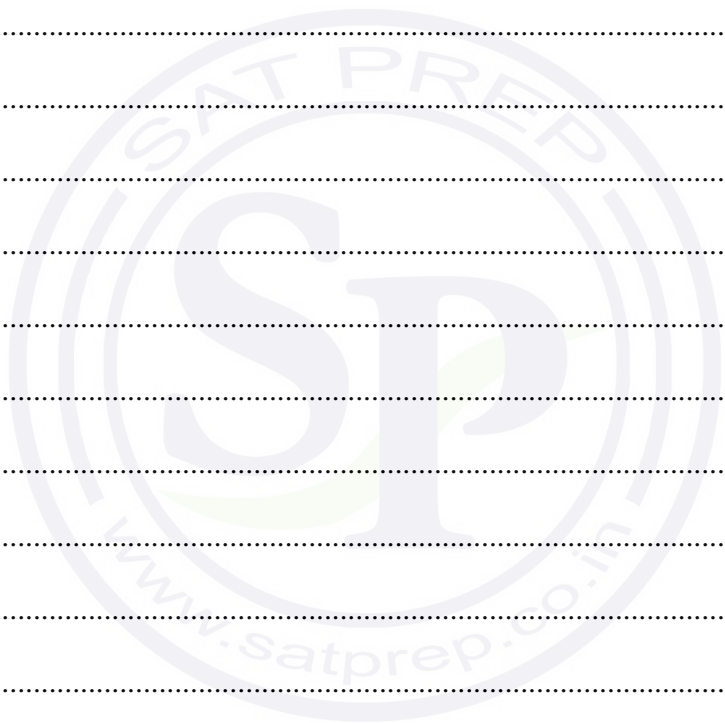
$$v = 0.6t^2 - 0.12t^3.$$

- (i) Show that the distance OP is 6.25 m. [5]

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It is given that the particle passes point P with velocity 1.25 m s^{-1} at time $t = 5$.

(ii) Find the values of the constants k and c . [5]

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MATHEMATICS

9709/42

Paper 4 Mechanics 1 (M1)

October/November 2019

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: List of Formulae (MF9)

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- 1** A particle moves in a straight line. The displacement of the particle at time t s is s m, where

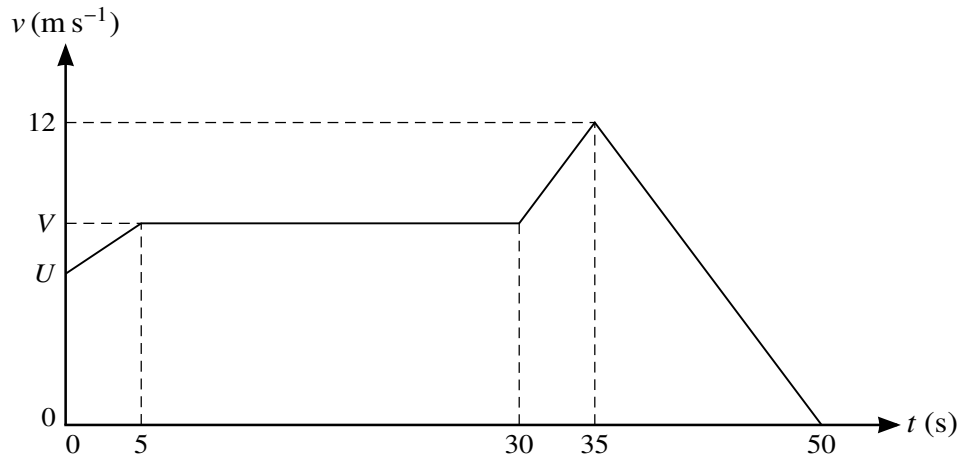
$$s = t^3 - 6t^2 + 4t.$$

Find the velocity of the particle at the instant when its acceleration is zero.

[4]

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2



The diagram shows a velocity-time graph which models the motion of a tractor. The graph consists of four straight line segments. The tractor passes a point O at time $t = 0$ with speed $U \text{ m s}^{-1}$. The tractor accelerates to a speed of $V \text{ m s}^{-1}$ over a period of 5 s, and then travels at this speed for a further 25 s. The tractor then accelerates to a speed of 12 m s^{-1} over a period of 5 s. The tractor then decelerates to rest over a period of 15 s.

- (i) Given that the acceleration of the tractor between $t = 30$ and $t = 35$ is 0.8 m s^{-2} , find the value of V . [2]

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- (ii) Given also that the total distance covered by the tractor in the 50 seconds of motion is 375 m, find the value of U . [3]

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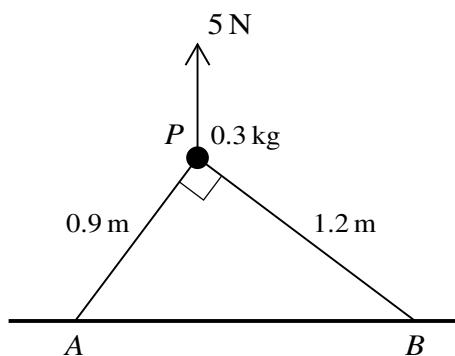
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[5]

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- 4 A lorry of mass 25 000 kg travels along a straight horizontal road. There is a constant force of 3000 N resisting the motion.

(i) Find the power required to maintain a constant speed of 30 m s^{-1} . [2]

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The lorry comes to a straight hill inclined at 2° to the horizontal. The driver switches off the engine of the lorry at the point *A* which is at the foot of the hill. Point *B* is further up the hill. The speeds of the lorry at *A* and *B* are 30 m s^{-1} and 25 m s^{-1} respectively. The resistance force is still 3000 N.

(ii) Use an energy method to find the height of *B* above the level of *A*. [5]

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- (i) Find the height above the ground at which the two particles collide. [4]

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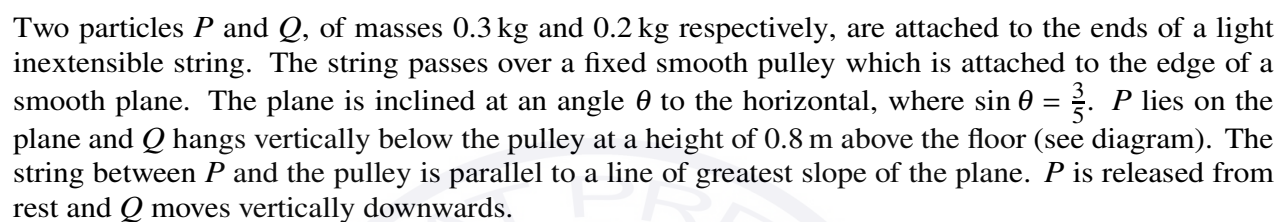
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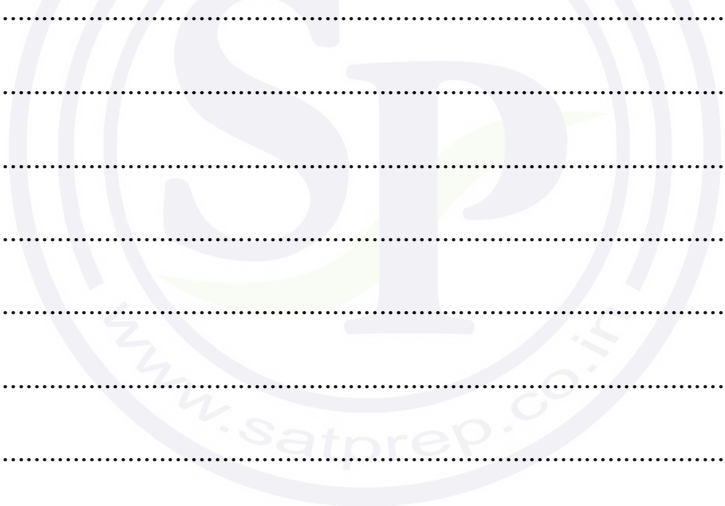
- (i) Find the magnitude of the frictional force on the block. [4]



- [illegible]

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(ii) Find the time, from the instant at which P is released, for Q to reach the floor. [2]

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MATHEMATICS

9709/43

Paper 4 Mechanics 1 (M1)

October/November 2019

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: List of Formulae (MF9)

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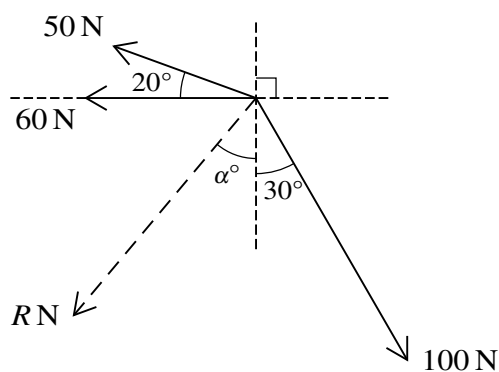


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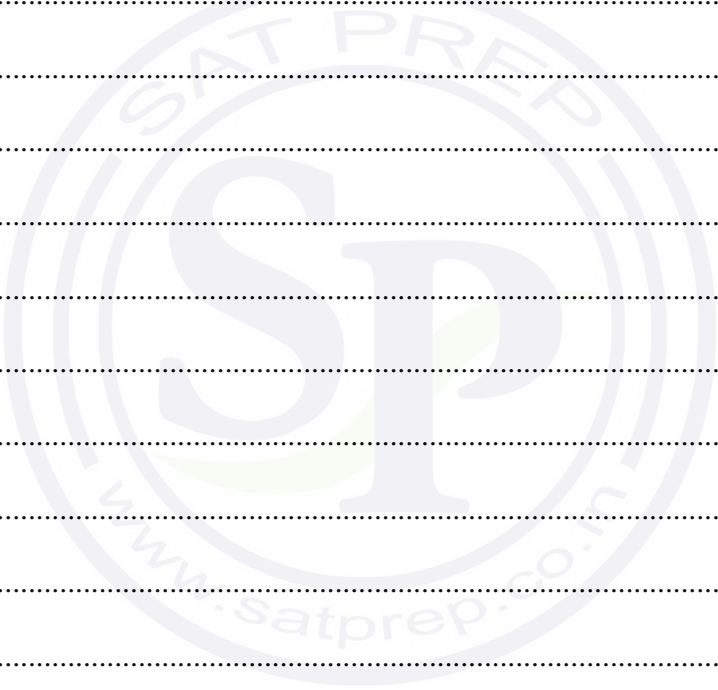


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Three coplanar forces of magnitudes 50 N, 60 N and 100 N act at a point. The resultant of the forces has magnitude R N. The directions of these forces are shown in the diagram. Find the values of R and α . [6]

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- (i) Show that the acceleration of the car is 0.8 m s^{-2} . [3]

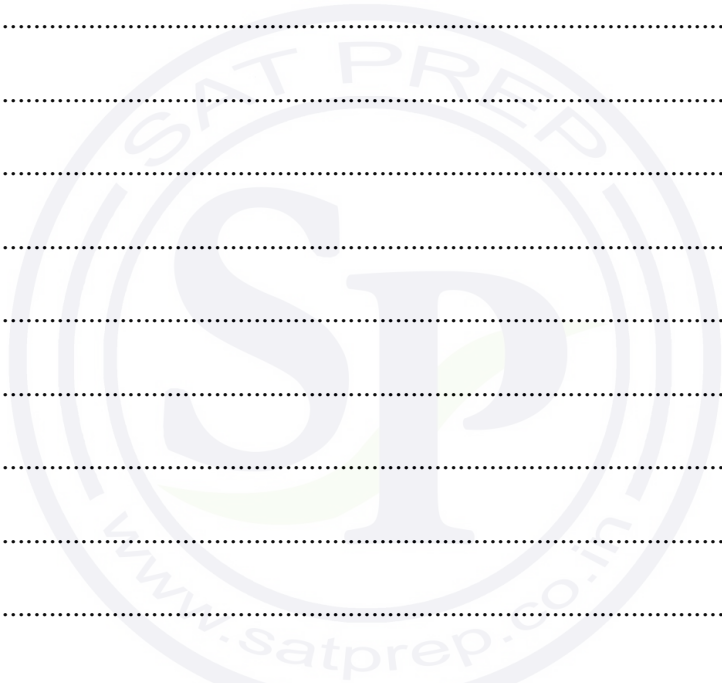
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- (i) Show that the resistance to the cyclist's motion is 16 N. [3]



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- (iii) The cyclist later ascends a straight hill inclined at 3° to the horizontal. His power output and the resistance force are still both unchanged. Find his acceleration when he is travelling at 4 m s^{-1} . [3]

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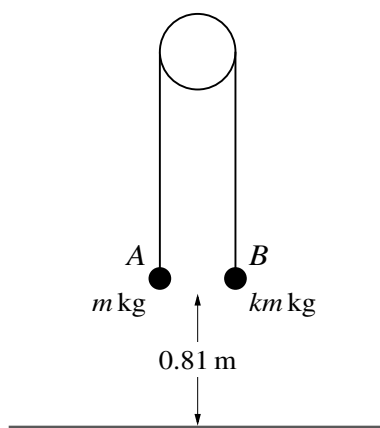
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- (i) Find the values of the constants c and k . [6]

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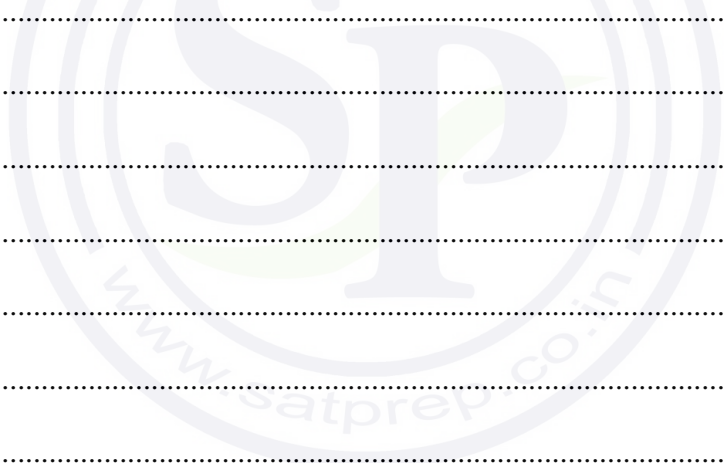
(ii) Show that the acceleration of P is a minimum when $t = 2.5$.

[3]



Two particles A and B have masses m kg and km kg respectively, where $k > 1$. 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 0.81 m above horizontal ground (see diagram). The system is released from rest and particle B reaches the ground 0.9 s later. The particle A does not reach the pulley in its subsequent motion.

- (i) Find the value of k and show that the tension in the string before B reaches the ground is equal to $12m\text{ N}$. [7]



(ii) Show that the speed of *A* when it reaches the ground is 5.97 m s^{-1} , correct to 3 significant figures, and find the time taken, after the string breaks, for *A* to reach the ground. [4]

(iii) Sketch a velocity-time graph for the motion of particle *A* from the instant when the system is released until *A* reaches the ground. [2]

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9709/41

Paper 4 Mechanics 1 (M1)

May/June 2019

1 hour 15 minutes

Candidates answer on the Question Paper.

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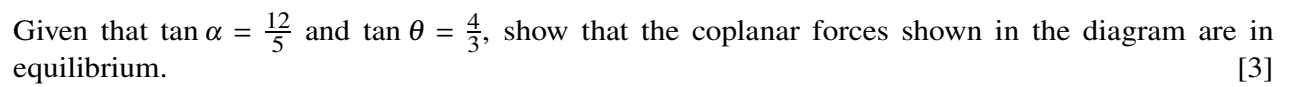
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- 2 A particle P is projected vertically upwards with speed 25 m s^{-1} from a point 3 m above horizontal ground.

(i) Find the time taken for P to reach its greatest height. [2]

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(ii) Find the length of time for which P is higher than 23 m above the ground. [3]

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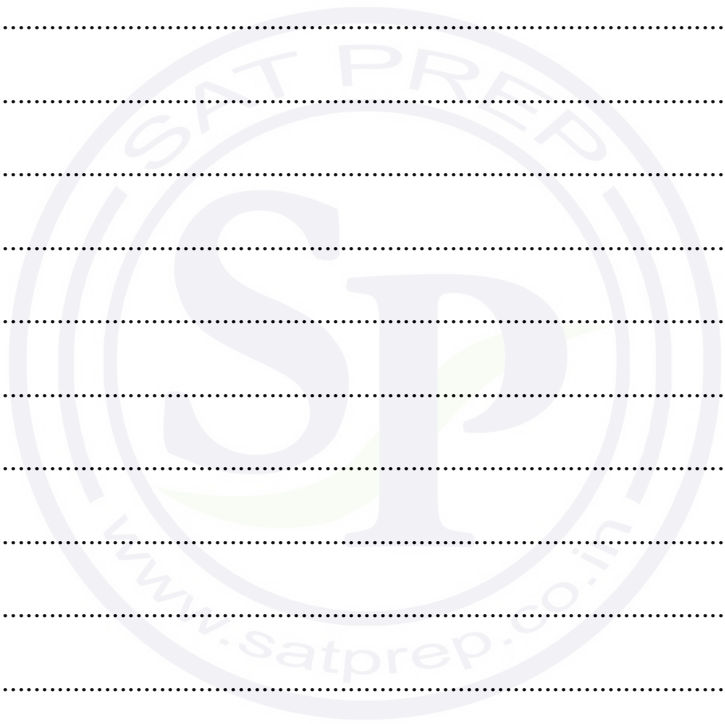
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(iii) P is higher than h m above the ground for 1 second. Find h .

[2]

3 A lorry has mass 12 000 kg.

- (i) The lorry moves at a constant speed of 5 m s^{-1} up a hill inclined at an angle of θ to the horizontal, where $\sin \theta = 0.08$. At this speed, the magnitude of the resistance to motion on the lorry is 1500 N . Show that the power of the lorry's engine is 55.5 kW . [3]

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When the speed of the lorry is $v \text{ m s}^{-1}$ the magnitude of the resistance to motion is $kv^2 \text{ N}$, where k is a constant.

- (ii) Show that $k = 60$. [1]

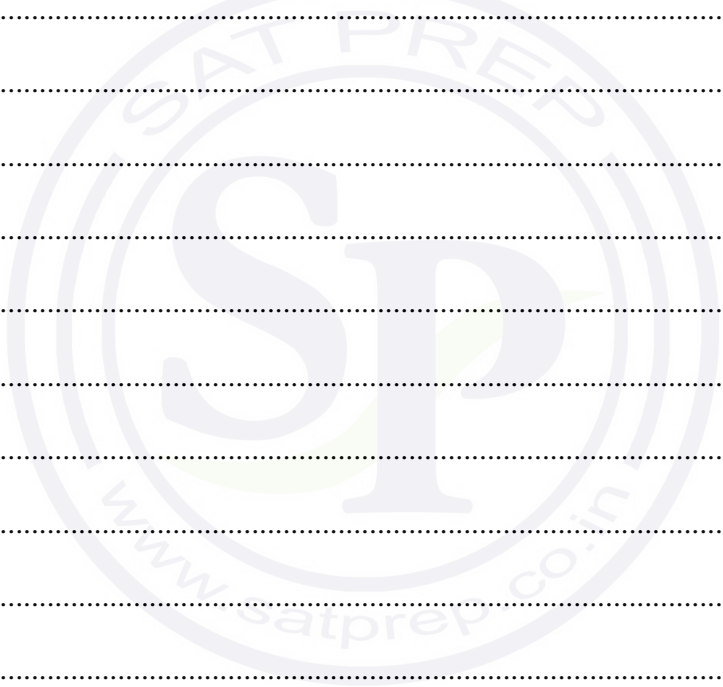
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- (iii)** The lorry now moves at a constant speed on a straight level road. Given that its engine is still working at 55.5 kW, find the lorry's speed. [3]

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The force of magnitude 20 N is now removed.

(ii) Find the acceleration of the particle. [2]

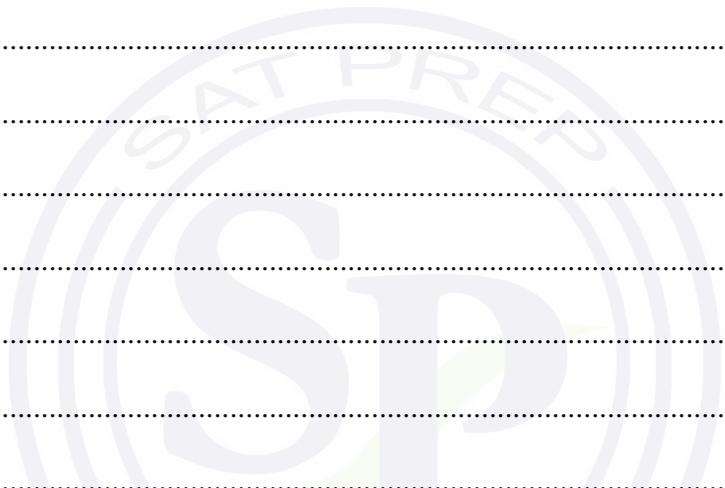
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(iii) Find the work done against friction during the first 2 s of motion. [3]

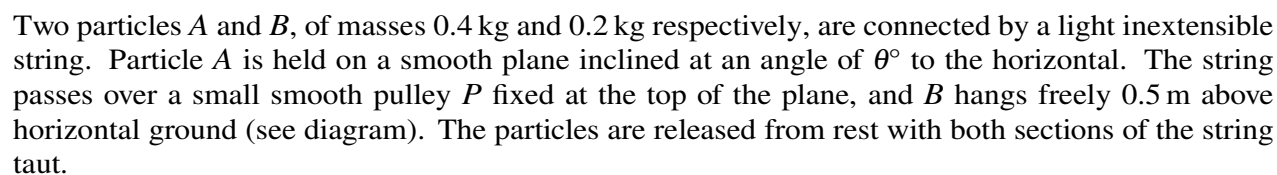


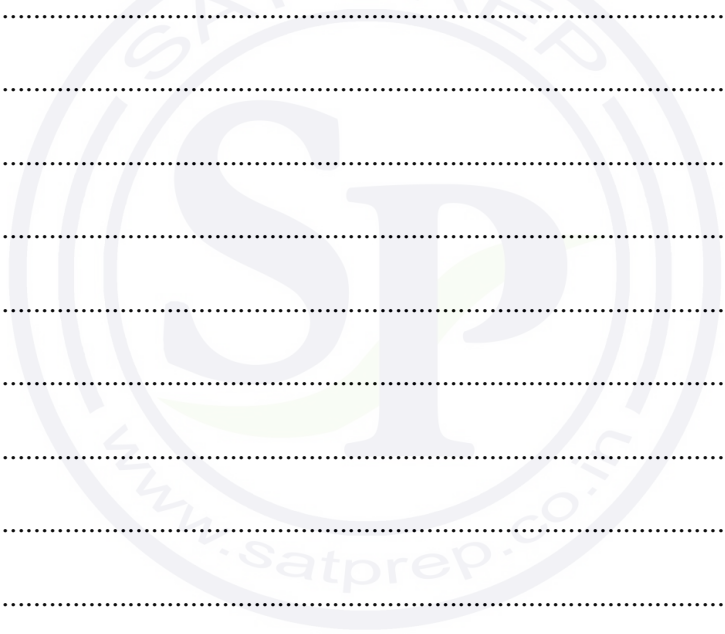
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- (i) Find the minimum velocity of P . [3]

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- (a) Find the tension in the string and the acceleration of the system. [4]

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- [illegible]

[Question 6 continues on the next page.]

- (c) Use an energy method to find the total distance A moves up the plane before coming to instantaneous rest. [5]

[illegible]

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9709/42

Paper 4 Mechanics 1 (M1)

May/June 2019

1 hour 15 minutes

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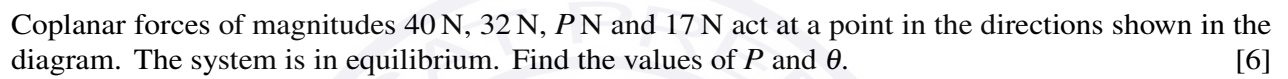
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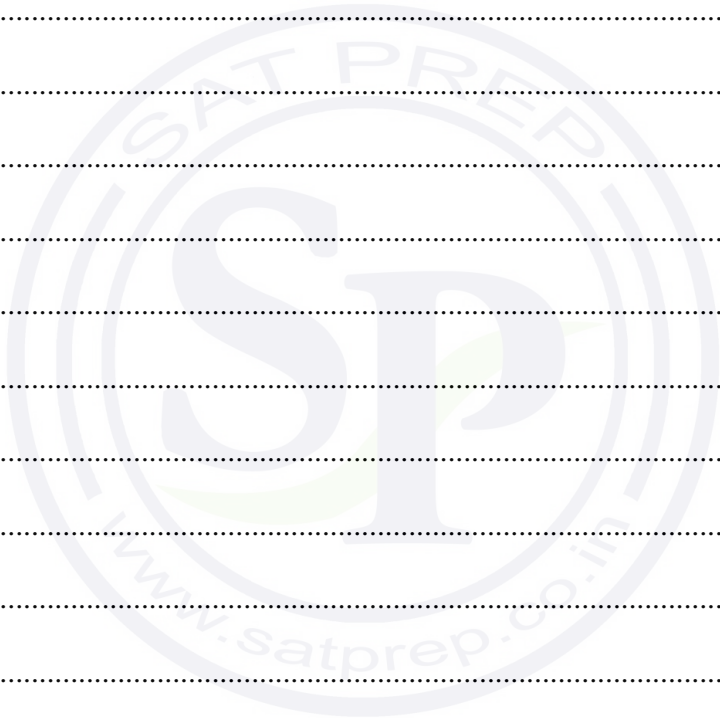


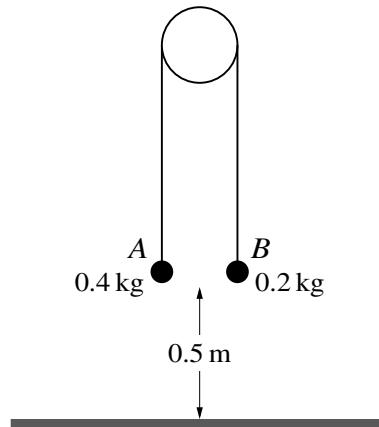


- 2** A car moves in a straight line with initial speed $u \text{ m s}^{-1}$ and constant acceleration $a \text{ m s}^{-2}$. The car takes 5 s to travel the first 80 m and it takes 8 s to travel the first 160 m. Find a and u . [6]

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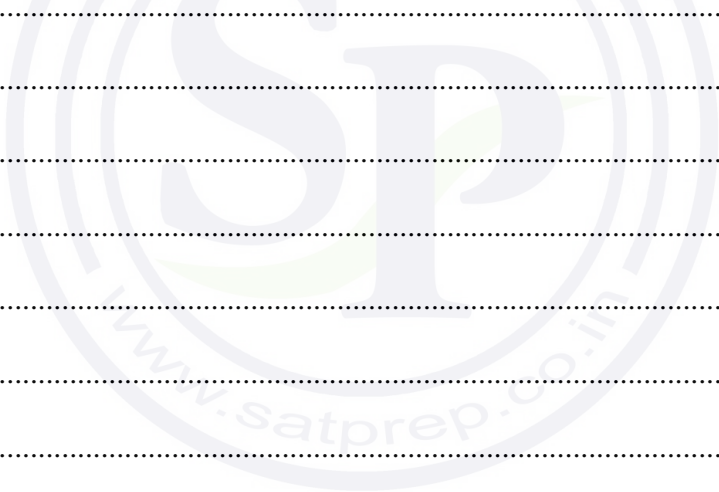
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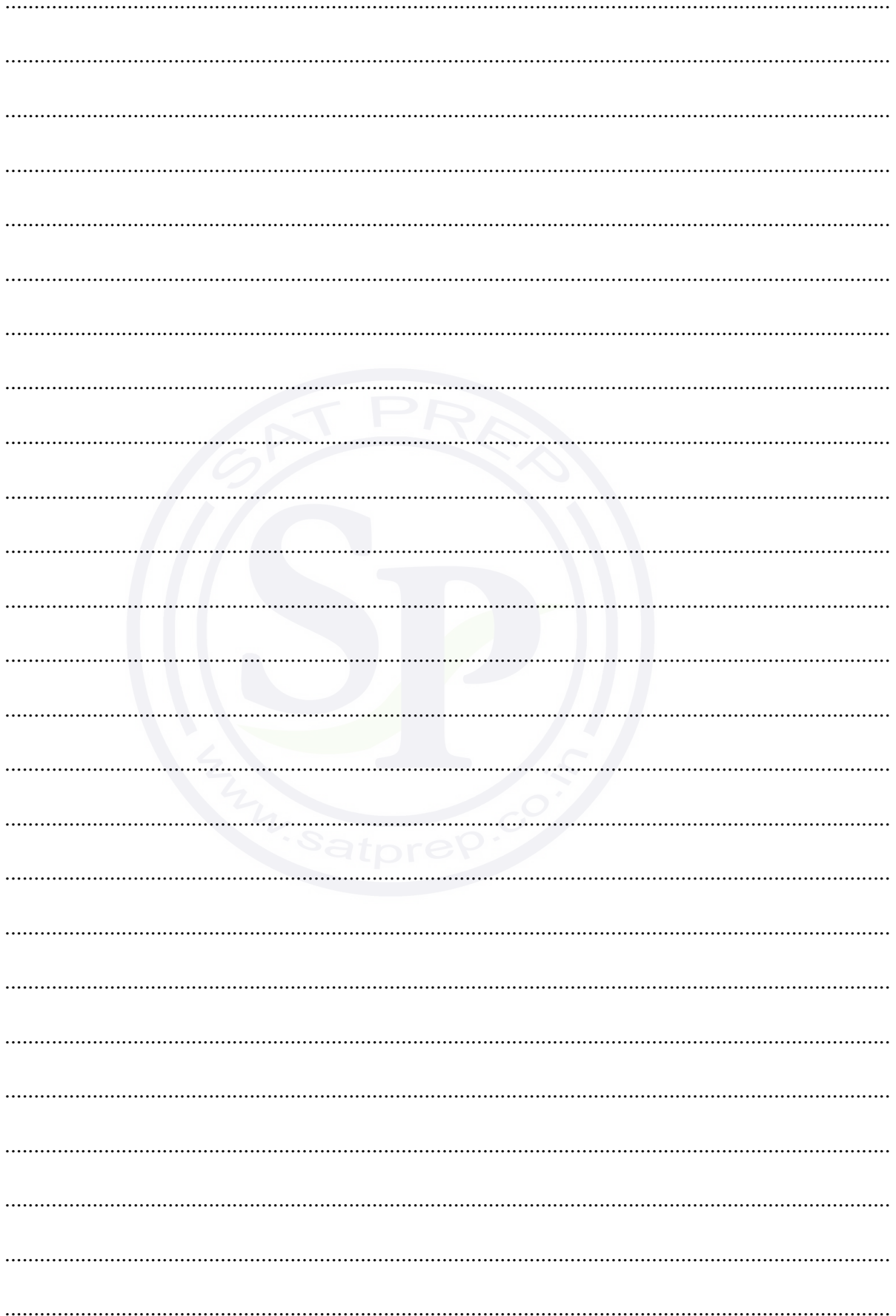


Two particles A and B , of masses 0.4 kg and 0.2 kg respectively, are connected by a light inextensible string which passes over a fixed smooth pulley. Both A and B are 0.5 m above the ground. The particles hang vertically (see diagram). The particles are released from rest. In the subsequent motion B does not reach the pulley and A remains at rest after reaching the ground.

- (i) For the motion before A reaches the ground, show that the magnitude of the acceleration of each particle is $\frac{10}{3} \text{ m s}^{-2}$ and find the tension in the string. [4]



[4]



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- 7 Particles P and Q leave a fixed point A at the same time and travel in the same straight line. The velocity of P after t seconds is $6t(t - 3) \text{ m s}^{-1}$ and the velocity of Q after t seconds is $(10 - 2t) \text{ m s}^{-1}$.

(i) Sketch, on the same axes, velocity-time graphs for P and Q for $0 \leq t \leq 5$. [3]

(ii) Verify that P and Q meet after 5 seconds. [4]

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[4]

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MATHEMATICS

9709/43

Paper 4 Mechanics 1 (**M1**)

May/June 2019

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: List of Formulae (MF9)

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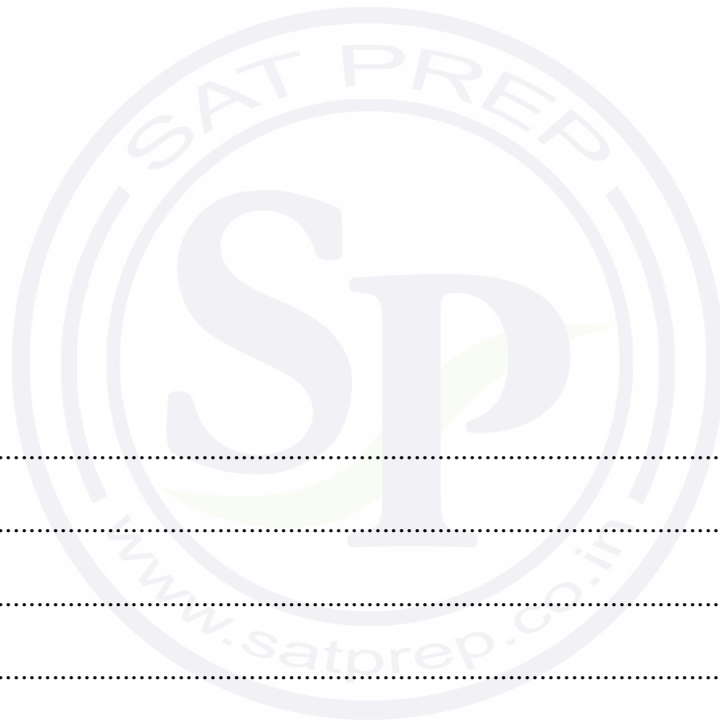
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- 1 A bus moves in a straight line between two bus stops. The bus starts from rest and accelerates at 2.1 m s^{-2} for 5 s. The bus then travels for 24 s at constant speed and finally slows down, with a constant deceleration, stopping in a further 6 s. Sketch a velocity-time graph for the motion and hence find the distance between the two bus stops. [5]



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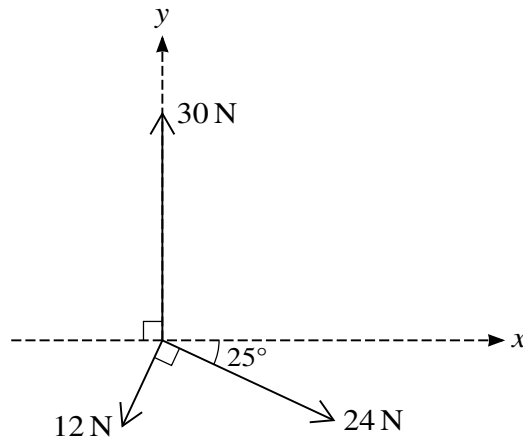
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Coplanar forces of magnitudes 12 N, 24 N and 30 N act at a point in the directions shown in the diagram.

- (i) Find the components of the resultant of the three forces in the x -direction and in the y -direction. [4]

Component in x -direction.....

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Component in y -direction.....

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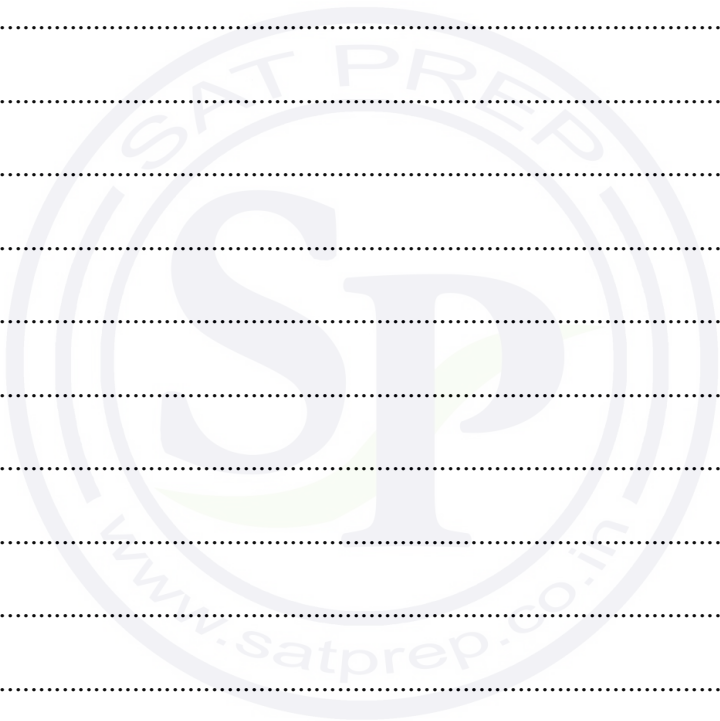
- (ii) Hence find the direction of the resultant. [2]

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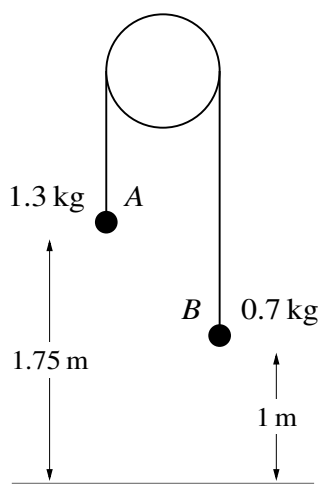
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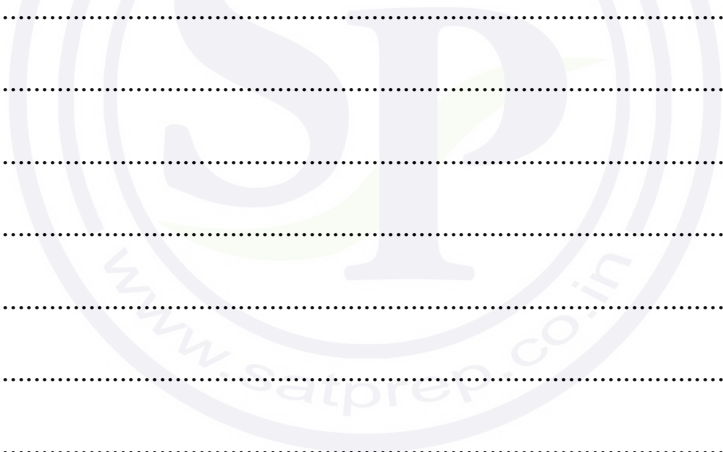
- (ii) The greatest possible constant speed at which the car can travel up the hill is 40 m s^{-1} . Find the maximum possible power of the engine. [3]

[illegible]



Two particles A and B , of masses 1.3 kg and 0.7 kg respectively, are connected by a light inextensible string which passes over a smooth fixed pulley. Particle A is 1.75 m above the floor and particle B is 1 m above the floor (see diagram). The system is released from rest with the string taut, and the particles move vertically. When the particles are at the same height the string breaks.

- (i) Show that, before the string breaks, the magnitude of the acceleration of each particle is 3 m s^{-2} and find the tension in the string. [4]



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- 5 A particle of mass 18 kg is on a plane inclined at an angle of 30° to the horizontal. The particle is projected up a line of greatest slope of the plane with a speed of 20 m s^{-1} .

- (i) Given that the plane is smooth, use an energy method to find the distance the particle moves up the plane before coming to instantaneous rest. [4]

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- (ii) Given instead that the plane is rough and the coefficient of friction between the particle and the plane is 0.25, find the speed of the particle as it returns to its starting point. [8]

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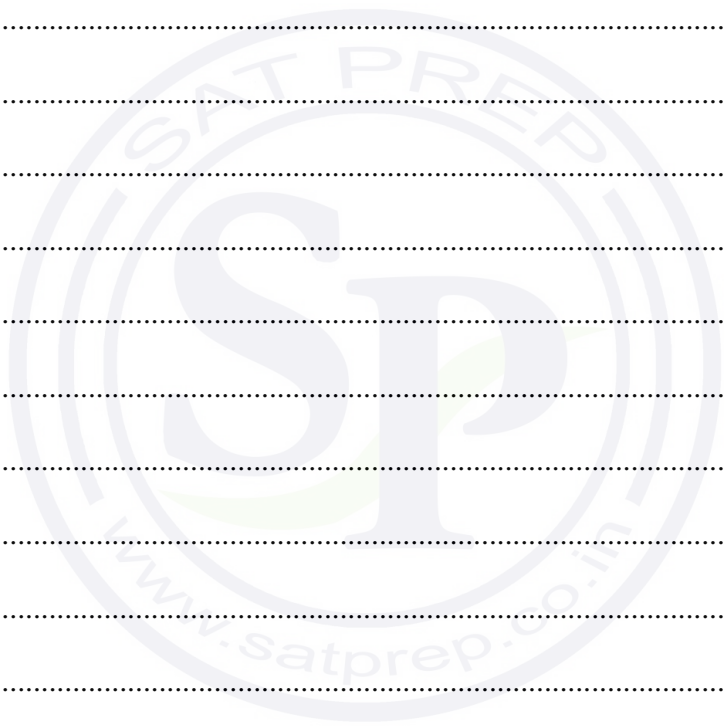
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- (i) Show that $s = t^3 - 6t^2 + pt + q$, where p and q are constants to be found. [4]

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- (ii) Find the values of t when P is at instantaneous rest. [2]

[illegible]

- (iii) Find the total distance travelled by P in the interval $0 \leq t \leq 4$. [4]

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MATHEMATICS

9709/42

Paper 4 Mechanics 1 (**M1**)

February/March 2019

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: List of Formulae (MF9)

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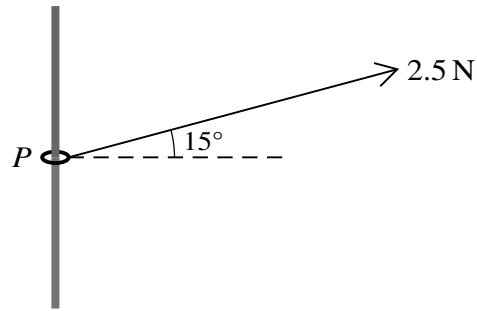
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A small ring P of mass 0.03 kg is threaded on a rough vertical rod. A light inextensible string is attached to the ring and is pulled upwards at an angle of 15° to the horizontal. The tension in the string is 2.5 N (see diagram). The ring is in limiting equilibrium and on the point of sliding up the rod. Find the coefficient of friction between the ring and the rod. [4]

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2 A particle is projected vertically upwards with speed 30 m s^{-1} from a point on horizontal ground.

- (i) Show that the maximum height above the ground reached by the particle is 45 m. [2]

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- (ii) Find the time that it takes for the particle to reach a height of 33.75 m above the ground for the first time. Find also the speed of the particle at this time. [4]

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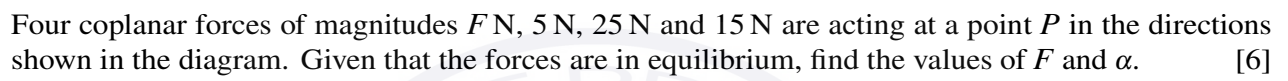
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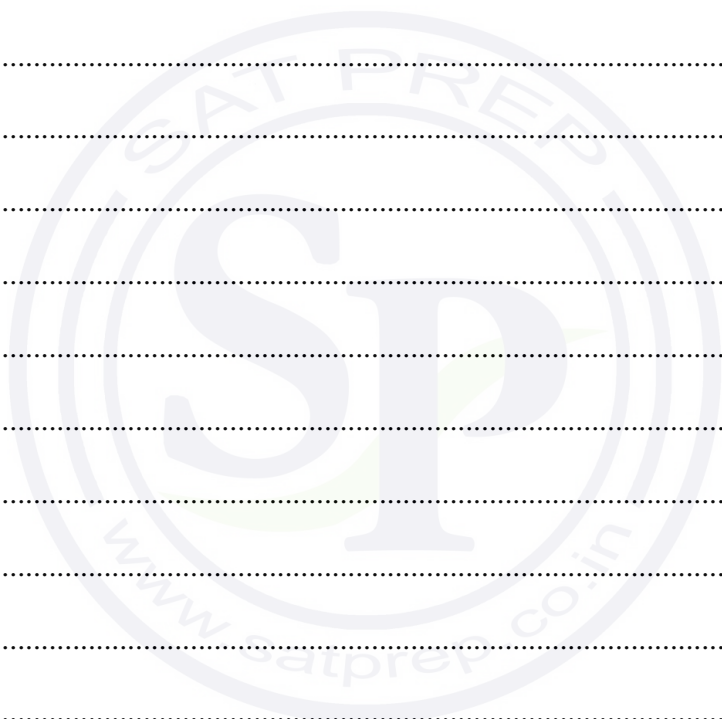
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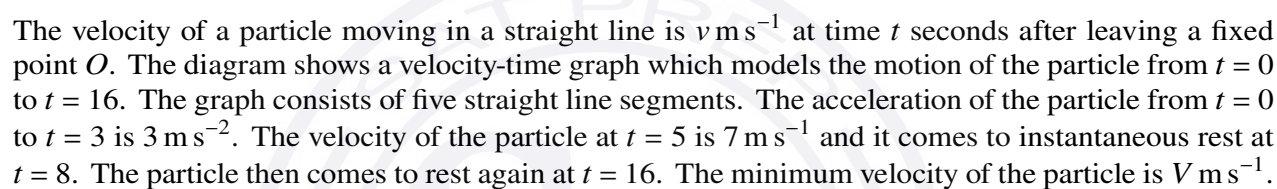
- 4 A car of mass 1500 kg is pulling a trailer of mass 300 kg along a straight horizontal road at a constant speed of 20 m s^{-1} . The system of the car and trailer is modelled as two particles, connected by a light rigid horizontal rod. The power of the car's engine is 6000 W. There are constant resistances to motion of $R \text{ N}$ on the car and 80 N on the trailer.

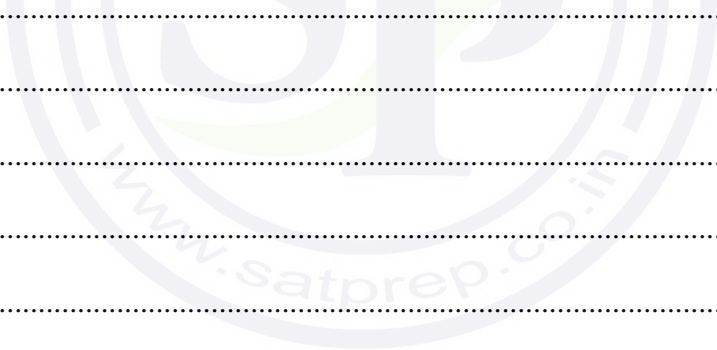
(i) Find the value of R .

[2]

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- (ii) Given that when the particle comes to rest at $t = 16$ its displacement from O is 32 m, find the value of V . [4]

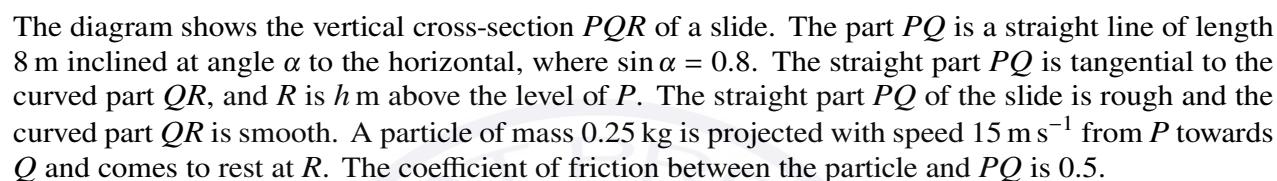
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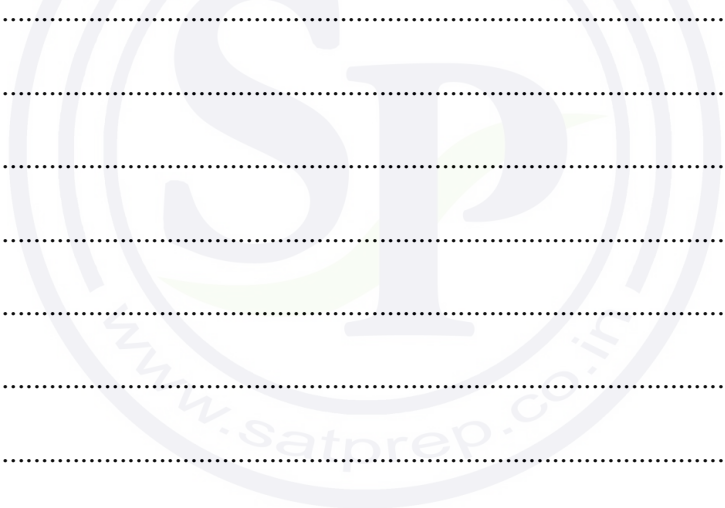
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- (ii)** Find the displacement of the particle from O at $t = 5$.

[3]

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(ii) Hence find the speed of the particle at Q .

[4]

[illegible]

(iii) Find the value of h .

[3]

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MATHEMATICS

9709/41

Paper 4 Mechanics 1 (**M1**)

October/November 2018

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: List of Formulae (MF9)

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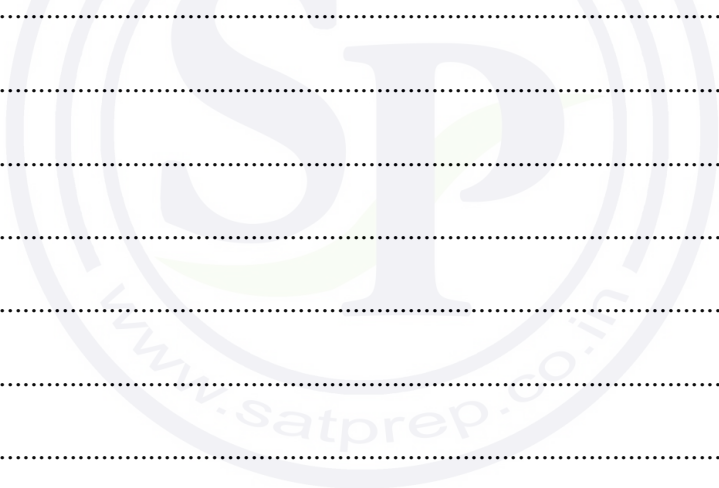
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- (i) Show that the resistance force is 48 000 N. [1]

(ii) The train comes to a hill inclined at an angle θ° above the horizontal, where $\sin \theta^\circ = \frac{1}{200}$. Given that the resistance force is unchanged, find the power required for the train to keep moving at the same constant speed of 85 m s^{-1} . [3]



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- 4 Two particles A and B , of masses m kg and 0.3 kg respectively, are attached to the ends of a light inextensible string. The string passes over a fixed smooth pulley and the particles hang freely below it. The system is released from rest, with both particles 0.8 m above horizontal ground. Particle A reaches the ground with a speed of 0.6 m s^{-1} .

(i) Find the tension in the string during the motion before A reaches the ground. [4]

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(ii) Find the value of m . [2]

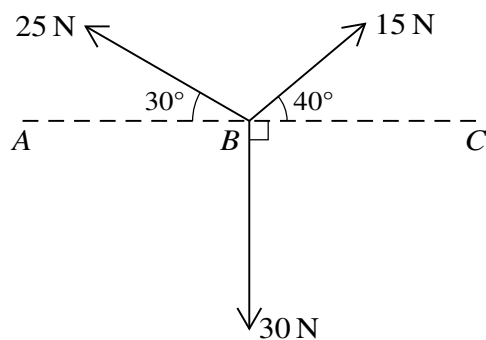
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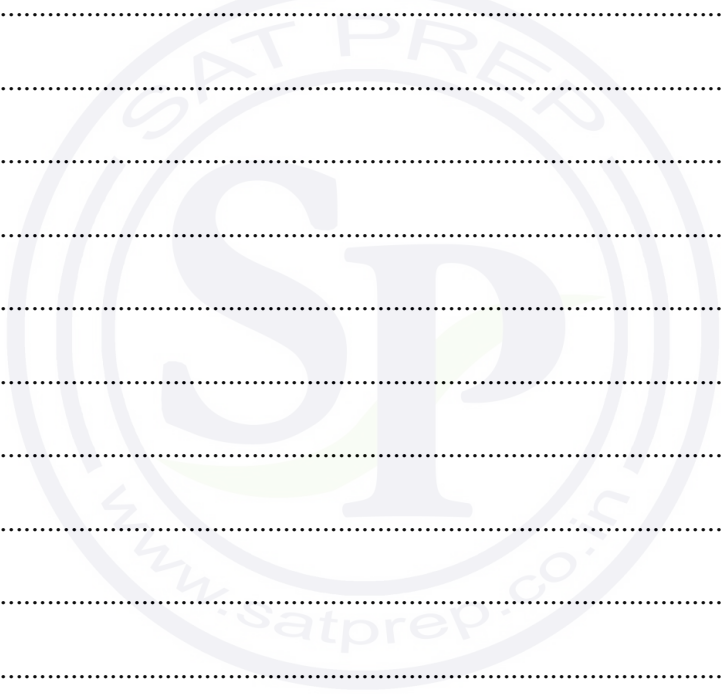
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(i) Find the magnitude and direction of the resultant force. [6]

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- (ii) The force of magnitude 15 N is now replaced by a force of magnitude F N acting in the same direction. The new resultant force has zero component in the direction BC . Find the value of F , and find also the magnitude and direction of the new resultant force. [3]

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- (i) Show that the deceleration of the particle is $\frac{2}{3} \text{ m s}^{-2}$ and hence find u , giving your answer as an exact fraction. [6]

[illegible]

- 7 A particle moves in a straight line starting from rest from a point O . The acceleration of the particle at time t s after leaving O is $a \text{ m s}^{-2}$, where

$$a = 5.4 - 1.62t.$$

- (i) Find the positive value of t at which the velocity of the particle is zero, giving your answer as an exact fraction. [4]

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- (ii) Find the velocity of the particle at $t = 10$ and sketch the velocity-time graph for the first ten seconds of the motion. [3]

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Paper 4 Mechanics 1 (**M1**)

October/November 2018

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: List of Formulae (MF9)

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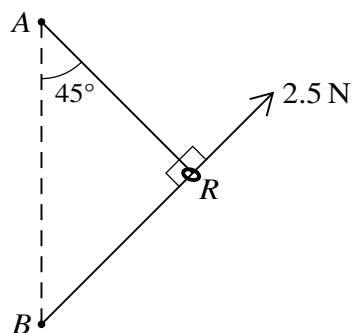
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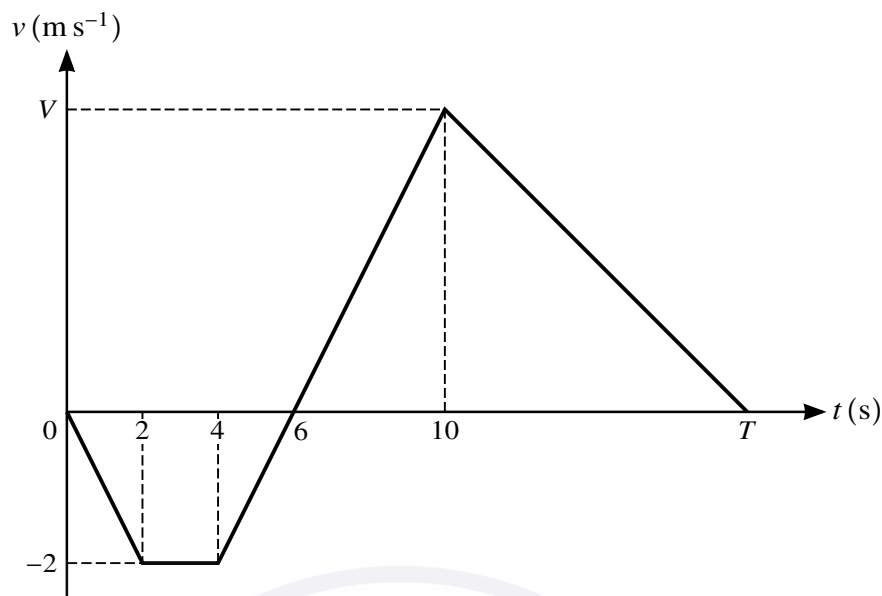


[4]

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3



The velocity of a particle moving in a straight line is $v \text{ m s}^{-1}$ at time t seconds. The diagram shows a velocity-time graph which models the motion of the particle from $t = 0$ to $t = T$. The graph consists of four straight line segments. The particle reaches its maximum velocity $V \text{ m s}^{-1}$ at $t = 10$.

- (i) Find the acceleration of the particle during the first 2 seconds.

[1]

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- (ii) Find the value of V .

[2]

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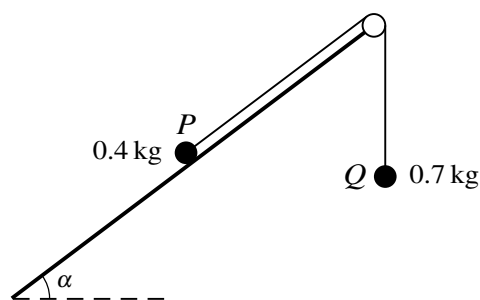
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At $t = 6$, the particle is instantaneously at rest at the point A . At $t = T$, the particle comes to rest at the point B . At $t = 0$ the particle starts from rest at a point one third of the way from A to B .

(iii) Find the distance AB and hence find the value of T . [4]



(i) Show that the greatest value of X for which P remains stationary is 6.2. [4]

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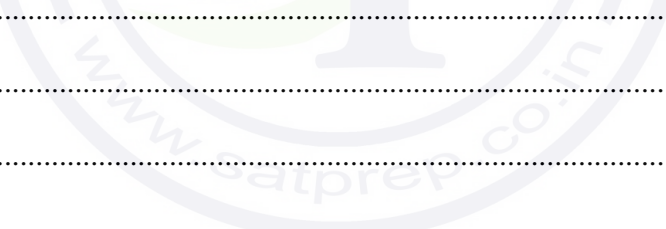
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- (i) At time T s after leaving O the particle reaches its maximum velocity. Find the value of T . [2]

[illegible]

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- (i) Find the power of the car's engine. [1]

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(ii) The car starts to descend the hill with reduced power and with an acceleration of 0.12 m s^{-2} . Given that there is no change in the resistance force, find the new power of the car's engine at the instant when it starts to descend the hill. [3]

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- 7 A particle of mass 0.3 kg is released from rest above a tank containing water. The particle falls vertically, taking 0.8 s to reach the water surface. There is no instantaneous change of speed when the particle enters the water. The depth of water in the tank is 1.25 m . The water exerts a force on the particle resisting its motion. The work done against this resistance force from the instant that the particle enters the water until it reaches the bottom of the tank is 1.2 J .

(i) Use an energy method to find the speed of the particle when it reaches the bottom of the tank.

[4]

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When the particle reaches the bottom of the tank, it bounces back vertically upwards with initial speed 7 m s^{-1} . As the particle rises through the water, it experiences a constant resistance force of 1.8 N . The particle comes to instantaneous rest t seconds after it bounces on the bottom of the tank.

(ii) Find the value of t .

[7]

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9709/43

Paper 4 Mechanics 1 (**M1**)

October/November 2018

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: List of Formulae (MF9)

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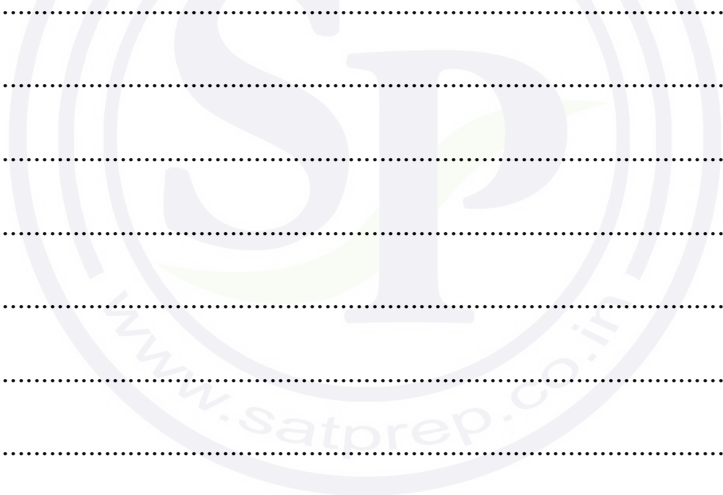
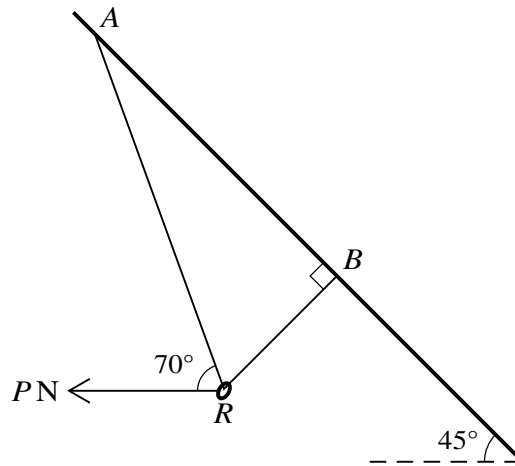
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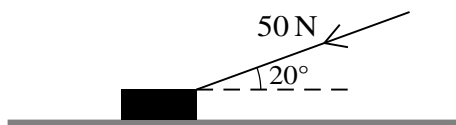
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A block is pushed along a horizontal floor by a force of magnitude 50 N which acts at an angle of 20° to the horizontal (see diagram). The coefficient of friction between the block and the floor is 0.3. Given that the speed of the block is constant, find the mass of the block. [5]

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- 3** A particle of mass 1.2 kg moves in a straight line AB . It is projected with speed 7.5 m s^{-1} from A towards B and experiences a resistance force. The work done against this resistance force in moving from A to B is 25 J .

(i) Given that AB is horizontal, find the speed of the particle at B . [2]

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(ii) It is given instead that AB is inclined at 30° below the horizontal and that the speed of the particle at B is 9 m s^{-1} . The work done against the resistance force remains the same. Find the distance AB . [3]

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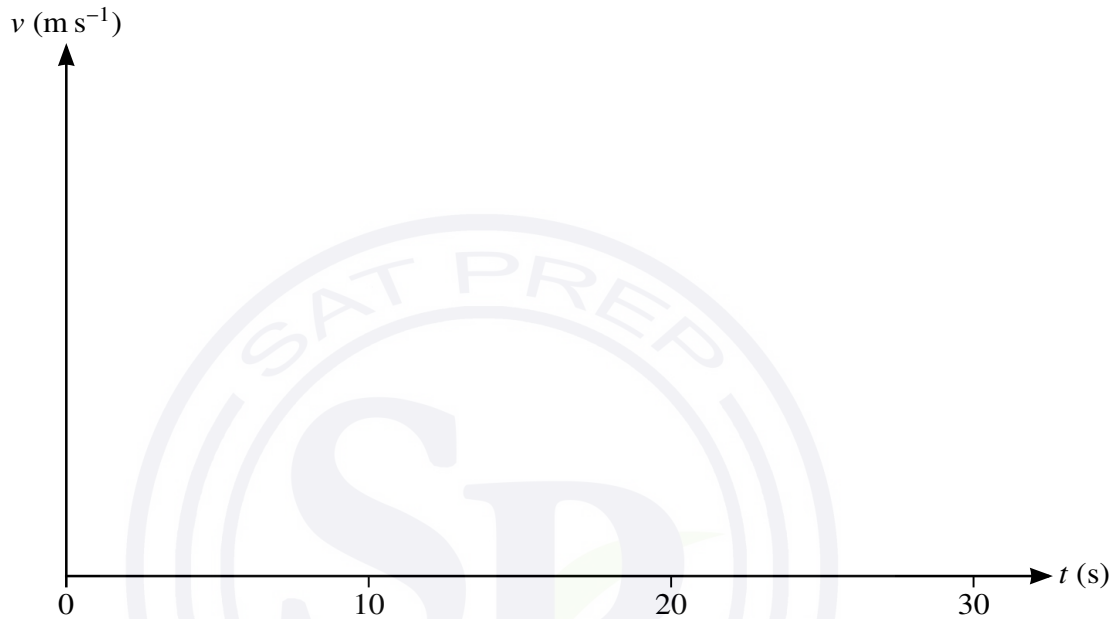
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- 4 A runner sets off from a point P at time $t = 0$, where t is in seconds. The runner starts from rest and accelerates at 1.2 m s^{-2} for 5 s. For the next 12 s the runner moves at constant speed before decelerating uniformly over a period of 3 s, coming to rest at Q . A cyclist sets off from P at time $t = 10$ and accelerates uniformly for 10 s, before immediately decelerating uniformly to rest at Q at time $t = 30$.

- (i) Sketch the velocity-time graph for the runner and show that the distance PQ is 96 m. [4]



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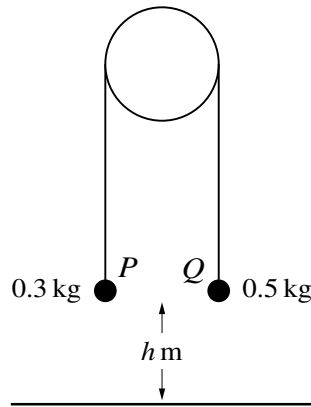
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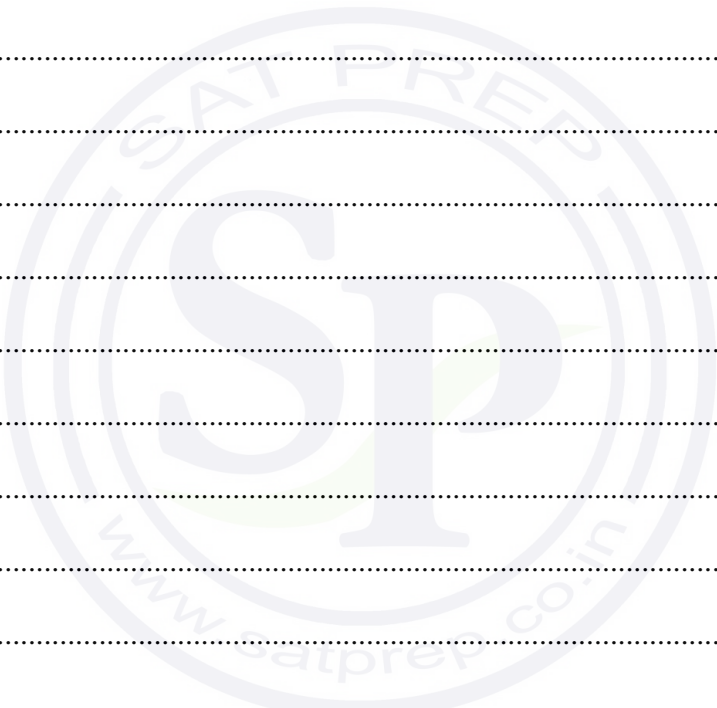
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Two particles P and Q , of masses 0.3 kg and 0.5 kg respectively, are attached to the ends of a light inextensible string. The string passes over a fixed smooth pulley with the particles hanging freely below it. Q is held at rest with the string taut at a height of $h\text{ m}$ above a horizontal floor (see diagram). Q is now released and both particles start to move. The pulley is sufficiently high so that P does not reach it at any stage. The time taken for Q to reach the floor is 0.6 s .

- (i) Find the acceleration of Q before it reaches the floor and hence find the value of h . [6]

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- 6** A van of mass 3200 kg travels along a horizontal road. The power of the van's engine is constant and equal to 36 kW, and there is a constant resistance to motion acting on the van.

(i) When the speed of the van is 20 m s^{-1} , its acceleration is 0.2 m s^{-2} . Find the resistance force.

[3]

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When the van is travelling at 30 m s^{-1} , it begins to ascend a hill inclined at 1.5° to the horizontal. The power is increased and the resistance force is still equal to the value found in part (i).

(ii) Find the power required to maintain this speed of 30 m s^{-1} .

[3]

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- (iii) The engine is now stopped, with the van still travelling at 30 m s^{-1} , and the van decelerates to rest. Find the distance the van moves up the hill from the point at which the engine is stopped until it comes to rest. [4]

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- 7 A particle moves in a straight line. The particle is initially at rest at a point O on the line. At time t s after leaving O , the acceleration $a \text{ m s}^{-2}$ of the particle is given by $a = 25 - t^2$ for $0 \leq t \leq 9$.

(i) Find the maximum velocity of the particle in this time period. [4]

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(ii) Find the total distance travelled until the maximum velocity is reached. [2]

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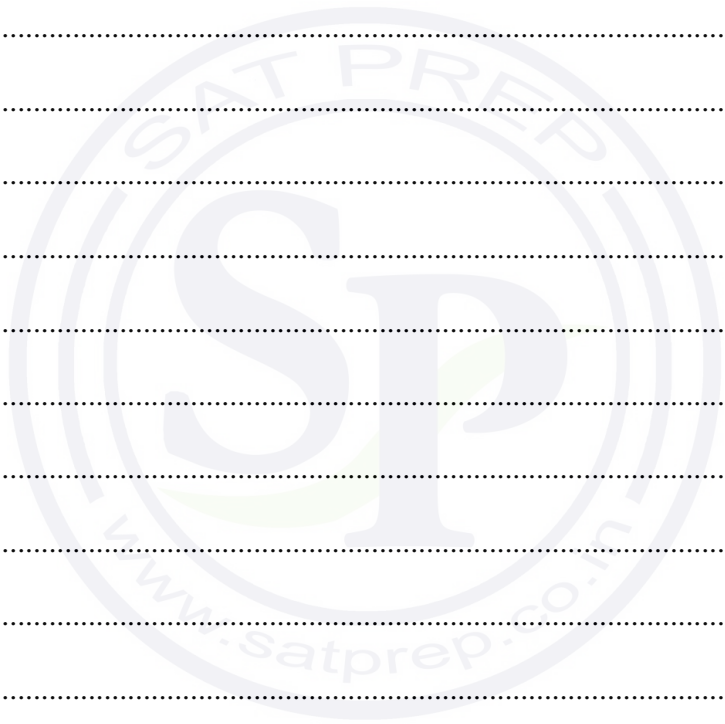
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The acceleration of the particle for $t > 9$ is given by $a = -3t^{-\frac{1}{2}}$.

- (iii) Find the velocity of the particle when $t = 25$. [4]

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MATHEMATICS

9709/41

Paper 4 Mechanics 1 (**M1**)

May/June 2018

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: List of Formulae (MF9)

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

The use of an electronic calculator is expected, where appropriate.

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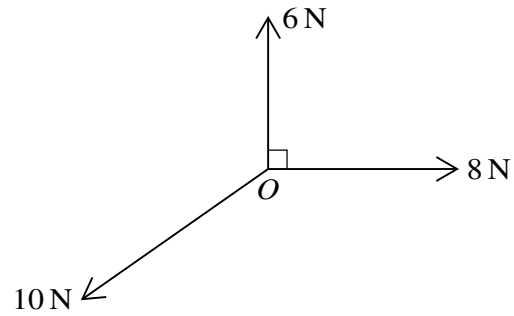
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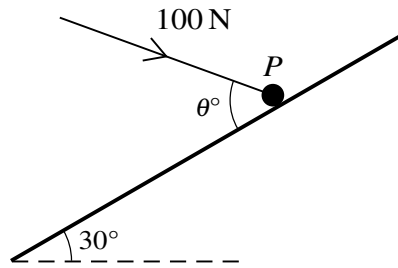
- 1** A particle P is projected vertically upwards with speed 24 m s^{-1} from a point 5 m above ground level. Find the time from projection until P reaches the ground. [3]

[illegible]



The diagram shows three coplanar forces acting at the point O . The magnitudes of the forces are 6 N, 8 N and 10 N. The angle between the 6 N force and the 8 N force is 90° . The forces are in equilibrium. Find the other angles between the forces. [4]

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A particle P of mass 8 kg is on a smooth plane inclined at an angle of 30° to the horizontal. A force of magnitude 100 N , making an angle of θ° with a line of greatest slope and lying in the vertical plane containing the line of greatest slope, acts on P (see diagram).

- (i) Given that P is in equilibrium, show that $\theta = 66.4$, correct to 1 decimal place, and find the normal reaction between the plane and P . [4]

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- (ii) Given instead that $\theta = 30$, find the acceleration of P .

[2]

- 4 A particle P moves in a straight line starting from a point O . At time t s after leaving O , the displacement s m from O is given by $s = t^3 - 4t^2 + 4t$ and the velocity is $v \text{ m s}^{-1}$.

(i) Find an expression for v in terms of t .

[2]

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(ii) Find the two values of t for which P is at instantaneous rest.

[2]

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(iii) Find the minimum velocity of P .

[3]

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- 5 A sprinter runs a race of 200 m. His total time for running the race is 20 s. He starts from rest and accelerates uniformly for 6 s, reaching a speed of 12 m s^{-1} . He maintains this speed for the next 10 s, before decelerating uniformly to cross the finishing line with speed $V \text{ m s}^{-1}$.

- (i) Find the distance travelled by the sprinter in the first 16 s of the race. Hence sketch a displacement-time graph for the 20 s of the sprinter's race. [6]

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displacement (m)

200

0

0

20

time (s)

(ii) Find the value of V .

[2]

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6 A car has mass 1250 kg.

- (i) The car is moving along a straight level road at a constant speed of 36 m s^{-1} and is subject to a constant resistance of magnitude 850 N. Find, in kW, the rate at which the engine of the car is working. [2]

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- (ii) The car travels at a constant speed up a hill and is subject to the same resistance as in part (i). The hill is inclined at an angle of θ° to the horizontal, where $\sin \theta^\circ = 0.1$, and the engine is working at 63 kW. Find the speed of the car. [3]

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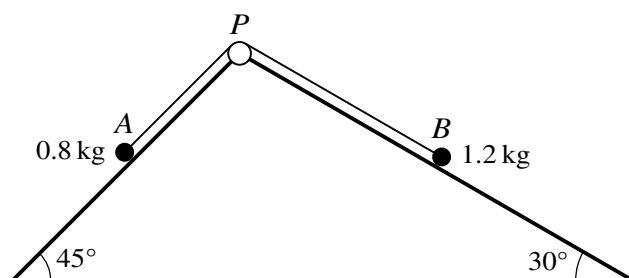
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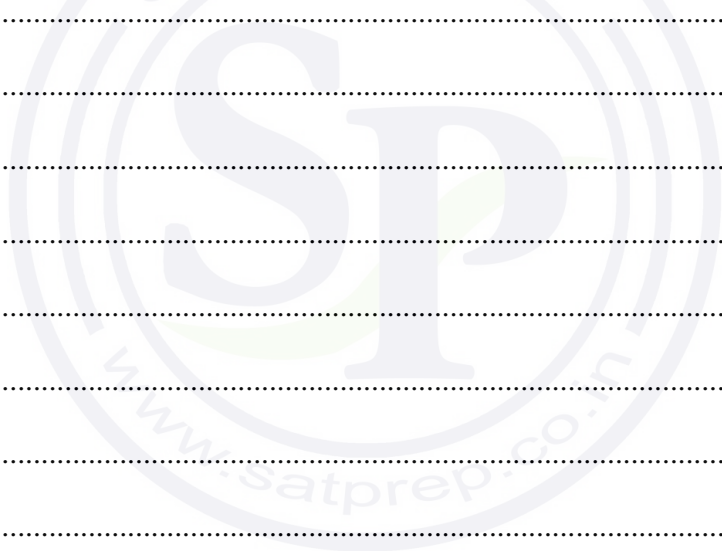
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The diagram shows a triangular block with sloping faces inclined to the horizontal at 45° and 30° . Particle A of mass 0.8 kg lies on the face inclined at 45° and particle B of mass 1.2 kg lies on the face inclined at 30° . The particles are connected by a light inextensible string which passes over a small smooth pulley P fixed at the top of the faces. The parts AP and BP of the string are parallel to lines of greatest slope of the respective faces. The particles are released from rest with both parts of the string taut. In the subsequent motion neither particle reaches the pulley and neither particle reaches the bottom of a face.

- (i) Given that both faces are smooth, find the speed of A after each particle has travelled a distance of 0.4 m. [6]



- (ii) It is given instead that both faces are rough. The coefficient of friction between each particle and a face of the block is μ . Find the value of μ for which the system is in limiting equilibrium. [6]

[illegible]

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MATHEMATICS

9709/42

Paper 4 Mechanics 1 (**M1**)

May/June 2018

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: List of Formulae (MF9)

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

The use of an electronic calculator is expected, where appropriate.

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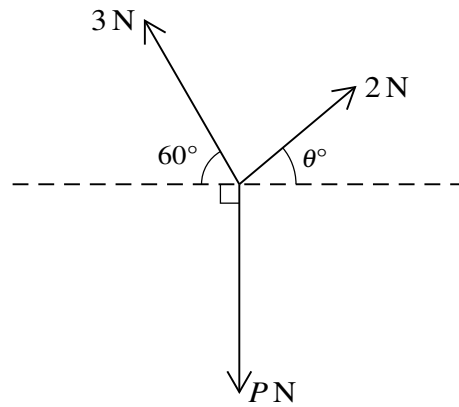
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- 2 A train of mass 240 000 kg travels up a slope inclined at an angle of 4° to the horizontal. There is a constant resistance of magnitude 18 000 N acting on the train. At an instant when the speed of the train is 15 m s^{-1} its deceleration is 0.2 m s^{-2} . Find the power of the engine of the train. [4]

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The three coplanar forces shown in the diagram have magnitudes 3 N, 2 N and P N. Given that the three forces are in equilibrium, find the values of θ and P . [4]

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- (i) Show that the acceleration of P is 3 m s^{-2} and find the speed of P at A . [6]

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- (ii) P reaches D with a speed of 61 m s^{-1} . Find the distance CD .

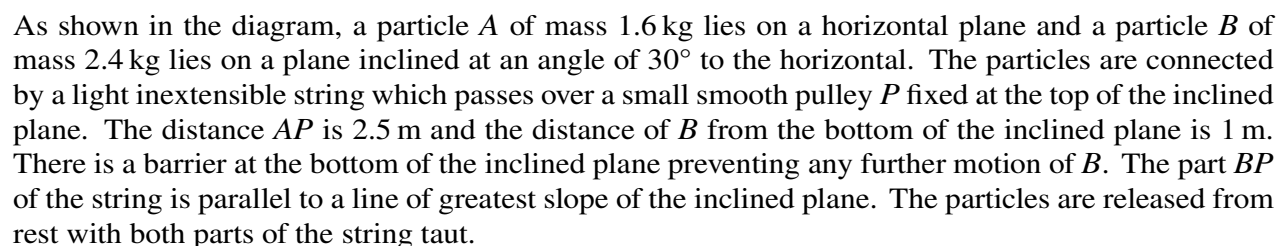
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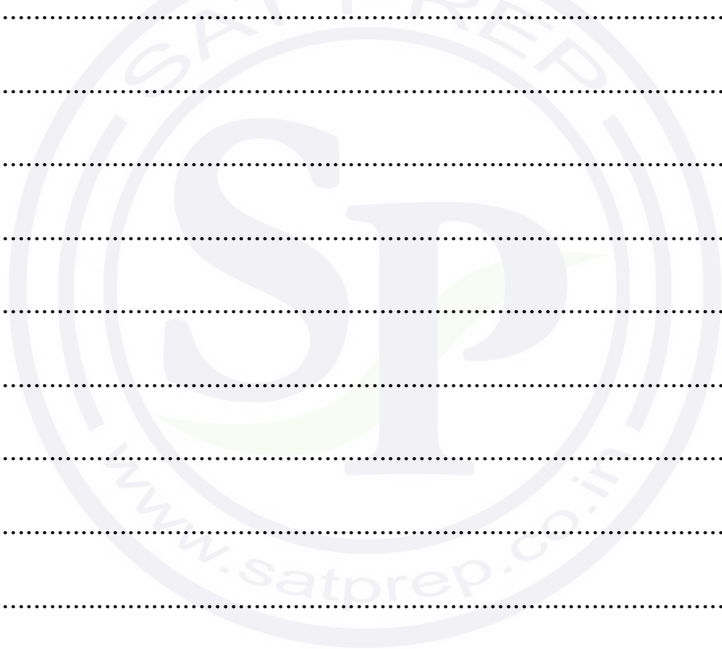
- 5 A particle of mass 20 kg is on a rough plane inclined at an angle of 60° to the horizontal. Equilibrium is maintained by a force of magnitude P N acting on the particle, in a direction parallel to a line of greatest slope of the plane. The greatest possible value of P is twice the least possible value of P . Find the value of the coefficient of friction between the particle and the plane. [7]

- (i) Find the value of t at which the particle is again at instantaneous rest. [5]



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- (ii) It is given instead that the horizontal plane is rough and that the coefficient of friction between A and the horizontal plane is 0.2. The inclined plane is smooth. Find the total distance travelled by A. [9]

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9709/43

Paper 4 Mechanics 1 (**M1**)

May/June 2018

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: List of Formulae (MF9)

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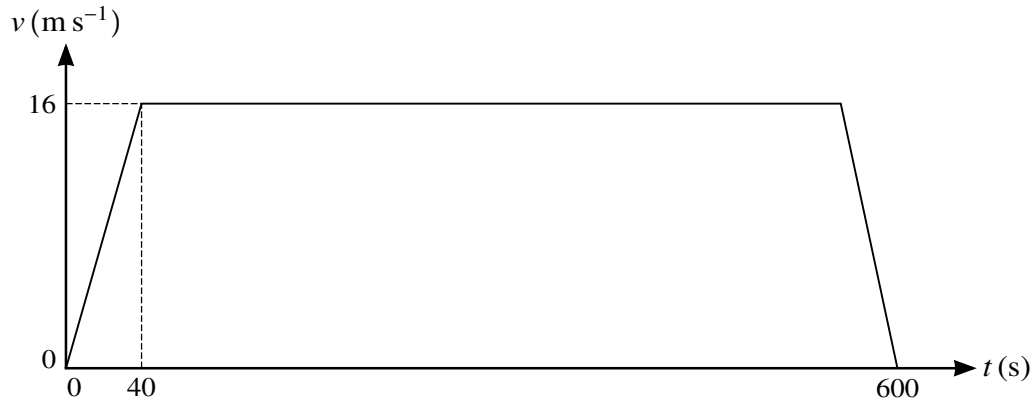
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1



The diagram shows the velocity-time graph for a train which travels from rest at one station to rest at the next station. The graph consists of three straight line segments. The distance between the two stations is 9040 m.

- (i) Find the acceleration of the train during the first 40 s. [1]

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- (ii) Find the length of time for which the train is travelling at constant speed. [2]

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- (iii) Find the distance travelled by the train while it is decelerating. [2]

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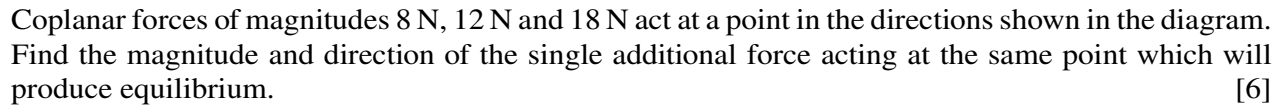
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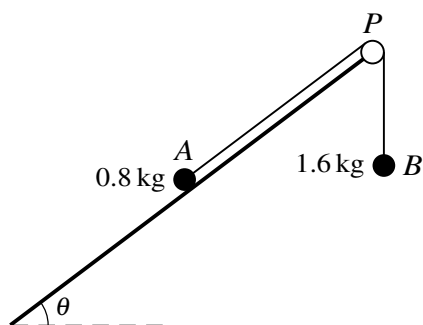
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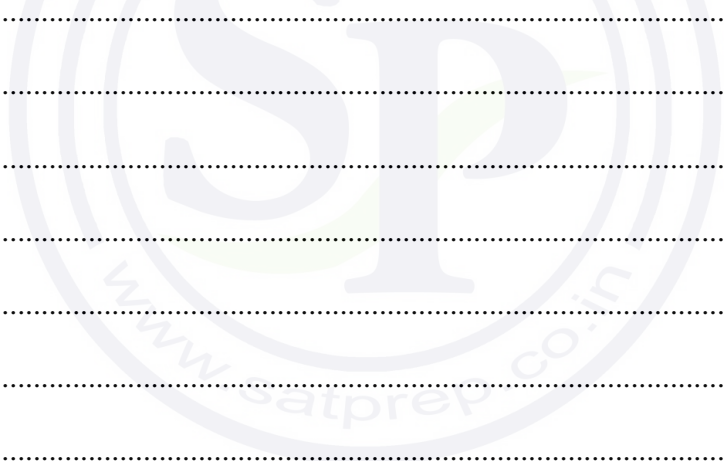
[6]

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- (i) Find, in kW, the greatest possible power of the car's engine. [2]

[illegible]

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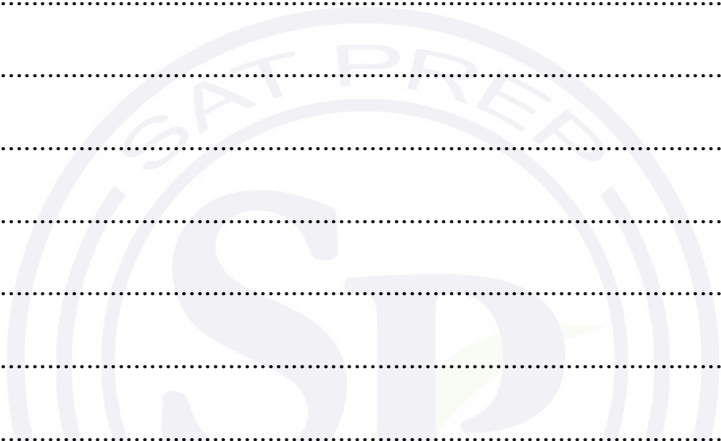
- (iii)** The car travels down a hill inclined at an angle of θ° to the horizontal at a constant speed of 50 m s^{-1} . The power of the car's engine is 60 kW . Find the value of θ . [4]

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

$$v = 12t - 4t^2 \quad \text{for } 0 \leq t \leq 2,$$

$$v = 16 - 4t \quad \text{for } 2 \leq t \leq 4.$$

- (i) Find the maximum velocity of P during the first 2 s. [3]



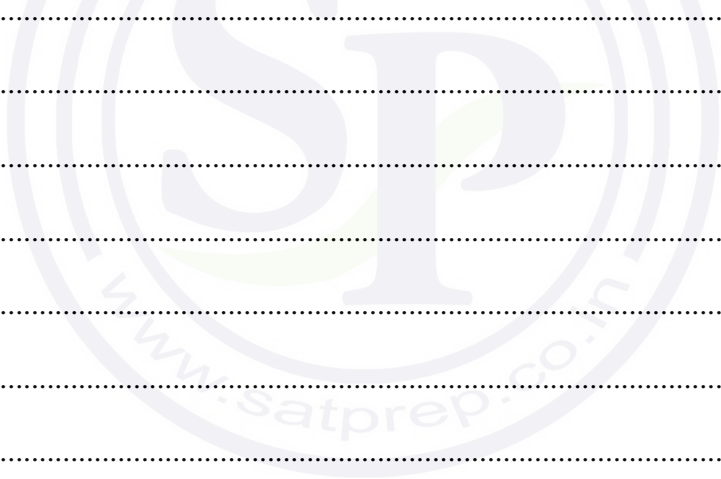
- (ii)** Determine, with justification, whether there is any instantaneous change in the acceleration of P when $t = 2$. [2]

Handwriting practice lines with a dotted midline and a dashed baseline. A faint watermark logo is visible in the background.

A blank velocity-time graph. The vertical axis is labeled $v \text{ (m s}^{-1}\text{)}$ and the horizontal axis is labeled $t \text{ (s)}$. The horizontal axis has tick marks at 0, 2, and 4. The graph area is shaded light blue.

- (iv)** Find the distance travelled by P in the interval $0 \leq t \leq 4$.

[5]



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MATHEMATICS

9709/42

Paper 4 Mechanics 1 (M1)

February/March 2018

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: List of Formulae (MF9)

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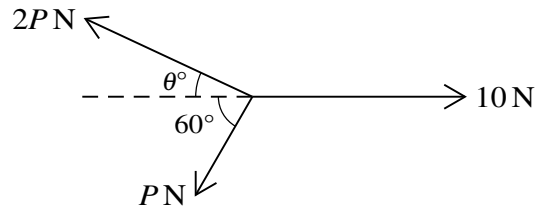
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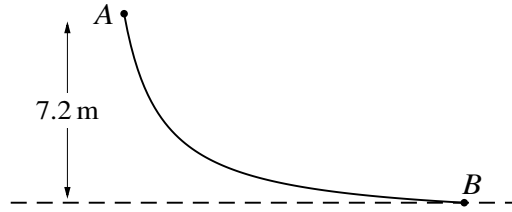
The three coplanar forces shown in the diagram are in equilibrium. Find the values of θ and P . [4]

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3



A girl, of mass 40 kg, slides down a slide in a water park. The girl starts at the point A and slides to the point B which is 7.2 metres vertically below the level of A , as shown in the diagram.

- (i) Given that the slide is smooth and that the girl starts from rest at A , find the speed of the girl at B . [2]

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- (ii) It is given instead that the slide is rough. On one occasion the girl starts from rest at A and reaches B with a speed of 10 m s^{-1} . On another occasion the girl is pushed from A with an initial speed $V \text{ m s}^{-1}$ and reaches B with speed 11 m s^{-1} . Given that the work done against friction is the same on both occasions, find V . [3]

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- [illegible]

- (i) Show that the speed of the rocket after 10 s is 40 m s^{-1} and find the acceleration of the rocket during the first 10 s. [4]



- (ii) After 10 s, the rocket's fuel stops burning and there is no upward force acting on the rocket. Find the maximum height above ground level reached by the rocket. [2]

- (iii) Find the total time from the instant the rocket is fired until it returns to the ground. [4]

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- (i) Find the greatest possible power of the car. [2]

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- (iii) The car travels at a constant speed up a hill inclined at an angle of $\sin^{-1}(\frac{7}{48})$ to the horizontal. Find the greatest possible speed of the car. [5]

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

$$v = 4 + 0.2t \quad \text{for } 0 \leq t \leq 10,$$

$$v = -2 + \frac{800}{t^2} \quad \text{for } 10 \leq t \leq 20.$$

- (i) Find the acceleration of P during the first 10 s. [1]

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- (ii) Find the acceleration of P when $t = 20$. [2]

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- (iii) Sketch the velocity-time graph for $0 \leq t \leq 20$. [3]

[5]

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MATHEMATICS

9709/43

Paper 4 Mechanics 1 (M1)

October/November 2017

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: List of Formulae (MF9)

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Answer **all** the questions.

Give non-exact numerical answers correct to 3 significant figures, or 1 decimal place in the case of angles in degrees, unless a different level of accuracy is specified in the question.

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

The use of an electronic calculator is expected, where appropriate.

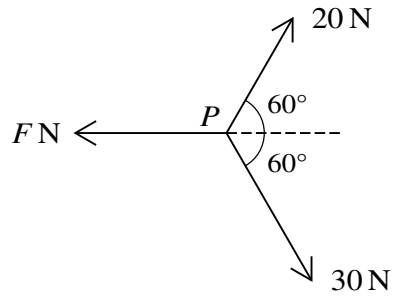
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Three coplanar forces of magnitudes F N, 20 N and 30 N act at a point P , as shown in the diagram. The resultant of the three forces acts in a direction perpendicular to the force of magnitude F N. Find the value of F . [3]

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- 2 A lorry of mass 7850 kg travels on a straight hill which is inclined at an angle of 3° to the horizontal. There is a constant resistance to motion of 1480 N.

(i) Find the power of the lorry's engine when the lorry is going up the hill at a constant speed of 10 m s^{-1} . [3]

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(ii) Find the power of the lorry's engine at an instant when the lorry is going down the hill at a speed of 15 m s^{-1} with an acceleration of 0.8 m s^{-2} . [3]

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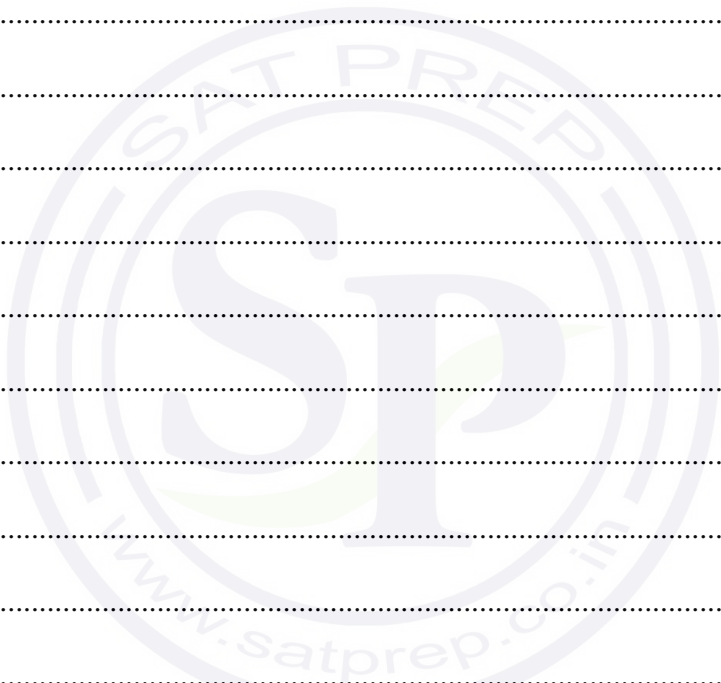
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- (i) Find the acceleration of the particle. [4]

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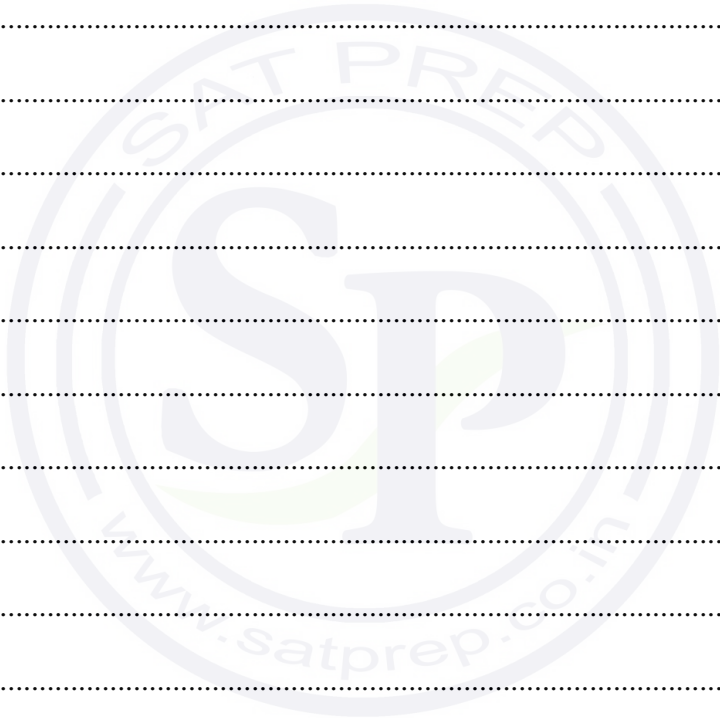
- [illegible]

- (i) Find the speed of A at the instant that B reaches the ground. [5]

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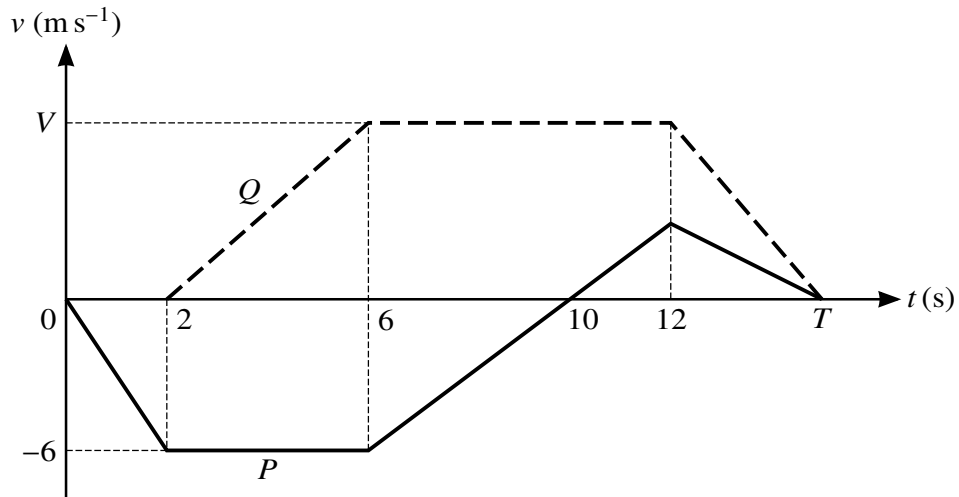
- (i) Show that the value of k is 0.1. [5]

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(iii) Hence verify that the particle is again at the origin at $t = 2$. [1]

[Turn over

6



The diagram shows the velocity-time graphs for two particles, P and Q , which are moving in the same straight line. The graph for P consists of four straight line segments. The graph for Q consists of three straight line segments. Both particles start from the same initial position O on the line. Q starts 2 seconds after P and both particles come to rest at time $t = T$. The greatest velocity of Q is $V \text{ m s}^{-1}$.

- (i) Find the displacement of P from O at $t = 10$. [1]

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- (ii) Find the velocity of P at $t = 12$. [2]

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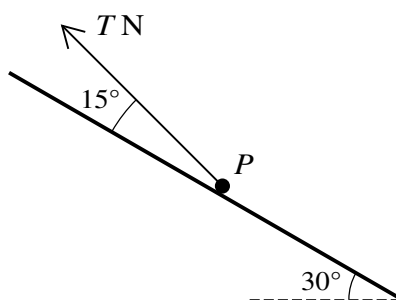
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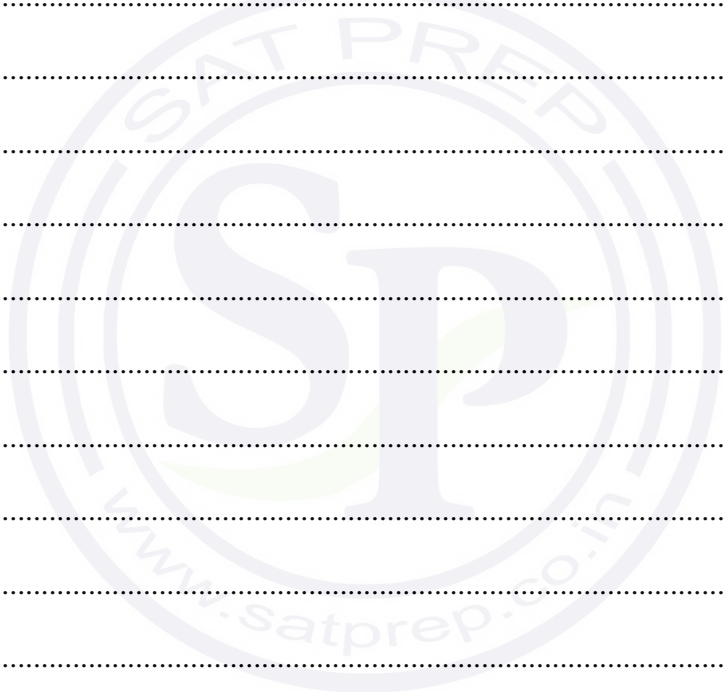
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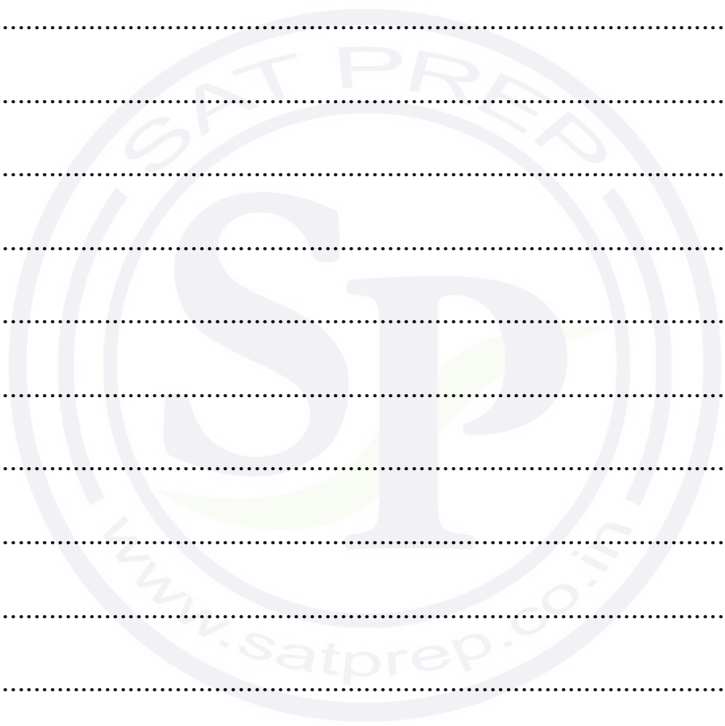
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(i) Find the least value of T for which the particle remains at rest. [6]

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(ii) Use an energy method to find the speed of P at A . [5]

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MATHEMATICS

9709/42

Paper 4 Mechanics 1 (M1)

October/November 2017

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: List of Formulae (MF9)

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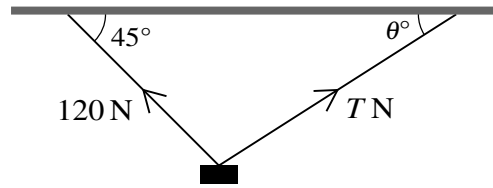
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of friction between the particle and the plane is 0.6. A force of magnitude $10g$ N acts on the particle down a line of greatest slope of the plane. The particle starts from rest and moves down the plane with constant acceleration.

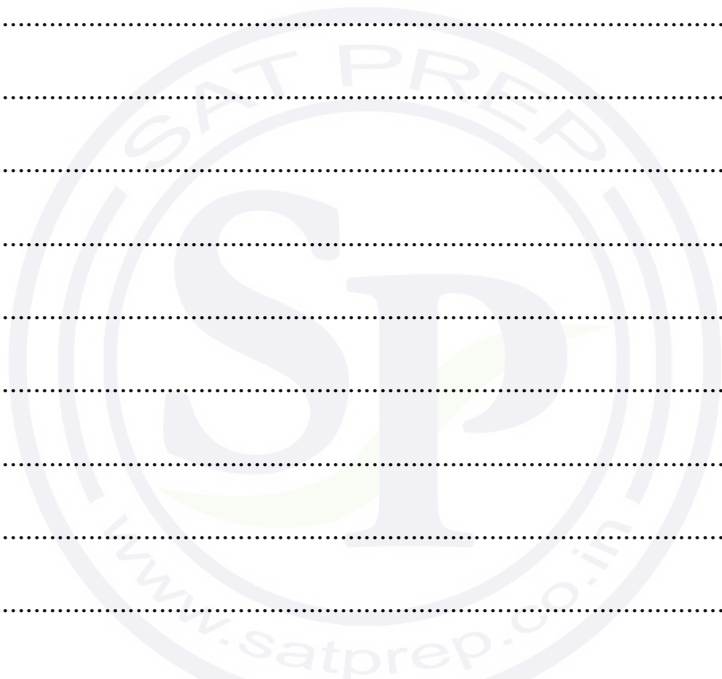
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A block of mass 15 kg hangs in equilibrium below a horizontal ceiling attached to two strings as shown in the diagram. One of the strings is inclined at 45° to the horizontal and the tension in this string is 120 N. The other string is inclined at θ° to the horizontal and the tension in this string is T N. Find the values of T and θ . [6]

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- (i) Write down an expression for the distance AB in terms of the acceleration of the car. Write down a similar expression for the distance AC . Hence show that the acceleration of the car is 4 m s^{-2} . [4]

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- [illegible]

- 4** A particle P is projected vertically upwards from horizontal ground with speed 12 m s^{-1} .

(i) Find the time taken for P to return to the ground. [2]

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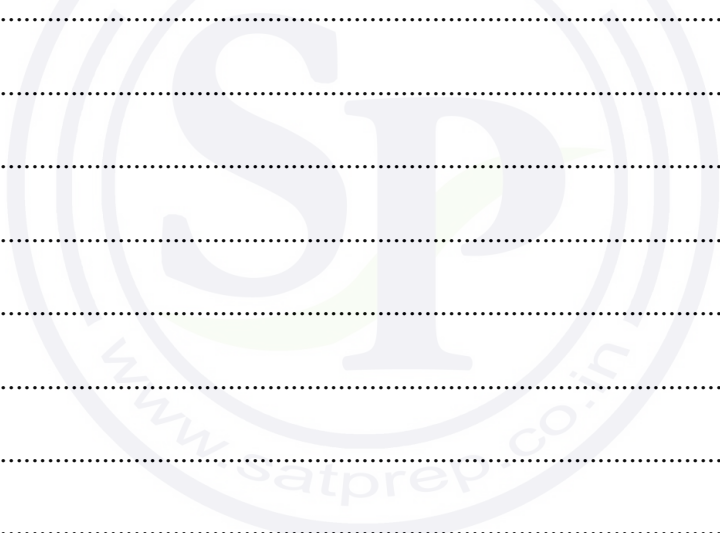
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The time in seconds after P is projected is denoted by t . When $t = 1$, a second particle Q is projected vertically upwards with speed 10 m s^{-1} from a point which is 5 m above the ground. Particles P and Q move in different vertical lines.

(ii) Find the set of values of t for which the two particles are moving in the same direction. [4]



- of 25 m is 600 J.

[4]

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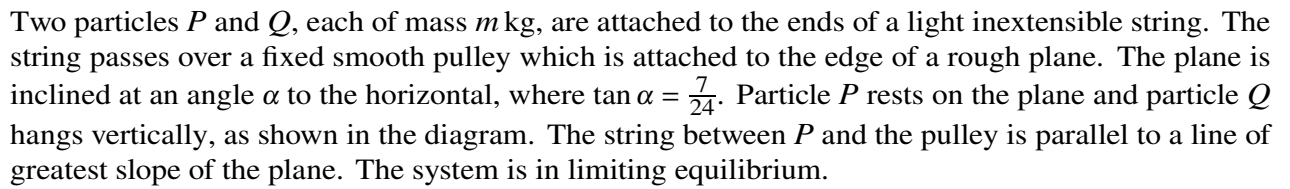
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The cyclist reaches the top of the hill, where the road becomes horizontal, with speed 4 m s^{-1} . The cyclist continues to work at the same rate on the horizontal part of the road.

- (ii)** Find the speed of the cyclist 10 seconds after reaching the top of the hill, given that the work done by the cyclist during this period against the resistance force is 1200 J. [4]

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A force of magnitude 10 N is applied to P , acting up a line of greatest slope of the plane, and P accelerates at 2.5 m s^{-2} .

(ii) Find the value of m .

[5]

[illegible]

- 7 A particle starts from rest and moves in a straight line. The velocity of the particle at time t s after the start is $v \text{ m s}^{-1}$, where

$$v = -0.01t^3 + 0.22t^2 - 0.4t.$$

- (i) Find the two positive values of t for which the particle is instantaneously at rest. [2]

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- (ii) Find the time at which the acceleration of the particle is greatest. [3]

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MATHEMATICS

9709/41

Paper 4 Mechanics 1 (**M1**)

October/November 2017

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: List of Formulae (MF9)

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

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The total number of marks for this paper is 50.

This document consists of **11** printed pages and **1** blank page.

- [illegible]

- (i) Find the power output of the tractor's engine. [1]

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(iii) Find the constant speed that the tractor could maintain on the hill when working at this power. [2]

- [2]

- 3** A roller-coaster car (including passengers) has a mass of 840 kg. The roller-coaster ride includes a section where the car climbs a straight ramp of length 8 m inclined at 30° above the horizontal. The car then immediately descends another ramp of length 10 m inclined at 20° below the horizontal. The resistance to motion acting on the car is 640 N throughout the motion.

- (i)** Find the total work done against the resistance force as the car ascends the first ramp and descends the second ramp. [2]

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- (ii)** The speed of the car at the bottom of the first ramp is 14 m s^{-1} . Use an energy method to find the speed of the car when it reaches the bottom of the second ramp. [4]

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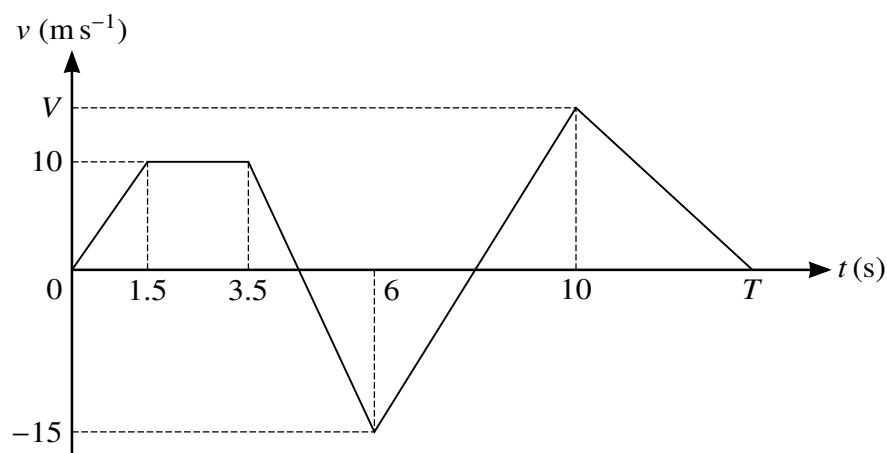
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The diagram shows the velocity-time graph of a particle which moves in a straight line. The graph consists of 5 straight line segments. The particle starts from rest at a point A at time $t = 0$, and initially travels towards point B on the line.

- (i) Show that the acceleration of the particle between $t = 3.5$ and $t = 6$ is -10 m s^{-2} . [1]

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- (ii) The acceleration of the particle between $t = 6$ and $t = 10$ is 7.5 m s^{-2} . When $t = 10$ the velocity of the particle is $V \text{ m s}^{-1}$. Find the value of V . [2]

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- (iii) The particle comes to rest at B at time T s. Given that the total distance travelled by the particle between $t = 0$ and $t = T$ is 100 m, find the value of T . [4]

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

$$v = 1.5 + 0.4t \quad \text{for } 0 \leq t \leq 5,$$

$$v = \frac{100}{t^2} - 0.1t \quad \text{for } t \geq 5.$$

- (i) Find the acceleration of the particle during the first 5 seconds of motion. [1]

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- (ii) Find the value of t when the particle is instantaneously at rest. [2]

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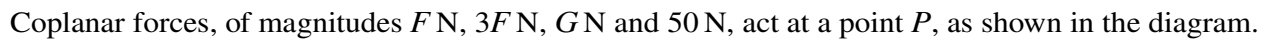
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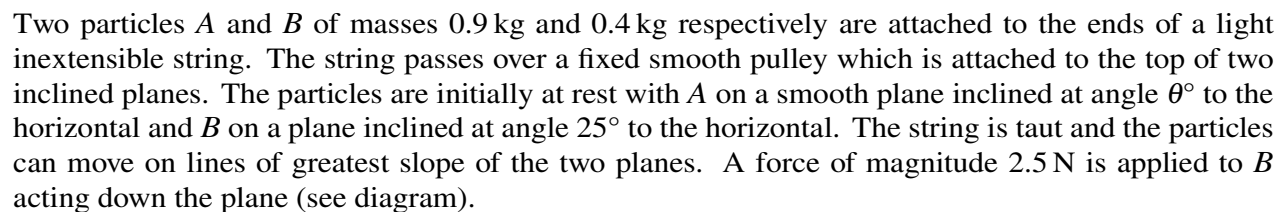


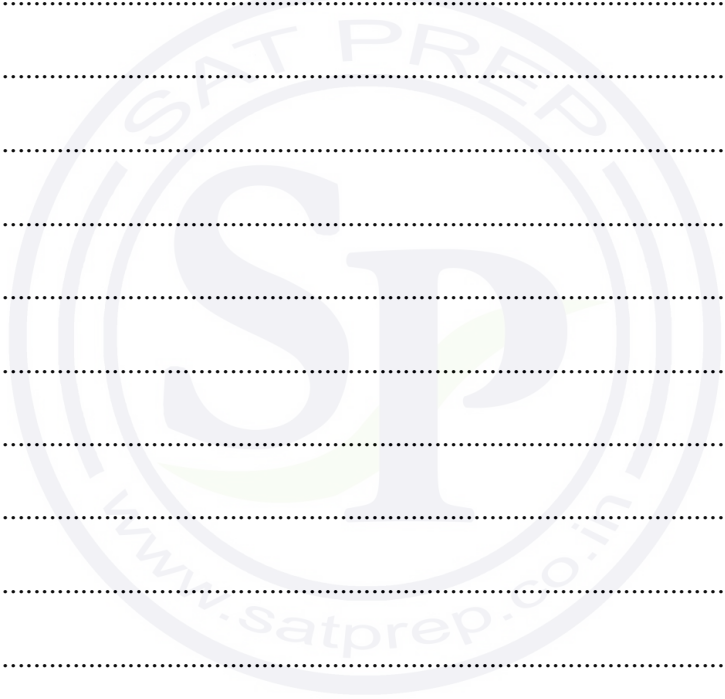
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9709/43

Paper 4 Mechanics 1 (M1)

May/June 2017

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: List of Formulae (MF9)

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This document consists of **12** printed pages.

- 1** A man pushes a wheelbarrow of mass 25 kg along a horizontal road with a constant force of magnitude 35 N at an angle of 20° below the horizontal. There is a constant resistance to motion of 15 N. The wheelbarrow moves a distance of 12 m from rest.

(i) Find the work done by the man.

[2]

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(ii) Find the speed attained by the wheelbarrow after 12 m.

[3]

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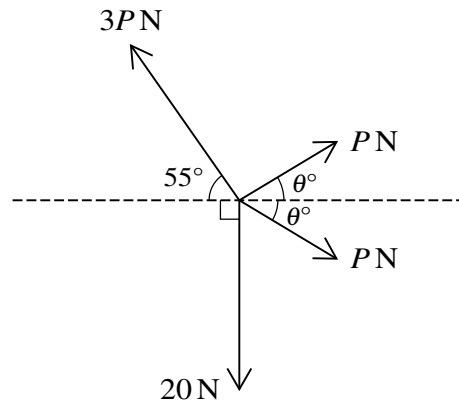
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The four coplanar forces shown in the diagram are in equilibrium. Find the values of P and θ . [5]

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- 3 A train travels between two stations, A and B . The train starts from rest at A and accelerates at a constant rate for T s until it reaches a speed of 25 m s^{-1} . It then travels at this constant speed before decelerating at a constant rate, coming to rest at B . The magnitude of the train's deceleration is twice the magnitude of its acceleration. The total time taken for the journey is 180 s.

(i) Sketch the velocity-time graph for the train's journey from A to B .

[1]



- (ii) Find an expression, in terms of T , for the length of time for which the train is travelling with constant speed.

[2]

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- (iii) The distance from A to B is 3300 m. Find how far the train travels while it is decelerating.

[3]

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- (i) Find the values of t when the acceleration of P is 54 m s^{-2} . [3]

[illegible]

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- A particle is projected vertically upwards from a point O with a speed of 12 m s^{-1} . Two seconds later a second particle is projected vertically upwards from O with a speed of 20 m s^{-1} . At time $t \text{ s}$ after the second particle is projected, the two particles collide.

(i) Find t .

[5]

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(ii) Hence find the height above O at which the particles collide.

[1]

6 A car of mass 1200 kg is travelling along a horizontal road.

(i) It is given that there is a constant resistance to motion.

- (a)** The engine of the car is working at 16 kW while the car is travelling at a constant speed of 40 m s^{-1} . Find the resistance to motion. [2]

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- (b)** The power is now increased to 22.5 kW. Find the acceleration of the car at the instant it is travelling at a speed of 45 m s^{-1} . [3]

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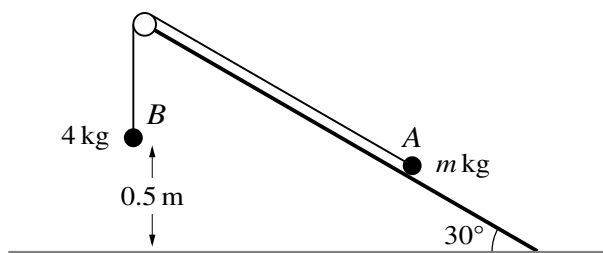
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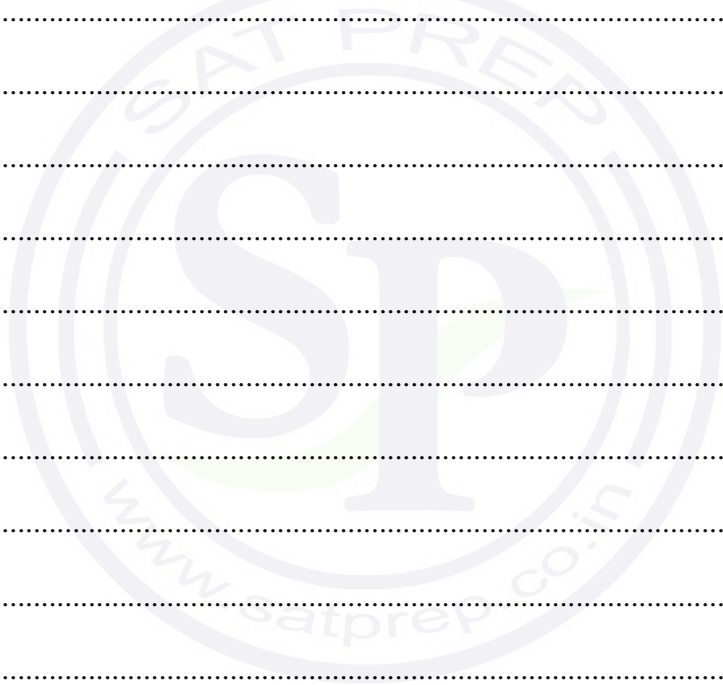
- (ii) It is given instead that the resistance to motion of the car is $(590 + 2v)$ N when the speed of the car is $v \text{ m s}^{-1}$. The car travels at a constant speed with the engine working at 16 kW. Find this speed. [3]

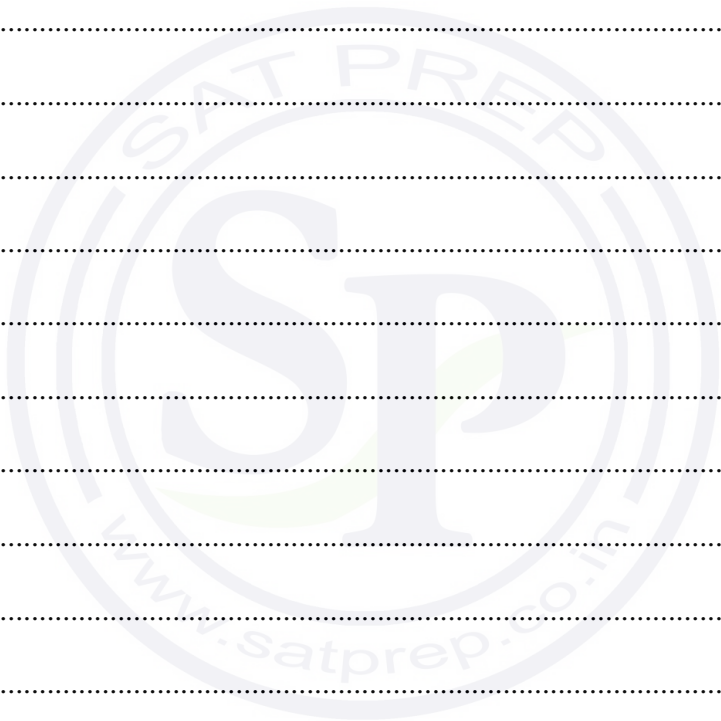
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Two particles A and B of masses m kg and 4 kg respectively are connected by a light inextensible string that passes over a fixed smooth pulley. Particle A is on a rough fixed slope which is at an angle of 30° to the horizontal ground. Particle B hangs vertically below the pulley and is 0.5 m above the ground (see diagram). The coefficient of friction between the slope and particle A is 0.2 .

- (i) In the case where the system is in equilibrium with particle A on the point of moving directly up the slope, show that $m = 5.94$, correct to 3 significant figures. [6]



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MATHEMATICS

9709/41

Paper 4 Mechanics 1 (M1)

May/June 2017

1 hour 15 minutes

Candidates answer on the Question Paper.

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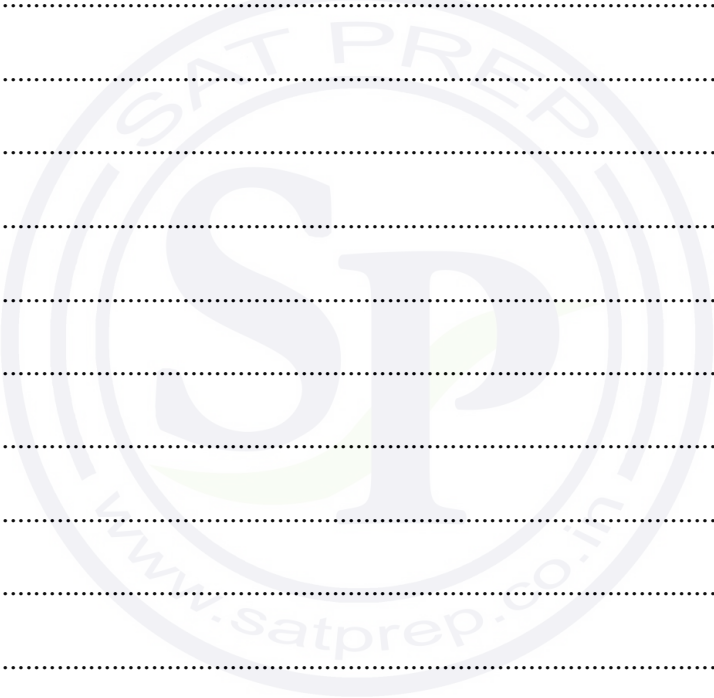
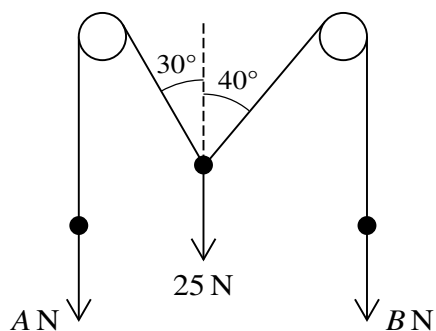
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- [illegible]

- (i) Find the acceleration of the particle. [4]

[illegible]

- [illegible]

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- 4** A car of mass 800 kg is moving up a hill inclined at θ° to the horizontal, where $\sin \theta = 0.15$. The initial speed of the car is 8 m s^{-1} . Twelve seconds later the car has travelled 120 m up the hill and has speed 14 m s^{-1} .

(i) Find the change in the kinetic energy and the change in gravitational potential energy of the car. [3]

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(ii) The engine of the car is working at a constant rate of 32 kW. Find the total work done against the resistive forces during the twelve seconds. [3]

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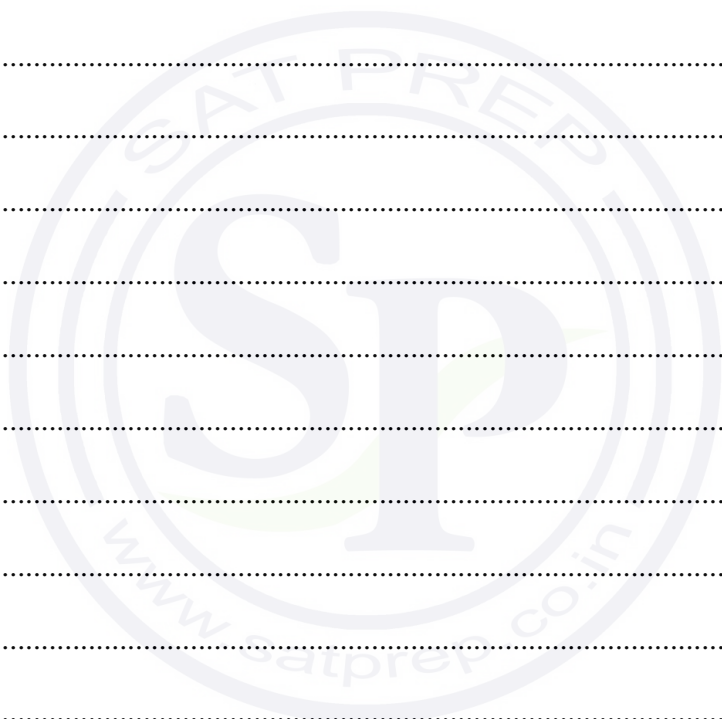
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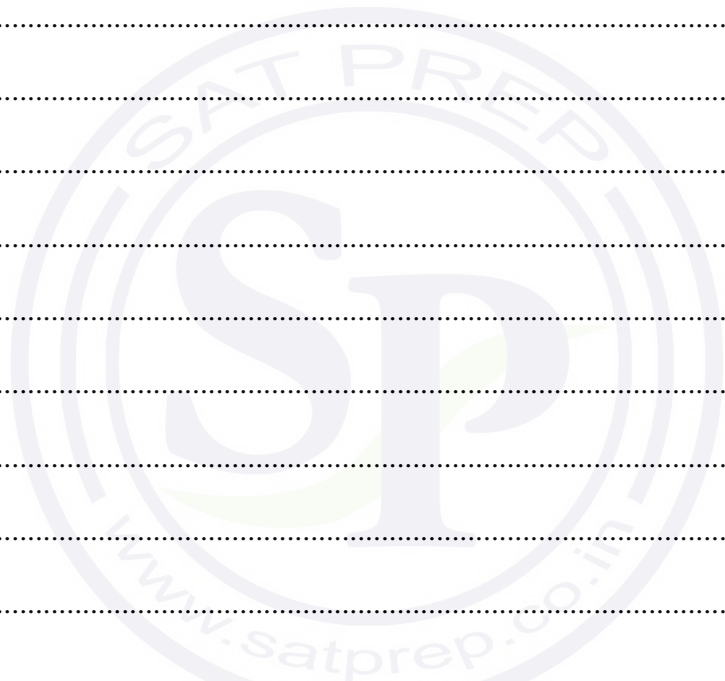
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- (i) Find the ratio of distances $AB : BC$. [4]

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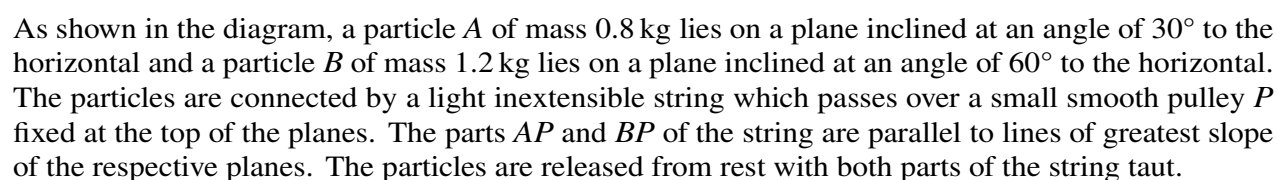
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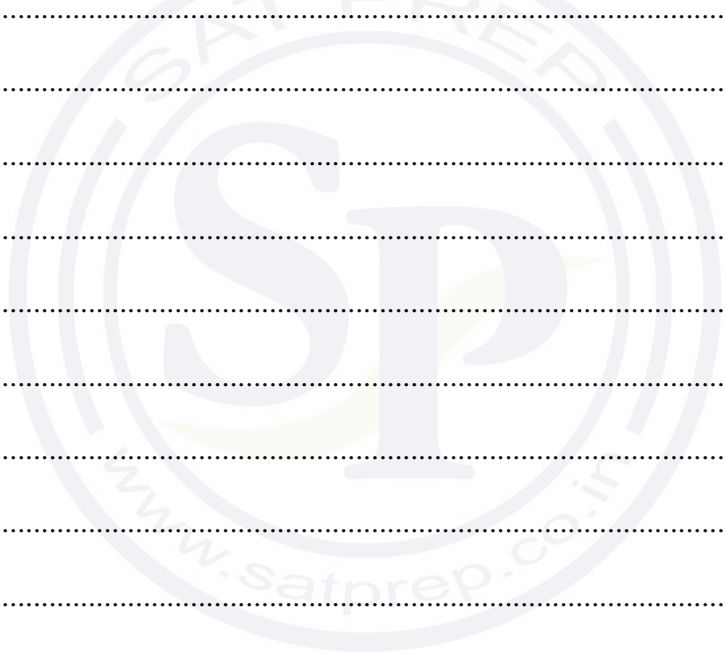
- (i) Show that, when $t = 0.5$, the acceleration of P is 4 m s^{-2} . [4]



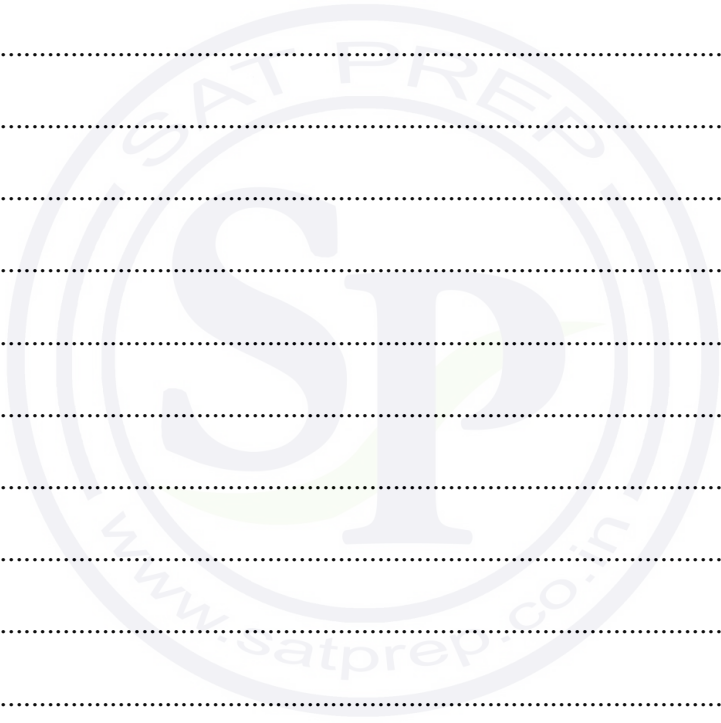
- [illegible]

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- (ii) It is given instead that both planes are rough, with the same coefficient of friction, μ , for both particles. Find the value of μ for which the system is in limiting equilibrium. [6]



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CANDIDATE
NAME

CENTRE
NUMBER

CANDIDATE
NUMBER

MATHEMATICS

9709/42

Paper 4 Mechanics 1 (M1)

May/June 2017

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: List of Formulae (MF9)

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name in the spaces at the top of this page.

Write in dark blue or black pen.

You may use an HB pencil for any diagrams or graphs.

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Answer **all** the questions.

Give non-exact numerical answers correct to 3 significant figures, or 1 decimal place in the case of angles in degrees, unless a different level of accuracy is specified in the question.

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

The use of an electronic calculator is expected, where appropriate.

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This document consists of **11** printed pages and **1** blank page.

- 1 One end of a light inextensible string is attached to a block. The string makes an angle of θ° with the horizontal. The tension in the string is 20 N. The string pulls the block along a horizontal surface at a constant speed of 1.5 m s^{-1} for 12 s. The work done by the tension in the string is 50 J. Find θ . [3]

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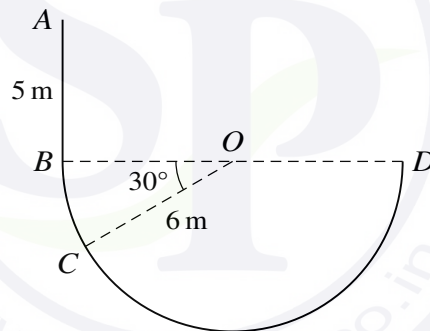
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The diagram shows a wire $ABCD$ consisting of a straight part AB of length 5 m and a part BCD in the shape of a semicircle of radius 6 m and centre O . The diameter BD of the semicircle is horizontal and AB is vertical. A small ring is threaded onto the wire and slides along the wire. The ring starts from rest at A . The part AB of the wire is rough, and the ring accelerates at a constant rate of 2.5 m s^{-2} between A and B .

- (i) Show that the speed of the ring as it reaches B is 5 m s^{-1} . [1]

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(ii) (a) Find the speed of the ring at C , where angle $BOC = 30^\circ$. [4]

(b) Find the greatest speed of the ring. [2]

- 3 A particle A moves in a straight line with constant speed 10 m s^{-1} . Two seconds after A passes a point O on the line, a particle B passes through O , moving along the line in the same direction as A . Particle B has speed 16 m s^{-1} at O and has a constant deceleration of 2 m s^{-2} .

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

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- (ii) Find the distance between the particles when B comes to instantaneous rest. [3]

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- 4** A car of mass 1200 kg is moving on a straight road against a constant force of 850 N resisting the motion.

(i) On a part of the road that is horizontal, the car moves with a constant speed of 42 m s^{-1} .

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

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- (b) Given that this power is suddenly increased by 6 kW, find the instantaneous acceleration of the car. [3]

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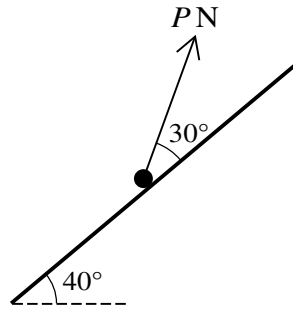
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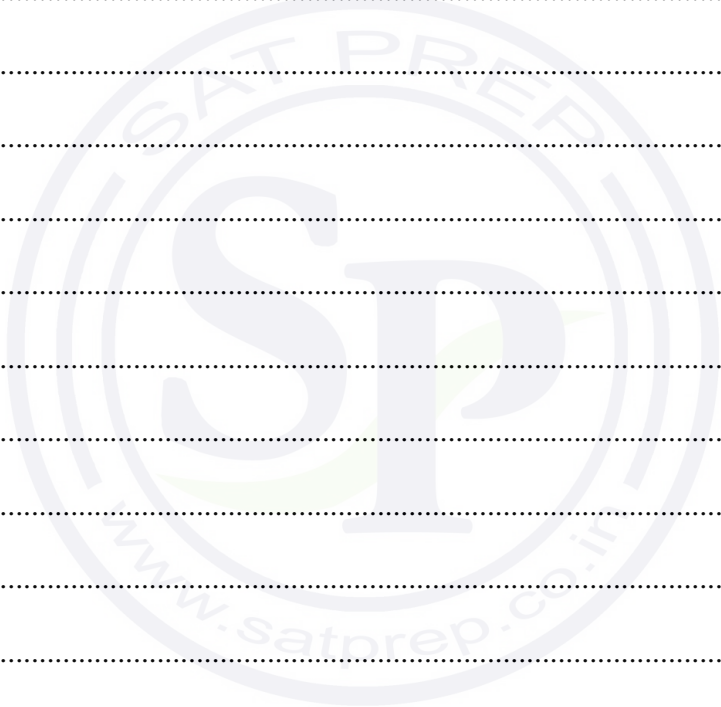
- (ii) On a part of the road that is inclined at θ° to the horizontal, the car moves up the hill at a constant speed of 24 m s^{-1} , with the engine working at 80 kW . Find θ . [4]

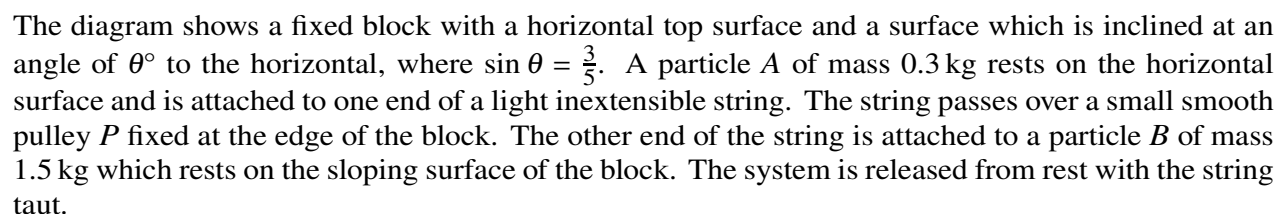
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A particle of mass 0.12 kg is placed on a plane which is inclined at an angle of 40° to the horizontal. The particle is kept in equilibrium by a force of magnitude $P\text{ N}$ acting up the plane at an angle of 30° above a line of greatest slope, as shown in the diagram. The coefficient of friction between the particle and the plane is 0.32 . Find the set of possible values of P . [8]

[8]





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MATHEMATICS

9709/42

Paper 4 Mechanics 1 (M1)

February/March 2017

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: List of Formulae (MF9)

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name in the spaces at the top of this page.

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

The use of an electronic calculator is expected, where appropriate.

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The total number of marks for this paper is 50.

This document consists of **11** printed pages and **1** blank page.

- 1** A particle of mass 0.4 kg is projected with a speed of 12 m s^{-1} up a line of greatest slope of a smooth plane inclined at 30° to the horizontal.

(i) Find the initial kinetic energy of the particle. [1]

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

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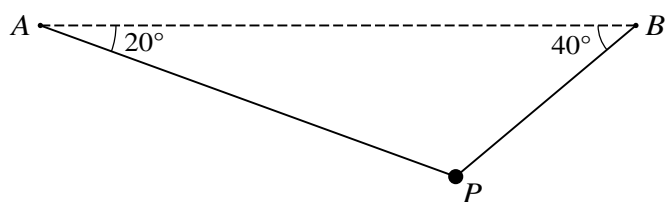
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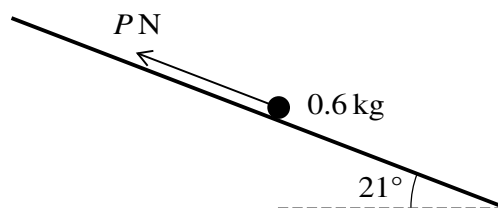
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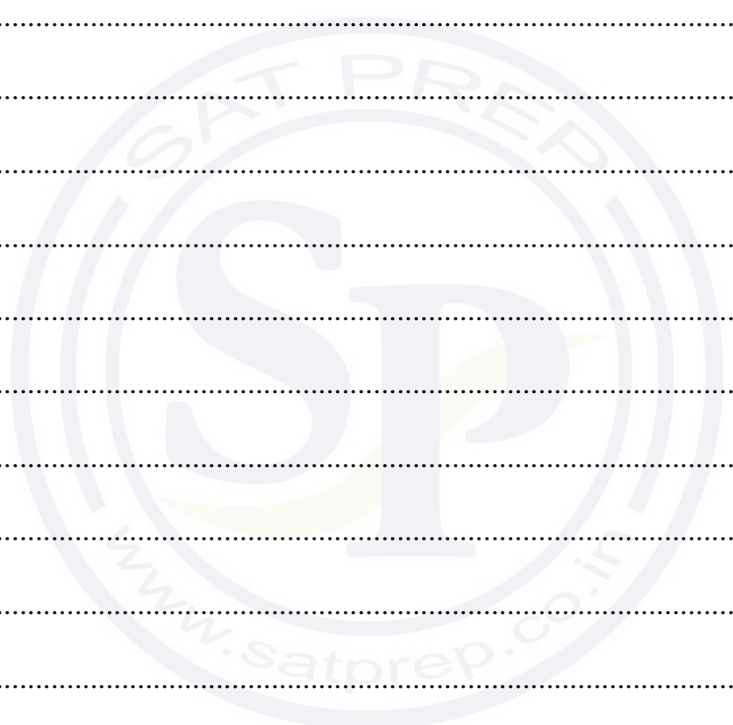


A particle P of mass 1.6 kg is suspended in equilibrium by two light inextensible strings attached to points A and B . The strings make angles of 20° and 40° respectively with the horizontal (see diagram). Find the tensions in the two strings. [6]

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[6]

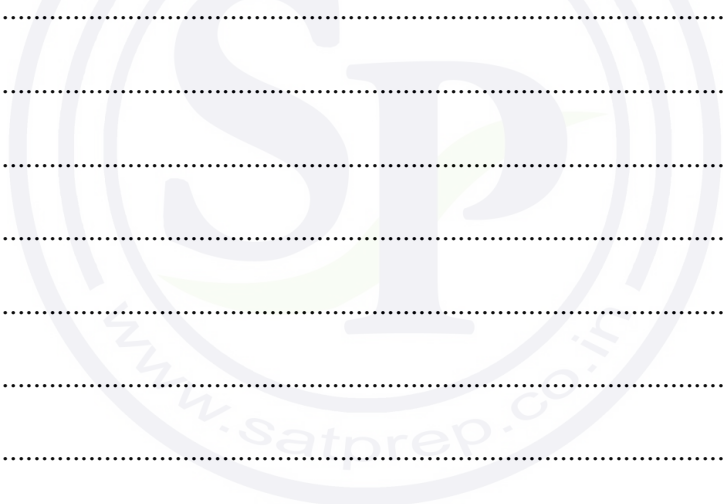
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- (i) The car moves from A to B at a constant speed in 120 s. Find the speed of the car and the distance AB . [3]

is switched off at B .

BC is 450 m. Find the speed of the car at C .

- (ii) The distance BC is 450 m. Find the speed of the car at C . [3]



- (iii) The car comes to rest at D . The distance AD is 6637.5 m. Find the deceleration of the car and the value of R . [4]

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- 5** A particle P moves in a straight line starting from a point O and comes to rest 35 s later. At time t s after leaving O , the velocity $v \text{ m s}^{-1}$ of P is given by

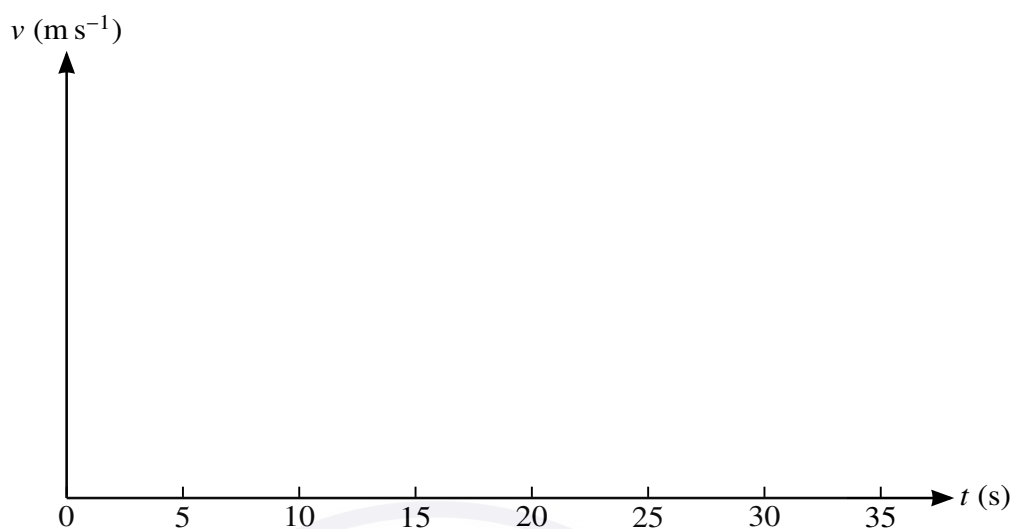
$$\begin{aligned} v &= \frac{4}{5}t^2 & 0 \leq t \leq 5, \\ v &= 2t + 10 & 5 \leq t \leq 15, \\ v &= a + bt^2 & 15 \leq t \leq 35, \end{aligned}$$

where a and b are constants such that $a > 0$ and $b < 0$.

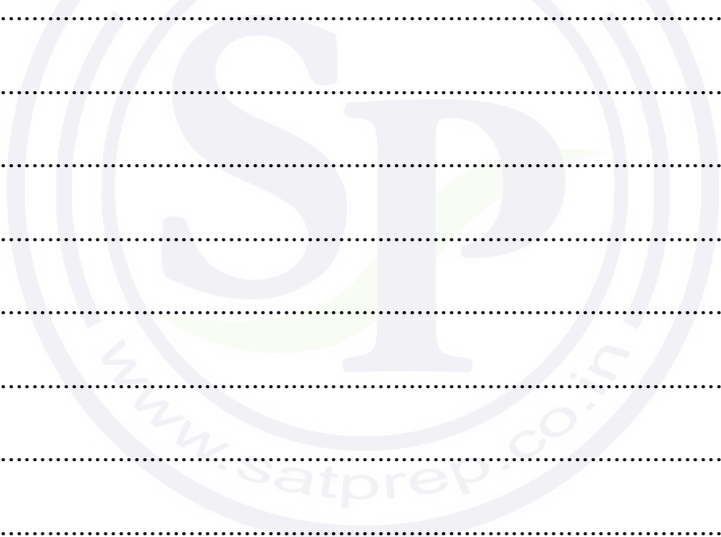
- (i) Show that the values of a and b are 49 and -0.04 respectively. [3]

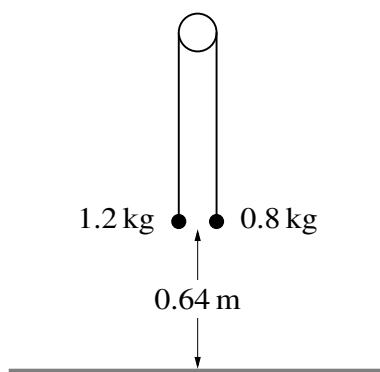
[illegible]

- [4]



- [5]





Two particles of masses 1.2 kg and 0.8 kg are connected by a light inextensible string that passes over a fixed smooth pulley. The particles hang vertically. The system is released from rest with both particles 0.64 m above the floor (see diagram). In the subsequent motion the 0.8 kg particle does not reach the pulley.

- (i) Show that the acceleration of the particles is 2 m s^{-2} and find the tension in the string. [4]

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- (ii) Find the total distance travelled by the 0.8 kg particle during the first second after the particles are released. [8]

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MATHEMATICS

9709/43

Paper 4 Mechanics 1 (M1)

October/November 2016

1 hour 15 minutes

Additional Materials: List of Formulae (MF9)

READ THESE INSTRUCTIONS FIRST

An answer booklet is provided inside this question paper. You should follow the instructions on the front cover of the answer booklet. If you need additional answer paper ask the invigilator for a continuation booklet.

Answer **all** the questions.

Give non-exact numerical answers correct to 3 significant figures, or 1 decimal place in the case of angles in degrees, unless a different level of accuracy is specified in the question.

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

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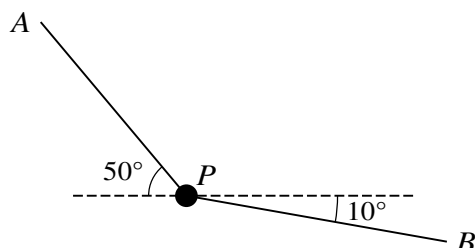
This document consists of **3** printed pages, **1** blank page and **1** insert.

- 1 A crane is used to raise a block of mass 50 kg vertically upwards at constant speed through a height of 3.5 m. There is a constant resistance to motion of 25 N.

(i) Find the work done by the crane. [3]

(ii) Given that the time taken to raise the block is 2 s, find the power of the crane. [2]

2



The diagram shows a small object P of mass 20 kg held in equilibrium by light ropes attached to fixed points A and B . The rope PA is inclined at an angle of 50° above the horizontal, the rope PB is inclined at an angle of 10° below the horizontal, and both ropes are in the same vertical plane. Find the tension in the rope PA and the tension in the rope PB . [5]

3



Particles P and Q , of masses 7 kg and 3 kg respectively, are attached to the two ends of a light inextensible string. The string passes over two small smooth pulleys attached to the two ends of a horizontal table. The two particles hang vertically below the two pulleys. The two particles are both initially at rest, 0.5 m below the level of the table, and 0.4 m above the horizontal floor (see diagram).

(i) Find the acceleration of the particles and the speed of P immediately before it reaches the floor. [4]

(ii) Determine whether Q comes to instantaneous rest before it reaches the pulley directly above it. [2]

- 4 A ball A is released from rest at the top of a tall tower. One second later, another ball B is projected vertically upwards from ground level near the bottom of the tower with a speed of 20 m s^{-1} . The two balls are at the same height 1.5 s after ball B is projected.

(i) Show that the height of the tower is 50 m. [3]

(ii) Find the length of time for which ball B has been in motion when ball A reaches the ground. Hence find the total distance travelled by ball B up to the instant when ball A reaches the ground. [5]

- 5 A particle P starts from a fixed point O and moves in a straight line. At time t s after leaving O , the velocity v m s⁻¹ of P is given by $v = 6t - 0.3t^2$. The particle comes to instantaneous rest at point X .

(i) Find the distance OX . [4]

A second particle Q starts from rest from O , at the same instant as P , and also travels in a straight line. The acceleration a m s⁻² of Q is given by $a = k - 12t$, where k is a constant. The displacement of Q from O is 400 m when $t = 10$.

(ii) Find the value of k . [4]

- 6 A cyclist is cycling with constant power of 160 W along a horizontal straight road. There is a constant resistance to motion of 20 N. At an instant when the cyclist's speed is 5 m s⁻¹, his acceleration is 0.15 m s⁻².

(i) Show that the total mass of the cyclist and bicycle is 80 kg. [3]

The cyclist comes to a hill inclined at 2° to the horizontal. When the cyclist starts climbing the hill, he increases his power to a constant 300 W. The resistance to motion remains 20 N.

(ii) Show that the steady speed up the hill which the cyclist can maintain when working at this power is 6.26 m s⁻¹, correct to 3 significant figures. [2]

(iii) Find the acceleration at an instant when the cyclist is travelling at 90% of the speed in part (ii). [4]

- 7 A box of mass 50 kg is at rest on a plane inclined at 10° to the horizontal.

(i) Find an inequality for the coefficient of friction between the box and the plane. [2]

In fact the coefficient of friction between the box and the plane is 0.19.

(ii) A girl pushes the box with a force of 50 N, acting down a line of greatest slope of the plane, for a distance of 5 m. She then stops pushing. Use an energy method to find the speed of the box when it has travelled a further 5 m. [5]

The box then comes to a plane inclined at 20° below the horizontal. The box moves down a line of greatest slope of this plane. The coefficient of friction is still 0.19 and the girl is not pushing the box.

(iii) Find the acceleration of the box. [2]

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MATHEMATICS

9709/42

Paper 4 Mechanics 1 (M1)

October/November 2016

1 hour 15 minutes

Additional Materials: List of Formulae (MF9)

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This document consists of 3 printed pages, 1 blank page and 1 insert.

- 1 A particle of mass 2 kg is initially at rest on a rough horizontal plane. A force of magnitude 10 N is applied to the particle at 15° above the horizontal. It is given that 10 s after the force is applied, the particle has a speed of 3.5 m s^{-1} .

(i) Show that the magnitude of the frictional force is 8.96 N, correct to 3 significant figures. [3]

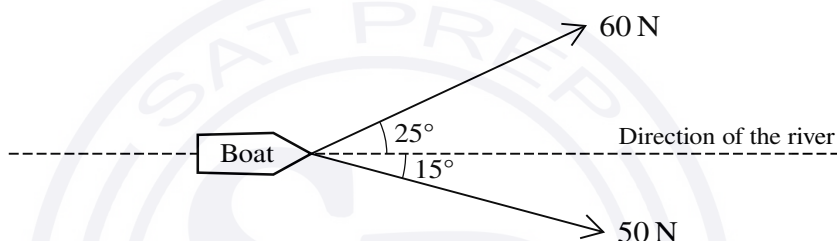
(ii) Find the coefficient of friction between the particle and the plane. [3]

- 2 A particle moves in a straight line. Its displacement t s after leaving a fixed point O on the line is s m, where $s = 2t^2 - \frac{80}{3}t^{\frac{3}{2}}$.

(i) Find the time at which the acceleration of the particle is zero. [4]

(ii) Find the displacement and velocity of the particle at this instant. [2]

3



A boat is being pulled along a river by two people. One of the people walks along a path on one side of the river and the other person walks along a path on the opposite side of the river. The first person exerts a horizontal force of 60 N at an angle of 25° to the direction of the river. The second person exerts a horizontal force of 50 N at an angle of 15° to the direction of the river (see diagram).

(i) Find the total force exerted by the two people in the direction of the river. [2]

(ii) Find the magnitude and direction of the resultant force exerted by the two people. [4]

- 4 A girl on a sledge starts, with a speed of 5 m s^{-1} , at the top of a slope of length 100 m which is at an angle of 20° to the horizontal. The sledge slides directly down the slope.

(i) Given that there is no resistance to the sledge's motion, find the speed of the sledge at the bottom of the slope. [3]

(ii) It is given instead that the sledge experiences a resistance to motion such that the total work done against the resistance is 8500 J, and the speed of the sledge at the bottom of the slope is 21 m s^{-1} . Find the total mass of the girl and the sledge. [3]

- 5 A particle of mass m kg is resting on a rough plane inclined at 30° to the horizontal. A force of magnitude 10 N applied to the particle up a line of greatest slope of the plane is just sufficient to stop the particle sliding down the plane. When a force of 75 N is applied to the particle up a line of greatest slope of the plane, the particle is on the point of sliding up the plane. Find m and the coefficient of friction between the particle and the plane. [6]

- 6** A van of mass 3000 kg is pulling a trailer of mass 500 kg along a straight horizontal road at a constant speed of 25 m s^{-1} . The system of the van and the trailer is modelled as two particles connected by a light inextensible cable. There is a constant resistance to motion of 300 N on the van and 100 N on the trailer.

(i) Find the power of the van's engine. [2]

(ii) Write down the tension in the cable. [1]

The van reaches the bottom of a hill inclined at 4° to the horizontal with speed 25 m s^{-1} . The power of the van's engine is increased to 25 000 W.

(iii) Assuming that the resistance forces remain the same, find the new tension in the cable at the instant when the speed of the van up the hill is 20 m s^{-1} . [5]

- 7** A car starts from rest and moves in a straight line from point *A* with constant acceleration 3 m s^{-2} for 10 s. The car then travels at constant speed for 30 s before decelerating uniformly, coming to rest at point *B*. The distance *AB* is 1.5 km.

(i) Find the total distance travelled in the first 40 s of motion. [3]

When the car has been moving for 20 s, a motorcycle starts from rest and accelerates uniformly in a straight line from point *A* to a speed $V \text{ m s}^{-1}$. It then maintains this speed for 30 s before decelerating uniformly to rest at point *B*. The motorcycle comes to rest at the same time as the car.

(ii) Given that the magnitude of the acceleration $a \text{ m s}^{-2}$ of the motorcycle is three times the magnitude of its deceleration, find the value of a . [6]

(iii) Sketch the displacement-time graph for the motion of the car. [3]

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MATHEMATICS

9709/41

Paper 4 Mechanics 1 (M1)

October/November 2016

1 hour 15 minutes

Additional Materials: List of Formulae (MF9)

READ THESE INSTRUCTIONS FIRST

An answer booklet is provided inside this question paper. You should follow the instructions on the front cover of the answer booklet. If you need additional answer paper ask the invigilator for a continuation booklet.

Answer **all** the questions.

Give non-exact numerical answers correct to 3 significant figures, or 1 decimal place in the case of angles in degrees, unless a different level of accuracy is specified in the question.

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

The use of an electronic calculator is expected, where appropriate.

You are reminded of the need for clear presentation in your answers.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [] at the end of each question or part question.

The total number of marks for this paper is 50.

This document consists of **4** printed pages and **1** insert.

1



Two particles P and Q , of masses 0.6 kg and 0.4 kg respectively, are connected by a light inextensible string. The string passes over a small smooth light pulley fixed at the edge of a smooth horizontal table. Initially P is held at rest on the table and Q hangs vertically (see diagram). P is then released. Find the tension in the string and the acceleration of Q . [4]

- 2 A particle of mass 0.1 kg is released from rest on a rough plane inclined at 20° to the horizontal. It is given that, 5 seconds after release, the particle has a speed of 2 m s^{-1} .

(i) Find the acceleration of the particle and hence show that the magnitude of the frictional force acting on the particle is 0.302 N , correct to 3 significant figures. [3]

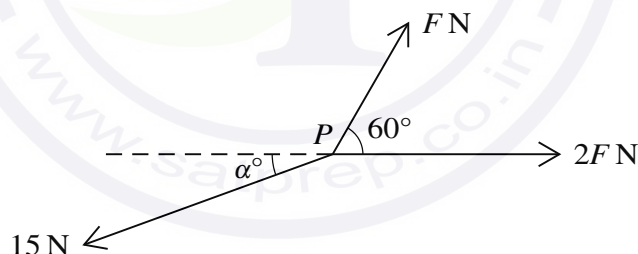
(ii) Find the coefficient of friction between the particle and the plane. [2]

- 3 A particle P is projected vertically upwards from a point O . When the particle is at a height of 0.5 m , its speed is 6 m s^{-1} . Find

(i) the greatest height reached by the particle above O , [3]

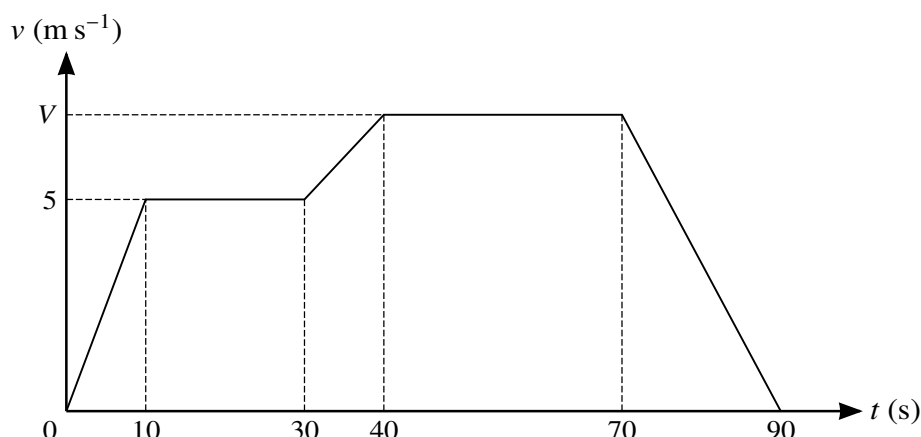
(ii) the time after projection at which the particle returns to O . [3]

4



Three coplanar forces of magnitudes $F\text{ N}$, $2F\text{ N}$ and 15 N act at a point P , as shown in the diagram. Given that the forces are in equilibrium, find the values of F and α . [6]

5



The diagram shows a velocity-time graph which models the motion of a cyclist. The graph consists of five straight line segments. The cyclist accelerates from rest to a speed of 5 m s^{-1} over a period of 10 s, and then travels at this speed for a further 20 s. The cyclist then descends a hill, accelerating to speed $V \text{ m s}^{-1}$ over a period of 10 s. This speed is maintained for a further 30 s. The cyclist then decelerates to rest over a period of 20 s.

(i) Find the acceleration of the cyclist during the first 10 seconds. [1]

(ii) Show that the total distance travelled by the cyclist in the 90 seconds of motion may be expressed as $(45V + 150) \text{ m}$. Hence find V , given that the total distance travelled by the cyclist is 465 m. [3]

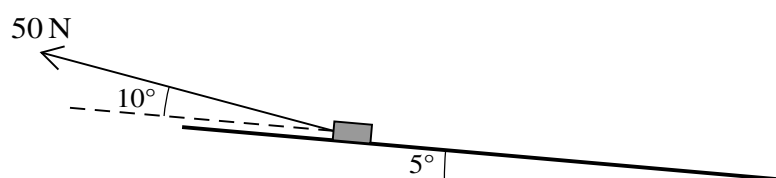
(iii) The combined mass of the cyclist and the bicycle is 80 kg. The cyclist experiences a constant resistance to motion of 20 N. Use an energy method to find the vertical distance which the cyclist descends during the downhill section from $t = 30$ to $t = 40$, assuming that the cyclist does no work during this time. [4]

6 A block of mass 25 kg is pulled along horizontal ground by a force of magnitude 50 N inclined at 10° above the horizontal. The block starts from rest and travels a distance of 20 m. There is a constant resistance force of magnitude 30 N opposing motion.

(i) Find the work done by the pulling force. [2]

(ii) Use an energy method to find the speed of the block when it has moved a distance of 20 m. [2]

(iii) Find the greatest power exerted by the 50 N force. [2]



After the block has travelled the 20 m, it comes to a plane inclined at 5° to the horizontal. The force of 50 N is now inclined at an angle of 10° to the plane and pulls the block directly up the plane (see diagram). The resistance force remains 30 N.

(iv) Find the time it takes for the block to come to rest from the instant when it reaches the foot of the inclined plane. [4]

- 7 A racing car is moving in a straight line. The acceleration $a \text{ m s}^{-2}$ at time $t \text{ s}$ after the car starts from rest is given by

$$a = 15t - 3t^2 \quad \text{for } 0 \leq t \leq 5,$$

$$a = -\frac{625}{t^2} \quad \text{for } 5 < t \leq k,$$

where k is a constant.

- (i) Find the maximum acceleration of the car in the first five seconds of its motion. [3]
- (ii) Find the distance of the car from its starting point when $t = 5$. [3]
- (iii) The car comes to rest when $t = k$. Find the value of k . [5]



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MATHEMATICS

9709/43

Paper 4 Mechanics 1 (M1)

May/June 2016

1 hour 15 minutes

Additional Materials: List of Formulae (MF9)

READ THESE INSTRUCTIONS FIRST

An answer booklet is provided inside this question paper. You should follow the instructions on the front cover of the answer booklet. If you need additional answer paper ask the invigilator for a continuation booklet.

Answer **all** the questions.

Give non-exact numerical answers correct to 3 significant figures, or 1 decimal place in the case of angles in degrees, unless a different level of accuracy is specified in the question.

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

The use of an electronic calculator is expected, where appropriate.

You are reminded of the need for clear presentation in your answers.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [] at the end of each question or part question.

The total number of marks for this paper is 50.

This document consists of **3** printed pages, **1** blank page and **1** insert.

- 1 A particle of mass 8 kg is pulled at a constant speed a distance of 20 m up a rough plane inclined at an angle of 30° to the horizontal by a force acting along a line of greatest slope.

(i) Find the change in gravitational potential energy of the particle. [2]

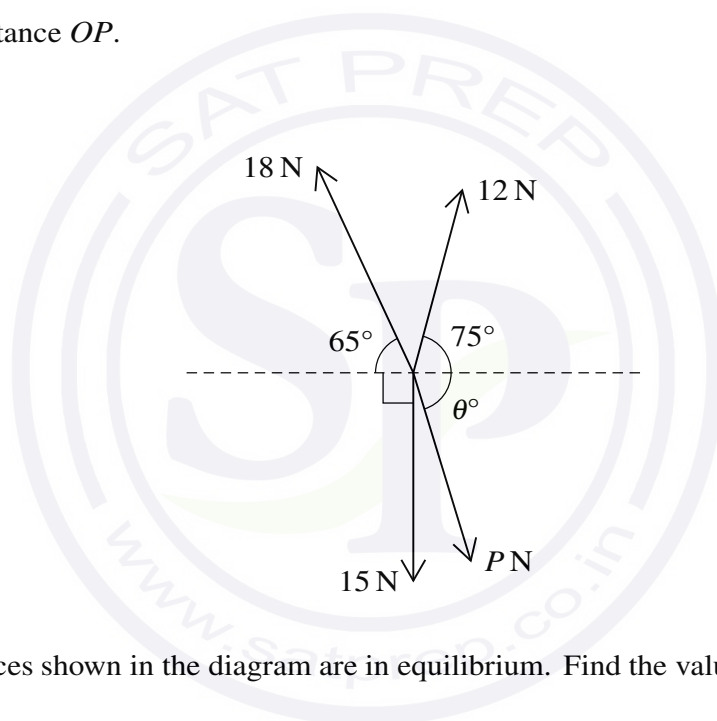
(ii) The total work done against gravity and friction is 1146 J. Find the frictional force acting on the particle. [2]

- 2 Alan starts walking from a point O , at a constant speed of 4 m s^{-1} , along a horizontal path. Ben walks along the same path, also starting from O . Ben starts from rest 5 s after Alan and accelerates at 1.2 m s^{-2} for 5 s. Ben then continues to walk at a constant speed until he is at the same point, P , as Alan.

(i) Find how far Ben has travelled when he has been walking for 5 s and find his speed at this instant. [2]

(ii) Find the distance OP . [3]

3



The coplanar forces shown in the diagram are in equilibrium. Find the values of P and θ . [6]

- 4 A particle of mass 15 kg is stationary on a rough plane inclined at an angle of 20° to the horizontal. The coefficient of friction between the particle and the plane is 0.2. A force of magnitude $X \text{ N}$ acting parallel to a line of greatest slope of the plane is used to keep the particle in equilibrium. Show that the least possible value of X is 23.1, correct to 3 significant figures, and find the greatest possible value of X . [7]

- 5** The motion of a car of mass 1400 kg is resisted by a constant force of magnitude 650 N.
- (i) Find the constant speed of the car on a horizontal road, assuming that the engine works at a rate of 20 kW. [2]
 - (ii) The car is travelling at a constant speed of 10 m s^{-1} up a hill inclined at an angle of θ to the horizontal, where $\sin \theta = \frac{1}{7}$. Find the power of the car's engine. [3]
 - (iii) The car descends the same hill with the engine working at 80% of the power found in part (ii). Find the acceleration of the car at an instant when the speed is 20 m s^{-1} . [3]
- 6** Two particles of masses 1.3 kg and 0.7 kg are connected by a light inextensible string that passes over a fixed smooth pulley. The particles are held at the same vertical height with the string taut. The distance of each particle above a horizontal plane is 2 m, and the distance of each particle below the pulley is 4 m. The particles are released from rest.
- (i) Find
 - (a) the tension in the string before the particle of mass 1.3 kg reaches the plane,
 - (b) the time taken for the particle of mass 1.3 kg to reach the plane. [6]
 - (ii) Find the greatest height of the particle of mass 0.7 kg above the plane. [4]
- 7** A particle P moves in a straight line. At time t s, the displacement of P from O is s m and the acceleration of P is $a \text{ m s}^{-2}$, where $a = 6t - 2$. When $t = 1$, $s = 7$ and when $t = 3$, $s = 29$.
- (i) Find the set of values of t for which the particle is decelerating. [2]
 - (ii) Find s in terms of t . [5]
 - (iii) Find the time when the velocity of the particle is 10 m s^{-1} . [3]

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MATHEMATICS

9709/42

Paper 4 Mechanics 1 (M1)

May/June 2016

1 hour 15 minutes

Additional Materials: List of Formulae (MF9)

READ THESE INSTRUCTIONS FIRST

An answer booklet is provided inside this question paper. You should follow the instructions on the front cover of the answer booklet. If you need additional answer paper ask the invigilator for a continuation booklet.

Answer **all** the questions.

Give non-exact numerical answers correct to 3 significant figures, or 1 decimal place in the case of angles in degrees, unless a different level of accuracy is specified in the question.

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

The use of an electronic calculator is expected, where appropriate.

You are reminded of the need for clear presentation in your answers.

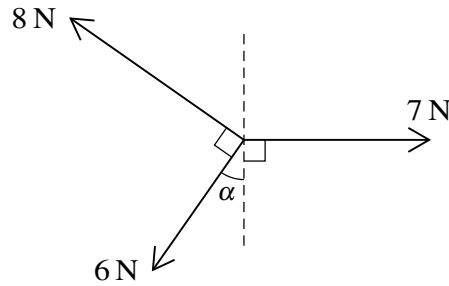
At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [] at the end of each question or part question.

The total number of marks for this paper is 50.

This document consists of **3** printed pages, **1** blank page and **1** insert.

1



Coplanar forces of magnitudes 7 N, 6 N and 8 N act at a point in the directions shown in the diagram. Given that $\sin \alpha = \frac{3}{5}$, find the magnitude and direction of the resultant of the three forces. [5]

- 2 A particle P moves in a straight line, starting from a point O . At time t s after leaving O , the velocity of P , $v \text{ m s}^{-1}$, is given by $v = 4t^2 - 8t + 3$.

(i) Find the two values of t at which P is at instantaneous rest. [2]

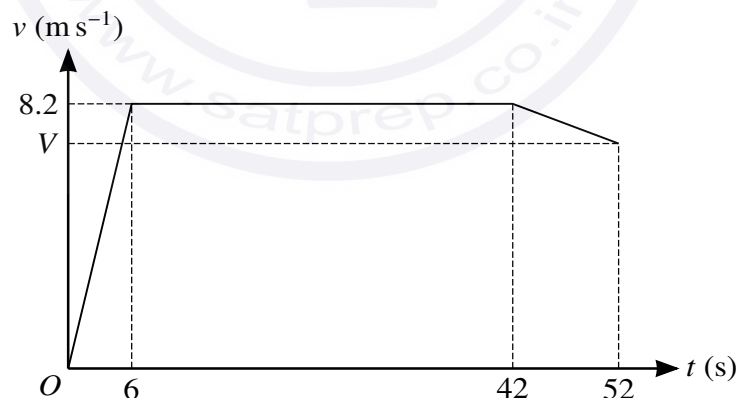
(ii) Find the distance travelled by P between these two times. [3]

- 3 A particle of mass 8 kg is projected with a speed of 5 m s^{-1} up a line of greatest slope of a rough plane inclined at an angle α to the horizontal, where $\sin \alpha = \frac{5}{13}$. The motion of the particle is resisted by a constant frictional force of magnitude 15 N. The particle comes to instantaneous rest after travelling a distance x m up the plane.

(i) Express the change in gravitational potential energy of the particle in terms of x . [2]

(ii) Use an energy method to find x . [4]

4



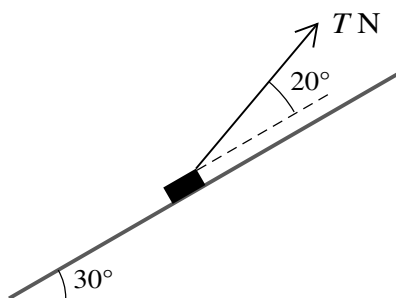
A sprinter runs a race of 400 m. His total time for running the race is 52 s. The diagram shows the velocity-time graph for the motion of the sprinter. He starts from rest and accelerates uniformly to a speed of 8.2 m s^{-1} in 6 s. The sprinter maintains a speed of 8.2 m s^{-1} for 36 s, and he then decelerates uniformly to a speed of $V \text{ m s}^{-1}$ at the end of the race.

(i) Calculate the distance covered by the sprinter in the first 42 s of the race. [2]

(ii) Show that $V = 7.84$. [3]

(iii) Calculate the deceleration of the sprinter in the last 10 s of the race. [2]

5

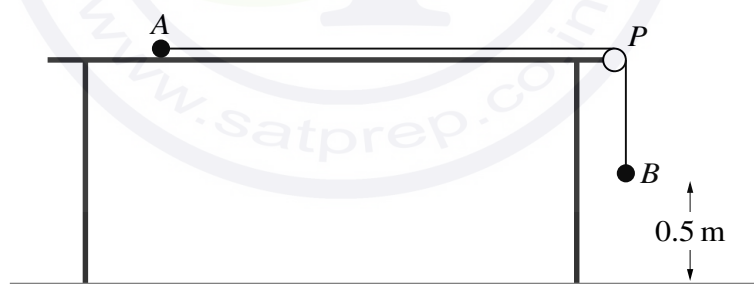


A block of mass 2.5 kg is placed on a plane which is inclined at an angle of 30° to the horizontal. The block is kept in equilibrium by a light string making an angle of 20° above a line of greatest slope. The tension in the string is $T \text{ N}$, as shown in the diagram. The coefficient of friction between the block and plane is $\frac{1}{4}$. The block is in limiting equilibrium and is about to move up the plane. Find the value of T . [7]

6 A car of mass 1100 kg is moving on a road against a constant force of 1550 N resisting the motion.

- (i) The car moves along a straight horizontal road at a constant speed of 40 m s^{-1} .
 - (a) Calculate, in kW, the power developed by the engine of the car. [2]
 - (b) Given that this power is suddenly decreased by 22 kW , find the instantaneous deceleration of the car. [3]
- (ii) The car now travels at constant speed up a straight road inclined at 8° to the horizontal, with the engine working at 80 kW . Assuming the resistance force remains the same, find this constant speed. [3]

7



A particle A of mass 1.6 kg rests on a horizontal table and is attached to one end of a light inextensible string. The string passes over a small smooth pulley P fixed at the edge of the table. The other end of the string is attached to a particle B of mass 2.4 kg which hangs freely below the pulley. The system is released from rest with the string taut and with B at a height of 0.5 m above the ground, as shown in the diagram. In the subsequent motion A does not reach P before B reaches the ground.

- (i) Given that the table is smooth, find the time taken by B to reach the ground. [5]
- (ii) Given instead that the table is rough and that the coefficient of friction between A and the table is $\frac{3}{8}$, find the total distance travelled by A . You may assume that A does not reach the pulley. [7]

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MATHEMATICS

9709/41

Paper 4 Mechanics 1 (M1)

May/June 2016

1 hour 15 minutes

Additional Materials: List of Formulae (MF9)

READ THESE INSTRUCTIONS FIRST

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Answer **all** the questions.

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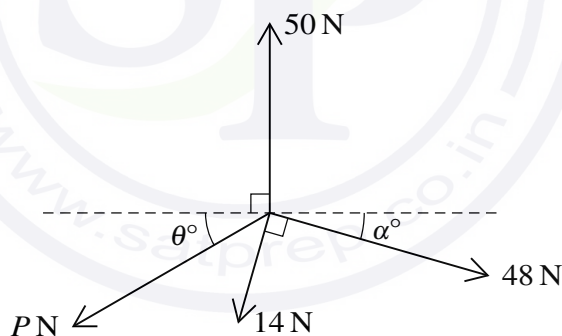
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The total number of marks for this paper is 50.

This document consists of **3** printed pages, **1** blank page and **1** insert.

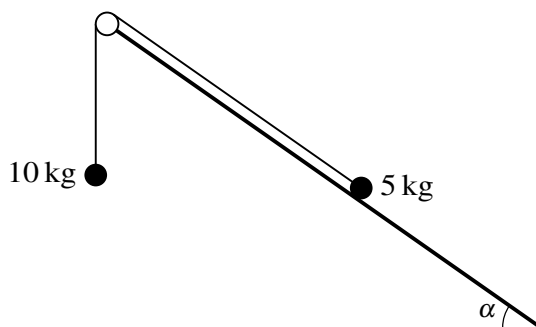
- 1** A lift moves upwards from rest and accelerates at 0.9 m s^{-2} for 3 s. The lift then travels for 6 s at constant speed and finally slows down, with a constant deceleration, stopping in a further 4 s.
- (i) Sketch a velocity-time graph for the motion. [3]
- (ii) Find the total distance travelled by the lift. [2]
- 2** A box of mass 25 kg is pulled, at a constant speed, a distance of 36 m up a rough plane inclined at an angle of 20° to the horizontal. The box moves up a line of greatest slope against a constant frictional force of 40 N. The force pulling the box is parallel to the line of greatest slope. Find
- (i) the work done against friction, [1]
- (ii) the change in gravitational potential energy of the box, [2]
- (iii) the work done by the pulling force. [2]
- 3** A car of mass 1000 kg is moving along a straight horizontal road against resistances of total magnitude 300 N.
- (i) Find, in kW, the rate at which the engine of the car is working when the car has a constant speed of 40 m s^{-1} . [3]
- (ii) Find the acceleration of the car when its speed is 25 m s^{-1} and the engine is working at 90% of the power found in part (i). [3]

4



Coplanar forces of magnitudes 50 N, 48 N, 14 N and P N act at a point in the directions shown in the diagram. The system is in equilibrium. Given that $\tan \alpha = \frac{7}{24}$, find the values of P and θ . [6]

5



Two particles of masses 5 kg and 10 kg are connected by a light inextensible string that passes over a fixed smooth pulley. The 5 kg particle is on a rough fixed slope which is at an angle of α to the horizontal, where $\tan \alpha = \frac{3}{4}$. The 10 kg particle hangs below the pulley (see diagram). The coefficient of friction between the slope and the 5 kg particle is $\frac{1}{2}$. The particles are released from rest. Find the acceleration of the particles and the tension in the string. [7]

- 6 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 a velocity $v \text{ m s}^{-1}$, where $v = 6t^2 - 30t + 24$.
- (i) Find the set of values of t for which the acceleration of the particle is negative. [2]
 - (ii) Find the distance between the two positions at which P is at instantaneous rest. [4]
 - (iii) Find the two positive values of t at which P passes through O . [3]
- 7 A particle of mass 30 kg is on a plane inclined at an angle of 20° to the horizontal. Starting from rest, the particle is pulled up the plane by a force of magnitude 200 N acting parallel to a line of greatest slope.
- (i) Given that the plane is smooth, find
 - (a) the acceleration of the particle, [2]
 - (b) the change in kinetic energy after the particle has moved 12 m up the plane. [2]
 - (ii) It is given instead that the plane is rough and the coefficient of friction between the particle and the plane is 0.12.
 - (a) Find the acceleration of the particle. [4]
 - (b) The direction of the force of magnitude 200 N is changed, and the force now acts at an angle of 10° above the line of greatest slope. Find the acceleration of the particle. [4]

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MATHEMATICS

9709/42

Paper 4 Mechanics 1 (M1)

February/March 2016

1 hour 15 minutes

Additional Materials: Answer Booklet/Paper
Graph Paper
List of Formulae (MF9)

READ THESE INSTRUCTIONS FIRST

If you have been given an Answer Booklet, follow the instructions on the front cover of the Booklet.

Write your Centre number, candidate number and name on all the work you hand in.

Write in dark blue or black pen.

You may use an HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

DO NOT WRITE IN ANY BARCODES.

Answer **all** the questions.

Give non-exact numerical answers correct to 3 significant figures, or 1 decimal place in the case of angles in degrees, unless a different level of accuracy is specified in the question.

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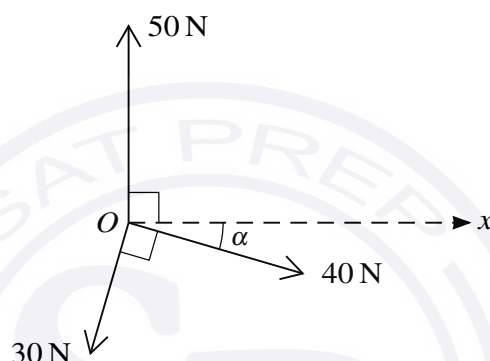
The total number of marks for this paper is 50.

Questions carrying smaller numbers of marks are printed earlier in the paper, and questions carrying larger numbers of marks later in the paper.

This document consists of **3** printed pages and **1** blank page.

- 1 A cyclist has mass 85 kg and rides a bicycle of mass 20 kg. The cyclist rides along a horizontal road against a total resistance force of 40 N. Find the total work done by the cyclist in increasing his speed from 5 m s^{-1} to 10 m s^{-1} while travelling a distance of 50 m. [3]
- 2 A constant resistance of magnitude 1350 N acts on a car of mass 1200 kg.
- (i) The car is moving along a straight level road at a constant speed of 32 m s^{-1} . Find, in kW, the rate at which the engine of the car is working. [2]
- (ii) The car travels at a constant speed up a hill inclined at an angle of θ to the horizontal, where $\sin \theta = 0.1$, with the engine working at 76.5 kW. Find this speed. [3]

3



Coplanar forces of magnitudes 50 N, 40 N and 30 N act at a point O in the directions shown in the diagram, where $\tan \alpha = \frac{7}{24}$.

- (i) Find the magnitude and direction of the resultant of the three forces. [6]
- (ii) The force of magnitude 50 N is replaced by a force of magnitude P N acting in the same direction. The resultant of the three forces now acts in the positive x -direction. Find the value of P . [1]
- 4 A particle P of mass 0.8 kg is placed on a rough horizontal table. The coefficient of friction between P and the table is μ . A force of magnitude 5 N, acting upwards at an angle α above the horizontal, where $\tan \alpha = \frac{3}{4}$, is applied to P . The particle is on the point of sliding on the table.
- (i) Find the value of μ . [4]
- (ii) The magnitude of the force acting on P is increased to 10 N, with the direction of the force remaining the same. Find the acceleration of P . [3]
- 5 A car of mass 1200 kg is pulling a trailer of mass 800 kg up a hill inclined at an angle α to the horizontal, where $\sin \alpha = 0.1$. The system of the car and the trailer is modelled as two particles connected by a light inextensible cable. The driving force of the car's engine is 2500 N and the resistances to the car and trailer are 100 N and 150 N respectively.
- (i) Find the acceleration of the system and the tension in the cable. [4]
- (ii) When the car and trailer are travelling at a speed of 30 m s^{-1} , the driving force becomes zero. The cable remains taut. Find the time, in seconds, before the system comes to rest. [3]

- 6** Two particles A and B , of masses 0.8 kg and 0.2 kg respectively, are connected by a light inextensible string. Particle A is placed on a horizontal surface. The string passes over a small smooth pulley P fixed at the edge of the surface, and B hangs freely. The horizontal section of the string, AP , is of length 2.5 m . The particles are released from rest with both sections of the string taut.

(i) Given that the surface is smooth, find the time taken for A to reach the pulley. [5]

(ii) Given instead that the surface is rough and the coefficient of friction between A and the surface is 0.1 , find the speed of A immediately before it reaches the pulley. [5]

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

$$\begin{aligned} v &= 5t(t - 2) && \text{for } 0 \leq t \leq 4, \\ v &= k && \text{for } 4 \leq t \leq 14, \\ v &= 68 - 2t && \text{for } 14 \leq t \leq 20, \end{aligned}$$

where k is a constant.

(i) Find k . [1]

(ii) Sketch the velocity-time graph for $0 \leq t \leq 20$. [3]

(iii) Find the set of values of t for which the acceleration of P is positive. [2]

(iv) Find the total distance travelled by P in the interval $0 \leq t \leq 20$. [5]

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MATHEMATICS

9709/43

Paper 4 Mechanics 1 (M1)

October/November 2015

1 hour 15 minutes

Additional Materials: Answer Booklet/Paper
Graph Paper
List of Formulae (MF9)

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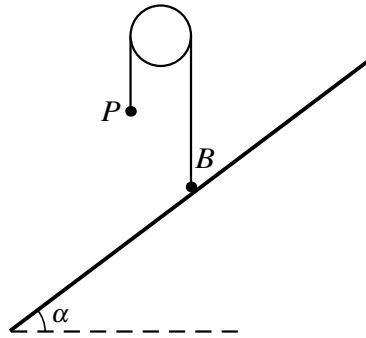
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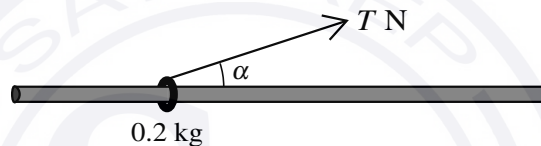
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1



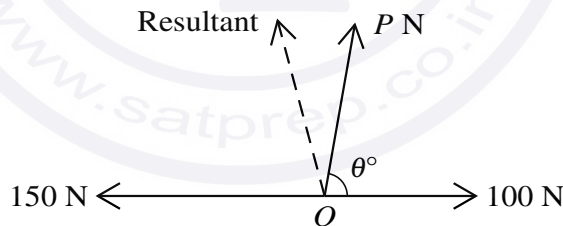
A small ball B of mass 4 kg is attached to one end of a light inextensible string. A particle P of mass 3 kg is attached to the other end of the string. The string passes over a fixed smooth pulley. The system is in equilibrium with the string taut and its straight parts vertical. B is at rest on a rough plane inclined to the horizontal at an angle of α , where $\cos \alpha = 0.8$ (see diagram). State the tension in the string and find the normal component of the contact force exerted on B by the plane. [3]

2



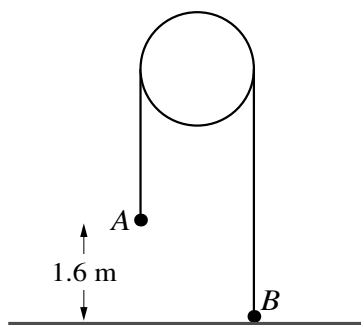
A ring of mass 0.2 kg is threaded on a fixed rough horizontal rod and a light inextensible string is attached to the ring at an angle α above the horizontal, where $\cos \alpha = 0.96$. The ring is in limiting equilibrium with the tension in the string $T\text{ N}$ (see diagram). Given that the coefficient of friction between the ring and the rod is 0.25 , find the value of T . [5]

3



Three horizontal forces of magnitudes 150 N , 100 N and $P\text{ N}$ have directions as shown in the diagram. The resultant of the three forces is shown by the broken line in the diagram. This resultant has magnitude 120 N and makes an angle 75° with the 150 N force. Find the values of P and θ . [7]

4



Particles A and B , of masses 0.35 kg and 0.15 kg respectively, are attached to the ends of a light inextensible string which passes over a fixed smooth pulley. The system is at rest with B held on the horizontal floor, the string taut and its straight parts vertical. A is at a height of 1.6 m above the floor (see diagram). B is released and the system begins to move; B does not reach the pulley. Find

- (i) the acceleration of the particles and the tension in the string before A reaches the floor, [4]
- (ii) the greatest height above the floor reached by B . [3]

- 5 A cyclist and his bicycle have a total mass of 90 kg . The cyclist starts to move with speed 3 m s^{-1} from the top of a straight hill, of length 500 m , which is inclined at an angle of $\sin^{-1} 0.05$ to the horizontal. The cyclist moves with constant acceleration until he reaches the bottom of the hill with speed 5 m s^{-1} . The cyclist generates 420 W of power while moving down the hill. The resistance to the motion of the cyclist and his bicycle, $R\text{ N}$, and the cyclist's speed, $v\text{ m s}^{-1}$, both vary.

- (i) Show that $R = \frac{420}{v} + 43.56$. [5]
- (ii) Find the cyclist's speed at the mid-point of the hill. Hence find the decrease in the value of R when the cyclist moves from the top of the hill to the mid-point of the hill, and when the cyclist moves from the mid-point of the hill to the bottom of the hill. [3]

- 6 A particle P starts from rest at a point O of a straight line and moves along the line. The displacement of the particle at time $t\text{ s}$ after leaving O is $x\text{ m}$, where

$$x = 0.08t^2 - 0.0002t^3.$$

- (i) Find the value of t when P returns to O and find the speed of P as it passes through O on its return. [4]
- (ii) For the motion of P until the instant it returns to O , find
 - (a) the total distance travelled, [3]
 - (b) the average speed. [2]

[Question 7 is printed on the next page.]

- 7 A straight hill AB has length 400 m with A at the top and B at the bottom and is inclined at an angle of 4° to the horizontal. A straight horizontal road BC has length 750 m. A car of mass 1250 kg has a speed of 5 m s^{-1} at A when starting to move down the hill. While moving down the hill the resistance to the motion of the car is 2000 N and the driving force is constant. The speed of the car on reaching B is 8 m s^{-1} .

(i) By using work and energy, find the driving force of the car. [5]

On reaching B the car moves along the road BC . The driving force is constant and twice that when the car was on the hill. The resistance to the motion of the car continues to be 2000 N. Find

(ii) the acceleration of the car while moving from B to C , [3]

(iii) the power of the car's engine as the car reaches C . [3]



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MATHEMATICS

9709/42

Paper 4 Mechanics 1 (M1)

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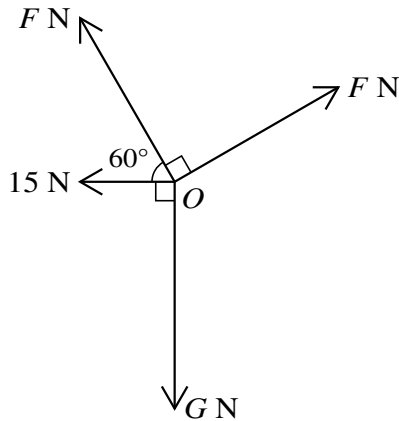
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1



Four horizontal forces act at a point O and are in equilibrium. The magnitudes of the forces are $F\text{ N}$, $G\text{ N}$, 15 N and $F\text{ N}$, and the forces act in directions as shown in the diagram.

(i) Show that $F = 41.0$, correct to 3 significant figures. [3]

(ii) Find the value of G . [2]

2 A particle is released from rest at a point $H\text{ m}$ above horizontal ground and falls vertically. The particle passes through a point 35 m above the ground with a speed of $(V - 10)\text{ m s}^{-1}$ and reaches the ground with a speed of $V\text{ m s}^{-1}$. Find

(i) the value of V , [3]

(ii) the value of H . [2]

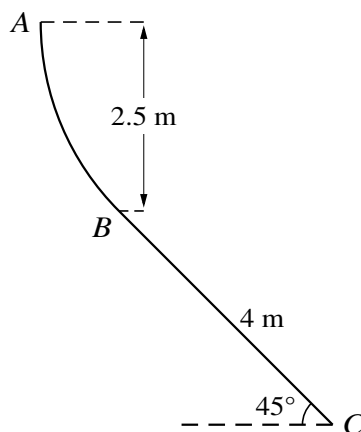
3 A particle P moves along a straight line for 100 s . It starts at a point O and at time t seconds after leaving O the velocity of P is $v\text{ m s}^{-1}$, where

$$v = 0.000\,04t^3 - 0.006t^2 + 0.288t.$$

(i) Find the values of t at which the acceleration of P is zero. [3]

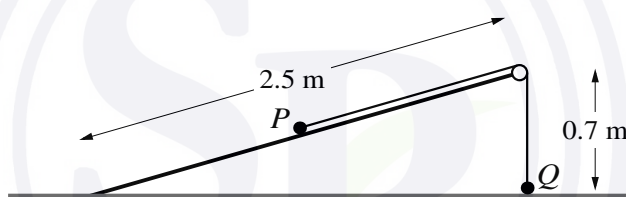
(ii) Find the displacement of P from O when $t = 100$. [3]

4



The diagram shows a vertical cross-section ABC of a surface. The part of the surface containing AB is smooth and A is 2.5 m above the level of B . The part of the surface containing BC is rough and is at 45° to the horizontal. The distance BC is 4 m (see diagram). A particle P of mass 0.2 kg is released from rest at A and moves in contact with the curve AB and then with the straight line BC . The coefficient of friction between P and the part of the surface containing BC is 0.4. Find the speed with which P reaches C . [6]

5



A smooth inclined plane of length 2.5 m is fixed with one end on the horizontal floor and the other end at a height of 0.7 m above the floor. Particles P and Q , of masses 0.5 kg and 0.1 kg respectively, are attached to the ends of a light inextensible string which passes over a small smooth pulley fixed at the top of the plane. Particle Q is held at rest on the floor vertically below the pulley. The string is taut and P is at rest on the plane (see diagram). Q is released and starts to move vertically upwards towards the pulley and P moves down the plane.

- (i) Find the tension in the string and the magnitude of the acceleration of the particles before Q reaches the pulley. [5]

At the instant just before Q reaches the pulley the string breaks; P continues to move down the plane and reaches the floor with a speed of 2 m s^{-1} .

- (ii) Find the length of the string. [3]

[Questions 6 and 7 are printed on the next page.]

6

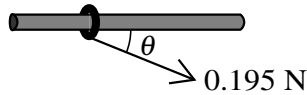


Fig. 1

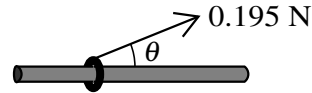


Fig. 2

A small ring of mass 0.024 kg is threaded on a fixed rough horizontal rod. A light inextensible string is attached to the ring and the string is pulled with a force of magnitude 0.195 N at an angle of θ with the horizontal, where $\sin \theta = \frac{5}{13}$. When the angle θ is below the horizontal (see Fig. 1) the ring is in limiting equilibrium.

- (i) Find the coefficient of friction between the ring and the rod. [6]

When the angle θ is above the horizontal (see Fig. 2) the ring moves.

- (ii) Find the acceleration of the ring. [4]

- 7 A car of mass 1600 kg moves with constant power 14 kW as it travels along a straight horizontal road. The car takes 25 s to travel between two points A and B on the road.

- (i) Find the work done by the car's engine while the car travels from A to B . [2]

The resistance to the car's motion is constant and equal to 235 N . The car has accelerations at A and B of 0.5 m s^{-2} and 0.25 m s^{-2} respectively. Find

- (ii) the gain in kinetic energy by the car in moving from A to B , [5]
 (iii) the distance AB . [3]

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MATHEMATICS

9709/41

Paper 4 Mechanics 1 (M1)

October/November 2015

1 hour 15 minutes

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- 1 A weightlifter performs an exercise in which he raises a mass of 200 kg from rest vertically through a distance of 0.7 m and holds it at that height.

- (i) Find the work done by the weightlifter. [2]
- (ii) Given that the time taken to raise the mass is 1.2 s, find the average power developed by the weightlifter. [2]

- 2 A particle of mass 0.5 kg starts from rest and slides down a line of greatest slope of a smooth plane. The plane is inclined at an angle of 30° to the horizontal.

- (i) Find the time taken for the particle to reach a speed of 2.5 m s^{-1} . [3]

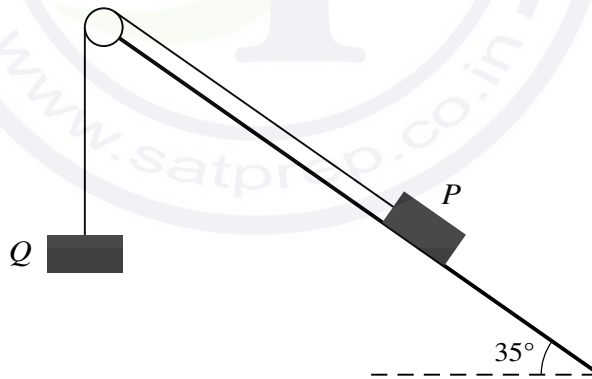
When the particle has travelled 3 m down the slope from its starting point, it reaches rough horizontal ground at the bottom of the slope. The frictional force acting on the particle is 1 N.

- (ii) Find the distance that the particle travels along the ground before it comes to rest. [3]

- 3 A lorry of mass 24 000 kg is travelling up a hill which is inclined at 3° to the horizontal. The power developed by the lorry's engine is constant, and there is a constant resistance to motion of 3200 N.

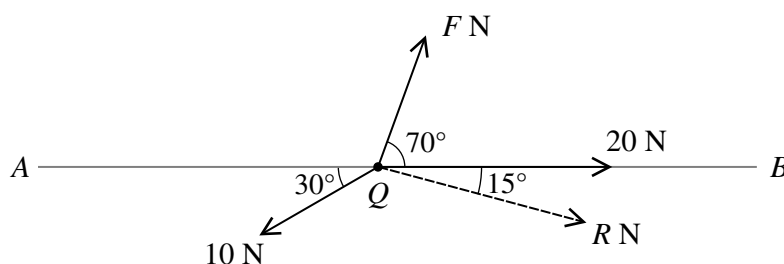
- (i) When the speed of the lorry is 25 m s^{-1} , its acceleration is 0.2 m s^{-2} . Find the power developed by the lorry's engine. [4]
- (ii) Find the steady speed at which the lorry moves up the hill if the power is 500 kW and the resistance remains 3200 N. [2]

4



Blocks P and Q , of mass m kg and 5 kg respectively, are attached to the ends of a light inextensible string. The string passes over a small smooth pulley which is fixed at the top of a rough plane inclined at 35° to the horizontal. Block P is at rest on the plane and block Q hangs vertically below the pulley (see diagram). The coefficient of friction between block P and the plane is 0.2. Find the set of values of m for which the two blocks remain at rest. [6]

5



A small bead Q can move freely along a smooth horizontal straight wire AB of length 3 m. Three horizontal forces of magnitudes F N, 10 N and 20 N act on the bead in the directions shown in the diagram. The magnitude of the resultant of the three forces is R N in the direction shown in the diagram.

(i) Find the values of F and R . [5]

(ii) Initially the bead is at rest at A . It reaches B with a speed of 11.7 m s^{-1} . Find the mass of the bead. [3]

- 6 A particle P moves in a straight line, starting from a point O . The velocity of P , measured in m s^{-1} , at time t s after leaving O is given by

$$v = 0.6t - 0.03t^2.$$

(i) Verify that, when $t = 5$, the particle is 6.25 m from O . Find the acceleration of the particle at this time. [4]

(ii) Find the values of t at which the particle is travelling at half of its maximum velocity. [6]

- 7 A cyclist starts from rest at point A and moves in a straight line with acceleration 0.5 m s^{-2} for a distance of 36 m. The cyclist then travels at constant speed for 25 s before slowing down, with constant deceleration, to come to rest at point B . The distance AB is 210 m.

(i) Find the total time that the cyclist takes to travel from A to B . [5]

24 s after the cyclist leaves point A , a car starts from rest from point A , with constant acceleration 4 m s^{-2} , towards B . It is given that the car overtakes the cyclist while the cyclist is moving with constant speed.

(ii) Find the time that it takes from when the cyclist starts until the car overtakes her. [5]

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MATHEMATICS

9709/43

Paper 4 Mechanics 1 (M1)

May/June 2015

1 hour 15 minutes

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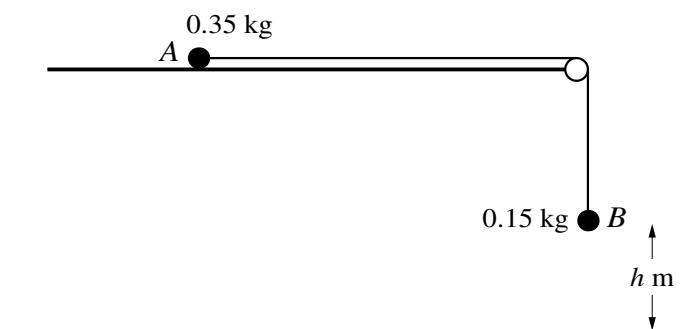
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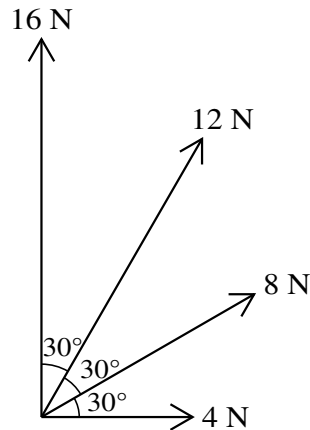
- 1 A block is pulled along a horizontal floor by a horizontal rope. The tension in the rope is 500 N and the block moves at a constant speed of 2.75 m s^{-1} . Find the work done by the tension in 40 s and find the power applied by the tension. [4]

2



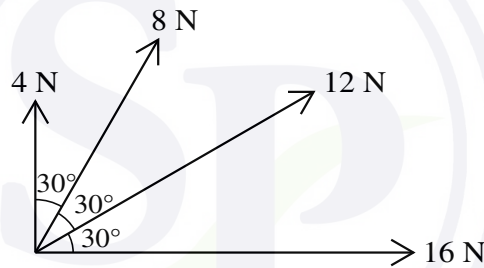
Particles A and B , of masses 0.35 kg and 0.15 kg respectively, are attached to the ends of a light inextensible string. A is held at rest on a smooth horizontal surface with the string passing over a small smooth pulley fixed at the edge of the surface. B hangs vertically below the pulley at a distance $h\text{ m}$ above the floor (see diagram). A is released and the particles move. B reaches the floor and A subsequently reaches the pulley with a speed of 3 m s^{-1} .

- (i) Explain briefly why the speed with which B reaches the floor is 3 m s^{-1} . [1]
- (ii) Find the value of h . [4]
- 3 A car of mass 860 kg travels along a straight horizontal road. The power provided by the car's engine is $P\text{ W}$ and the resistance to the car's motion is $R\text{ N}$. The car passes through one point with speed 4.5 m s^{-1} and acceleration 4 m s^{-2} . The car passes through another point with speed 22.5 m s^{-1} and acceleration 0.3 m s^{-2} . Find the values of P and R . [6]
- 4 A lorry of mass $12\,000\text{ kg}$ moves up a straight hill of length 500 m , starting at the bottom with a speed of 24 m s^{-1} and reaching the top with a speed of 16 m s^{-1} . The top of the hill is 25 m above the level of the bottom of the hill. The resistance to motion of the lorry is 7500 N . Find the driving force of the lorry. [6]

**Fig. 1**

Four coplanar forces of magnitudes 4 N, 8 N, 12 N and 16 N act at a point. The directions in which the forces act are shown in Fig. 1.

- (i) Find the magnitude and direction of the resultant of the four forces. [5]

**Fig. 2**

The forces of magnitudes 4 N and 16 N exchange their directions and the forces of magnitudes 8 N and 12 N also exchange their directions (see Fig. 2).

- (ii) State the magnitude and direction of the resultant of the four forces in Fig. 2. [2]

- 6 A small box of mass 5 kg is pulled at a constant speed of 2.5 m s^{-1} down a line of greatest slope of a rough plane inclined at 10° to the horizontal. The pulling force has magnitude 20 N and acts downwards parallel to a line of greatest slope of the plane.

- (i) Find the coefficient of friction between the box and the plane. [5]

The pulling force is removed while the box is moving at 2.5 m s^{-1} .

- (ii) Find the distance moved by the box after the instant at which the pulling force is removed. [4]

[Question 7 is printed on the next page.]

- 7 A particle P moves on a straight line. It starts at a point O on the line and returns to O 100 s later. The velocity of P is $v \text{ m s}^{-1}$ at time $t \text{ s}$ after leaving O , where

$$v = 0.0001t^3 - 0.015t^2 + 0.5t.$$

- (i) Show that P is instantaneously at rest when $t = 0$, $t = 50$ and $t = 100$. [2]
- (ii) Find the values of v at the times for which the acceleration of P is zero, and sketch the velocity-time graph for P 's motion for $0 \leq t \leq 100$. [7]
- (iii) Find the greatest distance of P from O for $0 \leq t \leq 100$. [4]



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- 1 One end of a light inextensible string is attached to a block. The string makes an angle of 60° above the horizontal and is used to pull the block in a straight line on a horizontal floor with acceleration 0.5 m s^{-2} . The tension in the string is 8 N . The block starts to move with speed 0.3 m s^{-1} . For the first 5 s of the block's motion, find
- (i) the distance travelled, [2]
 - (ii) the work done by the tension in the string. [2]
- 2 The total mass of a cyclist and his cycle is 80 kg . The resistance to motion is zero.
- (i) The cyclist moves along a horizontal straight road working at a constant rate of $P \text{ W}$. Find the value of P given that the cyclist's speed is 5 m s^{-1} when his acceleration is 1.2 m s^{-2} . [2]
 - (ii) The cyclist moves up a straight hill inclined at an angle α , where $\sin \alpha = 0.035$. Find the acceleration of the cyclist at an instant when he is working at a rate of 450 W and has speed 3.6 m s^{-1} . [3]
- 3 A plane is inclined at an angle of $\sin^{-1}(\frac{1}{8})$ to the horizontal. A and B are two points on the same line of greatest slope with A higher than B . The distance AB is 12 m . A small object P of mass 8 kg is released from rest at A and slides down the plane, passing through B with speed 4.5 m s^{-1} . For the motion of P from A to B , find
- (i) the increase in kinetic energy of P and the decrease in potential energy of P , [3]
 - (ii) the magnitude of the constant resisting force that opposes the motion of P . [2]
- 4 A particle P moves in a straight line. At time t seconds after starting from rest at the point O on the line, the acceleration of P is $a \text{ m s}^{-2}$, where $a = 0.075t^2 - 1.5t + 5$.
- (i) Find an expression for the displacement of P from O in terms of t . [4]
 - (ii) Hence find the time taken for P to return to the point O . [3]
- 5 A particle P starts from rest at a point O on a horizontal straight line. P moves along the line with constant acceleration and reaches a point A on the line with a speed of 30 m s^{-1} . At the instant that P leaves O , a particle Q is projected vertically upwards from the point A with a speed of 20 m s^{-1} . Subsequently P and Q collide at A . Find
- (i) the acceleration of P , [4]
 - (ii) the distance OA . [2]

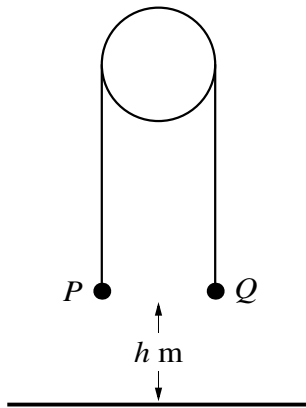


Fig. 1

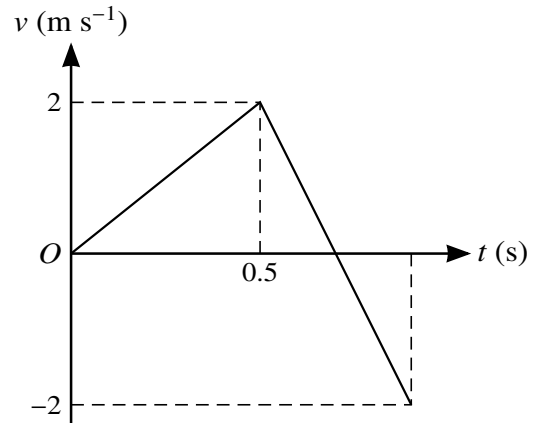
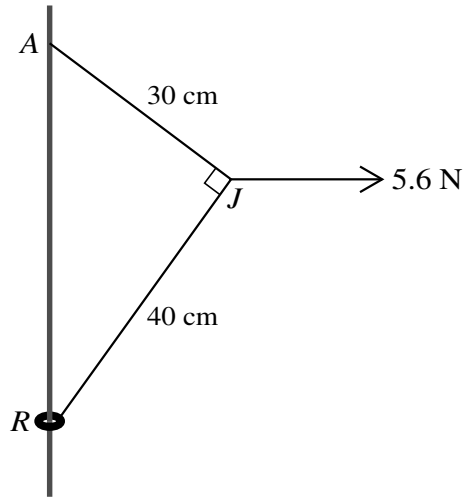


Fig. 2

Two particles P and Q have masses m kg and $(1 - m)$ kg respectively. The particles are attached to the ends of a light inextensible string which passes over a smooth fixed pulley. P is held at rest with the string taut and both straight parts of the string vertical. P and Q are each at a height of h m above horizontal ground (see Fig. 1). P is released and Q moves downwards. Subsequently Q hits the ground and comes to rest. Fig. 2 shows the velocity-time graph for P while Q is moving downwards or is at rest on the ground.

- (i) Find the value of h . [2]
- (ii) Find the value of m , and find also the tension in the string while Q is moving. [6]
- (iii) The string is slack while Q is at rest on the ground. Find the total time from the instant that P is released until the string becomes taut again. [3]

[Question 7 is printed on the next page.]



A small ring R is attached to one end of a light inextensible string of length 70 cm. A fixed rough vertical wire passes through the ring. The other end of the string is attached to a point A on the wire, vertically above R . A horizontal force of magnitude 5.6 N is applied to the point J of the string 30 cm from A and 40 cm from R . The system is in equilibrium with each of the parts AJ and JR of the string taut and angle AJR equal to 90° (see diagram).

- (i) Find the tension in the part AJ of the string, and find the tension in the part JR of the string. [5]

The ring R has mass 0.2 kg and is in limiting equilibrium, on the point of moving up the wire.

- (ii) Show that the coefficient of friction between R and the wire is 0.341, correct to 3 significant figures. [4]

A particle of mass m kg is attached to R and R is now in limiting equilibrium, on the point of moving down the wire.

- (iii) Given that the coefficient of friction is unchanged, find the value of m . [3]

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MATHEMATICS

9709/41

Paper 4 Mechanics 1 (M1)

May/June 2015

1 hour 15 minutes

Additional Materials: Answer Booklet/Paper
Graph Paper
List of Formulae (MF9)

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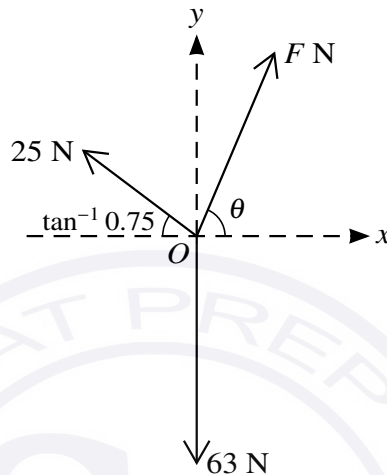
This document consists of **3** printed pages and **1** blank page.

- 1 A block B of mass 2.7 kg is pulled at constant speed along a straight line on a rough horizontal floor. The pulling force has magnitude 25 N and acts at an angle of θ above the horizontal. The normal component of the contact force acting on B has magnitude 20 N .

(i) Show that $\sin \theta = 0.28$. [2]

(ii) Find the work done by the pulling force in moving the block a distance of 5 m . [2]

2



Three horizontal forces of magnitudes $F \text{ N}$, 63 N and 25 N act at O , the origin of the x -axis and y -axis. The forces are in equilibrium. The force of magnitude $F \text{ N}$ makes an angle θ anticlockwise with the positive x -axis. The force of magnitude 63 N acts along the negative y -axis. The force of magnitude 25 N acts at $\tan^{-1} 0.75$ clockwise from the negative x -axis (see diagram). Find the value of F and the value of $\tan \theta$. [5]

- 3 A block of weight 6.1 N slides down a slope inclined at $\tan^{-1}(\frac{11}{60})$ to the horizontal. The coefficient of friction between the block and the slope is $\frac{1}{4}$. The block passes through a point A with speed 2 m s^{-1} . Find how far the block moves from A before it comes to rest. [5]

- 4 A lorry of mass $14\,000 \text{ kg}$ moves along a road starting from rest at a point O . It reaches a point A , and then continues to a point B which it reaches with a speed of 24 m s^{-1} . The part OA of the road is straight and horizontal and has length 400 m . The part AB of the road is straight and is inclined downwards at an angle of θ° to the horizontal and has length 300 m .

(i) For the motion from O to B , find the gain in kinetic energy of the lorry and express its loss in potential energy in terms of θ . [3]

The resistance to the motion of the lorry is 4800 N and the work done by the driving force of the lorry from O to B is 5000 kJ .

(ii) Find the value of θ . [3]

- 5 A cyclist and her bicycle have a total mass of 84 kg. She works at a constant rate of PW while moving on a straight road which is inclined to the horizontal at an angle θ , where $\sin \theta = 0.1$. When moving uphill, the cyclist's acceleration is 1.25 m s^{-2} at an instant when her speed is 3 m s^{-1} . When moving downhill, the cyclist's acceleration is 1.25 m s^{-2} at an instant when her speed is 10 m s^{-1} . The resistance to the cyclist's motion, whether the cyclist is moving uphill or downhill, is $R \text{ N}$. Find the values of P and R . [8]

- 6 Two particles A and B start to move at the same instant from a point O . The particles move in the same direction along the same straight line. The acceleration of A at time $t \text{ s}$ after starting to move is $a \text{ m s}^{-2}$, where $a = 0.05 - 0.0002t$.

(i) Find A 's velocity when $t = 200$ and when $t = 500$. [4]

B moves with constant acceleration for the first 200 s and has the same velocity as A when $t = 200$. B moves with constant retardation from $t = 200$ to $t = 500$ and has the same velocity as A when $t = 500$.

(ii) Find the distance between A and B when $t = 500$. [6]

7



Particles A and B , of masses 0.3 kg and 0.7 kg respectively, are attached to the ends of a light inextensible string. Particle A is held at rest on a rough horizontal table with the string passing over a smooth pulley fixed at the edge of the table. The coefficient of friction between A and the table is 0.2. Particle B hangs vertically below the pulley at a height of 0.5 m above the floor (see diagram). The system is released from rest and 0.25 s later the string breaks. A does not reach the pulley in the subsequent motion. Find

(i) the speed of B immediately before it hits the floor, [9]

(ii) the total distance travelled by A . [3]

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MATHEMATICS

9709/43

Paper 4 Mechanics 1 (M1)

October/November 2014

1 hour 15 minutes

Additional Materials: Answer Booklet/Paper
Graph Paper
List of Formulae (MF9)

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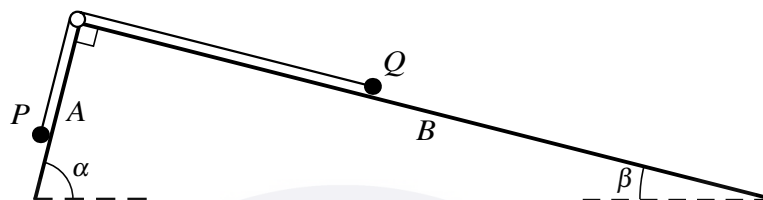
- 1 A car of mass 1400 kg moves on a horizontal straight road. The resistance to the car's motion is constant and equal to 800 N and the power of the car's engine is constant and equal to $P\text{ W}$. At an instant when the car's speed is 18 m s^{-1} its acceleration is 0.5 m s^{-2} .

(i) Find the value of P . [3]

The car continues and passes through another point with speed 25 m s^{-1} .

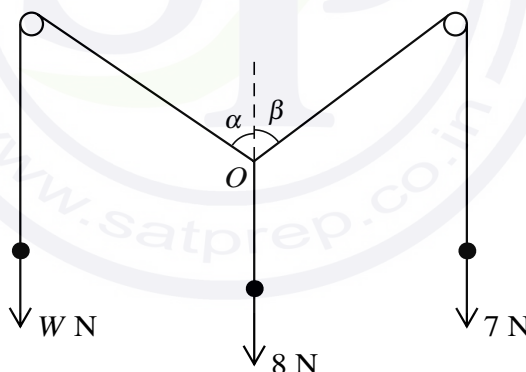
(ii) Find the car's acceleration at this point. [2]

2



The tops of each of two smooth inclined planes A and B meet at a right angle. Plane A is inclined at angle α to the horizontal and plane B is inclined at angle β to the horizontal, where $\sin \alpha = \frac{63}{65}$ and $\sin \beta = \frac{16}{65}$. A small smooth pulley is fixed at the top of the planes and a light inextensible string passes over the pulley. Two particles P and Q , each of mass 0.65 kg , are attached to the string, one at each end. Particle Q is held at rest at a point of the same line of greatest slope of the plane B as the pulley. Particle P rests freely below the pulley in contact with plane A (see diagram). Particle Q is released and the particles start to move with the string taut. Find the tension in the string. [5]

3



Each of three light inextensible strings has a particle attached to one of its ends. The other ends of the strings are tied together at a point O . Two of the strings pass over fixed smooth pegs and the particles hang freely in equilibrium. The weights of the particles and the angles between the sloping parts of the strings and the vertical are as shown in the diagram. It is given that $\sin \beta = 0.8$ and $\cos \beta = 0.6$.

(i) Show that $W \cos \alpha = 3.8$ and find the value of $W \sin \alpha$. [3]

(ii) Hence find the values of W and α . [3]

- 4 A particle P starts from rest and moves in a straight line for 18 seconds. For the first 8 seconds of the motion P has constant acceleration 0.25 m s^{-2} . Subsequently P 's velocity, $v \text{ m s}^{-1}$ at time t seconds after the motion started, is given by

$$v = -0.1t^2 + 2.4t - k,$$

where $8 \leq t \leq 18$ and k is a constant.

(i) Find the value of v when $t = 8$ and hence find the value of k . [2]

(ii) Find the maximum velocity of P . [2]

(iii) Find the displacement of P from its initial position when $t = 18$. [3]

- 5 A box of mass 8 kg is on a rough plane inclined at 5° to the horizontal. A force of magnitude $P \text{ N}$ acts on the box in a direction upwards and parallel to a line of greatest slope of the plane. When $P = 7X$ the box moves up the line of greatest slope with acceleration 0.15 m s^{-2} and when $P = 8X$ the box moves up the line of greatest slope with acceleration 1.15 m s^{-2} . Find the value of X and the coefficient of friction between the box and the plane. [8]

6

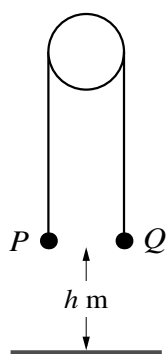


Fig. 1

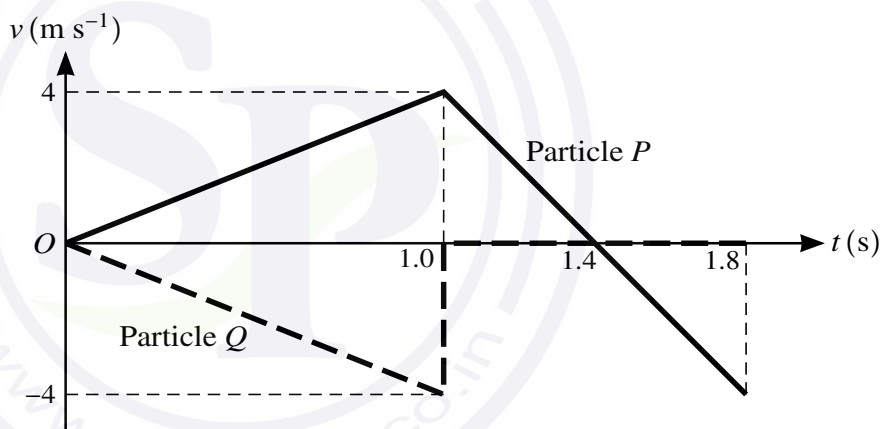
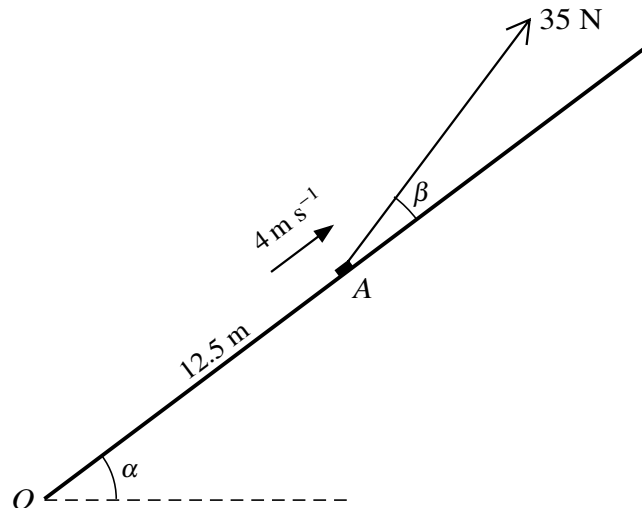


Fig. 2

Particles P and Q have a total mass of 1 kg . The particles are attached to opposite ends of a light inextensible string which passes over a smooth fixed pulley. P is held at rest and Q hangs freely, with both straight parts of the string vertical. Both particles are at a height of $h \text{ m}$ above the floor (see Fig. 1). P is released from rest and the particles start to move with the string taut. Fig. 2 shows the velocity-time graphs for P 's motion and for Q 's motion, where the positive direction for velocity is vertically upwards. Find

- (i) the magnitude of the acceleration with which the particles start to move and the mass of each of the particles, [5]
- (ii) the value of h , [1]
- (iii) the greatest height above the floor reached by particle P . [2]

[Question 7 is printed on the next page.]



A small block of mass 3 kg is initially at rest at the bottom O of a rough plane inclined at an angle α to the horizontal, where $\sin \alpha = 0.6$ and $\cos \alpha = 0.8$. A force of magnitude 35 N acts on the block at an angle β above the plane, where $\sin \beta = 0.28$ and $\cos \beta = 0.96$. The block starts to move up a line of greatest slope of the plane and passes through a point A with speed 4 m s^{-1} . The distance OA is 12.5 m (see diagram).

(i) For the motion of the block from O to A , find the work done against the frictional force acting on the block. [4]

(ii) Find the coefficient of friction between the block and the plane. [3]

At the instant that the block passes through A the force of magnitude 35 N ceases to act.

(iii) Find the distance the block travels up the plane after passing through A . [4]

MATHEMATICS

9709/42

Paper 4 Mechanics 1 (M1)

October/November 2014

1 hour 15 minutes

Additional Materials: Answer Booklet/Paper
Graph Paper
List of Formulae (MF9)

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The use of an electronic calculator is expected, where appropriate.

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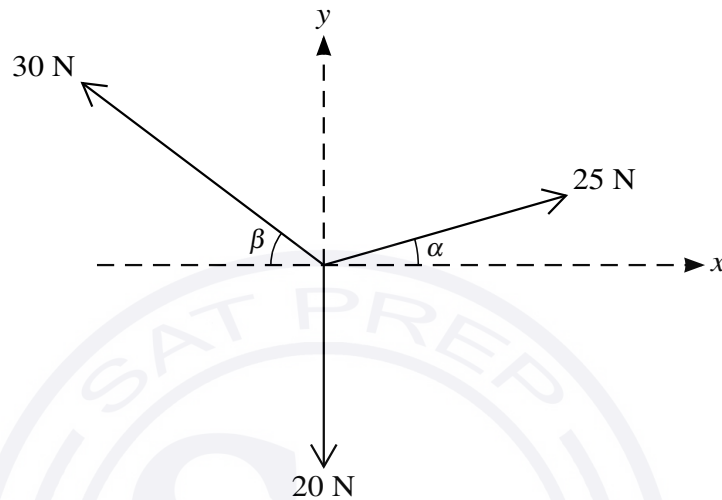
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- 1 A particle P is projected vertically upwards with speed 11 m s^{-1} from a point on horizontal ground. At the same instant a particle Q is released from rest at a point $h \text{ m}$ above the ground. P and Q hit the ground at the same instant, when Q has speed $V \text{ m s}^{-1}$.

(i) Find the time after projection at which P hits the ground. [2]

(ii) Hence find the values of h and V . [2]

2



Three coplanar forces act at a point. The magnitudes of the forces are 20 N, 25 N and 30 N, and the directions in which the forces act are as shown in the diagram, where $\sin \alpha = 0.28$ and $\cos \alpha = 0.96$, and $\sin \beta = 0.6$ and $\cos \beta = 0.8$.

(i) Show that the resultant of the three forces has a zero component in the x -direction. [2]

(ii) Find the magnitude and direction of the resultant of the three forces. [2]

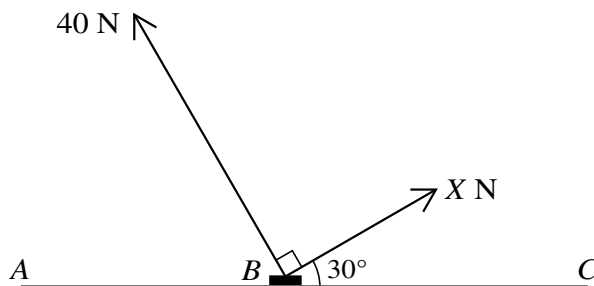
(iii) The force of magnitude 20 N is replaced by another force. The effect is that the resultant force is unchanged in magnitude but reversed in direction. State the magnitude and direction of the replacement force. [1]

- 3 A train of mass $200\,000 \text{ kg}$ moves on a horizontal straight track. It passes through a point A with speed 28 m s^{-1} and later it passes through a point B . The power of the train's engine at B is 1.2 times the power of the train's engine at A . The driving force of the train's engine at B is 0.96 times the driving force of the train's engine at A .

(i) Show that the speed of the train at B is 35 m s^{-1} . [2]

(ii) For the motion from A to B , find the work done by the train's engine given that the work done against the resistance to the train's motion is $2.3 \times 10^6 \text{ J}$. [3]

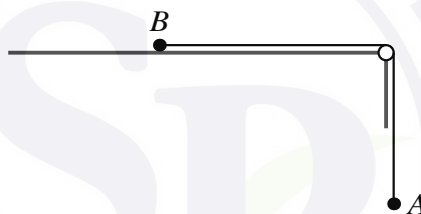
4



Forces of magnitude X N and 40 N act on a block B of mass 15 kg, which is in equilibrium in contact with a horizontal surface between points A and C on the surface. The forces act in the same vertical plane and in the directions shown in the diagram.

- (i) Given that the surface is smooth, find the value of X . [2]
- (ii) It is given instead that the surface is rough and that the block is in limiting equilibrium. The frictional force acting on the block has magnitude 10 N in the direction towards A . Find the coefficient of friction between the block and the surface. [5]

5



Particles A and B , each of mass 0.3 kg, are connected by a light inextensible string. The string passes over a small smooth pulley fixed at the edge of a rough horizontal surface. Particle A hangs freely and particle B is held at rest in contact with the surface (see diagram). The coefficient of friction between B and the surface is 0.7 . Particle B is released and moves on the surface without reaching the pulley.

- (i) Find, for the first 0.9 m of B 's motion,
- (a) the work done against the frictional force acting on B , [2]
- (b) the loss of potential energy of the system, [1]
- (c) the gain in kinetic energy of the system. [2]

At the instant when B has moved 0.9 m the string breaks. A is at a height of 0.54 m above a horizontal floor at this instant.

- (ii) Find the speed with which A reaches the floor. [3]

[Questions 6 and 7 are printed on the next page.]

- 6 ABC is a line of greatest slope of a plane inclined at angle α to the horizontal, where $\sin \alpha = 0.28$ and $\cos \alpha = 0.96$. The point A is at the top of the plane, the point C is at the bottom of the plane and the length of AC is 5 m. The part of the plane above the level of B is smooth and the part below the level of B is rough. A particle P is released from rest at A and reaches C with a speed of 2 m s^{-1} . The coefficient of friction between P and the part of the plane below B is 0.5. Find

(i) the acceleration of P while moving

(a) from A to B ,

(b) from B to C ,

[3]

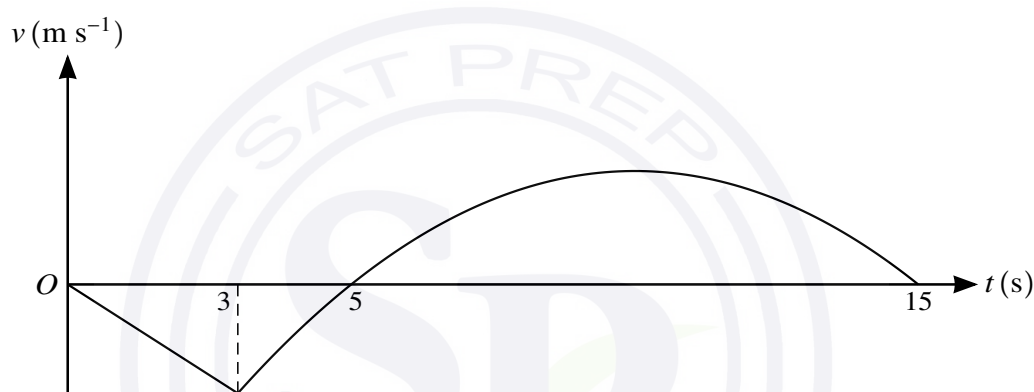
(ii) the distance AB ,

[3]

(iii) the time taken for P to move from A to C .

[3]

7



The diagram shows the velocity-time graph for the motion of a particle P which moves on a straight line BAC . It starts at A and travels to B taking 5 s. It then reverses direction and travels from B to C taking 10 s. For the first 3 s of P 's motion its acceleration is constant. For the remaining 12 s the velocity of P is $v \text{ m s}^{-1}$ at time $t \text{ s}$ after leaving A , where

$$v = -0.2t^2 + 4t - 15 \quad \text{for } 3 \leq t \leq 15.$$

(i) Find the value of v when $t = 3$ and the magnitude of the acceleration of P for the first 3 s of its motion.

[3]

(ii) Find the maximum velocity of P while it is moving from B to C .

[3]

(iii) Find the average speed of P ,

(a) while moving from A to B ,

(b) for the whole journey.

[6]

MATHEMATICS

9709/41

Paper 4 Mechanics 1 (M1)

October/November 2014

1 hour 15 minutes

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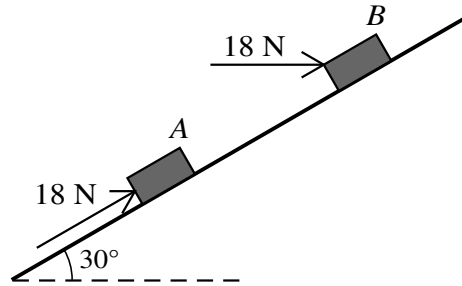
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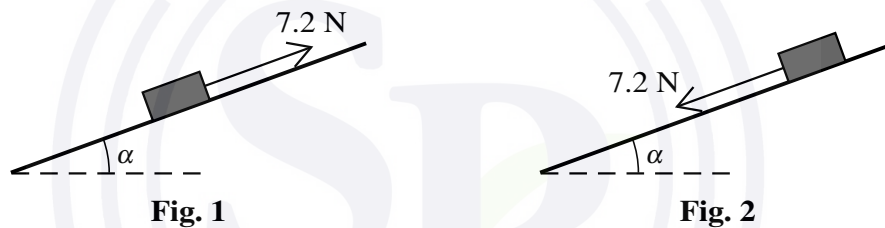
- 1 A car of mass 800 kg is moving on a straight horizontal road with its engine working at a rate of 22.5 kW . Find the resistance to the car's motion at an instant when the car's speed is 18 m s^{-1} and its acceleration is 1.2 m s^{-2} . [4]

2



Small blocks A and B are held at rest on a smooth plane inclined at 30° to the horizontal. Each is held in equilibrium by a force of magnitude 18 N . The force on A acts upwards parallel to a line of greatest slope of the plane, and the force on B acts horizontally in the vertical plane containing a line of greatest slope (see diagram). Find the weight of A and the weight of B . [4]

3



A block of weight 7.5 N is at rest on a plane which is inclined to the horizontal at angle α , where $\tan \alpha = \frac{7}{24}$. The coefficient of friction between the block and the plane is μ . A force of magnitude 7.2 N acting parallel to a line of greatest slope is applied to the block. When the force acts up the plane (see Fig. 1) the block remains at rest.

- (i) Show that $\mu \geq \frac{17}{24}$. [4]

When the force acts down the plane (see Fig. 2) the block slides downwards.

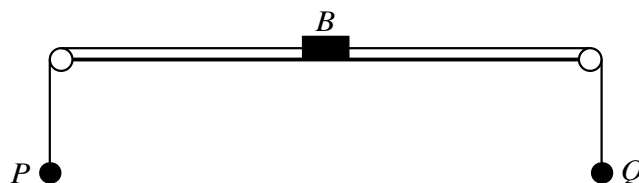
- (ii) Show that $\mu < \frac{31}{24}$. [2]

- 4 Particles P and Q move on a straight line AOB . The particles leave O simultaneously, with P moving towards A and with Q moving towards B . The initial speed of P is 1.3 m s^{-1} and its acceleration in the direction OA is 0.1 m s^{-2} . Q moves with acceleration in the direction OB of $0.016t\text{ m s}^{-2}$, where t seconds is the time elapsed since the instant that P and Q started to move from O . When $t = 20$, particle P passes through A and particle Q passes through B .

- (i) Given that the speed of Q at B is the same as the speed of P at A , find the speed of Q at time $t = 0$. [4]

- (ii) Find the distance AB . [3]

5



A small block B of mass 0.25 kg is attached to the mid-point of a light inextensible string. Particles P and Q , of masses 0.2 kg and 0.3 kg respectively, are attached to the ends of the string. The string passes over two smooth pulleys fixed at opposite sides of a rough table, with B resting in limiting equilibrium on the table between the pulleys and particles P and Q and block B are in the same vertical plane (see diagram).

- (i) Find the coefficient of friction between B and the table. [3]

Q is now removed so that P and B begin to move.

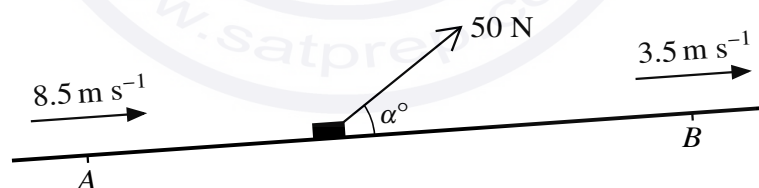
- (ii) Find the acceleration of P and the tension in the part PB of the string. [6]

- 6 A particle of mass 3 kg falls from rest at a point 5 m above the surface of a liquid which is in a container. There is no instantaneous change in speed of the particle as it enters the liquid. The depth of the liquid in the container is 4 m . The downward acceleration of the particle while it is moving in the liquid is 5.5 m s^{-2} .

- (i) Find the resistance to motion of the particle while it is moving in the liquid. [2]

- (ii) Sketch the velocity-time graph for the motion of the particle, from the time it starts to move until the time it reaches the bottom of the container. Show on your sketch the velocity and the time when the particle enters the liquid, and when the particle reaches the bottom of the container. [7]

7



A block of mass 60 kg is pulled up a hill in the line of greatest slope by a force of magnitude 50 N acting at an angle α° above the hill. The block passes through points A and B with speeds 8.5 m s^{-1} and 3.5 m s^{-1} respectively (see diagram). The distance AB is 250 m and B is 17.5 m above the level of A . The resistance to motion of the block is 6 N . Find the value of α . [11]

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MATHEMATICS

9709/43

Paper 4 Mechanics 1 (M1)

May/June 2014

1 hour 15 minutes

Additional Materials: Answer Booklet/Paper
Graph Paper
List of Formulae (MF9)

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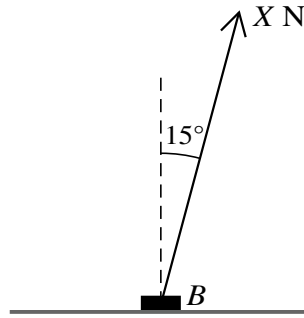
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1

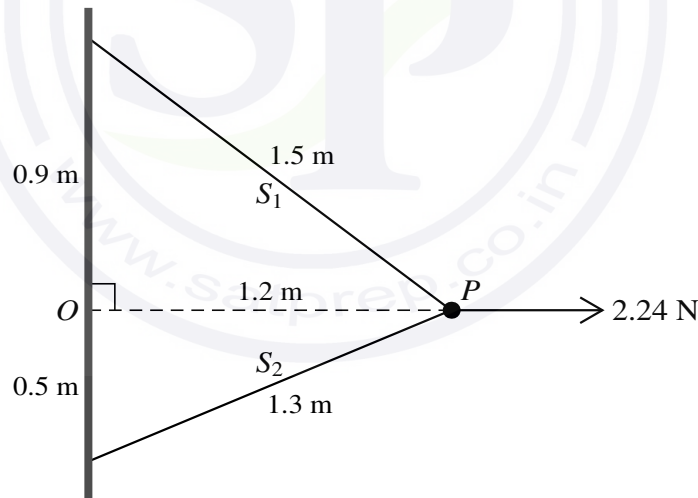


A block B of mass 7 kg is at rest on rough horizontal ground. A force of magnitude $X\text{ N}$ acts on B at an angle of 15° to the upward vertical (see diagram).

- (i) Given that B is in equilibrium find, in terms of X , the normal component of the force exerted on B by the ground. [2]
- (ii) The coefficient of friction between B and the ground is 0.4 . Find the value of X for which B is in limiting equilibrium. [3]

- 2 A car of mass 1250 kg travels up a straight hill inclined at an angle α to the horizontal, where $\sin \alpha = 0.02$. The power provided by the car's engine is 23 kW . The resistance to motion is constant and equal to 600 N . Find the speed of the car at an instant when its acceleration is 0.5 m s^{-2} . [5]

3



A particle P of weight 1.4 N is attached to one end of a light inextensible string S_1 of length 1.5 m , and to one end of another light inextensible string S_2 of length 1.3 m . The other end of S_1 is attached to a wall at the point 0.9 m vertically above a point O of the wall. The other end of S_2 is attached to the wall at the point 0.5 m vertically below O . The particle is held in equilibrium, at the same horizontal level as O , by a horizontal force of magnitude 2.24 N acting away from the wall and perpendicular to it (see diagram). Find the tensions in the strings. [6]

- 4 A small ball of mass 0.4 kg is released from rest at a point 5 m above horizontal ground. At the instant the ball hits the ground it loses 12.8 J of kinetic energy and starts to move upwards.

(i) Show that the greatest height above the ground that the ball reaches after hitting the ground is 1.8 m. [4]

(ii) Find the time taken for the ball's motion from its release until reaching this greatest height. [3]

- 5 A lorry of mass 16 000 kg travels at constant speed from the bottom, O , to the top, A , of a straight hill. The distance OA is 1200 m and A is 18 m above the level of O . The driving force of the lorry is constant and equal to 4500 N.

(i) Find the work done against the resistance to the motion of the lorry. [3]

On reaching A the lorry continues along a straight horizontal road against a constant resistance of 2000 N. The driving force of the lorry is not now constant, and the speed of the lorry increases from 9 m s^{-1} at A to 21 m s^{-1} at the point B on the road. The distance AB is 2400 m.

(ii) Use an energy method to find F , where $F \text{ N}$ is the average value of the driving force of the lorry while moving from A to B . [3]

(iii) Given that the driving force at A is 1280 N greater than $F \text{ N}$ and that the driving force at B is 1280 N less than $F \text{ N}$, show that the power developed by the lorry's engine is the same at B as it is at A . [2]

- 6 A particle starts from rest at a point O and moves in a horizontal straight line. The velocity of the particle is $v \text{ m s}^{-1}$ at time $t \text{ s}$ after leaving O . For $0 \leq t < 60$, the velocity is given by

$$v = 0.05t - 0.0005t^2.$$

The particle hits a wall at the instant when $t = 60$, and reverses the direction of its motion. The particle subsequently comes to rest at the point A when $t = 100$, and for $60 < t \leq 100$ the velocity is given by

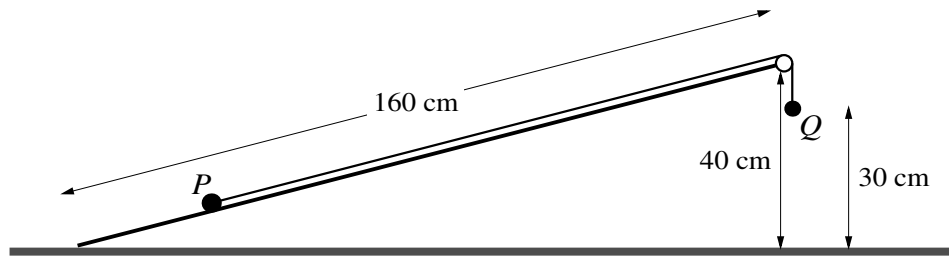
$$v = 0.025t - 2.5.$$

(i) Find the velocity of the particle immediately before it hits the wall, and its velocity immediately after it hits the wall. [2]

(ii) Find the total distance travelled by the particle. [4]

(iii) Find the maximum speed of the particle and sketch the particle's velocity-time graph for $0 \leq t \leq 100$, showing the value of t for which the speed is greatest. [4]

[Question 7 is printed on the next page.]



A smooth inclined plane of length 160 cm is fixed with one end at a height of 40 cm above the other end, which is on horizontal ground. Particles P and Q , of masses 0.76 kg and 0.49 kg respectively, are attached to the ends of a light inextensible string which passes over a small smooth pulley fixed at the top of the plane. Particle P is held at rest on the same line of greatest slope as the pulley and Q hangs vertically below the pulley at a height of 30 cm above the ground (see diagram). P is released from rest. It starts to move up the plane and does not reach the pulley. Find

- (i) the acceleration of the particles and the tension in the string before Q reaches the ground, [4]
- (ii) the speed with which Q reaches the ground, [2]
- (iii) the total distance travelled by P before it comes to instantaneous rest. [3]

MATHEMATICS

9709/42

Paper 4 Mechanics 1 (M1)

May/June 2014

1 hour 15 minutes

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 List of Formulae (MF9)

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- 1 A car of mass 600 kg travels along a straight horizontal road. The resistance to the car's motion is constant and equal to R N.

(i) Find the value of R , given that the car's acceleration is 1.4 m s^{-2} at an instant when the car's speed is 18 m s^{-1} and its engine is working at a rate of 22.5 kW. [4]

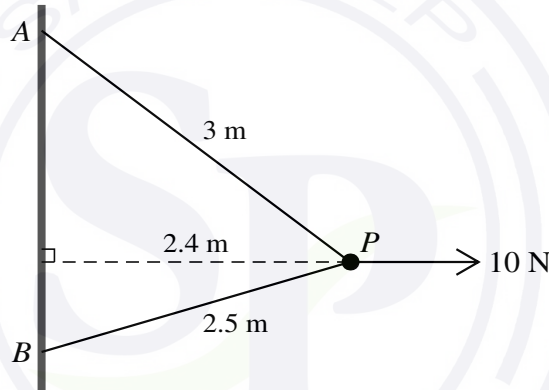
(ii) Find the rate of working of the car's engine when the car is moving with a constant speed of 15 m s^{-1} . [1]

- 2 A and B are two points which are 10 m apart on the same horizontal plane. A particle P starts to move from rest at A , directly towards B , with constant acceleration 0.5 m s^{-2} . Another particle Q is moving directly towards A with constant speed 0.75 m s^{-1} , and passes through B at the instant that P starts to move. At time T s after this instant, particles P and Q collide. Find

(i) the value of T , [4]

(ii) the speed of P immediately before the collision. [1]

3



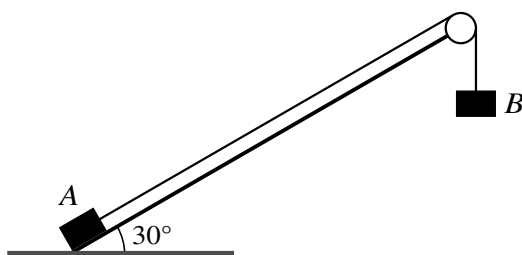
A and B are fixed points of a vertical wall with A vertically above B . A particle P of mass 0.7 kg is attached to A by a light inextensible string of length 3 m. P is also attached to B by a light inextensible string of length 2.5 m. P is maintained in equilibrium at a distance of 2.4 m from the wall by a horizontal force of magnitude 10 N acting on P (see diagram). Both strings are taut, and the 10 N force acts in the plane APB which is perpendicular to the wall. Find the tensions in the strings. [6]

- 4 A particle P moves on a straight line, starting from rest at a point O of the line. The time after P starts to move is t s, and the particle moves along the line with constant acceleration $\frac{1}{4} \text{ m s}^{-2}$ until it passes through a point A at time $t = 8$. After passing through A the velocity of P is $\frac{1}{2}t^{\frac{2}{3}} \text{ m s}^{-1}$.

(i) Find the acceleration of P immediately after it passes through A . Hence show that the acceleration of P decreases by $\frac{1}{12} \text{ m s}^{-2}$ as it passes through A . [4]

(ii) Find the distance moved by P from $t = 0$ to $t = 27$. [3]

5



A light inextensible rope has a block A of mass 5 kg attached at one end, and a block B of mass 16 kg attached at the other end. The rope passes over a smooth pulley which is fixed at the top of a rough plane inclined at an angle of 30° to the horizontal. Block A is held at rest at the bottom of the plane and block B hangs below the pulley (see diagram). The coefficient of friction between A and the plane is $\frac{1}{\sqrt{3}}$. Block A is released from rest and the system starts to move. When each of the blocks has moved a distance of $x\text{ m}$ each has speed $v\text{ m s}^{-1}$.

(i) Write down the gain in kinetic energy of the system in terms of v . [1]

(ii) Find, in terms of x ,

(a) the loss of gravitational potential energy of the system, [2]

(b) the work done against the frictional force. [3]

(iii) Show that $21v^2 = 220x$. [2]

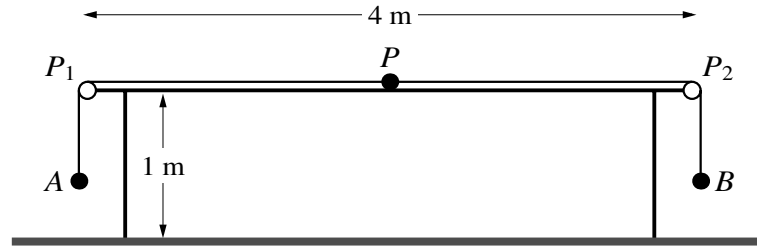
- 6 A particle P of mass 0.2 kg is released from rest at a point 7.2 m above the surface of the liquid in a container. P falls through the air and into the liquid. There is no air resistance and there is no instantaneous change of speed as P enters the liquid. When P is at a distance of 0.8 m below the surface of the liquid, P 's speed is 6 m s^{-1} . The only force on P due to the liquid is a constant resistance to motion of magnitude $R\text{ N}$.

(i) Find the deceleration of P while it is falling through the liquid, and hence find the value of R . [5]

The depth of the liquid in the container is 3.6 m . P is taken from the container and attached to one end of a light inextensible string. P is placed at the bottom of the container and then pulled vertically upwards with constant acceleration. The resistance to motion of $R\text{ N}$ continues to act. The particle reaches the surface 4 s after leaving the bottom of the container.

(ii) Find the tension in the string. [4]

[Question 7 is printed on the next page.]



A light inextensible string of length 5.28 m has particles A and B , of masses 0.25 kg and 0.75 kg respectively, attached to its ends. Another particle P , of mass 0.5 kg, is attached to the mid-point of the string. Two small smooth pulleys P_1 and P_2 are fixed at opposite ends of a rough horizontal table of length 4 m and height 1 m. The string passes over P_1 and P_2 with particle A held at rest vertically below P_1 , the string taut and B hanging freely below P_2 . Particle P is in contact with the table halfway between P_1 and P_2 (see diagram). The coefficient of friction between P and the table is 0.4. Particle A is released and the system starts to move with constant acceleration of magnitude $a \text{ m s}^{-2}$. The tension in the part AP of the string is $T_A \text{ N}$ and the tension in the part PB of the string is $T_B \text{ N}$.

- (i) Find T_A and T_B in terms of a . [3]
- (ii) Show by considering the motion of P that $a = 2$. [3]
- (iii) Find the speed of the particles immediately before B reaches the floor. [2]
- (iv) Find the deceleration of P immediately after B reaches the floor. [2]

MATHEMATICS

9709/41

Paper 4 Mechanics 1 (M1)

May/June 2014

1 hour 15 minutes

Additional Materials: Answer Booklet/Paper
 Graph Paper
 List of Formulae (MF9)

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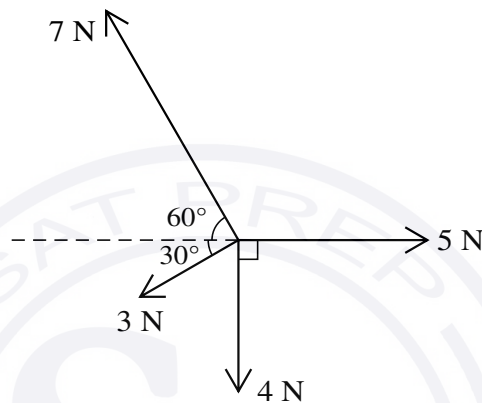
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- 1 A train is moving at constant speed $V \text{ m s}^{-1}$ along a horizontal straight track. Given that the power of the train's engine is 1330 kW and the total resistance to the train's motion is 28 kN, find the value of V . [3]
- 2 A rough plane is inclined at an angle of α° to the horizontal. A particle of mass 0.25 kg is in equilibrium on the plane. The normal reaction force acting on the particle has magnitude 2.4 N. Find
- (i) the value of α , [2]
- (ii) the least possible value of the coefficient of friction. [2]

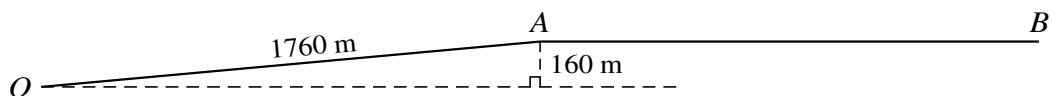
3



Four coplanar forces act at a point. The magnitudes of the forces are 5 N, 4 N, 3 N and 7 N, and the directions in which the forces act are shown in the diagram. Find the magnitude and direction of the resultant of the four forces. [6]

- 4 A particle is projected vertically upwards with speed 9 m s^{-1} from a point 3.15 m above horizontal ground. The particle moves freely under gravity until it hits the ground. For the particle's motion from the instant of projection until the particle hits the ground, find the total distance travelled and the total time taken. [6]

5



A car of mass 1100 kg starts from rest at O and travels along a road OAB . The section OA is straight, of length 1760 m, and inclined to the horizontal with A at a height of 160 m above the level of O . The section AB is straight and horizontal (see diagram). While the car is moving the driving force of the car is 1800 N and the resistance to the car's motion is 700 N. The speed of the car is $v \text{ m s}^{-1}$ when the car has travelled a distance of $x \text{ m}$ from O .

- (i) For the car's motion from O to A , write down its increase in kinetic energy in terms of v and its increase in potential energy in terms of x . Hence find the value of k for which $kv^2 = x$ for $0 \leq x \leq 1760$. [4]
- (ii) Show that $v^2 = 2x - 3200$ for $x \geq 1760$. [4]

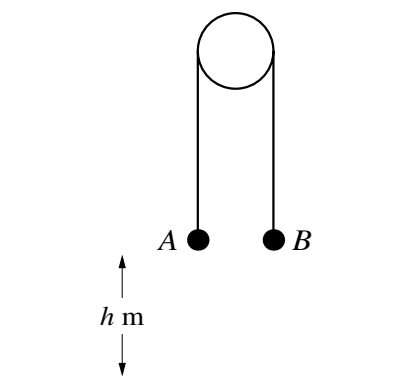


Fig. 1

Particles A of mass 0.25 kg and B of mass 0.75 kg are attached to opposite ends of a light inextensible string which passes over a fixed smooth pulley. The system is held at rest with the string taut and its straight parts vertical. Both particles are at a height of $h\text{ m}$ above the floor (see Fig. 1). The system is released from rest, and 0.6 s later, when both particles are in motion, the string breaks. The particle A does not reach the pulley in the subsequent motion.

- (i) Find the acceleration of A and the distance travelled by A before the string breaks. [4]

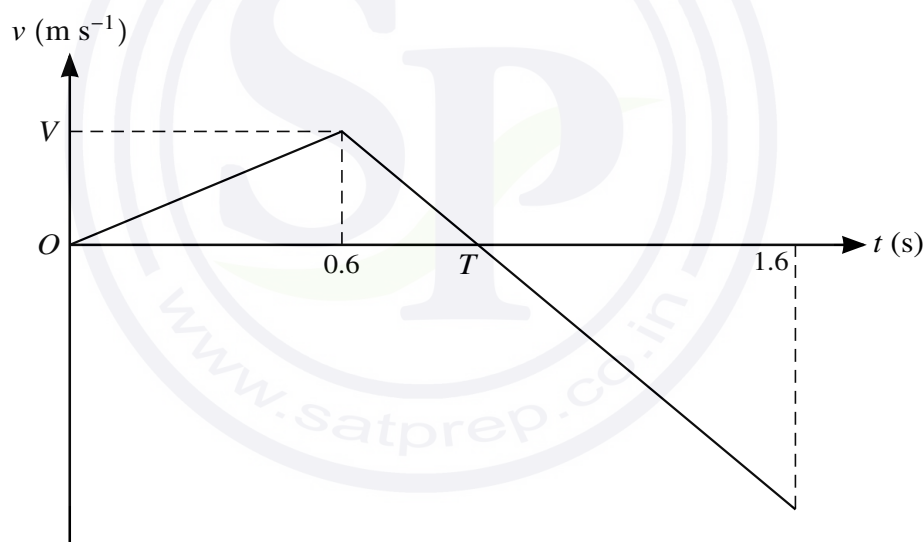


Fig. 2

The velocity-time graph shown in Fig. 2 is for the motion of particle A until it hits the floor. The velocity of A when the string breaks is $V\text{ m s}^{-1}$ and $T\text{ s}$ is the time taken for A to reach its greatest height.

- (ii) Find the value of V and the value of T . [3]
- (iii) Find the distance travelled by A upwards and the distance travelled by A downwards and hence find h . [3]

[Question 7 is printed on the next page.]

- 7 Two cyclists P and Q travel along a straight road ABC , starting simultaneously at A and arriving simultaneously at C . Both cyclists pass through B 400 s after leaving A . Cyclist P starts with speed 3 m s^{-1} and increases this speed with constant acceleration 0.005 m s^{-2} until he reaches B .

(i) Show that the distance AB is 1600 m and find P 's speed at B . [3]

Cyclist Q travels from A to B with speed $v \text{ m s}^{-1}$ at time t seconds after leaving A , where

$$v = 0.04t - 0.0001t^2 + k,$$

and k is a constant.

(ii) Find the value of k and the maximum speed of Q before he has reached B . [6]

Cyclist P travels from B to C , a distance of 1400 m, at the speed he had reached at B . Cyclist Q travels from B to C with constant acceleration $a \text{ m s}^{-2}$.

(iii) Find the time taken for the cyclists to travel from B to C and find the value of a . [4]





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

MATHEMATICS

9709/43

Paper 4 Mechanics 1 (M1)

October/November 2013

1 hour 15 minutes

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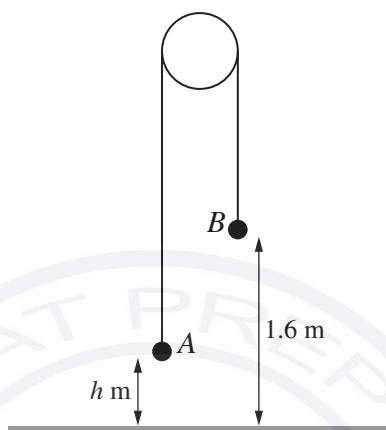


- 1 A particle moves up a line of greatest slope of a rough plane inclined at an angle α to the horizontal, where $\sin \alpha = 0.28$. The coefficient of friction between the particle and the plane is $\frac{1}{3}$.

(i) Show that the acceleration of the particle is -6 m s^{-2} . [3]

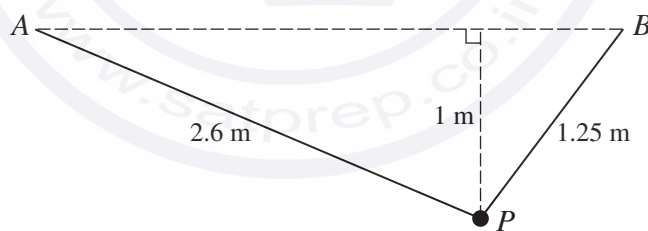
(ii) Given that the particle's initial speed is 5.4 m s^{-1} , find the distance that the particle travels up the plane. [2]

2



Particle A of mass 0.2 kg and particle B of mass 0.6 kg are attached to the ends of a light inextensible string. The string passes over a fixed smooth pulley. B is held at rest at a height of 1.6 m above the floor. A hangs freely at a height of $h \text{ m}$ above the floor. Both straight parts of the string are vertical (see diagram). B is released and both particles start to move. When B reaches the floor it remains at rest, but A continues to move vertically upwards until it reaches a height of 3 m above the floor. Find the speed of B immediately before it hits the floor, and hence find the value of h . [6]

3



A particle P of mass 1.05 kg is attached to one end of each of two light inextensible strings, of lengths 2.6 m and 1.25 m . The other ends of the strings are attached to fixed points A and B , which are at the same horizontal level. P hangs in equilibrium at a point 1 m below the level of A and B (see diagram). Find the tensions in the strings. [6]

- 4 A box of mass 30 kg is at rest on a rough plane inclined at an angle α to the horizontal, where $\sin \alpha = 0.1$, acted on by a force of magnitude 40 N. The force acts upwards and parallel to a line of greatest slope of the plane. The box is on the point of slipping up the plane.

(i) Find the coefficient of friction between the box and the plane. [5]

The force of magnitude 40 N is removed.

(ii) Determine, giving a reason, whether or not the box remains in equilibrium. [2]

- 5 A car travels in a straight line from A to B , a distance of 12 km, taking 552 seconds. The car starts from rest at A and accelerates for T_1 s at 0.3 m s^{-2} , reaching a speed of $V \text{ m s}^{-1}$. The car then continues to move at $V \text{ m s}^{-1}$ for T_2 s. It then decelerates for T_3 s at 1 m s^{-2} , coming to rest at B .

(i) Sketch the velocity-time graph for the motion and express T_1 and T_3 in terms of V . [3]

(ii) Express the total distance travelled in terms of V and show that $13V^2 - 3312V + 72\,000 = 0$. Hence find the value of V . [5]

- 6 A lorry of mass 12 500 kg travels along a road from A to C passing through a point B . The resistance to motion of the lorry is 4800 N for the whole journey from A to C .

(i) The section AB of the road is straight and horizontal. On this section of the road the power of the lorry's engine is constant and equal to 144 kW. The speed of the lorry at A is 16 m s^{-1} and its acceleration at B is 0.096 m s^{-2} . Find the acceleration of the lorry at A and show that its speed at B is 24 m s^{-1} . [3]

(ii) The section BC of the road has length 500 m, is straight and inclined upwards towards C . On this section of the road the lorry's driving force is constant and equal to 5800 N. The speed of the lorry at C is 16 m s^{-1} . Find the height of C above the level of AB . [5]

- 7 A vehicle starts from rest at a point O and moves in a straight line. Its speed $v \text{ m s}^{-1}$ at time t seconds after leaving O is defined as follows.

$$\text{For } 0 \leq t \leq 60, \quad v = k_1 t - 0.005 t^2,$$

$$\text{for } t \geq 60, \quad v = \frac{k_2}{\sqrt{t}}.$$

The distance travelled by the vehicle during the first 60 s is 540 m.

(i) Find the value of the constant k_1 and show that $k_2 = 12\sqrt{(60)}$. [5]

(ii) Find an expression in terms of t for the total distance travelled when $t \geq 60$. [2]

(iii) Find the speed of the vehicle when it has travelled a total distance of 1260 m. [3]

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9709/42

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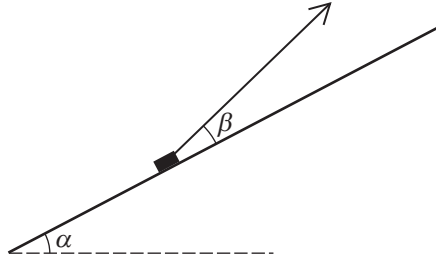
The total number of marks for this paper is 50.

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This document consists of 4 printed pages.



1



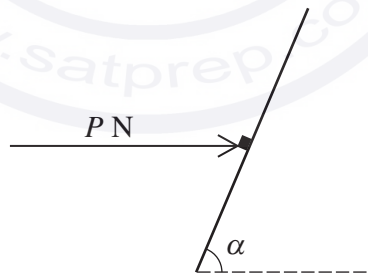
A small block of weight 5.1 N rests on a smooth plane inclined at an angle α to the horizontal, where $\sin \alpha = \frac{8}{17}$. The block is held in equilibrium by means of a light inextensible string. The string makes an angle β above the line of greatest slope on which the block rests, where $\sin \beta = \frac{7}{25}$ (see diagram). Find the tension in the string. [3]

- 2 A box of mass 25 kg is pulled in a straight line along a horizontal floor. The box starts from rest at a point A and has a speed of 3 m s^{-1} when it reaches a point B . The distance AB is 15 m . The pulling force has magnitude 220 N and acts at an angle of α° above the horizontal. The work done against the resistance to motion acting on the box, as the box moves from A to B , is 3000 J . Find the value of α . [5]

- 3 The resistance to motion acting on a runner of mass 70 kg is $kv \text{ N}$, where $v \text{ m s}^{-1}$ is the runner's speed and k is a constant. The greatest power the runner can exert is 100 W . The runner's greatest steady speed on horizontal ground is 4 m s^{-1} .

- (i) Show that $k = 6.25$. [2]
- (ii) Find the greatest steady speed of the runner while running uphill on a straight path inclined at an angle α to the horizontal, where $\sin \alpha = 0.05$. [4]

4



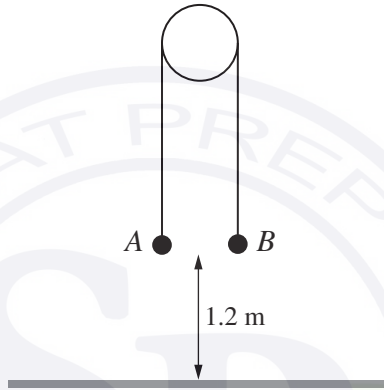
A rough plane is inclined at an angle α to the horizontal, where $\tan \alpha = 2.4$. A small block of mass 0.6 kg is held at rest on the plane by a horizontal force of magnitude $P \text{ N}$. This force acts in a vertical plane through a line of greatest slope (see diagram). The coefficient of friction between the block and the plane is 0.4 . The block is on the point of slipping down the plane. By resolving forces parallel to and perpendicular to the inclined plane, or otherwise, find the value of P . [8]

- 5 A particle P moves in a straight line. P starts from rest at O and travels to A where it comes to rest, taking 50 seconds. The speed of P at time t seconds after leaving O is $v \text{ m s}^{-1}$, where v is defined as follows.

$$\begin{aligned} \text{For } 0 \leq t \leq 5, \quad v &= t - 0.1t^2, \\ \text{for } 5 \leq t \leq 45, \quad v &\text{ is constant,} \\ \text{for } 45 \leq t \leq 50, \quad v &= 9t - 0.1t^2 - 200. \end{aligned}$$

- (i) Find the distance travelled by P in the first 5 seconds. [3]
- (ii) Find the total distance from O to A , and deduce the average speed of P for the whole journey from O to A . [6]

6



Particles A of mass 0.4 kg and B of mass 1.6 kg are attached to the ends of a light inextensible string which passes over a fixed smooth pulley. A is held at rest and B hangs freely, with both straight parts of the string vertical and both particles at a height of 1.2 m above the floor (see diagram). A is released and both particles start to move.

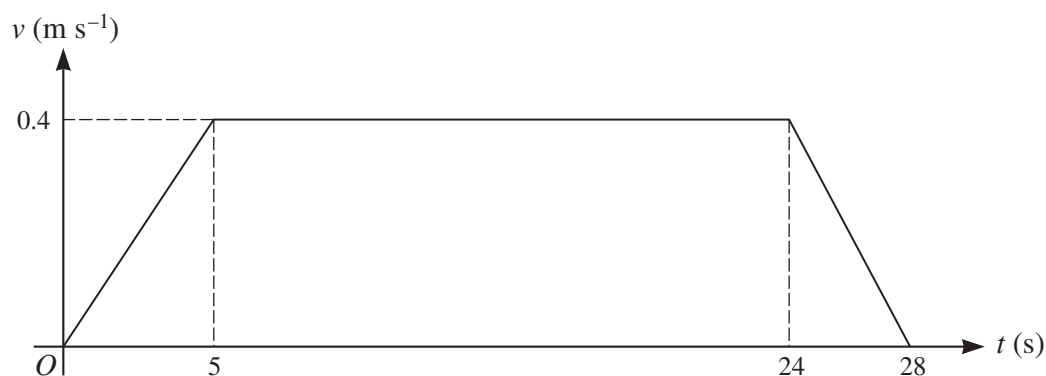
- (i) Find the work done on B by the tension in the string, as B moves to the floor. [5]

When particle B reaches the floor it remains at rest. Particle A continues to move upwards.

- (ii) Find the greatest height above the floor reached by particle A . [4]

[Question 7 is printed on the next page.]

7



An elevator is pulled vertically upwards by a cable. The velocity-time graph for the motion is shown above. Find

- (i) the distance travelled by the elevator, [2]
- (ii) the acceleration during the first stage and the deceleration during the third stage. [2]

The mass of the elevator is 800 kg and there is a box of mass 100 kg on the floor of the elevator.

- (iii) Find the tension in the cable in each of the three stages of the motion. [3]
- (iv) Find the greatest and least values of the magnitude of the force exerted on the box by the floor of the elevator. [3]



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

MATHEMATICS

9709/41

Paper 4 Mechanics 1 (M1)

October/November 2013

1 hour 15 minutes

Additional Materials: Answer Booklet/Paper
Graph Paper
List of Formulae (MF9)

READ THESE INSTRUCTIONS FIRST

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You may use a soft pencil for any diagrams or graphs.

Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** the questions.

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

The use of an electronic calculator is expected, where appropriate.

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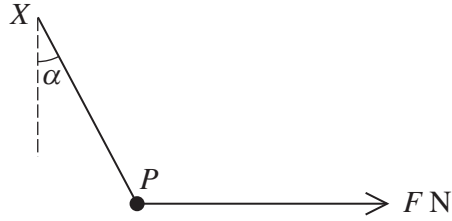
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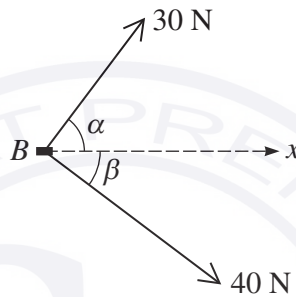


1



A particle P of mass 0.3 kg is attached to one end of a light inextensible string. The other end of the string is attached to a fixed point X . A horizontal force of magnitude $F \text{ N}$ is applied to the particle, which is in equilibrium when the string is at an angle α to the vertical, where $\tan \alpha = \frac{8}{15}$ (see diagram). Find the tension in the string and the value of F . [4]

2



A block B lies on a rough horizontal plane. Horizontal forces of magnitudes 30 N and 40 N , making angles of α and β respectively with the x -direction, act on B as shown in the diagram, and B is moving in the x -direction with constant speed. It is given that $\cos \alpha = 0.6$ and $\cos \beta = 0.8$.

(i) Find the total work done by the forces shown in the diagram when B has moved a distance of 20 m . [2]

(ii) Given that the coefficient of friction between the block and the plane is $\frac{5}{8}$, find the weight of the block. [3]

3 A cyclist exerts a constant driving force of magnitude $F \text{ N}$ while moving up a straight hill inclined at an angle α to the horizontal, where $\sin \alpha = \frac{36}{325}$. A constant resistance to motion of 32 N acts on the cyclist. The total weight of the cyclist and his bicycle is 780 N . The cyclist's acceleration is -0.2 m s^{-2} .

(i) Find the value of F . [4]

The cyclist's speed is 7 m s^{-1} at the bottom of the hill.

(ii) Find how far up the hill the cyclist travels before coming to rest. [2]

- 4 Particles P and Q are moving in a straight line on a rough horizontal plane. The frictional forces are the only horizontal forces acting on the particles.

(i) Find the deceleration of each of the particles given that the coefficient of friction between P and the plane is 0.2, and between Q and the plane is 0.25. [2]

At a certain instant, P passes through the point A and Q passes through the point B . The distance AB is 5 m. The velocities of P and Q at A and B are 8 m s^{-1} and 3 m s^{-1} , respectively, both in the direction AB .

(ii) Find the speeds of P and Q immediately before they collide. [5]

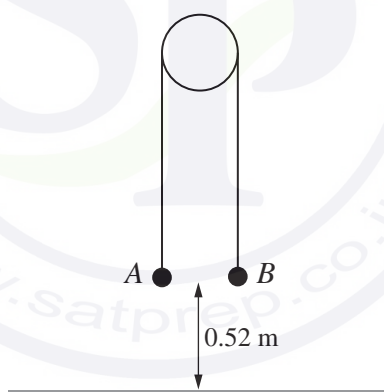
- 5 A lorry of mass 15 000 kg climbs from the bottom to the top of a straight hill, of length 1440 m, at a constant speed of 15 m s^{-1} . The top of the hill is 16 m above the level of the bottom of the hill. The resistance to motion is constant and equal to 1800 N.

(i) Find the work done by the driving force. [4]

On reaching the top of the hill the lorry continues on a straight horizontal road and passes through a point P with speed 24 m s^{-1} . The resistance to motion is constant and is now equal to 1600 N. The work done by the lorry's engine from the top of the hill to the point P is 5030 kJ.

(ii) Find the distance from the top of the hill to the point P . [3]

6



Particles A and B , of masses 0.3 kg and 0.7 kg respectively, are attached to the ends of a light inextensible string. The string passes over a fixed smooth pulley. A is held at rest and B hangs freely, with both straight parts of the string vertical and both particles at a height of 0.52 m above the floor (see diagram). A is released and both particles start to move.

(i) Find the tension in the string. [4]

When both particles are moving with speed 1.6 m s^{-1} the string breaks.

(ii) Find the time taken, from the instant that the string breaks, for A to reach the floor. [5]

[Question 7 is printed on the next page.]

- 7 A particle P starts from rest at a point O and moves in a straight line. P has acceleration $0.6t \text{ m s}^{-2}$ at time t seconds after leaving O , until $t = 10$.

(i) Find the velocity and displacement from O of P when $t = 10$. [5]

After $t = 10$, P has acceleration $-0.4t \text{ m s}^{-2}$ until it comes to rest at a point A .

(ii) Find the distance OA . [7]



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

MATHEMATICS

9709/43

Paper 4 Mechanics 1 (M1)

May/June 2013

1 hour 15 minutes

Additional Materials: Answer Booklet/Paper
Graph Paper
List of Formulae (MF9)

READ THESE INSTRUCTIONS FIRST

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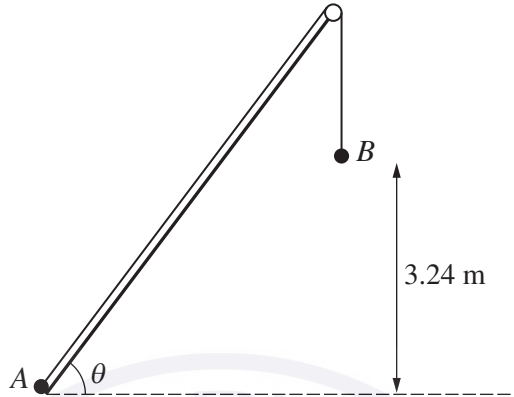
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This document consists of **3** printed pages and **1** blank page.



- 1 A straight ice track of length 50 m is inclined at 14° to the horizontal. A man starts at the top of the track, on a sledge, with speed 8 m s^{-1} . He travels on the sledge to the bottom of the track. The coefficient of friction between the sledge and the track is 0.02. Find the speed of the sledge and the man when they reach the bottom of the track. [4]

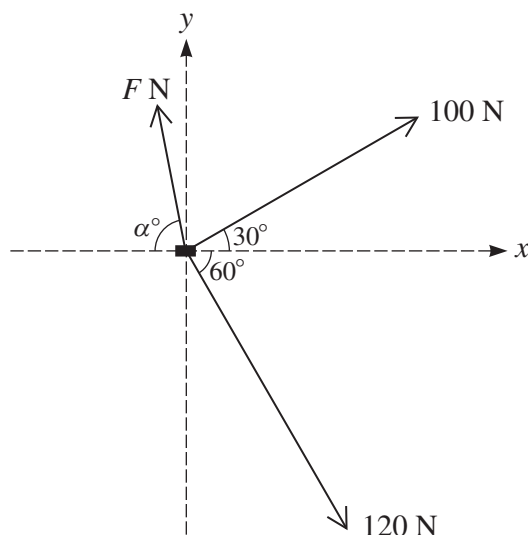
2



Particle A of mass 1.6 kg and particle B of mass 2 kg are attached to opposite ends of a light inextensible string. The string passes over a small smooth pulley fixed at the top of a smooth plane, which is inclined at angle θ , where $\sin \theta = 0.8$. Particle A is held at rest at the bottom of the plane and B hangs at a height of 3.24 m above the level of the bottom of the plane (see diagram). A is released from rest and the particles start to move.

- (i) Show that the loss of potential energy of the system, when B reaches the level of the bottom of the plane, is 23.328 J. [3]
 - (ii) Hence find the speed of the particles when B reaches the level of the bottom of the plane. [2]
- 3 A car has mass 800 kg. The engine of the car generates constant power P kW as the car moves along a straight horizontal road. The resistance to motion is constant and equal to R N. When the car's speed is 14 m s^{-1} its acceleration is 1.4 m s^{-2} , and when the car's speed is 25 m s^{-1} its acceleration is 0.33 m s^{-2} . Find the values of P and R . [6]
- 4 An aeroplane moves along a straight horizontal runway before taking off. It starts from rest at O and has speed 90 m s^{-1} at the instant it takes off. While the aeroplane is on the runway at time t seconds after leaving O , its acceleration is $(1.5 + 0.012t) \text{ m s}^{-2}$. Find
- (i) the value of t at the instant the aeroplane takes off, [4]
 - (ii) the distance travelled by the aeroplane on the runway. [3]
- 5 A particle P is projected vertically upwards from a point on the ground with speed 17 m s^{-1} . Another particle Q is projected vertically upwards from the same point with speed 7 m s^{-1} . Particle Q is projected T seconds later than particle P .
- (i) Given that the particles reach the ground at the same instant, find the value of T . [2]
 - (ii) At a certain instant when both P and Q are in motion, P is 5 m higher than Q . Find the magnitude and direction of the velocity of each of the particles at this instant. [6]

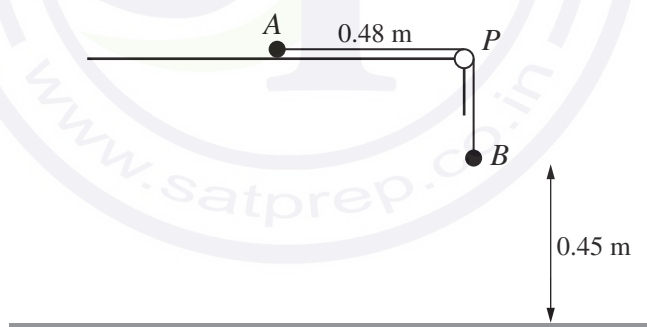
6



A small box of mass 40 kg is moved along a rough horizontal floor by three men. Two of the men apply horizontal forces of magnitudes 100 N and 120 N, making angles of 30° and 60° respectively with the positive x -direction. The third man applies a horizontal force of magnitude F N making an angle of α° with the negative x -direction (see diagram). The resultant of the three horizontal forces acting on the box is in the positive x -direction and has magnitude 136 N.

- (i) Find the values of F and α . [6]
- (ii) Given that the box is moving with constant speed, state the magnitude of the frictional force acting on the box and hence find the coefficient of friction between the box and the floor. [3]

7



Particle A of mass 1.26 kg and particle B of mass 0.9 kg are attached to the ends of a light inextensible string. The string passes over a small smooth pulley P which is fixed at the edge of a rough horizontal table. A is held at rest at a point 0.48 m from P , and B hangs vertically below P , at a height of 0.45 m above the floor (see diagram). The coefficient of friction between A and the table is $\frac{2}{7}$. A is released and the particles start to move.

- (i) Show that the magnitude of the acceleration of the particles is 2.5 m s^{-2} and find the tension in the string. [5]
- (ii) Find the speed with which B reaches the floor. [2]
- (iii) Find the speed with which A reaches the pulley. [4]

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MATHEMATICS

9709/42

Paper 4 Mechanics 1 (M1)

May/June 2013

1 hour 15 minutes

Additional Materials: Answer Booklet/Paper
Graph Paper
List of Formulae (MF9)

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

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- 1 A string is attached to a block of weight 30 N, which is in contact with a rough horizontal plane. When the string is horizontal and the tension in it is 24 N, the block is in limiting equilibrium.

(i) Find the coefficient of friction between the block and the plane. [2]

The block is now in motion and the string is at an angle of 30° upwards from the plane. The tension in the string is 25 N.

(ii) Find the acceleration of the block. [4]

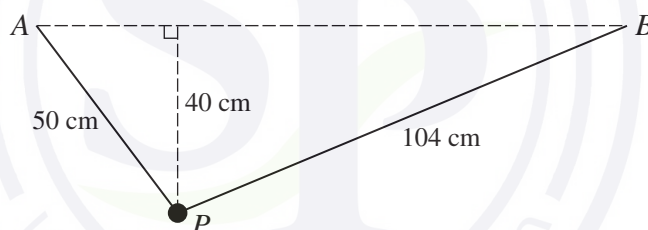
- 2 A and B are two points 50 metres apart on a straight path inclined at an angle θ to the horizontal, where $\sin \theta = 0.05$, with A above the level of B. A block of mass 16 kg is pulled down the path from A to B. The block starts from rest at A and reaches B with a speed of 10 m s^{-1} . The work done by the pulling force acting on the block is 1150 J.

(i) Find the work done against the resistance to motion. [3]

The block is now pulled up the path from B to A. The work done by the pulling force and the work done against the resistance to motion are the same as in the case of the downward motion.

(ii) Show that the speed of the block when it reaches A is the same as its speed when it started at B. [2]

3



A particle P of mass 2.1 kg is attached to one end of each of two light inextensible strings. The other ends of the strings are attached to points A and B which are at the same horizontal level. P hangs in equilibrium at a point 40 cm below the level of A and B , and the strings PA and PB have lengths 50 cm and 104 cm respectively (see diagram). Show that the tension in the string PA is 20 N, and find the tension in the string PB . [5]

- 4 A particle P is released from rest at the top of a smooth plane which is inclined at an angle α to the horizontal, where $\sin \alpha = \frac{16}{65}$. The distance travelled by P from the top to the bottom is S metres, and the speed of P at the bottom is 8 m s^{-1} .

(i) Find the value of S and hence find the speed of P when it has travelled $\frac{1}{2}S$ metres. [5]

The time taken by P to travel from the top to the bottom of the plane is T seconds.

(ii) Find the distance travelled by P at the instant when it has been moving for $\frac{1}{2}T$ seconds. [2]

- 5 A car of mass 1000 kg is travelling on a straight horizontal road. The power of its engine is constant and equal to P kW. The resistance to motion of the car is 600 N. At an instant when the car's speed is 25 m s^{-1} , its acceleration is 0.2 m s^{-2} . Find

- (i) the value of P , [4]
 (ii) the steady speed at which the car can travel. [3]

- 6 A particle P moves in a straight line. It starts from rest at a point O and moves towards a point A on the line. During the first 8 seconds P 's speed increases to 8 m s^{-1} with constant acceleration. During the next 12 seconds P 's speed decreases to 2 m s^{-1} with constant deceleration. P then moves with constant acceleration for 6 seconds, reaching A with speed 6.5 m s^{-1} .

- (i) Sketch the velocity-time graph for P 's motion. [2]

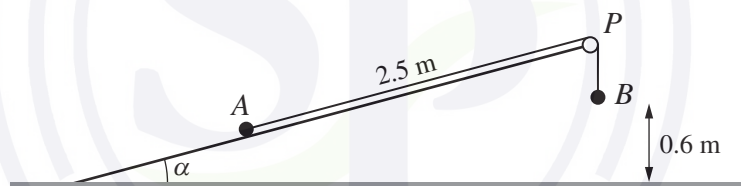
The displacement of P from O , at time t seconds after P leaves O , is s metres.

- (ii) Shade the region of the velocity-time graph representing s for a value of t where $20 \leq t \leq 26$. [1]

- (iii) Show that, for $20 \leq t \leq 26$,

$$s = 0.375t^2 - 13t + 202. \quad [6]$$

7



Particles A of mass 0.26 kg and B of mass 0.52 kg are attached to the ends of a light inextensible string. The string passes over a small smooth pulley P which is fixed at the top of a smooth plane. The plane is inclined at an angle α to the horizontal, where $\sin \alpha = \frac{16}{65}$ and $\cos \alpha = \frac{63}{65}$. A is held at rest at a point 2.5 metres from P , with the part AP of the string parallel to a line of greatest slope of the plane. B hangs freely below P at a point 0.6 m above the floor (see diagram). A is released and the particles start to move. Find

- (i) the magnitude of the acceleration of the particles and the tension in the string, [5]
 (ii) the speed with which B reaches the floor and the distance of A from P when A comes to instantaneous rest. [6]

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MATHEMATICS

9709/41

Paper 4 Mechanics 1 (M1)

May/June 2013

1 hour 15 minutes

Additional Materials: Answer Booklet/Paper
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List of Formulae (MF9)

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- 1** A block is at rest on a rough horizontal plane. The coefficient of friction between the block and the plane is 1.25.

(i) State, giving a reason for your answer, whether the minimum vertical force required to move the block is greater or less than the minimum horizontal force required to move the block. [2]

A horizontal force of continuously increasing magnitude P N and fixed direction is applied to the block.

(ii) Given that the weight of the block is 60 N, find the value of P when the acceleration of the block is 4 m s^{-2} . [2]

- 2** A car of mass 1250 kg travels from the bottom to the top of a straight hill of length 600 m, which is inclined at an angle of 2.5° to the horizontal. The resistance to motion of the car is constant and equal to 400 N. The work done by the driving force is 450 kJ. The speed of the car at the bottom of the hill is 30 m s^{-1} . Find the speed of the car at the top of the hill. [5]

- 3** The top of a cliff is 40 metres above the level of the sea. A man in a boat, close to the bottom of the cliff, is in difficulty and fires a distress signal vertically upwards from sea level. Find

(i) the speed of projection of the signal given that it reaches a height of 5 m above the top of the cliff, [2]

(ii) the length of time for which the signal is above the level of the top of the cliff. [2]

The man fires another distress signal vertically upwards from sea level. This signal is above the level of the top of the cliff for $\sqrt{17}$ s.

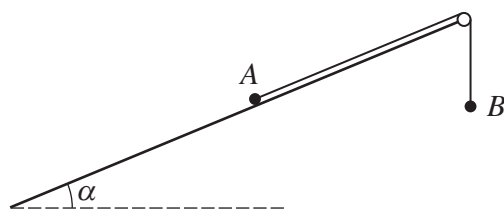
(iii) Find the speed of projection of the second signal. [3]

- 4** A train of mass 400 000 kg is moving on a straight horizontal track. The power of the engine is constant and equal to 1500 kW and the resistance to the train's motion is 30 000 N. Find

(i) the acceleration of the train when its speed is 37.5 m s^{-1} , [4]

(ii) the steady speed at which the train can move. [2]

5



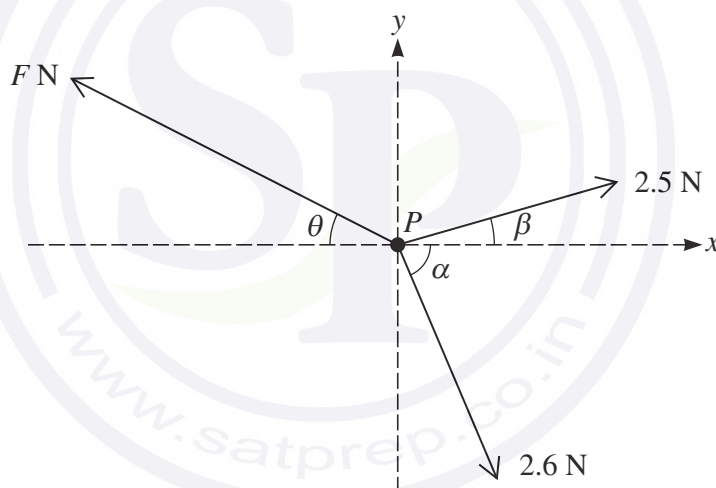
A light inextensible string has a particle A of mass 0.26 kg attached to one end and a particle B of mass 0.54 kg attached to the other end. The particle A is held at rest on a rough plane inclined at angle α to the horizontal, where $\sin \alpha = \frac{5}{13}$. The string is taut and parallel to a line of greatest slope of the plane. The string passes over a small smooth pulley at the top of the plane. Particle B hangs at rest vertically below the pulley (see diagram). The coefficient of friction between A and the plane is 0.2 . Particle A is released and the particles start to move.

- (i) Find the magnitude of the acceleration of the particles and the tension in the string. [6]

Particle A reaches the pulley 0.4 s after starting to move.

- (ii) Find the distance moved by each of the particles. [2]

6



A particle P of mass 0.5 kg lies on a smooth horizontal plane. Horizontal forces of magnitudes $F \text{ N}$, 2.5 N and 2.6 N act on P . The directions of the forces are as shown in the diagram, where $\tan \alpha = \frac{12}{5}$ and $\tan \beta = \frac{7}{24}$.

- (i) Given that P is in equilibrium, find the values of F and $\tan \theta$. [6]
- (ii) The force of magnitude $F \text{ N}$ is removed. Find the magnitude and direction of the acceleration with which P starts to move. [3]

[Question 7 is printed on the next page.]

- 7 A car driver makes a journey in a straight line from A to B , starting from rest. The speed of the car increases to a maximum, then decreases until the car is at rest at B . The distance travelled by the car t seconds after leaving A is $0.000\,011\,7(400t^3 - 3t^4)$ metres.
- (i) Find the distance AB . [3]
- (ii) Find the maximum speed of the car. [4]
- (iii) Find the acceleration of the car
- (a) as it starts from A ,
- (b) as it arrives at B . [2]
- (iv) Sketch the velocity-time graph for the journey. [2]

