



UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education
Advanced Subsidiary Level and Advanced Level

MATHEMATICS

9709/41

Paper 4 Mechanics 1 (M1)

May/June 2012

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 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.

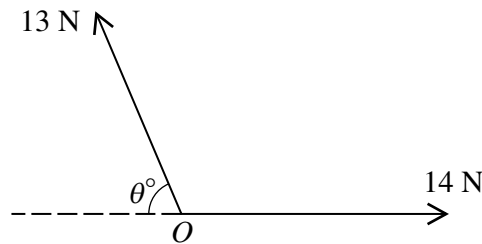
Questions carrying smaller numbers of marks are printed earlier in the paper, and questions carrying larger numbers of marks later in the paper.

This document consists of 4 printed pages.



- 1 A car of mass 880 kg travels along a straight horizontal road with its engine working at a constant rate of P W. The resistance to motion is 700 N. At an instant when the car's speed is 16 m s^{-1} its acceleration is 0.625 m s^{-2} . Find the value of P . [4]

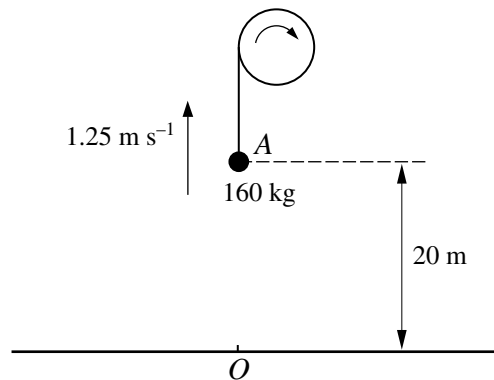
2



Forces of magnitudes 13 N and 14 N act at a point O in the directions shown in the diagram. The resultant of these forces has magnitude 15 N . Find

- (i) the value of θ , [3]
 (ii) the component of the resultant in the direction of the force of magnitude 14 N . [2]

3



A load of mass 160 kg is pulled vertically upwards, from rest at a fixed point O on the ground, using a winding drum. The load passes through a point A , 20 m above O , with a speed of 1.25 m s^{-1} (see diagram). Find, for the motion from O to A ,

- (i) the gain in the potential energy of the load, [1]
 (ii) the gain in the kinetic energy of the load. [2]

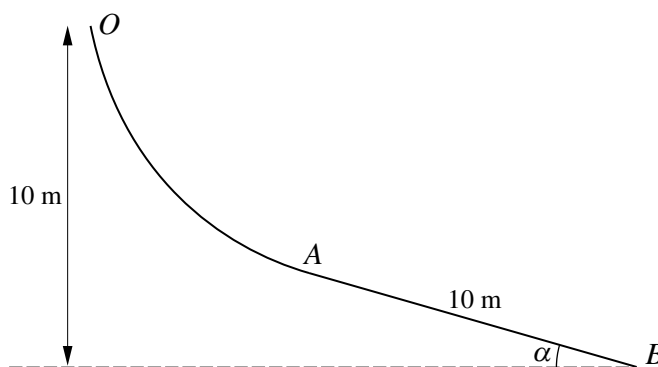
The power output of the winding drum is constant while the load is in motion.

- (iii) Given that the work done against the resistance to motion from O to A is 20 kJ and that the time taken for the load to travel from O to A is 41.7 s , find the power output of the winding drum. [3]

- 4 A particle P starts at the point O and travels in a straight line. At time t seconds after leaving O the velocity of P is $v \text{ m s}^{-1}$, where $v = 0.75t^2 - 0.0625t^3$. Find

- (i) the positive value of t for which the acceleration is zero, [3]
 (ii) the distance travelled by P before it changes its direction of motion. [5]

5



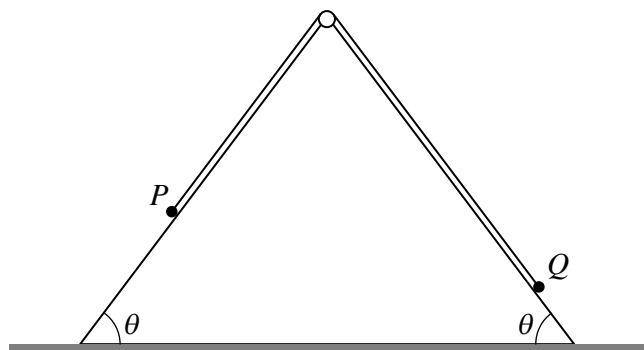
The diagram shows the vertical cross-section OAB of a slide. The straight line AB is tangential to the curve OA at A . The line AB is inclined at α to the horizontal, where $\sin \alpha = 0.28$. The point O is 10 m higher than B , and AB has length 10 m (see diagram). The part of the slide containing the curve OA is smooth and the part containing AB is rough. A particle P of mass 2 kg is released from rest at O and moves down the slide.

- (i) Find the speed of P when it passes through A . [3]

The coefficient of friction between P and the part of the slide containing AB is $\frac{1}{12}$. Find

- (ii) the acceleration of P when it is moving from A to B , [3]
 (iii) the speed of P when it reaches B . [2]

6

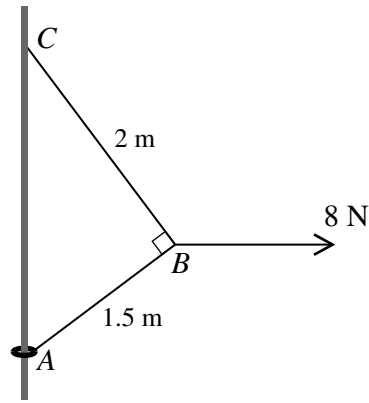


Particles P and Q , of masses 0.6 kg and 0.4 kg respectively, are attached to the ends of a light inextensible string. The string passes over a small smooth pulley which is fixed at the top of a vertical cross-section of a triangular prism. The base of the prism is fixed on horizontal ground and each of the sloping sides is smooth. Each sloping side makes an angle θ with the ground, where $\sin \theta = 0.8$. Initially the particles are held at rest on the sloping sides, with the string taut (see diagram). The particles are released and move along lines of greatest slope.

- (i) Find the tension in the string and the acceleration of the particles while both are moving. [5]

The speed of P when it reaches the ground is 2 m s^{-1} . On reaching the ground P comes to rest and remains at rest. Q continues to move up the slope but does not reach the pulley.

- (ii) Find the time taken from the instant that the particles are released until Q reaches its greatest height above the ground. [4]



A small ring of mass 0.2 kg is threaded on a fixed vertical rod. The end A of a light inextensible string is attached to the ring. The other end C of the string is attached to a fixed point of the rod above A . A horizontal force of magnitude 8 N is applied to the point B of the string, where $AB = 1.5 \text{ m}$ and $BC = 2 \text{ m}$. The system is in equilibrium with the string taut and AB at right angles to BC (see diagram).

- (i) Find the tension in the part AB of the string and the tension in the part BC of the string. [5]

The equilibrium is limiting with the ring on the point of sliding up the rod.

- (ii) Find the coefficient of friction between the ring and the rod. [5]



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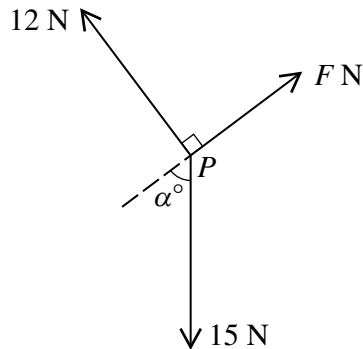
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- 1 A block is pulled in a straight line along horizontal ground by a force of constant magnitude acting at an angle of 60° above the horizontal. The work done by the force in moving the block a distance of 5 m is 75 J. Find the magnitude of the force. [3]

2



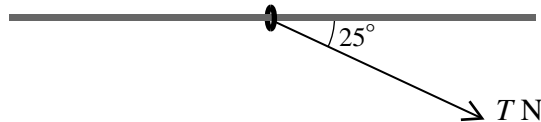
Three coplanar forces of magnitudes F N, 12 N and 15 N are in equilibrium acting at a point P in the directions shown in the diagram. Find α and F . [4]

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

(i) Show that $t^{\frac{5}{3}} = \frac{5}{6}$ when the velocity of P is 3 m s^{-1} . [4]

(ii) Find the distance of P from O when the velocity of P is 3 m s^{-1} . [3]

4



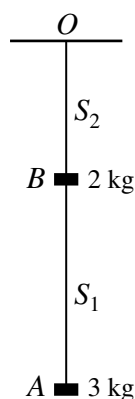
A ring of mass 4 kg is attached to one end of a light string. The ring is threaded on a fixed horizontal rod and the string is pulled at an angle of 25° below the horizontal (see diagram). With a tension in the string of T N the ring is in equilibrium.

(i) Find, in terms of T , the horizontal and vertical components of the force exerted on the ring by the rod. [4]

The coefficient of friction between the ring and the rod is 0.4.

(ii) Given that the equilibrium is limiting, find the value of T . [3]

5



A block A of mass 3 kg is attached to one end of a light inextensible string S_1 . Another block B of mass 2 kg is attached to the other end of S_1 , and is also attached to one end of another light inextensible string S_2 . The other end of S_2 is attached to a fixed point O and the blocks hang in equilibrium below O (see diagram).

- (i) Find the tension in S_1 and the tension in S_2 . [2]

The string S_2 breaks and the particles fall. The air resistance on A is 1.6 N and the air resistance on B is 4 N .

- (ii) Find the acceleration of the particles and the tension in S_1 . [5]

- 6 A car of mass 1250 kg travels from the bottom to the top of a straight hill which has length 400 m and is inclined to the horizontal at an angle of α , where $\sin \alpha = 0.125$. The resistance to the car's motion is 800 N . Find the work done by the car's engine in each of the following cases.

- (i) The car's speed is constant. [4]

- (ii) The car's initial speed is 6 m s^{-1} , the car's driving force is 3 times greater at the top of the hill than it is at the bottom, and the car's power output is 5 times greater at the top of the hill than it is at the bottom. [5]

7



The frictional force acting on a small block of mass 0.15 kg , while it is moving on a horizontal surface, has magnitude 0.12 N . The block is set in motion from a point X on the surface, with speed 3 m s^{-1} . It hits a vertical wall at a point Y on the surface 2 s later. The block rebounds from the wall and moves directly towards X before coming to rest at the point Z (see diagram). At the instant that the block hits the wall it loses 0.072 J of its kinetic energy. The velocity of the block, in the direction from X to Y , is $v\text{ m s}^{-1}$ at time $t\text{ s}$ after it leaves X .

- (i) Find the values of v when the block arrives at Y and when it leaves Y , and find also the value of t when the block comes to rest at Z . Sketch the velocity-time graph. [9]

- (ii) The displacement of the block from X , in the direction from X to Y , is $s\text{ m}$ at time $t\text{ s}$. Sketch the displacement-time graph. Show on your graph the values of s and t when the block is at Y and when it comes to rest at Z . [4]

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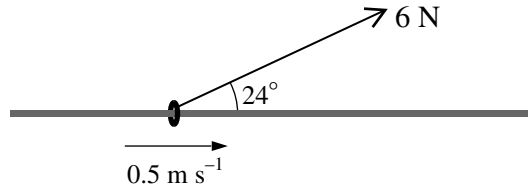
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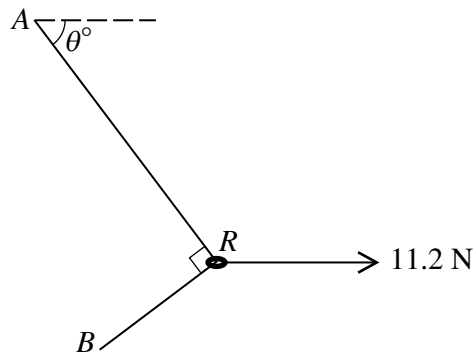


1



A ring is threaded on a fixed horizontal bar. The ring is attached to one end of a light inextensible string which is used to pull the ring along the bar at a constant speed of 0.5 m s^{-1} . The string makes a constant angle of 24° with the bar and the tension in the string is 6 N (see diagram). Find the work done by the tension in a period of 8 s . [3]

2



A smooth ring R of mass 0.16 kg is threaded on a light inextensible string. The ends of the string are attached to fixed points A and B . A horizontal force of magnitude 11.2 N acts on R , in the same vertical plane as A and B . The ring is in equilibrium. The string is taut with angle $ARB = 90^\circ$, and the part AR of the string makes an angle of θ° with the horizontal (see diagram). The tension in the string is $T \text{ N}$.

(i) Find two simultaneous equations involving $T \sin \theta$ and $T \cos \theta$. [3]

(ii) Hence find T and θ . [3]

3 A particle P travels from a point O along a straight line and comes to instantaneous rest at a point A . The velocity of P at time $t \text{ s}$ after leaving O is $v \text{ m s}^{-1}$, where $v = 0.027(10t^2 - t^3)$. Find

(i) the distance OA , [4]

(ii) the maximum velocity of P while moving from O to A . [3]

- 4 A car of mass 1230 kg increases its speed from 4 m s^{-1} to 21 m s^{-1} in 24.5 s . The table below shows corresponding values of time $t \text{ s}$ and speed $v \text{ m s}^{-1}$.

t	0	0.5	16.3	24.5
v	4	6	19	21

- (i) Using the values in the table, find the average acceleration of the car for $0 < t < 0.5$ and for $16.3 < t < 24.5$. [2]

While the car is increasing its speed the power output of its engine is constant and equal to $P \text{ W}$, and the resistance to the car's motion is constant and equal to $R \text{ N}$.

- (ii) Assuming that the values obtained in part (i) are approximately equal to the accelerations at $v = 5$ and at $v = 20$, find approximations for P and R . [5]

- 5 A lorry of mass $16\,000 \text{ kg}$ moves on a straight hill inclined at angle α° to the horizontal. The length of the hill is 500 m .

- (i) While the lorry moves from the bottom to the top of the hill at constant speed, the resisting force acting on the lorry is 800 N and the work done by the driving force is 2800 kJ . Find the value of α . [4]
- (ii) On the return journey the speed of the lorry is 20 m s^{-1} at the top of the hill. While the lorry travels down the hill, the work done by the driving force is 2400 kJ and the work done against the resistance to motion is 800 kJ . Find the speed of the lorry at the bottom of the hill. [4]

6

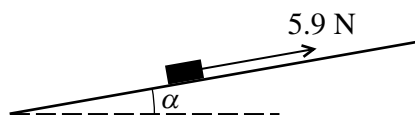


Fig. 1

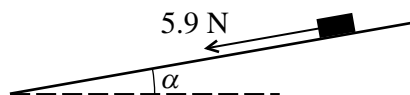
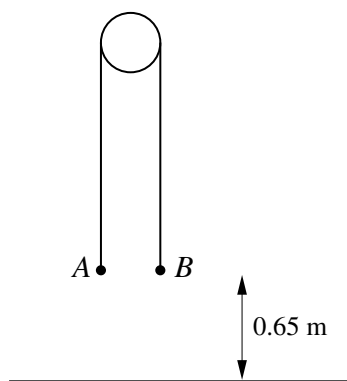


Fig. 2

A block of weight 6.1 N is at rest on a plane inclined at angle α to the horizontal, where $\tan \alpha = \frac{11}{60}$. The coefficient of friction between the block and the plane is μ . A force of magnitude 5.9 N acting parallel to a line of greatest slope is applied to the block.

- (i) When the force acts up the plane (see Fig. 1) the block remains at rest. Show that $\mu \geq \frac{4}{5}$. [5]
- (ii) When the force acts down the plane (see Fig. 2) the block slides downwards. Show that $\mu < \frac{7}{6}$. [2]
- (iii) Given that the acceleration of the block is 1.7 m s^{-2} when the force acts down the plane, find the value of μ . [2]

[Question 7 is printed on the next page.]



Two particles A and B have masses 0.12 kg and 0.38 kg respectively. The particles are attached to the ends of a light inextensible string which passes over a fixed smooth pulley. A is held at rest with the string taut and both straight parts of the string vertical. A and B are each at a height of 0.65 m above horizontal ground (see diagram). A is released and B moves downwards. Find

(i) the acceleration of B while it is moving downwards, [2]

(ii) the speed with which B reaches the ground and the time taken for it to reach the ground. [3]

B remains on the ground while A continues to move with the string slack, without reaching the pulley. The string remains slack until A is at a height of 1.3 m above the ground for a second time. At this instant A has been in motion for a total time of $T\text{ s}$.

(iii) Find the value of T and sketch the velocity-time graph for A for the first $T\text{ s}$ of its motion. [3]

(iv) Find the total distance travelled by A in the first $T\text{ s}$ of its motion. [2]