

MATHEMATICS

9709/41

Paper 4 Mechanics 1 (M1)

October/November 2014

1 hour 15 minutes

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

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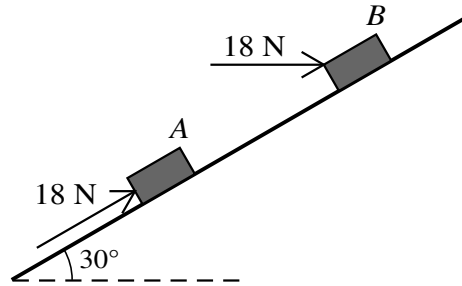
The total number of marks for this paper is 50.

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 **3** printed pages and **1** blank page.

- 1 A car of mass 800 kg is moving on a straight horizontal road with its engine working at a rate of 22.5 kW. Find the resistance to the car's motion at an instant when the car's speed is 18 m s^{-1} and its acceleration is 1.2 m s^{-2} . [4]

2



Small blocks A and B are held at rest on a smooth plane inclined at 30° to the horizontal. Each is held in equilibrium by a force of magnitude 18 N. The force on A acts upwards parallel to a line of greatest slope of the plane, and the force on B acts horizontally in the vertical plane containing a line of greatest slope (see diagram). Find the weight of A and the weight of B . [4]

3

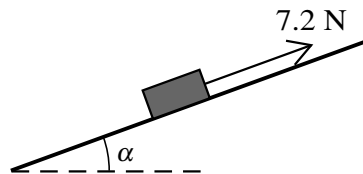


Fig. 1

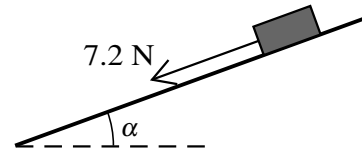


Fig. 2

A block of weight 7.5 N is at rest on a plane which is inclined to the horizontal at angle α , where $\tan \alpha = \frac{7}{24}$. The coefficient of friction between the block and the plane is μ . A force of magnitude 7.2 N acting parallel to a line of greatest slope is applied to the block. When the force acts up the plane (see Fig. 1) the block remains at rest.

- (i) Show that $\mu \geq \frac{17}{24}$. [4]

When the force acts down the plane (see Fig. 2) the block slides downwards.

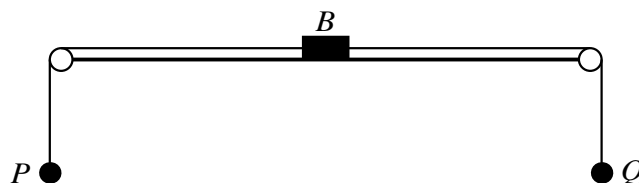
- (ii) Show that $\mu < \frac{31}{24}$. [2]

- 4 Particles P and Q move on a straight line AOB . The particles leave O simultaneously, with P moving towards A and with Q moving towards B . The initial speed of P is 1.3 m s^{-1} and its acceleration in the direction OA is 0.1 m s^{-2} . Q moves with acceleration in the direction OB of $0.016t \text{ m s}^{-2}$, where t seconds is the time elapsed since the instant that P and Q started to move from O . When $t = 20$, particle P passes through A and particle Q passes through B .

- (i) Given that the speed of Q at B is the same as the speed of P at A , find the speed of Q at time $t = 0$. [4]

- (ii) Find the distance AB . [3]

5



A small block B of mass 0.25 kg is attached to the mid-point of a light inextensible string. Particles P and Q , of masses 0.2 kg and 0.3 kg respectively, are attached to the ends of the string. The string passes over two smooth pulleys fixed at opposite sides of a rough table, with B resting in limiting equilibrium on the table between the pulleys and particles P and Q and block B are in the same vertical plane (see diagram).

- (i) Find the coefficient of friction between B and the table. [3]

Q is now removed so that P and B begin to move.

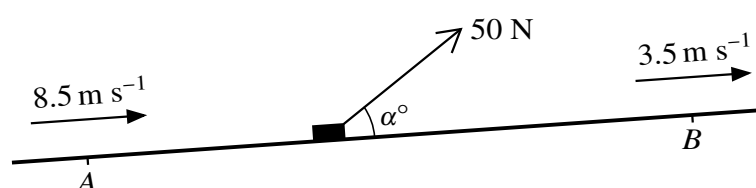
- (ii) Find the acceleration of P and the tension in the part PB of the string. [6]

- 6 A particle of mass 3 kg falls from rest at a point 5 m above the surface of a liquid which is in a container. There is no instantaneous change in speed of the particle as it enters the liquid. The depth of the liquid in the container is 4 m . The downward acceleration of the particle while it is moving in the liquid is 5.5 m s^{-2} .

- (i) Find the resistance to motion of the particle while it is moving in the liquid. [2]

- (ii) Sketch the velocity-time graph for the motion of the particle, from the time it starts to move until the time it reaches the bottom of the container. Show on your sketch the velocity and the time when the particle enters the liquid, and when the particle reaches the bottom of the container. [7]

7



A block of mass 60 kg is pulled up a hill in the line of greatest slope by a force of magnitude 50 N acting at an angle α° above the hill. The block passes through points A and B with speeds 8.5 m s^{-1} and 3.5 m s^{-1} respectively (see diagram). The distance AB is 250 m and B is 17.5 m above the level of A . The resistance to motion of the block is 6 N . Find the value of α . [11]

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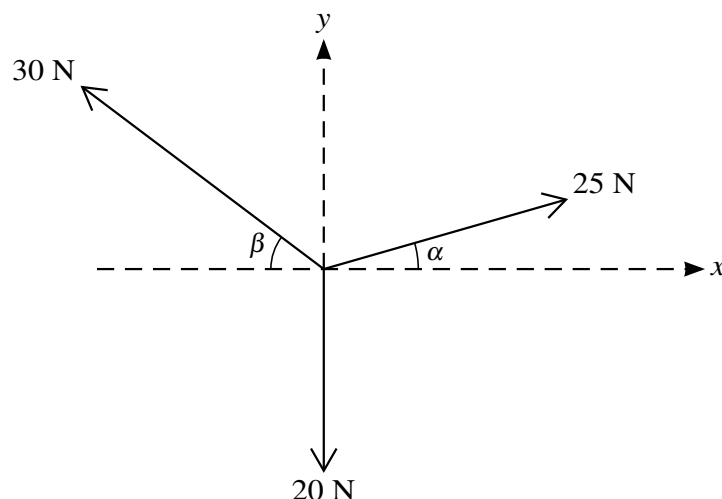
This document consists of 4 printed pages.

- 1 A particle P is projected vertically upwards with speed 11 m s^{-1} from a point on horizontal ground. At the same instant a particle Q is released from rest at a point $h \text{ m}$ above the ground. P and Q hit the ground at the same instant, when Q has speed $V \text{ m s}^{-1}$.

(i) Find the time after projection at which P hits the ground. [2]

(ii) Hence find the values of h and V . [2]

2



Three coplanar forces act at a point. The magnitudes of the forces are 20 N, 25 N and 30 N, and the directions in which the forces act are as shown in the diagram, where $\sin \alpha = 0.28$ and $\cos \alpha = 0.96$, and $\sin \beta = 0.6$ and $\cos \beta = 0.8$.

(i) Show that the resultant of the three forces has a zero component in the x -direction. [2]

(ii) Find the magnitude and direction of the resultant of the three forces. [2]

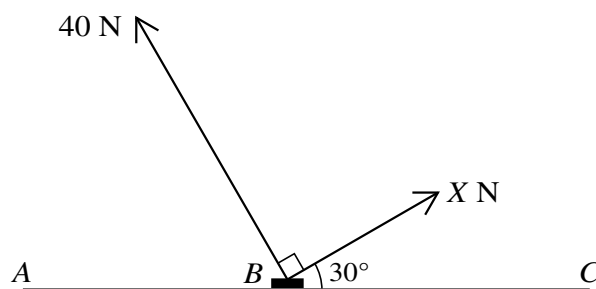
(iii) The force of magnitude 20 N is replaced by another force. The effect is that the resultant force is unchanged in magnitude but reversed in direction. State the magnitude and direction of the replacement force. [1]

- 3 A train of mass 200 000 kg moves on a horizontal straight track. It passes through a point A with speed 28 m s^{-1} and later it passes through a point B . The power of the train's engine at B is 1.2 times the power of the train's engine at A . The driving force of the train's engine at B is 0.96 times the driving force of the train's engine at A .

(i) Show that the speed of the train at B is 35 m s^{-1} . [2]

(ii) For the motion from A to B , find the work done by the train's engine given that the work done against the resistance to the train's motion is $2.3 \times 10^6 \text{ J}$. [3]

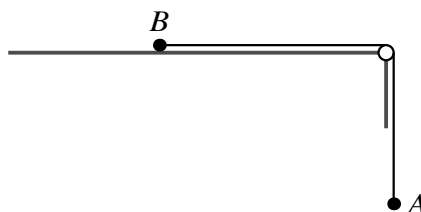
4



Forces of magnitude X N and 40 N act on a block B of mass 15 kg, which is in equilibrium in contact with a horizontal surface between points A and C on the surface. The forces act in the same vertical plane and in the directions shown in the diagram.

- (i) Given that the surface is smooth, find the value of X . [2]
- (ii) It is given instead that the surface is rough and that the block is in limiting equilibrium. The frictional force acting on the block has magnitude 10 N in the direction towards A . Find the coefficient of friction between the block and the surface. [5]

5



Particles A and B , each of mass 0.3 kg, are connected by a light inextensible string. The string passes over a small smooth pulley fixed at the edge of a rough horizontal surface. Particle A hangs freely and particle B is held at rest in contact with the surface (see diagram). The coefficient of friction between B and the surface is 0.7 . Particle B is released and moves on the surface without reaching the pulley.

- (i) Find, for the first 0.9 m of B 's motion,
- (a) the work done against the frictional force acting on B , [2]
- (b) the loss of potential energy of the system, [1]
- (c) the gain in kinetic energy of the system. [2]

At the instant when B has moved 0.9 m the string breaks. A is at a height of 0.54 m above a horizontal floor at this instant.

- (ii) Find the speed with which A reaches the floor. [3]

[Questions 6 and 7 are printed on the next page.]

- 6 ABC is a line of greatest slope of a plane inclined at angle α to the horizontal, where $\sin \alpha = 0.28$ and $\cos \alpha = 0.96$. The point A is at the top of the plane, the point C is at the bottom of the plane and the length of AC is 5 m. The part of the plane above the level of B is smooth and the part below the level of B is rough. A particle P is released from rest at A and reaches C with a speed of 2 m s^{-1} . The coefficient of friction between P and the part of the plane below B is 0.5. Find

(i) the acceleration of P while moving

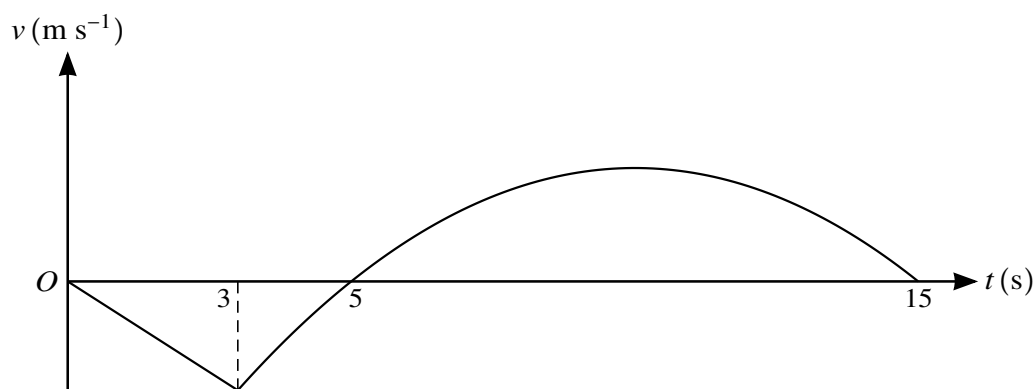
(a) from A to B ,

(b) from B to C , [3]

(ii) the distance AB , [3]

(iii) the time taken for P to move from A to C . [3]

7



The diagram shows the velocity-time graph for the motion of a particle P which moves on a straight line BAC . It starts at A and travels to B taking 5 s. It then reverses direction and travels from B to C taking 10 s. For the first 3 s of P 's motion its acceleration is constant. For the remaining 12 s the velocity of P is $v \text{ m s}^{-1}$ at time $t \text{ s}$ after leaving A , where

$$v = -0.2t^2 + 4t - 15 \quad \text{for } 3 \leq t \leq 15.$$

(i) Find the value of v when $t = 3$ and the magnitude of the acceleration of P for the first 3 s of its motion. [3]

(ii) Find the maximum velocity of P while it is moving from B to C . [3]

(iii) Find the average speed of P ,

(a) while moving from A to B ,

(b) for the whole journey. [6]

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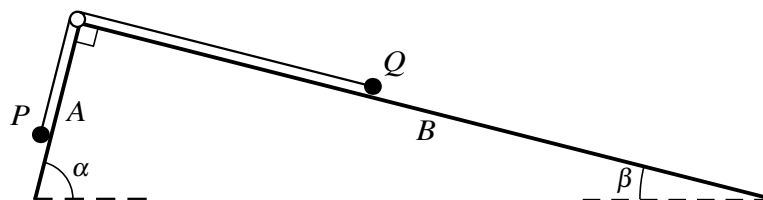
- 1 A car of mass 1400 kg moves on a horizontal straight road. The resistance to the car's motion is constant and equal to 800 N and the power of the car's engine is constant and equal to $P\text{ W}$. At an instant when the car's speed is 18 m s^{-1} its acceleration is 0.5 m s^{-2} .

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

The car continues and passes through another point with speed 25 m s^{-1} .

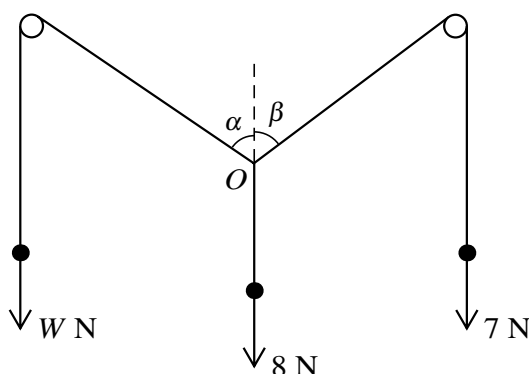
(ii) Find the car's acceleration at this point. [2]

2



The tops of each of two smooth inclined planes A and B meet at a right angle. Plane A is inclined at angle α to the horizontal and plane B is inclined at angle β to the horizontal, where $\sin \alpha = \frac{63}{65}$ and $\sin \beta = \frac{16}{65}$. A small smooth pulley is fixed at the top of the planes and a light inextensible string passes over the pulley. Two particles P and Q , each of mass 0.65 kg , are attached to the string, one at each end. Particle Q is held at rest at a point of the same line of greatest slope of the plane B as the pulley. Particle P rests freely below the pulley in contact with plane A (see diagram). Particle Q is released and the particles start to move with the string taut. Find the tension in the string. [5]

3



Each of three light inextensible strings has a particle attached to one of its ends. The other ends of the strings are tied together at a point O . Two of the strings pass over fixed smooth pegs and the particles hang freely in equilibrium. The weights of the particles and the angles between the sloping parts of the strings and the vertical are as shown in the diagram. It is given that $\sin \beta = 0.8$ and $\cos \beta = 0.6$.

(i) Show that $W \cos \alpha = 3.8$ and find the value of $W \sin \alpha$. [3]

(ii) Hence find the values of W and α . [3]

- 4 A particle P starts from rest and moves in a straight line for 18 seconds. For the first 8 seconds of the motion P has constant acceleration 0.25 m s^{-2} . Subsequently P 's velocity, $v \text{ m s}^{-1}$ at time t seconds after the motion started, is given by

$$v = -0.1t^2 + 2.4t - k,$$

where $8 \leq t \leq 18$ and k is a constant.

(i) Find the value of v when $t = 8$ and hence find the value of k . [2]

(ii) Find the maximum velocity of P . [2]

(iii) Find the displacement of P from its initial position when $t = 18$. [3]

- 5 A box of mass 8 kg is on a rough plane inclined at 5° to the horizontal. A force of magnitude $P \text{ N}$ acts on the box in a direction upwards and parallel to a line of greatest slope of the plane. When $P = 7X$ the box moves up the line of greatest slope with acceleration 0.15 m s^{-2} and when $P = 8X$ the box moves up the line of greatest slope with acceleration 1.15 m s^{-2} . Find the value of X and the coefficient of friction between the box and the plane. [8]

6

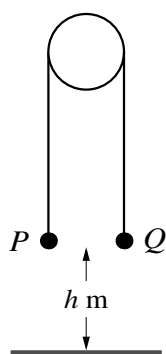


Fig. 1

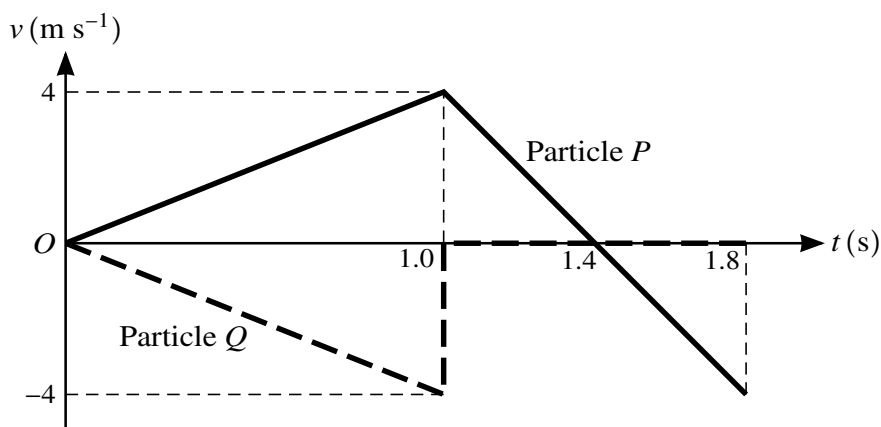
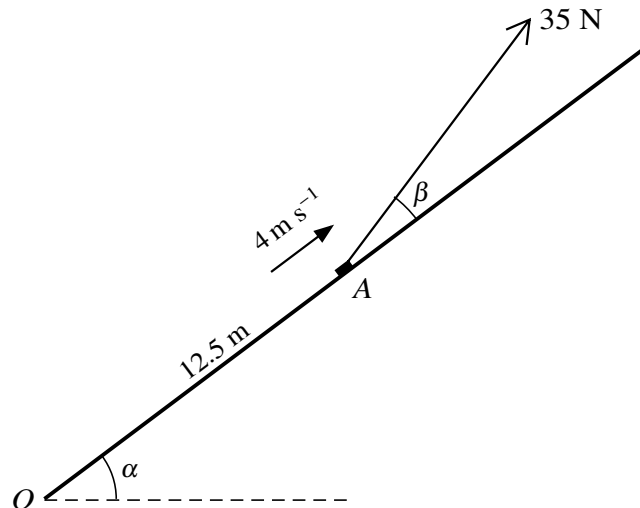


Fig. 2

Particles P and Q have a total mass of 1 kg . The particles are attached to opposite ends of a light inextensible string which passes over a smooth fixed pulley. P is held at rest and Q hangs freely, with both straight parts of the string vertical. Both particles are at a height of $h \text{ m}$ above the floor (see Fig. 1). P is released from rest and the particles start to move with the string taut. Fig. 2 shows the velocity-time graphs for P 's motion and for Q 's motion, where the positive direction for velocity is vertically upwards. Find

- (i) the magnitude of the acceleration with which the particles start to move and the mass of each of the particles, [5]
- (ii) the value of h , [1]
- (iii) the greatest height above the floor reached by particle P . [2]

[Question 7 is printed on the next page.]



A small block of mass 3 kg is initially at rest at the bottom O of a rough plane inclined at an angle α to the horizontal, where $\sin \alpha = 0.6$ and $\cos \alpha = 0.8$. A force of magnitude 35 N acts on the block at an angle β above the plane, where $\sin \beta = 0.28$ and $\cos \beta = 0.96$. The block starts to move up a line of greatest slope of the plane and passes through a point A with speed 4 m s^{-1} . The distance OA is 12.5 m (see diagram).

(i) For the motion of the block from O to A , find the work done against the frictional force acting on the block. [4]

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

At the instant that the block passes through A the force of magnitude 35 N ceases to act.

(iii) Find the distance the block travels up the plane after passing through A . [4]