

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

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Answer **all** the questions.

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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]

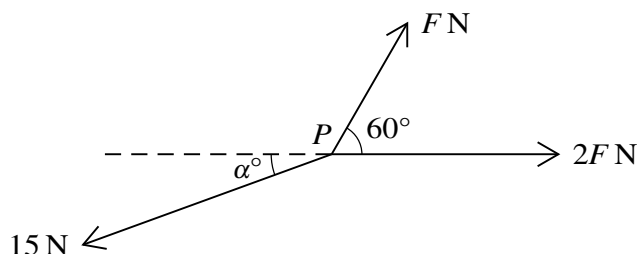
(ii) Find the coefficient of friction between the particle and the plane. [2]

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]

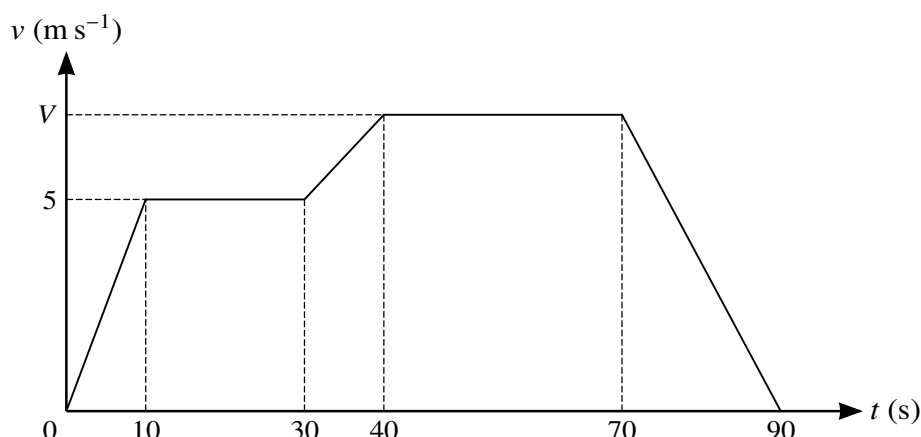
(ii) the time after projection at which the particle returns to O . [3]

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]

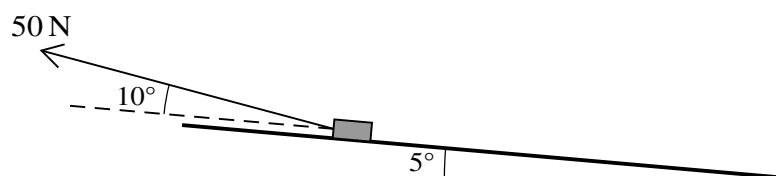
(iii) The combined mass of the cyclist and the bicycle is 80 kg. The cyclist experiences a constant resistance to motion of 20 N. Use an energy method to find the vertical distance which the cyclist descends during the downhill section from $t = 30$ to $t = 40$, assuming that the cyclist does no work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

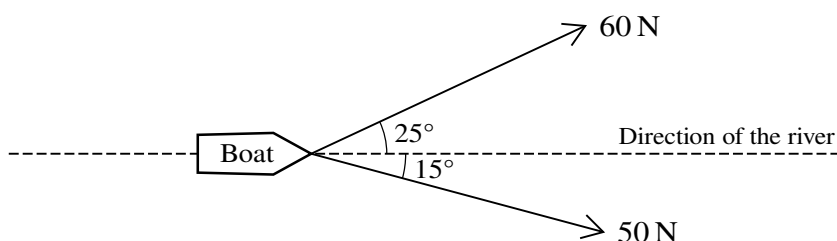
(ii) Find the coefficient of friction between the particle and the plane. [3]

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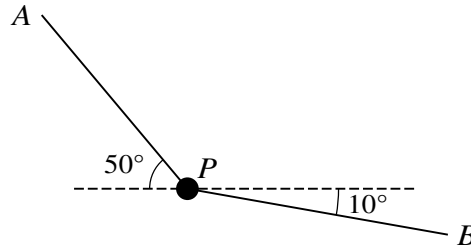
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(i) Find the work done by the crane. [3]

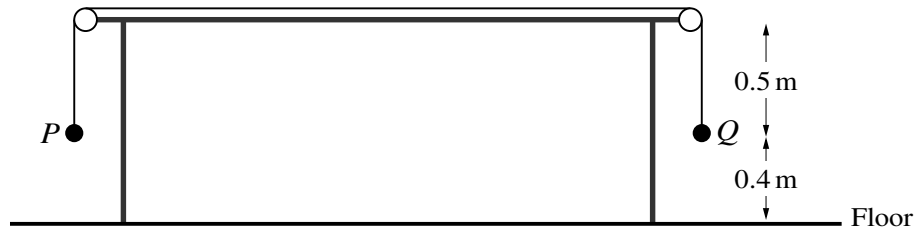
(ii) Given that the time taken to raise the block is 2 s, find the power of the crane. [2]

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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