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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)

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 in the space provided. If additional space is required, you should use the lined page at the end of this booklet. The question number(s) must be clearly shown.

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 **12** printed pages.



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- This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

- 2 A high-speed train of mass 490 000 kg is moving along a straight horizontal track at a constant speed of 85 m s^{-1} . The engines are supplying 4080 kW of power.

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

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(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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- 3** A van of mass 2500 kg descends a hill of length 0.4 km inclined at 4° to the horizontal. There is a constant resistance to motion of 600 N and the speed of the van increases from 20 m s^{-1} to 30 m s^{-1} as it descends the hill. Find the work done by the van's engine as it descends the hill. [5]

[illegible]

- 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]

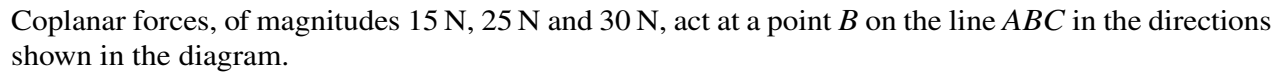
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- This image shows a full page of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page, typical of notebook or legal stationery. There are no margins, text, or other markings on the page.

- (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]

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

- 6** A particle is projected from a point P with initial speed $u \text{ m s}^{-1}$ up a line of greatest slope PQR of a rough inclined plane. The distances PQ and QR are both equal to 0.8 m . The particle takes 0.6 s to travel from P to Q and 1 s to travel from Q to R .

- (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]

- (ii) Given that the plane is inclined at 3° to the horizontal, find the value of the coefficient of friction between the particle and the plane. [4]

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

- 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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[illegible]

[illegible]

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MATHEMATICS

9709/42

Paper 4 Mechanics 1 (**M1**)

October/November 2018

1 hour 15 minutes

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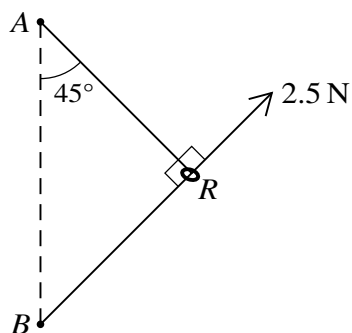
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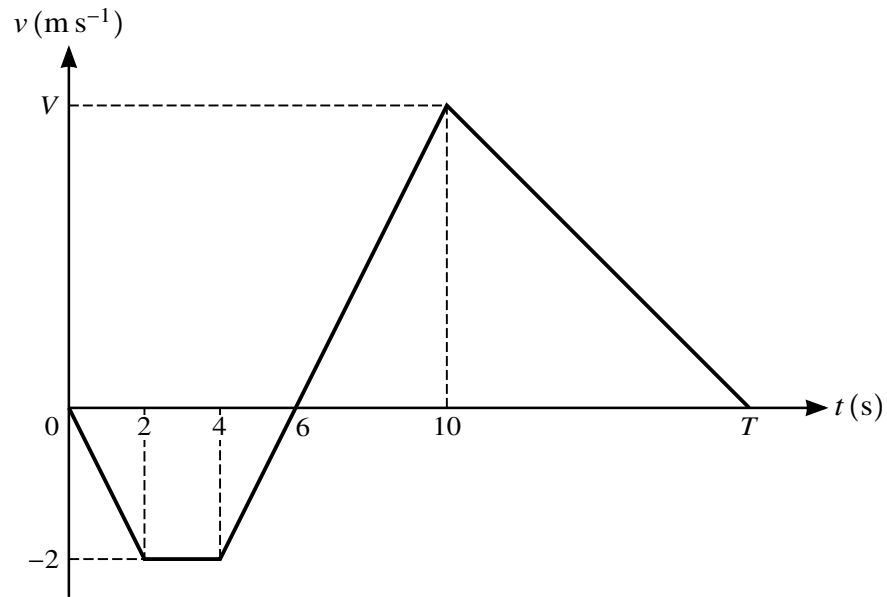
[4]

[illegible]

- 2 A block of mass 5 kg is being pulled by a rope up a rough plane inclined at 6° to the horizontal. The rope is parallel to a line of greatest slope of the plane and the block is moving at constant speed. The coefficient of friction between the block and the plane is 0.3. Find the tension in the rope. [4]

[illegible]

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.

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- (ii) Find the value of V .

[2]

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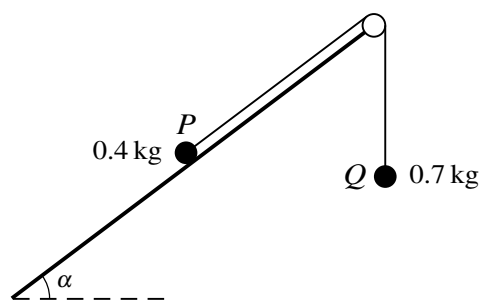
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At $t = 6$, the particle is instantaneously at rest at the point A . At $t = T$, the particle comes to rest at the point B . At $t = 0$ the particle starts from rest at a point one third of the way from A to B .

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

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



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

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[Turn over

- 5 A particle moves in a straight line starting from a point O with initial velocity 1 m s^{-1} . The acceleration of the particle at time $t \text{ s}$ after leaving O is $a \text{ m s}^{-2}$, where

$$a = 1.2t^{\frac{1}{2}} - 0.6t.$$

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

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- (ii) Find the velocity of the particle when its acceleration is maximum (you do not need to verify that the acceleration is a maximum rather than a minimum). [6]

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- 6 A car of mass 1200 kg is driving along a straight horizontal road at a constant speed of 15 m s^{-1} . There is a constant resistance to motion of 350 N.

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

[1]

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The car comes to a hill inclined at 1° to the horizontal, still travelling at 15 m s^{-1} .

- (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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- (iii)** When the car is travelling at 20 m s^{-1} down the hill, the power is cut off and the car gradually slows down. Assuming that the resistance force remains 350 N , find the distance travelled from the moment when the power is cut off until the speed of the car is reduced to 18 m s^{-1} . [4]

[illegible]

- 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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[illegible]

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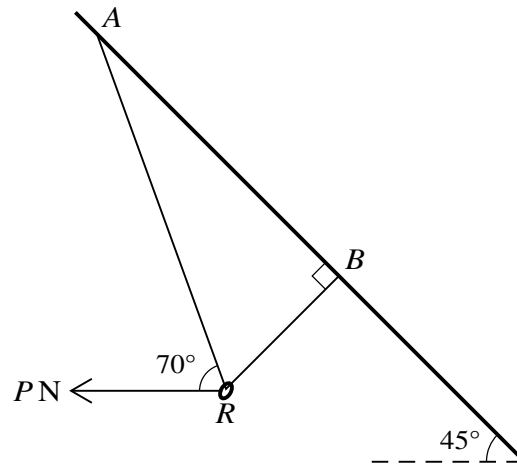
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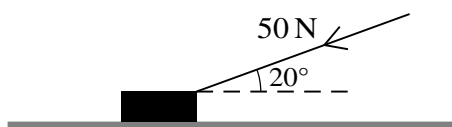


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A small smooth ring R of mass 0.2 kg is threaded onto a light inextensible string ARB . The two ends of the string are attached to points A and B on a sloping roof inclined at 45° to the horizontal. A horizontal force of magnitude $P\text{ N}$, acting in the plane ARB , is applied to the ring. The section BR of the string is perpendicular to the roof and the section AR of the string is inclined at 70° to the horizontal (see diagram). The system is in equilibrium. Find the tension in the string and the value of P . [4]

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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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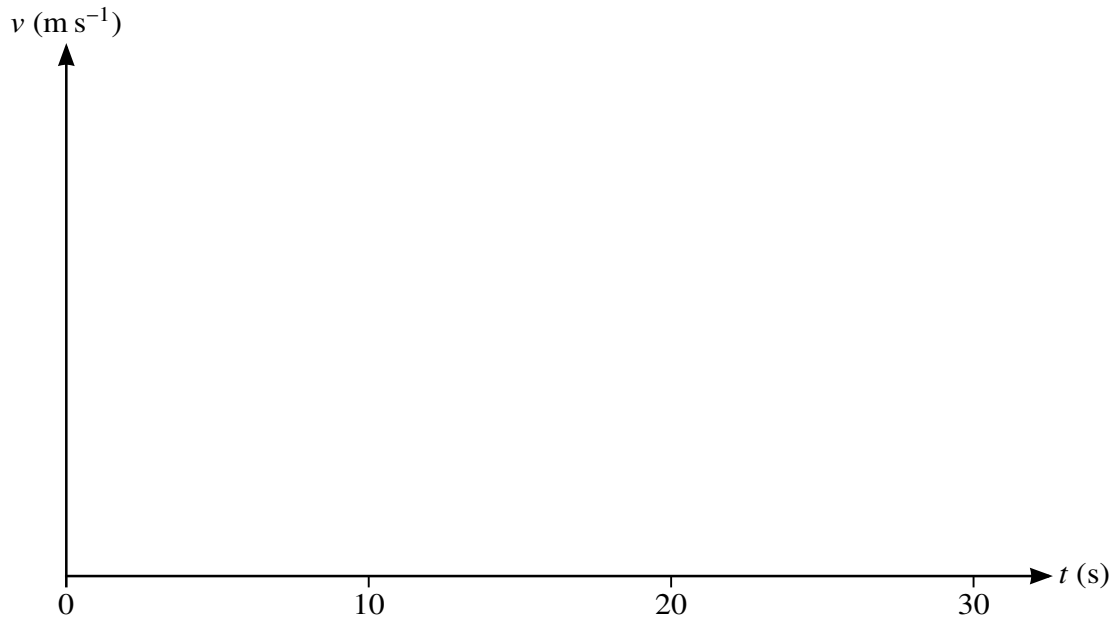
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- 4 A runner sets off from a point P at time $t = 0$, where t is in seconds. The runner starts from rest and accelerates at 1.2 m s^{-2} for 5 s. For the next 12 s the runner moves at constant speed before decelerating uniformly over a period of 3 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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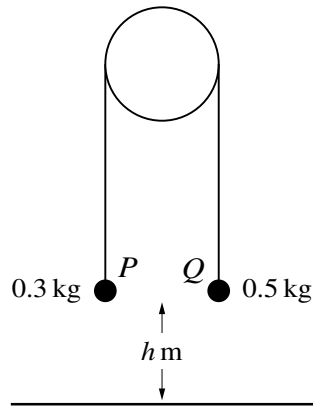
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- (ii)** Find the magnitude of the acceleration of the cyclist.

[3]

[illegible]



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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- [illegible]

- 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]

[illegible]

- 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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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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