



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 2011

1 hour 15 minutes

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

READ THESE INSTRUCTIONS FIRST

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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.

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Answer **all** the questions.

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

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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.

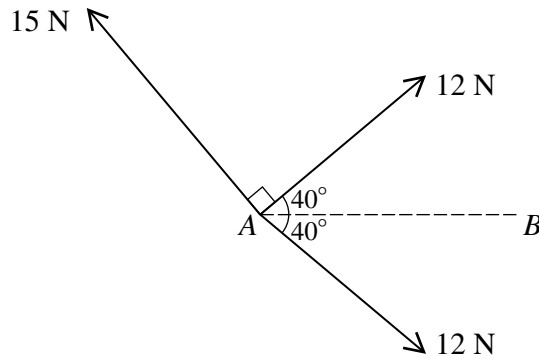
Questions carrying smaller numbers of marks are printed earlier in the paper, and questions carrying larger numbers of marks later in the paper.

This document consists of 4 printed pages.



- 1 One end of a light inextensible string is attached to a block. The string is used to pull the block along a horizontal surface with a speed of 2 m s^{-1} . The string makes an angle of 20° with the horizontal and the tension in the string is 25 N . Find the work done by the tension in a period of 8 seconds. [3]
- 2 Particles A of mass 0.65 kg and B of mass 0.35 kg are attached to the ends of a light inextensible string which passes over a fixed smooth pulley. B is held at rest with the string taut and both of its straight parts vertical. The system is released from rest and the particles move vertically. Find the tension in the string and the magnitude of the resultant force exerted on the pulley by the string. [5]

3



Three coplanar forces of magnitudes 15 N , 12 N and 12 N act at a point A in directions as shown in the diagram.

(i) Find the component of the resultant of the three forces

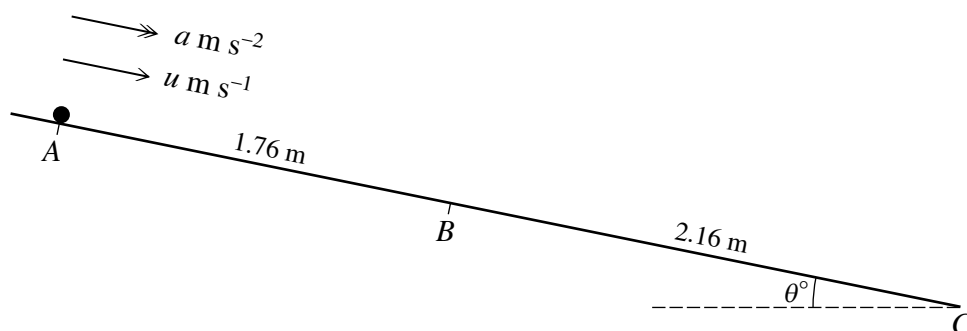
- (a) in the direction of AB ,
 (b) perpendicular to AB .

[3]

(ii) Hence find the magnitude and direction of the resultant of the three forces.

[3]

4



A , B and C are three points on a line of greatest slope of a smooth plane inclined at an angle of θ° to the horizontal. A is higher than B and B is higher than C , and the distances AB and BC are 1.76 m and 2.16 m respectively. A particle slides down the plane with constant acceleration $a \text{ m s}^{-2}$. The speed of the particle at A is $u \text{ m s}^{-1}$ (see diagram). The particle takes 0.8 s to travel from A to B and takes 1.4 s to travel from A to C . Find

(i) the values of u and a ,

[6]

(ii) the value of θ .

[2]

5

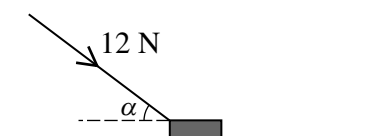


Fig. 1

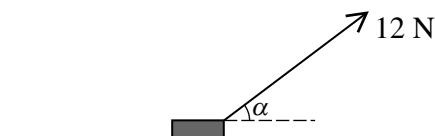


Fig. 2

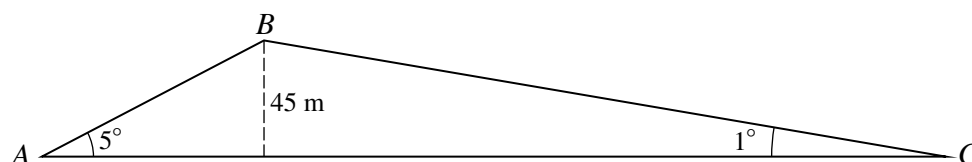
A block of mass 2 kg is at rest on a horizontal floor. The coefficient of friction between the block and the floor is μ . A force of magnitude 12 N acts on the block at an angle α to the horizontal, where $\tan \alpha = \frac{3}{4}$. When the applied force acts downwards as in Fig. 1 the block remains at rest.

- (i) Show that $\mu \geq \frac{6}{17}$. [5]

When the applied force acts upwards as in Fig. 2 the block slides along the floor.

- (ii) Find another inequality for μ . [3]

6



AB and BC are straight roads inclined at 5° to the horizontal and 1° to the horizontal respectively. A and C are at the same horizontal level and B is 45 m above the level of A and C (see diagram, which is not to scale). A car of mass 1200 kg travels from A to C passing through B .

- (i) For the motion from A to B , the speed of the car is constant and the work done against the resistance to motion is 360 kJ. Find the work done by the car's engine from A to B . [3]

The resistance to motion is constant throughout the whole journey.

- (ii) For the motion from B to C the work done by the driving force is 1660 kJ. Given that the speed of the car at B is 15 m s^{-1} , show that its speed at C is 29.9 m s^{-1} , correct to 3 significant figures. [4]

- (iii) The car's driving force immediately after leaving B is 1.5 times the driving force immediately before reaching C . Find, correct to 2 significant figures, the ratio of the power developed by the car's engine immediately after leaving B to the power developed immediately before reaching C . [3]

[Question 7 is printed on the next page.]

- 7 A particle P starts from a point O and moves along a straight line. P 's velocity t s after leaving O is $v \text{ m s}^{-1}$, where

$$v = 0.16t^{\frac{3}{2}} - 0.016t^2.$$

P comes to rest instantaneously at the point A .

- (i) Verify that the value of t when P is at A is 100. [1]
- (ii) Find the maximum speed of P in the interval $0 < t < 100$. [4]
- (iii) Find the distance OA . [3]
- (iv) Find the value of t when P passes through O on returning from A . [2]



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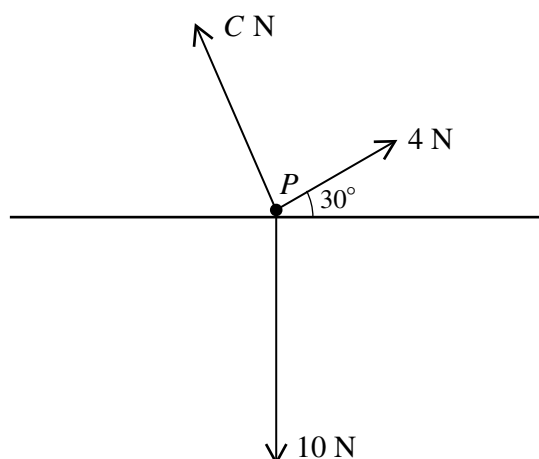
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- 1 A racing cyclist, whose mass with his cycle is 75 kg, works at a rate of 720 W while moving on a straight horizontal road. The resistance to the cyclist's motion is constant and equal to R N.
- (i) Given that the cyclist is accelerating at 0.16 m s^{-2} at an instant when his speed is 12 m s^{-1} , find the value of R . [3]
- (ii) Given that the cyclist's acceleration is positive, show that his speed is less than 15 m s^{-1} . [2]
- 2 A block of mass 6 kg is sliding down a line of greatest slope of a plane inclined at 8° to the horizontal. The coefficient of friction between the block and the plane is 0.2.
- (i) Find the deceleration of the block. [3]
- (ii) Given that the initial speed of the block is 3 m s^{-1} , find how far the block travels. [2]
- 3 A particle P moves in a straight line. It starts from a point O on the line with velocity 1.8 m s^{-1} . The acceleration of P at time t s after leaving O is $0.8t^{-0.75} \text{ m s}^{-2}$. Find the displacement of P from O when $t = 16$. [6]

4



A particle P has weight 10 N and is in limiting equilibrium on a rough horizontal table. The forces shown in the diagram represent the weight of P , an applied force of magnitude 4 N acting on P in a direction at 30° above the horizontal, and the contact force exerted on P by the table (the resultant of the frictional and normal components) of magnitude C N.

- (i) Find the value of C . [3]
- (ii) Find the coefficient of friction between P and the table. [2]

- 5 Particles A and B , of masses 0.9 kg and 0.6 kg respectively, are attached to the ends of a light inextensible string. The string passes over a fixed smooth pulley. The system is released from rest with the string taut, with its straight parts vertical and with the particles at the same height above the horizontal floor. In the subsequent motion, B does not reach the pulley.

(i) Find the acceleration of A and the tension in the string during the motion before A hits the floor. [4]

After A hits the floor, B continues to move vertically upwards for a further 0.3 s .

(ii) Find the height of the particles above the floor at the instant that they started to move. [4]

- 6 A lorry of mass $16\,000\text{ kg}$ climbs a straight hill $ABCD$ which makes an angle θ with the horizontal, where $\sin \theta = \frac{1}{20}$. For the motion from A to B , the work done by the driving force of the lorry is 1200 kJ and the resistance to motion is constant and equal to 1240 N . The speed of the lorry is 15 m s^{-1} at A and 12 m s^{-1} at B .

(i) Find the distance AB . [5]

For the motion from B to D the gain in potential energy of the lorry is 2400 kJ .

(ii) Find the distance BD . [1]

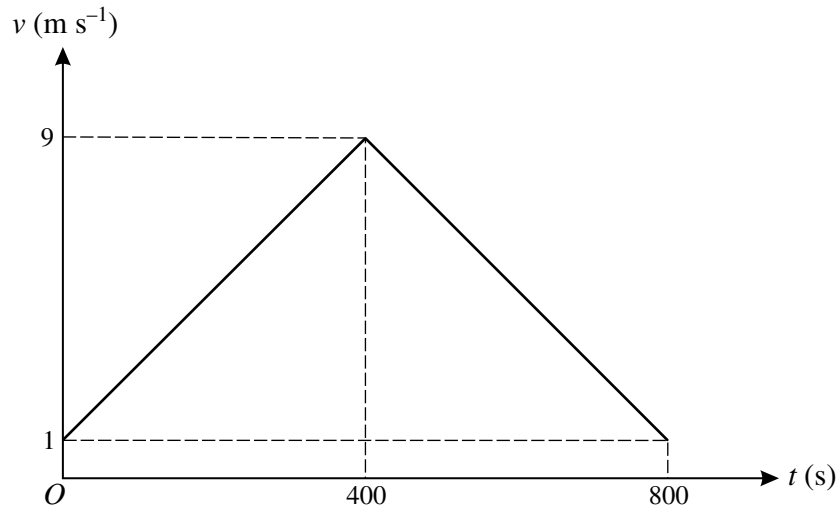
For the motion from B to D the driving force of the lorry is constant and equal to 7200 N . From B to C the resistance to motion is constant and equal to 1240 N and from C to D the resistance to motion is constant and equal to 1860 N .

(iii) Given that the speed of the lorry at D is 7 m s^{-1} , find the distance BC . [4]

[Question 7 is printed on the next page.]

- 7 A tractor travels in a straight line from a point A to a point B . The velocity of the tractor is $v \text{ m s}^{-1}$ at time $t \text{ s}$ after leaving A .

(i)



The diagram shows an approximate velocity-time graph for the motion of the tractor. The graph consists of two straight line segments. Use the graph to find an approximation for

- (a) the distance AB , [2]
 - (b) the acceleration of the tractor for $0 < t < 400$ and for $400 < t < 800$. [2]
- (ii) The actual velocity of the tractor is given by $v = 0.04t - 0.000\,05t^2$ for $0 \leq t \leq 800$.

- (a) Find the values of t for which the actual acceleration of the tractor is given correctly by the approximate velocity-time graph in part (i). [3]

For the interval $0 \leq t \leq 400$, the approximate velocity of the tractor in part (i) is denoted by $v_1 \text{ m s}^{-1}$.

- (b) Express v_1 in terms of t and hence show that $v_1 - v = 0.000\,05(t - 200)^2 - 1$. [2]
- (c) Deduce that $-1 \leq v_1 - v \leq 1$. [2]



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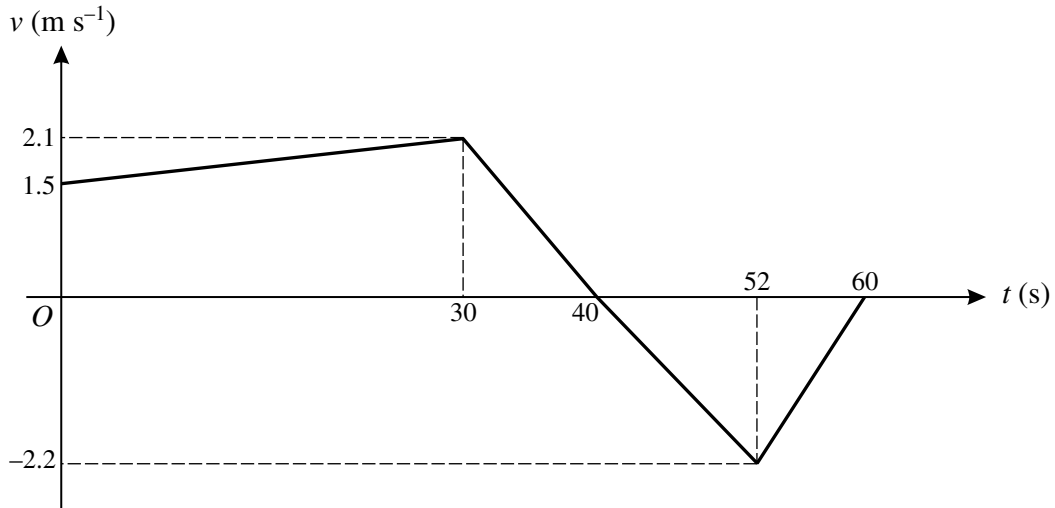
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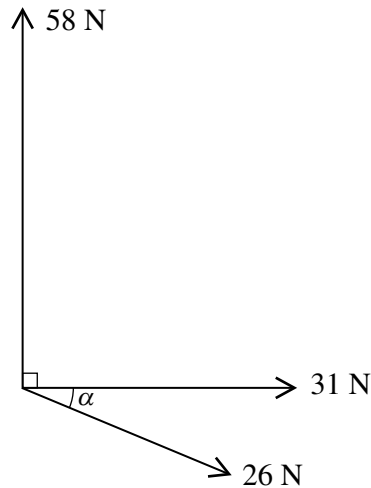
1



A woman walks in a straight line. The woman's velocity t seconds after passing through a fixed point A on the line is $v \text{ m s}^{-1}$. The graph of v against t consists of 4 straight line segments (see diagram). The woman is at the point B when $t = 60$. Find

- (i) the woman's acceleration for $0 < t < 30$ and for $30 < t < 40$, [3]
- (ii) the distance AB , [2]
- (iii) the total distance walked by the woman. [1]

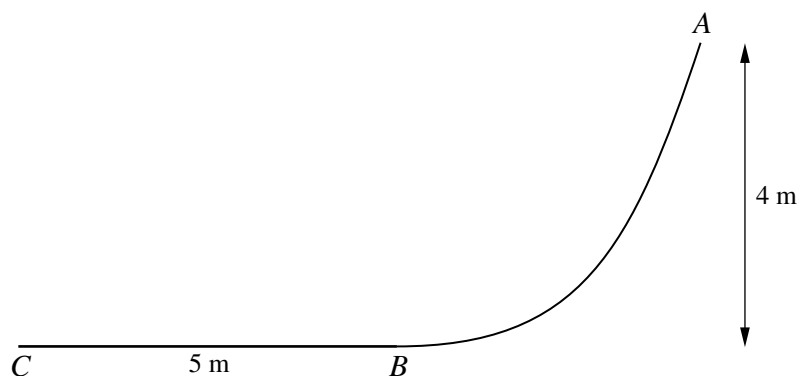
2



Coplanar forces of magnitudes 58 N, 31 N and 26 N act at a point in the directions shown in the diagram. Given that $\tan \alpha = \frac{5}{12}$, find the magnitude and direction of the resultant of the three forces. [6]

- 3 Particles P and Q are attached to opposite ends of a light inextensible string which passes over a fixed smooth pulley. The system is released from rest with the string taut, with its straight parts vertical, and with both particles at a height of 2 m above horizontal ground. P moves vertically downwards and does not rebound when it hits the ground. At the instant that P hits the ground, Q is at the point X , from where it continues to move vertically upwards without reaching the pulley. Given that P has mass 0.9 kg and that the tension in the string is 7.2 N while P is moving, find the total distance travelled by Q from the instant it first reaches X until it returns to X . [6]

4



ABC is a vertical cross-section of a surface. The part of the surface containing AB is smooth and A is 4 m higher than B . The part of the surface containing BC is horizontal and the distance BC is 5 m (see diagram). A particle of mass 0.8 kg is released from rest at A and slides along ABC . Find the speed of the particle at C in each of the following cases.

(i) The horizontal part of the surface is smooth. [3]

(ii) The coefficient of friction between the particle and the horizontal part of the surface is 0.3. [3]

5 A particle P moves in a straight line. It starts from rest at A and comes to rest instantaneously at B . The velocity of P at time t seconds after leaving A is $v \text{ m s}^{-1}$, where $v = 6t^2 - kt^3$ and k is a constant.

(i) Find an expression for the displacement of P from A in terms of t and k . [2]

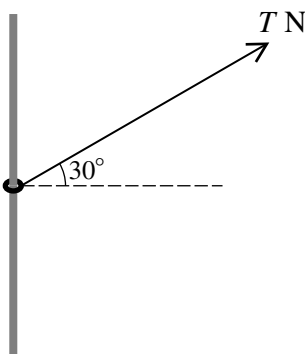
(ii) Find an expression for t in terms of k when P is at B . [1]

Given that the distance AB is 108 m, find

(iii) the value of k , [2]

(iv) the maximum value of v when the particle is moving from A towards B . [3]

6



The diagram shows a ring of mass 2 kg threaded on a fixed rough vertical rod. A light string is attached to the ring and is pulled upwards at an angle of 30° to the horizontal. The tension in the string is $T \text{ N}$. The coefficient of friction between the ring and the rod is 0.24. Find the two values of T for which the ring is in limiting equilibrium. [8]

- 7 A car of mass 600 kg travels along a straight horizontal road starting from a point A . The resistance to motion of the car is 750 N.
- (i) The car travels from A to B at constant speed in 100 s. The power supplied by the car's engine is constant and equal to 30 kW. Find the distance AB . [3]
- (ii) The car's engine is switched off at B and the car's speed decreases until the car reaches C with a speed of 20 m s^{-1} . Find the distance BC . [3]
- (iii) The car's engine is switched on at C and the power it supplies is constant and equal to 30 kW. The car takes 14 s to travel from C to D and reaches D with a speed of 30 m s^{-1} . Find the distance CD . [4]