



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 2010

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 a soft pencil for any diagrams or graphs.

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

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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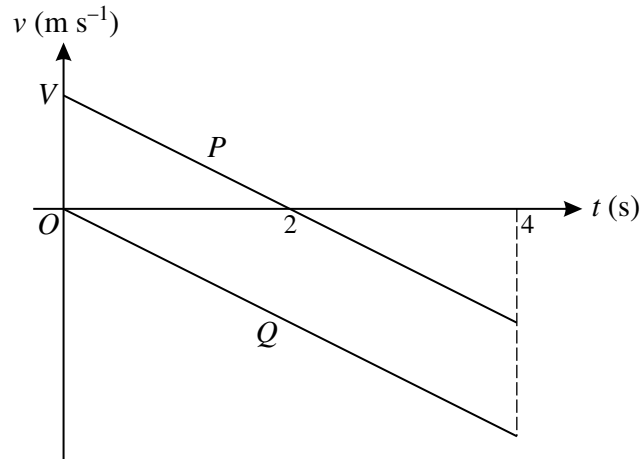
The total number of marks for this paper is 50.

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 4 printed pages.



1



Two particles P and Q move vertically under gravity. The graphs show the upward velocity $v \text{ m s}^{-1}$ of the particles at time $t \text{ s}$, for $0 \leq t \leq 4$. P starts with velocity $V \text{ m s}^{-1}$ and Q starts from rest.

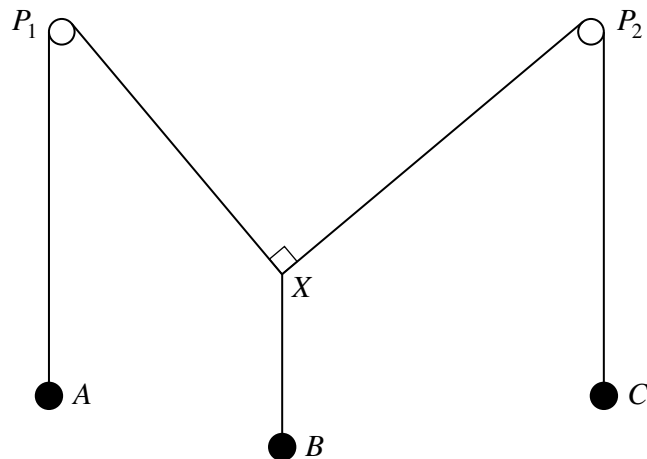
- (i) Find the value of V . [2]

Given that Q reaches the horizontal ground when $t = 4$, find

- (ii) the speed with which Q reaches the ground, [1]
 (iii) the height of Q above the ground when $t = 0$. [2]

- 2 A car of mass 600 kg travels along a horizontal straight road, with its engine working at a rate of 40 kW . The resistance to motion of the car is constant and equal to 800 N . The car passes through the point A on the road with speed 25 m s^{-1} . The car's acceleration at the point B on the road is half its acceleration at A . Find the speed of the car at B . [5]

3



The diagram shows three particles A , B and C hanging freely in equilibrium, each being attached to the end of a string. The other ends of the three strings are tied together and are at the point X . The strings carrying A and C pass over smooth fixed horizontal pegs P_1 and P_2 respectively. The weights of A , B and C are 5.5 N , 7.3 N and $W \text{ N}$ respectively, and the angle P_1XP_2 is a right angle. Find the angle AP_1X and the value of W . [5]

- 4 A particle P starts from a fixed point O at time $t = 0$, where t is in seconds, and moves with constant acceleration in a straight line. The initial velocity of P is 1.5 m s^{-1} and its velocity when $t = 10$ is 3.5 m s^{-1} .

(i) Find the displacement of P from O when $t = 10$. [2]

Another particle Q also starts from O when $t = 0$ and moves along the same straight line as P . The acceleration of Q at time t is $0.03t \text{ m s}^{-2}$.

(ii) Given that Q has the same velocity as P when $t = 10$, show that it also has the same displacement from O as P when $t = 10$. [5]

- 5 A particle of mass 0.8 kg slides down a rough inclined plane along a line of greatest slope AB . The distance AB is 8 m . The particle starts at A with speed 3 m s^{-1} and moves with constant acceleration 2.5 m s^{-2} .

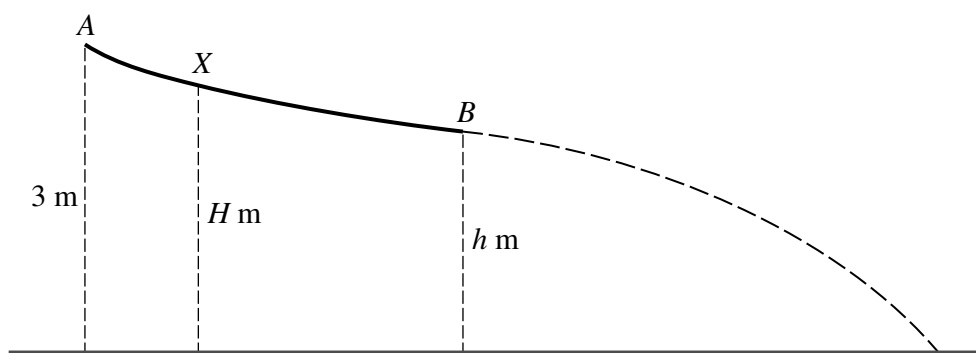
(i) Find the speed of the particle at the instant it reaches B . [2]

(ii) Given that the work done against the frictional force as the particle moves from A to B is 7 J , find the angle of inclination of the plane. [4]

When the particle is at the point X its speed is the same as the average speed for the motion from A to B .

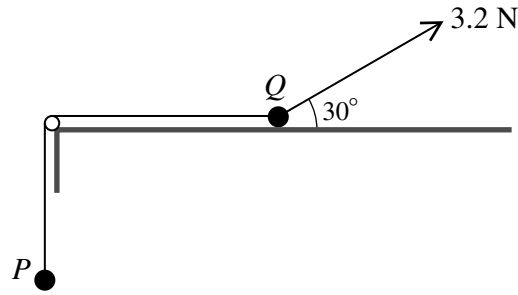
(iii) Find the work done by the frictional force for the particle's motion from A to X . [3]

6



A smooth slide AB is fixed so that its highest point A is 3 m above horizontal ground. B is $h \text{ m}$ above the ground. A particle P of mass 0.2 kg is released from rest at a point on the slide. The particle moves down the slide and, after passing B , continues moving until it hits the ground (see diagram). The speed of P at B is v_B and the speed at which P hits the ground is v_G .

- (i) In the case that P is released at A , it is given that the kinetic energy of P at B is 1.6 J . Find
- (a) the value of h , [3]
 - (b) the kinetic energy of the particle immediately before it reaches the ground, [1]
 - (c) the ratio $v_G : v_B$. [2]
- (ii) In the case that P is released at the point X of the slide, which is $H \text{ m}$ above the ground (see diagram), it is given that $v_G : v_B = 2.55$. Find the value of H correct to 2 significant figures. [3]



Particles P and Q , of masses 0.2 kg and 0.5 kg respectively, are connected by a light inextensible string. The string passes over a smooth pulley at the edge of a rough horizontal table. P hangs freely and Q is in contact with the table. A force of magnitude 3.2 N acts on Q , upwards and away from the pulley, at an angle of 30° to the horizontal (see diagram).

- (i) The system is in limiting equilibrium with P about to move upwards. Find the coefficient of friction between Q and the table. [6]

The force of magnitude 3.2 N is now removed and P starts to move downwards.

- (ii) Find the acceleration of the particles and the tension in the string. [4]



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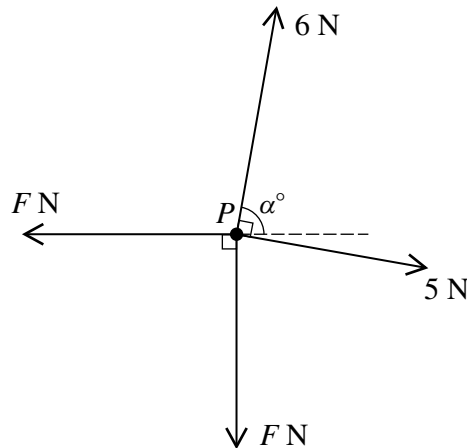
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- 1 A block of mass 400 kg rests in limiting equilibrium on horizontal ground. A force of magnitude 2000 N acts on the block at an angle of 15° to the upwards vertical. Find the coefficient of friction between the block and the ground, correct to 2 significant figures. [5]
- 2 A cyclist, working at a constant rate of 400 W, travels along a straight road which is inclined at 2° to the horizontal. The total mass of the cyclist and his cycle is 80 kg. Ignoring any resistance to motion, find, correct to 1 decimal place, the acceleration of the cyclist when he is travelling
- (i) uphill at 4 m s^{-1} ,
 - (ii) downhill at 4 m s^{-1} .

[5]

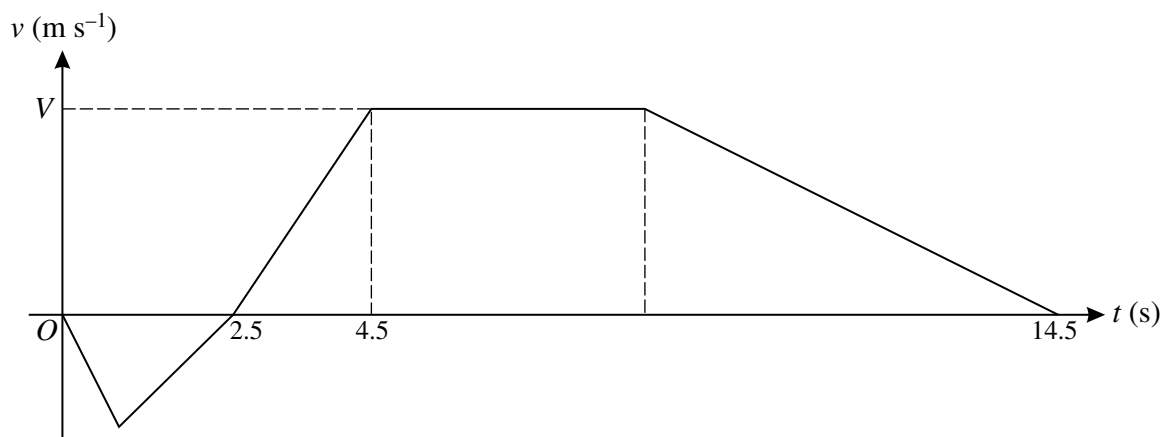
3



A particle P is in equilibrium on a smooth horizontal table under the action of four horizontal forces of magnitudes 6 N, 5 N, $F \text{ N}$ and $F \text{ N}$ acting in the directions shown. Find the values of α and F . [6]

- 4 A block of mass 20 kg is pulled from the bottom to the top of a slope. The slope has length 10 m and is inclined at 4.5° to the horizontal. The speed of the block is 2.5 m s^{-1} at the bottom of the slope and 1.5 m s^{-1} at the top of the slope.
- (i) Find the loss of kinetic energy and the gain in potential energy of the block. [3]
 - (ii) Given that the work done against the resistance to motion is 50 J, find the work done by the pulling force acting on the block. [2]
 - (iii) Given also that the pulling force is constant and acts at an angle of 15° upwards from the slope, find its magnitude. [2]
- 5 Particles P and Q are projected vertically upwards, from different points on horizontal ground, with velocities of 20 m s^{-1} and 25 m s^{-1} respectively. Q is projected 0.4 s later than P . Find
- (i) the time for which P 's height above the ground is greater than 15 m, [3]
 - (ii) the velocities of P and Q at the instant when the particles are at the same height. [5]

6



The diagram shows the velocity-time graph for a particle P which travels on a straight line AB , where $v \text{ m s}^{-1}$ is the velocity of P at time $t \text{ s}$. The graph consists of five straight line segments. The particle starts from rest when $t = 0$ at a point X on the line between A and B and moves towards A . The particle comes to rest at A when $t = 2.5$.

- (i) Given that the distance XA is 4 m, find the greatest speed reached by P during this stage of the motion. [2]

In the second stage, P starts from rest at A when $t = 2.5$ and moves towards B . The distance AB is 48 m. The particle takes 12 s to travel from A to B and comes to rest at B . For the first 2 s of this stage P accelerates at 3 m s^{-2} , reaching a velocity of $V \text{ m s}^{-1}$. Find

- (ii) the value of V , [2]
 (iii) the value of t at which P starts to decelerate during this stage, [3]
 (iv) the deceleration of P immediately before it reaches B . [2]

- 7 A particle P travels in a straight line. It passes through the point O of the line with velocity 5 m s^{-1} at time $t = 0$, where t is in seconds. P 's velocity after leaving O is given by

$$(0.002t^3 - 0.12t^2 + 1.8t + 5) \text{ m s}^{-1}.$$

The velocity of P is increasing when $0 < t < T_1$ and when $t > T_2$, and the velocity of P is decreasing when $T_1 < t < T_2$.

- (i) Find the values of T_1 and T_2 and the distance OP when $t = T_2$. [7]
 (ii) Find the velocity of P when $t = T_2$ and sketch the velocity-time graph for the motion of P . [3]

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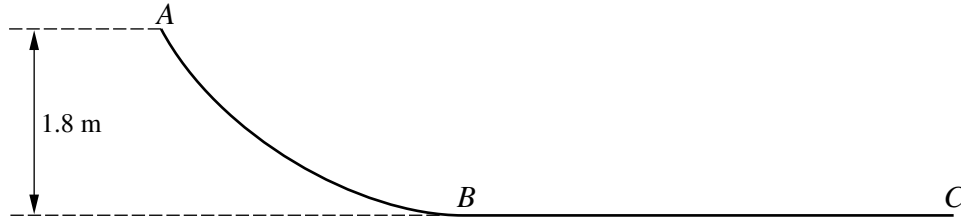


- 1 A particle P is released from rest at a point on a smooth plane inclined at 30° to the horizontal. Find the speed of P

- (i) when it has travelled 0.9 m,
(ii) 0.8 s after it is released.

[4]

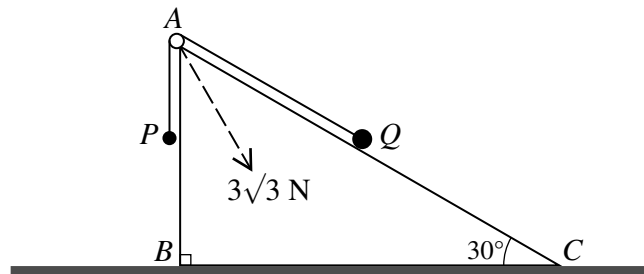
2



The diagram shows the vertical cross-section ABC of a fixed surface. AB is a curve and BC is a horizontal straight line. The part of the surface containing AB is smooth and the part containing BC is rough. A is at a height of 1.8 m above BC . A particle of mass 0.5 kg is released from rest at A and travels along the surface to C .

- (i) Find the speed of the particle at B . [2]
(ii) Given that the particle reaches C with a speed of 5 m s^{-1} , find the work done against the resistance to motion as the particle moves from B to C . [2]

3



A small smooth pulley is fixed at the highest point A of a cross-section ABC of a triangular prism. Angle $ABC = 90^\circ$ and angle $BCA = 30^\circ$. The prism is fixed with the face containing BC in contact with a horizontal surface. Particles P and Q are attached to opposite ends of a light inextensible string, which passes over the pulley. The particles are in equilibrium with P hanging vertically below the pulley and Q in contact with AC . The resultant force exerted on the pulley by the string is $3\sqrt{3} \text{ N}$ (see diagram).

- (i) Show that the tension in the string is 3 N. [2]

The coefficient of friction between Q and the prism is 0.75.

- (ii) Given that Q is in limiting equilibrium and on the point of moving upwards, find its mass. [5]

- 4 A particle starts from rest at a point X and moves in a straight line until, 60 seconds later, it reaches a point Y . At time t s after leaving X , the acceleration of the particle is

$$\begin{aligned} 0.75 \text{ m s}^{-2} & \quad \text{for} \quad 0 < t < 4, \\ 0 \text{ m s}^{-2} & \quad \text{for} \quad 4 < t < 54, \\ -0.5 \text{ m s}^{-2} & \quad \text{for} \quad 54 < t < 60. \end{aligned}$$

(i) Find the velocity of the particle when $t = 4$ and when $t = 60$, and sketch the velocity-time graph. [5]

(ii) Find the distance XY . [2]

- 5 A force of magnitude F N acts in a horizontal plane and has components 27.5 N and -24 N in the x -direction and the y -direction respectively. The force acts at an angle of α° below the x -axis.

(i) Find the values of F and α . [4]

A second force, of magnitude 87.6 N, acts in the same plane at 90° anticlockwise from the force of magnitude F N. The resultant of the two forces has magnitude R N and makes an angle of θ° with the positive x -axis.

(ii) Find the values of R and θ . [3]

- 6 A particle travels along a straight line. It starts from rest at a point A on the line and comes to rest again, 10 seconds later, at another point B on the line. The velocity t seconds after leaving A is

$$\begin{aligned} 0.72t^2 - 0.096t^3 & \quad \text{for} \quad 0 \leq t \leq 5, \\ 2.4t - 0.24t^2 & \quad \text{for} \quad 5 \leq t \leq 10. \end{aligned}$$

(i) Show that there is no instantaneous change in the acceleration of the particle when $t = 5$. [4]

(ii) Find the distance AB . [4]

[Question 7 is printed on the next page.]

- 7 A car of mass 1250 kg travels along a horizontal straight road. The power of the car's engine is constant and equal to 24 kW and the resistance to the car's motion is constant and equal to R N. The car passes through the point A on the road with speed 20 m s^{-1} and acceleration 0.32 m s^{-2} .

(i) Find the value of R . [3]

The car continues with increasing speed, passing through the point B on the road with speed 29.9 m s^{-1} . The car subsequently passes through the point C .

(ii) Find the acceleration of the car at B , giving the answer in m s^{-2} correct to 3 decimal places. [2]

(iii) Show that, while the car's speed is increasing, it cannot reach 30 m s^{-1} . [2]

(iv) Explain why the speed of the car is approximately constant between B and C . [1]

(v) State a value of the approximately constant speed, and the maximum possible error in this value at any point between B and C . [1]

The work done by the car's engine during the motion from B to C is 1200 kJ.

(vi) By assuming the speed of the car is constant from B to C , find, in either order,

(a) the approximate time taken for the car to travel from B to C ,

(b) an approximation for the distance BC .

[4]