

MATHEMATICS

9709/41

Paper 4 Mechanics 1 (M1)

May/June 2014

1 hour 15 minutes

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

READ THESE INSTRUCTIONS FIRST

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Write in dark blue or black pen.

You may use an HB pencil for any diagrams or graphs.

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DO **NOT** WRITE IN ANY BARCODES.

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.

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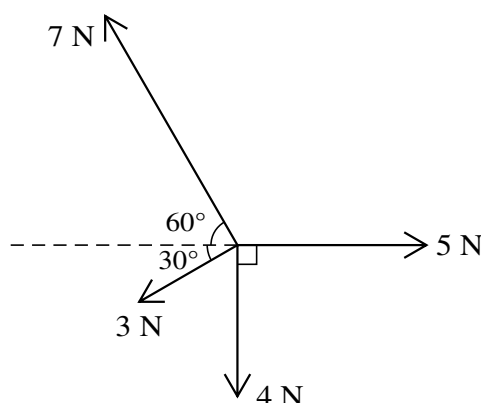
The total number of marks for this paper is 50.

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 A train is moving at constant speed $V \text{ m s}^{-1}$ along a horizontal straight track. Given that the power of the train's engine is 1330 kW and the total resistance to the train's motion is 28 kN, find the value of V . [3]
- 2 A rough plane is inclined at an angle of α° to the horizontal. A particle of mass 0.25 kg is in equilibrium on the plane. The normal reaction force acting on the particle has magnitude 2.4 N. Find
- (i) the value of α , [2]
- (ii) the least possible value of the coefficient of friction. [2]

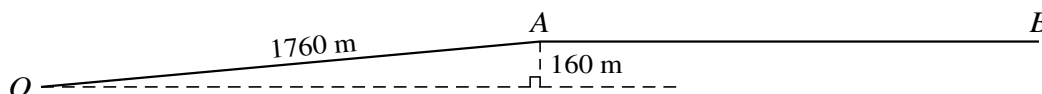
3



Four coplanar forces act at a point. The magnitudes of the forces are 5 N, 4 N, 3 N and 7 N, and the directions in which the forces act are shown in the diagram. Find the magnitude and direction of the resultant of the four forces. [6]

- 4 A particle is projected vertically upwards with speed 9 m s^{-1} from a point 3.15 m above horizontal ground. The particle moves freely under gravity until it hits the ground. For the particle's motion from the instant of projection until the particle hits the ground, find the total distance travelled and the total time taken. [6]

5



A car of mass 1100 kg starts from rest at O and travels along a road OAB . The section OA is straight, of length 1760 m, and inclined to the horizontal with A at a height of 160 m above the level of O . The section AB is straight and horizontal (see diagram). While the car is moving the driving force of the car is 1800 N and the resistance to the car's motion is 700 N. The speed of the car is $v \text{ m s}^{-1}$ when the car has travelled a distance of $x \text{ m}$ from O .

- (i) For the car's motion from O to A , write down its increase in kinetic energy in terms of v and its increase in potential energy in terms of x . Hence find the value of k for which $kv^2 = x$ for $0 \leq x \leq 1760$. [4]
- (ii) Show that $v^2 = 2x - 3200$ for $x \geq 1760$. [4]

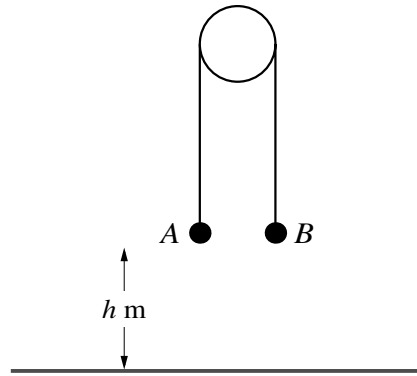


Fig. 1

Particles A of mass 0.25 kg and B of mass 0.75 kg are attached to opposite ends of a light inextensible string which passes over a fixed smooth pulley. The system is held at rest with the string taut and its straight parts vertical. Both particles are at a height of $h\text{ m}$ above the floor (see Fig. 1). The system is released from rest, and 0.6 s later, when both particles are in motion, the string breaks. The particle A does not reach the pulley in the subsequent motion.

- (i) Find the acceleration of A and the distance travelled by A before the string breaks. [4]

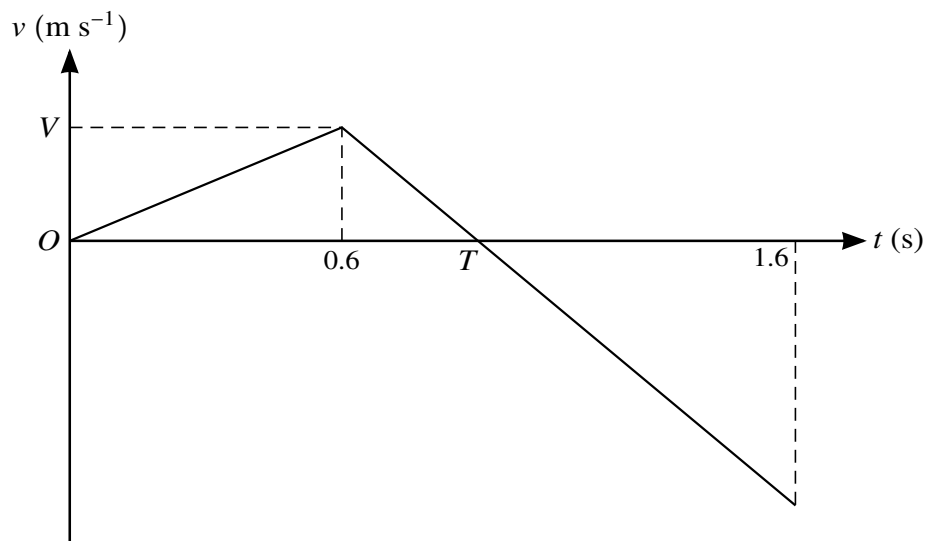


Fig. 2

The velocity-time graph shown in Fig. 2 is for the motion of particle A until it hits the floor. The velocity of A when the string breaks is $V\text{ m s}^{-1}$ and $T\text{ s}$ is the time taken for A to reach its greatest height.

- (ii) Find the value of V and the value of T . [3]
- (iii) Find the distance travelled by A upwards and the distance travelled by A downwards and hence find h . [3]

[Question 7 is printed on the next page.]

- 7 Two cyclists P and Q travel along a straight road ABC , starting simultaneously at A and arriving simultaneously at C . Both cyclists pass through B 400 s after leaving A . Cyclist P starts with speed 3 m s^{-1} and increases this speed with constant acceleration 0.005 m s^{-2} until he reaches B .

(i) Show that the distance AB is 1600 m and find P 's speed at B . [3]

Cyclist Q travels from A to B with speed $v \text{ m s}^{-1}$ at time t seconds after leaving A , where

$$v = 0.04t - 0.0001t^2 + k,$$

and k is a constant.

(ii) Find the value of k and the maximum speed of Q before he has reached B . [6]

Cyclist P travels from B to C , a distance of 1400 m, at the speed he had reached at B . Cyclist Q travels from B to C with constant acceleration $a \text{ m s}^{-2}$.

(iii) Find the time taken for the cyclists to travel from B to C and find the value of a . [4]

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- 1 A car of mass 600 kg travels along a straight horizontal road. The resistance to the car's motion is constant and equal to R N.

(i) Find the value of R , given that the car's acceleration is 1.4 m s^{-2} at an instant when the car's speed is 18 m s^{-1} and its engine is working at a rate of 22.5 kW. [4]

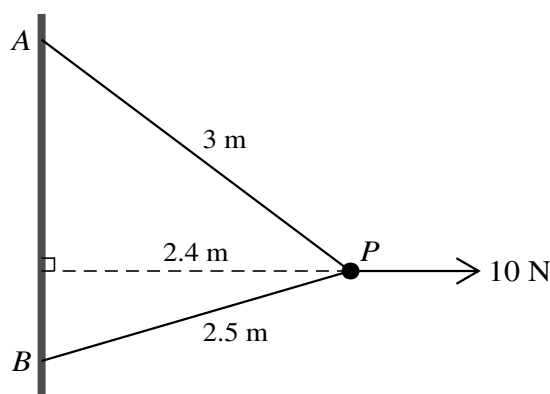
(ii) Find the rate of working of the car's engine when the car is moving with a constant speed of 15 m s^{-1} . [1]

- 2 A and B are two points which are 10 m apart on the same horizontal plane. A particle P starts to move from rest at A , directly towards B , with constant acceleration 0.5 m s^{-2} . Another particle Q is moving directly towards A with constant speed 0.75 m s^{-1} , and passes through B at the instant that P starts to move. At time T s after this instant, particles P and Q collide. Find

(i) the value of T , [4]

(ii) the speed of P immediately before the collision. [1]

3



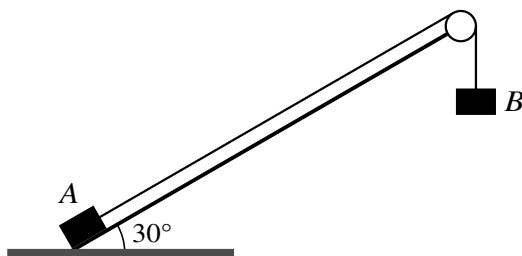
A and B are fixed points of a vertical wall with A vertically above B . A particle P of mass 0.7 kg is attached to A by a light inextensible string of length 3 m. P is also attached to B by a light inextensible string of length 2.5 m. P is maintained in equilibrium at a distance of 2.4 m from the wall by a horizontal force of magnitude 10 N acting on P (see diagram). Both strings are taut, and the 10 N force acts in the plane APB which is perpendicular to the wall. Find the tensions in the strings. [6]

- 4 A particle P moves on a straight line, starting from rest at a point O of the line. The time after P starts to move is t s, and the particle moves along the line with constant acceleration $\frac{1}{4} \text{ m s}^{-2}$ until it passes through a point A at time $t = 8$. After passing through A the velocity of P is $\frac{1}{2}t^{\frac{2}{3}} \text{ m s}^{-1}$.

(i) Find the acceleration of P immediately after it passes through A . Hence show that the acceleration of P decreases by $\frac{1}{12} \text{ m s}^{-2}$ as it passes through A . [4]

(ii) Find the distance moved by P from $t = 0$ to $t = 27$. [3]

5



A light inextensible rope has a block A of mass 5 kg attached at one end, and a block B of mass 16 kg attached at the other end. The rope passes over a smooth pulley which is fixed at the top of a rough plane inclined at an angle of 30° to the horizontal. Block A is held at rest at the bottom of the plane and block B hangs below the pulley (see diagram). The coefficient of friction between A and the plane is $\frac{1}{\sqrt{3}}$. Block A is released from rest and the system starts to move. When each of the blocks has moved a distance of $x\text{ m}$ each has speed $v\text{ m s}^{-1}$.

(i) Write down the gain in kinetic energy of the system in terms of v . [1]

(ii) Find, in terms of x ,

(a) the loss of gravitational potential energy of the system, [2]

(b) the work done against the frictional force. [3]

(iii) Show that $21v^2 = 220x$. [2]

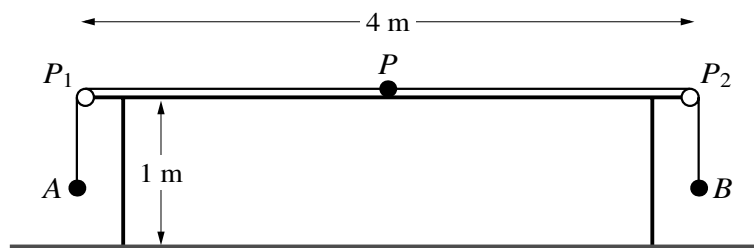
- 6 A particle P of mass 0.2 kg is released from rest at a point 7.2 m above the surface of the liquid in a container. P falls through the air and into the liquid. There is no air resistance and there is no instantaneous change of speed as P enters the liquid. When P is at a distance of 0.8 m below the surface of the liquid, P 's speed is 6 m s^{-1} . The only force on P due to the liquid is a constant resistance to motion of magnitude $R\text{ N}$.

(i) Find the deceleration of P while it is falling through the liquid, and hence find the value of R . [5]

The depth of the liquid in the container is 3.6 m . P is taken from the container and attached to one end of a light inextensible string. P is placed at the bottom of the container and then pulled vertically upwards with constant acceleration. The resistance to motion of $R\text{ N}$ continues to act. The particle reaches the surface 4 s after leaving the bottom of the container.

(ii) Find the tension in the string. [4]

[Question 7 is printed on the next page.]



A light inextensible string of length 5.28 m has particles A and B , of masses 0.25 kg and 0.75 kg respectively, attached to its ends. Another particle P , of mass 0.5 kg, is attached to the mid-point of the string. Two small smooth pulleys P_1 and P_2 are fixed at opposite ends of a rough horizontal table of length 4 m and height 1 m. The string passes over P_1 and P_2 with particle A held at rest vertically below P_1 , the string taut and B hanging freely below P_2 . Particle P is in contact with the table halfway between P_1 and P_2 (see diagram). The coefficient of friction between P and the table is 0.4. Particle A is released and the system starts to move with constant acceleration of magnitude $a \text{ m s}^{-2}$. The tension in the part AP of the string is $T_A \text{ N}$ and the tension in the part PB of the string is $T_B \text{ N}$.

- (i) Find T_A and T_B in terms of a . [3]
- (ii) Show by considering the motion of P that $a = 2$. [3]
- (iii) Find the speed of the particles immediately before B reaches the floor. [2]
- (iv) Find the deceleration of P immediately after B reaches the floor. [2]

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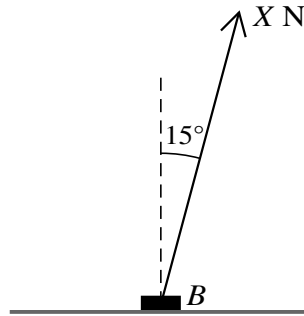
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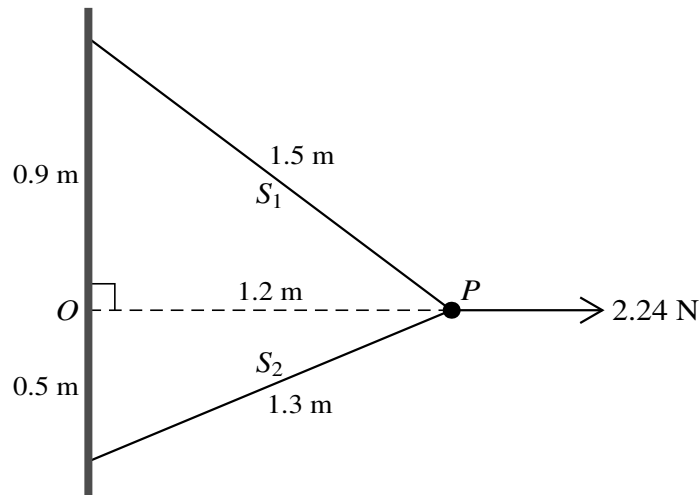


A block B of mass 7 kg is at rest on rough horizontal ground. A force of magnitude X N acts on B at an angle of 15° to the upward vertical (see diagram).

- (i) Given that B is in equilibrium find, in terms of X , the normal component of the force exerted on B by the ground. [2]
- (ii) The coefficient of friction between B and the ground is 0.4 . Find the value of X for which B is in limiting equilibrium. [3]

- 2 A car of mass 1250 kg travels up a straight hill inclined at an angle α to the horizontal, where $\sin \alpha = 0.02$. The power provided by the car's engine is 23 kW. The resistance to motion is constant and equal to 600 N. Find the speed of the car at an instant when its acceleration is 0.5 m s^{-2} . [5]

3



A particle P of weight 1.4 N is attached to one end of a light inextensible string S_1 of length 1.5 m, and to one end of another light inextensible string S_2 of length 1.3 m. The other end of S_1 is attached to a wall at the point 0.9 m vertically above a point O of the wall. The other end of S_2 is attached to the wall at the point 0.5 m vertically below O . The particle is held in equilibrium, at the same horizontal level as O , by a horizontal force of magnitude 2.24 N acting away from the wall and perpendicular to it (see diagram). Find the tensions in the strings. [6]

- 4 A small ball of mass 0.4 kg is released from rest at a point 5 m above horizontal ground. At the instant the ball hits the ground it loses 12.8 J of kinetic energy and starts to move upwards.

(i) Show that the greatest height above the ground that the ball reaches after hitting the ground is 1.8 m. [4]

(ii) Find the time taken for the ball's motion from its release until reaching this greatest height. [3]

- 5 A lorry of mass 16 000 kg travels at constant speed from the bottom, O , to the top, A , of a straight hill. The distance OA is 1200 m and A is 18 m above the level of O . The driving force of the lorry is constant and equal to 4500 N.

(i) Find the work done against the resistance to the motion of the lorry. [3]

On reaching A the lorry continues along a straight horizontal road against a constant resistance of 2000 N. The driving force of the lorry is not now constant, and the speed of the lorry increases from 9 m s^{-1} at A to 21 m s^{-1} at the point B on the road. The distance AB is 2400 m.

(ii) Use an energy method to find F , where $F \text{ N}$ is the average value of the driving force of the lorry while moving from A to B . [3]

(iii) Given that the driving force at A is 1280 N greater than $F \text{ N}$ and that the driving force at B is 1280 N less than $F \text{ N}$, show that the power developed by the lorry's engine is the same at B as it is at A . [2]

- 6 A particle starts from rest at a point O and moves in a horizontal straight line. The velocity of the particle is $v \text{ m s}^{-1}$ at time $t \text{ s}$ after leaving O . For $0 \leq t < 60$, the velocity is given by

$$v = 0.05t - 0.0005t^2.$$

The particle hits a wall at the instant when $t = 60$, and reverses the direction of its motion. The particle subsequently comes to rest at the point A when $t = 100$, and for $60 < t \leq 100$ the velocity is given by

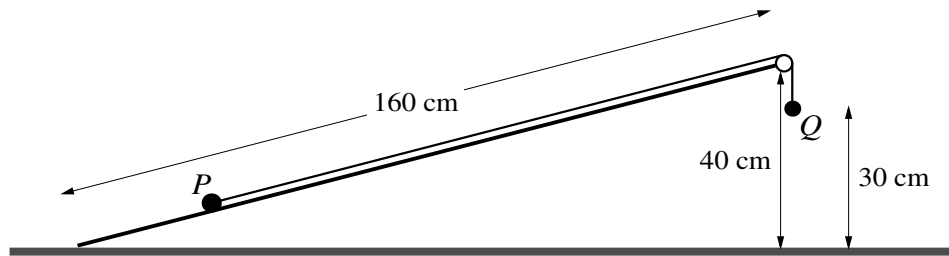
$$v = 0.025t - 2.5.$$

(i) Find the velocity of the particle immediately before it hits the wall, and its velocity immediately after it hits the wall. [2]

(ii) Find the total distance travelled by the particle. [4]

(iii) Find the maximum speed of the particle and sketch the particle's velocity-time graph for $0 \leq t \leq 100$, showing the value of t for which the speed is greatest. [4]

[Question 7 is printed on the next page.]



A smooth inclined plane of length 160 cm is fixed with one end at a height of 40 cm above the other end, which is on horizontal ground. Particles P and Q , of masses 0.76 kg and 0.49 kg respectively, are attached to the ends of a light inextensible string which passes over a small smooth pulley fixed at the top of the plane. Particle P is held at rest on the same line of greatest slope as the pulley and Q hangs vertically below the pulley at a height of 30 cm above the ground (see diagram). P is released from rest. It starts to move up the plane and does not reach the pulley. Find

- (i) the acceleration of the particles and the tension in the string before Q reaches the ground, [4]
- (ii) the speed with which Q reaches the ground, [2]
- (iii) the total distance travelled by P before it comes to instantaneous rest. [3]